Developer Guide

AWS Encryption SDK

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AWS Encryption SDK: Developer Guide

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What is the AWS Encryption SDK?

The AWS Encryption SDK is a client-side encryption library designed to make it easy for everyone to encrypt and decrypt data using industry standards and best practices. It enables you to focus on the core functionality of your application, rather than on how to best encrypt and decrypt your data. The AWS Encryption SDK is provided free of charge under the Apache 2.0 license.

The AWS Encryption SDK answers questions like the following for you:

- Which encryption algorithm should I use?
- How, or in which mode, should I use that algorithm?
- How do I generate the encryption key?
- How do I protect the encryption key, and where should I store it?
- How can I make my encrypted data portable?
- How do I ensure that the intended recipient can read my encrypted data?
- How can I ensure my encrypted data is not modified between the time it is written and when it is read?
- How do I use the data keys that AWS KMS returns?

With the AWS Encryption SDK, you define a master key provider or a keyring that determines which wrapping keys you use to protect your data. Then you encrypt and decrypt your data using straightforward methods provided by the AWS Encryption SDK. The AWS Encryption SDK does the rest.

Without the AWS Encryption SDK, you might spend more effort on building an encryption solution than on the core functionality of your application. The AWS Encryption SDK answers these questions by providing the following things.

A default implementation that adheres to cryptography best practices

By default, the AWS Encryption SDK generates a unique data key for each data object that it encrypts. This follows the cryptography best practice of using unique data keys for each encryption operation.

The AWS Encryption SDK encrypts your data using a secure, authenticated, symmetric key algorithm. For more information, see the section called “Supported algorithm suites”.

A framework for protecting data keys with wrapping keys

The AWS Encryption SDK protects the data keys that encrypt your data by encrypting them under one or more wrapping keys. By providing a framework to encrypt data keys with more than one wrapping key, the AWS Encryption SDK helps make your encrypted data portable.

For example, encrypt data under an AWS KMS key in AWS KMS and a key from your on-premises HSM. You can use either of the wrapping keys to decrypt the data, in case one is unavailable or the caller doesn't have permission to use both keys.

A formatted message that stores encrypted data keys with the encrypted data

The AWS Encryption SDK stores the encrypted data and encrypted data key together in an encrypted message that uses a defined data format. This means you don't need to keep track of or protect the data keys that encrypt your data because the AWS Encryption SDK does it for you.

Some language implementations of the AWS Encryption SDK require an AWS SDK, but the AWS Encryption SDK doesn't require an AWS account and it doesn't depend on any AWS service. You need an AWS account only if you choose to use AWS KMS keys to protect your data.

Developed in open-source repositories

The AWS Encryption SDK is developed in open-source repositories on GitHub. You can use these repositories to view the code, read and submit issues, and find information that is specific to your language implementation.

- AWS Encryption SDK for C — aws-encryption-sdk-c
- AWS Encryption SDK for .NET — .NET directory of the `aws-encryption-sdk` repository.
- AWS Encryption CLI — aws-encryption-sdk-cli
- AWS Encryption SDK for Java — aws-encryption-sdk-java
- AWS Encryption SDK for JavaScript — aws-encryption-sdk-javascript
- AWS Encryption SDK for Python — aws-encryption-sdk-python
- AWS Encryption SDK for Rust — Rust directory of the `aws-encryption-sdk` repository.
- AWS Encryption SDK for Go — Go directory of the `aws-encryption-sdk` repository

Compatibility with encryption libraries and services

The AWS Encryption SDK is supported in several programming languages. All language implementations are interoperable. You can encrypt with one language implementation and decrypt with another. Interoperability might be subject to language constraints. If so, these constraints are described in the topic about the language implementation. Also, when encrypting and decrypting, you must use compatible keyrings, or master keys and master key providers. For details, see the section called "Keyring compatibility".

However, the AWS Encryption SDK cannot interoperate with other libraries. Because each library returns encrypted data in a different format, you cannot encrypt with one library and decrypt with another.

DynamoDB Encryption Client and Amazon S3 client-side encryption

The AWS Encryption SDK cannot decrypt data encrypted by the DynamoDB Encryption Client or Amazon S3 client-side encryption. These libraries cannot decrypt the encrypted message the AWS Encryption SDK returns.

AWS Key Management Service (AWS KMS)

The AWS Encryption SDK can use AWS KMS keys and data keys to protect your data, including multi-Region KMS keys. For example, you can configure the AWS Encryption SDK to encrypt your data under one or more AWS KMS keys in your AWS account. However, you must use the AWS Encryption SDK to decrypt that data.

The AWS Encryption SDK cannot decrypt the ciphertext that the AWS KMS Encrypt or ReEncrypt operations return. Similarly, the AWS KMS Decrypt operation cannot decrypt the encrypted message the AWS Encryption SDK returns.

The AWS Encryption SDK supports only symmetric encryption KMS keys. You cannot use an asymmetric KMS key for encryption or signing in the AWS Encryption SDK. The AWS Encryption SDK generates its own ECDSA signing keys for algorithm suites that sign messages.

Support and maintenance

The AWS Encryption SDK uses the same maintenance policy that the AWS SDK and Tools use, including its versioning and life-cycle phases. As a best practice, we recommend that you use the latest available version of the AWS Encryption SDK for your programming language, and upgrade

as new versions are released. When a version requires significant changes, such as the upgrade from AWS Encryption SDK versions earlier than 1.7.*x* to versions 2.0.*x* and later, we provide detailed instructions to help you.

Each programming language implementation of the AWS Encryption SDK is developed in a separate open-source GitHub repository. The life-cycle and support phase of each version is likely to vary among repositories. For example, a given version of the AWS Encryption SDK might be in the general availability (full support) phase in one programming language, but the end-of-support phase in a different programming language. We recommend that you use a fully supported version whenever possible and avoid versions that are no longer supported.

To find the life-cycle phase of AWS Encryption SDK versions for your programming language, see the `SUPPORT_POLICY.rst` file in each AWS Encryption SDK repository.

- AWS Encryption SDK for C — SUPPORT_POLICY.rst
- AWS Encryption SDK for .NET — SUPPORT_POLICY.rst
- AWS Encryption CLI — SUPPORT_POLICY.rst
- AWS Encryption SDK for Java — SUPPORT_POLICY.rst
- AWS Encryption SDK for JavaScript — SUPPORT_POLICY.rst
- AWS Encryption SDK for Python — SUPPORT_POLICY.rst

For more information, see Versions of the AWS Encryption SDK and AWS SDKs and Tools maintenance policy in the AWS SDKs and Tools Reference Guide.

Learning more

For more information about the AWS Encryption SDK and client-side encryption, try these sources.

- For help with the terms and concepts used in this SDK, see Concepts in the AWS Encryption SDK.
- For best practice guidelines, see Best practices for the AWS Encryption SDK.
- For information about how this SDK works, see How the SDK works.
- For examples that show how to configure options in the AWS Encryption SDK, see Configuring the AWS Encryption SDK.
- For detailed technical information, see the *Reference*.
- For the technical specification for the AWS Encryption SDK, see the AWS Encryption SDK Specification in GitHub.

- For answers to your questions about using the AWS Encryption SDK, read and post on the AWS Crypto Tools Discussion Forum.

For information about implementations of the AWS Encryption SDK in different programming languages.

- **C**: See AWS Encryption SDK for C, the AWS Encryption SDK C documentation, and the aws-encryption-sdk-c repository on GitHub.
- **C#/.NET**: See AWS Encryption SDK for .NET and the aws-encryption-sdk-net directory of the `aws-encryption-sdk` repository on GitHub.
- **Command Line Interface**: See AWS Encryption SDK command line interface, Read the Docs for the AWS Encryption CLI, and the aws-encryption-sdk-cli repository on GitHub.
- **Java**: See AWS Encryption SDK for Java, the AWS Encryption SDK Javadoc, and the aws-encryption-sdk-java repository on GitHub.

  JavaScript: See the section called "JavaScript" and the aws-encryption-sdk-javascript repository on GitHub.
- **Python**: See AWS Encryption SDK for Python, the AWS Encryption SDK Python documentation, and the aws-encryption-sdk-python repository on GitHub.

Sending feedback

We welcome your feedback! If you have a question or comment, or an issue to report, please use the following resources.

- If you discover a potential security vulnerability in the AWS Encryption SDK, please notify AWS security. Do not create a public GitHub issue.
- To provide feedback on the AWS Encryption SDK, file an issue in the GitHub repository for the programming language you are using.
- To provide feedback on this documentation, use the **Feedback** links on this page. You can also file an issue or contribute to aws-encryption-sdk-docs, the open-source repository for this documentation on GitHub.

Concepts in the AWS Encryption SDK

This section introduces the concepts used in the AWS Encryption SDK, and provides a glossary and reference. It's designed to help you understand how the AWS Encryption SDK works and the terms we use to describe it.

Need help?

- Learn how the AWS Encryption SDK uses envelope encryption to protect your data.
- Learn about the elements of envelope encryption: the data keys that protect your data and the wrapping keys that protect your data keys.
- Learn about the keyrings and master key providers that determine which wrapping keys you use.
- Learn about the encryption context that adds integrity to your encryption process. It's optional, but it's a best practice that we recommend.
- Learn about the encrypted message that the encryption methods return.
- Then you're ready to use the AWS Encryption SDK in your preferred programming language.

Topics

- Envelope encryption
- Data key
- Wrapping key
- Keyrings and master key providers
- Encryption context
- Encrypted message
- Algorithm suite
- Cryptographic materials manager
- Symmetric and asymmetric encryption
- Key commitment
- Commitment policy
- Digital signatures

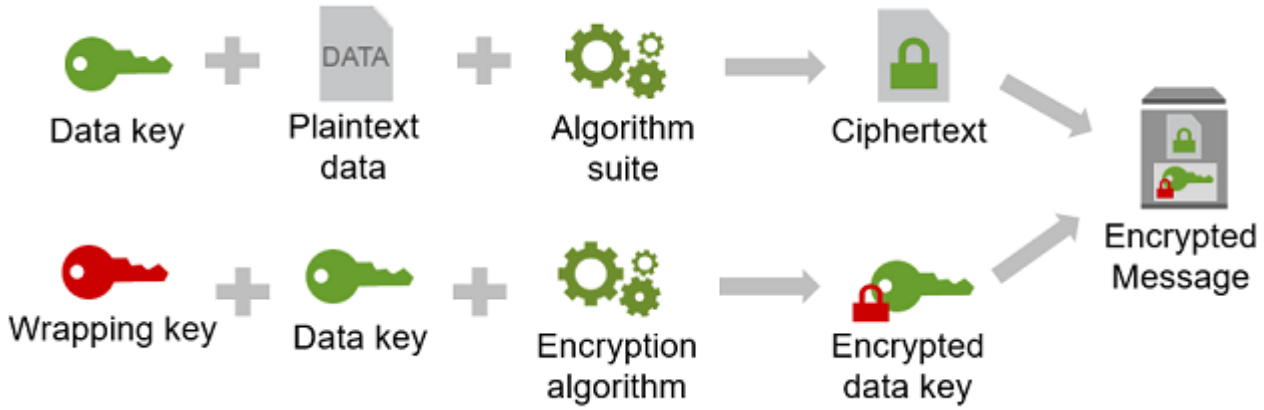
Envelope encryption

The security of your encrypted data depends in part on protecting the data key that can decrypt it. One accepted best practice for protecting the data key is to encrypt it. To do this, you need another encryption key, known as a *key-encryption key* or wrapping key. The practice of using a wrapping key to encrypt data keys is known as *envelope encryption*.

Protecting data keys

The AWS Encryption SDK encrypts each message with a unique data key. Then it encrypts the data key under the wrapping key you specify. It stores the encrypted data key with the encrypted data in the encrypted message that it returns.

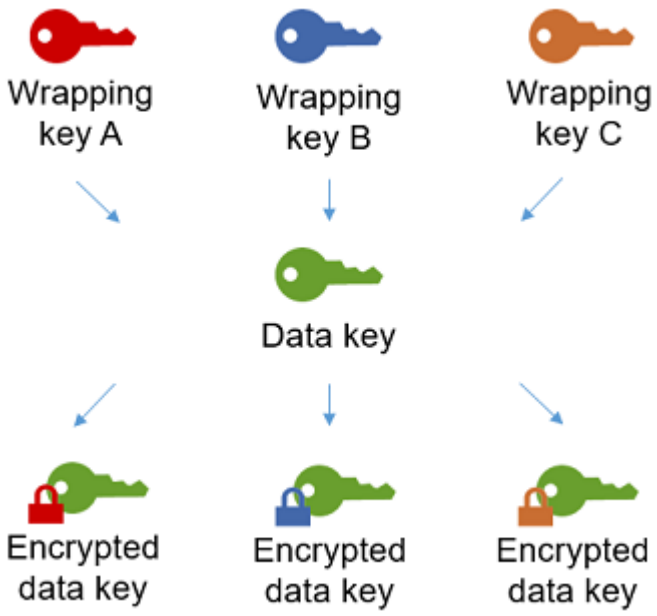
To specify your wrapping key, you use a keyring or master key provider.



Encrypting the same data under multiple wrapping keys

You can encrypt the data key under multiple wrapping keys. You might want to provide different wrapping keys for different users, or wrapping keys of different types, or in different locations. Each of the wrapping keys encrypts the same data key. The AWS Encryption SDK stores all of the encrypted data keys with the encrypted data in the encrypted message.

To decrypt the data, you need to provide a wrapping key that can decrypt one of the encrypted data keys.



Combining the strengths of multiple algorithms

To encrypt your data, by default, the AWS Encryption SDK uses a sophisticated algorithm suite with AES-GCM symmetric encryption, a key derivation function (HKDF), and signing. To encrypt the data key, you can specify a symmetric or asymmetric encryption algorithm appropriate to your wrapping key.

In general, symmetric key encryption algorithms are faster and produce smaller ciphertexts than asymmetric or *public key encryption*. But public key algorithms provide inherent separation of roles and easier key management. To combine the strengths of each, you can encrypt your data with symmetric key encryption, and then encrypt the data key with public key encryption.

Data key

A *data key* is an encryption key that the AWS Encryption SDK uses to encrypt your data. Each data key is a byte array that conforms to the requirements for cryptographic keys. Unless you're using data key caching, the AWS Encryption SDK uses a unique data key to encrypt each message.

You don't need to specify, generate, implement, extend, protect or use data keys. The AWS Encryption SDK does that work for you when you call the encrypt and decrypt operations.

To protect your data keys, the AWS Encryption SDK encrypts them under one or more *key-encryption keys* known as wrapping keys or master keys. After the AWS Encryption SDK uses your plaintext data keys to encrypt your data, it removes them from memory as soon as possible. Then

it stores the encrypted data keys with the encrypted data in the encrypted message that the encrypt operations return. For details, see the section called “How the SDK works”.

> **Tip**
>
> In the AWS Encryption SDK, we distinguish *data keys* from *data encryption keys*. Several of the supported algorithm suites, including the default suite, use a key derivation function that prevents the data key from hitting its cryptographic limits. The key derivation function takes the data key as input and returns a data encryption key that is actually used to encrypt the data. For this reason, we often say that data is encrypted "under" a data key rather than "by" the data key.

Each encrypted data key includes metadata, including the identifier of the wrapping key that encrypted it. This metadata makes it easier for the AWS Encryption SDK to identify valid wrapping keys when decrypting.

Wrapping key

A *wrapping key* is a key-encryption key that the AWS Encryption SDK uses to encrypt the data key that encrypts your data. Each plaintext data key can be encrypted under one or more wrapping keys. You determine which wrapping keys are used to protect your data when you configure a keyring or master key provider.

> **Note**
>
> *Wrapping key* refers to the keys in a keyring or master key provider. *Master key* is typically associated with the `MasterKey` class that you instantiate when you use a master key provider.

The AWS Encryption SDK supports several commonly used wrapping keys, such as AWS Key Management Service (AWS KMS) symmetric AWS KMS keys (including multi-Region KMS keys), raw AES-GCM (Advanced Encryption Standard/Galois Counter Mode) keys, and raw RSA keys. You can also extend or implement your own wrapping keys.

When you use envelope encryption, you need to protect your wrapping keys from unauthorized access. You can do this in any of the following ways:

- Use a web service designed for this purpose, such as AWS Key Management Service (AWS KMS).
- Use a hardware security module (HSM) such as those offered by AWS CloudHSM.
- Use other key management tools and services.

If you don't have a key management system, we recommend AWS KMS. The AWS Encryption SDK integrates with AWS KMS to help you protect and use your wrapping keys. However, the AWS Encryption SDK does not require AWS or any AWS service.

Keyrings and master key providers

To specify the wrapping keys you use for encryption and decryption, you use a keyring or a master key provider. You can use the keyrings and master key providers that the AWS Encryption SDK provides or design your own implementations. The AWS Encryption SDK provides keyrings and master key providers that are compatible with each other subject to language constraints. For details, see Keyring compatibility.

A *keyring* generates, encrypts, and decrypts data keys. When you define a keyring, you can specify the wrapping keys that encrypt your data keys. Most keyrings specify at least one wrapping key or a service that provides and protects wrapping keys. You can also define a keyring with no wrapping keys or a more complex keyring with additional configuration options. For help choosing and using the keyrings that the AWS Encryption SDK defines, see Keyrings.

Keyrings are supported in the following programming languages:

- AWS Encryption SDK for C
- AWS Encryption SDK for JavaScript
- AWS Encryption SDK for .NET
- Version 3.*x* of the AWS Encryption SDK for Java
- Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency.
- Version 1.*x* of the AWS Encryption SDK for Rust
- Version 0.1.*x* or later of the AWS Encryption SDK for Go

A *master key provider* is an alternative to a keyring. The master key provider returns the wrapping keys (or master keys) you specify. Each master key is associated with one master key provider, but a

master key provider typically provides multiple master keys. Master key providers are supported in Java, Python, and the AWS Encryption CLI.

You must specify a keyring (or master key provider) for encryption. You can specify the same keyring (or master key provider), or a different one, for decryption. When encrypting, the AWS Encryption SDK uses all of the wrapping keys you specify to encrypt the data key. When decrypting, the AWS Encryption SDK uses only the wrapping keys you specify to decrypt an encrypted data key. Specifying wrapping keys for decryption is optional, but it's a AWS Encryption SDK best practice.

For details about specifying wrapping keys, see Selecting wrapping keys.

Encryption context

To improve the security of your cryptographic operations, include an encryption context in all requests to encrypt data. Using an encryption context is optional, but it is a cryptographic best practice that we recommend.

An *encryption context* is a set of name-value pairs that contain arbitrary, non-secret additional authenticated data. The encryption context can contain any data you choose, but it typically consists of data that is useful in logging and tracking, such as data about the file type, purpose, or ownership. When you encrypt data, the encryption context is cryptographically bound to the encrypted data so that the same encryption context is required to decrypt the data. The AWS Encryption SDK includes the encryption context in plaintext in the header of the encrypted message that it returns.

The encryption context that the AWS Encryption SDK uses consists of the encryption context that you specify and a public key pair that the cryptographic materials manager (CMM) adds. Specifically, whenever you use an encryption algorithm with signing, the CMM adds a name-value pair to the encryption context that consists of a reserved name, `aws-crypto-public-key`, and a value that represents the public verification key. The `aws-crypto-public-key` name in the encryption context is reserved by the AWS Encryption SDK and cannot be used as a name in any other pair in the encryption context. For details, see AAD in the *Message Format Reference*.

The following example encryption context consists of two encryption context pairs specified in the request and the public key pair that the CMM adds.

```
"Purpose"="Test", "Department"="IT", aws-crypto-public-key=<public key>
```

To decrypt the data, you pass in the encrypted message. Because the AWS Encryption SDK can extract the encryption context from the encrypted message header, you are not required to provide the encryption context separately. However, the encryption context can help you to confirm that you are decrypting the correct encrypted message.

- In the AWS Encryption SDK Command Line Interface (CLI), if you provide an encryption context in a decrypt command, the CLI verifies that the values are present in the encryption context of the encrypted message before it returns the plaintext data.
- In other programming language implementations, the decrypt response includes the encryption context and the plaintext data. The decrypt function in your application should always verify that the encryption context in the decrypt response includes the encryption context in the encrypt request (or a subset) before it returns the plaintext data.

> **Note**
>
> The following versions support the required encryption context CMM, which you can use to require an encryption context in all encrypt requests.
>
> - Version 3.*x* of the AWS Encryption SDK for Java
> - Version 4.*x* of the AWS Encryption SDK for .NET
> - Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency.
> - Version 1.*x* of the AWS Encryption SDK for Rust
> - Version 0.1.*x* or later of the AWS Encryption SDK for Go

When choosing an encryption context, remember that it is not a secret. The encryption context is displayed in plaintext in the header of the encrypted message that the AWS Encryption SDK returns. If you are using AWS Key Management Service, the encryption context also might appear in plaintext in audit records and logs, such as AWS CloudTrail.

For examples of submitting and verifying an encryption context in your code, see the examples for your preferred programming language.

Encrypted message

When you encrypt data with the AWS Encryption SDK, it returns an encrypted message.

An *encrypted message* is a portable formatted data structure that includes the encrypted data along with encrypted copies of the data keys, the algorithm ID, and, optionally, an encryption context and a digital signature. Encrypt operations in the AWS Encryption SDK return an encrypted message and decrypt operations take an encrypted message as input.

Combining the encrypted data and its encrypted data keys streamlines the decryption operation and frees you from having to store and manage encrypted data keys independently of the data that they encrypt.

For technical information about the encrypted message, see Encrypted Message Format.

Algorithm suite

The AWS Encryption SDK uses an algorithm suite to encrypt and sign the data in the encrypted message that the encrypt and decrypt operations return. The AWS Encryption SDK supports several algorithm suites. All of the supported suites use Advanced Encryption Standard (AES) as the primary algorithm, and combine it with other algorithms and values.

The AWS Encryption SDK establishes a recommended algorithm suite as the default for all encryption operations. The default might change as standards and best practices improve. You can specify an alternate algorithm suite in requests to encrypt data or when creating a cryptographic materials manager (CMM), but unless an alternate is required for your situation, it is best to use the default. The current default is AES-GCM with an HMAC-based extract-and-expand key derivation function (HKDF), key commitment, an Elliptic Curve Digital Signature Algorithm (ECDSA) signature, and a 256-bit encryption key.

If your application requires high performance and the users who are encrypting data and those who are decrypting data are equally trusted, you might consider specifying an algorithm suite without a digital signature. However, we strongly recommend an algorithm suite that includes key commitment and a key derivation function. Algorithm suites without these features are supported only for backward compatibility.

Cryptographic materials manager

The cryptographic materials manager (CMM) assembles the cryptographic materials that are used to encrypt and decrypt data. The *cryptographic materials* include plaintext and encrypted data keys, and an optional message signing key. You never interact with the CMM directly. The encryption and decryption methods handle it for you.

You can use the default CMM or the caching CMM that the AWS Encryption SDK provides, or write a custom CMM. And you can specify a CMM, but it's not required. When you specify a keyring or master key provider, the AWS Encryption SDK creates a default CMM for you. The default CMM gets the encryption or decryption materials from the keyring or master key provider that you specify. This might involve a call to a cryptographic service, such as AWS Key Management Service(AWS KMS).

Because the CMM acts as a liaison between the AWS Encryption SDK and a keyring (or master key provider), it is an ideal point for customization and extension, such as support for policy enforcement and caching. The AWS Encryption SDK provides a caching CMM to support data key caching.

Symmetric and asymmetric encryption

Symmetric encryption uses the same key to encrypt and decrypt data.

Asymmetric encryption uses a mathematically related data key pair. One key in the pair encrypts the data; only the other key in the pair can decrypt the data.

The AWS Encryption SDK uses envelope encryption. It encrypts your data with a symmetric data key. It encrypts the symmetric data key with one or more symmetric or asymmetric wrapping keys. It returns an encrypted message that includes the encrypted data and at least one encrypted copy of the data key.

Encrypting your data (symmetric encryption)

To encrypt your data, the AWS Encryption SDK uses a symmetric data key and an algorithm suite that includes a symmetric encryption algorithm. To decrypt the data, the AWS Encryption SDK uses the same data key and the same algorithm suite.

Encrypting your data key (symmetric or asymmetric encryption)

The keyring or master key provider that you supply to an encrypt and decrypt operation determines how the symmetric data key is encrypted and decrypted. You can choose a keyring or master key provider that uses symmetric encryption, such as a AWS KMS keyring, or one that uses asymmetric encryption, such as a raw RSA keyring or `JceMasterKey`.

Key commitment

The AWS Encryption SDK supports *key commitment* (sometimes known as *robustness*), a security property that guarantees that each ciphertext can be decrypted only to a single plaintext. To do this, key commitment guarantees that only the data key that encrypted your message will be used to decrypt it. Encrypting and decrypting with key commitment is an AWS Encryption SDK best practice.

Most modern symmetric ciphers (including AES) encrypt a plaintext under a single secret key, such as the unique data key that the AWS Encryption SDK uses to encrypt each plaintext message. Decrypting this data with the same data key returns a plaintext that is identical to the original. Decrypting with a different key will usually fail. However, it's possible to decrypt a ciphertext under two different keys. In rare cases, it is feasible to find a key that can decrypt a few bytes of ciphertext into a different, but still intelligible, plaintext.

The AWS Encryption SDK always encrypts each plaintext message under one unique data key. It might encrypt that data key under multiple wrapping keys (or master keys), but the wrapping keys always encrypt the same data key. Nonetheless, a sophisticated, manually crafted encrypted message might actually contain different data keys, each encrypted by a different wrapping key. For example, if one user decrypts the encrypted message it returns 0x0 (false) while another user decrypting the same encrypted message gets 0x1 (true).

To prevent this scenario, the AWS Encryption SDK supports key commitment when encrypting and decrypting. When the AWS Encryption SDK encrypts a message with key commitment, it cryptographically binds the unique data key that produced the ciphertext to the *key commitment string*, a non-secret data key identifier. Then it stores key commitment string in the metadata of the encrypted message. When it decrypts a message with key commitment, the AWS Encryption SDK verifies that the data key is the one and only key for that encrypted message. If data key verification fails, the decrypt operation fails.

Support for key commitment is introduced in version 1.7.*x*, which can decrypt messages with key commitment, but won't encrypt with key commitment. You can use this version to fully deploy the ability to decrypt ciphertext with key commitment. Version 2.0.*x* includes full support for key commitment. By default, it encrypts and decrypts only with key commitment. This is an ideal configuration for applications that don't need to decrypt ciphertext encrypted by earlier versions of the AWS Encryption SDK.

Although encrypting and decrypting with key commitment is a best practice, we let you decide when it's used, and let you adjust the pace at which you adopt it. Beginning in version 1.7.*x*, AWS

Encryption SDK supports a commitment policy that sets the default algorithm suite and limits the algorithm suites that may be used. This policy determines whether your data is encrypted and decrypted with key commitment.

Key commitment results in a slightly larger (+ 30 bytes) encrypted message and takes more time to process. If your application is very sensitive to size or performance, you might choose to opt out of key commitment. But do so only if you must.

For more information about migrating to versions 1.7.*x* and 2.0.*x*, including their key commitment features, see Migrating your AWS Encryption SDK. For technical information about key commitment, see the section called "Algorithms reference" and the section called "Message format reference".

Commitment policy

A *commitment policy* is a configuration setting that determines whether your application encrypts and decrypts with key commitment. Encrypting and decrypting with key commitment is an AWS Encryption SDK best practice.

Commitment policy has three values.

> **Note**
>
> You might have to scroll horizontally or vertically to see the entire table.

Commitment policy values

Value	Encrypts with key commitment	Encrypts without key commitment	Decrypts with key commitment	Decrypts without key commitment
ForbidEncryptAllowDecrypt	✗	✓	✓	✓
RequireEncryptAllowDecrypt	✓	✗	✓	✓

Value	Encrypts with key commitment	Encrypts without key commitment	Decrypts with key commitment	Decrypts without key commitment
RequireEncryptRequireDecrypt	✓	✗	✓	✗

The commitment policy setting is introduced in AWS Encryption SDK version 1.7.*x*. It's valid in all supported programming languages.

- `ForbidEncryptAllowDecrypt` decrypts with or without key commitment, but it won't encrypt with key commitment. This value, introduced in version 1.7.*x*, is designed to prepare all hosts running your application to decrypt with key commitment before they ever encounter a ciphertext encrypted with key commitment.
- `RequireEncryptAllowDecrypt` always encrypts with key commitment. It can decrypt with or without key commitment. This value, introduced in version 2.0.*x*, lets you start encrypting with key commitment, but still decrypt legacy ciphertexts without key commitment.
- `RequireEncryptRequireDecrypt` encrypts and decrypts only with key commitment. This value is the default for version 2.0.*x*. Use this value when you are certain that all of your ciphertexts are encrypted with key commitment.

The commitment policy setting determines which algorithm suites you can use. Beginning in version 1.7.*x*, the AWS Encryption SDK supports algorithm suites for key commitment; with and without signing. If you specify an algorithm suite that conflicts with your commitment policy, the AWS Encryption SDK returns an error.

For help setting your commitment policy, see Setting your commitment policy.

Digital signatures

The AWS Encryption SDK encrypts your data using an authenticated encryption algorithm, AES-GCM, and the decryption process verifies the integrity and authenticity of an encrypted message without using a digital signature. But because AES-GCM uses symmetric keys, anyone who can decrypt the data key used to decrypt the ciphertext could also manually create a new encrypted ciphertext, causing a potential security concern. For instance, if you use an AWS KMS key as a

wrapping key, a user with `kms:Decrypt` permissions could create encrypted ciphertexts without calling `kms:Encrypt`.

To avoid this issue, the AWS Encryption SDK supports adding an Elliptic Curve Digital Signature Algorithm (ECDSA) signature to the end of encrypted messages. When a signing algorithm suite is used, the AWS Encryption SDK generates a temporary private key and public key pair for each encrypted message. The AWS Encryption SDK stores the public key in the encryption context of the data key and discards the private key. This ensures that no one can create another signature that verifies with the public key. The algorithm binds the public key to the encrypted data key as additional authenticated data in the message header, preventing users who can only decrypt messages from altering the public key or affecting signature verification.

Signature verification adds a significant performance cost on decryption. If the users encrypting data and the users decrypting data are equally trusted, consider using an algorithm suite that does not include signing.

> **Note**
>
> If the keyring or access to the wrapping cryptographic material doesn't delineate between encryptors and decryptors, digital signatures provide no cryptographic value.

AWS KMS keyrings, including the asymmetric RSA AWS KMS keyring, can delineate between encryptors and decryptors based on AWS KMS key policies and IAM policies.

Due to their cryptographic nature, the following keyrings cannot delineate between encryptors and decryptors:

- AWS KMS Hierarchical keyring
- AWS KMS ECDH keyring
- Raw AES keyring
- Raw RSA keyring
- Raw ECDH keyring

How the AWS Encryption SDK works

The workflows in this section explain how the AWS Encryption SDK encrypts data and decrypts encrypted messages. These workflows describes the basic process using the default features.

For details about defining and using custom components, see the GitHub repository for each supported language implementation.

The AWS Encryption SDK uses envelope encryption to protect your data. Each message is encrypted under a unique data key. Then the data key is encrypted by the wrapping keys you specify. To decrypt the encrypted message, the AWS Encryption SDK uses the wrapping keys you specify to decrypt at least one encrypted data key. Then it can decrypt the ciphertext and return a plaintext message.

Need help with the terminology we use in the AWS Encryption SDK? See the section called "Concepts".

How the AWS Encryption SDK encrypts data

The AWS Encryption SDK provides methods that encrypt strings, byte arrays, and byte streams. For code examples, see the Examples topic in each Programming languages section.

1. Create a keyring (or master key provider) that specifies the wrapping keys that protect your data.
2. Pass the keyring and plaintext data to an encryption method. We recommend that you pass in an optional, non-secret encryption context.
3. The encryption method asks the keyring for encryption materials. The keyring returns unique data encryption keys for the message: one plaintext data key and one copy of that data key encrypted by each of the specified wrapping keys.
4. The encryption method uses the plaintext data key to encrypt the data, and then discards the plaintext data key. If you provide an encryption context (an AWS Encryption SDK best practice), the encryption method cryptographically binds the encryption context to the encrypted data.
5. The encryption method returns an encrypted message that contains the encrypted data, the encrypted data keys, and other metadata, including the encryption context, if you used one.

How the AWS Encryption SDK decrypts an encrypted message

The AWS Encryption SDK provides methods that decrypt the encrypted message and return plaintext. For code examples, see the Examples topic in each Programming languages section.

The keyring (or master key provider) that decrypts the encrypted message must be compatible with the one used to encrypt the message. One of its wrapping keys must be able to decrypt an encrypted data key in the encrypted message. For information about compatibility with keyrings and master key providers, see the section called "Keyring compatibility".

1. Create a keyring or master key provider with wrapping keys that can decrypt your data. You can use the same keyring that you provided to the encryption method or a different one.
2. Pass the encrypted message and the keyring to a decryption method.
3. The decryption method asks the keyring or master key provider to decrypt one of the encrypted data keys in the encrypted message. It passes in information from the encrypted message, including the encrypted data keys.
4. The keyring uses its wrapping keys to decrypt one of the encrypted data keys. If it's successful, the response includes the plaintext data key. If none of the wrapping keys specified by the keyring or master key provider can decrypt an encrypted data key, the decrypt call fails.
5. The decryption method uses the plaintext data key to decrypt the data, discards the plaintext data key, and returns the plaintext data.

Supported algorithm suites in the AWS Encryption SDK

An *algorithm suite* is a collection of cryptographic algorithms and related values. Cryptographic systems use the algorithm implementation to generate the ciphertext message.

The AWS Encryption SDK algorithm suite uses the Advanced Encryption Standard (AES) algorithm in Galois/Counter Mode (GCM), known as AES-GCM, to encrypt raw data. The AWS Encryption SDK supports 256-bit, 192-bit, and 128-bit encryption keys. The length of the initialization vector (IV) is always 12 bytes. The length of the authentication tag is always 16 bytes.

By default, the AWS Encryption SDK uses an algorithm suite with AES-GCM with an HMAC-based extract-and-expand key derivation function (HKDF), signing, and a 256-bit encryption key. If the commitment policy requires key commitment, the AWS Encryption SDK selects an algorithm suite that also supports key commitment; otherwise, it selects an algorithm suite with key derivation and signing, but not key commitment.

Recommended: AES-GCM with key derivation, signing, and key commitment

The AWS Encryption SDK recommends an algorithm suite that derives an AES-GCM encryption key by supplying a 256-bit data encryption key to the HMAC-based extract-and-expand key derivation function (HKDF). The AWS Encryption SDK adds an Elliptic Curve Digital Signature Algorithm (ECDSA) signature. To support key commitment, this algorithm suite also derives a *key commitment string* – a non-secret data-key identifier – that is stored in the metadata of the encrypted message.

This key commitment string is also derived through HKDF using a procedure similar to deriving the data encryption key.

AWS Encryption SDK Algorithm Suite

Encryption algorithm	Data encryption key length (in bits)	Key derivation algorithm	Signature algorithm	Key commitment
AES-GCM	256	HKDF with SHA-384	ECDSA with P-384 and SHA-384	HKDF with SHA-512

The HKDF helps you avoid accidental reuse of a data encryption key and reduces the risk of overusing a data key.

For signing, this algorithm suite uses ECDSA with a cryptographic hash function algorithm (SHA-384). ECDSA is used by default, even when it is not specified by the policy for the underlying master key. Message signing verifies the message sender was authorized to encrypt messages and provides non-repudiation. It is particularly useful when the authorization policy for a master key allows one set of users to encrypt data and a different set of users to decrypt data.

Algorithm suites with key commitment ensure that each ciphertext decrypts to only one plaintext. They do this by validating the identity of the data key used as input to the encryption algorithm. When encrypting, these algorithm suites derive a key commitment string. Before decrypting, they validate that the data key matches the key commitment string. If it does not, the decrypt call fails.

Other supported algorithm suites

The AWS Encryption SDK supports the following alternate algorithm suites for backward compatibility. In general, we do not recommend these algorithm suites. However, we recognize that signing can hinder performance significantly, so we offer a key committing suite with key derivation for those cases. For applications that must make more significant performance tradeoffs, we continue to offer suites that lack signing, key commitment, and key derivation.

AES-GCM without key commitment

Algorithm suites without key commitment do not validate the data key before decrypting. As a result, these algorithm suites might decrypt a single ciphertext into different plaintext

messages. However, because algorithm suites with key commitment produce a slightly larger (+30 bytes) encrypted message and take longer to process, they might not be the best choice for every application.

The AWS Encryption SDK supports an algorithm suite with key derivation, key commitment, signing, and one with key derivation and key commitment, but not signing. We do not recommend using an algorithm suite without key commitment. If you must, we recommend an algorithm suite with key derivation and key commitment, but not signing. However, if your application performance profile supports using an algorithm suite, using an algorithm suite with key commitment, key derivation, and signing is a best practice.

AES-GCM without signing

Algorithm suites without signing lack the ECDSA signature that provides authenticity and non-repudiation. Use these suites only when the users who encrypt data and those who decrypt data are equally trusted.

When using an algorithm suite without signing, we recommend that you choose one with key derivation and key commitment.

AES-GCM without key derivation

Algorithm suites without key derivation use the data encryption key as the AES-GCM encryption key, instead of using a key derivation function to derive a unique key. We discourage using this suite to generate ciphertext, but the AWS Encryption SDK supports it for compatibility reasons.

For more information about how these suites are represented and used in the library, see the section called “Algorithms reference”.

Using the AWS Encryption SDK with AWS KMS

To use the AWS Encryption SDK, you need to configure keyrings or master key providers with wrapping keys. If you don't have a key infrastructure, we recommend using AWS Key Management Service (AWS KMS). Many of the code examples in the AWS Encryption SDK require an AWS KMS key.

To interact with AWS KMS, the AWS Encryption SDK requires the AWS SDK for your preferred programming language. The AWS Encryption SDK client library works with the AWS SDKs to support master keys stored in AWS KMS.

To prepare to use the AWS Encryption SDK with AWS KMS

1. Create an AWS account. To learn how, see How do I create and activate a new Amazon Web Services account? in the AWS Knowledge Center.
2. Create a symmetric encryption AWS KMS key. For help, see Creating Keys in the *AWS Key Management Service Developer Guide*.

   > **Tip**
   >
   > To use the AWS KMS key programmatically, you will need the key ID or Amazon Resource Name (ARN) of the AWS KMS key. For help finding the ID or ARN of an AWS KMS key, see Finding the Key ID and ARN in the *AWS Key Management Service Developer Guide*.

3. Generate an access key ID and security access key. You can use either the access key ID and secret access key for an IAM user or you can use the AWS Security Token Service to create a new session with temporary security credentials that include an access key ID, secret access key, and session token. As a security best practice, we recommend that you use temporary credentials instead of the long-term credentials associated with your IAM user or AWS (root) user accounts.

   To create an IAM user with an access key, see Creating IAM Users in the *IAM User Guide*.

   To generate temporary security credentials, see Requesting temporary security credentials in the *IAM User Guide*.
4. Set your AWS credentials using the instructions in the AWS SDK for Java, AWS SDK for JavaScript, AWS SDK for Python (Boto) or AWS SDK for C++ (for C), and the access key ID and

secret access key that you generated in step 3. If you generated temporary credentials, you will also need to specify the session token.

This procedure allows AWS SDKs to sign requests to AWS for you. Code samples in the AWS Encryption SDK that interact with AWS KMS assume that you have completed this step.

5. Download and install the AWS Encryption SDK. To learn how, see the installation instructions for the programming language that you want to use.

Best practices for the AWS Encryption SDK

The AWS Encryption SDK is designed to make it easy for you to protect your data using industry standards and best practices. While many best practices are selected for you in default values, some practices are optional but recommended whenever it's practical.

Use the latest version

When you start using the AWS Encryption SDK, use the latest version offered in your preferred programming language. If you've been using the AWS Encryption SDK, upgrade to each latest version as soon as possible. This assures that you're using the recommended configuration and taking advantage of new security properties to protect your data. For details about supported versions, including guidance for migration and deployment, see Support and maintenance and Versions of the AWS Encryption SDK.

If a new version deprecates elements in your code, replace them as soon as you can. Deprecation warnings and code comments typically recommend a good alternative.

To make significant upgrades easier and less prone to error, we occasionally provide a temporary or transitional release. Use these releases, and their accompanying documentation, to assure that you can upgrade your application without disrupting your production workflow.

Use default values

The AWS Encryption SDK designs best practices into its default values. Whenever possible, use them. For cases where the default is impractical, we provide alternatives, such as algorithm suites without signing. We also provide opportunities to advanced users for customization, such a custom keyrings, master key providers, and cryptographic material managers (CMMs). Use these advanced alternatives cautiously and have your choices verified by a security engineer whenever possible.

Use an encryption context

To improve the security of your cryptographic operations, include an encryption context with a meaningful value in all requests to encrypt data. Using an encryption context is optional, but it is a cryptographic best practice that we recommend. An encryption context provides additional authenticated data (AAD) for authenticated encryption in the AWS Encryption SDK. Although it is not secret, the encryption context can help you to protect the integrity and authenticity of your encrypted data.

In the AWS Encryption SDK, you specify an encryption context only when encrypting. When decrypting, the AWS Encryption SDK uses the encryption context in the header of the encrypted message that the AWS Encryption SDK returns. Before your application returns plaintext data, verify that the encryption context that you used to encrypt the message is included in the encryption context that was used to decrypt the message. For details, see the examples in your programming language.

When you use the command line interface, the AWS Encryption SDK verifies the encryption context for you.

Protect your wrapping keys

The AWS Encryption SDK generates a unique data key to encrypt each plaintext message. Then it encrypts the data key with wrapping keys that you supply. If your wrapping keys are lost or deleted, your encrypted data is unrecoverable. If your keys are not secured, your data might be vulnerable.

Use wrapping keys that are protected by a secure key infrastructure, such as AWS Key Management Service (AWS KMS). When using raw AES or raw RSA keys, use a source of randomness and durable storage that meets your security requirements. Generating and storing wrapping keys in a hardware security module (HSM), or a service that provides HSMs, such as AWS CloudHSM, is a best practice.

Use the authorization mechanisms of your key infrastructure to limit access to your wrapping keys to only the users that require it. Implement best practice principles, such as least privilege. When using AWS KMS keys, use key policies and IAM policies that implement best practice principles.

Specify your wrapping keys

It's always a best practice to specify your wrapping keys explicitly when decrypting, as well as encrypting. When you do, the AWS Encryption SDK uses only the keys that you specify. This practice assures that you only use the encryption keys that you intend. For AWS KMS wrapping keys, it also improves performance by preventing you from inadvertently using keys in a different AWS account or Region, or attempting to decrypt with keys that you don't have permission to use.

When encrypting, the keyrings and master key providers that the AWS Encryption SDK supplies require that you specify wrapping keys. They use all and only the wrapping keys you specify. You are also required to specify wrapping keys when encrypting and decrypting with raw AES keyrings, raw RSA keyrings, and JCEMasterKeys.

However, when decrypting with AWS KMS keyrings and master key providers, you are not required to specify wrapping keys. The AWS Encryption SDK can get the key identifier from the metadata of the encrypted data key. But specifying wrapping keys is a best practice that we recommend.

To support this best practice when working with AWS KMS wrapping keys, we recommend the following:

- Use AWS KMS keyrings that specify wrapping keys. When encrypting and decrypting, these keyrings use only the specified wrapping keys you specify.
- When using AWS KMS master keys and master key providers, use the strict mode constructors introduced in version 1.7.*x* of the AWS Encryption SDK. They create providers that encrypt and decrypt only with the wrapping keys you specify. Constructors for master key providers that always decrypt with any wrapping key are deprecated in version 1.7.*x* and deleted in version 2.0.*x*.

When specifying AWS KMS wrapping keys for decrypting is impractical, you can use discovery providers. The AWS Encryption SDK in C and JavaScript support AWS KMS discovery keyrings. Master key providers with a discovery mode are available for Java and Python in versions 1.7.*x* and later. These discovery providers, which are used only for decrypting with AWS KMS wrapping keys, explicitly direct the AWS Encryption SDK to use any wrapping key that encrypted a data key.

If you must use a discovery provider, use its *discovery filter* features to limit the wrapping keys they use. For example, the AWS KMS regional discovery keyring uses only the wrapping keys in a particular AWS Region. You can also configure AWS KMS keyrings and AWS KMS master key providers to use only the wrapping keys in particular AWS accounts. Also, as always, use key policies and IAM policies to control access to your AWS KMS wrapping keys.

Use digital signatures

It's a best practice to use an algorithm suite with signing. Digital signatures verify the message sender was authorized to send the message and protect the integrity of the message. All versions of the AWS Encryption SDK use algorithm suites with signing by default.

If your security requirements don't include digital signatures, you can select an algorithm suite without digital signatures. However, we recommend using digital signatures, especially when one group of users encrypts data and a different set of users decrypts that data.

Use key commitment

It is a best practice to use the key commitment security feature. By verifying the identity of the unique data key that encrypted your data, key commitment prevents you from decrypting any ciphertext that might result in more than one plaintext message.

The AWS Encryption SDK provides full support for encrypting and decrypting with key commitment beginning in version 2.0.*x*. By default, all of your messages are encrypted and decrypted with key commitment. Version 1.7.*x* of the AWS Encryption SDK can decrypt ciphertexts with key commitment. It is designed to help users of earlier versions deploy version 2.0.*x* successfully.

Support for key commitment includes new algorithm suites and a new message format that produces a ciphertext only 30 bytes larger than a ciphertext without key commitment. The design minimizes its impact on performance so most users can enjoy the benefits of key commitment. If your application is very sensitive to size and performance, you might decide to use the commitment policy setting to disable key commitment or allow the AWS Encryption SDK to decrypt messages without commitment, but do so only if you must.

Limit the number of encrypted data keys

It's a best practice to limit the number of encrypted data keys in messages that you decrypt, especially messages from untrusted sources. Decrypting a message with numerous encrypted data keys that you can't decrypt can cause extended delays, run up expenses, throttle your application and others that share your account, and potentially exhaust your key infrastructure. Without limits, an encrypted message can have up to 65,535 (2^16 - 1) encrypted data keys. For details, see Limiting encrypted data keys.

For more information about the AWS Encryption SDK security features that underlie these best practices, see Improved client-side encryption: Explicit KeyIds and key commitment in the *AWS Security Blog*.

Configuring the AWS Encryption SDK

The AWS Encryption SDK is designed to be easy to use. Although the AWS Encryption SDK has several configuration options, the default values are carefully chosen to be practical and secure for most applications. However, you might need to adjust your configuration to improve performance or include a custom feature in your design.

When configuring your implementation, review the AWS Encryption SDK best practices and implement as many as you can.

Topics

- Selecting a programming language
- Selecting wrapping keys
- Using multi-Region AWS KMS keys
- Choosing an algorithm suite
- Limiting encrypted data keys
- Creating a discovery filter
- Configuring the required encryption context CMM
- Setting a commitment policy
- Working with streaming data
- Caching data keys

Selecting a programming language

The AWS Encryption SDK is available in multiple programming languages. The language implementations are designed to be fully interoperable and to offer the same features, although they might be implemented in different ways. Typically, you use the library that is compatible with your application. However, you might select a programming language for a particular implementation. For example, if you prefer to work with keyrings, you might choose the AWS Encryption SDK for C or the AWS Encryption SDK for JavaScript.

Selecting wrapping keys

The AWS Encryption SDK generates a unique symmetric data key to encrypt each message. Unless you are using data key caching, you don't need to configure, manage, or use the data keys. The AWS Encryption SDK does it for you.

However, you must select one or more wrapping keys to encrypt each data key. The AWS Encryption SDK supports AES symmetric keys and RSA asymmetric keys in different sizes. It also supports AWS Key Management Service (AWS KMS) symmetric encryption AWS KMS keys. You are responsible for the safety and durability of your wrapping keys, so we recommend that you use an encryption key in a hardware security module or a key infrastructure service, such as AWS KMS.

To specify your wrapping keys for encryption and decryption, you use a keyring (C, Java, JavaScript, .NET, and Python) or a master key provider (Java, Python, AWS Encryption CLI). You can specify one wrapping key or multiple wrapping keys of the same or different types. If you use multiple wrapping keys to wrap a data key, each wrapping key will encrypt a copy of the same data key. The encrypted data keys (one per wrapping key) are stored with the encrypted data in the encrypted message that the AWS Encryption SDK returns. To decrypt the data, the AWS Encryption SDK must first use one of your wrapping keys to decrypt an encrypted data key.

To specify an AWS KMS key in a keyring or master key provider, use a supported AWS KMS key identifier. For details about the key identifiers for an AWS KMS key, see Key Identifiers in the *AWS Key Management Service Developer Guide*.

- When encrypting with the AWS Encryption SDK for Java, AWS Encryption SDK for JavaScript, AWS Encryption SDK for Python, or the AWS Encryption CLI, you can use any valid key identifier (key ID, key ARN, alias name, or alias ARN) for a KMS key. When encrypting with the AWS Encryption SDK for C, you can only use a key ID or key ARN.

  If you specify an alias name or alias ARN for a KMS key when encrypting, the AWS Encryption SDK saves the key ARN currently associated with that alias; it does not save the alias. Changes to the alias don't affect the KMS key used to decrypt your data keys.
- When decrypting in strict mode (where you specify particular wrapping keys), you must use a key ARN to identify AWS KMS keys. This requirement applies to all language implementations of the AWS Encryption SDK.

  When you encrypt with an AWS KMS keyring, the AWS Encryption SDK stores the key ARN of the AWS KMS key in the metadata of the encrypted data key. When decrypting in strict mode,

the AWS Encryption SDK verifies that the same key ARN appears in the keyring (or master key provider) before it attempts to use the wrapping key to decrypt the encrypted data key. If you use a different key identifier, the AWS Encryption SDK will not recognize or use the AWS KMS key, even if the identifiers refer to the same key.

To specify a raw AES key or a raw RSA key pair as a wrapping key in a keyring, you must specify a namespace and a name. In a master key provider, the `Provider ID` is the equivalent of the namespace and the `Key ID` is the equivalent of the name. When decrypting, you must use the exact same namespace and name for each raw wrapping key as you used when encrypting. If you use a different namespace or name, the AWS Encryption SDK will not recognize or use the wrapping key, even if the key material is the same.

Using multi-Region AWS KMS keys

You can use AWS Key Management Service (AWS KMS) multi-Region keys as wrapping keys in the AWS Encryption SDK. If you encrypt with a multi-Region key in one AWS Region, you can decrypt using a related multi-Region key in a different AWS Region. Support for multi-Region keys is introduced in version 2.3.*x* of the AWS Encryption SDK and version 3.0.*x* of the AWS Encryption CLI.

AWS KMS multi-Region keys are a set of AWS KMS keys in different AWS Regions that have the same key material and key ID. You can use these *related* keys as though they were the same key in different Regions. Multi-Region keys support common disaster recovery and backup scenarios that require encrypting in one Region and decrypting in a different Region without making a cross-Region call to AWS KMS. For information about multi-Region keys, see Using multi-Region keys in the *AWS Key Management Service Developer Guide*.

To support multi-Region keys, the AWS Encryption SDK includes AWS KMS multi-Region-aware keyrings and master key providers. The new multi-Region-aware symbol in each programming language supports both single-Region and multi-Region keys.

- For single-Region keys, the multi-Region-aware symbol behaves just like the single-Region AWS KMS keyring and master key provider. It attempts to decrypt ciphertext only with the single-Region key that encrypted the data.
- For multi-Region keys, the multi-Region-aware symbol attempts to decrypt ciphertext with the same multi-Region key that encrypted the data or with the related multi-Region replica key in the Region you specify.

In the multi-Region-aware keyrings and master key providers that take more than one KMS key, you can specify multiple single-Region and multi-Region keys. However, you can specify only one key from each set of related multi-Region replica keys. If you specify more than one key identifier with the same key ID, the constructor call fails.

You can also use a multi-Region key with the standard, single-Region AWS KMS keyrings and master key providers. However, you must use the same multi-Region key in the same Region to encrypt and decrypt. The single-Region keyrings and master key providers attempt to decrypt ciphertext only with the keys that encrypted the data.

The following examples show how to encrypt and decrypt data using multi-Region keys and the new multi-Region-aware keyrings and master key providers. These examples encrypt data in the `us-east-1` Region and decrypt the data in the `us-west-2` Region using related multi-Region replica keys in each Region. Before running these examples, replace the example multi-Region key ARN with a valid value from your AWS account.

C

To encrypt with a multi-Region key, use the `Aws::Cryptosdk::KmsMrkAwareSymmetricKeyring::Builder()` method to instantiate the keyring. Specify a multi-Region key.

This simple example does not include an encryption context. For an example that uses an encryption context in C, see Encrypting and decrypting strings.

For a complete example, see kms_multi_region_keys.cpp in the AWS Encryption SDK for C repository on GitHub.

```
/* Encrypt with a multi-Region KMS key in us-east-1 */

/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();

/* Initialize a multi-Region keyring */
const char *mrk_us_east_1 = "arn:aws:kms:us-east-1:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab";

struct aws_cryptosdk_keyring *mrk_keyring =
    Aws::Cryptosdk::KmsMrkAwareSymmetricKeyring::Builder().Build(mrk_us_east_1);

/* Create a session; release the keyring */
struct aws_cryptosdk_session *session =
```

```
    aws_cryptosdk_session_new_from_keyring_2(aws_default_allocator(),
 AWS_CRYPTOSDK_ENCRYPT, mrk_keyring);

aws_cryptosdk_keyring_release(mrk_keyring);

/* Encrypt the data
 *   aws_cryptosdk_session_process_full is designed for non-streaming data
 */
aws_cryptosdk_session_process_full(
    session, ciphertext, ciphertext_buf_sz, &ciphertext_len, plaintext,
 plaintext_len));

/* Clean up the session */
aws_cryptosdk_session_destroy(session);
```

C# / .NET

To encrypt with a multi-Region key in the US East (N. Virginia) (us-east-1) Region, instantiate a `CreateAwsKmsMrkKeyringInput` object with a key identifier for the multi-Region key and an AWS KMS client for the specified Region. Then use the `CreateAwsKmsMrkKeyring()` method to create the keyring.

The `CreateAwsKmsMrkKeyring()` method creates a keyring with exactly one multi-Region key. To encrypt with multiple wrapping keys, including a multi-Region key, use the `CreateAwsKmsMrkMultiKeyring()` method.

For a complete example, see AwsKmsMrkKeyringExample.cs in the AWS Encryption SDK for .NET repository on GitHub.

```
//Encrypt with a multi-Region KMS key in us-east-1 Region

// Instantiate the AWS Encryption SDK and material providers
var encryptionSdk = AwsEncryptionSdkFactory.CreateDefaultAwsEncryptionSdk();
var materialProviders =

 AwsCryptographicMaterialProvidersFactory.CreateDefaultAwsCryptographicMaterialProviders();


// Multi-Region keys have a distinctive key ID that begins with 'mrk'
// Specify a multi-Region key in us-east-1
string mrkUSEast1 = "arn:aws:kms:us-east-1:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab";
```

```
// Create the keyring
// You can specify the Region or get the Region from the key ARN
var createMrkEncryptKeyringInput = new CreateAwsKmsMrkKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(RegionEndpoint.USEast1),
    KmsKeyId = mrkUSEast1
};
var mrkEncryptKeyring =
 materialProviders.CreateAwsKmsMrkKeyring(createMrkEncryptKeyringInput);

// Define the encryption context
var encryptionContext = new Dictionary<string, string>()
{
    {"purpose", "test"}
};

// Encrypt your plaintext data.
var encryptInput = new EncryptInput
{
    Plaintext = plaintext,
    Keyring = mrkEncryptKeyring,
    EncryptionContext = encryptionContext
};
var encryptOutput = encryptionSdk.Encrypt(encryptInput);
```

AWS Encryption CLI

This example encrypts the `hello.txt` file under a multi-Region key in the us-east-1 Region. Because the example specifies a key ARN with a Region element, this example doesn't use the **region** attribute of the `--wrapping-keys` parameter.

When the key ID of the wrapping key doesn't specify a Region, you can use the **region** attribute of the `--wrapping-keys` to specify the region, such as `--wrapping-keys key=$keyID region=us-east-1`.

```
# Encrypt with a multi-Region KMS key in us-east-1 Region

# To run this example, replace the fictitious key ARN with a valid value.
$ mrkUSEast1=arn:aws:kms:us-east-1:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab

$ aws-encryption-cli --encrypt \
                     --input hello.txt \
```

```
                        --wrapping-keys key=$mrkUSEast1 \
                        --metadata-output ~/metadata \
                        --encryption-context purpose=test \
                        --output .
```

Java

To encrypt with a multi-Region key, instantiate an `AwsKmsMrkAwareMasterKeyProvider` and specify a multi-Region key.

For a complete example, see BasicMultiRegionKeyEncryptionExample.java in the AWS Encryption SDK for Java repository on GitHub.

```
//Encrypt with a multi-Region KMS key in us-east-1 Region

// Instantiate the client
final AwsCrypto crypto = AwsCrypto.builder()
    .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
    .build();

// Multi-Region keys have a distinctive key ID that begins with 'mrk'
// Specify a multi-Region key in us-east-1
final String mrkUSEast1 = "arn:aws:kms:us-east-1:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab";

// Instantiate an AWS KMS master key provider in strict mode for multi-Region keys
// Configure it to encrypt with the multi-Region key in us-east-1
final AwsKmsMrkAwareMasterKeyProvider kmsMrkProvider =
 AwsKmsMrkAwareMasterKeyProvider
    .builder()
    .buildStrict(mrkUSEast1);

// Create an encryption context
final Map<String, String> encryptionContext = Collections.singletonMap("Purpose",
 "Test");

// Encrypt your plaintext data
final CryptoResult<byte[], AwsKmsMrkAwareMasterKey> encryptResult =
 crypto.encryptData(
    kmsMrkProvider,
    encryptionContext,
    sourcePlaintext);
byte[] ciphertext = encryptResult.getResult();
```

JavaScript Browser

To encrypt with a multi-Region key, use the `buildAwsKmsMrkAwareStrictMultiKeyringBrowser()` method to create the keyring and specify a multi-Region key.

For a complete example, see kms_multi_region_simple.ts in the AWS Encryption SDK for JavaScript repository on GitHub.

```
/* Encrypt with a multi-Region KMS key in us-east-1 Region */

import {
  buildAwsKmsMrkAwareStrictMultiKeyringBrowser,
  buildClient,
  CommitmentPolicy,
  KMS,
} from '@aws-crypto/client-browser'


/* Instantiate an AWS Encryption SDK client */
const { encrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

declare const credentials: {
  accessKeyId: string
  secretAccessKey: string
  sessionToken: string
}

/* Instantiate an AWS KMS client
 * The AWS Encryption SDK for JavaScript gets the Region from the key ARN
 */
const clientProvider = (region: string) => new KMS({ region, credentials })


/* Specify a multi-Region key in us-east-1 */
const multiRegionUsEastKey =
    'arn:aws:kms:us-east-1:111122223333:key/mrk-1234abcd12ab34cd56ef1234567890ab'

/* Instantiate the keyring */
const encryptKeyring = buildAwsKmsMrkAwareStrictMultiKeyringBrowser({
    generatorKeyId: multiRegionUsEastKey,
```

```
    clientProvider,
  })


/* Set the encryption context */
const context = {
    purpose: 'test',
  }

/* Test data to encrypt */
const cleartext = new Uint8Array([1, 2, 3, 4, 5])

/* Encrypt the data */
const { result } = await encrypt(encryptKeyring, cleartext, {
    encryptionContext: context,
  })
```

JavaScript Node.js

To encrypt with a multi-Region key, use the `buildAwsKmsMrkAwareStrictMultiKeyringNode()` method to create the keyring and specify a multi-Region key.

For a complete example, see kms_multi_region_simple.ts in the AWS Encryption SDK for JavaScript repository on GitHub.

```
//Encrypt with a multi-Region KMS key in us-east-1 Region

import { buildClient } from '@aws-crypto/client-node'

/* Instantiate the AWS Encryption SDK client
const { encrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

/* Test string to encrypt */
const cleartext = 'asdf'

/* Multi-Region keys have a distinctive key ID that begins with 'mrk'
 * Specify a multi-Region key in us-east-1
 */
const multiRegionUsEastKey =
    'arn:aws:kms:us-east-1:111122223333:key/mrk-1234abcd12ab34cd56ef1234567890ab'
```

```
/* Create an AWS KMS keyring */
const mrkEncryptKeyring = buildAwsKmsMrkAwareStrictMultiKeyringNode({
    generatorKeyId: multiRegionUsEastKey,
  })

/* Specify an encryption context */
const context = {
    purpose: 'test',
  }

/* Create an encryption keyring */
const { result } = await encrypt(mrkEncryptKeyring, cleartext, {
    encryptionContext: context,
  })
```

Python

To encrypt with an AWS KMS multi-Region key, use the `MRKAwareStrictAwsKmsMasterKeyProvider()` method and specify a multi-Region key.

For a complete example, see mrk_aware_kms_provider.py in the AWS Encryption SDK for Python repository on GitHub.

```
* Encrypt with a multi-Region KMS key in us-east-1 Region

# Instantiate the client
client =
 aws_encryption_sdk.EncryptionSDKClient(commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_R

# Specify a multi-Region key in us-east-1
mrk_us_east_1 = "arn:aws:kms:us-east-1:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab"

# Use the multi-Region method to create the master key provider
# in strict mode
strict_mrk_key_provider = MRKAwareStrictAwsKmsMasterKeyProvider(
        key_ids=[mrk_us_east_1]
)

# Set the encryption context
encryption_context = {
        "purpose": "test"
```

```
    }

# Encrypt your plaintext data
ciphertext, encrypt_header = client.encrypt(
        source=source_plaintext,
        encryption_context=encryption_context,
        key_provider=strict_mrk_key_provider
)
```

Next, move your ciphertext to the `us-west-2` Region. You don't need to re-encrypt the ciphertext.

To decrypt the ciphertext in strict mode in the `us-west-2` Region, instantiate the multi-Region-aware symbol with the key ARN of the related multi-Region key in the `us-west-2` Region. If you specify the key ARN of a related multi-Region key in a different Region (including `us-east-1`, where it was encrypted), the multi-Region-aware symbol will make a cross-Region call for that AWS KMS key.

When decrypting in strict mode, the multi-Region-aware symbol requires a key ARN. It accepts only one key ARN from each set of related multi-Region keys.

Before running these examples, replace the example multi-Region key ARN with a valid value from your AWS account.

C

To decrypt in strict mode with a multi-Region key, use the `Aws::Cryptosdk::KmsMrkAwareSymmetricKeyring::Builder()` method to instantiate the keyring. Specify the related multi-Region key in the local (us-west-2) Region.

For a complete example, see kms_multi_region_keys.cpp in the AWS Encryption SDK for C repository on GitHub.

```
/* Decrypt with a related multi-Region KMS key in us-west-2 Region */

/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();

/* Initialize a multi-Region keyring */
const char *mrk_us_west_2 = "arn:aws:kms:us-west-2:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab";
```

```
struct aws_cryptosdk_keyring *mrk_keyring =
    Aws::Cryptosdk::KmsMrkAwareSymmetricKeyring::Builder().Build(mrk_us_west_2);

/* Create a session; release the keyring */
struct aws_cryptosdk_session *session =
    aws_cryptosdk_session_new_from_keyring_2(aws_default_allocator(),
 AWS_CRYPTOSDK_ENCRYPT, mrk_keyring);

aws_cryptosdk_session_set_commitment_policy(session,
    COMMITMENT_POLICY_REQUIRE_ENCRYPT_REQUIRE_DECRYPT);

aws_cryptosdk_keyring_release(mrk_keyring);

/* Decrypt the ciphertext
 *   aws_cryptosdk_session_process_full is designed for non-streaming data
 */
aws_cryptosdk_session_process_full(
    session, plaintext, plaintext_buf_sz, &plaintext_len, ciphertext,
 ciphertext_len));

/* Clean up the session */
aws_cryptosdk_session_destroy(session);
```

C# / .NET

To decrypt in strict mode with a single multi-Region key, use the same constructors and methods that you used to assemble the input and create the keyring for encrypting. Instantiate a `CreateAwsKmsMrkKeyringInput` object with the key ARN of a related multi-Region key and an AWS KMS client for the US West (Oregon) (us-west-2) Region. Then use the `CreateAwsKmsMrkKeyring()` method to create a multi-Region keyring with one multi-Region KMS key.

For a complete example, see AwsKmsMrkKeyringExample.cs in the AWS Encryption SDK for .NET repository on GitHub.

```
// Decrypt with a related multi-Region KMS key in us-west-2 Region

// Instantiate the AWS Encryption SDK and material providers
var encryptionSdk = AwsEncryptionSdkFactory.CreateDefaultAwsEncryptionSdk();
var materialProviders =

 AwsCryptographicMaterialProvidersFactory.CreateDefaultAwsCryptographicMaterialProviders();
```

```
// Specify the key ARN of the multi-Region key in us-west-2
string mrkUSWest2 = "arn:aws:kms:us-west-2:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab";

// Instantiate the keyring input
// You can specify the Region or get the Region from the key ARN
var createMrkDecryptKeyringInput = new CreateAwsKmsMrkKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(RegionEndpoint.USWest2),
    KmsKeyId = mrkUSWest2
};

// Create the multi-Region keyring
var mrkDecryptKeyring =
 materialProviders.CreateAwsKmsMrkKeyring(createMrkDecryptKeyringInput);

// Decrypt the ciphertext
var decryptInput = new DecryptInput
{
    Ciphertext = ciphertext,
    Keyring = mrkDecryptKeyring
};
var decryptOutput = encryptionSdk.Decrypt(decryptInput);
```

AWS Encryption CLI

To decrypt with the related multi-Region key in the us-west-2 Region, use the **key** attribute of the `--wrapping-keys` parameter to specify its key ARN.

```
# Decrypt with a related multi-Region KMS key in us-west-2 Region

# To run this example, replace the fictitious key ARN with a valid value.
$ mrkUSWest2=arn:aws:kms:us-west-2:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab

$ aws-encryption-cli --decrypt \
                     --input hello.txt.encrypted \
                     --wrapping-keys key=$mrkUSWest2 \
                     --commitment-policy require-encrypt-require-decrypt \
                     --encryption-context purpose=test \
                     --metadata-output ~/metadata \
                     --max-encrypted-data-keys 1 \
```

```
                        --buffer \
                        --output .
```

Java

To decrypt in strict mode, instantiate an `AwsKmsMrkAwareMasterKeyProvider` and specify the related multi-Region key in the local (us-west-2) Region.

For a complete example, see BasicMultiRegionKeyEncryptionExample.java in the AWS Encryption SDK for Java repository on GitHub.

```
// Decrypt with a related multi-Region KMS key in us-west-2 Region

// Instantiate the client
final AwsCrypto crypto = AwsCrypto.builder()
    .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
    .build();

// Related multi-Region keys have the same key ID. Their key ARNs differs only in
 the Region field.
String mrkUSWest2 = "arn:aws:kms:us-west-2:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab";

// Use the multi-Region method to create the master key provider
// in strict mode
AwsKmsMrkAwareMasterKeyProvider kmsMrkProvider =
 AwsKmsMrkAwareMasterKeyProvider.builder()
    .buildStrict(mrkUSWest2);

// Decrypt your ciphertext
CryptoResult<byte[], AwsKmsMrkAwareMasterKey> decryptResult = crypto.decryptData(
        kmsMrkProvider,
        ciphertext);
byte[] decrypted = decryptResult.getResult();
```

JavaScript Browser

To decrypt in strict mode, use the `buildAwsKmsMrkAwareStrictMultiKeyringBrowser()` method to create the keyring and specify the related multi-Region key in the local (us-west-2) Region.

For a complete example, see kms_multi_region_simple.ts in the AWS Encryption SDK for JavaScript repository on GitHub.

```
/* Decrypt with a related multi-Region KMS key in us-west-2 Region */

import {
  buildAwsKmsMrkAwareStrictMultiKeyringBrowser,
  buildClient,
  CommitmentPolicy,
  KMS,
} from '@aws-crypto/client-browser'


/* Instantiate an AWS Encryption SDK client */
const { decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

declare const credentials: {
  accessKeyId: string
  secretAccessKey: string
  sessionToken: string
}

/* Instantiate an AWS KMS client
 * The AWS Encryption SDK for JavaScript gets the Region from the key ARN
 */
const clientProvider = (region: string) => new KMS({ region, credentials })


/* Specify a multi-Region key in us-west-2 */
const multiRegionUsWestKey =
    'arn:aws:kms:us-west-2:111122223333:key/mrk-1234abcd12ab34cd56ef1234567890ab'

/* Instantiate the keyring */
const mrkDecryptKeyring = buildAwsKmsMrkAwareStrictMultiKeyringBrowser({
    generatorKeyId: multiRegionUsWestKey,
    clientProvider,
  })


/* Decrypt the data */
const { plaintext, messageHeader } = await decrypt(mrkDecryptKeyring, result)
```

JavaScript Node.js

To decrypt in strict mode, use the `buildAwsKmsMrkAwareStrictMultiKeyringNode()` method to create the keyring and specify the related multi-Region key in the local (us-west-2) Region.

For a complete example, see kms_multi_region_simple.ts in the AWS Encryption SDK for JavaScript repository on GitHub.

```
/* Decrypt with a related multi-Region KMS key in us-west-2 Region */

import { buildClient } from '@aws-crypto/client-node'

/* Instantiate the client
const { decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

/* Multi-Region keys have a distinctive key ID that begins with 'mrk'
 * Specify a multi-Region key in us-west-2
 */
const multiRegionUsWestKey =
    'arn:aws:kms:us-west-2:111122223333:key/mrk-1234abcd12ab34cd56ef1234567890ab'

/* Create an AWS KMS keyring */
const mrkDecryptKeyring = buildAwsKmsMrkAwareStrictMultiKeyringNode({
    generatorKeyId: multiRegionUsWestKey,
  })

/* Decrypt your ciphertext */
const { plaintext, messageHeader } = await decrypt(decryptKeyring, result)
```

Python

To decrypt in strict mode, use the `MRKAwareStrictAwsKmsMasterKeyProvider()` method to create the master key provider. Specify the related multi-Region key in the local (us-west-2) Region.

For a complete example, see mrk_aware_kms_provider.py in the AWS Encryption SDK for Python repository on GitHub.

```
# Decrypt with a related multi-Region KMS key in us-west-2 Region
```

```
# Instantiate the client
client =
 aws_encryption_sdk.EncryptionSDKClient(commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_R

# Related multi-Region keys have the same key ID. Their key ARNs differs only in the
 Region field
mrk_us_west_2 = "arn:aws:kms:us-west-2:111122223333:key/
mrk-1234abcd12ab34cd56ef1234567890ab"

# Use the multi-Region method to create the master key provider
# in strict mode
strict_mrk_key_provider = MRKAwareStrictAwsKmsMasterKeyProvider(
        key_ids=[mrk_us_west_2]
)

# Decrypt your ciphertext
plaintext, _ = client.decrypt(
        source=ciphertext,
        key_provider=strict_mrk_key_provider
)
```

You can also decrypt in *discovery mode* with AWS KMS multi-Region keys. When decrypting in discovery mode, you don't specify any AWS KMS keys. (For information about single-Region AWS KMS discovery keyrings, see Using an AWS KMS discovery keyring.)

If you encrypted with a multi-Region key, the multi-Region-aware symbol in discovery mode will try to decrypt by using a related multi-Region key in the local Region. If none exists; the call fails. In discovery mode, the AWS Encryption SDK will not attempt a cross-Region call for the multi-Region key used for encryption.

> **Note**
>
> If you use a multi-Region-aware symbol in discovery mode to encrypt data, the encrypt operation fails.

The following example shows how to decrypt with the multi-Region-aware symbol in discovery mode. Because you don't specify an AWS KMS key, the AWS Encryption SDK must get the Region from a different source. When possible, specify the local Region explicitly. Otherwise, the AWS

Encryption SDK gets the local Region from the Region configured in the AWS SDK for your programming language.

Before running these examples, replace the example account ID and multi-Region key ARN with valid values from your AWS account.

C

To decrypt in discovery mode with a multi-Region key, use the `Aws::Cryptosdk::KmsMrkAwareSymmetricKeyring::Builder()` method to build the keyring, and the `Aws::Cryptosdk::KmsKeyring::DiscoveryFilter::Builder()` method to build the discovery filter. To specify the local Region, define a `ClientConfiguration` and specify it in the AWS KMS client.

For a complete example, see kms_multi_region_keys.cpp in the AWS Encryption SDK for C repository on GitHub.

```
/* Decrypt in discovery mode with a multi-Region KMS key */

/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();

/* Construct a discovery filter for the account and partition. The
 *  filter is optional, but it's a best practice that we recommend.
 */
const char *account_id = "111122223333";
const char *partition = "aws";
const std::shared_ptr<Aws::Cryptosdk::KmsKeyring::DiscoveryFilter> discovery_filter
 =

 Aws::Cryptosdk::KmsKeyring::DiscoveryFilter::Builder(partition).AddAccount(account_id).Buil

/* Create an AWS KMS client in the desired region. */
const char *region = "us-west-2";

Aws::Client::ClientConfiguration client_config;
client_config.region = region;
const std::shared_ptr<Aws::KMS::KMSClient> kms_client =
    Aws::MakeShared<Aws::KMS::KMSClient>("AWS_SAMPLE_CODE", client_config);

struct aws_cryptosdk_keyring *mrk_keyring =
    Aws::Cryptosdk::KmsMrkAwareSymmetricKeyring::Builder()
        .WithKmsClient(kms_client)
```

```
        .BuildDiscovery(region, discovery_filter);

/* Create a session; release the keyring */
struct aws_cryptosdk_session *session =
    aws_cryptosdk_session_new_from_keyring_2(aws_default_allocator(),
 AWS_CRYPTOSDK_DECRYPT, mrk_keyring);

aws_cryptosdk_keyring_release(mrk_keyring);
commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
/* Decrypt the ciphertext
 *   aws_cryptosdk_session_process_full is designed for non-streaming data
 */
aws_cryptosdk_session_process_full(
    session, plaintext, plaintext_buf_sz, &plaintext_len, ciphertext,
 ciphertext_len));

/* Clean up the session */
aws_cryptosdk_session_destroy(session);
```

C# / .NET

To create a multi-Region-aware discovery keyring in the AWS Encryption SDK for .NET, instantiate a `CreateAwsKmsMrkDiscoveryKeyringInput` object that takes an AWS KMS client for a particular AWS Region, and an optional discovery filter that limits KMS keys to a particular AWS partition and account. Then call the `CreateAwsKmsMrkDiscoveryKeyring()` method with the input object. For a complete example, see AwsKmsMrkDiscoveryKeyringExample.cs in the AWS Encryption SDK for .NET repository on GitHub.

To create a multi-Region-aware discovery keyring for more than one AWS Region, use the `CreateAwsKmsMrkDiscoveryMultiKeyring()` method to create a multi-keyring, or use `CreateAwsKmsMrkDiscoveryKeyring()` to create several multi-Region-aware discovery keyrings and then use the `CreateMultiKeyring()` method to combine them in a multi-keyring.

For an example, see AwsKmsMrkDiscoveryMultiKeyringExample.cs.

```
// Decrypt in discovery mode with a multi-Region KMS key

// Instantiate the AWS Encryption SDK and material providers
var encryptionSdk = AwsEncryptionSdkFactory.CreateDefaultAwsEncryptionSdk();
var materialProviders =
```

```
 AwsCryptographicMaterialProvidersFactory.CreateDefaultAwsCryptographicMaterialProviders();

List<string> account = new List<string> { "111122223333" };

// Instantiate the discovery filter
DiscoveryFilter mrkDiscoveryFilter = new DiscoveryFilter()
{
    AccountIds = account,
    Partition = "aws"
}

// Create the keyring
var createMrkDiscoveryKeyringInput = new CreateAwsKmsMrkDiscoveryKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(RegionEndpoint.USWest2),
    DiscoveryFilter = mrkDiscoveryFilter
};
var mrkDiscoveryKeyring =
 materialProviders.CreateAwsKmsMrkDiscoveryKeyring(createMrkDiscoveryKeyringInput);


// Decrypt the ciphertext
var decryptInput = new DecryptInput
{
    Ciphertext = ciphertext,
    Keyring = mrkDiscoveryKeyring
};
var decryptOutput = encryptionSdk.Decrypt(decryptInput);
```

AWS Encryption CLI

To decrypt in discovery mode, use the **discovery** attribute of the `--wrapping-keys` parameter. The **discovery-account** and **discovery-partition** attributes create a discovery filter that is optional, but recommended.

To specify the Region, this command includes the **region** attribute of the `--wrapping-keys` parameter.

```
# Decrypt in discovery mode with a multi-Region KMS key

$ aws-encryption-cli --decrypt \
                     --input hello.txt.encrypted \
```

```
                        --wrapping-keys discovery=true \
                                        discovery-account=111122223333 \
                                        discovery-partition=aws \
                                        region=us-west-2 \
                        --encryption-context purpose=test \
                        --metadata-output ~/metadata \
                        --max-encrypted-data-keys 1 \
                        --buffer \
                        --output .
```

Java

To specify the local Region, use the `builder().withDiscoveryMrkRegion` parameter. Otherwise, the AWS Encryption SDK gets the local Region from the Region configured in the AWS SDK for Java.

For a complete example, see DiscoveryMultiRegionDecryptionExample.java in the AWS Encryption SDK for Java repository on GitHub.

```
// Decrypt in discovery mode with a multi-Region KMS key

// Instantiate the client
final AwsCrypto crypto = AwsCrypto.builder()
    .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
    .build();

DiscoveryFilter discoveryFilter = new DiscoveryFilter("aws", 111122223333);

AwsKmsMrkAwareMasterKeyProvider mrkDiscoveryProvider =
 AwsKmsMrkAwareMasterKeyProvider
    .builder()
    .withDiscoveryMrkRegion(Region.US_WEST_2)
    .buildDiscovery(discoveryFilter);

// Decrypt your ciphertext
final CryptoResult<byte[], AwsKmsMrkAwareMasterKey> decryptResult = crypto
    .decryptData(mrkDiscoveryProvider, ciphertext);
```

JavaScript Browser

To decrypt in discovery mode with a symmetric multi-Region key, use the `AwsKmsMrkAwareSymmetricDiscoveryKeyringBrowser()` method.

For a complete example, see kms_multi_region_discovery.ts in the AWS Encryption SDK for JavaScript repository on GitHub.

```
/* Decrypt in discovery mode with a multi-Region KMS key */

import {
  AwsKmsMrkAwareSymmetricDiscoveryKeyringBrowser,
  buildClient,
  CommitmentPolicy,
  KMS,
} from '@aws-crypto/client-browser'


/* Instantiate an AWS Encryption SDK client */
const { decrypt } = buildClient()

declare const credentials: {
  accessKeyId: string
  secretAccessKey: string
  sessionToken: string
}

/* Instantiate the KMS client with an explicit Region */
const client = new KMS({ region: 'us-west-2', credentials })


/* Create a discovery filter */
const discoveryFilter = { partition: 'aws', accountIDs: ['111122223333'] }


/* Create an AWS KMS discovery keyring */
const mrkDiscoveryKeyring = new AwsKmsMrkAwareSymmetricDiscoveryKeyringBrowser({
    client,
    discoveryFilter,
  })


/* Decrypt the data */
const { plaintext, messageHeader } = await decrypt(mrkDiscoveryKeyring, ciphertext)
```

JavaScript Node.js

To decrypt in discovery mode with a symmetric multi-Region key, use the `AwsKmsMrkAwareSymmetricDiscoveryKeyringNode()` method.

For a complete example, see kms_multi_region_discovery.ts in the AWS Encryption SDK for JavaScript repository on GitHub.

```
/* Decrypt in discovery mode with a multi-Region KMS key */

import {
  AwsKmsMrkAwareSymmetricDiscoveryKeyringNode,
  buildClient,
  CommitmentPolicy,
  KMS,
} from '@aws-crypto/client-node'

/* Instantiate the Encryption SDK client
const { decrypt } = buildClient()

/* Instantiate the KMS client with an explicit Region */
const client = new KMS({ region: 'us-west-2' })

/* Create a discovery filter */
const discoveryFilter = { partition: 'aws', accountIDs: ['111122223333'] }

/* Create an AWS KMS discovery keyring */
const mrkDiscoveryKeyring = new AwsKmsMrkAwareSymmetricDiscoveryKeyringNode({
    client,
    discoveryFilter,
  })

/* Decrypt your ciphertext */
const { plaintext, messageHeader } = await decrypt(mrkDiscoveryKeyring, result)
```

Python

To decrypt in discovery mode with a multi-Region key, use the `MRKAwareDiscoveryAwsKmsMasterKeyProvider()` method.

For a complete example, see mrk_aware_kms_provider.py in the AWS Encryption SDK for Python repository on GitHub.

```
# Decrypt in discovery mode with a multi-Region KMS key

# Instantiate the client
client = aws_encryption_sdk.EncryptionSDKClient()

# Create the discovery filter and specify the region
decrypt_kwargs = dict(
        discovery_filter=DiscoveryFilter(account_ids="111122223333",
 partition="aws"),
        discovery_region="us-west-2",
    )

# Use the multi-Region method to create the master key provider
# in discovery mode
mrk_discovery_key_provider =
 MRKAwareDiscoveryAwsKmsMasterKeyProvider(**decrypt_kwargs)

# Decrypt your ciphertext
plaintext, _ = client.decrypt(
        source=ciphertext,
        key_provider=mrk_discovery_key_provider
)
```

Choosing an algorithm suite

The AWS Encryption SDK supports several symmetric and asymmetric encryption algorithms for encrypting your data keys under the wrapping keys you specify. However, when it uses those data keys to encrypt your data, the AWS Encryption SDK defaults to a recommended algorithm suite that uses the AES-GCM algorithm with key derivation, digital signatures, and key commitment. Although the default algorithm suite is likely to be suitable for most applications, you can choose an alternate algorithm suite. For example, some trust models would be satisfied by an algorithm suite without digital signatures. For information about the algorithm suites that the AWS Encryption SDK supports, see Supported algorithm suites in the AWS Encryption SDK.

The following examples show you how to select an alternate algorithm suite when encrypting. These examples select a recommended AES-GCM algorithm suite with key derivation and key commitment, but without digital signatures. When you encrypt with an algorithm suite that does not include digital signatures, use the unsigned-only decryption mode when decrypting. This mode, which fails if it encounters a signed ciphertext, is most useful when streaming decryption.

C

To specify an alternate algorithm suite in the AWS Encryption SDK for C, you must create a CMM explicitly. Then use the `aws_cryptosdk_default_cmm_set_alg_id` with the CMM and the selected algorithm suite.

```
/* Specify an algorithm suite without signing */

/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();

/* Construct an AWS KMS keyring */
struct aws_cryptosdk_keyring *kms_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder().Build(key_arn);

/* To set an alternate algorithm suite, create an cryptographic
   materials manager (CMM) explicitly
 */
struct aws_cryptosdk_cmm *cmm =
 aws_cryptosdk_default_cmm_new(aws_default_allocator(), kms_keyring);
aws_cryptosdk_keyring_release(kms_keyring);

/* Specify the algorithm suite for the CMM */
aws_cryptosdk_default_cmm_set_alg_id(cmm, ALG_AES256_GCM_HKDF_SHA512_COMMIT_KEY);

/* Construct the session with the CMM,
   then release the CMM reference
 */
struct aws_cryptosdk_session *session = aws_cryptosdk_session_new_from_cmm_2(alloc,
 AWS_CRYPTOSDK_ENCRYPT, cmm);
aws_cryptosdk_cmm_release(cmm);

/* Encrypt the data
   Use aws_cryptosdk_session_process_full with non-streaming data
 */
if (AWS_OP_SUCCESS != aws_cryptosdk_session_process_full(
                          session,
                          ciphertext,
                          ciphertext_buf_sz,
                          &ciphertext_len,
                          plaintext,
                          plaintext_len)) {
    aws_cryptosdk_session_destroy(session);
```

```
    return AWS_OP_ERR;
}
```

When decrypting data that was encrypted without digital signatures, use `AWS_CRYPTOSDK_DECRYPT_UNSIGNED`. This causes the decrypt to fail if it encounters signed ciphertext.

```
/* Decrypt unsigned streaming data */

/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();

/* Construct an AWS KMS keyring */
struct aws_cryptosdk_keyring *kms_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder().Build(key_arn);

/* Create a session for decrypting with the AWS KMS keyring
   Then release the keyring reference
 */
struct aws_cryptosdk_session *session =

 aws_cryptosdk_session_new_from_keyring_2(alloc, AWS_CRYPTOSDK_DECRYPT_UNSIGNED,
 kms_keyring);
aws_cryptosdk_keyring_release(kms_keyring);

if (!session) {
    return AWS_OP_ERR;
}

/* Limit encrypted data keys */
aws_cryptosdk_session_set_max_encrypted_data_keys(session, 1);

/* Decrypt
   Use aws_cryptosdk_session_process_full with non-streaming data
 */
    if (AWS_OP_SUCCESS != aws_cryptosdk_session_process_full(
                          session,
                          plaintext,
                          plaintext_buf_sz,
                          &plaintext_len,
                          ciphertext,
                          ciphertext_len)) {
    aws_cryptosdk_session_destroy(session);
```

```
    return AWS_OP_ERR;
}
```

C# / .NET

To specify an alternate algorithm suite in the AWS Encryption SDK for .NET, specify the `AlgorithmSuiteId` property of an EncryptInput object. The AWS Encryption SDK for .NET includes constants that you can use to identify your preferred algorithm suite.

The AWS Encryption SDK for .NET doesn't have a method to detect signed ciphertext when streaming decryption because this library doesn't support streaming data.

```
// Specify an algorithm suite without signing

// Instantiate the AWS Encryption SDK and material providers
var encryptionSdk = AwsEncryptionSdkFactory.CreateDefaultAwsEncryptionSdk();
var materialProviders =

 AwsCryptographicMaterialProvidersFactory.CreateDefaultAwsCryptographicMaterialProviders();

// Create the keyring
var keyringInput = new CreateAwsKmsKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    KmsKeyId = keyArn
};
var keyring = materialProviders.CreateAwsKmsKeyring(keyringInput);

// Encrypt your plaintext data
var encryptInput = new EncryptInput
{
    Plaintext = plaintext,
    Keyring = keyring,
    AlgorithmSuiteId = AlgorithmSuiteId.ALG_AES_256_GCM_HKDF_SHA512_COMMIT_KEY
};
var encryptOutput = encryptionSdk.Encrypt(encryptInput);
```

AWS Encryption CLI

When encrypting the `hello.txt` file, this example uses the `--algorithm` parameter to specify an algorithm suite without digital signatures.

```
# Specify an algorithm suite without signing
```

```
# To run this example, replace the fictitious key ARN with a valid value.
$ keyArn=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

$ aws-encryption-cli --encrypt \
                     --input hello.txt \
                     --wrapping-keys key=$keyArn \
                     --algorithm AES_256_GCM_HKDF_SHA512_COMMIT_KEY \
                     --metadata-output ~/metadata \
                     --encryption-context purpose=test \
                     --commitment-policy require-encrypt-require-decrypt \
                     --output hello.txt.encrypted \
                     --decode
```

When decrypting, this example uses the `--decrypt-unsigned` parameter. This parameter is recommended to ensure that you are decrypting unsigned ciphertext, especially with the CLI, which is always streaming input and output.

```
# Decrypt unsigned streaming data

# To run this example, replace the fictitious key ARN with a valid value.
$ keyArn=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

$ aws-encryption-cli --decrypt-unsigned \
                     --input hello.txt.encrypted \
                     --wrapping-keys key=$keyArn \
                     --max-encrypted-data-keys 1 \
                     --commitment-policy require-encrypt-require-decrypt \
                     --encryption-context purpose=test \
                     --metadata-output ~/metadata \
                     --output .
```

Java

To specify an alternate algorithm suite, use the `AwsCrypto.builder().withEncryptionAlgorithm()` method. This example specifies an alternate algorithm suite without digital signatures.

```
// Specify an algorithm suite without signing

// Instantiate the client
AwsCrypto crypto = AwsCrypto.builder()
```

```
    .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
    .withEncryptionAlgorithm(CryptoAlgorithm.ALG_AES_256_GCM_HKDF_SHA512_COMMIT_KEY)
    .build();

String awsKmsKey = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

// Create a master key provider in strict mode
KmsMasterKeyProvider masterKeyProvider = KmsMasterKeyProvider.builder()
    .buildStrict(awsKmsKey);

// Create an encryption context to identify this ciphertext
        Map<String, String> encryptionContext = Collections.singletonMap("Example",
 "FileStreaming");

// Encrypt your plaintext data
CryptoResult<byte[], KmsMasterKey> encryptResult = crypto.encryptData(
    masterKeyProvider,
    sourcePlaintext,
    encryptionContext);
byte[] ciphertext = encryptResult.getResult();
```

When streaming data for decryption, use the `createUnsignedMessageDecryptingStream()` method to ensure that all ciphertext that you're decrypting is unsigned.

```
// Decrypt unsigned streaming data

// Instantiate the client
AwsCrypto crypto = AwsCrypto.builder()
  .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
  .withMaxEncryptedDataKeys(1)
  .build();

// Create a master key provider in strict mode
String awsKmsKey = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";
KmsMasterKeyProvider masterKeyProvider = KmsMasterKeyProvider.builder()
  .buildStrict(awsKmsKey);

// Decrypt the encrypted message
FileInputStream in = new FileInputStream(srcFile + ".encrypted");
```

```
CryptoInputStream<KmsMasterKey> decryptingStream =
 crypto.createUnsignedMessageDecryptingStream(masterKeyProvider, in);

// Return the plaintext data
// Write the plaintext data to disk
FileOutputStream out = new FileOutputStream(srcFile + ".decrypted");
IOUtils.copy(decryptingStream, out);
decryptingStream.close();
```

JavaScript Browser

To specify an alternate algorithm suite, use the `suiteId` parameter with an `AlgorithmSuiteIdentifier` enum value.

```
// Specify an algorithm suite without signing

// Instantiate the client
const { encrypt } = buildClient( CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT )

// Specify a KMS key
const generatorKeyId = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

// Create a keyring with the KMS key
const keyring = new KmsKeyringBrowser({ generatorKeyId })

// Encrypt your plaintext data
const { result } = await encrypt(keyring, cleartext, { suiteId:
 AlgorithmSuiteIdentifier.ALG_AES256_GCM_IV12_TAG16_HKDF_SHA512_COMMIT_KEY,
 encryptionContext: context, })
```

When decrypting, use the standard `decrypt` method. AWS Encryption SDK for JavaScript in the browser doesn't have a `decrypt-unsigned` mode because the browser doesn't support streaming.

```
// Decrypt unsigned streaming data

// Instantiate the client
const { decrypt } = buildClient( CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT )

// Create a keyring with the same KMS key used to encrypt
const generatorKeyId = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";
```

```
const keyring = new KmsKeyringBrowser({ generatorKeyId })

// Decrypt the encrypted message
const { plaintext, messageHeader } = await decrypt(keyring, ciphertextMessage)
```

JavaScript Node.js

To specify an alternate algorithm suite, use the `suiteId` parameter with an `AlgorithmSuiteIdentifier` enum value.

```
// Specify an algorithm suite without signing

// Instantiate the client
const { encrypt } = buildClient( CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT )

// Specify a KMS key
const generatorKeyId = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

// Create a keyring with the KMS key
const keyring = new KmsKeyringNode({ generatorKeyId })

// Encrypt your plaintext data
const { result } = await encrypt(keyring, cleartext, { suiteId:
 AlgorithmSuiteIdentifier.ALG_AES256_GCM_IV12_TAG16_HKDF_SHA512_COMMIT_KEY,
 encryptionContext: context, })
```

When decrypting data that was encrypted without digital signatures, use decryptUnsignedMessageStream. This method fails if it encounters signed ciphertext.

```
// Decrypt unsigned streaming data

// Instantiate the client
const { decryptUnsignedMessageStream } =
 buildClient( CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT )

// Create a keyring with the same KMS key used to encrypt
const generatorKeyId = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";
const keyring = new KmsKeyringNode({ generatorKeyId })

// Decrypt the encrypted message
```

```
const outputStream =
 createReadStream(filename) .pipe(decryptUnsignedMessageStream(keyring))
```

Python

To specify an alternate encryption algorithm, use the `algorithm` parameter with an `Algorithm` enum value.

```
# Specify an algorithm suite without signing

# Instantiate a client
client =
 aws_encryption_sdk.EncryptionSDKClient(commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_R
                                                    max_encrypted_data_keys=1)

# Create a master key provider in strict mode
aws_kms_key = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab"
aws_kms_strict_master_key_provider = StrictAwsKmsMasterKeyProvider(
        key_ids=[aws_kms_key]
)

# Encrypt the plaintext using an alternate algorithm suite
ciphertext, encrypted_message_header = client.encrypt(
    algorithm=Algorithm.AES_256_GCM_HKDF_SHA512_COMMIT_KEY, source=source_plaintext,
 key_provider=kms_key_provider
)
```

When decrypting messages that were encrypted without digital signatures, use the `decrypt-unsigned` streaming mode, especially when decrypting while streaming.

```
# Decrypt unsigned streaming data

# Instantiate the client
client =
 aws_encryption_sdk.EncryptionSDKClient(commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_R
                                                    max_encrypted_data_keys=1)

# Create a master key provider in strict mode
aws_kms_key = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab"
aws_kms_strict_master_key_provider = StrictAwsKmsMasterKeyProvider(
```

```
        key_ids=[aws_kms_key]
)

# Decrypt with decrypt-unsigned
with open(ciphertext_filename, "rb") as ciphertext, open(cycled_plaintext_filename,
 "wb") as plaintext:
    with client.stream(mode="decrypt-unsigned",
                       source=ciphertext,
                       key_provider=master_key_provider) as decryptor:
        for chunk in decryptor:
            plaintext.write(chunk)

# Verify that the encryption context
assert all(
   pair in decryptor.header.encryption_context.items() for pair in
 encryptor.header.encryption_context.items()
)
return ciphertext_filename, cycled_plaintext_filename
```

Rust

To specify an alternate algorithm suite in the AWS Encryption SDK for Rust, specify the `algorithm_suite_id` property in your encrypt request.

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Define the key namespace and key name
let key_namespace: &str = "HSM_01";
let key_name: &str = "AES_256_012";

// Optional: Create an encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Instantiate the material providers library
```

```
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create Raw AES keyring
let raw_aes_keyring = mpl
    .create_raw_aes_keyring()
    .key_name(key_name)
    .key_namespace(key_namespace)
    .wrapping_key(aws_smithy_types::Blob::new(AESWrappingKey))
    .wrapping_alg(AesWrappingAlg::AlgAes256GcmIv12Tag16)
    .send()
    .await?;

// Encrypt your plaintext data
let plaintext = example_data.as_bytes();

let encryption_response = esdk_client.encrypt()
    .plaintext(plaintext)
    .keyring(raw_aes_keyring.clone())
    .encryption_context(encryption_context.clone())
    .algorithm_suite_id(AlgAes256GcmHkdfSha512CommitKey)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
)
// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}
```

```
// Define the key namespace and key name
var keyNamespace = "HSM_01"
var keyName = "AES_256_012"

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create Raw AES keyring
aesKeyRingInput := mpltypes.CreateRawAesKeyringInput{
    KeyName:      keyName,
    KeyNamespace: keyNamespace,
    WrappingKey:  key,
    WrappingAlg:  mpltypes.AesWrappingAlgAlgAes256GcmIv12Tag16,
}
aesKeyring, err := matProv.CreateRawAesKeyring(context.Background(),
 aesKeyRingInput)
if err != nil {
    panic(err)
}

// Encrypt your plaintext data
algorithmSuiteId := mpltypes.ESDKAlgorithmSuiteIdAlgAes256GcmHkdfSha512CommitKey
res, err := encryptionClient.Encrypt(context.Background(), esdktypes.EncryptInput{
    Plaintext:         []byte(exampleText),
    EncryptionContext: encryptionContext,
    Keyring:           aesKeyring,
    AlgorithmSuiteId:  &algorithmSuiteId,
})
if err != nil {
    panic(err)
}
```

Limiting encrypted data keys

You can limit the number of encrypted data keys in an encrypted message. This best practice feature can help you detect a misconfigured keyring when encrypting or a malicious ciphertext when decrypting. It also prevents unnecessary, expensive, and potentially exhaustive calls to your key infrastructure. Limiting encrypted data keys is most valuable when you are decrypting messages from an untrusted source.

Although most encrypted messages have one encrypted data key for each wrapping key used in the encryption, an encrypted message can contain up to 65,535 encrypted data keys. A malicious actor might construct an encrypted message with thousands of encrypted data keys, none of which can be decrypted. As a result, the AWS Encryption SDK would attempt to decrypt each encrypted data key until it exhausted the encrypted data keys in the message.

To limit encrypted data keys, use the `MaxEncryptedDataKeys` parameter. This parameter is available for all supported programming languages beginning in versions 1.9.*x* and 2.2.*x* of the AWS Encryption SDK. It is optional and valid when encrypting and decrypting. The following examples decrypt data that was encrypted under three different wrapping keys. The `MaxEncryptedDataKeys` value is set to 3.

C

```
/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();

/* Construct an AWS KMS keyring */
struct aws_cryptosdk_keyring *kms_keyring =
      Aws::Cryptosdk::KmsKeyring::Builder().Build(key_arn1, { key_arn2, key_arn3 });

/* Create a session */
struct aws_cryptosdk_session *session =
    aws_cryptosdk_session_new_from_keyring_2(alloc, AWS_CRYPTOSDK_DECRYPT,
 kms_keyring);
aws_cryptosdk_keyring_release(kms_keyring);

/* Limit encrypted data keys */
aws_cryptosdk_session_set_max_encrypted_data_keys(session, 3);
```

```
/* Decrypt */
size_t ciphertext_consumed_output;
aws_cryptosdk_session_process(session,
    plaintext_output,
    plaintext_buf_sz_output,
    &plaintext_len_output,
    ciphertext_input,
    ciphertext_len_input,
    &ciphertext_consumed_output);
assert(aws_cryptosdk_session_is_done(session));
assert(ciphertext_consumed == ciphertext_len);
```

C# / .NET

To limit encrypted data keys in the AWS Encryption SDK for .NET, instantiate a client for the AWS Encryption SDK for .NET and set its optional `MaxEncryptedDataKeys` parameter to the desired value. Then, call the `Decrypt()` method on the configured AWS Encryption SDK instance.

```
// Decrypt with limited data keys

// Instantiate the material providers
var materialProviders =

 AwsCryptographicMaterialProvidersFactory.CreateDefaultAwsCryptographicMaterialProviders();

// Configure the commitment policy on the AWS Encryption SDK instance
var config = new AwsEncryptionSdkConfig
{
    MaxEncryptedDataKeys = 3
};
var encryptionSdk = AwsEncryptionSdkFactory.CreateAwsEncryptionSdk(config);

// Create the keyring
string keyArn = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";
var createKeyringInput = new CreateAwsKmsKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    KmsKeyId = keyArn
};
var decryptKeyring = materialProviders.CreateAwsKmsKeyring(createKeyringInput);
```

```
// Decrypt the ciphertext
var decryptInput = new DecryptInput
{
    Ciphertext = ciphertext,
    Keyring = decryptKeyring
};
var decryptOutput = encryptionSdk.Decrypt(decryptInput);
```

AWS Encryption CLI

```
# Decrypt with limited encrypted data keys

$ aws-encryption-cli --decrypt \
    --input hello.txt.encrypted \
    --wrapping-keys key=$key_arn1 key=$key_arn2 key=$key_arn3 \
    --buffer \
    --max-encrypted-data-keys 3 \
    --encryption-context purpose=test \
    --metadata-output ~/metadata \
    --output .
```

Java

```
// Construct a client with limited encrypted data keys
final AwsCrypto crypto = AwsCrypto.builder()
  .withMaxEncryptedDataKeys(3)
  .build();

// Create an AWS KMS master key provider
final KmsMasterKeyProvider keyProvider = KmsMasterKeyProvider.builder()
      .buildStrict(keyArn1, keyArn2, keyArn3);

// Decrypt
final CryptoResult<byte[], KmsMasterKey> decryptResult =
 crypto.decryptData(keyProvider, ciphertext)
```

JavaScript Browser

```
// Construct a client with limited encrypted data keys
const { encrypt, decrypt } = buildClient({ maxEncryptedDataKeys: 3 })

declare const credentials: {
```

```
  accessKeyId: string
  secretAccessKey: string
  sessionToken: string
}
const clientProvider = getClient(KMS, {
  credentials: { accessKeyId, secretAccessKey, sessionToken }
})

// Create an AWS KMS keyring
const keyring = new KmsKeyringBrowser({
  clientProvider,
  keyIds: [keyArn1, keyArn2, keyArn3],
})

// Decrypt
const { plaintext, messageHeader } = await decrypt(keyring, ciphertext)
```

JavaScript Node.js

```
// Construct a client with limited encrypted data keys
const { encrypt, decrypt } = buildClient({ maxEncryptedDataKeys: 3 })

// Create an AWS KMS keyring
const keyring = new KmsKeyringBrowser({
  keyIds: [keyArn1, keyArn2, keyArn3],
})

// Decrypt
const { plaintext, messageHeader } = await decrypt(keyring, ciphertext)
```

Python

```
# Instantiate a client with limited encrypted data keys
client = aws_encryption_sdk.EncryptionSDKClient(max_encrypted_data_keys=3)

# Create an AWS KMS master key provider
master_key_provider = aws_encryption_sdk.StrictAwsKmsMasterKeyProvider(
    key_ids=[key_arn1, key_arn2, key_arn3])

# Decrypt
plaintext, header = client.decrypt(source=ciphertext,
 key_provider=master_key_provider)
```

Rust

```
// Instantiate the AWS Encryption SDK client with limited encrypted data keys
let esdk_config = AwsEncryptionSdkConfig::builder()
                    .max_encrypted_data_keys(max_encrypted_data_keys)
                    .build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Define the key namespace and key name
let key_namespace: &str = "HSM_01";
let key_name: &str = "AES_256_012";

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

//  Generate `max_encrypted_data_keys` raw AES keyrings to use with your keyring
let mut raw_aes_keyrings: Vec<KeyringRef> = vec![];

assert!(max_encrypted_data_keys > 0, "max_encrypted_data_keys MUST be greater than
 0");

let mut i = 0;
while i < max_encrypted_data_keys {
    let aes_key_bytes = generate_aes_key_bytes();

    let raw_aes_keyring = mpl
        .create_raw_aes_keyring()
        .key_name(key_name)
        .key_namespace(key_namespace)
        .wrapping_key(aes_key_bytes)
        .wrapping_alg(AesWrappingAlg::AlgAes256GcmIv12Tag16)
        .send()
        .await?;

    raw_aes_keyrings.push(raw_aes_keyring);
    i += 1;
}

// Create a Multi Keyring with `max_encrypted_data_keys` AES Keyrings
let generator_keyring = raw_aes_keyrings.remove(0);

let multi_keyring = mpl
    .create_multi_keyring()
```

```
    .generator(generator_keyring)
    .child_keyrings(raw_aes_keyrings)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
)

// Instantiate the AWS Encryption SDK client with limited encrypted data keys
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{
    MaxEncryptedDataKeys: &maxEncryptedDataKeys,
})
if err != nil {
    panic(err)
}

// Define the key namespace and key name
var keyNamespace = "HSM_01"
var keyName = "RSA_2048_06"

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

//  Generate `maxEncryptedDataKeys` raw AES keyrings to use with your keyring
rawAESKeyrings := make([]mpltypes.IKeyring, 0, maxEncryptedDataKeys)
var i int64 = 0
for i < maxEncryptedDataKeys {
    key, err := generate256KeyBytesAES()
```

```
 if err != nil {
  panic(err)
 }
    aesKeyRingInput := mpltypes.CreateRawAesKeyringInput{
  KeyName:      keyName,
  KeyNamespace: keyNamespace,
  WrappingKey:  key,
  WrappingAlg:  mpltypes.AesWrappingAlgAlgAes256GcmIv12Tag16,
 }
 aesKeyring, err := matProv.CreateRawAesKeyring(context.Background(),
 aesKeyRingInput)
    if err != nil {
  panic(err)
 }
    rawAESKeyrings = append(rawAESKeyrings, aesKeyring)
    i++
}

// Create a Multi Keyring with `max_encrypted_data_keys` AES Keyrings
createMultiKeyringInput := mpltypes.CreateMultiKeyringInput{
    Generator:     rawAESKeyrings[0],
    ChildKeyrings: rawAESKeyrings[1:],
}
multiKeyring, err := matProv.CreateMultiKeyring(context.Background(),
 createMultiKeyringInput)
if err != nil {
    panic(err)
}
```

Creating a discovery filter

When decrypting data encrypted with KMS keys, it's a best practice to decrypt in *strict mode*, that is, to limit the wrapping keys used to only those that you specify. However, if necessary, you can also decrypt in *discovery mode*, where you don't specify any wrapping keys. In this mode, AWS KMS can decrypt the encrypted data key using the KMS key that encrypted it, regardless of who owns or has access to that KMS key.

If you must decrypt in discovery mode, we recommend that you always use a *discovery filter*, which limits the KMS keys that can be used to those in a specified AWS account and partition. The discovery filter is optional, but it's a best practice.

Use the following table to determine the partition value for your discovery filter.

Region	Partition
AWS Regions	`aws`
China Regions	`aws-cn`
AWS GovCloud (US) Regions	`aws-us-gov`

The examples in this section show how to create a discovery filter. Before using the code, replace the example values with valid values for the AWS account and partition.

C

For a complete examples, see kms_discovery.cpp in the AWS Encryption SDK for C.

```
/* Create a discovery filter for an AWS account and partition */

const char *account_id = "111122223333";
const char *partition = "aws";
const std::shared_ptr<Aws::Cryptosdk::KmsKeyring::DiscoveryFilter> discovery_filter
 =

 Aws::Cryptosdk::KmsKeyring::DiscoveryFilter::Builder(partition).AddAccount(account_id).Buil
```

C# / .NET

For a complete example, see DiscoveryFilterExample.cs in the AWS Encryption SDK for .NET.

```
// Create a discovery filter for an AWS account and partition

List<string> account = new List<string> { "111122223333" };

DiscoveryFilter exampleDiscoveryFilter = new DiscoveryFilter()
{
    AccountIds = account,
    Partition = "aws"
}
```

AWS Encryption CLI

```
# Decrypt in discovery mode with a discovery filter

$ aws-encryption-cli --decrypt \
                     --input hello.txt.encrypted \
                     --wrapping-keys discovery=true \
                                     discovery-account=111122223333 \
                                     discovery-partition=aws \
                     --encryption-context purpose=test \
                     --metadata-output ~/metadata \
                     --max-encrypted-data-keys 1 \
                     --buffer \
                     --output .
```

Java

For a complete example, see DiscoveryDecryptionExample.java in the AWS Encryption SDK for Java.

```
// Create a discovery filter for an AWS account and partition

DiscoveryFilter discoveryFilter = new DiscoveryFilter("aws", 111122223333);
```

JavaScript (Node and Browser)

For complete examples, see kms_filtered_discovery.ts (Node.js) and kms_multi_region_discovery.ts (Browser) in the AWS Encryption SDK for JavaScript.

```
/* Create a discovery filter for an AWS account and partition */
const discoveryFilter = {
  accountIDs: ['111122223333'],
  partition: 'aws',
}
```

Python

For a complete example, see discovery_kms_provider.py in the AWS Encryption SDK for Python.

```
# Create the discovery filter and specify the region
decrypt_kwargs = dict(
```

```
        discovery_filter=DiscoveryFilter(account_ids="111122223333",
 partition="aws"),
        discovery_region="us-west-2",
    )
```

Rust

```
let discovery_filter = DiscoveryFilter::builder()
    .account_ids(vec![111122223333.to_string()])
    .partition("aws".to_string())
    .build()?;
```

Go

```
import (
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
)

discoveryFilter := mpltypes.DiscoveryFilter{
    AccountIds: []string{111122223333},
    Partition:  "aws",
}
```

Configuring the required encryption context CMM

You can use the required encryption context CMM to require encryption contexts in your cryptographic operations. An encryption context is a set of non-secret key–value pairs. The encryption context is cryptographically bound to the encrypted data so that the same encryption context is required to decrypt the field. When you use the required encryption context CMM, you can specify one or more *required encryption context keys* (required keys) that must be included in all encrypt and decrypt calls.

> **Note**
>
> The required encryption context CMM is only supported by the following versions:
>
> - Version 3.*x* of the AWS Encryption SDK for Java
> - Version 4.*x* of the AWS Encryption SDK for .NET

- Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency.
- Version 0.1.*x* or later of the AWS Encryption SDK for Go

If you encrypt data using the required encryption context CMM, you can only decrypt it with one of these supported versions.

On encrypt, the AWS Encryption SDK verifies that all required encryption context keys are included in the encryption context that you specified. The AWS Encryption SDK signs the encryption contexts that you specified. Only the key-value pairs that are not required keys are serialized and stored in plaintext in the header of the encrypted message that the encrypt operation returns.

On decrypt, you must provide an encryption context that contains all of the key-value pairs that represent the required keys. The AWS Encryption SDK uses this encryption context and the key-value pairs stored in the encrypted message's header to reconstruct the original encryption context that you specified in the encrypt operation. If the AWS Encryption SDK cannot reconstruct the original encryption context, then the decrypt operation fails. If you provide a key-value pair that contains the required key with an incorrect value, the encrypted message cannot be decrypted. You must provide the same key-value pair that was specified on encrypt.

Important

Carefully consider which values you choose for the required keys in your encryption context. You must be able to provide the same keys and their corresponding values again on decrypt. If you're unable to reproduce the required keys, the encrypted message cannot be decrypted.

The following examples initializes an AWS KMS keyring with the required encryption context CMM.

C# / .NET

```
var encryptionContext = new Dictionary<string, string>()
{
    {"encryption", "context"},
    {"is not", "secret"},
    {"but adds", "useful metadata"},
```

```
    {"that can help you", "be confident that"},
    {"the data you are handling", "is what you think it is"}
};

// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());

// Instantiate the keyring input object
var createKeyringInput = new CreateAwsKmsKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    KmsKeyId = kmsKey
};

// Create the keyring
var kmsKeyring = mpl.CreateAwsKmsKeyring(createKeyringInput);

var createCMMInput = new CreateRequiredEncryptionContextCMMInput
{
    UnderlyingCMM = mpl.CreateDefaultCryptographicMaterialsManager(new
 CreateDefaultCryptographicMaterialsManagerInput{Keyring = kmsKeyring}),
    // If you pass in a keyring but no underlying cmm, it will result in a failure
 because only cmm is supported.
    RequiredEncryptionContextKeys = new List<string>(encryptionContext.Keys)
};

// Create the required encryption context CMM
var requiredEcCMM = mpl.CreateRequiredEncryptionContextCMM(createCMMInput);
```

Java

```
// Instantiate the AWS Encryption SDK
final AwsCrypto crypto = AwsCrypto.builder()
        .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
        .build();

// Create your encryption context
final Map<String, String> encryptionContext = new HashMap<>();
encryptionContext.put("encryption", "context");
encryptionContext.put("is not", "secret");
encryptionContext.put("but adds", "useful metadata");
encryptionContext.put("that can help you", "be confident that");
```

```
encryptionContext.put("the data you are handling", "is what you think it is");

// Create a list of required encryption contexts
final List<String> requiredEncryptionContextKeys = Arrays.asList("encryption",
 "context");

// Create the keyring
final MaterialProviders materialProviders = MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();
final CreateAwsKmsKeyringInput keyringInput = CreateAwsKmsKeyringInput.builder()
        .kmsKeyId(keyArn)
        .kmsClient(KmsClient.create())
        .build();
IKeyring kmsKeyring = materialProviders.CreateAwsKmsKeyring(keyringInput);

// Create the required encryption context CMM
ICryptographicMaterialsManager cmm =
    materialProviders.CreateDefaultCryptographicMaterialsManager(
        CreateDefaultCryptographicMaterialsManagerInput.builder()
            .keyring(kmsKeyring)
            .build()
    );
ICryptographicMaterialsManager requiredCMM =
    materialProviders.CreateRequiredEncryptionContextCMM(
        CreateRequiredEncryptionContextCMMInput.builder()
            .requiredEncryptionContextKeys(requiredEncryptionContextKeys)
            .underlyingCMM(cmm)
            .build()
        );
```

Python

To use the AWS Encryption SDK for Python with the required encryption context CMM, you must also use the material providers library (MPL).

```
# Instantiate the AWS Encryption SDK client
client = aws_encryption_sdk.EncryptionSDKClient(
    commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

# Create your encryption context
encryption_context: Dict[str, str] = {
```

```
    "key1": "value1",
    "key2": "value2",
    "requiredKey1": "requiredValue1",
    "requiredKey2": "requiredValue2"
}

# Create a list of required encryption context keys
required_encryption_context_keys: List[str] = ["requiredKey1", "requiredKey2"]

# Instantiate the material providers library
mpl: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create the AWS KMS keyring
 keyring_input: CreateAwsKmsKeyringInput = CreateAwsKmsKeyringInput(
    kms_key_id=kms_key_id,
    kms_client=boto3.client('kms', region_name="us-west-2")
)
kms_keyring: IKeyring = mpl.create_aws_kms_keyring(keyring_input)

# Create the required encryption context CMM
underlying_cmm: ICryptographicMaterialsManager = \
    mpl.create_default_cryptographic_materials_manager(
        CreateDefaultCryptographicMaterialsManagerInput(
            keyring=kms_keyring
        )
    )

required_ec_cmm: ICryptographicMaterialsManager = \
    mpl.create_required_encryption_context_cmm(
        CreateRequiredEncryptionContextCMMInput(
            required_encryption_context_keys=required_encryption_context_keys,
            underlying_cmm=underlying_cmm,
        )
    )
```

Rust

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;
```

```
// Create an AWS KMS client
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let kms_client = aws_sdk_kms::Client::new(&sdk_config);

// Create your encryption context
let encryption_context = HashMap::from([
    ("key1".to_string(), "value1".to_string()),
    ("key2".to_string(), "value2".to_string()),
    ("requiredKey1".to_string(), "requiredValue1".to_string()),
    ("requiredKey2".to_string(), "requiredValue2".to_string()),
]);

// Create a list of required encryption context keys
let required_encryption_context_keys: Vec<String> = vec![
    "requiredKey1".to_string(),
    "requiredKey2".to_string(),
];

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create the AWS KMS keyring
let kms_keyring = mpl
    .create_aws_kms_keyring()
    .kms_key_id(kms_key_id)
    .kms_client(kms_client)
    .send()
    .await?;

kms_multi_keyring: IKeyring = mat_prov.create_aws_kms_multi_keyring(
    input=kms_multi_keyring_input
)

// Create the required encryption context CMM
let underlying_cmm = mpl
    .create_default_cryptographic_materials_manager()
    .keyring(kms_keyring)
    .send()
    .await?;

let required_ec_cmm = mpl
    .create_required_encryption_context_cmm()
```

```
    .underlying_cmm(underlying_cmm.clone())
    .required_encryption_context_keys(required_encryption_context_keys)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
    "github.com/aws/aws-sdk-go-v2/config"
    "github.com/aws/aws-sdk-go-v2/service/kms"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS client
cfg, err := config.LoadDefaultConfig(context.TODO())
if err != nil {
    panic(err)
}
kmsClient := kms.NewFromConfig(cfg, func(o *kms.Options) {
    o.Region = defaultKmsKeyRegion
})

// Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
```

```
    "the data you are handling": "is what you think it is",
}

// Create a list of required encryption context keys
requiredEncryptionContextKeys := []string{}
requiredEncryptionContextKeys = append(requiredEncryptionContextKeys,
 "requiredKey1", "requiredKey2")

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create the AWS KMS keyring
awsKmsKeyringInput := mpltypes.CreateAwsKmsKeyringInput{
    KmsClient: kmsClient,
    KmsKeyId:  utils.GetDefaultKMSKeyId(),
}
awsKmsKeyring, err := matProv.CreateAwsKmsKeyring(context.Background(),
 awsKmsKeyringInput)
if err != nil {
    panic(err)
}

// Create the required encryption context CMM
underlyingCMM, err :=
 matProv.CreateDefaultCryptographicMaterialsManager(context.Background(),
 mpltypes.CreateDefaultCryptographicMaterialsManagerInput{Keyring: awsKmsKeyring})
if err != nil {
    panic(err)
}
requiredEncryptionContextInput := mpltypes.CreateRequiredEncryptionContextCMMInput{
    UnderlyingCMM: underlyingCMM,
    RequiredEncryptionContextKeys: requiredEncryptionContextKeys,
}
requiredEC, err := matProv.CreateRequiredEncryptionContextCMM(context.Background(),
 requiredEncryptionContextInput)
if err != nil {
    panic(err)
}
```

Setting a commitment policy

A *commitment policy* is a configuration setting that determines whether your application encrypts and decrypts with key commitment. Encrypting and decrypting with key commitment is an AWS Encryption SDK best practice.

Setting and adjusting your commitment policy is a critical step in migrating from versions 1.7.*x* and earlier of the AWS Encryption SDK to version 2.0.*x* and later. This progression is explained in detail in the migration topic.

The default commitment policy value in the latest versions of the AWS Encryption SDK (beginning in version 2.0.*x*), `RequireEncryptRequireDecrypt`, is ideal for most situations. However, if you need to decrypt ciphertext that was encrypted without key commitment, you might need to change your commitment policy to `RequireEncryptAllowDecrypt`. For examples of how to set a commitment policy in each programming language, see Setting your commitment policy.

Working with streaming data

When you stream data for decryption, be aware that the AWS Encryption SDK returns decrypted plaintext after the integrity checks are complete, but before the digital signature is verified. To ensure that you don't return or use plaintext until the signature is verified, we recommend that you buffer the streamed plaintext until the entire decryption process is complete.

This issue arises only when you are streaming ciphertext for decryption, and only when you are using an algorithm suite, such as the default algorithm suite, that includes digital signatures.

To make the buffering easier, some AWS Encryption SDK language implementations, such as AWS Encryption SDK for JavaScript in Node.js, include a buffering feature as part of the decrypt method. The AWS Encryption CLI, which always streams input and output introduced a `--buffer` parameter in versions 1.9.*x* and 2.2.*x*. In other language implementations, you can use existing buffering features. (The AWS Encryption SDK for .NET does not support streaming.)

If you are using an algorithm suite without digital signatures, be sure to use the `decrypt-unsigned` feature in each language implementation. This feature decrypts ciphertext but fails if it encounters signed ciphertext. For details, see Choosing an algorithm suite.

Caching data keys

In general, reusing data keys is discouraged, but the AWS Encryption SDK offers a data key caching option that provides limited reuse of data keys. Data key caching can improve the performance of some applications and reduce calls to your key infrastructure. Before using data key caching in production, adjust the security thresholds, and test to make sure that the benefits outweigh the disadvantages of reusing data keys.

Key stores in the AWS Encryption SDK

In the AWS Encryption SDK, a *key store* is a Amazon DynamoDB table that persists hierarchical data used by the AWS KMS Hierarchical keyring. The key store helps reduce the number of calls that you need to make to AWS KMS to perform cryptographic operations with the Hierarchical keyring.

The key store persists and manages the *branch keys* that the Hierarchical keyring uses to perform envelope encryption and protect data encryption keys. The key store stores the active branch key and all previous versions of the branch key. The *active* branch key is the most recent branch key version. The Hierarchical keyring uses a unique data encryption key for each encrypt request and encrypts each data encryption key with a unique wrapping key derived from the active branch key. The Hierarchical keyring is dependent on the hierarchy established between active branch keys and their derived wrapping keys.

Key store terminology and concepts

Key store

The DynamoDB table that persists hierarchical data, such as branch keys and beacon keys.

Root key

A symmetric encryption KMS key that generates and protects the branch keys and beacon keys in your key store.

Branch key

A data key that is reused to derive unique wrapping key for envelope encryption. You can create multiple branch keys in one key store, but each branch key can only have one active branch key version at a time. The *active* branch key is the most recent branch key version.

Branch keys are derived from AWS KMS keys using the kms:GenerateDataKeyWithoutPlaintext operation.

Wrapping key

A unique data key that is used to encrypt the data encryption key used in encrypt operations.

Wrapping keys are derived from branch keys. For more information on the key derivation process, see AWS KMS Hierarchical keyring technical details.

Data encryption key

A data key that is used in encrypt operations. The Hierarchical keyring uses a unique data encryption key for each encrypt request.

Implementing least privileged permissions

When using a key store and AWS KMS Hierarchical keyrings, we recommend that you follow the principle of least privilege by defining the following roles:

Key store administrator

Key store administrators are responsible for creating and managing the key store and the branch keys that it that persists and protects. Key store administrators should be the only users with write permissions to the Amazon DynamoDB table that serves as your key store. They should be the only users with access to privileged, administrator operations, such as `CreateKey` and `VersionKey`. You can only perform these operations when you statically configure your key store actions.

`CreateKey` is a privileged operation that can add a new KMS key ARN to your key store allowlist. This KMS key can create new active branch keys. We recommend limiting access to this operation because once a KMS key is added to the branch key store, it cannot be deleted.

Key store user

In most use cases, the key store user only interacts with key store via the Hierarchical keyring as they encrypt, decrypt, sign, and verify data. As a result, they only need read permissions to the Amazon DynamoDB table that serves as your key store. Key store users should only need access to the usage operations that make cryptographic operations possible, such as `GetActiveBranchKey`, `GetBranchKeyVersion`, and `GetBeaconKey`. They don't need permissions to create or manage the branch keys that they use.

You can perform usage operations when your key store actions are statically configured, or when they're configured for discovery. You cannot perform administrator operations (`CreateKey` and `VersionKey`) when your key store actions is configured for discovery.

If your branch key store administrator allowlisted multiple KMS keys in your branch key store, we recommend that your key store users configure their key store actions for discovery so that their Hierarchical keyring can use multiple KMS keys.

Create a key store

Before you can create branch keys or use an AWS KMS Hierarchical keyring, you must create your key store, a Amazon DynamoDB table that manages and protects your branch keys.

> **Important**
>
> Do not delete the DynamoDB table that persists your branch keys. If you delete this table, you will be unable to decrypt any data encrypted using the Hierarchical keyring.

Follow the Create a table procedures in the *Amazon DynamoDB Developer Guide*, using the following required string values for the partition key and sort key.

	Partition key	Sort key
Base table	`branch-key-id`	`type`

Logical key store name

When naming the DynamoDB table that serves as your key store, it's important to carefully consider the *logical key store name* that you'll specify when configuring your key store actions. The logical key store name acts as an identifier for your key store and cannot be changed after it is initially defined by the first user. You must always specify the same logical key store name in your key store actions.

There must be a one-to-one mapping between the DynamoDB table name and the logical key store name. The logical key store name is cryptographically bound to all data stored in the table to simplify DynamoDB restore operations. While the logical key store name can be different from your DynamoDB table name, we strongly recommend specifying your DynamoDB table name as the logical key store name. In the event that your table name changes after restoring your DynamoDB table from a backup, the logical key store name can be mapped to the new DynamoDB table name to ensure that the Hierarchical keyring can still access your key store.

Do not include confidential or sensitive information in your logical key store name. The logical key store name is displayed in plaintext in AWS KMS CloudTrail events as the `tablename`.

Next steps

1. the section called “Configure key store actions”
2. the section called “Create branch keys”
3. Create an AWS KMS Hierarchical keyring

Configure key store actions

Key store actions determine what operations your users can perform and how their AWS KMS Hierarchical keyring uses the KMS keys allowlisted in your key store. The AWS Encryption SDK supports the following key store action configurations.

Static

When you statically configure your key store, the key store can only use the KMS key associated with the KMS key ARN you provide in the `kmsConfiguration` when you configure your key store actions. An exception is thrown if a different KMS key ARN is encountered when creating, versioning, or getting a branch key.

You can specify a multi-Region KMS key in your `kmsConfiguration`, but the key's entire ARN, including the region, is persisted in the branch keys derived from the KMS key. You cannot specify a key in a different region, you must provide the exact same multi-region key for the values to match.

When you statically configure your key store actions, you can perform usage operations (`GetActiveBranchKey`, `GetBranchKeyVersion`, `GetBeaconKey`) and administrative operations (`CreateKey` and `VersionKey`). `CreateKey` is a privileged operation that can add a new KMS key ARN to your key store allowlist. This KMS key can create new active branch keys. We recommend limiting access to this operation because once a KMS key is added to the key store, it cannot be deleted.

Discovery

When you configure your key store actions for discovery, the key store can use any AWS KMS key ARN that is allowlisted in your key store. However, an exception is thrown when a multi-Region KMS key is encountered and the region in the key's ARN does not match the region of the AWS KMS client being used.

When you configure your key store for discovery, you cannot perform administrative operations, such as `CreateKey` and `VersionKey`. You can only perform the usage operations that enable encrypt, decrypt, sign, and verify operations. For more information, see the section called "Implementing least privileged permissions".

Configure your key store actions

Before you configure your key store actions, ensure the following prerequisites are met.

- Determine what operations you need to perform. For more information, see the section called "Implementing least privileged permissions".
- Choose a logical key store name

  There must be a one-to-one mapping between the DynamoDB table name and the logical key store name. The logical key store name is cryptographically bound to all data stored in the table to simplify DynamoDB restore operations, it cannot be changed after it is initially defined by the first user. You must always specify the same logical key store name in your key store actions. For more information, see logical key store name.

Static configuration

The following example statically configures key store actions. You must specify the name of the DynamoDB table that serves as your key store, a logical name for the key store, and the KMS key ARN that identifies a symmetric encryption KMS key.

> **Note**
>
> Carefully consider the KMS key ARN that you specify when statically configuring your key store service. The `CreateKey` operation adds the KMS key ARN to your branch key store allowlist. Once a KMS key is added to the branch key store, it cannot be deleted.

Java

```
final KeyStore keystore = KeyStore.builder().KeyStoreConfig(
                  KeyStoreConfig.builder()
                          .ddbClient(DynamoDbClient.create())
                          .ddbTableName(keyStoreName)
```

```
                            .logicalKeyStoreName(logicalKeyStoreName)
                            .kmsClient(KmsClient.create())
                            .kmsConfiguration(KMSConfiguration.builder()
                                    .kmsKeyArn(kmsKeyArn)
                                    .build())
                            .build()).build();
```

C# / .NET

```
var kmsConfig = new KMSConfiguration { KmsKeyArn = kmsKeyArn };
  var keystoreConfig = new KeyStoreConfig
  {
      KmsClient = new AmazonKeyManagementServiceClient(),
      KmsConfiguration = kmsConfig,
      DdbTableName = keyStoreName,
      DdbClient = new AmazonDynamoDBClient(),
      LogicalKeyStoreName = logicalKeyStoreName
  };
  var keystore = new KeyStore(keystoreConfig);
```

Python

```
keystore: KeyStore = KeyStore(
    config=KeyStoreConfig(
        ddb_client=ddb_client,
        ddb_table_name=key_store_name,
        logical_key_store_name=logical_key_store_name,
        kms_client=kms_client,
        kms_configuration=KMSConfigurationKmsKeyArn(
            value=kms_key_id
        ),
    )
)
```

Rust

```
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let key_store_config = KeyStoreConfig::builder()
    .kms_client(aws_sdk_kms::Client::new(&sdk_config))
    .ddb_client(aws_sdk_dynamodb::Client::new(&sdk_config))
    .ddb_table_name(key_store_name)
```

```
    .logical_key_store_name(logical_key_store_name)
    .kms_configuration(KmsConfiguration::KmsKeyArn(kms_key_arn.to_string()))
    .build()?;

let keystore = keystore_client::Client::from_conf(key_store_config)?;
```

Go

```
import (
 keystore "github.com/aws/aws-cryptographic-material-providers-library/mpl/
awscryptographykeystoresmithygenerated"
 keystoretypes "github.com/aws/aws-cryptographic-material-providers-library/mpl/
awscryptographykeystoresmithygeneratedtypes"
)

kmsConfig := keystoretypes.KMSConfigurationMemberkmsKeyArn{
    Value: kmsKeyArn,
}
keyStore, err := keystore.NewClient(keystoretypes.KeyStoreConfig{
    DdbTableName:        keyStoreTableName,
    KmsConfiguration:    &kmsConfig,
    LogicalKeyStoreName: logicalKeyStoreName,
    DdbClient:           ddbClient,
    KmsClient:           kmsClient,
})
if err != nil {
    panic(err)
}
```

Discovery configuration

The following example configures key store actions for discovery. You must specify the name of the DynamoDB table that serves as your key store and a logical key store name.

Java

```
final KeyStore keystore = KeyStore.builder().KeyStoreConfig(
                 KeyStoreConfig.builder()
                         .ddbClient(DynamoDbClient.create())
                         .ddbTableName(keyStoreName)
                         .logicalKeyStoreName(logicalKeyStoreName)
                         .kmsClient(KmsClient.create())
```

```
                            .kmsConfiguration(KMSConfiguration.builder()
                                    .discovery(Discovery.builder().build())
                                    .build())
                            .build()).build();
```

C# / .NET

```
var keystoreConfig = new KeyStoreConfig
 {
     KmsClient = new AmazonKeyManagementServiceClient(),
     KmsConfiguration = new KMSConfiguration {Discovery = new Discovery()},
     DdbTableName = keyStoreName,
     DdbClient = new AmazonDynamoDBClient(),
     LogicalKeyStoreName = logicalKeyStoreName
 };
 var keystore = new KeyStore(keystoreConfig);
```

Python

```
keystore: KeyStore = KeyStore(
    config=KeyStoreConfig(
        ddb_client=ddb_client,
        ddb_table_name=key_store_name,
        logical_key_store_name=logical_key_store_name,
        kms_client=kms_client,
        kms_configuration=KMSConfigurationDiscovery(
            value=Discovery()
        ),
    )
)
```

Rust

```
let key_store_config = KeyStoreConfig::builder()
        .kms_client(kms_client)
        .ddb_client(ddb_client)
        .ddb_table_name(key_store_name)
        .logical_key_store_name(logical_key_store_name)

 .kms_configuration(KmsConfiguration::Discovery(Discovery::builder().build()?))
        .build()?;
```

Go

```
import (
 keystore "github.com/aws/aws-cryptographic-material-providers-library/mpl/
awscryptographykeystoresmithygenerated"
 keystoretypes "github.com/aws/aws-cryptographic-material-providers-library/mpl/
awscryptographykeystoresmithygeneratedtypes"
)

kmsConfig := keystoretypes.KMSConfigurationMemberdiscovery{}
keyStore, err := keystore.NewClient(keystoretypes.KeyStoreConfig{
    DdbTableName:        keyStoreName,
    KmsConfiguration:    &kmsConfig,
    LogicalKeyStoreName: logicalKeyStoreName,
    DdbClient:           ddbClient,
    KmsClient:           kmsClient,
})
if err != nil {
    panic(err)
}
```

Create an active branch key

A *branch key* is a data key derived from an AWS KMS key that the AWS KMS Hierarchical keyring uses to reduce the number of calls made to AWS KMS. The *active* branch key is the most recent branch key version. The Hierarchical keyring generates a unique data key for every encrypt request and encrypts each data key with a unique wrapping key derived from the active branch key.

To create a new active branch key, you must statically configure your key store actions. `CreateKey` is a privileged operation that adds the KMS key ARN specified in your key store actions configuration to your key store allowlist. Then, the KMS key is used to generate the new active branch key. We recommend limiting access to this operation because once a KMS key is added to the key store, it cannot be deleted.

You can allowlist one KMS key in your key store, or you can allowlist multiple KMS keys by updating the KMS key ARN that you specify in your key store actions configuration and calling `CreateKey` again. If you allowlist multiple KMS keys, your key store users should configure their key store actions for discovery so that they can use any of the allowlisted keys in the key store that they have access to. For more information, see the section called “Configure key store actions”.

Required permissions

To create branch keys, you need kms:GenerateDataKeyWithoutPlaintext and kms:ReEncrypt permissions on the KMS key specified in your key store actions.

Create a branch key

The following operation creates a new active branch key using the KMS key that yousspecified in your key store actions configuration, and adds the active branch key to the DynamoDB table that serves as your key store.

When you call `CreateKey`, you can choose to specify the following optional values.

- `branchKeyIdentifier`: defines a custom `branch-key-id`.

  To create a custom `branch-key-id`, you must also include an additional encryption context with the `encryptionContext` parameter.
- `encryptionContext`: defines an optional set of non-secret key–value pairs that provides additional authenticated data (AAD) in the encryption context included in the kms:GenerateDataKeyWithoutPlaintext call.

  This additional encryption context is displayed with the `aws-crypto-ec:` prefix.

Java

```
final Map<String, String> additionalEncryptionContext =
 Collections.singletonMap("Additional Encryption Context for",
          "custom branch key id");

  final String BranchKey = keystore.CreateKey(
          CreateKeyInput.builder()
                  .branchKeyIdentifier(custom-branch-key-id) //OPTIONAL
                  .encryptionContext(additionalEncryptionContext) //OPTIONAL

                  .build()).branchKeyIdentifier();
```

C# / .NET

```
var additionalEncryptionContext = new Dictionary<string, string>();
  additionalEncryptionContext.Add("Additional Encryption Context for", "custom
 branch key id");
```

```
  var branchKeyId = keystore.CreateKey(new CreateKeyInput
  {
      BranchKeyIdentifier = "custom-branch-key-id", // OPTIONAL
      EncryptionContext = additionalEncryptionContext // OPTIONAL
  });
```

Python

```
additional_encryption_context = {"Additional Encryption Context for": "custom branch
 key id"}

branch_key_id: str = keystore.create_key(
    CreateKeyInput(
        branch_key_identifier = "custom-branch-key-id", # OPTIONAL
        encryption_context = additional_encryption_context, # OPTIONAL
    )
)
```

Rust

```
let additional_encryption_context = HashMap::from([
    ("Additional Encryption Context for".to_string(), "custom branch key
 id".to_string())
]);

let branch_key_id = keystore.create_key()
    .branch_key_identifier("custom-branch-key-id") // OPTIONAL
    .encryption_context(additional_encryption_context) // OPTIONAL
    .send()
    .await?
    .branch_key_identifier
    .unwrap();
```

Go

```
encryptionContext := map[string]string{
    "Additional Encryption Context for": "custom branch key id",
}

branchKey, err := keyStore.CreateKey(context.Background(),
 keystoretypes.CreateKeyInput{
    BranchKeyIdentifier: &customBranchKeyId,
```

```
    EncryptionContext:   additional_encryption_context,
})
if err != nil {
    return "", err
}
```

First, the `CreateKey` operation generates the following values.

- A version 4 Universally Unique Identifier (UUID) for the `branch-key-id` (unless you specified a custom `branch-key-id`).
- A version 4 UUID for the branch key version
- A `timestamp` in the ISO 8601 date and time format in Coordinated Universal Time (UTC).

Then, the `CreateKey` operation calls kms:GenerateDataKeyWithoutPlaintext using the following request.

```
{
     "EncryptionContext": {
        "branch-key-id" : "branch-key-id",
        "type" : "type",
        "create-time" : "timestamp",
        "logical-key-store-name" : "the logical table name for your key store",
        "kms-arn" : the KMS key ARN,
        "hierarchy-version" : "1",
        "aws-crypto-ec:contextKey": "contextValue"
     },
     "KeyId": "the KMS key ARN you specified in your key store actions",
     "NumberOfBytes": "32"
  }
```

Next, the `CreateKey` operation calls kms:ReEncrypt to create an active record for the branch key by updating the encryption context.

Last, the `CreateKey` operation calls ddb:TransactWriteItems to write a new item that will persist the branch key in the table you created in **Step 2**. The item has the following attributes.

```
{
      "branch-key-id" : branch-key-id,
      "type" : "branch:ACTIVE",
```

```
    "enc" : the branch key returned by the GenerateDataKeyWithoutPlaintext call,
    "version": "branch:version:the branch key version UUID",
    "create-time" : "timestamp",
    "kms-arn" : "the KMS key ARN you specified in Step 1",
    "hierarchy-version" : "1",
    "aws-crypto-ec:contextKey": "contextValue"
}
```

Rotate your active branch key

There can only be one active version for each branch key at a time. Typically, each active branch key version is used to satisfy multiple requests. But you control the extent to which active branch keys are reused and determine how often the active branch key is rotated.

Branch keys are not used to encrypt plaintext data keys. They are used to derive the unique wrapping keys that encrypt plaintext data keys. The wrapping key derivation process produces a unique 32 byte wrapping key with 28 bytes of randomness. This means that a branch key can derive more than 79 octillion, or 2^{96}, unique wrapping keys before cryptographic wear-out occurs. Despite this very low exhaustion risk, you might be required to rotate your active branch keys due to business or contract rules or government regulations.

The active version of the branch key remains active until you rotate it. Previous versions of the active branch key will not be used to perform encrypt operations and cannot be used to derive new wrapping keys, but they can still be queried and provide wrapping keys to decrypt the data keys that they encrypted while active.

Required permissions

To rotate branch keys, you need kms:GenerateDataKeyWithoutPlaintext and kms:ReEncrypt permissions on the KMS key specified in your key store actions.

Rotate an active branch key

Use the `VersionKey` operation to rotate your active branch key. When you rotate the active branch key, a new branch key is created to replace the previous version. The `branch-key-id` does not change when you rotate the active branch key. You must specify the `branch-key-id` that identifies the current active branch key when you call `VersionKey`.

Java

```
keystore.VersionKey(
```

```
    VersionKeyInput.builder()
        .branchKeyIdentifier("branch-key-id")
        .build()
);
```

C# / .NET

```
keystore.VersionKey(new VersionKeyInput{BranchKeyIdentifier = branchKeyId});
```

Python

```
keystore.version_key(
    VersionKeyInput(
        branch_key_identifier=branch_key_id
    )
)
```

Rust

```
keystore.version_key()
        .branch_key_identifier(branch_key_id)
        .send()
        .await?;
```

Go

```
_, err = keyStore.VersionKey(context.Background(), keystoretypes.VersionKeyInput{
    BranchKeyIdentifier: branchKeyId,
})
if err != nil {
    return err
}
```

Keyrings

Supported programming language implementations use *keyrings* to perform envelope encryption. Keyrings generate, encrypt, and decrypt data keys. Keyrings determine the source of the unique data keys that protect each message, and the wrapping keys that encrypt that data key. You specify a keyring when encrypting and the same or a different keyring when decrypting. You can use the keyrings that the SDK provides or write your own compatible custom keyrings.

You can use each keyring individually or combine keyrings into a multi-keyring. Although most keyrings can generate, encrypt, and decrypt data keys, you might create a keyring that performs only one particular operation, such as a keyring that only generates data keys, and use that keyring in combination with others.

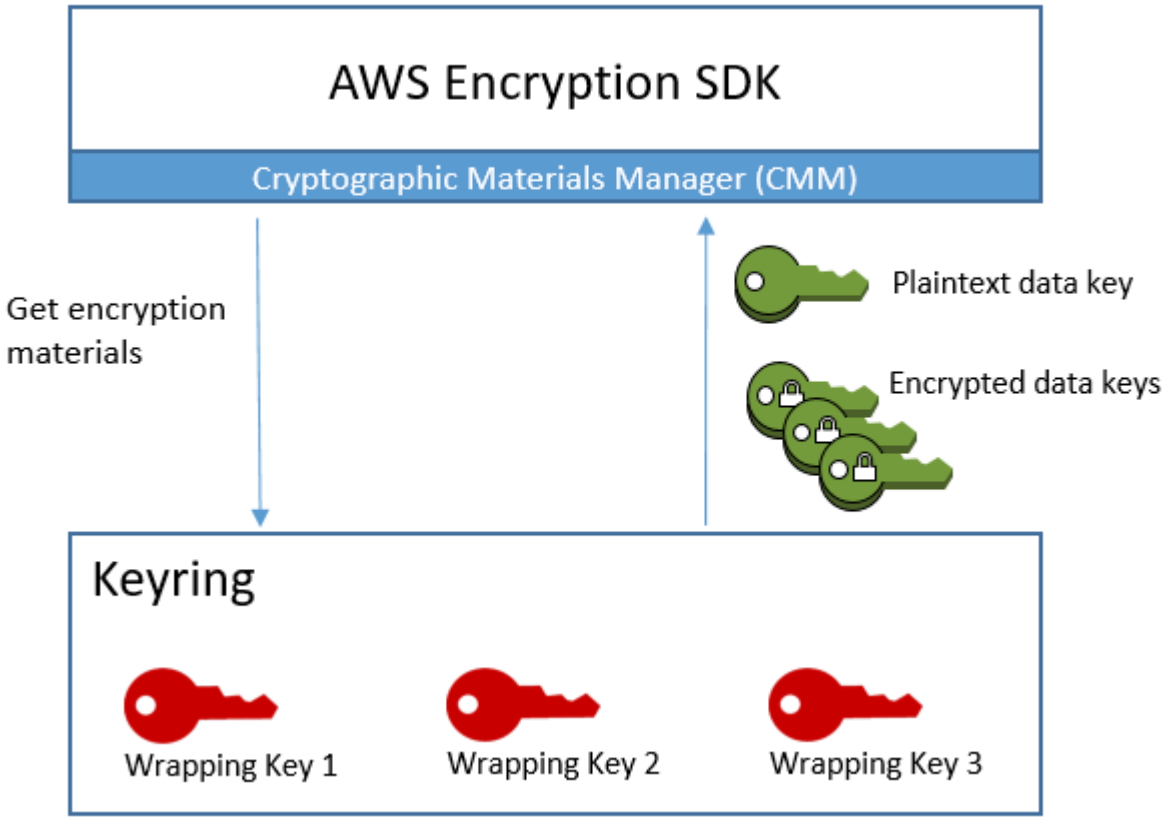
We recommend that you use a keyring that protects your wrapping keys and performs cryptographic operations within a secure boundary, such as the AWS KMS keyring, which uses AWS KMS keys that never leave AWS Key Management Service (AWS KMS) unencrypted. You can also write a keyring that uses wrapping keys that are stored in your hardware security modules (HSMs) or protected by other master key services. For details, see the Keyring Interface topic in the *AWS Encryption SDK Specification*.

Keyrings play the role of the master keys and master key providers used in other programming language implementations. If you use different language implementations of the AWS Encryption SDK to encrypt and decrypt your data, be sure to use compatible keyrings and master key providers. For details, see Keyring compatibility.

This topic explains how to use the keyring feature of the AWS Encryption SDK and how to choose a keyring.

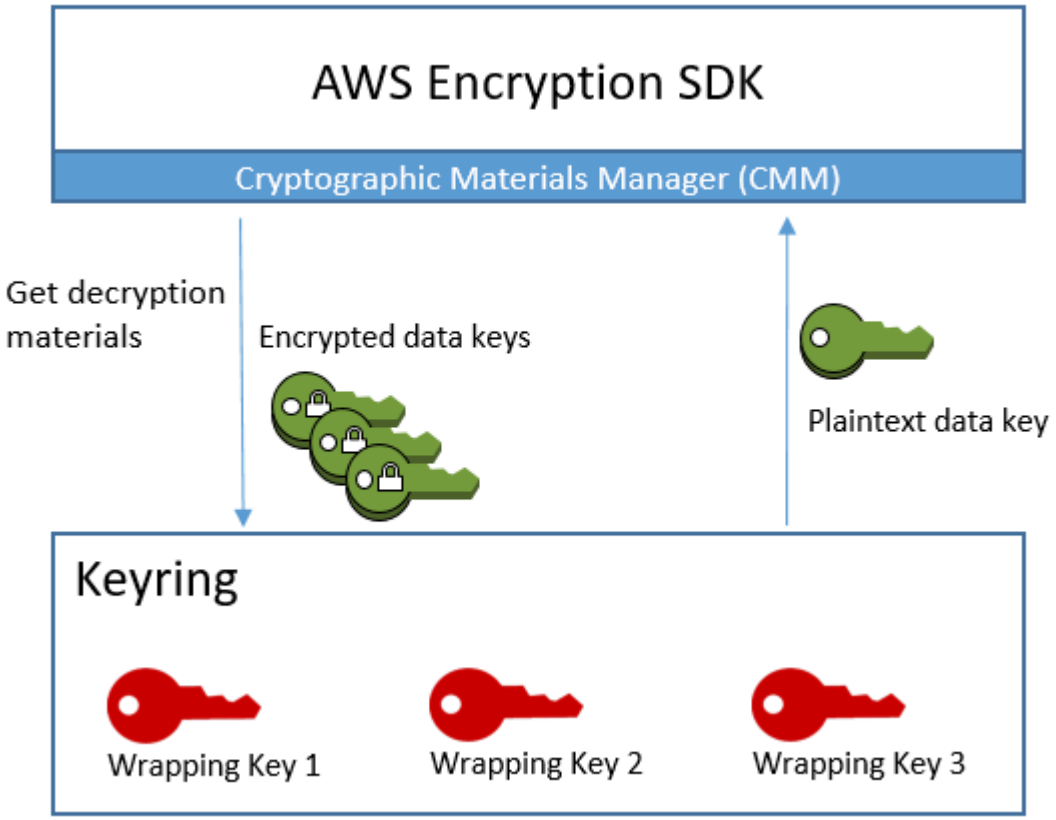
How keyrings work

When you encrypt data, the AWS Encryption SDK asks the keyring for encryption materials. The keyring returns a plaintext data key and a copy of the data key that's encrypted by each of the wrapping keys in the keyring. The AWS Encryption SDK uses the plaintext key to encrypt the data, and then destroys the plaintext data key. Then, the AWS Encryption SDK returns an encrypted message that includes the encrypted data keys and the encrypted data.



When you decrypt data, you can use the same keyring that you used to encrypt the data, or a different one. To decrypt the data, a decryption keyring must include (or have access to) at least one wrapping key in the encryption keyring.

The AWS Encryption SDK passes the encrypted data keys from the encrypted message to the keyring, and asks the keyring to decrypt any one of them. The keyring uses its wrapping keys to decrypt one of the encrypted data keys and returns a plaintext data key. The AWS Encryption SDK uses the plaintext data key to decrypt the data. If none of the wrapping keys in the keyring can decrypt any of the encrypted data keys, the decrypt operation fails.



You can use a single keyring or also combine keyrings of the same type or a different type into a multi-keyring. When you encrypt data, the multi-keyring returns a copy of the data key encrypted by all of the wrapping keys in all of the keyrings that comprise the multi-keyring. You can decrypt the data using a keyring with any one of the wrapping keys in the multi-keyring.

Keyring compatibility

Although the different language implementations of the AWS Encryption SDK have some architectural differences, they are fully compatible, subject to language constraints. You can encrypt your data using one language implementation and decrypt it with any other language implementation. However, you must use the same or corresponding wrapping keys to encrypt and decrypt your data keys. For information about language constraints, see the topic about each language implementation, such as the section called "Compatibility" in the AWS Encryption SDK for JavaScript topic.

Keyrings are supported in the following programming languages:

- AWS Encryption SDK for C

- AWS Encryption SDK for JavaScript
- AWS Encryption SDK for .NET
- Version 3.*x* of the AWS Encryption SDK for Java
- Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency.
- AWS Encryption SDK for Rust
- AWS Encryption SDK for Go

Varying requirements for encryption keyrings

In AWS Encryption SDK language implementations other than the AWS Encryption SDK for C, all wrapping keys in an encryption keyring (or multi-keyring) or master key provider must be able to encrypt the data key. If any wrapping key fails to encrypt, the encrypt method fails. As a result, the caller must have the required permissions for all keys in the keyring. If you use a discovery keyring to encrypt data, alone or in a multi-keyring, the encrypt operation fails.

The exception is the AWS Encryption SDK for C, where the encrypt operation ignores a standard discovery keyring, but fails if you specify a multi-Region discovery keyring, alone or in a multi-keyring.

Compatible Keyrings and Master Key Providers

The following table shows which master keys and master key providers are compatible with the keyrings that the AWS Encryption SDK supplies. Any minor incompatibility due to language constraints is explained in the topic about the language implementation.

Keyring:	Master Key Provider:
AWS KMS keyring	KMSMasterKey (Java) KMSMasterKeyProvider (Java) KMSMasterKey (Python) KMSMasterKeyProvider (Python)

Keyring:	Master Key Provider:
	Note The AWS Encryption SDK for Python and AWS Encryptio n SDK for Java don't include a master key or master key provider that is equivalent to the AWS KMS regional discovery keyring.
AWS KMS Hierarchical keyring	Supported by the following programming languages and versions: • Version 3.*x* of the AWS Encryption SDK for Java • Version 4.*x* of the AWS Encryption SDK for .NET • Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency. • Version 1.*x* of the AWS Encryption SDK for Rust • Version 0.1.*x* or later of the AWS Encryption SDK for Go
AWS KMS ECDH keyring	Supported by the following programming languages and versions: • Version 3.*x* of the AWS Encryption SDK for Java • Version 4.*x* of the AWS Encryption SDK for .NET • Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency. • Version 1.*x* of the AWS Encryption SDK for Rust • Version 0.1.*x* or later of the AWS Encryption SDK for Go
Raw AES keyring	When they are used with symmetric encryption keys: JceMasterKey (Java) RawMasterKey (Python)

Keyring:	Master Key Provider:
Raw RSA keyring	When they are used with asymmetric encryption keys: JceMasterKey (Java) RawMasterKey (Python) **Note** The Raw RSA keyring does not support asymmetric KMS keys. If you want to use asymmetric RSA KMS keys, version 4.*x* of the AWS Encryption SDK for .NET supports AWS KMS keyrings that use symmetric encryption (`SYMMETRIC_DEFAULT`) or asymmetric RSA AWS KMS keys.
Raw ECDH keyring	Supported by the following programming languages and versions: • Version 3.*x* of the AWS Encryption SDK for Java • Version 4.*x* of the AWS Encryption SDK for .NET • Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency. • Version 1.*x* of the AWS Encryption SDK for Rust • Version 0.1.*x* or later of the AWS Encryption SDK for Go

AWS KMS keyrings

An AWS KMS keyring uses AWS KMS keys to generate, encrypt, and decrypt data keys. AWS Key Management Service (AWS KMS) protects your KMS keys and performs cryptographic operations within the FIPS boundary. We recommend that you use a AWS KMS keyring, or a keyring with similar security properties, whenever possible.

All programming language implementations that support keyrings, support AWS KMS keyrings that use symmetric encryption KMS keys. The following programming language implementations also support AWS KMS keyrings that use asymmetric RSA KMS keys:

- Version 3.*x* of the AWS Encryption SDK for Java
- Version 4.*x* of theAWS Encryption SDK for .NET
- Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency.
- Version 1.*x* of the AWS Encryption SDK for Rust
- Version 0.1.*x* or later of the AWS Encryption SDK for Go

If you try to include an asymmetric KMS key in an encryption keyring in any other language implementation, the encrypt call fails. If you include it in a decryption keyring, it is ignored.

You can use an AWS KMS multi-Region key in an AWS KMS keyring or master key provider beginning in version 2.3.*x* of the AWS Encryption SDK and version 3.0.*x* of the AWS Encryption CLI. For details and examples of using the multi-Region-aware symbol, see Using multi-Region AWS KMS keys. For information about multi-Region keys, see Using multi-Region keys in the *AWS Key Management Service Developer Guide*.

> **Note**
>
> All mentions of *KMS keyrings* in the AWS Encryption SDK refer to AWS KMS keyrings.

AWS KMS keyrings can include two types of wrapping keys:

- **Generator key**: Generates a plaintext data key and encrypts it. A keyring that encrypts data must have one generator key.
- **Additional keys**: Encrypts the plaintext data key that the generator key generated. AWS KMS keyrings can have zero or more additional keys.

You use must have a generator key to encrypt messages. When an AWS KMS keyring has just one KMS key, that key is used to generate and encrypt the data key. When decrypting, the generator key is optional, and the distinction between generator keys and additional keys is ignored.

Like all keyrings, AWS KMS keyrings can be used independently or in a multi-keyring with other keyrings of the same or a different type.

Topics

- Required permissions for AWS KMS keyrings
- Identifying AWS KMS keys in an AWS KMS keyring
- Creating an AWS KMS keyring
- Using an AWS KMS discovery keyring
- Using an AWS KMS regional discovery keyring

Required permissions for AWS KMS keyrings

The AWS Encryption SDK doesn't require an AWS account and it doesn't depend on any AWS service. However, to use an AWS KMS keyring, you need an AWS account and the following minimum permissions on the AWS KMS keys in your keyring.

- To encrypt with an AWS KMS keyring, you need kms:GenerateDataKey permission on the generator key. You need kms:Encrypt permission on all additional keys in the AWS KMS keyring.
- To decrypt with an AWS KMS keyring, you need kms:Decrypt permission on at least one key in the AWS KMS keyring.
- To encrypt with a multi-keyring comprised of AWS KMS keyrings, you need kms:GenerateDataKey permission on the generator key in the generator keyring. You need kms:Encrypt permission on all other keys in all other AWS KMS keyrings.
- To encrypt with an asymmetric RSA AWS KMS keyring, you do not need kms:GenerateDataKey or kms:Encrypt because you must specify the public key material that you want to use for encryption when you create the keyring. No AWS KMS calls are made when encrypting with this keyring. To decrypt with an asymmetric RSA AWS KMS keyring, you need kms:Decrypt permission.

For detailed information about permissions for AWS KMS keys, see KMS key access and permissions in the *AWS Key Management Service Developer Guide*.

Identifying AWS KMS keys in an AWS KMS keyring

An AWS KMS keyring can include one or more AWS KMS keys. To specify an AWS KMS key in an AWS KMS keyring, use a supported AWS KMS key identifier. The key identifiers you can use to identify an AWS KMS key in a keyring vary with the operation and the language implementation. For details about the key identifiers for an AWS KMS key, see Key Identifiers in the *AWS Key Management Service Developer Guide*.

As a best practice, use the most specific key identifier that is practical for your task.

- In an encryption keyring for the AWS Encryption SDK for C, you can use a key ARN or alias ARN to identify KMS keys. In all other language implementations, you can use a key ID, key ARN, alias name, or alias ARN to encrypt data.
- In a decryption keyring, you must use a key ARN to identify AWS KMS keys. This requirement applies to all language implementations of the AWS Encryption SDK. For details, see Selecting wrapping keys.
- In a keyring used for encryption and decryption, you must use a key ARN to identify AWS KMS keys. This requirement applies to all language implementations of the AWS Encryption SDK.

If you specify an alias name or alias ARN for a KMS key in an encryption keyring, the encrypt operation saves the key ARN currently associated with the alias in the metadata of the encrypted data key. It does not save the alias. Changes to the alias don't affect the KMS key used to decrypt your encrypted data keys.

Creating an AWS KMS keyring

You can configure each AWS KMS keyring with a single AWS KMS key or multiple AWS KMS keys in the same or different AWS accounts and AWS Regions. The AWS KMS keys must be a symmetric encryption KMS keys (SYMMETRIC_DEFAULT) or an asymmetric RSA KMS key. You can also use a symmetric encryption multi-Region KMS key. You can use one or more AWS KMS keyrings in a multi-keyring.

You can create an AWS KMS keyring that encrypts and decrypts data, or you can create AWS KMS keyrings specifically for encrypting or decrypting. When you create an AWS KMS keyring to encrypt data, you must specify a *generator key*, which is an AWS KMS key that is used to generate a plaintext data key and encrypt it. The data key is mathematically unrelated to the KMS key. Then, if you choose, you can specify additional AWS KMS keys that encrypt the same plaintext data key. To decrypt an encrypted field protected by this keyring, the decryption keyring that you use must include at least one of the AWS KMS keys defined in the keyring, or no AWS KMS keys. (An AWS KMS keyring with no AWS KMS keys is known as an AWS KMS discovery keyring.)

In AWS Encryption SDK language implementations other than the AWS Encryption SDK for C, all wrapping keys in an encryption keyring or multi-keyring must be able to encrypt the data key. If any wrapping key fails to encrypt, the encrypt method fails. As a result, the caller must have the required permissions for all keys in the keyring. If you use a discovery keyring to encrypt data,

alone or in a multi-keyring, the encrypt operation fails. The exception is the AWS Encryption SDK for C, where the encrypt operation ignores a standard discovery keyring, but fails if you specify a multi-Region discovery keyring, alone or in a multi-keyring.

The following examples create an AWS KMS keyring with a generator key and one additional key. Both the generator key and additional key are symmetric encryption KMS keys. These examples use key ARNs to identify the KMS keys. This is a best practice for AWS KMS keyrings used for encryption, and a requirement for AWS KMS keyrings used for decryption. For details, see Identifying AWS KMS keys in an AWS KMS keyring.

C

To identify an AWS KMS key in an encryption keyring in the AWS Encryption SDK for C, specify a key ARN or alias ARN. In a decryption keyring, you must use a key ARN. For details, see Identifying AWS KMS keys in an AWS KMS keyring.

For a complete example, see string.cpp.

```
const char * generator_key = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab"

const char * additional_key = "arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321"

struct aws_cryptosdk_keyring *kms_encrypt_keyring =
       Aws::Cryptosdk::KmsKeyring::Builder().Build(generator_key,{additional_key});
```

C# / .NET

To create a keyring with one or more KMS keys in the AWS Encryption SDK for .NET, use the `CreateAwsKmsMultiKeyring()` method. This example uses two AWS KMS keys. To specify one KMS key, use only the `Generator` parameter. The `KmsKeyIds` parameter that specifies additional KMS keys is optional.

The input for this keyring doesn't take an AWS KMS client. Instead, the AWS Encryption SDK uses the default AWS KMS client for each Region represented by a KMS key in the keyring. For example, if the KMS key identified by the value of the `Generator` parameter is in the US West (Oregon) Region (`us-west-2`), the AWS Encryption SDK creates a default AWS KMS client for the `us-west-2` Region. If you need to customize the AWS KMS client, use the `CreateAwsKmsKeyring()` method.

When you specify an AWS KMS key for an encryption keyring in the AWS Encryption SDK for .NET, you can use any valid key identifier: a key ID, key ARN, alias name, or alias ARN. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

The following example uses version 4.*x* of the AWS Encryption SDK for .NET and the `CreateAwsKmsKeyring()` method to customize the AWS KMS client.

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());

string generatorKey = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";
List<string> additionalKeys = new List<string> { "arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321" };

// Instantiate the keyring input object
var createEncryptKeyringInput = new CreateAwsKmsMultiKeyringInput
{
    Generator = generatorKey,
    KmsKeyIds = additionalKeys
};

var kmsEncryptKeyring = mpl.CreateAwsKmsMultiKeyring(createEncryptKeyringInput);
```

JavaScript Browser

When you specify an AWS KMS key for an encryption keyring in the AWS Encryption SDK for JavaScript, you can use any valid key identifier: a key ID, key ARN, alias name, or alias ARN. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called “Limiting encrypted data keys”.

For a complete example, see kms_simple.ts in the AWS Encryption SDK for JavaScript repository in GitHub.

```
import {
```

```
  KmsKeyringNode,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const clientProvider = getClient(KMS, { credentials })
const generatorKeyId = 'arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'
const additionalKey = 'alias/exampleAlias'

const keyring = new KmsKeyringBrowser({
  clientProvider,
  generatorKeyId,
  keyIds: [additionalKey]
})
```

JavaScript Node.js

When you specify an AWS KMS key for an encryption keyring in the AWS Encryption SDK for JavaScript, you can use any valid key identifier: a key ID, key ARN, alias name, or alias ARN. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called “Limiting encrypted data keys”.

For a complete example, see kms_simple.ts in the AWS Encryption SDK for JavaScript repository in GitHub.

```
import {
  KmsKeyringNode,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
```

```
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const generatorKeyId = 'arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'

const additionalKey = 'alias/exampleAlias'

const keyring = new KmsKeyringNode({
  generatorKeyId,
  keyIds: [additionalKey]
})
```

Java

To create a keyring with one or more AWS KMS keys, use the `CreateAwsKmsMultiKeyring()` method. This example uses two KMS keys. To specify one KMS key, use only the `generator` parameter. The `kmsKeyIds` parameter that specifies additional KMS keys is optional.

The input for this keyring doesn't take an AWS KMS client. Instead, the AWS Encryption SDK uses the default AWS KMS client for each Region represented by a KMS key in the keyring. For example, if the KMS key identified by the value of the `Generator` parameter is in the US West (Oregon) Region (`us-west-2`), the AWS Encryption SDK creates a default AWS KMS client for the `us-west-2` Region. If you need to customize the AWS KMS client, use the `CreateAwsKmsKeyring()` method.

When you specify an AWS KMS key for an encryption keyring in the AWS Encryption SDK for Java, you can use any valid key identifier: a key ID, key ARN, alias name, or alias ARN. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

For a complete example, see BasicEncryptionKeyringExample.java in the AWS Encryption SDK for Java repository in GitHub.

```
// Instantiate the AWS Encryption SDK and material providers
final AwsCrypto crypto = AwsCrypto.builder().build();
final MaterialProviders materialProviders = MaterialProviders.builder()
            .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
            .build();

String generatorKey = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";
```

```
List<String> additionalKey = Collections.singletonList("arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321");
// Create the keyring
final CreateAwsKmsMultiKeyringInput keyringInput =
 CreateAwsKmsMultiKeyringInput.builder()
        .generator(generatorKey)
        .kmsKeyIds(additionalKey)
        .build();
final IKeyring kmsKeyring =
 materialProviders.CreateAwsKmsMultiKeyring(keyringInput);
```

Python

To create a keyring with one or more AWS KMS keys, use the `create_aws_kms_multi_keyring()` method. This example uses two KMS keys. To specify one KMS key, use only the `generator` parameter. The `kms_key_ids` parameter that specifies additional KMS keys is optional.

The input for this keyring doesn't take an AWS KMS client. Instead, the AWS Encryption SDK uses the default AWS KMS client for each Region represented by a KMS key in the keyring. For example, if the KMS key identified by the value of the `generator` parameter is in the US West (Oregon) Region (`us-west-2`), the AWS Encryption SDK creates a default AWS KMS client for the `us-west-2` Region. If you need to customize the AWS KMS client, use the `create_aws_kms_keyring()` method.

When you specify an AWS KMS key for an encryption keyring in the AWS Encryption SDK for Python, you can use any valid key identifier: a key ID, key ARN, alias name, or alias ARN. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

The following example instantiates the AWS Encryption SDK client with the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. For a complete example, see aws_kms_multi_keyring_example.py in the AWS Encryption SDK for Python repository in GitHub.

```
# Instantiate the AWS Encryption SDK client
client = aws_encryption_sdk.EncryptionSDKClient(
    commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

# Optional: Create an encryption context
```

```
encryption_context: Dict[str, str] = {
    "encryption": "context",
    "is not": "secret",
    "but adds": "useful metadata",
    "that can help you": "be confident that",
    "the data you are handling": "is what you think it is",
}

# Instantiate the material providers library
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create the AWS KMS keyring
kms_multi_keyring_input: CreateAwsKmsMultiKeyringInput =
 CreateAwsKmsMultiKeyringInput(
    generator="arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab",
    kms_key_ids="arn:aws:kms:us-west-2:111122223333:key/0987dcba-09fe-87dc-65ba-
ab0987654321"
)

kms_multi_keyring: IKeyring = mat_prov.create_aws_kms_multi_keyring(
    input=kms_multi_keyring_input
)
```

Rust

To create a keyring with one or more AWS KMS keys, use the `create_aws_kms_multi_keyring()` method. This example uses two KMS keys. To specify one KMS key, use only the `generator` parameter. The `kms_key_ids` parameter that specifies additional KMS keys is optional.

The input for this keyring doesn't take an AWS KMS client. Instead, the AWS Encryption SDK uses the default AWS KMS client for each Region represented by a KMS key in the keyring. For example, if the KMS key identified by the value of the `generator` parameter is in the US West (Oregon) Region (`us-west-2`), the AWS Encryption SDK creates a default AWS KMS client for the `us-west-2` Region. If you need to customize the AWS KMS client, use the `create_aws_kms_keyring()` method.

When you specify an AWS KMS key for an encryption keyring in the AWS Encryption SDK for Rust, you can use any valid key identifier: a key ID, key ARN, alias name, or alias ARN. For help

identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

The following example instantiates the AWS Encryption SDK client with the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. For a complete example, see aws_kms_keyring_example.rs in the Rust directory of the aws-encryption-sdk repository on GitHub.

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Create an AWS KMS client
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let kms_client = aws_sdk_kms::Client::new(&sdk_config);

// Optional: Create an encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create the AWS KMS keyring
let kms_keyring = mpl
    .create_aws_kms_keyring()
    .kms_key_id(kms_key_id)
    .kms_client(kms_client)
    .send()
    .await?;

kms_multi_keyring: IKeyring = mpl.create_aws_kms_multi_keyring(
    input=kms_multi_keyring_input
)
```

Go

To create a keyring with one or more AWS KMS keys, use the `create_aws_kms_multi_keyring()` method. This example uses two KMS keys. To specify one KMS key, use only the `generator` parameter. The `kms_key_ids` parameter that specifies additional KMS keys is optional.

The input for this keyring doesn't take an AWS KMS client. Instead, the AWS Encryption SDK uses the default AWS KMS client for each Region represented by a KMS key in the keyring. For example, if the KMS key identified by the value of the `generator` parameter is in the US West (Oregon) Region (`us-west-2`), the AWS Encryption SDK creates a default AWS KMS client for the `us-west-2` Region. If you need to customize the AWS KMS client, use the `create_aws_kms_keyring()` method.

When you specify an AWS KMS key for an encryption keyring in the AWS Encryption SDK for Go, you can use any valid key identifier: a key ID, key ARN, alias name, or alias ARN. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

The following example instantiates the AWS Encryption SDK client with the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`.

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}
```

```
// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create the AWS KMS keyring
awsKmsMultiKeyringInput := mpltypes.CreateAwsKmsMultiKeyringInput{
    Generator: "&arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab",
    KmsKeyIds: []string{"arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321"},
}
awsKmsMultiKeyring, err := matProv.CreateAwsKmsMultiKeyring(context.Background(),
 awsKmsMultiKeyringInput)
```

The AWS Encryption SDK also supports AWS KMS keyrings that use asymmetric RSA KMS keys. Asymmetric RSA AWS KMS keyrings can only contain one key pair.

To encrypt with an asymmetric RSA AWS KMS keyring, you do not need kms:GenerateDataKey or kms:Encrypt because you must specify the public key material that you want to use for encryption when you create the keyring. No AWS KMS calls are made when encrypting with this keyring. To decrypt with an asymmetric RSA AWS KMS keyring, you need kms:Decrypt permission.

> **Note**
>
> To create an AWS KMS keyring that uses asymmetric RSA KMS keys, you must use one of the following programming language implementations:
>
> - Version 3.*x* of the AWS Encryption SDK for Java
> - Version 4.*x* of theAWS Encryption SDK for .NET

- Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency.
- Version 1.*x* of the AWS Encryption SDK for Rust
- Version 0.1.*x* or later of the AWS Encryption SDK for Go

The following examples use the `CreateAwsKmsRsaKeyring` method to create an AWS KMS keyring with an asymmetric RSA KMS key. To create an asymmetric RSA AWS KMS keyring, provide the following values.

- `kmsClient`: create a new AWS KMS client
- `kmsKeyID`: the key ARN that identifies your asymmetric RSA KMS key
- `publicKey`: a ByteBuffer of a UTF-8 encoded PEM file that represents the public key of the key you passed to `kmsKeyID`
- `encryptionAlgorithm`: the encryption algorithm must be `RSAES_OAEP_SHA_256` or `RSAES_OAEP_SHA_1`

C# / .NET

To create an asymmetric RSA AWS KMS keyring, you must provide the public key and private key ARN from your asymmetric RSA KMS key. The public key must be PEM encoded. The following example creates an AWS KMS keyring with an asymmetric RSA key pair.

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());

var publicKey = new MemoryStream(Encoding.UTF8.GetBytes(AWS KMS RSA public key));

// Instantiate the keyring input object
var createKeyringInput = new CreateAwsKmsRsaKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    KmsKeyId = AWS KMS RSA private key ARN,
    PublicKey = publicKey,
    EncryptionAlgorithm = EncryptionAlgorithmSpec.RSAES_OAEP_SHA_256
};
```

```
// Create the keyring
var kmsRsaKeyring = mpl.CreateAwsKmsRsaKeyring(createKeyringInput);
```

Java

To create an asymmetric RSA AWS KMS keyring, you must provide the public key and private key ARN from your asymmetric RSA KMS key. The public key must be PEM encoded. The following example creates an AWS KMS keyring with an asymmetric RSA key pair.

```
// Instantiate the AWS Encryption SDK and material providers
final AwsCrypto crypto = AwsCrypto.builder()
        // Specify algorithmSuite without asymmetric signing here
        //
        // ALG_AES_128_GCM_IV12_TAG16_NO_KDF("0x0014"),
        // ALG_AES_192_GCM_IV12_TAG16_NO_KDF("0x0046"),
        // ALG_AES_256_GCM_IV12_TAG16_NO_KDF("0x0078"),
        // ALG_AES_128_GCM_IV12_TAG16_HKDF_SHA256("0x0114"),
        // ALG_AES_192_GCM_IV12_TAG16_HKDF_SHA256("0x0146"),
        // ALG_AES_256_GCM_IV12_TAG16_HKDF_SHA256("0x0178")

 .withEncryptionAlgorithm(CryptoAlgorithm.ALG_AES_256_GCM_IV12_TAG16_HKDF_SHA256)
        .build();

final MaterialProviders matProv = MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();

// Create a KMS RSA keyring.
//    This keyring takes in:
//     - kmsClient
//     - kmsKeyId: Must be an ARN representing an asymmetric RSA KMS key
//     - publicKey: A ByteBuffer of a UTF-8 encoded PEM file representing the public
//                  key for the key passed into kmsKeyId
//     - encryptionAlgorithm: Must be either RSAES_OAEP_SHA_256 or RSAES_OAEP_SHA_1
final CreateAwsKmsRsaKeyringInput createAwsKmsRsaKeyringInput =
        CreateAwsKmsRsaKeyringInput.builder()
                .kmsClient(KmsClient.create())
                .kmsKeyId(rsaKeyArn)
                .publicKey(publicKey)
                .encryptionAlgorithm(EncryptionAlgorithmSpec.RSAES_OAEP_SHA_256)
                .build();
IKeyring awsKmsRsaKeyring =
 matProv.CreateAwsKmsRsaKeyring(createAwsKmsRsaKeyringInput);
```

Python

To create an asymmetric RSA AWS KMS keyring, you must provide the public key and private key ARN from your asymmetric RSA KMS key. The public key must be PEM encoded. The following example creates an AWS KMS keyring with an asymmetric RSA key pair.

```
# Instantiate the AWS Encryption SDK client
client = aws_encryption_sdk.EncryptionSDKClient(
    commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

# Optional: Create an encryption context
encryption_context: Dict[str, str] = {
    "encryption": "context",
    "is not": "secret",
    "but adds": "useful metadata",
    "that can help you": "be confident that",
    "the data you are handling": "is what you think it is",
}

# Instantiate the material providers library
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create the AWS KMS keyring
keyring_input: CreateAwsKmsRsaKeyringInput = CreateAwsKmsRsaKeyringInput(
    public_key="public_key",
    kms_key_id="kms_key_id",
    encryption_algorithm="RSAES_OAEP_SHA_256",
    kms_client=kms_client
)

kms_rsa_keyring: IKeyring = mat_prov.create_aws_kms_rsa_keyring(
    input=keyring_input
)
```

Rust

To create an asymmetric RSA AWS KMS keyring, you must provide the public key and private key ARN from your asymmetric RSA KMS key. The public key must be PEM encoded. The following example creates an AWS KMS keyring with an asymmetric RSA key pair.

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Create an AWS KMS client
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let kms_client = aws_sdk_kms::Client::new(&sdk_config);

// Optional: Create an encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create the AWS KMS keyring
let kms_rsa_keyring = mpl
    .create_aws_kms_rsa_keyring()
    .kms_key_id(kms_key_id)
    .public_key(aws_smithy_types::Blob::new(public_key))

 .encryption_algorithm(aws_sdk_kms::types::EncryptionAlgorithmSpec::RsaesOaepSha256)
    .kms_client(kms_client)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
```

```
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
    "github.com/aws/aws-sdk-go-v2/config"
    "github.com/aws/aws-sdk-go-v2/service/kms"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS client
cfg, err := config.LoadDefaultConfig(context.TODO())
if err != nil {
    panic(err)
}
kmsClient := kms.NewFromConfig(cfg, func(o *kms.Options) {
    o.Region = KmsKeyRegion
})

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create the AWS KMS keyring
awsKmsRSAKeyringInput := mpltypes.CreateAwsKmsRsaKeyringInput{
    KmsClient:           kmsClient,
    KmsKeyId:            kmsKeyID,
    PublicKey:           kmsPublicKey,
    EncryptionAlgorithm: kmstypes.EncryptionAlgorithmSpecRsaesOaepSha256,
```

```
}
awsKmsRSAKeyring, err := matProv.CreateAwsKmsRsaKeyring(context.Background(),
 awsKmsRSAKeyringInput)
if err != nil {
    panic(err)
}
```

Using an AWS KMS discovery keyring

When decrypting, it's a best practice to specify the wrapping keys that the AWS Encryption SDK can use. To follow this best practice, use an AWS KMS decryption keyring that limits the AWS KMS wrapping keys to those that you specify. However, you can also create an *AWS KMS discovery keyring*, that is, an AWS KMS keyring that doesn't specify any wrapping keys.

The AWS Encryption SDK provides a standard AWS KMS discovery keyring and a discovery keyring for AWS KMS multi-Region keys. For information about using multi-Region keys with the AWS Encryption SDK, see Using multi-Region AWS KMS keys.

Because it doesn't specify any wrapping keys, a discovery keyring can't encrypt data. If you use a discovery keyring to encrypt data, alone or in a multi-keyring, the encrypt operation fails. The exception is the AWS Encryption SDK for C, where the encrypt operation ignores a standard discovery keyring, but fails if you specify a multi-Region discovery keyring, alone or in a multi-keyring.

When decrypting, a discovery keyring allows the AWS Encryption SDK to ask AWS KMS to decrypt any encrypted data key by using the AWS KMS key that encrypted it, regardless of who owns or has access to that AWS KMS key. The call succeeds only when the caller has `kms:Decrypt` permission on the AWS KMS key.

> **Important**
>
> If you include an AWS KMS discovery keyring in a decryption multi-keyring, the discovery keyring overrides all KMS key restrictions specified by other keyrings in the multi-keyring. The multi-keyring behaves like its least restrictive keyring. An AWS KMS discovery keyring has no effect on encryption when used by itself or in a multi-keyring.

The AWS Encryption SDK provides an AWS KMS discovery keyring for convenience. However, we recommend that you use a more limited keyring whenever possible for the following reasons.

- **Authenticity** – An AWS KMS discovery keyring can use any AWS KMS key that was used to encrypt a data key in the encrypted message, just so the caller has permission to use that AWS KMS key to decrypt. This might not be the AWS KMS key that the caller intends to use. For example, one of the encrypted data keys might have been encrypted under a less secure AWS KMS key that anyone can use.
- **Latency and performance** – An AWS KMS discovery keyring might be perceptibly slower than other keyrings because the AWS Encryption SDK tries to decrypt all of the encrypted data keys, including those encrypted by AWS KMS keys in other AWS accounts and Regions, and AWS KMS keys that the caller doesn't have permission to use for decryption.

If you use a discovery keyring, we recommend that you use a *discovery filter* to limit the KMS keys that can be used to those in specified AWS accounts and partitions. Discovery filters are supported in versions 1.7.*x* and later of the AWS Encryption SDK. For help finding your account ID and partition, see Your AWS account identifiers and ARN format in the *AWS General Reference*.

The following code instantiates an AWS KMS discovery keyring with a discovery filter that limits the KMS keys the AWS Encryption SDK can use to those in the `aws` partition and 111122223333 example account.

Before using this code, replace the example AWS account and partition values with valid values for your AWS account and partition. If your KMS keys are in China Regions, use the `aws-cn` partition value. If your KMS keys are in AWS GovCloud (US) Regions, use the `aws-us-gov` partition value. For all other AWS Regions, use the `aws` partition value.

C

For a complete example, see: kms_discovery.cpp.

```
std::shared_ptr<KmsKeyring::> discovery_filter(
    KmsKeyring::DiscoveryFilter::Builder("aws")
        .AddAccount("111122223333")
        .Build());

struct aws_cryptosdk_keyring *kms_discovery_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder()
       .BuildDiscovery(discovery_filter));
```

C# / .NET

The following example uses version 4.*x* of the AWS Encryption SDK for .NET.

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());

List<string> account = new List<string> { "111122223333" };

// In a discovery keyring, you specify an AWS KMS client and a discovery filter,
// but not a AWS KMS key
var kmsDiscoveryKeyringInput = new CreateAwsKmsDiscoveryKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    DiscoveryFilter = new DiscoveryFilter()
    {
        AccountIds = account,
        Partition = "aws"
    }
};

var kmsDiscoveryKeyring =
 mpl.CreateAwsKmsDiscoveryKeyring(kmsDiscoveryKeyringInput);
```

JavaScript Browser

In JavaScript, you must explicitly specify the discovery property.

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

```
import {
  KmsKeyringBrowser,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-browser'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const clientProvider = getClient(KMS, { credentials })
```

```
const discovery = true
const keyring = new KmsKeyringBrowser(clientProvider, {
    discovery,
    discoveryFilter: { accountIDs: [111122223333], partition: 'aws' }
})
```

JavaScript Node.js

In JavaScript, you must explicitly specify the discovery property.

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

```
import {
  KmsKeyringNode,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const discovery = true

const keyring = new KmsKeyringNode({
    discovery,
    discoveryFilter: { accountIDs: ['111122223333'], partition: 'aws' }
})
```

Java

```
// Create discovery filter
DiscoveryFilter discoveryFilter = DiscoveryFilter.builder()
        .partition("aws")
        .accountIds(111122223333)
        .build();
// Create the discovery keyring
CreateAwsKmsMrkDiscoveryMultiKeyringInput createAwsKmsMrkDiscoveryMultiKeyringInput
 = CreateAwsKmsMrkDiscoveryMultiKeyringInput.builder()
```

```
        .discoveryFilter(discoveryFilter)
        .build();
IKeyring decryptKeyring =
 matProv.CreateAwsKmsMrkDiscoveryMultiKeyring(createAwsKmsMrkDiscoveryMultiKeyringInput);
```

Python

```
# Instantiate the AWS Encryption SDK
client = aws_encryption_sdk.EncryptionSDKClient(
    commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

# Create a boto3 client for AWS KMS
kms_client = boto3.client('kms', region_name=aws_region)

# Optional: Create an encryption context
encryption_context: Dict[str, str] = {
    "encryption": "context",
    "is not": "secret",
    "but adds": "useful metadata",
    "that can help you": "be confident that",
    "the data you are handling": "is what you think it is",
}

# Instantiate the material providers
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create the AWS KMS discovery keyring
discovery_keyring_input: CreateAwsKmsDiscoveryKeyringInput =
 CreateAwsKmsDiscoveryKeyringInput(
    kms_client=kms_client,
    discovery_filter=DiscoveryFilter(
        account_ids=[aws_account_id],
        partition="aws"
    )
)

discovery_keyring: IKeyring = mat_prov.create_aws_kms_discovery_keyring(
    input=discovery_keyring_input
)
```

Rust

```
// Instantiate the AWS Encryption SDK
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Create a AWS KMS client.
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let kms_client = aws_sdk_kms::Client::new(&sdk_config);


// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create discovery filter
let discovery_filter = DiscoveryFilter::builder()
    .account_ids(vec![aws_account_id.to_string()])
    .partition("aws".to_string())
    .build()?;

// Create the AWS KMS discovery keyring
let discovery_keyring = mpl
    .create_aws_kms_discovery_keyring()
    .kms_client(kms_client.clone())
    .discovery_filter(discovery_filter)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
```

```
    "github.com/aws/aws-sdk-go-v2/config"
    "github.com/aws/aws-sdk-go-v2/service/kms"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS client
cfg, err := config.LoadDefaultConfig(context.TODO())
if err != nil {
    panic(err)
}
kmsClient := kms.NewFromConfig(cfg, func(o *kms.Options) {
    o.Region = KmsKeyRegion
})

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create discovery filter
discoveryFilter := mpltypes.DiscoveryFilter{
    AccountIds: []string{kmsKeyAccountID},
    Partition:  "aws",
}
awsKmsDiscoveryKeyringInput := mpltypes.CreateAwsKmsDiscoveryKeyringInput{
    KmsClient:       kmsClient,
    DiscoveryFilter: &discoveryFilter,
}
```

```
awsKmsDiscoveryKeyring, err :=
 matProv.CreateAwsKmsDiscoveryKeyring(context.Background(),
 awsKmsDiscoveryKeyringInput)
if err != nil {
    panic(err)
}
```

Using an AWS KMS regional discovery keyring

An *AWS KMS regional discovery keyring* is a keyring that doesn't specify the ARNs of KMS keys. Instead, it allows the AWS Encryption SDK to decrypt using only the KMS keys in particular AWS Regions.

When decrypting with an AWS KMS regional discovery keyring, the AWS Encryption SDK decrypts any encrypted data key that was encrypted under an AWS KMS key in the specified AWS Region. To succeed, the caller must have `kms:Decrypt` permission on at least one of the AWS KMS keys in the specified AWS Region that encrypted a data key.

Like other discovery keyrings, the regional discovery keyring has no effect on encryption. It works only when decrypting encrypted messages. If you use a regional discovery keyring in a multi-keyring that is used for encrypting and decrypting, it is effective only when decrypting. If you use a multi-Region discovery keyring to encrypt data, alone or in a multi-keyring, the encrypt operation fails.

> **Important**
>
> If you include an AWS KMS regional discovery keyring in a decryption multi-keyring, the regional discovery keyring overrides all KMS key restrictions specified by other keyrings in the multi-keyring. The multi-keyring behaves like its least restrictive keyring. An AWS KMS discovery keyring has no effect on encryption when used by itself or in a multi-keyring.

The regional discovery keyring in the AWS Encryption SDK for C attempts to decrypt only with KMS keys in the specified Region. When you use a discovery keyring in the AWS Encryption SDK for JavaScript and AWS Encryption SDK for .NET, you configure the Region on the AWS KMS client. These AWS Encryption SDK implementations don't filter KMS keys by Region, but AWS KMS will fail a decrypt request for KMS keys outside of the specified Region.

If you use a discovery keyring, we recommend that you use a *discovery filter* to limit the KMS keys used in decryption to those in specified AWS accounts and partitions. Discovery filters are supported in versions 1.7.*x* and later of the AWS Encryption SDK.

For example, the following code creates an AWS KMS regional discovery keyring with a discovery filter. This keyring limits the AWS Encryption SDK to KMS keys in account 111122223333 in the US West (Oregon) Region (us-west-2).

C

To view this keyring, and the `create_kms_client` method, in a working example, see kms_discovery.cpp.

```
std::shared_ptr<KmsKeyring::DiscoveryFilter> discovery_filter(
    KmsKeyring::DiscoveryFilter::Builder("aws")
        .AddAccount("111122223333")
        .Build());

struct aws_cryptosdk_keyring *kms_regional_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder()

 .WithKmsClient(create_kms_client(Aws::Region::US_WEST_2)).BuildDiscovery(discovery_filter))
```

C# / .NET

The AWS Encryption SDK for .NET does not have a dedicated regional discovery keyring. However, you can use several techniques to limit the KMS keys used when decrypting to a particular Region.

The most efficient way to limit the Regions in a discovery keyring is to use a multi-Region-aware discovery keyring, even if you encrypted the data using only single-Region keys. When it encounters single-Region keys, the multi-Region-aware keyring does not use any multi-Region features.

The keyring returned by the `CreateAwsKmsMrkDiscoveryKeyring()` method filters KMS keys by Region before calling AWS KMS. It sends a decrypt request to AWS KMS only when the encrypted data key was encrypted by a KMS key in the Region specified by the `Region` parameter in the `CreateAwsKmsMrkDiscoveryKeyringInput` object.

The following examples uses version 4.*x* of the AWS Encryption SDK for .NET.

```
// Instantiate the AWS Encryption SDK and material providers
```

```
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());

List<string> account = new List<string> { "111122223333" };

// Create the discovery filter
var filter = DiscoveryFilter = new DiscoveryFilter
{
    AccountIds = account,
    Partition = "aws"
};

var regionalDiscoveryKeyringInput = new CreateAwsKmsMrkDiscoveryKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(RegionEndpoint.USWest2),
    Region = RegionEndpoint.USWest2,
    DiscoveryFilter = filter
};

var kmsRegionalDiscoveryKeyring =
 mpl.CreateAwsKmsMrkDiscoveryKeyring(regionalDiscoveryKeyringInput);
```

You can also limit KMS keys to a particular AWS Region by specifying a Region in your instance of the AWS KMS client (AmazonKeyManagementServiceClient). However, this configuration is less efficient and potentially more costly than using a multi-Region-aware discovery keyring. Instead of filtering KMS keys by Region before calling AWS KMS, the AWS Encryption SDK for .NET calls AWS KMS for each encrypted data key (until it decrypts one) and relies on AWS KMS to limit the KMS keys it uses to the specified Region.

The following example uses version 4.*x* of the AWS Encryption SDK for .NET.

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());

List<string> account = new List<string> { "111122223333" };

// Create the discovery filter,
// but not a AWS KMS key
var createRegionalDiscoveryKeyringInput = new CreateAwsKmsDiscoveryKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(RegionEndpoint.USWest2),
    DiscoveryFilter = new DiscoveryFilter()
```

```
    {
        AccountIds = account,
        Partition = "aws"
    }
};

var kmsRegionalDiscoveryKeyring =
 mlp.CreateAwsKmsDiscoveryKeyring(createRegionalDiscoveryKeyringInput);
```

JavaScript Browser

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

```
import {
  KmsKeyringNode,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const clientProvider = getClient(KMS, { credentials })

const discovery = true
const clientProvider = limitRegions(['us-west-2'], getKmsClient)
const keyring = new KmsKeyringBrowser(clientProvider, {
    discovery,
    discoveryFilter: { accountIDs: ['111122223333'], partition: 'aws' }
})
```

JavaScript Node.js

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

To view this keyring, and the `limitRegions` function, in a working example, see kms_regional_discovery.ts.

```
import {
  KmsKeyringNode,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const discovery = true
const clientProvider = limitRegions(['us-west-2'], getKmsClient)
const keyring = new KmsKeyringNode({
    clientProvider,
    discovery,
    discoveryFilter: { accountIDs: ['111122223333'], partition: 'aws' }
})
```

Java

```
// Create the discovery filter
DiscoveryFilter discoveryFilter = DiscoveryFilter.builder()
        .partition("aws")
        .accountIds(111122223333)
        .build();
// Create the discovery keyring
CreateAwsKmsMrkDiscoveryMultiKeyringInput createAwsKmsMrkDiscoveryMultiKeyringInput
 = CreateAwsKmsMrkDiscoveryMultiKeyringInput.builder()
        .discoveryFilter(discoveryFilter)
        .regions("us-west-2")
        .build();
IKeyring decryptKeyring =
 matProv.CreateAwsKmsMrkDiscoveryMultiKeyring(createAwsKmsMrkDiscoveryMultiKeyringInput);
```

Python

```
# Instantiate the AWS Encryption SDK
client = aws_encryption_sdk.EncryptionSDKClient(
    commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
```

```
)

# Create a boto3 client for AWS KMS
kms_client = boto3.client('kms', region_name=aws_region)

# Optional: Create an encryption context
encryption_context: Dict[str, str] = {
    "encryption": "context",
    "is not": "secret",
    "but adds": "useful metadata",
    "that can help you": "be confident that",
    "the data you are handling": "is what you think it is",
}

# Instantiate the material providers
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create the AWS KMS regional discovery keyring
regional_discovery_keyring_input: CreateAwsKmsMrkDiscoveryKeyringInput = \
    CreateAwsKmsMrkDiscoveryKeyringInput(
        kms_client=kms_client,
        region=mrk_replica_decrypt_region,
        discovery_filter=DiscoveryFilter(
            account_ids=[111122223333],
            partition="aws"
        )
)

    regional_discovery_keyring: IKeyring =
 mat_prov.create_aws_kms_mrk_discovery_keyring(
        input=regional_discovery_keyring_input
    )
```

Rust

```
// Instantiate the AWS Encryption SDK
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;
```

```
// Optional: Create an encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create an AWS KMS client
let decrypt_kms_config = aws_sdk_kms::config::Builder::from(&sdk_config)
    .region(Region::new(mrk_replica_decrypt_region.clone()))
    .build();
let decrypt_kms_client = aws_sdk_kms::Client::from_conf(decrypt_kms_config);


// Create discovery filter
let discovery_filter = DiscoveryFilter::builder()
    .account_ids(vec![aws_account_id.to_string()])
    .partition("aws".to_string())
    .build()?;

// Create the regional discovery keyring
let discovery_keyring = mpl
    .create_aws_kms_mrk_discovery_keyring()
    .kms_client(decrypt_kms_client)
    .region(mrk_replica_decrypt_region)
    .discovery_filter(discovery_filter)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
```

```
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
    "github.com/aws/aws-sdk-go-v2/config"
    "github.com/aws/aws-sdk-go-v2/service/kms"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS client
cfg, err := config.LoadDefaultConfig(context.TODO())
if err != nil {
    panic(err)
}
kmsClient := kms.NewFromConfig(cfg, func(o *kms.Options) {
    o.Region = KmsKeyRegion
})

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Create discovery filter
discoveryFilter := mpltypes.DiscoveryFilter{
    AccountIds: []string{awsAccountID},
    Partition:  "aws",
}

// Create the regional discovery keyring
awsKmsMrkDiscoveryInput := mpltypes.CreateAwsKmsMrkDiscoveryKeyringInput{
    KmsClient:       kmsClient,
    Region:          alternateRegionMrkKeyRegion,
```

```
    DiscoveryFilter: &discoveryFilter,
}
awsKmsMrkDiscoveryKeyring, err :=
 matProv.CreateAwsKmsMrkDiscoveryKeyring(context.Background(),
 awsKmsMrkDiscoveryInput)
if err != nil {
    panic(err)
}
```

The AWS Encryption SDK for JavaScript also exports an `excludeRegions` function for Node.js and the browser. This function creates an AWS KMS regional discovery keyring that omits AWS KMS keys in particular regions. The following example creates an AWS KMS regional discovery keyring that can use AWS KMS keys in account 111122223333 in every AWS Region except for US East (N. Virginia) (us-east-1).

The AWS Encryption SDK for C does not have an analogous method, but you can implement one by creating a custom ClientSupplier.

This example shows the code for Node.js.

```
const discovery = true
const clientProvider = excludeRegions(['us-east-1'], getKmsClient)
const keyring = new KmsKeyringNode({
    clientProvider,
    discovery,
    discoveryFilter: { accountIDs: [111122223333], partition: 'aws' }
})
```

AWS KMS Hierarchical keyrings

With the AWS KMS Hierarchical keyring, you can protect your cryptographic materials under a symmetric encryption KMS key without calling AWS KMS every time you encrypt or decrypt data. It is a good choice for applications that need to minimize calls to AWS KMS, and applications that can reuse some cryptographic materials without violating their security requirements.

The Hierarchical keyring is a cryptographic materials caching solution that reduces the number of AWS KMS calls by using AWS KMS protected *branch keys* persisted in an Amazon DynamoDB table, and then locally caching branch key materials used in encrypt and decrypt operations. The DynamoDB table serves as the key store that manages and protects branch keys. It stores the

active branch key and all previous versions of the branch key. The *active* branch key is the most recent branch key version. The Hierarchical keyring uses a unique data key to encrypt each message and encrypts each data encryption key for each encrypt request and encrypts each data encryption key with a unique wrapping key derived from the active branch key. The Hierarchical keyring is dependent on the hierarchy established between active branch keys and their derived wrapping keys.

The Hierarchical keyring typically uses each branch key version to satisfy multiple requests. But you control the extent to which active branch keys are reused and determine how often the active branch key is rotated. The active version of the branch key remains active until you rotate it. Previous versions of the active branch key will not be used to perform encrypt operations, but they can still be queried and used in decrypt operations.

When you instantiate the Hierarchical keyring, it creates a local cache. You specify a cache limit that defines the maximum amount of time that the branch key materials are stored within the local cache before they expire and are evicted from the cache. The Hierarchical keyring makes one AWS KMS call to decrypt the branch key and assemble the branch key materials the first time a `branch-key-id` is specified in an operation. Then, the branch key materials are stored in the local cache and reused for all encrypt and decrypt operations that specify that `branch-key-id` until the cache limit expires. Storing branch key materials in the local cache reduces AWS KMS calls. For example, consider a cache limit of 15 minutes. If you perform 10,000 encrypt operations within that cache limit, the traditional AWS KMS keyring would need to make 10,000 AWS KMS calls to satisfy 10,000 encrypt operations. If you have one active `branch-key-id`, the Hierarchical keyring only needs to make one AWS KMS call to satisfy 10,000 encrypt operations.

The local cache separates encryption materials from decryption materials. The encryption materials are assembled from the active branch key and reused for all encrypt operations until the cache limit expires. The decryption materials are assembled from the branch key ID and version that is identified in the encrypted field's metadata, and they are reused for all decrypt operations related to the branch key ID and version until the cache limit expires. The local cache can store multiple versions of the same branch key at a time. When the local cache is configured to use a branch key ID supplier, it can also store branch key materials from multiple active branch keys at a time.

> **Note**
>
> All mentions of *Hierarchical keyring* in the AWS Encryption SDK refer to the AWS KMS Hierarchical keyring.

Programming language compatibility

The Hierarchical keyring is supported by the following programming languages and versions:

- Version 3.*x* of the AWS Encryption SDK for Java
- Version 4.*x* of the AWS Encryption SDK for .NET
- Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional MPL dependency.
- Version 1.*x* of the AWS Encryption SDK for Rust
- Version 0.1.*x* or later of the AWS Encryption SDK for Go

Topics

- How it works
- Prerequisites
- Required permissions
- Choose a cache
- Create a Hierarchical keyring

How it works

The following walkthroughs describe how the Hierarchical keyring assembles encryption and decryption materials, and the different calls that the keyring makes for encrypt and decrypt operations. For technical details on the wrapping key derivation and plaintext data key encryption processes, see AWS KMS Hierarchical keyring technical details.

Encrypt and sign

The following walkthrough describes how the Hierarchical keyring assembles encryption materials and derives a unique wrapping key.

1. The encryption method asks the Hierarchical keyring for encryption materials. The keyring generates a plaintext data key, then checks to see if there are valid branch materials in the local cache to generate the wrapping key. If there are valid branch key materials, the keyring proceeds to **Step 4**.
2. If there are no valid branch key materials, the Hierarchical keyring queries the key store for the active branch key.

   a. The key store calls AWS KMS to decrypt the active branch key and returns the plaintext active branch key. Data identifying the active branch key is serialized to provide additional authenticated data (AAD) in the decrypt call to AWS KMS.
   b. The key store returns the plaintext branch key and data that identifies it, such as the branch key version.
3. The Hierarchical keyring assembles branch key materials (the plaintext branch key and branch key version) and stores a copy of them in the local cache.
4. The Hierarchical keyring derives a unique wrapping key from the plaintext branch key and a 16-byte random salt. It uses the derived wrapping key to encrypt a copy of the plaintext data key.

The encryption method uses the encryption materials to encrypt the data. For more information, see How the AWS Encryption SDK encrypts data.

Decrypt and verify

The following walkthrough describes how the Hierarchical keyring assembles decryption materials and decrypts the encrypted data key.

1. The decryption method identifies the encrypted data key from the encrypted message, and passes it to the Hierarchical keyring.
2. The Hierarchical keyring deserializes data identifying the encrypted data key, including the branch key version, the 16-byte salt, and other information describing how the data key was encrypted.

   For more information, see AWS KMS Hierarchical keyring technical details.
3. The Hierarchical keyring checks to see if there are valid branch key materials in the local cache that match the branch key version identified in **Step 2**. If there are valid branch key materials, the keyring proceeds to **Step 6**.
4. If there are no valid branch key materials, the Hierarchical keyring queries the key store for the branch key that matches the branch key version identified in **Step 2**.
   a. The key store calls AWS KMS to decrypt the branch key and returns the plaintext active branch key. Data identifying the active branch key is serialized to provide additional authenticated data (AAD) in the decrypt call to AWS KMS.

   b. The key store returns the plaintext branch key and data that identifies it, such as the branch key version.

5. The Hierarchical keyring assembles branch key materials (the plaintext branch key and branch key version) and stores a copy of them in the local cache.
6. The Hierarchical keyring uses the assembled branch key materials and the 16-byte salt identified in **Step 2** to reproduce the unique wrapping key that encrypted the data key.
7. The Hierarchical keyring uses the reproduced wrapping key to decrypt the data key and returns the plaintext data key.

The decryption method uses the decryption materials and plaintext data key to decrypt the encrypted message. For more information , see How the AWS Encryption SDK decrypts an encrypted message.

Prerequisites

Before you create and use a Hierarchical keyring, ensure the following prerequisites are met.

- You, or your key store administrator, have created a key store and created at least one active branch key.
- You have configured your key store actions.

> **Note**
>
> How you configure your key store actions determines what operations you can perform and what KMS keys the Hierarchical keyring can use. For more information, see Key store actions.

- You have the required AWS KMS permissions to access and use the key store and branch keys. For more information, see the section called “Required permissions”.
- You have reviewed the supported cache types and configured the cache type that best fits your needs. For more information, see the section called “Choose a cache”

Required permissions

The AWS Encryption SDK doesn't require an AWS account and it doesn't depend on any AWS service. However, to use an Hierarchical keyring, you need an AWS account and the following minimum permissions on the symmetric encryption AWS KMS key(s) in your key store.

- To encrypt and decrypt data with the Hierarchical keyring, you need kms:Decrypt.
- To create and rotate branch keys, you need kms:GenerateDataKeyWithoutPlaintext and kms:ReEncrypt.

For more information on controlling access to your branch keys and key store, see the section called "Implementing least privileged permissions".

Choose a cache

The Hierarchical keyring reduces the number of calls made to AWS KMS by locally caching the branch key materials used in encrypt and decrypt operations. Before you create your Hierarchical keyring, you need to decide what type of cache you want to use. You can use the default cache or customize the cache to best fits your needs.

The Hierarchical keyring supports the following cache types:

- the section called "Default cache"
- the section called "MultiThreaded cache"
- the section called "StormTracking cache"
- the section called "Shared cache"

> **Important**
>
> All supported cache types are designed to support multithreaded environments. However, when used with the AWS Encryption SDK for Python, the Hierarchical keyring does not support multithreaded environments. For more information, see the Python README.rst file in the aws-cryptographic-material-providers-library repository on GitHub.

Default cache

For most users, the Default cache fulfills their threading requirements. The Default cache is designed to support heavily multithreaded environments. When a branch key materials entry expires, the Default cache prevents multiple threads from calling AWS KMS by notifying one thread that the branch key materials entry is going to expire 10 seconds in advance. This ensures that only one thread sends a request to AWS KMS to refresh the cache.

The Default and StormTracking caches support the same threading model, but you only need to specify the entry capacity to use the Default cache. For more granular cache customizations, use the the section called "StormTracking cache".

Unless you want to customize the number of branch key materials entries that can be stored in the local cache, you do not need to specify a cache type when you create the Hierarchical keyring. If you do not specify a cache type, the Hierarchical keyring uses the Default cache type and sets the entry capacity to 1000.

To customize the Default cache, specify the following values:

- **Entry capacity**: limits the number of branch key materials entries that can be stored in the local cache.

Java

```
.cache(CacheType.builder()
        .Default(DefaultCache.builder()
        .entryCapacity(100)
        .build())
```

C# / .NET

```
CacheType defaultCache = new CacheType
{
    Default = new DefaultCache{EntryCapacity = 100}
};
```

Python

```
default_cache = CacheTypeDefault(
    value=DefaultCache(
```

```
        entry_capacity=100
    )
)
```

Rust

```
let cache: CacheType = CacheType::Default(
    DefaultCache::builder()
        .entry_capacity(100)
        .build()?,
);
```

Go

```
cache := mpltypes.CacheTypeMemberDefault{
  Value: mpltypes.DefaultCache{
   EntryCapacity: 100,
  },
 }
```

MultiThreaded cache

The MultiThreaded cache is safe to use in multithreaded environments, but it does not provide any functionality to minimize AWS KMS or Amazon DynamoDB calls. As a result, when a branch key materials entry expires, all threads will be notified at the same time. This can result in multiple AWS KMS calls to refresh the cache.

To use the MultiThreaded cache, specify the following values:

- **Entry capacity**: limits the number of branch key materials entries that can be stored in the local cache.
- **Entry pruning tail size**: defines the number of entries to prune if the entry capacity is reached.

Java

```
.cache(CacheType.builder()
        .MultiThreaded(MultiThreadedCache.builder()
        .entryCapacity(100)
        .entryPruningTailSize(1)
```

```
        .build())
```

C# / .NET

```
CacheType multithreadedCache = new CacheType
{
    MultiThreaded = new MultiThreadedCache
    {
        EntryCapacity = 100,
        EntryPruningTailSize = 1
    }
};
```

Python

```
multithreaded_cache = CacheTypeMultiThreaded(
    value=MultiThreadedCache(
        entry_capacity=100,
        entry_pruning_tail_size=1
    )
)
```

Rust

```
CacheType::MultiThreaded(
            MultiThreadedCache::builder()
                    .entry_capacity(100)
                    .entry_pruning_tail_size(1)
                    .build()?)
```

Go

```
var entryPruningTailSize int32 = 1
 cache := mpltypes.CacheTypeMemberMultiThreaded{
  Value: mpltypes.MultiThreadedCache{
   EntryCapacity:        100,
   EntryPruningTailSize: &entryPruningTailSize,
  },
 }
```

StormTracking cache

The StormTracking cache is designed to support heavily multithreaded environments. When a branch key materials entry expires, the StormTracking cache prevents multiple threads from calling AWS KMS by notifying one thread that the branch key materials entry is going to expire in advance. This ensures that only one thread sends a request to AWS KMS to refresh the cache.

To use the StormTracking cache, specify the following values:

- **Entry capacity**: limits the number of branch key materials entries that can be stored in the local cache.

  Default value: 1000 entries
- **Entry pruning tail size**: defines the number of branch key materials entries to prune at a time.

  Default value: 1 entry
- **Grace period**: defines the number of seconds before expiration that an attempt to refresh branch key materials is made.

  Default value: 10 seconds
- **Grace interval**: defines the number of seconds between attempts to refresh the branch key materials.

  Default value: 1 second
- **Fan out**: defines the number of simultaneous attempts that can be made to refresh the branch key materials.

  Default value: 20 attempts
- **In flight time to live (TTL)**: defines the number of seconds until an attempt to refresh the branch key materials times out. Any time the cache returns `NoSuchEntry` in response to a `GetCacheEntry`, that branch key is considered to be *in flight* until the same key is written with a `PutCache` entry.

  Default value: 10 seconds
- **Sleep**: defines the number of milliseconds that a thread should sleep if the `fanOut` is exceeded.

  Default value: 20 milliseconds

Java

```
.cache(CacheType.builder()
        .StormTracking(StormTrackingCache.builder()
        .entryCapacity(100)
        .entryPruningTailSize(1)
        .gracePeriod(10)
        .graceInterval(1)
        .fanOut(20)
        .inFlightTTL(10)
        .sleepMilli(20)
        .build())
```

C# / .NET

```
CacheType stormTrackingCache = new CacheType
{
    StormTracking = new StormTrackingCache
    {
        EntryCapacity = 100,
        EntryPruningTailSize = 1,
        FanOut = 20,
        GraceInterval = 1,
        GracePeriod = 10,
        InFlightTTL = 10,
        SleepMilli = 20
    }
};
```

Python

```
storm_tracking_cache = CacheTypeStormTracking(
    value=StormTrackingCache(
        entry_capacity=100,
        entry_pruning_tail_size=1,
        fan_out=20,
        grace_interval=1,
        grace_period=10,
        in_flight_ttl=10,
        sleep_milli=20
    )
)
```

Rust

```
CacheType::StormTracking(
                StormTrackingCache::builder()
                    .entry_capacity(100)
                    .entry_pruning_tail_size(1)
                    .grace_period(10)
                    .grace_interval(1)
                    .fan_out(20)
                    .in_flight_ttl(10)
                    .sleep_milli(20)
                    .build()?)
```

Go

```
var entryPruningTailSize int32 = 1
 cache := mpltypes.CacheTypeMemberStormTracking{
  Value: mpltypes.StormTrackingCache{
   EntryCapacity:        100,
   EntryPruningTailSize: &entryPruningTailSize,
   GraceInterval:        1,
   GracePeriod:          10,
   FanOut:               20,
   InFlightTTL:          10,
   SleepMilli:           20,
  },
 }
```

Shared cache

By default, the Hierarchical keyring creates a new local cache every time you instantiate the keyring. However, the Shared cache can help conserve memory by enabling you to share a cache across multiple Hierarchical keyrings. Rather than creating a new cryptographic materials cache for each Hierarchical keyring you instantiate, the Shared cache stores only one cache in memory, which can be used by all the Hierarchical keyrings that reference it. The Shared cache helps optimize memory usage by avoiding the duplication of cryptographic materials across keyrings. Instead, the Hierarchical keyrings can access the same underlying cache, reducing the overall memory footprint.

When you create your Shared cache, you still define the cache type. You can specify a the section called "Default cache", the section called "MultiThreaded cache", or the section called "StormTracking cache" as the cache type, or substitute any compatible custom cache.

Partitions

Multiple Hierarchical keyrings can use a single Shared cache. When you create a Hierarchical keyring with a Shared cache you can define an optional **partition ID**. The partition ID distinguishes which Hierarchical keyring is writing to the cache. If two Hierarchical keyrings reference the same partition ID, logical key store name, and branch key ID the two keyrings will share the same cache entries in the cache. If you create two Hierarchical keyrings with the same Shared cache, but different partition IDs, each keyring will only access the cache entries from its own designated partition within the Shared cache. The partitions act as logical divisions within the shared cache, allowing each Hierarchical keyring to operate independently on its own designated partition, without interfering with the data stored in the other partition.

If you intend to reuse or share the cache entries in a partition, you must define your own partition ID. When you pass the partition ID to your Hierarchical keyring, the keyring can reuse the cache entries that are already present in the Shared cache, rather than having to retrieve and re-authorize the branch key materials again. If you do not specify a partition ID, a unique partition ID is automatically assigned to the keyring each time you instantiate the Hierarchical keyring.

The following procedures demonstrate how to create a Shared cache with the Default cache type and pass it to a Hierarchical keyring.

1. Create a `CryptographicMaterialsCache` (CMC) using the Material Providers Library (MPL).

   Java

```
// Instantiate the MPL
final MaterialProviders matProv =
    MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();

// Create a CacheType object for the Default cache
final CacheType cache =
    CacheType.builder()
        .Default(DefaultCache.builder().entryCapacity(100).build())
```

```
        .build();

// Create a CMC using the default cache
final CreateCryptographicMaterialsCacheInput cryptographicMaterialsCacheInput =
    CreateCryptographicMaterialsCacheInput.builder()
        .cache(cache)
        .build();

final ICryptographicMaterialsCache sharedCryptographicMaterialsCache =
    matProv.CreateCryptographicMaterialsCache(cryptographicMaterialsCacheInput);
```

C# / .NET

```
// Instantiate the MPL
var materialProviders = new MaterialProviders(new MaterialProvidersConfig());

// Create a CacheType object for the Default cache
var cache = new CacheType { Default = new DefaultCache{EntryCapacity = 100} };

// Create a CMC using the default cache
var cryptographicMaterialsCacheInput = new
 CreateCryptographicMaterialsCacheInput {Cache = cache};

var sharedCryptographicMaterialsCache =
 materialProviders.CreateCryptographicMaterialsCache(cryptographicMaterialsCacheInput);
```

Python

```
# Instantiate the MPL
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create a CacheType object for the default cache
cache: CacheType = CacheTypeDefault(
    value=DefaultCache(
        entry_capacity=100,
    )
)

# Create a CMC using the default cache
cryptographic_materials_cache_input = CreateCryptographicMaterialsCacheInput(
    cache=cache,
```

```
)

shared_cryptographic_materials_cache =
 mat_prov.create_cryptographic_materials_cache(
    cryptographic_materials_cache_input
)
```

Rust

```
// Instantiate the MPL
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create a CacheType object for the default cache
let cache: CacheType = CacheType::Default(
    DefaultCache::builder()
        .entry_capacity(100)
        .build()?,
);

// Create a CMC using the default cache
let shared_cryptographic_materials_cache: CryptographicMaterialsCacheRef = mpl.
    create_cryptographic_materials_cache()
    .cache(cache)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
)

// Instantiate the MPL
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}
```

```
// Create a CacheType object for the default cache
cache := mpltypes.CacheTypeMemberDefault{
    Value: mpltypes.DefaultCache{
        EntryCapacity: 100,
    },
}

// Create a CMC using the default cache
cmcCacheInput := mpltypes.CreateCryptographicMaterialsCacheInput{
    Cache: &cache,
}
sharedCryptographicMaterialsCache, err :=
 matProv.CreateCryptographicMaterialsCache(context.Background(), cmcCacheInput)
if err != nil {
    panic(err)
}
```

2. Create a `CacheType` object for the Shared cache.

   Pass the `sharedCryptographicMaterialsCache` you created in **Step 1** to the new `CacheType` object.

   Java

   ```
   // Create a CacheType object for the sharedCryptographicMaterialsCache
   final CacheType sharedCache =
       CacheType.builder()
           .Shared(sharedCryptographicMaterialsCache)
           .build();
   ```

   C# / .NET

   ```
   // Create a CacheType object for the sharedCryptographicMaterialsCache
   var sharedCache = new CacheType { Shared = sharedCryptographicMaterialsCache };
   ```

   Python

   ```
   # Create a CacheType object for the shared_cryptographic_materials_cache
   shared_cache: CacheType = CacheTypeShared(
       value=shared_cryptographic_materials_cache
   )
   ```

Rust

```
// Create a CacheType object for the shared_cryptographic_materials_cache
let shared_cache: CacheType =
 CacheType::Shared(shared_cryptographic_materials_cache);
```

Go

```
// Create a CacheType object for the shared_cryptographic_materials_cache
shared_cache :=
 mpltypes.CacheTypeMemberShared{sharedCryptographicMaterialsCache}
```

3. Pass the `sharedCache` object from **Step 2** to your Hierarchical keyring.

   When you create a Hierarchical keyring with a Shared cache, you can optionally define a `partitionID` to share cache entries across multiple Hierarchical keyrings. If you do not specify a partition ID, the Hierarchical keyring automatically assigns the keyring a unique partition ID.

   > **Note**
   >
   > Your Hierarchical keyrings will share the same cache entries in a Shared cache if you create two or more keyrings that reference the same partition ID, logical key store name, and branch key ID. If you do not want multiple keyrings to share the same cache entries, you must use a unique partition ID for each Hierarchical keyring.

   The following example creates a Hierarchical keyring with a branch key ID supplier, and a cache limit of 600 seconds. For more information on the values defined in following Hierarchical keyring configuration, see the section called "Create a Hierarchical keyring".

   Java

```
// Create the Hierarchical keyring
final CreateAwsKmsHierarchicalKeyringInput keyringInput =
    CreateAwsKmsHierarchicalKeyringInput.builder()
        .keyStore(keystore)
        .branchKeyIdSupplier(branchKeyIdSupplier)
```

```
        .ttlSeconds(600)
        .cache(sharedCache)
        .partitionID(partitionID)
        .build();
final IKeyring hierarchicalKeyring =
 matProv.CreateAwsKmsHierarchicalKeyring(keyringInput);
```

C# / .NET

```
// Create the Hierarchical keyring
var createKeyringInput = new CreateAwsKmsHierarchicalKeyringInput
{
   KeyStore = keystore,
   BranchKeyIdSupplier = branchKeyIdSupplier,
   Cache = sharedCache,
   TtlSeconds = 600,
   PartitionId = partitionID
};
var keyring =
 materialProviders.CreateAwsKmsHierarchicalKeyring(createKeyringInput);
```

Python

```
# Create the Hierarchical keyring
keyring_input: CreateAwsKmsHierarchicalKeyringInput =
 CreateAwsKmsHierarchicalKeyringInput(
    key_store=keystore,
    branch_key_id_supplier=branch_key_id_supplier,
    ttl_seconds=600,
    cache=shared_cache,
    partition_id=partition_id
)

hierarchical_keyring: IKeyring = mat_prov.create_aws_kms_hierarchical_keyring(
    input=keyring_input
)
```

Rust

```
// Create the Hierarchical keyring
let keyring1 = mpl
    .create_aws_kms_hierarchical_keyring()
```

```
    .key_store(key_store1)
    .branch_key_id(branch_key_id.clone())
    // CryptographicMaterialsCacheRef is an Rc (Reference Counted), so if you
 clone it to
    // pass it to different Hierarchical Keyrings, it will still point to the
 same
    // underlying cache, and increment the reference count accordingly.
    .cache(shared_cache.clone())
    .ttl_seconds(600)
    .partition_id(partition_id.clone())
    .send()
    .await?;
```

Go

```
// Create the Hierarchical keyring
hkeyringInput := mpltypes.CreateAwsKmsHierarchicalKeyringInput{
    KeyStore:    keyStore1,
    BranchKeyId: &branchKeyId,
    TtlSeconds:  600,
    Cache:       &shared_cache,
    PartitionId: &partitionId,
}
keyring, err := matProv.CreateAwsKmsHierarchicalKeyring(context.Background(),
 hkeyringInput)
if err != nil {
    panic(err)
}
```

Create a Hierarchical keyring

To create a Hierarchical keyring, you must provide the following values:

- **A key store name**

  The name of the DynamoDB table you, or your key store administrator, created to serve as your key store.

- **A cache limit time to live (TTL)**

The amount of time in seconds that a branch key materials entry within the local cache can be used before it expires. The cache limit TTL dictates how often the client calls AWS KMS to authorize use of the branch keys. This value must be greater than zero. After the cache limit TTL expires, the entry is never served, and will be evicted from the local cache.

- **A branch key identifier**

  You can either statically configure the `branch-key-id` that identifies a single active branch key in your key store, or provide a branch key ID supplier.

  The *branch key ID supplier* uses the fields stored in the encryption context to determine which branch key is required to decrypt a record.

  We strongly recommend using a branch key ID supplier for multitenant databases where each tenant has their own branch key. You can use the branch key ID supplier to create a friendly name for your branch key IDs to make it easy to recognize the correct branch key ID for a specific tenant. For example, the friendly name lets you refer to a branch key as `tenant1` instead of `b3f61619-4d35-48ad-a275-050f87e15122`.

  For decrypt operations, you can either statically configure a single Hierarchical keyring to restrict decryption to a single tenant, or you can use the branch key ID supplier to identify which tenant is responsible for decrypting a record.

- **(Optional) A cache**

  If you want to customize your cache type or the number of branch key materials entries that can be stored in the local cache, specify the cache type and entry capacity when you initialize the keyring.

  The Hierarchical keyring supports the following cache types: Default, MultiThreaded, StormTracking, and Shared. For more information and examples demonstrating how to define each cache type, see the section called “Choose a cache”.

  If you do not specify a cache, the Hierarchical keyring automatically uses the Default cache type and sets the entry capacity to 1000.

- **(Optional) A partition ID**

If you specify the the section called "Shared cache", you can optionally define a partition ID. The partition ID distinguishes which Hierarchical keyring is writing to the cache. If you intend to reuse or share the cache entries in a partition, you must define your own partition ID. You can specify any string for the partition ID. If you do not specify a partition ID, a unique partition ID is automatically assigned to the keyring at creation.

For more information, see Partitions.

> **Note**
>
> Your Hierarchical keyrings will share the same cache entries in a Shared cache if you create two or more keyrings that reference the same partition ID, logical key store name, and branch key ID. If you do not want multiple keyrings to share the same cache entries, you must use a unique partition ID for each Hierarchical keyring.

- **(Optional) A list of Grant Tokens**

  If you control access to the KMS key in your Hierarchical keyring with grants, you must provide all necessary grant tokens when you initialize the keyring.

Create a Hierarchical keyring with a static branch key ID

The following examples demonstrate how to create a Hierarchical keyring with a static branch key ID, the the section called "Default cache", and a cache limit TTL of 600 seconds.

Java

```
final MaterialProviders matProv = MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();
final CreateAwsKmsHierarchicalKeyringInput keyringInput =
 CreateAwsKmsHierarchicalKeyringInput.builder()
        .keyStore(branchKeyStoreName)
        .branchKeyId(branch-key-id)
        .ttlSeconds(600)
        .build();
final Keyring hierarchicalKeyring =
 matProv.CreateAwsKmsHierarchicalKeyring(keyringInput);
```

C# / .NET

```
var matProv = new MaterialProviders(new MaterialProvidersConfig());
var keyringInput = new CreateAwsKmsHierarchicalKeyringInput
{
   KeyStore = keystore,
   BranchKeyId = branch-key-id,
   TtlSeconds = 600
};
var hierarchicalKeyring = matProv.CreateAwsKmsHierarchicalKeyring(keyringInput);
```

Python

```
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

keyring_input: CreateAwsKmsHierarchicalKeyringInput =
 CreateAwsKmsHierarchicalKeyringInput(
    key_store=keystore,
    branch_key_id=branch_key_id,
    ttl_seconds=600
)

hierarchical_keyring: IKeyring = mat_prov.create_aws_kms_hierarchical_keyring(
    input=keyring_input
)
```

Rust

```
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

let hierarchical_keyring = mpl
        .create_aws_kms_hierarchical_keyring()
        .key_store(key_store.clone())
        .branch_key_id(branch_key_id)
        .ttl_seconds(600)
        .send()
        .await?;
```

Go

```
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}
hkeyringInput := mpltypes.CreateAwsKmsHierarchicalKeyringInput{
    KeyStore:    keyStore,
    BranchKeyId: &branchKeyID,
    TtlSeconds:  600,
}
hKeyRing, err := matProv.CreateAwsKmsHierarchicalKeyring(context.Background(),
 hkeyringInput)
if err != nil {
    panic(err)
}
```

Create a Hierarchical keyring with a branch key ID supplier

The following procedures demonstrate how to create a Hierarchical keyring with a branch key ID supplier.

1. Create a branch key ID supplier

   The following example creates friendly names for two branch keys and calls `CreateDynamoDbEncryptionBranchKeyIdSupplier` to create a branch key ID supplier.

   Java

```
// Create friendly names for each branch-key-id
class ExampleBranchKeyIdSupplier implements IDynamoDbKeyBranchKeyIdSupplier {
    private static String branchKeyIdForTenant1;
    private static String branchKeyIdForTenant2;

    public ExampleBranchKeyIdSupplier(String tenant1Id, String tenant2Id) {
        this.branchKeyIdForTenant1 = tenant1Id;
        this.branchKeyIdForTenant2 = tenant2Id;
    }
// Create the branch key ID supplier
final DynamoDbEncryption ddbEnc = DynamoDbEncryption.builder()
        .DynamoDbEncryptionConfig(DynamoDbEncryptionConfig.builder().build())
```

```
        .build();
final BranchKeyIdSupplier branchKeyIdSupplier =
 ddbEnc.CreateDynamoDbEncryptionBranchKeyIdSupplier(
    CreateDynamoDbEncryptionBranchKeyIdSupplierInput.builder()
            .ddbKeyBranchKeyIdSupplier(new ExampleBranchKeyIdSupplier(branch-
key-ID-tenant1, branch-key-ID-tenant2))
            .build()).branchKeyIdSupplier();
```

C# / .NET

```
// Create friendly names for each branch-key-id
 class ExampleBranchKeyIdSupplier : DynamoDbKeyBranchKeyIdSupplierBase {
    private String _branchKeyIdForTenant1;
    private String _branchKeyIdForTenant2;

    public ExampleBranchKeyIdSupplier(String tenant1Id, String tenant2Id) {
        this._branchKeyIdForTenant1 = tenant1Id;
        this._branchKeyIdForTenant2 = tenant2Id;
    }
// Create the branch key ID supplier
var ddbEnc = new DynamoDbEncryption(new DynamoDbEncryptionConfig());
var branchKeyIdSupplier = ddbEnc.CreateDynamoDbEncryptionBranchKeyIdSupplier(
    new CreateDynamoDbEncryptionBranchKeyIdSupplierInput
    {
        DdbKeyBranchKeyIdSupplier = new ExampleBranchKeyIdSupplier(branch-key-
ID-tenant1, branch-key-ID-tenant2)
    }).BranchKeyIdSupplier;
```

Python

```
# Create branch key ID supplier that maps the branch key ID to a friendly name
branch_key_id_supplier: IBranchKeyIdSupplier = ExampleBranchKeyIdSupplier(
        tenant_1_id=branch_key_id_a,
        tenant_2_id=branch_key_id_b,
)
```

Rust

```
// Create branch key ID supplier that maps the branch key ID to a friendly name
let branch_key_id_supplier = ExampleBranchKeyIdSupplier::new(
    &branch_key_id_a,
    &branch_key_id_b
```

```
);
```

Go

```
// Create branch key ID supplier that maps the branch key ID to a friendly name
keySupplier := branchKeySupplier{branchKeyA: branchKeyA, branchKeyB: branchKeyB}
```

2. Create a Hierarchical keyring

The following examples initialize a Hierarchical keyring with the branch key ID supplier created in **Step 1**, a cache limit TLL of 600 seconds, and a maximum cache size of 1000.

Java

```
final MaterialProviders matProv = MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();
final CreateAwsKmsHierarchicalKeyringInput keyringInput =
 CreateAwsKmsHierarchicalKeyringInput.builder()
        .keyStore(keystore)
        .branchKeyIdSupplier(branchKeyIdSupplier)
        .ttlSeconds(600)
        .cache(CacheType.builder() //OPTIONAL
                .Default(DefaultCache.builder()
                .entryCapacity(100)
                .build())
        .build();
final Keyring hierarchicalKeyring =
 matProv.CreateAwsKmsHierarchicalKeyring(keyringInput);
```

C# / .NET

```
var matProv = new MaterialProviders(new MaterialProvidersConfig());
var keyringInput = new CreateAwsKmsHierarchicalKeyringInput
{
   KeyStore = keystore,
   BranchKeyIdSupplier = branchKeyIdSupplier,
   TtlSeconds = 600,
   Cache = new CacheType
   {
        Default = new DefaultCache { EntryCapacity = 100 }
   }
```

```
};
var hierarchicalKeyring = matProv.CreateAwsKmsHierarchicalKeyring(keyringInput);
```

Python

```
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

keyring_input: CreateAwsKmsHierarchicalKeyringInput =
 CreateAwsKmsHierarchicalKeyringInput(
    key_store=keystore,
    branch_key_id_supplier=branch_key_id_supplier,
    ttl_seconds=600,
    cache=CacheTypeDefault(
        value=DefaultCache(
            entry_capacity=100
        )
    ),
)

hierarchical_keyring: IKeyring = mat_prov.create_aws_kms_hierarchical_keyring(
    input=keyring_input
)
```

Rust

```
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

let hierarchical_keyring = mpl
    .create_aws_kms_hierarchical_keyring()
    .key_store(key_store.clone())
    .branch_key_id_supplier(branch_key_id_supplier)
    .ttl_seconds(600)
    .send()
    .await?;
```

Go

```
hkeyringInput := mpltypes.CreateAwsKmsHierarchicalKeyringInput{
    KeyStore:            keyStore,
```

```
    BranchKeyIdSupplier: &keySupplier,
    TtlSeconds:          600,
}
hKeyRing, err := matProv.CreateAwsKmsHierarchicalKeyring(context.Background(),
 hkeyringInput)
if err != nil {
    panic(err)
}
```

AWS KMS ECDH keyrings

An AWS KMS ECDH keyring uses asymmetric key agreement AWS KMS keys to derive a shared symmetric wrapping key between two parties. First, the keyring uses the Elliptic Curve Diffie-Hellman (ECDH) key agreement algorithm to derive a shared secret from the private key in the sender's KMS key pair and the recipient's public key. Then, the keyring uses the shared secret to derive the shared wrapping key that protects your data encryption keys. The key derivation function that the AWS Encryption SDK uses (`KDF_CTR_HMAC_SHA384`) to derive the shared wrapping key conforms to NIST recommendations for key derivation.

The key derivation function returns 64 bytes of keying material. To ensure that both parties use the correct keying material, the AWS Encryption SDK uses the first 32 bytes as a commitment key and the last 32 bytes as the shared wrapping key. On decrypt, if the keyring cannot reproduce the same commitment key and shared wrapping key that is stored on the message header ciphertext, the operation fails. For example, if you encrypt data with a keyring configured with **Alice's** private key and **Bob's** public key, a keyring configured with **Bob's** private key and **Alice's** public key will reproduce the same commitment key and shared wrapping key and be able to decrypt the data. If Bob's public key is not from a KMS key pair, then Bob can create a Raw ECDH keyring to decrypt the data.

The AWS KMS ECDH keyring encrypts data with a symmetric key using AES-GCM. The data key is then envelope encrypted with the derived shared wrapping key using AES-GCM. Each AWS KMS ECDH keyring can have only one shared wrapping key, but you can include multiple AWS KMS ECDH keyrings, alone or with other keyrings, in a multi-keyring.

Programming language compatibility

The AWS KMS ECDH keyring is introduced in version 1.5.0 of the Cryptographic Material Providers Library (MPL) and is supported by the following programming languages and versions:

- Version 3.*x* of the AWS Encryption SDK for Java
- Version 4.*x* of the AWS Encryption SDK for .NET
- Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional MPL dependency.
- Version 1.*x* of the AWS Encryption SDK for Rust
- Version 0.1.*x* or later of the AWS Encryption SDK for Go

Topics

- Required permissions for AWS KMS ECDH keyrings
- Creating an AWS KMS ECDH keyring
- Creating an AWS KMS ECDH discovery keyring

Required permissions for AWS KMS ECDH keyrings

The AWS Encryption SDK doesn't require an AWS account and it doesn't depend on any AWS service. However, to use an AWS KMS ECDH keyring, you need an AWS account and the following minimum permissions on the AWS KMS keys in your keyring. The permissions vary based on which key agreement schema you use.

- To encrypt and decrypt data using the `KmsPrivateKeyToStaticPublicKey` key agreement schema, you need kms:GetPublicKey and kms:DeriveSharedSecret on the *sender's* asymmetric KMS key pair. If you directly provide the sender's DER-encoded public key when you instantiate your keyring, you only need kms:DeriveSharedSecret permission on the sender's asymmetric KMS key pair.
- To decrypt data using the `KmsPublicKeyDiscovery` key agreement schema, you need kms:DeriveSharedSecret and kms:GetPublicKey permissions on the specified asymmetric KMS key pair.

Creating an AWS KMS ECDH keyring

To create an AWS KMS ECDH keyring that encrypts and decrypts data, you must use the `KmsPrivateKeyToStaticPublicKey` key agreement schema. To initialize an AWS KMS ECDH keyring with the `KmsPrivateKeyToStaticPublicKey` key agreement schema, provide the following values:

- **Sender's AWS KMS key ID**

  Must identify an asymmetric NIST-recommended elliptic curve (ECC) KMS key pair with a `KeyUsage` value of `KEY_AGREEMENT`. The sender's private key is used to derive the shared secret.

- **(Optional) Sender's public key**

  Must be a DER-encoded X.509 public key, also known as `SubjectPublicKeyInfo` (SPKI), as defined in RFC 5280.

  The AWS KMS GetPublicKey operation returns the public key of an asymmetric KMS key pair in the required DER-encoded format.

  To reduce the number of AWS KMS calls that your keyring makes, you can directly provide the sender's public key. If no value is provided for the sender's public key, the keyring calls AWS KMS to retrieve the sender's public key.

- **Recipient's public key**

  You must provide the recipient's DER-encoded X.509 public key, also known as `SubjectPublicKeyInfo` (SPKI), as defined in RFC 5280.

  The AWS KMS GetPublicKey operation returns the public key of an asymmetric KMS key pair in the required DER-encoded format.

- **Curve specification**

  Identifies the elliptic curve specification in the specified key pairs. Both the sender and recipient's key pairs must have the same curve specification.

  Valid values: `ECC_NIST_P256`, `ECC_NIS_P384`, `ECC_NIST_P512`

- **(Optional) A list of Grant Tokens**

  If you control access to the KMS key in your AWS KMS ECDH keyring with grants, you must provide all necessary grant tokens when you initialize the keyring.

C# / .NET

The following example creates an AWS KMS ECDH keyring with the with the sender's KMS key, the sender's public key, and the recipient's public key. This example uses the optional `SenderPublicKey` parameter to provide the sender's public key. If you do not provide the

sender's public key, the keyring calls AWS KMS to retrieve the sender's public key. Both the sender and recipient's key pairs are on the `ECC_NIST_P256` curve.

```
// Instantiate material providers
var materialProviders = new MaterialProviders(new MaterialProvidersConfig());

// Must be DER-encoded X.509 public keys
var BobPublicKey = new MemoryStream(new byte[] { });
var AlicePublicKey = new MemoryStream(new byte[] { });

// Create the AWS KMS ECDH static keyring
var staticConfiguration = new KmsEcdhStaticConfigurations
{
    KmsPrivateKeyToStaticPublicKey = new KmsPrivateKeyToStaticPublicKeyInput
    {
        SenderKmsIdentifier = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab",
        SenderPublicKey = BobPublicKey,
        RecipientPublicKey = AlicePublicKey
    }
};

var createKeyringInput = new CreateAwsKmsEcdhKeyringInput
{
    CurveSpec = ECDHCurveSpec.ECC_NIST_P256,
    KmsClient = new AmazonKeyManagementServiceClient(),
    KeyAgreementScheme = staticConfiguration
};

var keyring = materialProviders.CreateAwsKmsEcdhKeyring(createKeyringInput);
```

Java

The following example creates an AWS KMS ECDH keyring with the with the sender's KMS key, the sender's public key, and the recipient's public key. This example uses the optional `senderPublicKey` parameter to provide the sender's public key. If you do not provide the sender's public key, the keyring calls AWS KMS to retrieve the sender's public key. Both the sender and recipient's key pairs are on the `ECC_NIST_P256` curve.

```
// Retrieve public keys
// Must be DER-encoded X.509 public keys
```

```
ByteBuffer BobPublicKey = getPublicKeyBytes("arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab");
        ByteBuffer AlicePublicKey = getPublicKeyBytes("arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321");

// Create the AWS KMS ECDH static keyring
        final CreateAwsKmsEcdhKeyringInput senderKeyringInput =
          CreateAwsKmsEcdhKeyringInput.builder()
            .kmsClient(KmsClient.create())
            .curveSpec(ECDHCurveSpec.ECC_NIST_P256)
            .KeyAgreementScheme(
              KmsEcdhStaticConfigurations.builder()
                .KmsPrivateKeyToStaticPublicKey(
                  KmsPrivateKeyToStaticPublicKeyInput.builder()
                    .senderKmsIdentifier("arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab")
                    .senderPublicKey(BobPublicKey)
                    .recipientPublicKey(AlicePublicKey)
                    .build()).build()).build();
```

Python

The following example creates an AWS KMS ECDH keyring with the with the sender's KMS key, the sender's public key, and the recipient's public key. This example uses the optional `senderPublicKey` parameter to provide the sender's public key. If you do not provide the sender's public key, the keyring calls AWS KMS to retrieve the sender's public key. Both the sender and recipient's key pairs are on the `ECC_NIST_P256` curve.

```
import boto3
from aws_cryptographic_materialproviders.mpl.models import (
    CreateAwsKmsEcdhKeyringInput,
    KmsEcdhStaticConfigurationsKmsPrivateKeyToStaticPublicKey,
    KmsPrivateKeyToStaticPublicKeyInput,
)
from aws_cryptography_primitives.smithygenerated.aws_cryptography_primitives.models
 import ECDHCurveSpec

# Instantiate the material providers library
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Retrieve public keys
```

```
# Must be DER-encoded X.509 public keys
bob_public_key = get_public_key_bytes("arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab")
alice_public_key = get_public_key_bytes("arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321")

# Create the AWS KMS ECDH static keyring
sender_keyring_input = CreateAwsKmsEcdhKeyringInput(
    kms_client = boto3.client('kms', region_name="us-west-2"),
    curve_spec = ECDHCurveSpec.ECC_NIST_P256,
    key_agreement_scheme =
 KmsEcdhStaticConfigurationsKmsPrivateKeyToStaticPublicKey(
        KmsPrivateKeyToStaticPublicKeyInput(
            sender_kms_identifier = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab",
            sender_public_key = bob_public_key,
            recipient_public_key = alice_public_key,

        )
    )
)

keyring = mat_prov.create_aws_kms_ecdh_keyring(sender_keyring_input)
```

Rust

The following example creates an AWS KMS ECDH keyring with the with the sender's KMS key, the sender's public key, and the recipient's public key. This example uses the optional `sender_public_key` parameter to provide the sender's public key. If you do not provide the sender's public key, the keyring calls AWS KMS to retrieve the sender's public key.

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Create the AWS KMS client
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let kms_client = aws_sdk_kms::Client::new(&sdk_config);

// Optional: Create your encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
```

```
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Retrieve public keys
// Must be DER-encoded X.509 keys
let public_key_file_content_sender =
 std::fs::read_to_string(Path::new(EXAMPLE_KMS_ECC_PUBLIC_KEY_FILENAME_SENDER))?;
let parsed_public_key_file_content_sender = parse(public_key_file_content_sender)?;
let public_key_sender_utf8_bytes = parsed_public_key_file_content_sender.contents();

let public_key_file_content_recipient =
 std::fs::read_to_string(Path::new(EXAMPLE_KMS_ECC_PUBLIC_KEY_FILENAME_RECIPIENT))?;
let parsed_public_key_file_content_recipient =
 parse(public_key_file_content_recipient)?;
let public_key_recipient_utf8_bytes =
 parsed_public_key_file_content_recipient.contents();

// Create KmsPrivateKeyToStaticPublicKeyInput
let kms_ecdh_static_configuration_input =
    KmsPrivateKeyToStaticPublicKeyInput::builder()
        .sender_kms_identifier(arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab)
        // Must be a UTF8 DER-encoded X.509 public key
        .sender_public_key(public_key_sender_utf8_bytes)
        // Must be a UTF8 DER-encoded X.509 public key
        .recipient_public_key(public_key_recipient_utf8_bytes)
        .build()?;

let kms_ecdh_static_configuration =
 KmsEcdhStaticConfigurations::KmsPrivateKeyToStaticPublicKey(kms_ecdh_static_configuration_i

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create AWS KMS ECDH keyring
let kms_ecdh_keyring = mpl
    .create_aws_kms_ecdh_keyring()
    .kms_client(kms_client)
    .curve_spec(ecdh_curve_spec)
```

```
    .key_agreement_scheme(kms_ecdh_static_configuration)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
    "github.com/aws/aws-sdk-go-v2/config"
    "github.com/aws/aws-sdk-go-v2/service/kms"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS client
cfg, err := config.LoadDefaultConfig(context.TODO())
if err != nil {
    panic(err)
}
kmsClient := kms.NewFromConfig(cfg, func(o *kms.Options) {
    o.Region = KmsKeyRegion
})

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
```

```
}

// Retrieve public keys
// Must be DER-encoded X.509 keys
publicKeySender, err := utils.LoadPublicKeyFromPEM(kmsEccPublicKeyFileNameSender)
if err != nil {
    panic(err)
}
publicKeyRecipient, err :=
 utils.LoadPublicKeyFromPEM(kmsEccPublicKeyFileNameRecipient)
if err != nil {
    panic(err)
}

// Create KmsPrivateKeyToStaticPublicKeyInput
kmsEcdhStaticConfigurationInput := mpltypes.KmsPrivateKeyToStaticPublicKeyInput{
    RecipientPublicKey:  publicKeyRecipient,
    SenderKmsIdentifier: arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab,
    SenderPublicKey:     publicKeySender,
}
kmsEcdhStaticConfiguration :=
 &mpltypes.KmsEcdhStaticConfigurationsMemberKmsPrivateKeyToStaticPublicKey{
    Value: kmsEcdhStaticConfigurationInput,
}

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create AWS KMS ECDH keyring
awsKmsEcdhKeyringInput := mpltypes.CreateAwsKmsEcdhKeyringInput{
    CurveSpec:          ecdhCurveSpec,
    KeyAgreementScheme: kmsEcdhStaticConfiguration,
    KmsClient:          kmsClient,
}
awsKmsEcdhKeyring, err := matProv.CreateAwsKmsEcdhKeyring(context.Background(),
 awsKmsEcdhKeyringInput)
if err != nil {
    panic(err)
}
```

Creating an AWS KMS ECDH discovery keyring

When decrypting, it's a best practice to specify the keys that the AWS Encryption SDK can use. To follow this best practice, use an AWS KMS ECDH keyring with the `KmsPrivateKeyToStaticPublicKey` key agreement schema. However, you can also create an AWS KMS ECDH discovery keyring, that is, an AWS KMS ECDH keyring that can decrypt any message where the public key of the specified KMS key pair matches the *recipient's* public key stored on the message ciphertext.

> **Important**
>
> When you decrypt messages using the `KmsPublicKeyDiscovery` key agreement schema, you accept all public keys, regardless of who owns it.

To initialize an AWS KMS ECDH keyring with the `KmsPublicKeyDiscovery` key agreement schema, provide the following values:

- **Recipient's AWS KMS key ID**

  Must identify an asymmetric NIST-recommended elliptic curve (ECC) KMS key pair with a `KeyUsage` value of `KEY_AGREEMENT`.
- **Curve specification**

  Identifies the elliptic curve specification in the recipient's KMS key pair.

  Valid values: `ECC_NIST_P256`, `ECC_NIS_P384`, `ECC_NIST_P512`
- **(Optional) A list of Grant Tokens**

  If you control access to the KMS key in your AWS KMS ECDH keyring with grants, you must provide all necessary grant tokens when you initialize the keyring.

C# / .NET

The following example creates an AWS KMS ECDH discovery keyring with a KMS key pair on the `ECC_NIST_P256` curve. You must have kms:GetPublicKey and kms:DeriveSharedSecret permissions on the specified KMS key pair. This keyring can decrypt any message where the public key of the specified KMS key pair matches the recipient's public key stored on the message ciphertext.

```
// Instantiate material providers
var materialProviders = new MaterialProviders(new MaterialProvidersConfig());

// Create the AWS KMS ECDH discovery keyring
var discoveryConfiguration = new KmsEcdhStaticConfigurations
{
    KmsPublicKeyDiscovery = new KmsPublicKeyDiscoveryInput
    {
        RecipientKmsIdentifier = "arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321"
    }

};
var createKeyringInput = new CreateAwsKmsEcdhKeyringInput
{
    CurveSpec = ECDHCurveSpec.ECC_NIST_P256,
    KmsClient = new AmazonKeyManagementServiceClient(),
    KeyAgreementScheme = discoveryConfiguration
};
var keyring = materialProviders.CreateAwsKmsEcdhKeyring(createKeyringInput);
```

Java

The following example creates an AWS KMS ECDH discovery keyring with a KMS key pair on the ECC_NIST_P256 curve. You must have kms:GetPublicKey and kms:DeriveSharedSecret permissions on the specified KMS key pair. This keyring can decrypt any message where the public key of the specified KMS key pair matches the recipient's public key stored on the message ciphertext.

```
// Create the AWS KMS ECDH discovery keyring
final CreateAwsKmsEcdhKeyringInput recipientKeyringInput =
  CreateAwsKmsEcdhKeyringInput.builder()
    .kmsClient(KmsClient.create())
    .curveSpec(ECDHCurveSpec.ECC_NIST_P256)
    .KeyAgreementScheme(
      KmsEcdhStaticConfigurations.builder()
        .KmsPublicKeyDiscovery(
          KmsPublicKeyDiscoveryInput.builder()
            .recipientKmsIdentifier("arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321").build()
        ).build())
    .build();
```

Python

The following example creates an AWS KMS ECDH discovery keyring with a KMS key pair on the `ECC_NIST_P256` curve. You must have kms:GetPublicKey and kms:DeriveSharedSecret permissions on the specified KMS key pair. This keyring can decrypt any message where the public key of the specified KMS key pair matches the recipient's public key stored on the message ciphertext.

```
import boto3
from aws_cryptographic_materialproviders.mpl.models import (
    CreateAwsKmsEcdhKeyringInput,
    KmsEcdhStaticConfigurationsKmsPublicKeyDiscovery,
    KmsPublicKeyDiscoveryInput,
)
from aws_cryptography_primitives.smithygenerated.aws_cryptography_primitives.models
 import ECDHCurveSpec

# Instantiate the material providers library
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create the AWS KMS ECDH discovery keyring
create_keyring_input = CreateAwsKmsEcdhKeyringInput(
    kms_client = boto3.client('kms', region_name="us-west-2"),
    curve_spec = ECDHCurveSpec.ECC_NIST_P256,
    key_agreement_scheme = KmsEcdhStaticConfigurationsKmsPublicKeyDiscovery(
        KmsPublicKeyDiscoveryInput(
            recipient_kms_identifier = "arn:aws:kms:us-
west-2:111122223333:key/0987dcba-09fe-87dc-65ba-ab0987654321",
        )
    )
)

keyring = mat_prov.create_aws_kms_ecdh_keyring(create_keyring_input)
```

Rust

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Create the AWS KMS client
```

```
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let kms_client = aws_sdk_kms::Client::new(&sdk_config);

// Optional: Create your encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Create KmsPublicKeyDiscoveryInput
let kms_ecdh_discovery_static_configuration_input =
    KmsPublicKeyDiscoveryInput::builder()
        .recipient_kms_identifier(ecc_recipient_key_arn)
        .build()?;

let kms_ecdh_discovery_static_configuration =
 KmsEcdhStaticConfigurations::KmsPublicKeyDiscovery(kms_ecdh_discovery_static_configuration_

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create AWS KMS ECDH discovery keyring
let kms_ecdh_discovery_keyring = mpl
    .create_aws_kms_ecdh_keyring()
    .kms_client(kms_client.clone())
    .curve_spec(ecdh_curve_spec)
    .key_agreement_scheme(kms_ecdh_discovery_static_configuration)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
```

```
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
    "github.com/aws/aws-sdk-go-v2/config"
    "github.com/aws/aws-sdk-go-v2/service/kms"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS client
cfg, err := config.LoadDefaultConfig(context.TODO())
if err != nil {
    panic(err)
}
kmsClient := kms.NewFromConfig(cfg, func(o *kms.Options) {
    o.Region = KmsKeyRegion
})

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Create KmsPublicKeyDiscoveryInput
kmsEcdhDiscoveryStaticConfigurationInput := mpltypes.KmsPublicKeyDiscoveryInput{
    RecipientKmsIdentifier: eccRecipientKeyArn,
}
kmsEcdhDiscoveryStaticConfiguration :=
 &mpltypes.KmsEcdhStaticConfigurationsMemberKmsPublicKeyDiscovery{
    Value: kmsEcdhDiscoveryStaticConfigurationInput,
}

// Instantiate the material providers library
```

```
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create AWS KMS ECDH discovery keyring
awsKmsEcdhDiscoveryKeyringInput := mpltypes.CreateAwsKmsEcdhKeyringInput{
    CurveSpec:          ecdhCurveSpec,
    KeyAgreementScheme: kmsEcdhDiscoveryStaticConfiguration,
    KmsClient:          kmsClient,
}
awsKmsEcdhDiscoveryKeyring, err :=
 matProv.CreateAwsKmsEcdhKeyring(context.Background(),
 awsKmsEcdhDiscoveryKeyringInput)
if err != nil {
    panic(err)
}
```

Raw AES keyrings

The AWS Encryption SDK lets you use an AES symmetric key that you provide as a wrapping key that protects your data key. You need to generate, store, and protect the key material, preferably in a hardware security module (HSM) or key management system. Use a Raw AES keyring when you need to provide the wrapping key and encrypt the data keys locally or offline.

The Raw AES keyring encrypts data by using the AES-GCM algorithm and a wrapping key that you specify as a byte array. You can specify only one wrapping key in each Raw AES keyring, but you can include multiple Raw AES keyrings, alone or with other keyrings, in a multi-keyring.

The Raw AES keyring is equivalent to and interoperates with the JceMasterKey class in the AWS Encryption SDK for Java and the RawMasterKey class in the AWS Encryption SDK for Python when they are used with an AES encryption keys. You can encrypt data with one implementation and decrypt the data with any other implementation using the same wrapping key. For details, see Keyring compatibility.

Key namespaces and names

To identify the AES key in a keyring, the Raw AES keyring uses a *key namespace* and *key name* that you provide. These values are not secret. They appear in plain text in the header of the encrypted

message that the encrypt operation returns. We recommend using a key namespace your HSM or key management system and a key name that identifies the AES key in that system.

> **Note**
>
> The key namespace and key name are equivalent to the *Provider ID* (or *Provider*) and *Key ID* fields in the `JceMasterKey` and `RawMasterKey`.
> The AWS Encryption SDK for C and AWS Encryption SDK for .NET reserve the `aws-kms` key namespace value for KMS keys. Do not use this namespace value in a Raw AES keyring or Raw RSA keyring with these libraries.

If you construct different keyrings to encrypt and decrypt a given message, the namespace and name values are critical. If the key namespace and key name in the decryption keyring isn't an exact, case-sensitive match for the key namespace and key name in the encryption keyring, the decryption keyring isn't used, even if the key material bytes are identical.

For example, you might define a Raw AES keyring with key namespace `HSM_01` and key name `AES_256_012`. Then, you use that keyring to encrypt some data. To decrypt that data, construct a Raw AES keyring with the same key namespace, key name, and key material.

The following examples show how to create a Raw AES keyring. The `AESWrappingKey` variable represents the key material you provide.

C

To instantiate a Raw AES keyring in the AWS Encryption SDK for C, use `aws_cryptosdk_raw_aes_keyring_new()`. For a complete example, see raw_aes_keyring.c.

```
struct aws_allocator *alloc = aws_default_allocator();

AWS_STATIC_STRING_FROM_LITERAL(wrapping_key_namespace, "HSM_01");
AWS_STATIC_STRING_FROM_LITERAL(wrapping_key_name, "AES_256_012");

struct aws_cryptosdk_keyring *raw_aes_keyring = aws_cryptosdk_raw_aes_keyring_new(
        alloc, wrapping_key_namespace, wrapping_key_name, aes_wrapping_key,
 wrapping_key_len);
```

C# / .NET

To create a Raw AES keyring in AWS Encryption SDK for .NET, use the `materialProviders.CreateRawAesKeyring()` method. For a complete example, see RawAESKeyringExample.cs.

The following example uses version 4.*x* of the AWS Encryption SDK for .NET.

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());

var keyNamespace = "HSM_01";
var keyName = "AES_256_012";

// This example uses the key generator in Bouncy Castle to generate the key
 material.
// In production, use key material from a secure source.
var aesWrappingKey = new
 MemoryStream(GeneratorUtilities.GetKeyGenerator("AES256").GenerateKey());

// Create the keyring that determines how your data keys are protected.
var createKeyringInput = new CreateRawAesKeyringInput
{
    KeyNamespace = keyNamespace,
    KeyName = keyName,
    WrappingKey = aesWrappingKey,
    WrappingAlg = AesWrappingAlg.ALG_AES256_GCM_IV12_TAG16
};

var keyring = materialProviders.CreateRawAesKeyring(createKeyringInput);
```

JavaScript Browser

The AWS Encryption SDK for JavaScript in the browser gets its cryptographic primitives from the WebCrypto API. Before you construct the keyring, you must use `RawAesKeyringWebCrypto.importCryptoKey()` to import the raw key material into the WebCrypto backend. This assures that the keyring is complete even though all calls to WebCrypto are asynchronous.

Then, to instantiate a Raw AES keyring, use the `RawAesKeyringWebCrypto()` method. You must specify the AES wrapping algorithm ("wrapping suite) based on the length of your key material. For a complete example, see aes_simple.ts (JavaScript Browser).

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

```
import {
  RawAesWrappingSuiteIdentifier,
  RawAesKeyringWebCrypto,
  synchronousRandomValues,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-browser'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const keyNamespace = 'HSM_01'
const keyName = 'AES_256_012'

const wrappingSuite =
  RawAesWrappingSuiteIdentifier.AES256_GCM_IV12_TAG16_NO_PADDING

/* Import the plaintext AES key into the WebCrypto backend. */
const aesWrappingKey = await RawAesKeyringWebCrypto.importCryptoKey(
  rawAesKey,
  wrappingSuite
)

const rawAesKeyring = new RawAesKeyringWebCrypto({
  keyName,
  keyNamespace,
  wrappingSuite,
  aesWrappingKey
})
```

JavaScript Node.js

To instantiate a Raw AES keyring in the AWS Encryption SDK for JavaScript for Node.js, create an instance of the `RawAesKeyringNode` class. You must specify the AES wrapping algorithm ("wrapping suite") based on the length of your key material. For a complete example, see aes_simple.ts (JavaScript Node.js).

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

```
import {
  RawAesKeyringNode,
  buildClient,
  CommitmentPolicy,
  RawAesWrappingSuiteIdentifier,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const keyName = 'AES_256_012'
const keyNamespace = 'HSM_01'

const wrappingSuite =
  RawAesWrappingSuiteIdentifier.AES256_GCM_IV12_TAG16_NO_PADDING

const rawAesKeyring = new RawAesKeyringNode({
  keyName,
  keyNamespace,
  aesWrappingKey,
  wrappingSuite,
})
```

Java

To instantiate a Raw AES keyring in the AWS Encryption SDK for Java, use `matProv.CreateRawAesKeyring()`.

```
final CreateRawAesKeyringInput keyringInput = CreateRawAesKeyringInput.builder()
```

```
        .keyName("AES_256_012")
        .keyNamespace("HSM_01")
        .wrappingKey(AESWrappingKey)
        .wrappingAlg(AesWrappingAlg.ALG_AES256_GCM_IV12_TAG16)
        .build();
final MaterialProviders matProv = MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();
IKeyring rawAesKeyring = matProv.CreateRawAesKeyring(keyringInput);
```

Python

The following example instantiates the AWS Encryption SDK client with the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. For a complete example, see raw_aes_keyring_example.py in the AWS Encryption SDK for Python repository in GitHub.

```
# Instantiate the AWS Encryption SDK client
client = aws_encryption_sdk.EncryptionSDKClient(
    commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

# Define the key namespace and key name
key_name_space = "HSM_01"
key_name = "AES_256_012"

# Optional: Create an encryption context
encryption_context: Dict[str, str] = {
    "encryption": "context",
    "is not": "secret",
    "but adds": "useful metadata",
    "that can help you": "be confident that",
    "the data you are handling": "is what you think it is",
}

# Instantiate the material providers
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create Raw AES keyring
keyring_input: CreateRawAesKeyringInput = CreateRawAesKeyringInput(
    key_namespace=key_name_space,
    key_name=key_name,
```

```
    wrapping_key=AESWrappingKey,
    wrapping_alg=AesWrappingAlg.ALG_AES256_GCM_IV12_TAG16
)

raw_aes_keyring: IKeyring = mat_prov.create_raw_aes_keyring(
    input=keyring_input
)
```

Rust

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Define the key namespace and key name
let key_namespace: &str = "HSM_01";
let key_name: &str = "AES_256_012";

// Optional: Create an encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create Raw AES keyring
let raw_aes_keyring = mpl
    .create_raw_aes_keyring()
    .key_name(key_name)
    .key_namespace(key_namespace)
    .wrapping_key(aws_smithy_types::Blob::new(AESWrappingKey))
    .wrapping_alg(AesWrappingAlg::AlgAes256GcmIv12Tag16)
    .send()
    .await?;
```

Go

```
import (
    mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
    client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
    esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
)
//Instantiate the AWS Encryption SDK client.
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}
// Define the key namespace and key name
var keyNamespace = "A managed aes keys"
var keyName = "My 256-bit AES wrapping key"

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}
// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}
// Create Raw AES keyring
aesKeyRingInput := mpltypes.CreateRawAesKeyringInput{
    KeyName:      keyName,
    KeyNamespace: keyNamespace,
    WrappingKey:  aesWrappingKey,
    WrappingAlg:  mpltypes.AesWrappingAlgAlgAes256GcmIv12Tag16,
}
aesKeyring, err := matProv.CreateRawAesKeyring(context.Background(),
 aesKeyRingInput)
if err != nil {
```

```
    panic(err)
}
```

Raw RSA keyrings

The Raw RSA keyring performs asymmetric encryption and decryption of data keys in local memory with an RSA public and private keys that you provide. You need to generate, store, and protect the private key, preferably in a hardware security module (HSM) or key management system. The encryption function encrypts the data key under the RSA public key. The decryption function decrypts the data key using the private key. You can select from among the several RSA padding modes.

A Raw RSA keyring that encrypts and decrypts must include an asymmetric public key and private key pair. However, you can encrypt data with a Raw RSA keyring that has only a public key, and you can decrypt data with a Raw RSA keyring that has only a private key. You can include any Raw RSA keyring in a multi-keyring. If you configure a Raw RSA keyring with a public and private key, be sure that they are part of the same key pair. Some language implementations of the AWS Encryption SDK will not construct a Raw RSA keyring with keys from different pairs. Others rely on you to verify that your keys are from the same key pair.

The Raw RSA keyring is equivalent to and interoperates with the JceMasterKey in the AWS Encryption SDK for Java and the RawMasterKey in the AWS Encryption SDK for Python when they are used with RSA asymmetric encryption keys. You can encrypt data with one implementation and decrypt the data with any other implementation using the same wrapping key. For details, see Keyring compatibility.

> **Note**
>
> The Raw RSA keyring does not support asymmetric KMS keys. If you want to use asymmetric RSA KMS keys, the following programming languages support AWS KMS keyrings that use asymmetric RSA AWS KMS keys:
>
> - Version 3.*x* of the AWS Encryption SDK for Java
> - Version 4.*x* of theAWS Encryption SDK for .NET
> - Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional Cryptographic Material Providers Library (MPL) dependency.

- Version 0.1.*x* or later of the AWS Encryption SDK for Go

If you encrypt data with a Raw RSA keyring that includes the public key of an RSA KMS key, neither the AWS Encryption SDK nor AWS KMS can decrypt it. You cannot export the private key of an AWS KMS asymmetric KMS key into a Raw RSA keyring. The AWS KMS Decrypt operation cannot decrypt the encrypted message that the AWS Encryption SDK returns.

When constructing a Raw RSA keyring in the AWS Encryption SDK for C, be sure to provide the *contents* of the PEM file that includes each key as a null-terminated C-string, not as a path or file name. When constructing a Raw RSA keyring in JavaScript, be aware of potential incompatibility with other language implementations.

Namespaces and names

To identify the RSA key material in a keyring, the Raw RSA keyring uses a *key namespace* and *key name* that you provide. These values are not secret. They appear in plain text in the header of the encrypted message that the encrypt operation returns. We recommend using the key namespace and key name that identifies the RSA key pair (or its private key) in your HSM or key management system.

Note

The key namespace and key name are equivalent to the *Provider ID* (or *Provider*) and *Key ID* fields in the `JceMasterKey` and `RawMasterKey`.
The AWS Encryption SDK for C reserves the `aws-kms` key namespace value for KMS keys. Do not use it in a Raw AES keyring or Raw RSA keyring with the AWS Encryption SDK for C.

If you construct different keyrings to encrypt and decrypt a given message, the namespace and name values are critical. If the key namespace and key name in the decryption keyring isn't an exact, case-sensitive match for the key namespace and key name in the encryption keyring, the decryption keyring isn't used, even if the keys are from the same key pair.

The key namespace and key name of the key material in the encryption and decryption keyrings must be same whether the keyring contains the RSA public key, the RSA private key, or both keys in the key pair. For example, suppose you encrypt data with a Raw RSA keyring for an RSA public key

with key namespace `HSM_01` and key name `RSA_2048_06`. To decrypt that data, construct a Raw RSA keyring with the private key (or key pair), and the same key namespace and name.

Padding mode

You must specify a padding mode for Raw RSA keyrings used for encryption and decryption, or use features of your language implementation that specify it for you.

The AWS Encryption SDK supports the following padding modes, subjects to the constraints of each language. We recommend an OAEP padding mode, particularly OAEP with SHA-256 and MGF1 with SHA-256 Padding. The PKCS1 padding mode is supported only for backward compatibility.

- OAEP with SHA-1 and MGF1 with SHA-1 Padding
- OAEP with SHA-256 and MGF1 with SHA-256 Padding
- OAEP with SHA-384 and MGF1 with SHA-384 Padding
- OAEP with SHA-512 and MGF1 with SHA-512 Padding
- PKCS1 v1.5 Padding

The following examples show how to create a Raw RSA keyring with the public and private key of an RSA key pair and the OAEP with SHA-256 and MGF1 with SHA-256 padding mode. The `RSAPublicKey` and `RSAPrivateKey` variables represent the key material you provide.

C

To create a Raw RSA keyring in the AWS Encryption SDK for C, use `aws_cryptosdk_raw_rsa_keyring_new`.

When constructing a Raw RSA keyring in the AWS Encryption SDK for C, be sure to provide the *contents* of the PEM file that includes each key as a null-terminated C-string, not as a path or file name. For a complete example, see raw_rsa_keyring.c.

```
struct aws_allocator *alloc = aws_default_allocator();

AWS_STATIC_STRING_FROM_LITERAL(key_namespace, "HSM_01");
AWS_STATIC_STRING_FROM_LITERAL(key_name, "RSA_2048_06");

struct aws_cryptosdk_keyring *rawRsaKeyring = aws_cryptosdk_raw_rsa_keyring_new(
    alloc,
    key_namespace,
```

```
    key_name,
    private_key_from_pem,
    public_key_from_pem,
    AWS_CRYPTOSDK_RSA_OAEP_SHA256_MGF1);
```

C# / .NET

To instantiate a Raw RSA keyring in the AWS Encryption SDK for .NET, use the `materialProviders.CreateRawRsaKeyring()` method. For a complete example, see RawRSAKeyringExample.cs.

The following example uses version 4.*x* of the AWS Encryption SDK for .NET.

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());

var keyNamespace = "HSM_01";
var keyName = "RSA_2048_06";

// Get public and private keys from PEM files
var publicKey = new
 MemoryStream(System.IO.File.ReadAllBytes("RSAKeyringExamplePublicKey.pem"));
var privateKey = new
 MemoryStream(System.IO.File.ReadAllBytes("RSAKeyringExamplePrivateKey.pem"));

// Create the keyring input
var createRawRsaKeyringInput = new CreateRawRsaKeyringInput
{
    KeyNamespace = keyNamespace,
    KeyName = keyName,
    PaddingScheme = PaddingScheme.OAEP_SHA512_MGF1,
    PublicKey = publicKey,
    PrivateKey = privateKey
};

// Create the keyring
var rawRsaKeyring = materialProviders.CreateRawRsaKeyring(createRawRsaKeyringInput);
```

JavaScript Browser

The AWS Encryption SDK for JavaScript in the browser gets its cryptographic primitives from the WebCrypto library. Before you construct the keyring, you must use `importPublicKey()`

and/or `importPrivateKey()` to import the raw key material into the WebCrypto backend. This assures that the keyring is complete even though all calls to WebCrypto are asynchronous. The object that the import methods take includes the wrapping algorithm and its padding mode.

After importing the key material, use the `RawRsaKeyringWebCrypto()` method to instantiate the keyring. When constructing a Raw RSA keyring in JavaScript, be aware of potential incompatibility with other language implementations.

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

For a complete example, see rsa_simple.ts (JavaScript Browser).

```
import {
  RsaImportableKey,
  RawRsaKeyringWebCrypto,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-browser'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const privateKey = await RawRsaKeyringWebCrypto.importPrivateKey(
  privateRsaJwKKey
)

const publicKey = await RawRsaKeyringWebCrypto.importPublicKey(
  publicRsaJwKKey
)

const keyNamespace = 'HSM_01'
const keyName = 'RSA_2048_06'

const keyring = new RawRsaKeyringWebCrypto({
  keyName,
  keyNamespace,
  publicKey,
```

```
  privateKey,
})
```

JavaScript Node.js

To instantiate a Raw RSA keyring in AWS Encryption SDK for JavaScript for Node.js, create a new instance of the `RawRsaKeyringNode` class. The `wrapKey` parameter holds the public key. The `unwrapKey` parameter holds the private key. The `RawRsaKeyringNode` constructor calculates a default padding mode for you, although you can specify a preferred padding mode.

When constructing a raw RSA keyring in JavaScript, be aware of potential incompatibility with other language implementations.

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

For a complete example, see rsa_simple.ts (JavaScript Node.js).

```
import {
  RawRsaKeyringNode,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const keyNamespace = 'HSM_01'
const keyName = 'RSA_2048_06'

const keyring = new RawRsaKeyringNode({ keyName, keyNamespace, rsaPublicKey,
 rsaPrivateKey})
```

Java

```
final CreateRawRsaKeyringInput keyringInput = CreateRawRsaKeyringInput.builder()
        .keyName("RSA_2048_06")
        .keyNamespace("HSM_01")
        .paddingScheme(PaddingScheme.OAEP_SHA256_MGF1)
```

```
        .publicKey(RSAPublicKey)
        .privateKey(RSAPrivateKey)
        .build();
final MaterialProviders matProv = MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();
IKeyring rawRsaKeyring = matProv.CreateRawRsaKeyring(keyringInput);
```

Python

The following example instantiates the AWS Encryption SDK client with the default commitment policy, REQUIRE_ENCRYPT_REQUIRE_DECRYPT. For a complete example, see raw_rsa_keyring_example.py in the AWS Encryption SDK for Python repository in GitHub.

```
# Define the key namespace and key name
key_name_space = "HSM_01"
key_name = "RSA_2048_06"

# Instantiate the material providers
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Create Raw RSA keyring
keyring_input: CreateRawRsaKeyringInput = CreateRawRsaKeyringInput(
    key_namespace=key_name_space,
    key_name=key_name,
    padding_scheme=PaddingScheme.OAEP_SHA256_MGF1,
    public_key=RSAPublicKey,
    private_key=RSAPrivateKey
)

raw_rsa_keyring: IKeyring = mat_prov.create_raw_rsa_keyring(
    input=keyring_input
)
```

Rust

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Optional: Create an encryption context
```

```
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Define the key namespace and key name
let key_namespace: &str = "HSM_01";
let key_name: &str = "RSA_2048_06";

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create Raw RSA keyring
let raw_rsa_keyring = mpl
    .create_raw_rsa_keyring()
    .key_name(key_name)
    .key_namespace(key_namespace)
    .padding_scheme(PaddingScheme::OaepSha256Mgf1)
    .public_key(aws_smithy_types::Blob::new(RSAPublicKey))
    .private_key(aws_smithy_types::Blob::new(RSAPrivateKey))
    .send()
    .await?;
```

Go

```
// Instantiate the material providers library
matProv, err :=
 awscryptographymaterialproviderssmithygenerated.NewClient(awscryptographymaterialproviderss

// Create Raw RSA keyring
rsaKeyRingInput :=
 awscryptographymaterialproviderssmithygeneratedtypes.CreateRawRsaKeyringInput{
 KeyName:       "rsa",
 KeyNamespace:  "rsa-keyring",
 PaddingScheme:
 awscryptographymaterialproviderssmithygeneratedtypes.PaddingSchemePkcs1,
 PublicKey:     pem.EncodeToMemory(publicKeyBlock),
 PrivateKey:    pem.EncodeToMemory(privateKeyBlock),
```

```
}

rsaKeyring, err := matProv.CreateRawRsaKeyring(context.Background(),
 rsaKeyRingInput)
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Define the key namespace and key name
var keyNamespace = "HSM_01"
var keyName = "RSA_2048_06"

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
```

```
}

// Create Raw RSA keyring
rsaKeyRingInput := mpltypes.CreateRawRsaKeyringInput{
    KeyName:       keyName,
    KeyNamespace:  keyNamespace,
    PaddingScheme: mpltypes.PaddingSchemeOaepSha512Mgf1,
    PublicKey:     (RSAPublicKey),
    PrivateKey:    (RSAPrivateKey),
}
rsaKeyring, err := matProv.CreateRawRsaKeyring(context.Background(),
 rsaKeyRingInput)
if err != nil {
    panic(err)
}
```

Raw ECDH keyrings

The Raw ECDH keyring uses the elliptic curve public-private key pairs that you provide to derive a shared wrapping key between two parties. First, the keyring derives a shared secret using the sender's private key, the recipient's public key, and the Elliptic Curve Diffie-Hellman (ECDH) key agreement algorithm. Then, the keyring uses the shared secret to derive the shared wrapping key that protects your data encryption keys. The key derivation function that the AWS Encryption SDK uses (KDF_CTR_HMAC_SHA384) to derive the shared wrapping key conforms to NIST recommendations for key derivation.

The key derivation function returns 64 bytes of key material. To ensure that both parties use the correct key material, the AWS Encryption SDK uses the first 32 bytes as a commitment key and the last 32 bytes as the shared wrapping key. On decrypt, if the keyring cannot reproduce the same commitment key and shared wrapping key that is stored on the message header ciphertext, the operation fails. For example, if you encrypt data with a keyring configured with **Alice's** private key and **Bob's** public key, a keyring configured with **Bob's** private key and **Alice's** public key will reproduce the same commitment key and shared wrapping key and be able to decrypt the data. If Bob's public key is from an AWS KMS key pair, then Bob can create an AWS KMS ECDH keyring to decrypt the data.

The Raw ECDH keyring encrypts data with a symmetric key using AES-GCM. The data key is then envelope encrypted with the derived shared wrapping key using AES-GCM. Each Raw ECDH keyring

can have only one shared wrapping key, but you can include multiple Raw ECDH keyrings, alone or with other keyrings, in a multi-keyring.

You are responsible for generating, storing, and protecting your private keys, preferably in a hardware security module (HSM) or key management system. The sender and recipient's key pairs much be on the same elliptic curve. The AWS Encryption SDK supports the following elliptic curve specifications:

- `ECC_NIST_P256`
- `ECC_NIST_P384`
- `ECC_NIST_P512`

Programming language compatibility

The Raw ECDH keyring is introduced in version 1.5.0 of the Cryptographic Material Providers Library (MPL) and is supported by the following programming languages and versions:

- Version 3.*x* of the AWS Encryption SDK for Java
- Version 4.*x* of the AWS Encryption SDK for .NET
- Version 4.*x* of the AWS Encryption SDK for Python, when used with the optional MPL dependency.
- Version 1.*x* of the AWS Encryption SDK for Rust
- Version 0.1.*x* or later of the AWS Encryption SDK for Go

Creating a Raw ECDH keyring

The Raw ECDH keyring supports three key agreement schemas: `RawPrivateKeyToStaticPublicKey`, `EphemeralPrivateKeyToStaticPublicKey`, and `PublicKeyDiscovery`. The key agreement schema that you select determines which cryptographic operations you can perform and how the keying materials are assembled.

Topics

- RawPrivateKeyToStaticPublicKey
- EphemeralPrivateKeyToStaticPublicKey
- PublicKeyDiscovery

RawPrivateKeyToStaticPublicKey

Use the `RawPrivateKeyToStaticPublicKey` key agreement schema to statically configure the sender's private key and the recipient's public key in the keyring. This key agreement schema can encrypt and decrypt data.

To initialize a Raw ECDH keyring with the `RawPrivateKeyToStaticPublicKey` key agreement schema, provide the following values:

- **Sender's private key**

  You must provide the sender's PEM-encoded private key (PKCS #8 PrivateKeyInfo structures), as defined in RFC 5958.

- **Recipient's public key**

  You must provide the recipient's DER-encoded X.509 public key, also known as `SubjectPublicKeyInfo` (SPKI), as defined in RFC 5280.

  You can specify the public key of an asymmetric key agreement KMS key pair or the public key from a key pair generated outside of AWS.

- **Curve specification**

  Identifies the elliptic curve specification in the specified key pairs. Both the sender and recipient's key pairs must have the same curve specification.

  Valid values: `ECC_NIST_P256`, `ECC_NIS_P384`, `ECC_NIST_P512`

C# / .NET

```
// Instantiate material providers
var materialProviders = new MaterialProviders(new MaterialProvidersConfig());
     var BobPrivateKey = new MemoryStream(new byte[] { });
     var AlicePublicKey = new MemoryStream(new byte[] { });

     // Create the Raw ECDH static keyring
     var staticConfiguration = new RawEcdhStaticConfigurations()
     {
      RawPrivateKeyToStaticPublicKey = new RawPrivateKeyToStaticPublicKeyInput
      {
       SenderStaticPrivateKey = BobPrivateKey,
       RecipientPublicKey = AlicePublicKey
```

```
      }
     };

     var createKeyringInput = new CreateRawEcdhKeyringInput()
     {
      CurveSpec = ECDHCurveSpec.ECC_NIST_P256,
      KeyAgreementScheme = staticConfiguration
     };

     var keyring = materialProviders.CreateRawEcdhKeyring(createKeyringInput);
```

Java

The following Java example uses the `RawPrivateKeyToStaticPublicKey` key agreement schema to statically configure the sender's private key and the recipient's public key. Both key pairs are on the `ECC_NIST_P256` curve.

```
private static void StaticRawKeyring() {
    // Instantiate material providers
    final MaterialProviders materialProviders =
      MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();

    KeyPair senderKeys = GetRawEccKey();
    KeyPair recipient = GetRawEccKey();

    // Create the Raw ECDH static keyring
    final CreateRawEcdhKeyringInput rawKeyringInput =
      CreateRawEcdhKeyringInput.builder()
        .curveSpec(ECDHCurveSpec.ECC_NIST_P256)
        .KeyAgreementScheme(
          RawEcdhStaticConfigurations.builder()
            .RawPrivateKeyToStaticPublicKey(
                RawPrivateKeyToStaticPublicKeyInput.builder()
                  // Must be a PEM-encoded private key

 .senderStaticPrivateKey(ByteBuffer.wrap(senderKeys.getPrivate().getEncoded()))
                  // Must be a DER-encoded X.509 public key

 .recipientPublicKey(ByteBuffer.wrap(recipient.getPublic().getEncoded()))
                  .build()
            )
```

```
            .build()
        ).build();

    final IKeyring staticKeyring =
 materialProviders.CreateRawEcdhKeyring(rawKeyringInput);
}
```

Python

The following Python example uses the `RawEcdhStaticConfigurationsRawPrivateKeyToStaticPublicKey` key agreement schema to statically configure the sender's private key and the recipient's public key. Both key pairs are on the `ECC_NIST_P256` curve.

```
import boto3
from aws_cryptographic_materialproviders.mpl.models import (
    CreateRawEcdhKeyringInput,
    RawEcdhStaticConfigurationsRawPrivateKeyToStaticPublicKey,
    RawPrivateKeyToStaticPublicKeyInput,
)
from aws_cryptography_primitives.smithygenerated.aws_cryptography_primitives.models
 import ECDHCurveSpec

# Instantiate the material providers library
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Must be a PEM-encoded private key
bob_private_key = get_private_key_bytes()
# Must be a DER-encoded X.509 public key
alice_public_key = get_public_key_bytes()

# Create the raw ECDH static keyring
raw_keyring_input = CreateRawEcdhKeyringInput(
    curve_spec = ECDHCurveSpec.ECC_NIST_P256,
    key_agreement_scheme =
 RawEcdhStaticConfigurationsRawPrivateKeyToStaticPublicKey(
        RawPrivateKeyToStaticPublicKeyInput(
            sender_static_private_key = bob_private_key,
            recipient_public_key = alice_public_key,
        )
    )
```

```
)

keyring = mat_prov.create_raw_ecdh_keyring(raw_keyring_input)
```

Rust

The following Python example uses the `raw_ecdh_static_configuration` key agreement schema to statically configure the sender's private key and the recipient's public key. Both key pairs must be on the same curve.

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Optional: Create your encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Create keyring input
let raw_ecdh_static_configuration_input =
    RawPrivateKeyToStaticPublicKeyInput::builder()
        // Must be a UTF8 PEM-encoded private key
        .sender_static_private_key(private_key_sender_utf8_bytes)
        // Must be a UTF8 DER-encoded X.509 public key
        .recipient_public_key(public_key_recipient_utf8_bytes)
        .build()?;

let raw_ecdh_static_configuration =
 RawEcdhStaticConfigurations::RawPrivateKeyToStaticPublicKey(raw_ecdh_static_configuration_i

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create raw ECDH static keyring
let raw_ecdh_keyring = mpl
    .create_raw_ecdh_keyring()
```

```
    .curve_spec(ecdh_curve_spec)
    .key_agreement_scheme(raw_ecdh_static_configuration)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Optional: Create your encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Create keyring input
rawEcdhStaticConfigurationInput := mpltypes.RawPrivateKeyToStaticPublicKeyInput{
    SenderStaticPrivateKey: privateKeySender,
    RecipientPublicKey:     publicKeyRecipient,
}
rawECDHStaticConfiguration :=
 &mpltypes.RawEcdhStaticConfigurationsMemberRawPrivateKeyToStaticPublicKey{
    Value: rawEcdhStaticConfigurationInput,
```

```
}
rawEcdhKeyRingInput := mpltypes.CreateRawEcdhKeyringInput{
    CurveSpec:          ecdhCurveSpec,
    KeyAgreementScheme: rawECDHStaticConfiguration,
}

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create raw ECDH static keyring
rawEcdhKeyring, err := matProv.CreateRawEcdhKeyring(context.Background(),
 rawEcdhKeyRingInput)
if err != nil {
    panic(err)
}
```

EphemeralPrivateKeyToStaticPublicKey

Keyrings configured with the `EphemeralPrivateKeyToStaticPublicKey` key agreement schema create a new key pair locally and derive a unique shared wrapping key for each encrypt call.

This key agreement schema can only encrypt messages. To decrypt messages encrypted with the `EphemeralPrivateKeyToStaticPublicKey` key agreement schema, you must use a discovery key agreement schema configured with the same recipient's public key. To decrypt, you can use a Raw ECDH keyring with the `PublicKeyDiscovery` key agreement algorithm, or, if the recipient's public key is from an asymmetric key agreement KMS key pair, you can use an AWS KMS ECDH keyring with the KmsPublicKeyDiscovery key agreement schema.

To initialize a Raw ECDH keyring with the `EphemeralPrivateKeyToStaticPublicKey` key agreement schema, provide the following values:

- **Recipient's public key**

  You must provide the recipient's DER-encoded X.509 public key, also known as `SubjectPublicKeyInfo` (SPKI), as defined in RFC 5280.

  You can specify the public key of an asymmetric key agreement KMS key pair or the public key from a key pair generated outside of AWS.

- **Curve specification**

  Identifies the elliptic curve specification in the specified public key.

  On encrypt, the keyring creates a new key pair on the specified curve and uses the new private key and specified public key to derive a shared wrapping key.

  Valid values: `ECC_NIST_P256`, `ECC_NIS_P384`, `ECC_NIST_P512`

C# / .NET

The following example creates a Raw ECDH keyring with the `EphemeralPrivateKeyToStaticPublicKey` key agreement schema. On encrypt, the keyring will create a new key pair locally on the specified `ECC_NIST_P256` curve.

```
// Instantiate material providers
var materialProviders = new MaterialProviders(new MaterialProvidersConfig());
     var AlicePublicKey = new MemoryStream(new byte[] { });

     // Create the Raw ECDH ephemeral keyring
     var ephemeralConfiguration = new RawEcdhStaticConfigurations()
     {
      EphemeralPrivateKeyToStaticPublicKey = new
 EphemeralPrivateKeyToStaticPublicKeyInput
      {
       RecipientPublicKey = AlicePublicKey
      }
     };

     var createKeyringInput = new CreateRawEcdhKeyringInput()
     {
      CurveSpec = ECDHCurveSpec.ECC_NIST_P256,
      KeyAgreementScheme = ephemeralConfiguration
     };

     var keyring = materialProviders.CreateRawEcdhKeyring(createKeyringInput);
```

Java

The following example creates a Raw ECDH keyring with the `EphemeralPrivateKeyToStaticPublicKey` key agreement schema. On encrypt, the keyring will create a new key pair locally on the specified `ECC_NIST_P256` curve.

```
private static void EphemeralRawEcdhKeyring() {
    // Instantiate material providers
    final MaterialProviders materialProviders =
      MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();

    ByteBuffer recipientPublicKey = getPublicKeyBytes();

    // Create the Raw ECDH ephemeral keyring
    final CreateRawEcdhKeyringInput ephemeralInput =
      CreateRawEcdhKeyringInput.builder()
        .curveSpec(ECDHCurveSpec.ECC_NIST_P256)
        .KeyAgreementScheme(
          RawEcdhStaticConfigurations.builder()
            .EphemeralPrivateKeyToStaticPublicKey(
              EphemeralPrivateKeyToStaticPublicKeyInput.builder()
                .recipientPublicKey(recipientPublicKey)
                .build()
            )
            .build()
        ).build();

    final IKeyring ephemeralKeyring =
 materialProviders.CreateRawEcdhKeyring(ephemeralInput);
}
```

Python

The following example creates a Raw ECDH keyring with the `RawEcdhStaticConfigurationsEphemeralPrivateKeyToStaticPublicKey` key agreement schema. On encrypt, the keyring will create a new key pair locally on the specified `ECC_NIST_P256` curve.

```
import boto3
from aws_cryptographic_materialproviders.mpl.models import (
    CreateRawEcdhKeyringInput,
    RawEcdhStaticConfigurationsEphemeralPrivateKeyToStaticPublicKey,
    EphemeralPrivateKeyToStaticPublicKeyInput,
)
from aws_cryptography_primitives.smithygenerated.aws_cryptography_primitives.models
 import ECDHCurveSpec
```

```
# Instantiate the material providers library
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Your get_public_key_bytes must return a DER-encoded X.509 public key
recipient_public_key = get_public_key_bytes()

# Create the raw ECDH ephemeral private key keyring
ephemeral_input = CreateRawEcdhKeyringInput(
    curve_spec = ECDHCurveSpec.ECC_NIST_P256,
    key_agreement_scheme =
 RawEcdhStaticConfigurationsEphemeralPrivateKeyToStaticPublicKey(
        EphemeralPrivateKeyToStaticPublicKeyInput(
            recipient_public_key = recipient_public_key,
        )
    )
)

keyring = mat_prov.create_raw_ecdh_keyring(ephemeral_input)
```

Rust

The following example creates a Raw ECDH keyring with the `ephemeral_raw_ecdh_static_configuration` key agreement schema. On encrypt, the keyring will create a new key pair locally on the specified curve.

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Optional: Create your encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Load public key from UTF-8 encoded PEM files into a DER encoded public key.
```

```
let public_key_file_content =
 std::fs::read_to_string(Path::new(EXAMPLE_ECC_PUBLIC_KEY_FILENAME_RECIPIENT))?;
let parsed_public_key_file_content = parse(public_key_file_content)?;
let public_key_recipient_utf8_bytes = parsed_public_key_file_content.contents();

// Create EphemeralPrivateKeyToStaticPublicKeyInput
let ephemeral_raw_ecdh_static_configuration_input =
    EphemeralPrivateKeyToStaticPublicKeyInput::builder()
        // Must be a UTF8 DER-encoded X.509 public key
        .recipient_public_key(public_key_recipient_utf8_bytes)
        .build()?;

let ephemeral_raw_ecdh_static_configuration =

 RawEcdhStaticConfigurations::EphemeralPrivateKeyToStaticPublicKey(ephemeral_raw_ecdh_static

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create raw ECDH ephemeral private key keyring
let ephemeral_raw_ecdh_keyring = mpl
    .create_raw_ecdh_keyring()
    .curve_spec(ecdh_curve_spec)
    .key_agreement_scheme(ephemeral_raw_ecdh_static_configuration)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
)
```

```
// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Optional: Create your encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Load public key from UTF-8 encoded PEM files into a DER encoded public key
publicKeyRecipient, err := LoadPublicKeyFromPEM(eccPublicKeyFileNameRecipient)
if err != nil {
    panic(err)
}

// Create EphemeralPrivateKeyToStaticPublicKeyInput
ephemeralRawEcdhStaticConfigurationInput :=
 mpltypes.EphemeralPrivateKeyToStaticPublicKeyInput{
    RecipientPublicKey: publicKeyRecipient,
}
ephemeralRawECDHStaticConfiguration :=
    mpltypes.RawEcdhStaticConfigurationsMemberEphemeralPrivateKeyToStaticPublicKey{
        Value: ephemeralRawEcdhStaticConfigurationInput,
    }

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create raw ECDH ephemeral private key keyring
rawEcdhKeyRingInput := mpltypes.CreateRawEcdhKeyringInput{
    CurveSpec:          ecdhCurveSpec,
    KeyAgreementScheme: &ephemeralRawECDHStaticConfiguration,
}
ecdhKeyring, err := matProv.CreateRawEcdhKeyring(context.Background(),
 rawEcdhKeyRingInput)
```

```
if err != nil {
    panic(err)
}
```

PublicKeyDiscovery

When decrypting, it's a best practice to specify the wrapping keys that the AWS Encryption SDK can use. To follow this best practice, use an ECDH keyring that specifies both a sender's private key and recipient's public key. However, you can also create a Raw ECDH discovery keyring, that is, a Raw ECDH keyring that can decrypt any message where the specified key's public key matches the recipient's public key stored on the message ciphertext. This key agreement schema can only decrypt messages.

> **Important**
>
> When you decrypt messages using the `PublicKeyDiscovery` key agreement schema, you accept all public keys, regardless of who owns it.

To initialize a Raw ECDH keyring with the `PublicKeyDiscovery` key agreement schema, provide the following values:

- **Recipient's static private key**

  You must provide the recipient's PEM-encoded private key (PKCS #8 PrivateKeyInfo structures), as defined in RFC 5958.

- **Curve specification**

  Identifies the elliptic curve specification in the specified private key. Both the sender and recipient's key pairs must have the same curve specification.

  Valid values: `ECC_NIST_P256`, `ECC_NIS_P384`, `ECC_NIST_P512`

C# / .NET

The following example creates a Raw ECDH keyring with the `PublicKeyDiscovery` key agreement schema. This keyring can decrypt any message where the public key of the specified private key matches the recipient's public key stored on the message ciphertext.

```
// Instantiate material providers
var materialProviders = new MaterialProviders(new MaterialProvidersConfig());
     var AlicePrivateKey = new MemoryStream(new byte[] { });

     // Create the Raw ECDH discovery keyring
     var discoveryConfiguration = new RawEcdhStaticConfigurations()
     {
      PublicKeyDiscovery = new PublicKeyDiscoveryInput
      {
       RecipientStaticPrivateKey = AlicePrivateKey
      }
     };

     var createKeyringInput = new CreateRawEcdhKeyringInput()
     {
      CurveSpec = ECDHCurveSpec.ECC_NIST_P256,
      KeyAgreementScheme = discoveryConfiguration
     };

     var keyring = materialProviders.CreateRawEcdhKeyring(createKeyringInput);
```

Java

The following example creates a Raw ECDH keyring with the `PublicKeyDiscovery` key agreement schema. This keyring can decrypt any message where the public key of the specified private key matches the recipient's public key stored on the message ciphertext.

```
private static void RawEcdhDiscovery() {
    // Instantiate material providers
    final MaterialProviders materialProviders =
      MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();

    KeyPair recipient = GetRawEccKey();

    // Create the Raw ECDH discovery keyring
```

```
    final CreateRawEcdhKeyringInput rawKeyringInput =
      CreateRawEcdhKeyringInput.builder()
        .curveSpec(ECDHCurveSpec.ECC_NIST_P256)
        .KeyAgreementScheme(
          RawEcdhStaticConfigurations.builder()
            .PublicKeyDiscovery(
              PublicKeyDiscoveryInput.builder()
                // Must be a PEM-encoded private key

 .recipientStaticPrivateKey(ByteBuffer.wrap(sender.getPrivate().getEncoded()))
                .build()
            )
            .build()
        ).build();

    final IKeyring publicKeyDiscovery  =
 materialProviders.CreateRawEcdhKeyring(rawKeyringInput);
}
```

Python

The following example creates a Raw ECDH keyring with the `RawEcdhStaticConfigurationsPublicKeyDiscovery` key agreement schema. This keyring can decrypt any message where the public key of the specified private key matches the recipient's public key stored on the message ciphertext.

```
import boto3
from aws_cryptographic_materialproviders.mpl.models import (
    CreateRawEcdhKeyringInput,
    RawEcdhStaticConfigurationsPublicKeyDiscovery,
    PublicKeyDiscoveryInput,
)
from aws_cryptography_primitives.smithygenerated.aws_cryptography_primitives.models
 import ECDHCurveSpec

# Instantiate the material providers library
mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

# Your get_private_key_bytes must return a PEM-encoded private key
recipient_private_key = get_private_key_bytes()
```

```
# Create the raw ECDH discovery keyring
raw_keyring_input = CreateRawEcdhKeyringInput(
    curve_spec = ECDHCurveSpec.ECC_NIST_P256,
    key_agreement_scheme = RawEcdhStaticConfigurationsPublicKeyDiscovery(
        PublicKeyDiscoveryInput(
            recipient_static_private_key = recipient_private_key,
        )
    )
)

keyring = mat_prov.create_raw_ecdh_keyring(raw_keyring_input)
```

Rust

The following example creates a Raw ECDH keyring with the `discovery_raw_ecdh_static_configuration` key agreement schema. This keyring can decrypt any message where the public key of the specified private key matches the recipient's public key stored on the message ciphertext.

```
// Instantiate the AWS Encryption SDK client and material providers library
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;


// Optional: Create your encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Load keys from UTF-8 encoded PEM files.
let mut file = File::open(Path::new(EXAMPLE_ECC_PRIVATE_KEY_FILENAME_RECIPIENT))?;
let mut private_key_recipient_utf8_bytes = Vec::new();
file.read_to_end(&mut private_key_recipient_utf8_bytes)?;

// Create PublicKeyDiscoveryInput
```

```
let discovery_raw_ecdh_static_configuration_input =
    PublicKeyDiscoveryInput::builder()
        // Must be a UTF8 PEM-encoded private key
        .recipient_static_private_key(private_key_recipient_utf8_bytes)
        .build()?;

let discovery_raw_ecdh_static_configuration =

 RawEcdhStaticConfigurations::PublicKeyDiscovery(discovery_raw_ecdh_static_configuration_inp

// Create raw ECDH discovery private key keyring
let discovery_raw_ecdh_keyring = mpl
    .create_raw_ecdh_keyring()
    .curve_spec(ecdh_curve_spec)
    .key_agreement_scheme(discovery_raw_ecdh_static_configuration)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Optional: Create your encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
```

```
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}

// Load keys from UTF-8 encoded PEM files.
privateKeyRecipient, err := os.ReadFile(eccPrivateKeyFileNameRecipient)
if err != nil {
    panic(err)
}

// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create PublicKeyDiscoveryInput
discoveryRawEcdhStaticConfigurationInput := mpltypes.PublicKeyDiscoveryInput{
    RecipientStaticPrivateKey: privateKeyRecipient,
}

discoveryRawEcdhStaticConfiguration :=
 &mpltypes.RawEcdhStaticConfigurationsMemberPublicKeyDiscovery{
    Value: discoveryRawEcdhStaticConfigurationInput,
}

// Create raw ECDH discovery private key keyring
discoveryRawEcdhKeyringInput := mpltypes.CreateRawEcdhKeyringInput{
    CurveSpec:          ecdhCurveSpec,
    KeyAgreementScheme: discoveryRawEcdhStaticConfiguration,
}

discoveryRawEcdhKeyring, err := matProv.CreateRawEcdhKeyring(context.Background(),
 discoveryRawEcdhKeyringInput)
if err != nil {
    panic(err)
}
```

Multi-keyrings

You can combine keyrings into a multi-keyring. A *multi-keyring* is a keyring that consists of one or more individual keyrings of the same or a different type. The effect is like using several keyrings in a series. When you use a multi-keyring to encrypt data, any of the wrapping keys in any of its keyrings can decrypt that data.

When you create a multi-keyring to encrypt data, you designate one of the keyrings as the *generator keyring*. All other keyrings are known as *child keyrings*. The generator keyring generates and encrypts the plaintext data key. Then, all of the wrapping keys in all of the child keyrings encrypt the same plaintext data key. The multi-keyring returns the plaintext key and one encrypted data key for each wrapping key in the multi-keyring. If the generator keyring is a KMS keyring, the generator key in the AWS KMS keyring generates and encrypts the plaintext key. Then, all additional AWS KMS keys in the AWS KMS keyring, and all wrapping keys in all child keyrings in the multi-keyring, encrypt the same plaintext key.

If you create a multi-keyring with no generator keyring, you can use it by itself to decrypt data, but not to encrypt. Or, to use a multi-keyring with no genertor keyring in encrypt operations, you can specify it as a child keyring in another multi-keyring. A multi-keyring with no generator keyring cannot be designated as the generator keyring in another multi-keyring.

When decrypting, the AWS Encryption SDK uses the keyrings to try to decrypt one of the encrypted data keys. The keyrings are called in the order that they are specified in the multi-keyring. Processing stops as soon as any key in any keyring can decrypt an encrypted data key.

Beginning in version 1.7.*x*, when an encrypted data key is encrypted under an AWS Key Management Service (AWS KMS) keyring (or master key provider), the AWS Encryption SDK always passes the key ARN of the AWS KMS key to the `KeyId` parameter of the AWS KMS Decrypt operation. This is an AWS KMS best practice that assures that you decrypt the encrypted data key with the wrapping key you intend to use.

To see a working example of a multi-keyring, see:

- C: multi_keyring.cpp
- C# / .NET: MultiKeyringExample.cs
- JavaScript Node.js: multi_keyring.ts
- JavaScript Browser: multi_keyring.ts
- Java: MultiKeyringExample.java

- Python: multi_keyring_example.py

To create a multi-keyring, first instantiate the child keyrings. In this example, we use an AWS KMS keyring and a Raw AES keyring, but you can combine any supported keyrings in a multi-keyring.

C

```
/* Define an AWS KMS keyring. For details, see string.cpp */
struct aws_cryptosdk_keyring *kms_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder().Build(example_key);

// Define a Raw AES keyring. For details, see raw_aes_keyring.c */
struct aws_cryptosdk_keyring *aes_keyring = aws_cryptosdk_raw_aes_keyring_new(
        alloc, wrapping_key_namespace, wrapping_key_name, wrapping_key,
 AWS_CRYPTOSDK_AES256);
```

C# / .NET

```
// Define an AWS KMS keyring. For details, see AwsKmsKeyringExample.cs.
var kmsKeyring = materialProviders.CreateAwsKmsKeyring(createKmsKeyringInput);

// Define a Raw AES keyring. For details, see RawAESKeyringExample.cs.
var aesKeyring = materialProviders.CreateRawAesKeyring(createAesKeyringInput);
```

JavaScript Browser

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called “Limiting encrypted data keys”.

```
import {
  KmsKeyringBrowser,
  KMS,
  getClient,
  RawAesKeyringWebCrypto,
  RawAesWrappingSuiteIdentifier,
  MultiKeyringWebCrypto,
  buildClient,
  CommitmentPolicy,
  synchronousRandomValues,
```

```
} from '@aws-crypto/client-browser'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

const clientProvider = getClient(KMS, { credentials })

// Define an AWS KMS keyring. For details, see kms_simple.ts.
const kmsKeyring = new KmsKeyringBrowser({ generatorKeyId: exampleKey })

// Define a Raw AES keyring. For details, see aes_simple.ts.
const aesKeyring = new RawAesKeyringWebCrypto({ keyName, keyNamespace,
 wrappingSuite, masterKey })
```

JavaScript Node.js

The following example uses the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

```
import {
  MultiKeyringNode,
  KmsKeyringNode,
  RawAesKeyringNode,
  RawAesWrappingSuiteIdentifier,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

// Define an AWS KMS keyring. For details, see kms_simple.ts.
const kmsKeyring = new KmsKeyringNode({ generatorKeyId: exampleKey })

// Define a Raw AES keyring. For details, see raw_aes_keyring_node.ts.
const aesKeyring = new RawAesKeyringNode({ keyName, keyNamespace, wrappingSuite,
 unencryptedMasterKey })
```

Java

```
// Define the raw AES keyring.
final MaterialProviders matProv = MaterialProviders.builder()
        .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
        .build();
final CreateRawAesKeyringInput createRawAesKeyringInput =
 CreateRawAesKeyringInput.builder()
        .keyName("AES_256_012")
        .keyNamespace("HSM_01")
        .wrappingKey(AESWrappingKey)
        .wrappingAlg(AesWrappingAlg.ALG_AES256_GCM_IV12_TAG16)
        .build();
IKeyring rawAesKeyring = matProv.CreateRawAesKeyring(createRawAesKeyringInput);

// Define the AWS KMS keyring.
final CreateAwsKmsMrkMultiKeyringInput createAwsKmsMrkMultiKeyringInput =
 CreateAwsKmsMrkMultiKeyringInput.builder()
        .generator(kmsKeyArn)
        .build();
IKeyring awsKmsMrkMultiKeyring =
 matProv.CreateAwsKmsMrkMultiKeyring(createAwsKmsMrkMultiKeyringInput);
```

Python

The following example instantiates the AWS Encryption SDK client with the [default commitment policy](), REQUIRE_ENCRYPT_REQUIRE_DECRYPT.

```
# Create the AWS KMS keyring
kms_client = boto3.client('kms', region_name="us-west-2")

mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
    config=MaterialProvidersConfig()
)

kms_keyring_input: CreateAwsKmsKeyringInput = CreateAwsKmsKeyringInput(
    generator=arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab,
    kms_client=kms_client
)

kms_keyring: IKeyring = mat_prov.create_aws_kms_keyring(
    input=kms_keyring_input
```

```
)

# Create Raw AES keyring
key_name_space = "HSM_01"
key_name = "AES_256_012"

raw_aes_keyring_input: CreateRawAesKeyringInput = CreateRawAesKeyringInput(
    key_namespace=key_name_space,
    key_name=key_name,
    wrapping_key=AESWrappingKey,
    wrapping_alg=AesWrappingAlg.ALG_AES256_GCM_IV12_TAG16
)

raw_aes_keyring: IKeyring = mat_prov.create_raw_aes_keyring(
    input=raw_aes_keyring_input
)
```

Rust

```
// Instantiate the AWS Encryption SDK client
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Create the AWS KMS client
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let kms_client = aws_sdk_kms::Client::new(&sdk_config);

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create an AWS KMS keyring
let kms_keyring = mpl
    .create_aws_kms_keyring()
    .kms_key_id(kms_key_id)
    .kms_client(kms_client)
    .send()
    .await?;

// Create a Raw AES keyring
let key_namespace: &str = "my-key-namespace";
let key_name: &str = "my-aes-key-name";
```

```
let raw_aes_keyring = mpl
    .create_raw_aes_keyring()
    .key_name(key_name)
    .key_namespace(key_namespace)
    .wrapping_key(aws_smithy_types::Blob::new(AESWrappingKey))
    .wrapping_alg(AesWrappingAlg::AlgAes256GcmIv12Tag16)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
    "github.com/aws/aws-sdk-go-v2/config"
    "github.com/aws/aws-sdk-go-v2/service/kms"
)

// Instantiate the AWS Encryption SDK client
encryptionClient, err := client.NewClient(esdktypes.AwsEncryptionSdkConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS client
cfg, err := config.LoadDefaultConfig(context.TODO())
if err != nil {
    panic(err)
}
kmsClient := kms.NewFromConfig(cfg, func(o *kms.Options) {
    o.Region = KmsKeyRegion
})

// Instantiate the material providers library
```

```
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS keyring
awsKmsKeyringInput := mpltypes.CreateAwsKmsKeyringInput{
    KmsClient: kmsClient,
    KmsKeyId:  kmsKeyId,
}
awsKmsKeyring, err := matProv.CreateAwsKmsKeyring(context.Background(),
 awsKmsKeyringInput)
if err != nil {
    panic(err)
}

// Create a Raw AES keyring
var keyNamespace = "my-key-namespace"
var keyName = "my-aes-key-name"

aesKeyRingInput := mpltypes.CreateRawAesKeyringInput{
    KeyName:      keyName,
    KeyNamespace: keyNamespace,
    WrappingKey:  AESWrappingKey,
    WrappingAlg:  mpltypes.AesWrappingAlgAlgAes256GcmIv12Tag16,
}
aesKeyring, err := matProv.CreateRawAesKeyring(context.Background(),
 aesKeyRingInput)
```

Next, create the multi-keyring and specify its generator keyring, if any. In this example, we create a multi-keyring in which the AWS KMS keyring is the generator keyring and the AES keyring is the child keyring.

C

In the multi-keyring constructor in C, you specify only its generator keyring.

```
struct aws_cryptosdk_keyring *multi_keyring = aws_cryptosdk_multi_keyring_new(alloc,
 kms_keyring);
```

To add a child keyring to your multi-keyring, use the `aws_cryptosdk_multi_keyring_add_child` method. You need to call the method once for each child keyring that you add.

```
// Add the Raw AES keyring (C only)
aws_cryptosdk_multi_keyring_add_child(multi_keyring, aes_keyring);
```

C# / .NET

The .NET `CreateMultiKeyringInput` constructor lets you define a generator keyring and child keyrings. The resulting `CreateMultiKeyringInput` object is immutable.

```
var createMultiKeyringInput = new CreateMultiKeyringInput
{
    Generator = kmsKeyring,
    ChildKeyrings = new List<IKeyring>() {aesKeyring}
};

var multiKeyring = materialProviders.CreateMultiKeyring(createMultiKeyringInput);
```

JavaScript Browser

JavaScript multi-keyrings are immutable. The JavaScript multi-keyring constructor lets you specify the generator keyring and multiple child keyrings.

```
const clientProvider = getClient(KMS, { credentials })

const multiKeyring = new MultiKeyringWebCrypto(generator: kmsKeyring, children:
 [aesKeyring]);
```

JavaScript Node.js

JavaScript multi-keyrings are immutable. The JavaScript multi-keyring constructor lets you specify the generator keyring and multiple child keyrings.

```
const multiKeyring = new MultiKeyringNode(generator: kmsKeyring, children:
 [aesKeyring]);
```

Java

The Java `CreateMultiKeyringInput` constructor lets you define a generator keyring and child keyrings. The resulting `createMultiKeyringInput` object is immutable.

```
final CreateMultiKeyringInput createMultiKeyringInput =
 CreateMultiKeyringInput.builder()
        .generator(awsKmsMrkMultiKeyring)
        .childKeyrings(Collections.singletonList(rawAesKeyring))
        .build();
IKeyring multiKeyring = matProv.CreateMultiKeyring(createMultiKeyringInput);
```

Python

```
multi_keyring_input: CreateMultiKeyringInput = CreateMultiKeyringInput(
    generator=kms_keyring,
    child_keyrings=[raw_aes_keyring]
)

multi_keyring: IKeyring = mat_prov.create_multi_keyring(
    input=multi_keyring_input
)
```

Rust

```
let multi_keyring = mpl
    .create_multi_keyring()
    .generator(kms_keyring.clone())
    .child_keyrings(vec![raw_aes_keyring.clone()])
    .send()
    .await?;
```

Go

```
createMultiKeyringInput := mpltypes.CreateMultiKeyringInput{
  Generator:     awsKmsKeyring,
  ChildKeyrings: []mpltypes.IKeyring{rawAESKeyring},
 }
 multiKeyring, err := matProv.CreateMultiKeyring(context.Background(),
 createMultiKeyringInput)
 if err != nil {
  panic(err)
 }
```

Now, you can use the multi-keyring to encrypt and decrypt data.

AWS Encryption SDK programming languages

The AWS Encryption SDK is available for the following programming languages. All language implementations are interoperable. You can encrypt with one language implementation and decrypt with another. Interoperability might be subject to language constraints. If so, these constraints are described in the topic about the language implementation. Also, when encrypting and decrypting, you must use compatible keyrings, or master keys and master key providers. For details, see the section called "Keyring compatibility".

Topics

- AWS Encryption SDK for C
- AWS Encryption SDK for .NET
- AWS Encryption SDK for Go
- AWS Encryption SDK for Java
- AWS Encryption SDK for JavaScript
- AWS Encryption SDK for Python
- AWS Encryption SDK for Rust
- AWS Encryption SDK command line interface

AWS Encryption SDK for C

The AWS Encryption SDK for C provides a client-side encryption library for developers who are writing applications in C. It also serves as a foundation for implementations of the AWS Encryption SDK in higher-level programming languages.

Like all implementations of the AWS Encryption SDK, the AWS Encryption SDK for C offers advanced data protection features. These include envelope encryption, additional authenticated data (AAD), and secure, authenticated, symmetric key algorithm suites, such as 256-bit AES-GCM with key derivation and signing.

All language-specific implementations of the AWS Encryption SDK are fully interoperable. For example, you can encrypt data with the AWS Encryption SDK for C and decrypt it with any supported language implementation, including the AWS Encryption CLI.

The AWS Encryption SDK for C requires the AWS SDK for C++ to interact with AWS Key Management Service (AWS KMS). You need to use it only if you're using the optional AWS KMS keyring. However, the AWS Encryption SDK doesn't require AWS KMS or any other AWS service.

Learn More

- For details about programming with the AWS Encryption SDK for C, see the C examples, the examples in the aws-encryption-sdk-c repository on GitHub, and the AWS Encryption SDK for C API documentation.
- For a discussion about how to use the AWS Encryption SDK for C to encrypt data so that you can decrypt it in multiple AWS Regions, see How to decrypt ciphertexts in multiple regions with the AWS Encryption SDK in C in the AWS Security Blog.

Topics

- Installing the AWS Encryption SDK for C
- Using the AWS Encryption SDK for C
- AWS Encryption SDK for C examples

Installing the AWS Encryption SDK for C

Install the latest version of the AWS Encryption SDK for C.

> **Note**
>
> All versions of the AWS Encryption SDK for C earlier than 2.0.0 are in the end-of-support phase.
> You can safely update from version 2.0.*x* and later to the latest version of the AWS Encryption SDK for C without any code or data changes. However, new security features introduced in version 2.0.*x* are not backward-compatible. To update from versions earlier than 1.7.*x* to version 2.0.*x* and later, you must first update to the latest 1.*x* version of the AWS Encryption SDK for C. For details, see Migrating your AWS Encryption SDK.

You can find detailed instructions for installing and building the AWS Encryption SDK for C in the README file of the aws-encryption-sdk-c repository. It includes instructions for building on Amazon Linux, Ubuntu, macOS, and Windows platforms.

Before you begin, decide whether you want to use AWS KMS keyrings in the AWS Encryption SDK. If you use an AWS KMS keyring, you need to install the AWS SDK for C++. The AWS SDK is required to interact with AWS Key Management Service (AWS KMS). When you use AWS KMS keyrings, the AWS Encryption SDK uses AWS KMS to generate and protect the encryption keys that protect your data.

You do not need to install the AWS SDK for C++ if you are using another keyring type, such as a raw AES keyring, a raw RSA keyring, or a multi-keyring that doesn't include an AWS KMS keyring. However, when using a raw keyring type, you need to generate and protect your own raw wrapping keys.

If you're having trouble with your installation, file an issue in the `aws-encryption-sdk-c` repository or use any of the feedback links on this page.

Using the AWS Encryption SDK for C

This topic explains some of the features of the AWS Encryption SDK for C that are not supported in other programming language implementations.

The examples in this section show how to use version 2.0.*x* and later of the AWS Encryption SDK for C. For examples that use earlier versions, find your release in the Releases list of the aws-encryption-sdk-c repository repository on GitHub.

For details about programming with the AWS Encryption SDK for C, see the C examples, the examples in the aws-encryption-sdk-c repository on GitHub, and the AWS Encryption SDK for C API documentation.

See also: Keyrings

Topics

- Patterns for encrypting and decrypting data
- Reference counting

Patterns for encrypting and decrypting data

When you use the AWS Encryption SDK for C, you follow a pattern similar to this: create a keyring, create a CMM that uses the keyring, create a session that uses the CMM (and keyring), and then process the session.

1. Load error strings.

   Call the `aws_cryptosdk_load_error_strings()` method in your C or C++ code. It loads error information that is very useful for debugging.

   You only need to call it once, such as in your `main` method.

   ```
   /* Load error strings for debugging */
   aws_cryptosdk_load_error_strings();
   ```

2. Create a keyring.

   Configure your keyring with the wrapping keys that you want to use to encrypt your data keys. This example uses an AWS KMS keyring with one AWS KMS key, but you can use any type of keyring in its place.

   To identify an AWS KMS key in an encryption keyring in the AWS Encryption SDK for C, specify a key ARN or alias ARN. In a decryption keyring, you must use a key ARN. For details, see Identifying AWS KMS keys in an AWS KMS keyring.

   ```
   const char * KEY_ARN = "arn:aws:kms:us-
   west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab"
   struct aws_cryptosdk_keyring *kms_keyring =
          Aws::Cryptosdk::KmsKeyring::Builder().Build(KEY_ARN);
   ```

3. Create a session.

   In the AWS Encryption SDK for C, you use a *session* to encrypt a single plaintext message or decrypt a single ciphertext message, regardless of its size. The session maintains the state of the message throughout its processing.

   Configure your session with an allocator, a keyring, and a mode: `AWS_CRYPTOSDK_ENCRYPT` or `AWS_CRYPTOSDK_DECRYPT`. If you need to change the mode of the session, use the `aws_cryptosdk_session_reset` method.

   When you create a session with a keyring, the AWS Encryption SDK for C automatically creates a default cryptographic materials manager (CMM) for you. You don't need to create, maintain, or destroy this object.

   For example, the following session uses the allocator and the keyring that was defined in step 1. When you encrypt data, the mode is `AWS_CRYPTOSDK_ENCRYPT`.

```
struct aws_cryptosdk_session * session =
 aws_cryptosdk_session_new_from_keyring_2(allocator, AWS_CRYPTOSDK_ENCRYPT,
 kms_keyring);
```

4. Encrypt or decrypt the data.

   To process the data in the session, use the `aws_cryptosdk_session_process` method. If the input buffer is large enough to hold the entire plaintext, and the output buffer is large enough to hold the entire ciphertext, you can call `aws_cryptosdk_session_process_full`. However, if you need to handle streaming data, you can call `aws_cryptosdk_session_process` in a loop. For an example, see the file_streaming.cpp example. The `aws_cryptosdk_session_process_full` is introduced in AWS Encryption SDK versions 1.9.*x* and 2.2.*x*.

   When the session is configured to encrypt data, the plaintext fields describe the input and the ciphertext fields describe the output. The `plaintext` field holds the message that you want to encrypt and the `ciphertext` field gets the encrypted message that the encrypt method returns.

```
/* Encrypting data */
aws_cryptosdk_session_process_full(session,
                                   ciphertext,
                                   ciphertext_buffer_size,
                                   &ciphertext_length,
                                   plaintext,
                                   plaintext_length)
```

   When the session is configured to decrypt data, the ciphertext fields describe the input and the plaintext fields describe the output. The `ciphertext` field holds the encrypted message that the encrypt method returned, and the `plaintext` field gets the plaintext message that the decrypt method returns.

   To decrypt the data, call the `aws_cryptosdk_session_process_full` method.

```
/* Decrypting data */
aws_cryptosdk_session_process_full(session,
                                   plaintext,
                                   plaintext_buffer_size,
```

```
                                        &plaintext_length,
                                        ciphertext,
                                        ciphertext_length)
```

Reference counting

To prevent memory leaks, be sure to release your references to all objects that you create when you are finished with them. Otherwise, you end up with memory leaks. The SDK provides methods to make this task easier.

Whenever you create a parent object with one of the following child objects, the parent object gets and maintains a reference to the child object, as follows:

- A keyring, such as creating a session with a keyring
- A default cryptographic materials manager (CMM), such as creating a session or custom CMM with a default CMM
- A data key cache, such as creating a caching CMM with a keyring and cache

Unless you need an independent reference to the child object, you can release your reference to the child object as soon as you create the parent object. The remaining reference to the child object is released when the parent object is destroyed. This pattern ensures that you maintain the reference to each object only for as long as you need it, and you don't leak memory due to unreleased references.

You are only responsible for releasing references to the child objects that you create explicitly. You are not responsible for managing references to any objects that the SDK creates for you. If the SDK creates an object, such as the default CMM that the `aws_cryptosdk_caching_cmm_new_from_keyring` method adds to a session, the SDK manages the creation and destruction of the object and its references.

In the following example, when you create a session with a keyring, the session gets a reference to the keyring, and maintains that reference until the session is destroyed. If you do not need to maintain an additional reference to the keyring, you can use the `aws_cryptosdk_keyring_release` method to release the keyring object as soon as the session is created. This method decrements the reference count for the keyring. The session's reference to the keyring is released when you call `aws_cryptosdk_session_destroy` to destroy the session.

```
// The session gets a reference to the keyring.
struct aws_cryptosdk_session *session =
 aws_cryptosdk_session_new_from_keyring_2(alloc, AWS_CRYPTOSDK_ENCRYPT, keyring);

// After you create a session with a keyring, release the reference to the keyring
 object.
aws_cryptosdk_keyring_release(keyring);
```

For more complex tasks, such as reusing a keyring for multiple sessions or specifying an algorithm suite in a CMM, you might need to maintain an independent reference to the object. If so, don't call the release methods immediately. Instead, release your references when you are no longer using the objects, in addition to destroying the session.

This reference counting technique also works when you are using alternate CMMs, such as the caching CMM for data key caching. When you create a caching CMM from a cache and a keyring, the caching CMM gets a reference to both objects. Unless you need them for another task, you can release your independent references to the cache and keyring as soon as the caching CMM is created. Then, when you create a session with the caching CMM, you can release your reference to the caching CMM.

Notice that you are only responsible for releasing references to objects that you create explicitly. Objects that the methods create for you, such as the default CMM that underlies the caching CMM, are managed by the method.

```
/ Create the caching CMM from a cache and a keyring.
struct aws_cryptosdk_cmm *caching_cmm =
 aws_cryptosdk_caching_cmm_new_from_keyring(allocator, cache, kms_keyring, NULL, 60,
 AWS_TIMESTAMP_SECS);

// Release your references to the cache and the keyring.
aws_cryptosdk_materials_cache_release(cache);
aws_cryptosdk_keyring_release(kms_keyring);

// Create a session with the caching CMM.
struct aws_cryptosdk_session *session = aws_cryptosdk_session_new_from_cmm_2(allocator,
 AWS_CRYPTOSDK_ENCRYPT, caching_cmm);

// Release your references to the caching CMM.
aws_cryptosdk_cmm_release(caching_cmm);

// ...
```

```
aws_cryptosdk_session_destroy(session);
```

AWS Encryption SDK for C examples

The following examples show you how to use the AWS Encryption SDK for C to encrypt and decrypt data.

The examples in this section show how to use versions 2.0.*x* and later of the AWS Encryption SDK for C. For examples that use earlier versions, find your release in the Releases list of the aws-encryption-sdk-c repository repository on GitHub.

When you install and build the AWS Encryption SDK for C, the source code for these and other examples are included in the `examples` subdirectory, and they are compiled and built into the `build` directory. You can also find them in the examples subdirectory of the aws-encryption-sdk-c repository on GitHub.

Topics

- Encrypting and decrypting strings

Encrypting and decrypting strings

The following example shows you how to use the AWS Encryption SDK for C to encrypt and decrypt a string.

This example features the AWS KMS keyring, a type of keyring that uses an AWS KMS key in AWS Key Management Service (AWS KMS) to generate and encrypt data keys. The example includes code written in C++. The AWS Encryption SDK for C requires the AWS SDK for C++ to call AWS KMS when using AWS KMS keyrings. If you're using a keyring that doesn't interact with AWS KMS, such as a raw AES keyring, a raw RSA keyring, or a multi-keyring that doesn't include an AWS KMS keyring, the AWS SDK for C++ is not required.

For help creating an AWS KMS key, see Creating Keys in the *AWS Key Management Service Developer Guide*. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

See the complete code sample: string.cpp

Topics

- Encrypt a string
- Decrypt a string

Encrypt a string

The first part of this example uses an AWS KMS keyring with one AWS KMS key to encrypt a plaintext string.

Step 1. Load error strings.

Call the `aws_cryptosdk_load_error_strings()` method in your C or C++ code. It loads error information that is very useful for debugging.

You only need to call it once, such as in your `main` method.

```
/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();
```

Step 2: Construct the keyring.

Create an AWS KMS keyring for encryption. The keyring in this example is configured with one AWS KMS key, but you can configure an AWS KMS keyring with multiple AWS KMS keys, including AWS KMS keys in different AWS Regions and different accounts.

To identify an AWS KMS key in an encryption keyring in the AWS Encryption SDK for C, specify a key ARN or alias ARN. In a decryption keyring, you must use a key ARN. For details, see Identifying AWS KMS keys in an AWS KMS keyring.

Identifying AWS KMS keys in an AWS KMS keyring

When you create a keyring with multiple AWS KMS keys, you specify the AWS KMS key used to generate and encrypt the plaintext data key, and an optional array of additional AWS KMS keys that encrypt the same plaintext data key. In this case, you specify only the generator AWS KMS key.

Before running this code, replace the example key ARN with a valid one.

```
const char * key_arn = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

struct aws_cryptosdk_keyring *kms_keyring =
```

```
        Aws::Cryptosdk::KmsKeyring::Builder().Build(key_arn);
```

Step 3: Create a session.

Create a session using the allocator, a mode enumerator, and the keyring.

Every session requires a mode: either `AWS_CRYPTOSDK_ENCRYPT` to encrypt or `AWS_CRYPTOSDK_DECRYPT` to decrypt. To change the mode of an existing session, use the `aws_cryptosdk_session_reset` method.

After you create a session with the keyring, you can release your reference to the keyring using the method that the SDK provides. The session retains a reference to the keyring object during its lifetime. References to the keyring and session objects are released when you destroy the session. This reference counting technique helps to prevent memory leaks and to prevent the objects from being released while they are in use.

```
struct aws_cryptosdk_session *session =
       aws_cryptosdk_session_new_from_keyring_2(alloc, AWS_CRYPTOSDK_ENCRYPT,
 kms_keyring);

/* When you add the keyring to the session, release the keyring object */
aws_cryptosdk_keyring_release(kms_keyring);
```

Step 4: Set the encryption context.

An encryption context is arbitrary, non-secret additional authenticated data. When you provide an encryption context on encrypt, the AWS Encryption SDK cryptographically binds the encryption context to the ciphertext so that the same encryption context is required to decrypt the data. Using an encryption context is optional, but we recommend it as a best practice.

First, create a hash table that includes the encryption context strings.

```
/* Allocate a hash table for the encryption context */
int set_up_enc_ctx(struct aws_allocator *alloc, struct aws_hash_table *my_enc_ctx)

// Create encryption context strings
AWS_STATIC_STRING_FROM_LITERAL(enc_ctx_key1, "Example");
AWS_STATIC_STRING_FROM_LITERAL(enc_ctx_value1, "String");
AWS_STATIC_STRING_FROM_LITERAL(enc_ctx_key2, "Company");
AWS_STATIC_STRING_FROM_LITERAL(enc_ctx_value2, "MyCryptoCorp");
```

```
// Put the key-value pairs in the hash table
aws_hash_table_put(my_enc_ctx, enc_ctx_key1, (void *)enc_ctx_value1, &was_created)
aws_hash_table_put(my_enc_ctx, enc_ctx_key2, (void *)enc_ctx_value2, &was_created)
```

Get a mutable pointer to the encryption context in the session. Then, use the `aws_cryptosdk_enc_ctx_clone` function to copy the encryption context into the session. Keep the copy in `my_enc_ctx` so you can validate the value after decrypting the data.

The encryption context is part of the session, not a parameter passed to the session process function. This guarantees that the same encryption context is used for every segment of a message, even if the session process function is called multiple times to encrypt the entire message.

```
struct aws_hash_table *session_enc_ctx =
 aws_cryptosdk_session_get_enc_ctx_ptr_mut(session);

aws_cryptosdk_enc_ctx_clone(alloc, session_enc_ctx, my_enc_ctx)
```

Step 5: Encrypt the string.

To encrypt the plaintext string, use the `aws_cryptosdk_session_process_full` method with the session in encryption mode. This method, introduced in AWS Encryption SDK versions 1.9.*x* and 2.2.*x*, is designed for non-streaming encryption and decryption. To handle streaming data, call the `aws_cryptosdk_session_process` in a loop.

When encrypting, the plaintext fields are input fields; the ciphertext fields are output fields. When the processing is complete, the `ciphertext_output` field contains the encrypted message, including the actual ciphertext, encrypted data keys, and the encryption context. You can decrypt this encrypted message by using the AWS Encryption SDK for any supported programming language.

```
/* Gets the length of the plaintext that the session processed */
size_t ciphertext_len_output;
if (AWS_OP_SUCCESS != aws_cryptosdk_session_process_full(session,
                                  ciphertext_output,
                                  ciphertext_buf_sz_output,
                                  &ciphertext_len_output,
                                  plaintext_input,
                                  plaintext_len_input)) {
    aws_cryptosdk_session_destroy(session);
    return 8;
```

```
}
```

Step 6: Clean up the session.

The final step destroys the session including references to the CMM and the keyring.

If you prefer, instead of destroying the session, you can reuse the session with the same keyring and CMM to decrypt the string, or to encrypt or decrypt other messages. To use the session for decrypting, use the `aws_cryptosdk_session_reset` method to change the mode to `AWS_CRYPTOSDK_DECRYPT`.

Decrypt a string

The second part of this example decrypts an encrypted message that contains the ciphertext of the original string.

Step 1: Load error strings.

Call the `aws_cryptosdk_load_error_strings()` method in your C or C++ code. It loads error information that is very useful for debugging.

You only need to call it once, such as in your `main` method.

```
/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();
```

Step 2: Construct the keyring.

When you decrypt data in AWS KMS, you pass in the encrypted message that the encrypt API returned. The Decrypt API doesn't take an AWS KMS key as input. Instead, AWS KMS uses the same AWS KMS key to decrypt the ciphertext that it used to encrypt it. However, the AWS Encryption SDK lets you specify an AWS KMS keyring with AWS KMS keys on encrypt and decrypt.

On decrypt, you can configure a keyring with only the AWS KMS keys that you want to use to decrypt the encrypted message. For example, you might want to create a keyring with only the AWS KMS key that is used by a particular role in your organization. The AWS Encryption SDK will never use an AWS KMS key unless it appears in the decryption keyring. If the SDK can't decrypt the encrypted data keys by using the AWS KMS keys in the keyring that you provide, either because none of AWS KMS keys in the keyring were used to encrypt any of the data

keys, or because the caller doesn't have permission to use the AWS KMS keys in the keyring to decrypt, the decrypt call fails.

When you specify an AWS KMS key for a decryption keyring, you must use its key ARN. Alias ARNs are permitted only in encryption keyrings. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring.

In this example, we specify a keyring configured with the same AWS KMS key used to encrypt the string. Before running this code, replace the example key ARN with a valid one.

```
const char * key_arn = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab"

struct aws_cryptosdk_keyring *kms_keyring =
        Aws::Cryptosdk::KmsKeyring::Builder().Build(key_arn);
```

Step 3: Create a session.

Create a session using the allocator and the keyring. To configure the session for decryption, configure the session with the `AWS_CRYPTOSDK_DECRYPT` mode.

After you create a session with a keyring, you can release your reference to the keyring using the method that the SDK provides. The session retains a reference to the keyring object during its lifetime, and both the session and keyring are released when you destroy the session. This reference counting technique helps to prevent memory leaks and to prevent the objects from being released while they are in use.

```
struct aws_cryptosdk_session *session =
 aws_cryptosdk_session_new_from_keyring_2(alloc, AWS_CRYPTOSDK_DECRYPT,
 kms_keyring);

/* When you add the keyring to the session, release the keyring object */
aws_cryptosdk_keyring_release(kms_keyring);
```

Step 4: Decrypt the string.

To decrypt the string, use the `aws_cryptosdk_session_process_full` method with the session that is configured for decryption. This method, introduced in AWS Encryption SDK versions 1.9.*x* and 2.2.*x*, is designed for non-streaming encryption and decryption. To handle streaming data, call the `aws_cryptosdk_session_process` in a loop.

When decrypting, the ciphertext fields are input fields and the plaintext fields are output fields. The `ciphertext_input` field holds the encrypted message that the encrypt method returned. When the processing is complete, the `plaintext_output` field contains the plaintext (decrypted) string.

```
size_t plaintext_len_output;

if (AWS_OP_SUCCESS != aws_cryptosdk_session_process_full(session,
                                plaintext_output,
                                plaintext_buf_sz_output,
                                &plaintext_len_output,
                                ciphertext_input,
                                ciphertext_len_input)) {
    aws_cryptosdk_session_destroy(session);
    return 13;
}
```

Step 5: Verify the encryption context.

Be sure that the actual encryption context — the one that was used to decrypt the message — contains the encryption context that you provided when encrypting the message. The actual encryption context might include extra pairs, because the cryptographic materials manager (CMM) can add pairs to the provided encryption context before encrypting the message.

In the AWS Encryption SDK for C, you are not required to provide an encryption context when decrypting because the encryption context is included in the encrypted message that the SDK returns. But, before it returns the plaintext message, your decrypt function should verify that all pairs in the provided encryption context appear in the encryption context that was used to decrypt the message.

First, get a read-only pointer to the hash table in the session. This hash table contains the encryption context that was used to decrypt the message.

```
const struct aws_hash_table *session_enc_ctx =
 aws_cryptosdk_session_get_enc_ctx_ptr(session);
```

Then, loop through the encryption context in the `my_enc_ctx` hash table that you copied when encrypting. Verify that each pair in the `my_enc_ctx` hash table that was used to encrypt appears in the `session_enc_ctx` hash table that was used to decrypt. If any key is missing, or that key has a different value, stop processing and write an error message.

```
for (struct aws_hash_iter iter = aws_hash_iter_begin(my_enc_ctx); !
aws_hash_iter_done(&iter);
      aws_hash_iter_next(&iter)) {
     struct aws_hash_element *session_enc_ctx_kv_pair;
     aws_hash_table_find(session_enc_ctx, iter.element.key,
 &session_enc_ctx_kv_pair)

    if (!session_enc_ctx_kv_pair ||
        !aws_string_eq(
            (struct aws_string *)iter.element.value, (struct aws_string
 *)session_enc_ctx_kv_pair->value)) {
        fprintf(stderr, "Wrong encryption context!\n");
        abort();
    }
}
```

Step 6: Clean up the session.

After you verify the encryption context, you can destroy the session, or reuse it. If you need to reconfigure the session, use the `aws_cryptosdk_session_reset` method.

```
aws_cryptosdk_session_destroy(session);
```

AWS Encryption SDK for .NET

The AWS Encryption SDK for .NET is a client-side encryption library for developers who are writing applications in C# and other .NET programming languages. It is supported on Windows, macOS, and Linux.

> **Note**
>
> Version 4.0.0 of the AWS Encryption SDK for .NET deviates from the AWS Encryption SDK Message Specification. As a result, messages encrypted by version 4.0.0 can only be decrypted by version 4.0.0 or later of the AWS Encryption SDK for .NET. They cannot be decrypted by any other programming language implementation.
> Version 4.0.1 of the AWS Encryption SDK for .NET writes messages according to the AWS Encryption SDK Message Specification, and is interoperable with other programming language implementations. By default, version 4.0.1 can read messages encrypted by version 4.0.0. However, if you do not want to decrypt messages encrypted by version 4.0.0,

you can specify the `NetV4_0_0_RetryPolicy` property to prevent the client from reading these messages. For more information, see the v4.0.1 release notes in the aws-encryption-sdk repository on GitHub.

The AWS Encryption SDK for .NET differs from some of the other programming language implementations of the AWS Encryption SDK in the following ways:

- No support for data key caching

> **Note**
>
> Version 4.*x* of the AWS Encryption SDK for .NET supports the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.

- No support for streaming data
- No logging or stack traces from the AWS Encryption SDK for .NET
- Requires the AWS SDK for .NET

The AWS Encryption SDK for .NET includes all of the security features introduced in versions 2.0.*x* and later of other language implementations of the AWS Encryption SDK. However, if you are using the AWS Encryption SDK for .NET to decrypt data that was encrypted by a pre-2.0.*x* version another language implementation of the AWS Encryption SDK, you might need to adjust your commitment policy. For details, see How to set your commitment policy.

The AWS Encryption SDK for .NET is a product of the AWS Encryption SDK in Dafny, a formal verification language in which you write specifications, the code to implement them, and the proofs to test them. The result is a library that implements the features of the AWS Encryption SDK in a framework that assures functional correctness.

Learn More

- For examples showing how to configure options in the AWS Encryption SDK, such as specifying an alternate algorithm suite, limiting encrypted data keys, and using AWS KMS multi-Region keys, see Configuring the AWS Encryption SDK.
- For details about programming with the AWS Encryption SDK for .NET, see the `aws-encryption-sdk-net` directory of the aws-encryption-sdk repository on GitHub.

Topics

- Installing the AWS Encryption SDK for .NET
- Debugging the AWS Encryption SDK for .NET
- AWS Encryption SDK for .NET examples

Installing the AWS Encryption SDK for .NET

The AWS Encryption SDK for .NET is available as the `AWS.Cryptography.EncryptionSDK` package in NuGet. For details about installing and building the AWS Encryption SDK for .NET, see the README.md file in the `aws-encryption-sdk-net` repository.

Version 3.x

Version 3.*x* of the AWS Encryption SDK for .NET supports .NET Framework 4.5.2 – 4.8 only on Windows. It supports .NET Core 3.0+ and .NET 5.0 and later on all supported operating systems.

Version 4.x

Version 4.*x* of the AWS Encryption SDK for .NET supports .NET 6.0 and .NET Framework net48 and later.

The AWS Encryption SDK for .NET requires the SDK for .NET even if you aren't using AWS Key Management Service (AWS KMS) keys. It's installed with the NuGet package. However, unless you are using AWS KMS keys, AWS Encryption SDK for .NET does not require an AWS account, AWS credentials, or interaction with any AWS service. For help setting up an AWS account if you need it, see Using the AWS Encryption SDK with AWS KMS.

Debugging the AWS Encryption SDK for .NET

The AWS Encryption SDK for .NET does not generate any logs. Exceptions in the AWS Encryption SDK for .NET generate an exception message, but no stack traces.

To help you debug, be sure to enable logging in the SDK for .NET. The logs and error messages from the SDK for .NET can help you distinguish errors arising in the SDK for .NET from those in the AWS Encryption SDK for .NET. For help with SDK for .NET logging, see AWSLogging in the *AWS SDK for .NET Developer Guide*. (To see the topic, expand the **Open to view .NET Framework content** section.)

AWS Encryption SDK for .NET examples

The following examples show the basic coding patterns that you use when programming with the AWS Encryption SDK for .NET. Specifically, you instantiate the AWS Encryption SDK and the material providers library. Then, before calling each method, you instantiate an object that defines the input for the method. This is much like the coding pattern you use in the SDK for .NET.

For examples showing how to configure options in the AWS Encryption SDK, such as specifying an alternate algorithm suite, limiting encrypted data keys, and using AWS KMS multi-Region keys, see Configuring the AWS Encryption SDK.

For more examples of programming with the AWS Encryption SDK for .NET, see the examples in the `aws-encryption-sdk-net` directory of the `aws-encryption-sdk` repository on GitHub.

Encrypting data in the AWS Encryption SDK for .NET

This example shows the basic pattern for encrypting data. It encrypts a small file with data keys that are protected by one AWS KMS wrapping key.

Step 1: Instantiate the AWS Encryption SDK and the material providers library.

Begin by instantiating the AWS Encryption SDK and the material providers library. You'll use the methods in the AWS Encryption SDK to encrypt and decrypt data. You'll use the methods in the material providers library to create the keyrings that specify which keys protect your data.

The way you instantiate the AWS Encryption SDK and the material providers library differs between versions 3.*x* and 4.*x* of the AWS Encryption SDK for .NET. All of the following steps are the same for both version 3.*x* and 4.*x* of the AWS Encryption SDK for .NET.

Version 3.x

```
// Instantiate the AWS Encryption SDK and material providers
var encryptionSdk = AwsEncryptionSdkFactory.CreateDefaultAwsEncryptionSdk();
var materialProviders =

 AwsCryptographicMaterialProvidersFactory.CreateDefaultAwsCryptographicMaterialProviders(
```

Version 4.x

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());
```

Step 2: Create an input object for the keyring.

Each method that creates a keyring has a corresponding input object class. For example, to create the input object for the `CreateAwsKmsKeyring()` method, create an instance of the `CreateAwsKmsKeyringInput` class.

Even though the input for this keyring doesn't specify a generator key, the single KMS key specified by the `KmsKeyId` parameter is the generator key. It generates and encrypts the data key that encrypts the data.

This input object requires an AWS KMS client for the AWS Region of the KMS key. To create a AWS KMS client, instantiate the `AmazonKeyManagementServiceClient` class in the SDK for .NET. Calling the `AmazonKeyManagementServiceClient()` constructor with no parameters creates a client with the default values.

In an AWS KMS keyring used for encrypting with the AWS Encryption SDK for .NET, you can identify the KMS keys by using the key ID, key ARN, alias name, or alias ARN. In an AWS KMS keyring used for decrypting, you must use a key ARN to identify each KMS key. If you plan to reuse your encryption keyring for decrypting, use a key ARN identifier for all KMS keys.

```
string keyArn = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

// Instantiate the keyring input object
var kmsKeyringInput = new CreateAwsKmsKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    KmsKeyId = keyArn
};
```

Step 3: Create the keyring.

To create the keyring, call the keyring method with the keyring input object. This example uses the `CreateAwsKmsKeyring()` method, which takes just one KMS key.

```
var keyring = materialProviders.CreateAwsKmsKeyring(kmsKeyringInput);
```

Step 4: Define an encryption context.

An encryption context is an optional, but strongly recommended element of cryptographic operations in the AWS Encryption SDK. You can define one or more non-secret key-value pairs.

> **Note**
>
> With version 4.*x* of the AWS Encryption SDK for .NET, you can require an encryption context in all encrypt requests with the required encryption context CMM.

```
// Define the encryption context
var encryptionContext = new Dictionary<string, string>()
{
    {"purpose", "test"}
};
```

Step 5: Create the input object for encrypting.

Before calling the `Encrypt()` method, create an instance of the `EncryptInput` class.

```
string plaintext = File.ReadAllText("C:\\Documents\\CryptoTest\\TestFile.txt");

// Define the encrypt input
var encryptInput = new EncryptInput
{
    Plaintext = plaintext,
    Keyring = keyring,
    EncryptionContext = encryptionContext
};
```

Step 6: Encrypt the plaintext.

Use the `Encrypt()` method of the AWS Encryption SDK to encrypt the plaintext using the keyring you defined.

The `EncryptOutput` that the `Encrypt()` method returns has methods for getting the encrypted message (`Ciphertext`), encryption context, and algorithm suite.

```
var encryptOutput = encryptionSdk.Encrypt(encryptInput);
```

Step 7: Get the encrypted message.

The `Decrypt()` method in the AWS Encryption SDK for .NET takes the `Ciphertext` member of the `EncryptOutput` instance.

The `Ciphertext` member of the `EncryptOutput` object is the encrypted message, a portable object that includes the encrypted data, encrypted data keys, and metadata, including the encryption context. You can safely store the encrypted message for an extended time or submit it to the `Decrypt()` method to recover the plaintext.

```
var encryptedMessage = encryptOutput.Ciphertext;
```

Decrypting in strict mode in the AWS Encryption SDK for .NET

Best practices recommend that you specify the keys that you use to decrypt data, an option known as *strict mode*. The AWS Encryption SDK uses only the KMS keys that you specify in your keyring to decrypt the ciphertext. The keys in your decryption keyring must include at least one of the keys that encrypted the data.

This example shows the basic pattern of decrypting in strict mode with the AWS Encryption SDK for .NET.

Step 1: Instantiate the AWS Encryption SDK and material providers library.

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());
```

Step 2: Create the input object for your keyring.

To specify the parameters for the keyring method, create an input object. Each keyring method in the AWS Encryption SDK for .NET has a corresponding input object. Because this example uses the `CreateAwsKmsKeyring()` method to create the keyring, it instantiates the `CreateAwsKmsKeyringInput` class for the input.

In a decryption keyring, you must use a key ARN to identify KMS keys.

```
string keyArn = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

// Instantiate the keyring input object
var kmsKeyringInput = new CreateAwsKmsKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    KmsKeyId = keyArn
```

```
};
```

Step 3: Create the keyring.

To create the decryption keyring, this example uses the `CreateAwsKmsKeyring()` method and the keyring input object.

```
var keyring = materialProviders.CreateAwsKmsKeyring(kmsKeyringInput);
```

Step 4: Create the input object for decrypting.

To create the input object for the `Decrypt()` method, instantiate the `DecryptInput` class.

The `Ciphertext` parameter of the `DecryptInput()` constructor takes the `Ciphertext` member of the `EncryptOutput` object that the `Encrypt()` method returned. The `Ciphertext` property represents the encrypted message, which includes the encrypted data, encrypted data keys, and metadata that the AWS Encryption SDK needs to decrypt the message.

With version 4.*x* of the AWS Encryption SDK for .NET, you can use the optional `EncryptionContext` parameter to specify your encryption context in the `Decrypt()` method.

Use the `EncryptionContext` parameter to verify that the encryption context used on encrypt *is included* in the encryption context used to decrypt the ciphertext. The AWS Encryption SDK adds pairs to the encryption context, including the digital signature if you're using an algorithm suite with signing, such as the default algorithm suite.

```
var encryptedMessage = encryptOutput.Ciphertext;

var decryptInput = new DecryptInput
{
    Ciphertext = encryptedMessage,
    Keyring = keyring,
    EncryptionContext = encryptionContext // OPTIONAL
};
```

Step 5: Decrypt the ciphertext.

```
var decryptOutput = encryptionSdk.Decrypt(decryptInput);
```

Step 6: Verify the encryption context – Version 3.*x*

The `Decrypt()` method of version 3.*x* of the AWS Encryption SDK for .NET does not take an encryption context. It gets the encryption context values from the metadata in the encrypted message. However, before returning or using the plaintext, it's a best practice to verify that encryption context that was used to decrypt the ciphertext includes the encryption context you provided when encrypting.

Verify that the encryption context used on encrypt *is included* in the encryption context that used to decrypt the ciphertext. The AWS Encryption SDK adds pairs to the encryption context, including the digital signature if you're using an algorithm suite with signing, such as the default algorithm suite.

```
// Verify the encryption context
string contextKey = "purpose";
string contextValue = "test";

if (!decryptOutput.EncryptionContext.TryGetValue(contextKey, out var
 decryptContextValue)
    || !decryptContextValue.Equals(contextValue))
{
    throw new Exception("Encryption context does not match expected values");
}
```

Decrypting with a discovery keyring in the AWS Encryption SDK for .NET

Rather than specifying the KMS keys for decryption, you can provide a AWS KMS *discovery keyring*, which is a keyring that doesn't specify any KMS keys. A discovery keyring lets the AWS Encryption SDK decrypt the data by using whichever KMS key encrypted it, provided that the caller has decrypt permission on the key. For best practices, add a discovery filter that limits the KMS keys that can be used to those in particular AWS accounts of a specified partition.

The AWS Encryption SDK for .NET provides a basic discovery keyring that requires an AWS KMS client and a discovery multi-keyring that requires you to specify one or more AWS Regions. The client and Regions both limit the KMS keys that can be used to decrypt the encrypted message. The input objects for both keyrings take the recommended discovery filter.

The following example shows the pattern for decrypting data with an AWS KMS discovery keyring and discovery filter.

Step 1: Instantiate the AWS Encryption SDK and the material providers library.

```
// Instantiate the AWS Encryption SDK and material providers
var esdk =  new ESDK(new AwsEncryptionSdkConfig());
var mpl = new MaterialProviders(new MaterialProvidersConfig());
```

Step 2: Create the input object for the keyring.

To specify the parameters for the keyring method, create an input object. Each keyring method in the AWS Encryption SDK for .NET has a corresponding input object. Because this example uses the `CreateAwsKmsDiscoveryKeyring()` method to create the keyring, it instantiates the `CreateAwsKmsDiscoveryKeyringInput` class for the input.

```
List<string> accounts = new List<string> { "111122223333" };

var discoveryKeyringInput = new CreateAwsKmsDiscoveryKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    DiscoveryFilter = new DiscoveryFilter()
    {
        AccountIds = accounts,
        Partition = "aws"
    }
};
```

Step 3: Create the keyring.

To create the decryption keyring, this example uses the `CreateAwsKmsDiscoveryKeyring()` method and the keyring input object.

```
var discoveryKeyring =
 materialProviders.CreateAwsKmsDiscoveryKeyring(discoveryKeyringInput);
```

Step 4: Create the input object for decrypting.

To create the input object for the `Decrypt()` method, instantiate the `DecryptInput` class. The value of the `Ciphertext` parameter is the `Ciphertext` member of the `EncryptOutput` object that the `Encrypt()` method returns.

With version 4.*x* of the AWS Encryption SDK for .NET, you can use the optional `EncryptionContext` parameter to specify your encryption context in the `Decrypt()` method.

Use the `EncryptionContext` parameter to verify that the encryption context used on encrypt *is included* in the encryption context used to decrypt the ciphertext. The AWS Encryption SDK adds pairs to the encryption context, including the digital signature if you're using an algorithm suite with signing, such as the default algorithm suite.

```
var ciphertext = encryptOutput.Ciphertext;

var decryptInput = new DecryptInput
{
    Ciphertext = ciphertext,
    Keyring = discoveryKeyring,
    EncryptionContext = encryptionContext // OPTIONAL

};
var decryptOutput = encryptionSdk.Decrypt(decryptInput);
```

Step 5: Verify the encryption context – Version 3.*x*

The `Decrypt()` method of version 3.*x* of the AWS Encryption SDK for .NET does not take an encryption context on `Decrypt()`. It gets the encryption context values from the metadata in the encrypted message. However, before returning or using the plaintext, it's a best practice to verify that encryption context that was used to decrypt the ciphertext includes the encryption context you provided when encrypting.

Verify that the encryption context used on encrypt *is included* in the encryption context that was used to decrypt the ciphertext. The AWS Encryption SDK adds pairs to the encryption context, including the digital signature if you're using an algorithm suite with signing, such as the default algorithm suite.

```
// Verify the encryption context
string contextKey = "purpose";
string contextValue = "test";

if (!decryptOutput.EncryptionContext.TryGetValue(contextKey, out var
 decryptContextValue)
    || !decryptContextValue.Equals(contextValue))
{
```

```
    throw new Exception("Encryption context does not match expected values");
}
```

AWS Encryption SDK for Go

This topic explains how to install and use the AWS Encryption SDK for Go. For details about programming with the AWS Encryption SDK for Go, see go directory of the aws-encryption-sdk repository on GitHub.

The AWS Encryption SDK for Go differs from some of the other programming language implementations of the AWS Encryption SDK in the following ways:

- No support for data key caching. However, the AWS Encryption SDK for Go supports the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.
- No support for streaming data

The AWS Encryption SDK for Go includes all of the security features introduced in versions 2.0.*x* and later of other language implementations of the AWS Encryption SDK. However, if you are using the AWS Encryption SDK for Go to decrypt data that was encrypted by a pre-2.0.*x* version another language implementation of the AWS Encryption SDK, you might need to adjust your commitment policy. For details, see How to set your commitment policy.

The AWS Encryption SDK for Go is a product of the AWS Encryption SDK in Dafny, a formal verification language in which you write specifications, the code to implement them, and the proofs to test them. The result is a library that implements the features of the AWS Encryption SDK in a framework that assures functional correctness.

Learn More

- For examples showing how to configure options in the AWS Encryption SDK, such as specifying an alternate algorithm suite, limiting encrypted data keys, and using AWS KMS multi-Region keys, see Configuring the AWS Encryption SDK.
- For examples showing how to configure and use the AWS Encryption SDK for Go, see the Go examples in the aws-encryption-sdk repository on GitHub.

Topics

- Prerequisites

- Installation

Prerequisites

Before you install the AWS Encryption SDK for Go, be sure you have the following prerequisites.

A supported version of Go

Go 1.23 or later is required by AWS Encryption SDK for Go.

For more information on downloading and installing Go, see Go installation.

Installation

Install the latest version of the AWS Encryption SDK for Go. For details on installing and building the AWS Encryption SDK for Go, see the README.md in the go directory of the aws-encryption-sdk repository on GitHub.

To install the latest version

- Install the AWS Encryption SDK for Go

```
go get github.com/aws/aws-encryption-sdk/releases/go/encryption-sdk@latest
```

- Install the Cryptographic Material Providers Library (MPL)

```
go get github.com/aws/aws-cryptographic-material-providers-library/releases/go/mpl
```

AWS Encryption SDK for Java

This topic explains how to install and use the AWS Encryption SDK for Java. For details about programming with the AWS Encryption SDK for Java, see the aws-encryption-sdk-java repository on GitHub. For API documentation, see the Javadoc for the AWS Encryption SDK for Java.

Topics

- Prerequisites
- Installation
- AWS Encryption SDK for Java examples

Prerequisites

Before you install the AWS Encryption SDK for Java, be sure you have the following prerequisites.

A Java development environment

You will need Java 8 or later. On the Oracle website, go to Java SE Downloads, and then download and install the Java SE Development Kit (JDK).

If you use the Oracle JDK, you must also download and install the Java Cryptography Extension (JCE) Unlimited Strength Jurisdiction Policy Files.

Bouncy Castle

The AWS Encryption SDK for Java requires Bouncy Castle.

- AWS Encryption SDK for Java versions 1.6.1 and later use Bouncy Castle to serialize and deserialize cryptographic objects. You can use Bouncy Castle or Bouncy Castle FIPS to satisfy this requirement. For help installing and configuring Bouncy Castle FIPS, see BC FIPS Documentation, especially the **User Guides** and **Security Policy** PDFs.
- Earlier versions of the AWS Encryption SDK for Java use Bouncy Castle's cryptography API for Java. This requirement is satisfied only by non-FIPS Bouncy Castle.

If you don't have Bouncy Castle, go to Download Bouncy Castle for Java to download the provider file that corresponds to your JDK. You can also use Apache Maven to get the artifact for the standard Bouncy Castle provider (bcprov-ext-jdk15on) or the artifact for Bouncy Castle FIPS (bc-fips).

AWS SDK for Java

Version 3.*x* of the AWS Encryption SDK for Java requires the AWS SDK for Java 2.x, even if you don't use AWS KMS keyrings.

Version 2.*x* or earlier of the AWS Encryption SDK for Java does not require the AWS SDK for Java. However, the AWS SDK for Java is required to use AWS Key Management Service (AWS KMS) as a master key provider. Beginning in the AWS Encryption SDK for Java version 2.4.0, the AWS Encryption SDK for Java supports both version 1.x and 2.x of the AWS SDK for Java. AWS Encryption SDK code for the AWS SDK for Java 1.x and 2.x are interoperable. For example, you can encrypt data with AWS Encryption SDK code that supports AWS SDK for Java 1.x and decrypt it using code that supports AWS SDK for Java 2.x (or vice versa). Versions of the AWS Encryption SDK for Java earlier than 2.4.0 support only AWS SDK for Java 1.x. For information

about updating your version of the AWS Encryption SDK, see Migrating your AWS Encryption SDK.

When updating your AWS Encryption SDK for Java code from the AWS SDK for Java 1.x to AWS SDK for Java 2.x, replace references to the `AWSKMS` interface in AWS SDK for Java 1.x with references to the `KmsClient` interface in AWS SDK for Java 2.x. The AWS Encryption SDK for Java does not support the `KmsAsyncClient` interface. Also, update your code to use the AWS KMS-related objects in the `kmssdkv2` namespace, instead of the `kms` namespace.

To install the AWS SDK for Java, use Apache Maven.

- To import the entire AWS SDK for Java as a dependency, declare it in your `pom.xml` file.
- To create a dependency only for the AWS KMS module in AWS SDK for Java 1.x, follow the instructions for specifying particular modules, and set the `artifactId` to `aws-java-sdk-kms`.
- To create a dependency only for the AWS KMS module in AWS SDK for Java 2.x, follow the instructions for specifying particular modules. Set the `groupId` to `software.amazon.awssdk` and the `artifactId` to `kms`.

For more changes, see What's different between the AWS SDK for Java 1.x and 2.x in the AWS SDK for Java 2.x Developer Guide.

Java examples in the AWS Encryption SDK Developer Guide use the AWS SDK for Java 2.x.

Installation

Install the latest version of the AWS Encryption SDK for Java.

> **Note**
>
> All versions of the AWS Encryption SDK for Java earlier than 2.0.0 are in the end-of-support phase.
> You can safely update from version 2.0.*x* and later to the latest version of the AWS Encryption SDK for Java without any code or data changes. However, new security features introduced in version 2.0.*x* are not backward-compatible. To update from versions earlier than 1.7.*x* to version 2.0.*x* and later, you must first update to the latest 1.*x* version of the AWS Encryption SDK. For details, see Migrating your AWS Encryption SDK.

You can install the AWS Encryption SDK for Java in the following ways.

Manually

To install the AWS Encryption SDK for Java, clone or download the aws-encryption-sdk-java GitHub repository.

Using Apache Maven

The AWS Encryption SDK for Java is available through Apache Maven with the following dependency definition.

```
<dependency>
  <groupId>com.amazonaws</groupId>
  <artifactId>aws-encryption-sdk-java</artifactId>
  <version>3.0.0</version>
</dependency>
```

After you install the SDK, get started by looking at the example Java code in this guide and the Javadoc on GitHub.

AWS Encryption SDK for Java examples

The following examples show you how to use the AWS Encryption SDK for Java to encrypt and decrypt data. These examples show how to use version 3.*x* and later of the AWS Encryption SDK for Java. Version 3.*x* of the AWS Encryption SDK for Java requires the AWS SDK for Java 2.x. Version 3.*x* of the AWS Encryption SDK for Java replaces master key providers with keyrings. For examples that use earlier versions, find your release in the Releases list of the aws-encryption-sdk-java repository on GitHub.

Topics

- Encrypting and decrypting strings
- Encrypting and decrypting byte streams
- Encrypting and decrypting byte streams with a multi-keyring

Encrypting and decrypting strings

The following example shows you how to use version 3.*x* of the AWS Encryption SDK for Java to encrypt and decrypt strings. Before using the string, convert it into a byte array.

This example uses an AWS KMS keyring. When you encrypt with an AWS KMS keyring, you can use a key ID, key ARN, alias name, or alias ARN to identify the KMS keys. When decrypting, you must use a key ARN to identify KMS keys.

When you call the `encryptData()` method, it returns an encrypted message (`CryptoResult`) that includes the ciphertext, the encrypted data keys, and the encryption context. When you call `getResult` on the `CryptoResult` object, it returns a base-64-encoded string version of the encrypted message that you can pass to the `decryptData()` method.

Similarly, when you call `decryptData()`, the `CryptoResult` object it returns contains the plaintext message and an AWS KMS key ID. Before your application returns the plaintext, verify that the AWS KMS key ID and the encryption context in the encrypted message are the ones that you expect.

```
// Copyright Amazon.com Inc. or its affiliates. All Rights Reserved.
// SPDX-License-Identifier: Apache-2.0

package com.amazonaws.crypto.keyrings;

import com.amazonaws.encryptionsdk.AwsCrypto;
import com.amazonaws.encryptionsdk.CommitmentPolicy;
import com.amazonaws.encryptionsdk.CryptoResult;
import software.amazon.cryptography.materialproviders.IKeyring;
import software.amazon.cryptography.materialproviders.MaterialProviders;
import
 software.amazon.cryptography.materialproviders.model.CreateAwsKmsMultiKeyringInput;
import software.amazon.cryptography.materialproviders.model.MaterialProvidersConfig;

import java.nio.charset.StandardCharsets;
import java.util.Arrays;
import java.util.Collections;
import java.util.Map;

/**
 * Encrypts and then decrypts data using an AWS KMS Keyring.
 *
 * <p>Arguments:
 *
 * <ol>
 *   <li>Key ARN: For help finding the Amazon Resource Name (ARN) of your AWS KMS
 customer master
 *       key (CMK), see 'Viewing Keys' at
```

```
 *       http://docs.aws.amazon.com/kms/latest/developerguide/viewing-keys.html
 * </ol>
 */
public class BasicEncryptionKeyringExample {

  private static final byte[] EXAMPLE_DATA = "Hello
 World".getBytes(StandardCharsets.UTF_8);

  public static void main(final String[] args) {
    final String keyArn = args[0];

    encryptAndDecryptWithKeyring(keyArn);
  }

  public static void encryptAndDecryptWithKeyring(final String keyArn) {
    // 1. Instantiate the SDK
    // This builds the AwsCrypto client with the RequireEncryptRequireDecrypt
 commitment policy,
    // which means this client only encrypts using committing algorithm suites and
 enforces
    // that the client will only decrypt encrypted messages that were created with a
 committing
    // algorithm suite.
    // This is the default commitment policy if you build the client with
    // `AwsCrypto.builder().build()`
    // or `AwsCrypto.standard()`.
    final AwsCrypto crypto =
        AwsCrypto.builder()
            .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
            .build();

    // 2. Create the AWS KMS keyring.
    // This example creates a multi keyring, which automatically creates the KMS
 client.
    final MaterialProviders materialProviders =
        MaterialProviders.builder()
            .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
            .build();
    final CreateAwsKmsMultiKeyringInput keyringInput =
        CreateAwsKmsMultiKeyringInput.builder().generator(keyArn).build();
    final IKeyring kmsKeyring =
 materialProviders.CreateAwsKmsMultiKeyring(keyringInput);

    // 3. Create an encryption context
```

```
    // We recommend using an encryption context whenever possible
    // to protect integrity. This sample uses placeholder values.
    // For more information see:
    // blogs.aws.amazon.com/security/post/Tx2LZ6WBJJANTNW/How-to-Protect-the-Integrity-
of-Your-Encrypted-Data-by-Using-AWS-Key-Management
    final Map<String, String> encryptionContext =
        Collections.singletonMap("ExampleContextKey", "ExampleContextValue");

    // 4. Encrypt the data
    final CryptoResult<byte[], ?> encryptResult =
        crypto.encryptData(kmsKeyring, EXAMPLE_DATA, encryptionContext);
    final byte[] ciphertext = encryptResult.getResult();

    // 5. Decrypt the data
    final CryptoResult<byte[], ?> decryptResult =
        crypto.decryptData(
            kmsKeyring,
            ciphertext,
            // Verify that the encryption context in the result contains the
            // encryption context supplied to the encryptData method
            encryptionContext);

    // 6. Verify that the decrypted plaintext matches the original plaintext
    assert Arrays.equals(decryptResult.getResult(), EXAMPLE_DATA);
  }
}
```

Encrypting and decrypting byte streams

The following example shows you how to use the AWS Encryption SDK to encrypt and decrypt byte streams.

This example uses a Raw AES keyring.

When encrypting, this example uses the `AwsCrypto.builder() .withEncryptionAlgorithm()` method to specify an algorithm suite without digital signatures. When decrypting, to ensure that the ciphertext is unsigned, this example uses the `createUnsignedMessageDecryptingStream()` method. The `createUnsignedMessageDecryptingStream()` method, fails if it encounters a ciphertext with a digital signature.

If you're encrypting with the default algorithm suite, which includes digital signatures, use the `createDecryptingStream()` method instead, as shown in the next example.

```
// Copyright Amazon.com Inc. or its affiliates. All Rights Reserved.
// SPDX-License-Identifier: Apache-2.0

package com.amazonaws.crypto.keyrings;

import com.amazonaws.encryptionsdk.AwsCrypto;
import com.amazonaws.encryptionsdk.CommitmentPolicy;
import com.amazonaws.encryptionsdk.CryptoAlgorithm;
import com.amazonaws.encryptionsdk.CryptoInputStream;
import com.amazonaws.encryptionsdk.jce.JceMasterKey;
import com.amazonaws.util.IOUtils;
import software.amazon.cryptography.materialproviders.IKeyring;
import software.amazon.cryptography.materialproviders.MaterialProviders;
import software.amazon.cryptography.materialproviders.model.AesWrappingAlg;
import software.amazon.cryptography.materialproviders.model.CreateRawAesKeyringInput;
import software.amazon.cryptography.materialproviders.model.MaterialProvidersConfig;

import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.io.IOException;
import java.nio.ByteBuffer;
import java.security.SecureRandom;
import java.util.Collections;
import java.util.Map;
import javax.crypto.SecretKey;
import javax.crypto.spec.SecretKeySpec;


/**
 * <p>
 * Encrypts and then decrypts a file under a random key.
 *
 * <p>
 * Arguments:
 * <ol>
 * <li>Name of file containing plaintext data to encrypt
 * </ol>
 *
 * <p>
```

```
 * This program demonstrates using a standard Java {@link SecretKey} object as a {@link
 IKeyring} to
 * encrypt and decrypt streaming data.
 */
public class FileStreamingKeyringExample {
    private static String srcFile;

    public static void main(String[] args) throws IOException {
        srcFile = args[0];

        // In this example, we generate a random key. In practice,
        // you would get a key from an existing store
        SecretKey cryptoKey = retrieveEncryptionKey();

        // Create a Raw Aes Keyring using the random key and an AES-GCM encryption
 algorithm
        final MaterialProviders materialProviders = MaterialProviders.builder()
                .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
                .build();
        final CreateRawAesKeyringInput keyringInput =
 CreateRawAesKeyringInput.builder()
                .wrappingKey(ByteBuffer.wrap(cryptoKey.getEncoded()))
                .keyNamespace("Example")
                .keyName("RandomKey")
                .wrappingAlg(AesWrappingAlg.ALG_AES128_GCM_IV12_TAG16)
                .build();
        IKeyring keyring = materialProviders.CreateRawAesKeyring(keyringInput);

        // Instantiate the SDK.
        // This builds the AwsCrypto client with the RequireEncryptRequireDecrypt
 commitment policy,
        // which means this client only encrypts using committing algorithm suites and
 enforces
        // that the client will only decrypt encrypted messages that were created with
 a committing
        // algorithm suite.
        // This is the default commitment policy if you build the client with
        // `AwsCrypto.builder().build()`
        // or `AwsCrypto.standard()`.
        // This example encrypts with an algorithm suite that doesn't include signing
 for faster decryption,
        // since this use case assumes that the contexts that encrypt and decrypt are
 equally trusted.
        final AwsCrypto crypto = AwsCrypto.builder()
```

```
                .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)

.withEncryptionAlgorithm(CryptoAlgorithm.ALG_AES_256_GCM_HKDF_SHA512_COMMIT_KEY)
                .build();

        // Create an encryption context to identify the ciphertext
        Map<String, String> context = Collections.singletonMap("Example",
"FileStreaming");

        // Because the file might be too large to load into memory, we stream the data,
instead of
        //loading it all at once.
        FileInputStream in = new FileInputStream(srcFile);
        CryptoInputStream<JceMasterKey> encryptingStream =
crypto.createEncryptingStream(keyring, in, context);

        FileOutputStream out = new FileOutputStream(srcFile + ".encrypted");
        IOUtils.copy(encryptingStream, out);
        encryptingStream.close();
        out.close();

        // Decrypt the file. Verify the encryption context before returning the
plaintext.
        // Since the data was encrypted using an unsigned algorithm suite, use the
recommended
        // createUnsignedMessageDecryptingStream method, which only accepts unsigned
messages.
        in = new FileInputStream(srcFile + ".encrypted");
        CryptoInputStream<JceMasterKey> decryptingStream =
crypto.createUnsignedMessageDecryptingStream(keyring, in);
        // Does it contain the expected encryption context?
        if
(!"FileStreaming".equals(decryptingStream.getCryptoResult().getEncryptionContext().get("Exampl
{
            throw new IllegalStateException("Bad encryption context");
        }

        // Write the plaintext data to disk.
        out = new FileOutputStream(srcFile + ".decrypted");
        IOUtils.copy(decryptingStream, out);
        decryptingStream.close();
        out.close();
    }
```

```
    /**
     * In practice, this key would be saved in a secure location.
     * For this demo, we generate a new random key for each operation.
     */
    private static SecretKey retrieveEncryptionKey() {
        SecureRandom rnd = new SecureRandom();
        byte[] rawKey = new byte[16]; // 128 bits
        rnd.nextBytes(rawKey);
        return new SecretKeySpec(rawKey, "AES");
    }
}
```

Encrypting and decrypting byte streams with a multi-keyring

The following example shows you how to use the AWS Encryption SDK with a multi-keyring. When you use a multi-keyring to encrypt data, any of the wrapping keys in any of its keyrings can decrypt that data. This example uses an AWS KMS keyring and a Raw RSA keyring as the child keyrings.

This example encrypts with the default algorithm suite, which includes a digital signature. When streaming, the AWS Encryption SDK releases plaintext after integrity checks, but before it has verified the digital signature. To avoid using the plaintext until the signature is verified, this example buffers the plaintext, and writes it to disk only when decryption and verification are complete.

```
// Copyright Amazon.com Inc. or its affiliates. All Rights Reserved.
// SPDX-License-Identifier: Apache-2.0

package com.amazonaws.crypto.keyrings;

import com.amazonaws.encryptionsdk.AwsCrypto;
import com.amazonaws.encryptionsdk.CommitmentPolicy;
import com.amazonaws.encryptionsdk.CryptoOutputStream;
import com.amazonaws.util.IOUtils;
import software.amazon.cryptography.materialproviders.IKeyring;
import software.amazon.cryptography.materialproviders.MaterialProviders;
import
 software.amazon.cryptography.materialproviders.model.CreateAwsKmsMultiKeyringInput;
import software.amazon.cryptography.materialproviders.model.CreateMultiKeyringInput;
import software.amazon.cryptography.materialproviders.model.CreateRawRsaKeyringInput;
import software.amazon.cryptography.materialproviders.model.MaterialProvidersConfig;
import software.amazon.cryptography.materialproviders.model.PaddingScheme;
```

```
import java.io.ByteArrayInputStream;
import java.io.ByteArrayOutputStream;
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.nio.ByteBuffer;
import java.security.GeneralSecurityException;
import java.security.KeyPair;
import java.security.KeyPairGenerator;
import java.util.Collections;

/**
 * <p>
 * Encrypts a file using both AWS KMS Key and an asymmetric key pair.
 *
 * <p>
 * Arguments:
 * <ol>
 * <li>Key ARN: For help finding the Amazon Resource Name (ARN) of your AWS KMS key,
 *   see 'Viewing Keys' at http://docs.aws.amazon.com/kms/latest/developerguide/
viewing-keys.html
 *
 * <li>Name of file containing plaintext data to encrypt
 * </ol>
 * <p>
 * You might use AWS Key Management Service (AWS KMS) for most encryption and
 decryption operations, but
 * still want the option of decrypting your data offline independently of AWS KMS. This
 sample
 * demonstrates one way to do this.
 * <p>
 * The sample encrypts data under both an AWS KMS key and an "escrowed" RSA key pair
 * so that either key alone can decrypt it. You might commonly use the AWS KMS key for
 decryption. However,
 * at any time, you can use the private RSA key to decrypt the ciphertext independent
 of AWS KMS.
 * <p>
 * This sample uses the RawRsaKeyring to generate a RSA public-private key pair
 * and saves the key pair in memory. In practice, you would store the private key in a
 secure offline
 * location, such as an offline HSM, and distribute the public key to your development
 team.
 */
public class EscrowedEncryptKeyringExample {
    private static ByteBuffer publicEscrowKey;
```

```
    private static ByteBuffer privateEscrowKey;

    public static void main(final String[] args) throws Exception {
        // This sample generates a new random key for each operation.
        // In practice, you would distribute the public key and save the private key in
secure
        // storage.
        generateEscrowKeyPair();

        final String kmsArn = args[0];
        final String fileName = args[1];

        standardEncrypt(kmsArn, fileName);
        standardDecrypt(kmsArn, fileName);

        escrowDecrypt(fileName);
    }

    private static void standardEncrypt(final String kmsArn, final String fileName)
throws Exception {
        // Encrypt with the KMS key and the escrowed public key
        // 1. Instantiate the SDK
        // This builds the AwsCrypto client with the RequireEncryptRequireDecrypt
commitment policy,
        // which means this client only encrypts using committing algorithm suites and
enforces
        // that the client will only decrypt encrypted messages that were created with
a committing
        // algorithm suite.
        // This is the default commitment policy if you build the client with
        // `AwsCrypto.builder().build()`
        // or `AwsCrypto.standard()`.
        final AwsCrypto crypto = AwsCrypto.builder()
                .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
                .build();

        // 2. Create the AWS KMS keyring.
        // This example creates a multi keyring, which automatically creates the KMS
client.
        final MaterialProviders matProv = MaterialProviders.builder()
                .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
                .build();
        final CreateAwsKmsMultiKeyringInput keyringInput =
CreateAwsKmsMultiKeyringInput.builder()
```

```
                .generator(kmsArn)
                .build();
        IKeyring kmsKeyring = matProv.CreateAwsKmsMultiKeyring(keyringInput);

        // 3. Create the Raw Rsa Keyring with Public Key.
        final CreateRawRsaKeyringInput encryptingKeyringInput =
CreateRawRsaKeyringInput.builder()
                .keyName("Escrow")
                .keyNamespace("Escrow")
                .paddingScheme(PaddingScheme.OAEP_SHA512_MGF1)
                .publicKey(publicEscrowKey)
                .build();
        IKeyring rsaPublicKeyring =
matProv.CreateRawRsaKeyring(encryptingKeyringInput);

        // 4. Create the multi-keyring.
        final CreateMultiKeyringInput createMultiKeyringInput =
CreateMultiKeyringInput.builder()
                .generator(kmsKeyring)
                .childKeyrings(Collections.singletonList(rsaPublicKeyring))
                .build();
        IKeyring multiKeyring = matProv.CreateMultiKeyring(createMultiKeyringInput);

        // 5. Encrypt the file
        // To simplify this code example, we omit the encryption context. Production
code should always
        // use an encryption context.
        final FileInputStream in = new FileInputStream(fileName);
        final FileOutputStream out = new FileOutputStream(fileName + ".encrypted");
        final CryptoOutputStream<?> encryptingStream =
crypto.createEncryptingStream(multiKeyring, out);

        IOUtils.copy(in, encryptingStream);
        in.close();
        encryptingStream.close();
    }

    private static void standardDecrypt(final String kmsArn, final String fileName)
throws Exception {
        // Decrypt with the AWS KMS key and the escrow public key.

        // 1. Instantiate the SDK.
        // This builds the AwsCrypto client with the RequireEncryptRequireDecrypt
commitment policy,
```

```
        // which means this client only encrypts using committing algorithm suites and
enforces
        // that the client will only decrypt encrypted messages that were created with
a committing
        // algorithm suite.
        // This is the default commitment policy if you build the client with
        // `AwsCrypto.builder().build()`
        // or `AwsCrypto.standard()`.
        final AwsCrypto crypto = AwsCrypto.builder()
                .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
                .build();

        // 2. Create the AWS KMS keyring.
        // This example creates a multi keyring, which automatically creates the KMS
client.
        final MaterialProviders matProv = MaterialProviders.builder()
                .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
                .build();
        final CreateAwsKmsMultiKeyringInput keyringInput =
CreateAwsKmsMultiKeyringInput.builder()
                .generator(kmsArn)
                .build();
        IKeyring kmsKeyring = matProv.CreateAwsKmsMultiKeyring(keyringInput);

        // 3. Create the Raw Rsa Keyring with Public Key.
        final CreateRawRsaKeyringInput encryptingKeyringInput =
CreateRawRsaKeyringInput.builder()
                .keyName("Escrow")
                .keyNamespace("Escrow")
                .paddingScheme(PaddingScheme.OAEP_SHA512_MGF1)
                .publicKey(publicEscrowKey)
                .build();
        IKeyring rsaPublicKeyring =
matProv.CreateRawRsaKeyring(encryptingKeyringInput);

        // 4. Create the multi-keyring.
        final CreateMultiKeyringInput createMultiKeyringInput =
CreateMultiKeyringInput.builder()
                .generator(kmsKeyring)
                .childKeyrings(Collections.singletonList(rsaPublicKeyring))
                .build();
        IKeyring multiKeyring = matProv.CreateMultiKeyring(createMultiKeyringInput);

        // 5. Decrypt the file
```

```
        // To simplify this code example, we omit the encryption context. Production
code should always
        // use an encryption context.
        final FileInputStream in = new FileInputStream(fileName + ".encrypted");
        final FileOutputStream out = new FileOutputStream(fileName + ".decrypted");
        // Since we are using a signing algorithm suite, we avoid streaming decryption
directly to the output file,
        // to ensure that the trailing signature is verified before writing any
untrusted plaintext to disk.
        final ByteArrayOutputStream plaintextBuffer = new ByteArrayOutputStream();
        final CryptoOutputStream<?> decryptingStream =
crypto.createDecryptingStream(multiKeyring, plaintextBuffer);
        IOUtils.copy(in, decryptingStream);
        in.close();
        decryptingStream.close();
        final ByteArrayInputStream plaintextReader = new
ByteArrayInputStream(plaintextBuffer.toByteArray());
        IOUtils.copy(plaintextReader, out);
        out.close();
    }

    private static void escrowDecrypt(final String fileName) throws Exception {
        // You can decrypt the stream using only the private key.
        // This method does not call AWS KMS.

        // 1. Instantiate the SDK
        final AwsCrypto crypto = AwsCrypto.standard();

        // 2. Create the Raw Rsa Keyring with Private Key.
        final MaterialProviders matProv = MaterialProviders.builder()
                .MaterialProvidersConfig(MaterialProvidersConfig.builder().build())
                .build();
        final CreateRawRsaKeyringInput encryptingKeyringInput =
CreateRawRsaKeyringInput.builder()
                .keyName("Escrow")
                .keyNamespace("Escrow")
                .paddingScheme(PaddingScheme.OAEP_SHA512_MGF1)
                .publicKey(publicEscrowKey)
                .privateKey(privateEscrowKey)
                .build();
        IKeyring escrowPrivateKeyring =
matProv.CreateRawRsaKeyring(encryptingKeyringInput);
```

```
        // 3. Decrypt the file
        // To simplify this code example, we omit the encryption context. Production
 code should always
        // use an encryption context.
        final FileInputStream in = new FileInputStream(fileName + ".encrypted");
        final FileOutputStream out = new FileOutputStream(fileName + ".deescrowed");
        final CryptoOutputStream<?> decryptingStream =
 crypto.createDecryptingStream(escrowPrivateKeyring, out);
        IOUtils.copy(in, decryptingStream);
        in.close();
        decryptingStream.close();

    }

    private static void generateEscrowKeyPair() throws GeneralSecurityException {
        final KeyPairGenerator kg = KeyPairGenerator.getInstance("RSA");
        kg.initialize(4096); // Escrow keys should be very strong
        final KeyPair keyPair = kg.generateKeyPair();
        publicEscrowKey = RawRsaKeyringExample.getPEMPublicKey(keyPair.getPublic());
        privateEscrowKey = RawRsaKeyringExample.getPEMPrivateKey(keyPair.getPrivate());

    }
}
```

AWS Encryption SDK for JavaScript

The AWS Encryption SDK for JavaScript is designed to provide a client-side encryption library for developers who are writing web browser applications in JavaScript or web server applications in Node.js.

Like all implementations of the AWS Encryption SDK, the AWS Encryption SDK for JavaScript offers advanced data protection features. These include envelope encryption, additional authenticated data (AAD), and secure, authenticated, symmetric key algorithm suites, such as 256-bit AES-GCM with key derivation and signing.

All language-specific implementations of the AWS Encryption SDK are designed to be interoperable, subject to the constraints of the language. For details about language constraints for JavaScript, see the section called “Compatibility”.

Learn More

- For details about programming with the AWS Encryption SDK for JavaScript, see the aws-encryption-sdk-javascript repository on GitHub.
- For programming examples, see the section called "Examples" and the example-browser and example-node modules in the aws-encryption-sdk-javascript repository.
- For a real-world example of using the AWS Encryption SDK for JavaScript to encrypt data in a web application, see How to enable encryption in a browser with the AWS Encryption SDK for JavaScript and Node.js in the AWS Security Blog.

Topics

- Compatibility of the AWS Encryption SDK for JavaScript
- Installing the AWS Encryption SDK for JavaScript
- Modules in the AWS Encryption SDK for JavaScript
- AWS Encryption SDK for JavaScript examples

Compatibility of the AWS Encryption SDK for JavaScript

The AWS Encryption SDK for JavaScript is designed to be interoperable with other language implementations of the AWS Encryption SDK. In most cases, you can encrypt data with the AWS Encryption SDK for JavaScript and decrypt it with any other language implementation, including the AWS Encryption SDK Command Line Interface. And you can use the AWS Encryption SDK for JavaScript to decrypt encrypted messages produced by other language implementations of the AWS Encryption SDK.

However, when you use the AWS Encryption SDK for JavaScript, you need to be aware of some compatibility issues in the JavaScript language implementation and in web browsers.

Also, when using different language implementations, be sure to configure compatible master key providers, master keys, and keyrings. For details, see Keyring compatibility.

AWS Encryption SDK for JavaScript compatibility

The JavaScript implementation of the AWS Encryption SDK differs from other language implementations in the following ways:

- The encrypt operation of the AWS Encryption SDK for JavaScript doesn't return nonframed ciphertext. However, the AWS Encryption SDK for JavaScript will decrypt framed and nonframed ciphertext returned by other language implementations of the AWS Encryption SDK.

- Beginning in Node.js version 12.9.0, Node.js supports the following RSA key wrapping options:
  - OAEP with SHA1, SHA256, SHA384, or SHA512
  - OAEP with SHA1 and MGF1 with SHA1
  - PKCS1v15
- Before version 12.9.0, Node.js supports only the following RSA key wrapping options:
  - OAEP with SHA1 and MGF1 with SHA1
  - PKCS1v15

Browser compatibility

Some web browsers don't support basic cryptographic operations that the AWS Encryption SDK for JavaScript requires. You can compensate for some of the missing operations by configuring a fallback for the WebCrypto API that the browser implements.

Web browser limitations

The following limitations are common to all web browsers:

- The WebCrypto API doesn't support PKCS1v15 key wrapping.
- Browsers don't support 192-bit keys.

Required cryptographic operations

The AWS Encryption SDK for JavaScript requires the following operations in web browsers. If a browser doesn't support these operations, it's incompatible with the AWS Encryption SDK for JavaScript.

- The browser must include `crypto.getRandomValues()`, which is a method for generating cryptographically random values. For information about the web browser versions that support `crypto.getRandomValues()`, see Can I Use crypto.getRandomValues()?.

Required fallback

The AWS Encryption SDK for JavaScript requires the following libraries and operations in web browsers. If you support a web browser that doesn't fulfill these requirements, you must configure a fallback. Otherwise, attempts to use the AWS Encryption SDK for JavaScript with the browser will fail.

- The WebCrypto API, which performs basic cryptographic operations in web applications, isn't available for all browsers. For information about the web browser versions that support web cryptography, see Can I Use Web Cryptography?.
- Modern versions of the Safari web browser don't support AES-GCM encryption of zero bytes, which the AWS Encryption SDK requires. If the browser implements the WebCrypto API, but can't use AES-GCM to encrypt zero bytes, the AWS Encryption SDK for JavaScript uses the fallback library only for zero-byte encryption. It uses the WebCrypto API for all other operations.

To configure a fallback for either limitation, add the following statements to your code. In the configureFallback function, specify a library that supports the missing features. The following example uses the Microsoft Research JavaScript Cryptography Library (`msrcrypto`), but you can replace it with a compatible library. For a complete example, see fallback.ts.

```
import { configureFallback } from '@aws-crypto/client-browser'
configureFallback(msrCrypto)
```

Installing the AWS Encryption SDK for JavaScript

The AWS Encryption SDK for JavaScript consists of a collection of interdependent modules. Several of the modules are just collections of modules that are designed to work together. Some modules are designed to work independently. A few modules are required for all implementations; a few others are required only for special cases. For information about the modules in the AWS Encryption SDK for JavaScript, see Modules in the AWS Encryption SDK for JavaScript and the `README.md` file in each of the modules in the aws-encryption-sdk-javascript repository on GitHub.

> **Note**
>
> All versions of the AWS Encryption SDK for JavaScript earlier than 2.0.0 are in the end-of-support phase.
> You can safely update from version 2.0.*x* and later to the latest version of the AWS Encryption SDK for JavaScript without any code or data changes. However, new security features introduced in version 2.0.*x* are not backward-compatible. To update from versions earlier than 1.7.*x* to version 2.0.*x* and later, you must first update to the latest 1.*x* version of the AWS Encryption SDK for JavaScript. For details, see Migrating your AWS Encryption SDK.

To install the modules, use the npm package manager.

For example, to install the `client-node` module, which includes all of the modules you need to program with the AWS Encryption SDK for JavaScript in Node.js, use the following command.

```
npm install @aws-crypto/client-node
```

To install the `client-browser` module, which includes all of the modules you need to program with the AWS Encryption SDK for JavaScript in the browser, use the following command.

```
npm install @aws-crypto/client-browser
```

For working examples of how to use the AWS Encryption SDK for JavaScript, see the examples in the `example-node` and `example-browser` modules in the aws-encryption-sdk-javascript repository on GitHub.

Modules in the AWS Encryption SDK for JavaScript

The modules in the AWS Encryption SDK for JavaScript make it easy to install the code that you need for your projects.

Modules for JavaScript Node.js

client-node

Includes all of the modules you need to program with the AWS Encryption SDK for JavaScript in Node.js.

caching-materials-manager-node

Exports functions that support the data key caching feature in the AWS Encryption SDK for JavaScript in Node.js.

decrypt-node

Exports functions that decrypt and verify encrypted messages representing data and data streams. Included in the `client-node` module.

encrypt-node

Exports functions that encrypt and sign different types of data. Included in the `client-node` module.

example-node

Exports working examples of programming with the AWS Encryption SDK for JavaScript in Node.js. Includes example of different types of keyrings and different types of data.

hkdf-node

Exports an HMAC-based Key Derivation Function (HKDF) that the AWS Encryption SDK for JavaScript in Node.js uses in particular algorithm suites. The AWS Encryption SDK for JavaScript in the browser uses the native HKDF function in the WebCrypto API.

integration-node

Defines tests that verify that the AWS Encryption SDK for JavaScript in Node.js is compatible with other language implementations of the AWS Encryption SDK.

kms-keyring-node

Exports functions that support AWS KMS keyrings in Node.js.

raw-aes-keyring-node

Exports functions that support Raw AES keyrings in Node.js.

raw-rsa-keyring-node

Exports functions that support Raw RSA keyrings in Node.js.

Modules for JavaScript Browser

client-browser

Includes all of the modules you need to program with the AWS Encryption SDK for JavaScript in the browser.

caching-materials-manager-browser

Exports functions that support the data key caching feature for JavaScript in the browser.

decrypt-browser

Exports functions that decrypt and verify encrypted messages representing data and data streams.

encrypt-browser

Exports functions that encrypt and sign different types of data.

example-browser

Working examples of programming with the AWS Encryption SDK for JavaScript in the browser. Includes examples of different types of keyrings and different types of data.

integration-browser

Defines tests that verify that the AWS Encryption SDK for JavaScript in the browser is compatible with other language implementations of the AWS Encryption SDK.

kms-keyring-browser

Exports functions that support AWS KMS keyrings in the browser.

raw-aes-keyring-browser

Exports functions that support Raw AES keyrings in the browser.

raw-rsa-keyring-browser

Exports functions that support Raw RSA keyrings in the browser.

Modules for all implementations

cache-material

Supports the data key caching feature. Provides code for assembling the cryptographic materials that are cached with each data key.

kms-keyring

Exports functions that support KMS keyrings.

material-management

Implements the cryptographic materials manager (CMM).

raw-keyring

Exports functions required for raw AES and RSA keyrings.

serialize

Exports functions that the SDK uses to serialize its output.

web-crypto-backend

Exports functions that use the WebCrypto API in the AWS Encryption SDK for JavaScript in the browser.

AWS Encryption SDK for JavaScript examples

The following examples show you how to use the AWS Encryption SDK for JavaScript to encrypt and decrypt data.

You can find more examples of using the AWS Encryption SDK for JavaScript in the example-node and example-browser modules in the aws-encryption-sdk-javascript repository on GitHub. These example modules are not installed when you install the `client-browser` or `client-node` modules.

See the complete code samples: Node: kms_simple.ts, Browser: kms_simple.ts

Topics

- Encrypting data with an AWS KMS keyring
- Decrypting data with an AWS KMS keyring

Encrypting data with an AWS KMS keyring

The following example shows you how to use the AWS Encryption SDK for JavaScript to encrypt and decrypt a short string or byte array.

This example features an AWS KMS keyring, a type of keyring that uses an AWS KMS key to generate and encrypt data keys. For help creating an AWS KMS key, see Creating Keys in the *AWS Key Management Service Developer Guide*. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring

Step 1: Set the commitment policy.

> Beginning in version 1.7.*x* of the AWS Encryption SDK for JavaScript, you can set the commitment policy when you call the new `buildClient` function that instantiates an AWS Encryption SDK client. The `buildClient` function takes an enumerated value that represents your commitment policy. It returns updated `encrypt` and `decrypt` functions that enforce your commitment policy when you encrypt and decrypt.
>
> The following examples use the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called “Limiting encrypted data keys”.

JavaScript Browser

```
import {
  KmsKeyringBrowser,
  KMS,
  getClient,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-browser'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)
```

JavaScript Node.js

```
import {
  KmsKeyringNode,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)
```

Step 2: Construct the keyring.

Create an AWS KMS keyring for encryption.

When encrypting with an AWS KMS keyring, you must specify a *generator key*, that is, an AWS KMS key that is used to generate the plaintext data key and encrypt it. You can also specify zero or more *additional keys* that encrypt the same plaintext data key. The keyring returns the plaintext data key and one encrypted copy of that data key for each AWS KMS key in the keyring, including the generator key. To decrypt the data, you need to decrypt any one of the encrypted data keys.

To specify the AWS KMS keys for an encryption keyring in the AWS Encryption SDK for JavaScript, you can use any supported AWS KMS key identifier. This example uses a generator key, which is identified by its alias ARN, and one additional key, which is identified by a key ARN.

> **Note**
>
> If you plan to reuse your AWS KMS keyring for decrypting, you must use key ARNs to identify the AWS KMS keys in the keyring.

Before running this code, replace the example AWS KMS key identifiers with valid identifiers. You must have the permissions required to use the AWS KMS keys in the keyring.

JavaScript Browser

Begin by providing your credentials to the browser. The AWS Encryption SDK for JavaScript examples use the webpack.DefinePlugin, which replaces the credential constants with your actual credentials. But you can use any method to provide your credentials. Then, use the credentials to create an AWS KMS client.

```
declare const credentials: {accessKeyId: string, secretAccessKey:string,
 sessionToken:string }

const clientProvider = getClient(KMS, {
  credentials: {
    accessKeyId,
    secretAccessKey,
    sessionToken
  }
})
```

Next, specify the AWS KMS keys for the generator key and additional key. Then, create an AWS KMS keyring using the AWS KMS client and the AWS KMS keys.

```
const generatorKeyId = 'arn:aws:kms:us-west-2:111122223333:alias/EncryptDecrypt'
const keyIds = ['arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab']

const keyring = new KmsKeyringBrowser({ clientProvider, generatorKeyId, keyIds })
```

JavaScript Node.js

```
const generatorKeyId = 'arn:aws:kms:us-west-2:111122223333:alias/EncryptDecrypt'
const keyIds = ['arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab']
```

```
const keyring = new KmsKeyringNode({ generatorKeyId, keyIds })
```

Step 3: Set the encryption context.

An encryption context is arbitrary, non-secret additional authenticated data. When you provide an encryption context on encrypt, the AWS Encryption SDK cryptographically binds the encryption context to the ciphertext so that the same encryption context is required to decrypt the data. Using an encryption context is optional, but we recommend it as a best practice.

Create a simple object that includes the encryption context pairs. The key and value in each pair must be a string.

JavaScript Browser

```
const context = {
  stage: 'demo',
  purpose: 'simple demonstration app',
  origin: 'us-west-2'
}
```

JavaScript Node.js

```
const context = {
  stage: 'demo',
  purpose: 'simple demonstration app',
  origin: 'us-west-2'
}
```

Step 4: Encrypt the data.

To encrypt the plaintext data, call the `encrypt` function. Pass in the AWS KMS keyring, the plaintext data, and the encryption context.

The `encrypt` function returns an encrypted message (`result`) that contains the encrypted data, the encrypted data keys, and important metadata, including the encryption context and signature.

You can decrypt this encrypted message by using the AWS Encryption SDK for any supported programming language.

JavaScript Browser

```
const plaintext = new Uint8Array([1, 2, 3, 4, 5])

const { result } = await encrypt(keyring, plaintext, { encryptionContext:
 context })
```

JavaScript Node.js

```
const plaintext = 'asdf'

const { result } = await encrypt(keyring, plaintext, { encryptionContext:
 context })
```

Decrypting data with an AWS KMS keyring

You can use the AWS Encryption SDK for JavaScript to decrypt the encrypted message and recover the original data.

In this example, we decrypt the data that we encrypted in the the section called "Encrypting data with an AWS KMS keyring" example.

Step 1: Set the commitment policy.

Beginning in version 1.7.*x* of the AWS Encryption SDK for JavaScript, you can set the commitment policy when you call the new `buildClient` function that instantiates an AWS Encryption SDK client. The `buildClient` function takes an enumerated value that represents your commitment policy. It returns updated `encrypt` and `decrypt` functions that enforce your commitment policy when you encrypt and decrypt.

The following examples use the `buildClient` function to specify the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. You can also use the `buildClient` to limit the number of encrypted data keys in an encrypted message. For more information, see the section called "Limiting encrypted data keys".

JavaScript Browser

```
import {
  KmsKeyringBrowser,
  KMS,
  getClient,
```

```
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-browser'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)
```

JavaScript Node.js

```
import {
  KmsKeyringNode,
  buildClient,
  CommitmentPolicy,
} from '@aws-crypto/client-node'

const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)
```

Step 2: Construct the keyring.

To decrypt the data, pass in the encrypted message (`result`) that the `encrypt` function returned. The encrypted message includes the encrypted data, the encrypted data keys, and important metadata, including the encryption context and signature.

You must also specify an AWS KMS keyring when decrypting. You can use the same keyring that was used to encrypt the data or a different keyring. To succeed, at least one AWS KMS key in the decryption keyring must be able to decrypt one of the encrypted data keys in the encrypted message. Because no data keys are generated, you do not need to specify a generator key in a decryption keyring. If you do, the generator key and additional keys are treated the same way.

To specify an AWS KMS key for a decryption keyring in the AWS Encryption SDK for JavaScript, you must use the key ARN. Otherwise, the AWS KMS key is not recognized. For help identifying the AWS KMS keys in an AWS KMS keyring, see Identifying AWS KMS keys in an AWS KMS keyring

> **Note**
>
> If you use the same keyring for encrypting and decrypting, use key ARNs to identify the AWS KMS keys in the keyring.

In this example, we create a keyring that includes only one of the AWS KMS keys in the encryption keyring. Before running this code, replace the example key ARN with a valid one. You must have `kms:Decrypt` permission on the AWS KMS key.

JavaScript Browser

Begin by providing your credentials to the browser. The AWS Encryption SDK for JavaScript examples use the webpack.DefinePlugin, which replaces the credential constants with your actual credentials. But you can use any method to provide your credentials. Then, use the credentials to create an AWS KMS client.

```
declare const credentials: {accessKeyId: string, secretAccessKey:string,
 sessionToken:string }

const clientProvider = getClient(KMS, {
  credentials: {
    accessKeyId,
    secretAccessKey,
    sessionToken
  }
})
```

Next, create an AWS KMS keyring using the AWS KMS client. This example uses just one of the AWS KMS keys from the encryption keyring.

```
const keyIds = ['arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab']

const keyring = new KmsKeyringBrowser({ clientProvider, keyIds })
```

JavaScript Node.js

```
const keyIds = ['arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab']

const keyring = new KmsKeyringNode({ keyIds })
```

Step 3: Decrypt the data.

Next, call the `decrypt` function. Pass in the decryption keyring that you just created (`keyring`) and the encrypted message that the `encrypt` function returned (`result`). The AWS Encryption

SDK uses the keyring to decrypt one of the encrypted data keys. Then it uses the plaintext data key to decrypt the data.

If the call succeeds, the `plaintext` field contains the plaintext (decrypted) data. The `messageHeader` field contains metadata about the decryption process, including the encryption context that was used to decrypt the data.

JavaScript Browser

```
const { plaintext, messageHeader } = await decrypt(keyring, result)
```

JavaScript Node.js

```
const { plaintext, messageHeader } = await decrypt(keyring, result)
```

Step 4: Verify the encryption context.

The encryption context that was used to decrypt the data is included in the message header (`messageHeader`) that the `decrypt` function returns. Before your application returns the plaintext data, verify that the encryption context that you provided when encrypting is included in the encryption context that was used when decrypting. A mismatch might indicate that the data was tampered with, or that you didn't decrypt the right ciphertext.

When verifying the encryption context, do not require an exact match. When you use an encryption algorithm with signing, the cryptographic materials manager (CMM) adds the public signing key to the encryption context before encrypting the message. But all of the encryption context pairs that you submitted should be included in the encryption context that was returned.

First, get the encryption context from the message header. Then, verify that each key-value pair in the original encryption context (`context`) matches a key-value pair in the returned encryption context (`encryptionContext`).

JavaScript Browser

```
const { encryptionContext } = messageHeader

Object
  .entries(context)
  .forEach(([key, value]) => {
```

```
    if (encryptionContext[key] !== value) throw new Error('Encryption Context
 does not match expected values')
})
```

JavaScript Node.js

```
const { encryptionContext } = messageHeader

Object
  .entries(context)
  .forEach(([key, value]) => {
    if (encryptionContext[key] !== value) throw new Error('Encryption Context
 does not match expected values')
})
```

If the encryption context check succeeds, you can return the plaintext data.

AWS Encryption SDK for Python

This topic explains how to install and use the AWS Encryption SDK for Python. For details about programming with the AWS Encryption SDK for Python, see the aws-encryption-sdk-python repository on GitHub. For API documentation, see Read the Docs.

Topics

- Prerequisites
- Installation
- AWS Encryption SDK for Python example code

Prerequisites

Before you install the AWS Encryption SDK for Python, be sure you have the following prerequisites.

A supported version of Python

Python 3.8 or later is required by the AWS Encryption SDK for Python versions 3.2.0 and later.

> **Note**
>
> The AWS Cryptographic Material Providers Library (MPL) is an optional dependency for the AWS Encryption SDK for Python introduced in version 4.*x*. If you intend to install the MPL, you must use Python 3.11 or later.

Earlier versions of the AWS Encryption SDK support Python 2.7 and Python 3.4 and later, but we recommend that you use the latest version of the AWS Encryption SDK.

To download Python, see Python downloads.

The pip installation tool for Python

`pip` is included in Python 3.6 and later versions, although you might want to upgrade it. For more information about upgrading or installing `pip`, see Installation in the `pip` documentation.

Installation

Install the latest version of the AWS Encryption SDK for Python.

> **Note**
>
> All versions of the AWS Encryption SDK for Python earlier than 3.0.0 are in the end-of-support phase.
> You can safely update from version 2.0.*x* and later to the latest version of the AWS Encryption SDK without any code or data changes. However, new security features introduced in version 2.0.*x* are not backward-compatible. To update from versions earlier than 1.7.*x* to version 2.0.*x* and later, you must first update to the latest 1.*x* version of the AWS Encryption SDK. For details, see Migrating your AWS Encryption SDK.

Use `pip` to install the AWS Encryption SDK for Python, as shown in the following examples.

To install the latest version

```
pip install "aws-encryption-sdk[MPL]"
```

The `[MPL]` suffix installs the AWS Cryptographic Material Providers Library (MPL). The MPL contains constructs for encrypting and decrypting your data. The MPL is an optional dependency for the AWS Encryption SDK for Python introduced in version 4.*x*. We highly recommend installing the MPL. However, if you do not intend to use the MPL, you can omit the `[MPL]` suffix.

For more details about using pip to install and upgrade packages, see Installing Packages.

The AWS Encryption SDK for Python requires the cryptography library (pyca/cryptography) on all platforms. All versions of `pip` automatically install and build the `cryptography` library on Windows. `pip` 8.1 and later automatically installs and builds `cryptography` on Linux. If you are using an earlier version of `pip` and your Linux environment doesn't have the tools needed to build the `cryptography` library, you need to install them. For more information, see Building Cryptography on Linux.

Versions 1.10.0 and 2.5.0 of the AWS Encryption SDK for Python pin the cryptography dependency between 2.5.0 and 3.3.2. Other versions of the AWS Encryption SDK for Python install the latest version of cryptography. If you require a version of cryptography later than 3.3.2, we recommend that you use the latest major version of the AWS Encryption SDK for Python.

For the latest development version of the AWS Encryption SDK for Python, go to the aws-encryption-sdk-python repository in GitHub.

After you install the AWS Encryption SDK for Python, get started by looking at the Python example code in this guide.

AWS Encryption SDK for Python example code

The following examples show you how to use the AWS Encryption SDK for Python to encrypt and decrypt data.

The examples in this section show how to use version 4.*x* of the AWS Encryption SDK for Python with the optional Cryptographic Material Providers Library dependency (`aws-cryptographic-material-providers`). To view examples that use earlier versions, or installations without the material providers library (MPL), find your release in the Releases list of the aws-encryption-sdk-python repository on GitHub.

When you use version 4.*x* of the AWS Encryption SDK for Python with the MPL, it uses keyrings to perform envelope encryption. The AWS Encryption SDK provides keyrings that are compatible with

the master key providers that you used in previous versions. For more information, see the section called "Keyring compatibility". For examples on migrating from master key providers to keyrings, see Migration Examples in the `aws-encryption-sdk-python` repository on GitHub;

Topics

- Encrypting and decrypting strings
- Encrypting and decrypting byte streams

Encrypting and decrypting strings

The following example shows you how to use the AWS Encryption SDK to encrypt and decrypt strings. This example uses an AWS KMS keyring with a symmetric encryption KMS key.

This example instantiates the AWS Encryption SDK client with the default commitment policy, `REQUIRE_ENCRYPT_REQUIRE_DECRYPT`. For more information, see the section called "Setting your commitment policy".

```
# Copyright Amazon.com Inc. or its affiliates. All Rights Reserved.
# SPDX-License-Identifier: Apache-2.0
"""
This example sets up the KMS Keyring

The AWS KMS keyring uses symmetric encryption KMS keys to generate, encrypt and
decrypt data keys. This example creates a KMS Keyring and then encrypts a custom input
 EXAMPLE_DATA
with an encryption context. This example also includes some sanity checks for
 demonstration:
1. Ciphertext and plaintext data are not the same
2. Encryption context is correct in the decrypted message header
3. Decrypted plaintext value matches EXAMPLE_DATA
These sanity checks are for demonstration in the example only. You do not need these in
 your code.

AWS KMS keyrings can be used independently or in a multi-keyring with other keyrings
of the same or a different type.

"""

import boto3
from aws_cryptographic_material_providers.mpl import AwsCryptographicMaterialProviders
from aws_cryptographic_material_providers.mpl.config import MaterialProvidersConfig
```

```
from aws_cryptographic_material_providers.mpl.models import CreateAwsKmsKeyringInput
from aws_cryptographic_material_providers.mpl.references import IKeyring
from typing import Dict  # noqa pylint: disable=wrong-import-order

import aws_encryption_sdk
from aws_encryption_sdk import CommitmentPolicy

EXAMPLE_DATA: bytes = b"Hello World"


def encrypt_and_decrypt_with_keyring(
    kms_key_id: str
):
    """Demonstrate an encrypt/decrypt cycle using an AWS KMS keyring.

    Usage: encrypt_and_decrypt_with_keyring(kms_key_id)
    :param kms_key_id: KMS Key identifier for the KMS key you want to use for
 encryption and
    decryption of your data keys.
    :type kms_key_id: string

    """
    # 1. Instantiate the encryption SDK client.
    # This builds the client with the REQUIRE_ENCRYPT_REQUIRE_DECRYPT commitment
 policy,
    # which enforces that this client only encrypts using committing algorithm suites
 and enforces
    # that this client will only decrypt encrypted messages that were created with a
 committing
    # algorithm suite.
    # This is the default commitment policy if you were to build the client as
    # `client = aws_encryption_sdk.EncryptionSDKClient()`.
    client = aws_encryption_sdk.EncryptionSDKClient(
        commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
    )

    # 2. Create a boto3 client for KMS.
    kms_client = boto3.client('kms', region_name="us-west-2")

    # 3. Optional: create encryption context.
    # Remember that your encryption context is NOT SECRET.
    encryption_context: Dict[str, str] = {
        "encryption": "context",
        "is not": "secret",
```

```
        "but adds": "useful metadata",
        "that can help you": "be confident that",
        "the data you are handling": "is what you think it is",
    }

    # 4. Create your keyring
    mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
        config=MaterialProvidersConfig()
    )

    keyring_input: CreateAwsKmsKeyringInput = CreateAwsKmsKeyringInput(
        kms_key_id=kms_key_id,
        kms_client=kms_client
    )

    kms_keyring: IKeyring = mat_prov.create_aws_kms_keyring(
        input=keyring_input
    )

    # 5. Encrypt the data with the encryptionContext.
    ciphertext, _ = client.encrypt(
        source=EXAMPLE_DATA,
        keyring=kms_keyring,
        encryption_context=encryption_context
    )

    # 6. Demonstrate that the ciphertext and plaintext are different.
    # (This is an example for demonstration; you do not need to do this in your own
 code.)
    assert ciphertext != EXAMPLE_DATA, \
        "Ciphertext and plaintext data are the same. Invalid encryption"

    # 7. Decrypt your encrypted data using the same keyring you used on encrypt.
    plaintext_bytes, _ = client.decrypt(
        source=ciphertext,
        keyring=kms_keyring,
        # Provide the encryption context that was supplied to the encrypt method
        encryption_context=encryption_context,
    )

    # 8. Demonstrate that the decrypted plaintext is identical to the original
 plaintext.
    # (This is an example for demonstration; you do not need to do this in your own
 code.)
```

```
    assert plaintext_bytes == EXAMPLE_DATA, \
        "Decrypted plaintext should be identical to the original plaintext. Invalid
 decryption"
```

Encrypting and decrypting byte streams

The following example shows you how to use the AWS Encryption SDK to encrypt and decrypt byte streams. This example uses a Raw AES keyring.

This example instantiates the AWS Encryption SDK client with the default commitment policy, REQUIRE_ENCRYPT_REQUIRE_DECRYPT. For more information, see the section called "Setting your commitment policy".

```
# Copyright Amazon.com Inc. or its affiliates. All Rights Reserved.
# SPDX-License-Identifier: Apache-2.0
"""
This example demonstrates file streaming for encryption and decryption.

File streaming is useful when the plaintext or ciphertext file/data is too large to
 load into
memory. Therefore, the AWS Encryption SDK allows users to stream the data, instead of
 loading it
all at once in memory. In this example, we demonstrate file streaming for encryption
 and decryption
using a Raw AES keyring. However, you can use any keyring with streaming.

This example creates a Raw AES Keyring and then encrypts an input stream from the file
`plaintext_filename` with an encryption context to an output (encrypted) file
 `ciphertext_filename`.
It then decrypts the ciphertext from `ciphertext_filename` to a new file
 `decrypted_filename`.
This example also includes some sanity checks for demonstration:
1. Ciphertext and plaintext data are not the same
2. Encryption context is correct in the decrypted message header
3. Decrypted plaintext value matches EXAMPLE_DATA
These sanity checks are for demonstration in the example only. You do not need these in
 your code.

See raw_aes_keyring_example.py in the same directory for another raw AES keyring
 example
in the AWS Encryption SDK for Python.
"""
import filecmp
```

```
import secrets

from aws_cryptographic_material_providers.mpl import AwsCryptographicMaterialProviders
from aws_cryptographic_material_providers.mpl.config import MaterialProvidersConfig
from aws_cryptographic_material_providers.mpl.models import AesWrappingAlg,
 CreateRawAesKeyringInput
from aws_cryptographic_material_providers.mpl.references import IKeyring
from typing import Dict  # noqa pylint: disable=wrong-import-order

import aws_encryption_sdk
from aws_encryption_sdk import CommitmentPolicy


def encrypt_and_decrypt_with_keyring(
    plaintext_filename: str,
    ciphertext_filename: str,
    decrypted_filename: str
):
    """Demonstrate a streaming encrypt/decrypt cycle.

    Usage: encrypt_and_decrypt_with_keyring(plaintext_filename
                                            ciphertext_filename
                                            decrypted_filename)
    :param plaintext_filename: filename of the plaintext data
    :type plaintext_filename: string
    :param ciphertext_filename: filename of the ciphertext data
    :type ciphertext_filename: string
    :param decrypted_filename: filename of the decrypted data
    :type decrypted_filename: string
    """
    # 1. Instantiate the encryption SDK client.
    # This builds the client with the REQUIRE_ENCRYPT_REQUIRE_DECRYPT commitment
 policy,
    # which enforces that this client only encrypts using committing algorithm suites
 and enforces
    # that this client will only decrypt encrypted messages that were created with a
 committing
    # algorithm suite.
    # This is the default commitment policy if you were to build the client as
    # `client = aws_encryption_sdk.EncryptionSDKClient()`.
    client = aws_encryption_sdk.EncryptionSDKClient(
        commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
    )
```

```
    # 2. The key namespace and key name are defined by you.
    # and are used by the Raw AES keyring to determine
    # whether it should attempt to decrypt an encrypted data key.
    key_name_space = "Some managed raw keys"
    key_name = "My 256-bit AES wrapping key"

    # 3. Optional: create encryption context.
    # Remember that your encryption context is NOT SECRET.
    encryption_context: Dict[str, str] = {
        "encryption": "context",
        "is not": "secret",
        "but adds": "useful metadata",
        "that can help you": "be confident that",
        "the data you are handling": "is what you think it is",
    }

    # 4. Generate a 256-bit AES key to use with your keyring.
    # In practice, you should get this key from a secure key management system such as
an HSM.

    # Here, the input to secrets.token_bytes() = 32 bytes = 256 bits
    static_key = secrets.token_bytes(32)

    # 5. Create a Raw AES keyring
    # We choose to use a raw AES keyring, but any keyring can be used with streaming.
    mat_prov: AwsCryptographicMaterialProviders = AwsCryptographicMaterialProviders(
        config=MaterialProvidersConfig()
    )

    keyring_input: CreateRawAesKeyringInput = CreateRawAesKeyringInput(
        key_namespace=key_name_space,
        key_name=key_name,
        wrapping_key=static_key,
        wrapping_alg=AesWrappingAlg.ALG_AES256_GCM_IV12_TAG16
    )

    raw_aes_keyring: IKeyring = mat_prov.create_raw_aes_keyring(
        input=keyring_input
    )

    # 6. Encrypt the data stream with the encryptionContext
    with open(plaintext_filename, 'rb') as pt_file, open(ciphertext_filename, 'wb') as
ct_file:
        with client.stream(
```

```
            mode='e',
            source=pt_file,
            keyring=raw_aes_keyring,
            encryption_context=encryption_context
        ) as encryptor:
            for chunk in encryptor:
                ct_file.write(chunk)

    # 7. Demonstrate that the ciphertext and plaintext are different.
    # (This is an example for demonstration; you do not need to do this in your own
code.)
    assert not filecmp.cmp(plaintext_filename, ciphertext_filename), \
        "Ciphertext and plaintext data are the same. Invalid encryption"

    # 8. Decrypt your encrypted data stream using the same keyring you used on
encrypt.
    with open(ciphertext_filename, 'rb') as ct_file, open(decrypted_filename, 'wb') as
pt_file:
        with client.stream(
            mode='d',
            source=ct_file,
            keyring=raw_aes_keyring,
            encryption_context=encryption_context
        ) as decryptor:
            for chunk in decryptor:
                pt_file.write(chunk)

    # 10. Demonstrate that the decrypted plaintext is identical to the original
plaintext.
    # (This is an example for demonstration; you do not need to do this in your own
code.)
    assert filecmp.cmp(plaintext_filename, decrypted_filename), \
        "Decrypted plaintext should be identical to the original plaintext. Invalid
decryption"
```

AWS Encryption SDK for Rust

This topic explains how to install and use the AWS Encryption SDK for Rust. For details about programming with the AWS Encryption SDK for Rust, see the Rust directory of the aws-encryption-sdk repository on GitHub.

The AWS Encryption SDK for Rust differs from some of the other programming language implementations of the AWS Encryption SDK in the following ways:

- No support for data key caching. However, the AWS Encryption SDK for Rust supports the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.
- No support for streaming data

The AWS Encryption SDK for Rust includes all of the security features introduced in versions 2.0.*x* and later of other language implementations of the AWS Encryption SDK. However, if you are using the AWS Encryption SDK for Rust to decrypt data that was encrypted by a pre-2.0.*x* version another language implementation of the AWS Encryption SDK, you might need to adjust your commitment policy. For details, see How to set your commitment policy.

The AWS Encryption SDK for Rust is a product of the AWS Encryption SDK in Dafny, a formal verification language in which you write specifications, the code to implement them, and the proofs to test them. The result is a library that implements the features of the AWS Encryption SDK in a framework that assures functional correctness.

Learn More

- For examples showing how to configure options in the AWS Encryption SDK, such as specifying an alternate algorithm suite, limiting encrypted data keys, and using AWS KMS multi-Region keys, see Configuring the AWS Encryption SDK.
- For examples showing how to configure and use the AWS Encryption SDK for Rust, see the Rust examples in the aws-encryption-sdk repository on GitHub.

Topics

- Prerequisites
- Installation
- AWS Encryption SDK for Rust example code

Prerequisites

Before you install the AWS Encryption SDK for Rust, be sure you have the following prerequisites.

Install Rust and Cargo

Install the current stable release of Rust using rustup.

For more information on downloading and installing rustup, see the installation procedures in The Cargo Book.

Installation

The AWS Encryption SDK for Rust is available as the `aws-esdk` crate on Crates.io. For details on installing and building the AWS Encryption SDK for Rust, see the README.md in the aws-encryption-sdk repository on GitHub.

You can install the AWS Encryption SDK for Rust in the following ways.

Manually

To install the AWS Encryption SDK for Rust, clone or download the aws-encryption-sdk GitHub repository.

Using Crates.io

Run the following Cargo command in your project directory:

```
cargo add aws-esdk
```

Or add the following line to your Cargo.toml:

```
aws-esdk = "<version>"
```

AWS Encryption SDK for Rust example code

The following examples show the basic coding patterns that you use when programming with the AWS Encryption SDK for Rust. Specifically, you instantiate the AWS Encryption SDK and the material providers library. Then, before calling each method, you instantiate the object that defines the input for the method.

For examples showing how to configure options in the AWS Encryption SDK, such as specifying an alternate algorithm suite and limiting encrypted data keys, see the Rust examples in the aws-encryption-sdk repository on GitHub.

Encrypting and decrypting data in the AWS Encryption SDK for Rust

This example shows the basic pattern for encrypting and decrypting data. It encrypts a small file with data keys that are protected by one AWS KMS wrapping key.

Step 1: Instantiate the AWS Encryption SDK.

You'll use the methods in the AWS Encryption SDK to encrypt and decrypt data.

```
let esdk_config = AwsEncryptionSdkConfig::builder().build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;
```

Step 2: Create an AWS KMS client.

```
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
let kms_client = aws_sdk_kms::Client::new(&sdk_config);
```

Optional: Create your encryption context.

```
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);
```

Step 3: Instantiate the material providers library.

You'll use the methods in the material providers library to create the keyrings that specify which keys protect your data.

```
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;
```

Step 4: Create an AWS KMS keyring.

To create the keyring, call the keyring method with the keyring input object. This example uses the `create_aws_kms_keyring()` method and specifies one KMS key.

```
let kms_keyring = mpl
    .create_aws_kms_keyring()
    .kms_key_id(kms_key_id)
    .kms_client(kms_client)
    .send()
    .await?;
```

Step 5: Encrypt the plaintext.

```
let plaintext = example_data.as_bytes();

let encryption_response = esdk_client.encrypt()
    .plaintext(plaintext)
    .keyring(kms_keyring.clone())
    .encryption_context(encryption_context.clone())
    .send()
    .await?;

let ciphertext = encryption_response
                    .ciphertext
                    .expect("Unable to unwrap ciphertext from encryption response");
```

Step 6: Decrypt your encrypted data using the same keyring you used on encrypt.

```
let decryption_response = esdk_client.decrypt()
    .ciphertext(ciphertext)
    .keyring(kms_keyring)
    // Provide the encryption context that was supplied to the encrypt method
    .encryption_context(encryption_context)
    .send()
    .await?;

let decrypted_plaintext = decryption_response
                           .plaintext
                           .expect("Unable to unwrap plaintext from decryption
 response");
```

AWS Encryption SDK command line interface

The AWS Encryption SDK Command Line Interface (AWS Encryption CLI) enables you to use the AWS Encryption SDK to encrypt and decrypt data interactively at the command line and in scripts. You don't need cryptography or programming expertise.

> **Note**
>
> Versions of the AWS Encryption CLI earlier than 4.0.0 are in the end-of-support phase. You can safely update from version 2.1.*x* and later to the latest version of the AWS Encryption CLI without any code or data changes. However, new security features introduced in version 2.1.*x* are not backward-compatible. To update from version 1.7.*x* or earlier, you must first update to the latest 1.*x* version of the AWS Encryption CLI. For details, see Migrating your AWS Encryption SDK.
> New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

Like all implementations of the AWS Encryption SDK, the AWS Encryption CLI offers advanced data protection features. These include envelope encryption, additional authenticated data (AAD), and secure, authenticated, symmetric key algorithm suites, such as 256-bit AES-GCM with key derivation, key commitment, and signing.

The AWS Encryption CLI is built on the AWS Encryption SDK for Python and is supported on Linux, macOS, and Windows. You can run commands and scripts to encrypt and decrypt your data in your preferred shell on Linux or macOS, in a Command Prompt window (cmd.exe) on Windows, and in a PowerShell console on any system.

All language-specific implementations of the AWS Encryption SDK, including the AWS Encryption CLI, are interoperable. For example, you can encrypt data with the AWS Encryption SDK for Java and decrypt it with the AWS Encryption CLI.

This topic introduces the AWS Encryption CLI, explains how to install and use it, and provides several examples to help you get started. For a quick start, see How to Encrypt and Decrypt Your Data with the AWS Encryption CLI in the AWS Security Blog. For more detailed information, see

Read The Docs, and join us in developing the AWS Encryption CLI in the aws-encryption-sdk-cli repository on GitHub.

Performance

The AWS Encryption CLI is built on the AWS Encryption SDK for Python. Each time you run the CLI, you start a new instance of the Python runtime. To improve performance, whenever possible, use a single command instead of a series of independent commands. For example, run one command that processes the files in a directory recursively instead of running separate commands for each file.

Topics

- Installing the AWS Encryption SDK command line interface
- How to use the AWS Encryption CLI
- Examples of the AWS Encryption CLI
- AWS Encryption SDK CLI syntax and parameter reference
- Versions of the AWS Encryption CLI

Installing the AWS Encryption SDK command line interface

This topic explains how to install the AWS Encryption CLI. For detailed information, see the aws-encryption-sdk-cli repository on GitHub and Read the Docs.

Topics

- Installing the prerequisites
- Installing and updating the AWS Encryption CLI

Installing the prerequisites

The AWS Encryption CLI is built on the AWS Encryption SDK for Python. To install the AWS Encryption CLI, you need Python and `pip`, the Python package management tool. Python and `pip` are available on all supported platforms.

Install the following prerequisites before you install the AWS Encryption CLI,

Python

Python 3.8 or later is required by the AWS Encryption CLI versions 4.2.0 and later.

Earlier versions of the AWS Encryption CLI support Python 2.7 and 3.4 and later, but we recommend that you use the latest version of the AWS Encryption CLI.

Python is included in most Linux and macOS installations, but you need to upgrade to Python 3.6 or later. We recommend that you use the latest version of Python. On Windows, you have to install Python; it is not installed by default. To download and install Python, see Python downloads.

To determine whether Python is installed, at the command line, type the following.

```
python
```

To check the Python version, use the `-V` (uppercase V) parameter.

```
python -V
```

On Windows, after you install Python, add the path to the `Python.exe` file to the value of the **Path** environment variable.

By default, Python is installed in the all users directory or in a user profile directory ($home or `%userprofile%`) in the `AppData\Local\Programs\Python` subdirectory. To find the location of the `Python.exe` file on your system, check one of the following registry keys. You can use PowerShell to search the registry.

```
PS C:\> dir HKLM:\Software\Python\PythonCore\version\InstallPath
# -or-
PS C:\> dir HKCU:\Software\Python\PythonCore\version\InstallPath
```

pip

`pip` is the Python package manager. To install the AWS Encryption CLI and its dependencies, you need `pip` 8.1 or later. For help installing or upgrading `pip`, see Installation in the `pip` documentation.

On Linux installations, versions of `pip` earlier than 8.1 can't build the **cryptography** library that the AWS Encryption CLI requires. If you choose not to update your `pip` version, you can install the build tools separately. For more information, see Building cryptography on Linux.

AWS Command Line Interface

The AWS Command Line Interface (AWS CLI) is required only if you are using AWS KMS keys in AWS Key Management Service (AWS KMS) with the AWS Encryption CLI. If you are using a different master key provider, the AWS CLI is not required.

To use AWS KMS keys with the AWS Encryption CLI, you need to install and configure the AWS CLI. The configuration makes the credentials that you use to authenticate to AWS KMS available to the AWS Encryption CLI.

Installing and updating the AWS Encryption CLI

Install the latest version of the AWS Encryption CLI. When you use `pip` to install the AWS Encryption CLI, it automatically installs the libraries that the CLI needs, including the AWS Encryption SDK for Python, the Python cryptography library, and the AWS SDK for Python (Boto3).

> **Note**
>
> Versions of the AWS Encryption CLI earlier than 4.0.0 are in the end-of-support phase. You can safely update from version 2.1.*x* and later to the latest version of the AWS Encryption CLI without any code or data changes. However, new security features introduced in version 2.1.*x* are not backward-compatible. To update from version 1.7.*x* or earlier, you must first update to the latest 1.*x* version of the AWS Encryption CLI. For details, see Migrating your AWS Encryption SDK.
> New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

To install the latest version of the AWS Encryption CLI

```
pip install aws-encryption-sdk-cli
```

To upgrade to the latest version of the AWS Encryption CLI

```
pip install --upgrade aws-encryption-sdk-cli
```

To find the version numbers of your AWS Encryption CLI and AWS Encryption SDK

```
aws-encryption-cli --version
```

The output lists the version numbers of both libraries.

```
aws-encryption-sdk-cli/2.1.0 aws-encryption-sdk/2.0.0
```

To upgrade to the latest version of the AWS Encryption CLI

```
pip install --upgrade aws-encryption-sdk-cli
```

Installing the AWS Encryption CLI also installs the latest version of the AWS SDK for Python (Boto3), if it's not already installed. If Boto3 is installed, the installer verifies the Boto3 version and updates it if required.

To find your installed version of Boto3

```
pip show boto3
```

To update to the latest version of Boto3

```
pip install --upgrade boto3
```

To install the version of the AWS Encryption CLI currently in development, see the aws-encryption-sdk-cli repository on GitHub.

For more details about using `pip` to install and upgrade Python packages, see the pip documentation.

How to use the AWS Encryption CLI

This topic explains how to use the parameters in the AWS Encryption CLI. For examples, see Examples of the AWS Encryption CLI. For complete documentation, see Read the Docs. The syntax shown in these examples is for AWS Encryption CLI version 2.1.*x* and later.

> **Note**
>
> Versions of the AWS Encryption CLI earlier than 4.0.0 are in the end-of-support phase. You can safely update from version 2.1.*x* and later to the latest version of the AWS Encryption CLI without any code or data changes. However, new security features introduced in version 2.1.*x* are not backward-compatible. To update from version 1.7.*x* or earlier, you must first update to the latest 1.*x* version of the AWS Encryption CLI. For details, see Migrating your AWS Encryption SDK.
> New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

For an example showing how to use the security feature that limits encrypted data keys, see Limiting encrypted data keys.

For an example showing how to use AWS KMS multi-Region keys, see Using multi-Region AWS KMS keys.

Topics

- How to encrypt and decrypt data
- How to specify wrapping keys
- How to provide input
- How to specify the output location
- How to use an encryption context
- How to specify a commitment policy
- How to store parameters in a configuration file

How to encrypt and decrypt data

The AWS Encryption CLI uses the features of the AWS Encryption SDK to make it easy to encrypt and decrypt data securely.

> **Note**
>
> The `--master-keys` parameter is deprecated in version 1.8.*x* of the AWS Encryption CLI and removed in version 2.1.*x*. Instead, use the `--wrapping-keys` parameter. Beginning in version 2.1.*x*, the `--wrapping-keys` parameter is required when encrypting and decrypting. For details, see AWS Encryption SDK CLI syntax and parameter reference.

- When you encrypt data in the AWS Encryption CLI, you specify your plaintext data and a wrapping key (or *master key*), such as an AWS KMS key in AWS Key Management Service (AWS KMS). If you are using a custom master key provider, you also need to specify the provider. You also specify output locations for the encrypted message and for metadata about the encryption operation. An encryption context is optional, but recommended.

  In version 1.8.*x*, the `--commitment-policy` parameter is required when you use the `--wrapping-keys` parameter; otherwise it's not valid. Beginning in version 2.1.*x*, the `--commitment-policy` parameter is optional, but recommended.

  ```
  aws-encryption-cli --encrypt --input myPlaintextData \
                     --wrapping-keys key=1234abcd-12ab-34cd-56ef-1234567890ab \
                     --output myEncryptedMessage \
                     --metadata-output ~/metadata \
                     --encryption-context purpose=test \
                     --commitment-policy require-encrypt-require-decrypt
  ```

  The AWS Encryption CLI encrypts your data under a unique data key. Then it encrypts the data key under the wrapping keys you specify. It returns an encrypted message and metadata about the operation. The encrypted message contains your encrypted data (*ciphertext*) and an encrypted copy of the data key. You don't have to worry about storing, managing, or losing the data key.

- When you decrypt data, you pass in your encrypted message, the optional encryption context, and location for the plaintext output and the metadata. You also specify the wrapping keys that the AWS Encryption CLI can use to decrypt the message, or tell the AWS Encryption CLI it can use any wrapping keys that encrypted the message.

Beginning in version 1.8.*x*, the `--wrapping-keys` parameter is optional when decrypting, but recommended. Beginning in version 2.1.*x*, the `--wrapping-keys` parameter is required when encrypting and decrypting.

When decrypting, you can use the **key** attribute of the `--wrapping-keys` parameter to specify the wrapping keys that decrypt your data. Specifying an AWS KMS wrapping key when decrypting is optional, but it's a best practice that prevents you from using a key you didn't intend to use. If you're using a custom master key provider, you must specify the provider and wrapping key.

If you don't use the **key** attribute, you must set the **discovery** attribute of the `--wrapping-keys` parameter to `true`, which lets the AWS Encryption CLI decrypt using any wrapping key that encrypted the message.

As a best practice, use the `--max-encrypted-data-keys` parameter to avoid decrypting a malformed message with an excessive number of encrypted data keys. Specify the expected number of encrypted data keys (one for each wrapping key used in encryption) or a reasonable maximum (such as 5). For details, see Limiting encrypted data keys.

The `--buffer` parameter returns plaintext only after all input is processed, including verifying the digital signature if one is present.

The `--decrypt-unsigned` parameter decrypts ciphertext and ensures that messages are unsigned before decryption. Use this parameter if you used the `--algorithm` parameter and selected an algorithm suite without digital signing to encrypt data. If the ciphertext is signed, decryption fails.

You can use `--decrypt` or `--decrypt-unsigned` for decryption but not both.

```
aws-encryption-cli --decrypt --input myEncryptedMessage \
                   --wrapping-keys key=1234abcd-12ab-34cd-56ef-1234567890ab \
                   --output myPlaintextData \
                   --metadata-output ~/metadata \
                   --max-encrypted-data-keys 1 \
                   --buffer \
                   --encryption-context purpose=test \
                   --commitment-policy require-encrypt-require-decrypt
```

The AWS Encryption CLI uses the wrapping key to decrypt the data key in the encrypted message. Then it uses the data key to decrypt your data. It returns your plaintext data and metadata about the operation.

How to specify wrapping keys

When you encrypt data in the AWS Encryption CLI, you need to specify at least one wrapping key (or *master key*). You can use AWS KMS keys in AWS Key Management Service (AWS KMS), wrapping keys from a custom master key provider, or both. The custom master key provider can be any compatible Python master key provider.

To specify wrapping keys in versions 1.8.*x* and later, use the `--wrapping-keys` parameter (`-w`). The value of this parameter is a collection of attributes with the `attribute=value` format. The attributes that you use depend on the master key provider and the command.

- **AWS KMS**. In encrypt commands, you must specify a `--wrapping-keys` parameter with a **key** attribute. Beginning in version 2.1.*x*, the `--wrapping-keys` parameter is also required in decrypt commands. When decrypting, the `--wrapping-keys` parameter must have a **key** attribute or a **discovery** attribute with a value of `true` (but not both). Other attributes are optional.
- **Custom master key provider**. You must specify a `--wrapping-keys` parameter in every command. The parameter value must have **key** and **provider** attributes.

You can include multiple `--wrapping-keys` parameters and multiple **key** attributes in the same command.

Wrapping key parameter attributes

The value of the `--wrapping-keys` parameter consists of the following attributes and their values. A `--wrapping-keys` parameter (or `--master-keys` parameter) is required in all encrypt commands. Beginning in version 2.1.*x*, the `--wrapping-keys` parameter is also required when decrypting.

If an attribute name or value includes spaces or special characters, enclose both the name and value in quotation marks. For example, `--wrapping-keys key=12345 "provider=my cool provider"`.

Key: Specify a wrapping key

Use the **key** attribute to identify a wrapping key. When encrypting, the value can be any key identifier that the master key provider recognizes.

```
--wrapping-keys key=1234abcd-12ab-34cd-56ef-1234567890ab
```

In an encrypt command, you must include at least one **key** attribute and value. To encrypt your data key under multiple wrapping keys, use multiple **key** attributes.

```
aws-encryption-cli --encrypt --wrapping-keys
 key=1234abcd-12ab-34cd-56ef-1234567890ab key=1a2b3c4d-5e6f-1a2b-3c4d-5e6f1a2b3c4d
```

In encrypt commands that use AWS KMS keys, the value of **key** can be the key ID, its key ARN, an alias name, or alias ARN. For example, this encrypt command uses an alias ARN in the value of the **key** attribute. For details about the key identifiers for an AWS KMS key, see Key Identifiers in the *AWS Key Management Service Developer Guide*.

```
aws-encryption-cli --encrypt --wrapping-keys key=arn:aws:kms:us-
west-2:111122223333:alias/ExampleAlias
```

In decrypt commands that use a custom master key provider, **key** and **provider** attributes are required.

```
\\ Custom master key provider
aws-encryption-cli --decrypt --wrapping-keys provider='myProvider' key='100101'
```

In decrypt commands that use AWS KMS, you can use the **key** attribute to specify the AWS KMS keys to use for decrypting, or the **discovery** attribute with a value of `true`, which lets the AWS Encryption CLI use any AWS KMS key that was used to encrypt the message. If you specify an AWS KMS key, it must be one of the wrapping keys used to encrypt the message.

Specifying the wrapping key is an AWS Encryption SDK best practice. It assures that you use the AWS KMS key you intend to use.

In a decrypt command, the value of the **key** attribute must be a key ARN.

```
\\ AWS KMS key
aws-encryption-cli --decrypt --wrapping-keys key=arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab
```

Discovery: Use any AWS KMS key when decrypting

If you don't need to limit the AWS KMS keys to use when decrypting, you can use the **discovery** attribute with a value of `true`. A value of `true` allows the AWS Encryption CLI to decrypt using any AWS KMS key that encrypted the message. If you don't specify a **discovery** attribute, discovery is `false` (default). The **discovery** attribute is valid only in decrypt commands and only when the message was encrypted with AWS KMS keys.

The **discovery** attribute with a value of `true` is an alternative to using the **key** attribute to specify AWS KMS keys. When decrypting a message encrypted with AWS KMS keys, each `--wrapping-keys` parameter must have a **key** attribute or a **discovery** attribute with a value of `true`, but not both.

When discovery is true, it's a best practice to use the **discovery-partition** and **discovery-account** attributes to limit the AWS KMS keys used to those in the AWS accounts you specify. In the following example, the **discovery** attributes allow the AWS Encryption CLI to use any AWS KMS key in the specified AWS accounts.

```
aws-encryption-cli --decrypt --wrapping-keys \
    discovery=true \
    discovery-partition=aws \
    discovery-account=111122223333 \
    discovery-account=444455556666
```

Provider: Specify the master key provider

The **provider** attribute identifies the master key provider. The default value is `aws-kms`, which represents AWS KMS. If you are using a different master key provider, the **provider** attribute is required.

```
--wrapping-keys key=12345 provider=my_custom_provider
```

For more information about using custom (non-AWS KMS) master key providers, see the **Advanced Configuration** topic in the README file for the AWS Encryption CLI repository.

Region: Specify an AWS Region

Use the **region** attribute to specify the AWS Region of an AWS KMS key. This attribute is valid only in encrypt commands and only when the master key provider is AWS KMS.

```
--encrypt --wrapping-keys key=alias/primary-key region=us-east-2
```

AWS Encryption CLI commands use the AWS Region that is specified in the **key** attribute value if it includes a region, such as an ARN. if the **key** value specifies a AWS Region, the **region** attribute is ignored.

The **region** attribute takes precedence over other region specifications. If you don't use a region attribute, AWS Encryption CLI commands uses the AWS Region specified in your AWS CLI named profile, if any, or your default profile.

Profile: Specify a named profile

Use the **profile** attribute to specify an AWS CLI named profile. Named profiles can include credentials and an AWS Region. This attribute is valid only when the master key provider is AWS KMS.

```
--wrapping-keys key=alias/primary-key profile=admin-1
```

You can use the **profile** attribute to specify alternate credentials in encrypt and decrypt commands. In an encrypt command, the AWS Encryption CLI uses the AWS Region in the named profile only when the **key** value does not include a region and there is no **region** attribute. In a decrypt command, the AWS Region in the name profile is ignored.

How to specify multiple wrapping keys

You can specify multiple wrapping keys (or *master keys*) in each command.

If you specify more than one wrapping key, the first wrapping key generates and encrypts the data key that is used to encrypt your data. The other wrapping keys encrypt the same data key. The resulting encrypted message contains the encrypted data ("ciphertext") and a collection of encrypted data keys, one encrypted by each wrapping key. Any of the wrapping can decrypt one encrypted data key and then decrypt the data.

There are two ways to specify multiple wrapping keys:

- Include multiple **key** attributes in the `--wrapping-keys` parameter value.

```
$key_oregon=arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab
$key_ohio=arn:aws:kms:us-east-2:111122223333:key/0987ab65-43cd-21ef-09ab-87654321cdef

--wrapping-keys key=$key_oregon key=$key_ohio
```

- Include multiple `--wrapping-keys` parameters in the same command. Use this syntax when the attribute values that you specify do not apply to all of the wrapping keys in the command.

```
--wrapping-keys region=us-east-2 key=alias/test_key \
--wrapping-keys region=us-west-1 key=alias/test_key
```

The **discovery** attribute with a value of `true` lets the AWS Encryption CLI use any AWS KMS key that encrypted the message. If you use multiple `--wrapping-keys` parameters in the same command, using `discovery=true` in any `--wrapping-keys` parameter effectively overrides the limits of the **key** attribute in other `--wrapping-keys` parameters.

For example, in the following command, the **key** attribute in the first `--wrapping-keys` parameter limits the AWS Encryption CLI to the specified AWS KMS key. However, the **discovery** attribute in the second `--wrapping-keys` parameter lets the AWS Encryption CLI use any AWS KMS key in the specified accounts to decrypt the message.

```
aws-encryption-cli --decrypt \
    --wrapping-keys key=arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab \
    --wrapping-keys discovery=true \
                    discovery-partition=aws \
                    discovery-account=111122223333 \
                    discovery-account=444455556666
```

How to provide input

The encrypt operation in the AWS Encryption CLI takes plaintext data as input and returns an encrypted message. The decrypt operation takes an encrypted message as input and returns plaintext data.

The `--input` parameter (`-i`) , which tells the AWS Encryption CLI where to find the input, is required in all AWS Encryption CLI commands.

You can provide input in any of the following ways:

- Use a file.

```
--input myData.txt
```

- Use a file name pattern.

```
--input testdir/*.xml
```

- Use a directory or directory name pattern. When the input is a directory, the `--recursive` parameter (`-r`, `-R`) is required.

```
--input testdir --recursive
```

- Pipe input to the command (stdin). Use a value of `-` for the `--input` parameter. (The `--input` parameter is always required.)

```
echo 'Hello World' | aws-encryption-cli --encrypt --input -
```

How to specify the output location

The `--output` parameter tells the AWS Encryption CLI where to write the results of the encryption or decryption operation. It is required in every AWS Encryption CLI command. The AWS Encryption CLI creates a new output file for every input file in the operation.

If an output file already exists, by default, the AWS Encryption CLI prints a warning, then overwrites the file. To prevent overwriting, use the `--interactive` parameter, which prompts you for confirmation before overwriting, or `--no-overwrite`, which skips the input if the output would cause an overwrite. To suppress the overwrite warning, use `--quiet`. To capture errors and warnings from the AWS Encryption CLI, use the 2>&1 redirection operator to write them to the output stream.

> **Note**
>
> Commands that overwrite output files begin by deleting the output file. If the command fails, the output file might already be deleted.

You can the output location in several ways.

- Specify a file name. If you specify a path to the file, all directories in the path must exist before the command runs.

```
--output myEncryptedData.txt
```

- Specify a directory. The output directory must exist before the command runs.

  If the input contains subdirectories, the command reproduces the subdirectories under the specified directory.

  ```
  --output Test
  ```

  When the output location is a directory (without file names), the AWS Encryption CLI creates output file names based on the input file names plus a suffix. Encrypt operations append `.encrypted` to the input file name and the decrypt operations append `.decrypted`. To change the suffix, use the `--suffix` parameter.

  For example, if you encrypt `file.txt`, the encrypt command creates `file.txt.encrypted`. If you decrypt `file.txt.encrypted`, the decrypt command creates `file.txt.encrypted.decrypted`.

- Write to the command line (stdout). Enter a value of `-` for the `--output` parameter. You can use `--output -` to pipe output to another command or program.

  ```
  --output -
  ```

How to use an encryption context

The AWS Encryption CLI lets you provide an encryption context in encrypt and decrypt commands. It is not required, but it is a cryptographic best practice that we recommend.

An *encryption context* is a type of arbitrary, non-secret *additional authenticated data*. In the AWS Encryption CLI, the encryption context consists of a collection of `name=value` pairs. You can use any content in the pairs, including information about the files, data that helps you to find the encryption operation in logs, or data that your grants or policies require.

In an encrypt command

The encryption context that you specify in an encrypt command, along with any additional pairs that the CMM adds, is cryptographically bound to the encrypted data. It is also included (in plaintext) in the encrypted message that the command returns. If you are using an AWS KMS

key, the encryption context also might appear in plaintext in audit records and logs, such as AWS CloudTrail.

The following example shows an encryption context with three `name=value` pairs.

```
--encryption-context purpose=test dept=IT class=confidential
```

In a decrypt command

In a decrypt command, the encryption context helps you to confirm that you are decrypting the right encrypted message.

You are not required to provide an encryption context in a decrypt command, even if an encryption context was used on encrypt. However, if you do, the AWS Encryption CLI verifies that every element in the encryption context of the decrypt command matches an element in the encryption context of the encrypted message. If any element does not match, the decrypt command fails.

For example, the following command decrypts the encrypted message only if its encryption context includes `dept=IT`.

```
aws-encryption-cli --decrypt --encryption-context dept=IT ...
```

An encryption context is an important part of your security strategy. However, when choosing an encryption context, remember that its values are not secret. Do not include any confidential data in the encryption context.

To specify an encryption context

- In an **encrypt** command, use the `--encryption-context` parameter with one or more `name=value` pairs. Use a space to separate each pair.

  ```
  --encryption-context name=value [name=value] ...
  ```

- In a **decrypt** command, the `--encryption-context` parameter value can include `name=value` pairs, `name` elements (with no values), or a combination of both.

  ```
  --encryption-context name[=value] [name] [name=value] ...
  ```

If the `name` or `value` in a `name=value` pair includes spaces or special characters, enclose the entire pair in quotation marks.

```
--encryption-context "department=software engineering" "AWS Region=us-west-2"
```

For example, this encrypt command includes an encryption context with two pairs, `purpose=test` and `dept=23`.

```
aws-encryption-cli --encrypt --encryption-context purpose=test dept=23 ...
```

These decrypt command would succeed. The encryption context in each commands is a subset of the original encryption context.

```
\\ Any one or both of the encryption context pairs
aws-encryption-cli --decrypt --encryption-context dept=23 ...

\\ Any one or both of the encryption context names
aws-encryption-cli --decrypt --encryption-context purpose ...

\\ Any combination of names and pairs
aws-encryption-cli --decrypt --encryption-context dept purpose=test ...
```

However, these decrypt commands would fail. The encryption context in the encrypted message does not contain the specified elements.

```
aws-encryption-cli --decrypt --encryption-context dept=Finance ...
aws-encryption-cli --decrypt --encryption-context scope ...
```

How to specify a commitment policy

To set the commitment policy for the command, use the `--commitment-policy` parameter. This parameter is introduced in version 1.8.*x*. It is valid in encrypt and decrypt commands. The commitment policy you set is valid only for the command in which it appears. If you do not set a commitment policy for a command, the AWS Encryption CLI uses the default value.

For example, the following parameter value sets the commitment policy to `require-encrypt-allow-decrypt`, which always encrypts with key commitment, but will decrypt a ciphertext that was encrypted with or without key commitment.

```
--commitment-policy require-encrypt-allow-decrypt
```

How to store parameters in a configuration file

You can save time and avoid typing errors by saving frequently used AWS Encryption CLI parameters and values in configuration files.

A *configuration file* is a text file that contains parameters and values for an AWS Encryption CLI command. When you refer to a configuration file in a AWS Encryption CLI command, the reference is replaced by the parameters and values in the configuration file. The effect is the same is if you typed the file content at the command line. A configuration file can have any name and it can be located in any directory that the current user can access.

The following example configuration file, `key.conf`, specifies two AWS KMS keys in different Regions.

```
--wrapping-keys key=arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab
--wrapping-keys key=arn:aws:kms:us-
east-2:111122223333:key/0987ab65-43cd-21ef-09ab-87654321cdef
```

To use the configuration file in a command, prefix the file name with an at sign (@). In a PowerShell console, use a backtick character to escape the at sign (`@).

This example command uses the `key.conf` file in an encrypt command.

Bash

```
$ aws-encryption-cli -e @key.conf -i hello.txt -o testdir
```

PowerShell

```
PS C:\> aws-encryption-cli -e `@key.conf -i .\Hello.txt -o .\TestDir
```

Configuration file rules

The rules for using configuration files are as follows:

- You can include multiple parameters in each configuration file and list them in any order. List each parameter with its values (if any) on a separate line.

- Use # to add a comment to all or part of a line.
- You can include references to other configuration files. Do not use a backtick to escape the @ sign, even in PowerShell.
- If you use quotes in a configuration file, the quoted text cannot span multiple lines.

For example, this is the contents of an example `encrypt.conf` file.

```
# Archive Files
--encrypt
--output /archive/logs
--recursive
--interactive
--encryption-context class=unclassified dept=IT
--suffix  # No suffix
--metadata-output ~/metadata
@caching.conf  # Use limited caching
```

You can also include multiple configuration files in a command. This example command uses both the `encrypt.conf` and `master-keys.conf` configurations files.

Bash

```
$  aws-encryption-cli -i /usr/logs @encrypt.conf @master-keys.conf
```

PowerShell

```
PS C:\> aws-encryption-cli -i $home\Test\*.log `@encrypt.conf `@master-keys.conf
```

Next: Try the AWS Encryption CLI examples

Examples of the AWS Encryption CLI

Use the following examples to try the AWS Encryption CLI on the platform you prefer. For help with master keys and other parameters, see How to use the AWS Encryption CLI. For a quick reference, see AWS Encryption SDK CLI syntax and parameter reference.

> **Note**
>
> The following examples use the syntax for AWS Encryption CLI version 2.1.*x*.

New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

For an example showing how to use the security feature that limits encrypted data keys, see Limiting encrypted data keys.

For an example showing how to use AWS KMS multi-Region keys, see Using multi-Region AWS KMS keys.

Topics

- Encrypting a file
- Decrypting a file
- Encrypting all files in a directory
- Decrypting all files in a directory
- Encrypting and decrypting on the command line
- Using multiple master keys
- Encrypting and decrypting in scripts
- Using data key caching

Encrypting a file

This example uses the AWS Encryption CLI to encrypt the contents of the `hello.txt` file, which contains a "Hello World" string.

When you run an encrypt command on a file, the AWS Encryption CLI gets the contents of the file, generates a unique data key, encrypts the file contents under the data key, and then writes the encrypted message to a new file.

The first command saves the key ARN of an AWS KMS key in the `$keyArn` variable. When encrypting with an AWS KMS key, you can identify it by using a key ID, key ARN, alias name, or alias ARN. For details about the key identifiers for an AWS KMS key, see Key Identifiers in the *AWS Key Management Service Developer Guide*.

The second command encrypts the file contents. The command uses the `--encrypt` parameter to specify the operation and the `--input` parameter to indicate the file to encrypt. The `--wrapping-keys` parameter, and its required **key** attribute, tell the command to use the AWS KMS key represented by the key ARN.

The command uses the `--metadata-output` parameter to specify a text file for the metadata about the encryption operation. As a best practice, the command uses the `--encryption-context` parameter to specify an encryption context.

This command also uses the `--commitment-policy` parameter to set the commitment policy explicitly. In version 1.8.*x*, this parameter is required when you use the `--wrapping-keys` parameter. Beginning in version 2.1.*x*, the `--commitment-policy` parameter is optional, but recommended.

The value of the `--output` parameter, a dot (.), tells the command to write the output file to the current directory.

Bash

```
\\ To run this example, replace the fictitious key ARN with a valid value.
$ keyArn=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

$ aws-encryption-cli --encrypt \
                     --input hello.txt \
                     --wrapping-keys key=$keyArn \
                     --metadata-output ~/metadata \
                     --encryption-context purpose=test \
                     --commitment-policy require-encrypt-require-decrypt \
                     --output .
```

PowerShell

```
# To run this example, replace the fictitious key ARN with a valid value.
PS C:\> $keyArn = 'arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'

PS C:\> aws-encryption-cli --encrypt `
                           --input Hello.txt `
                           --wrapping-keys key=$keyArn `
                           --metadata-output $home\Metadata.txt `
                           --commitment-policy require-encrypt-require-decrypt `
                           --encryption-context purpose=test `
```

```
                                --output .
```

When the encrypt command succeeds, it does not return any output. To determine whether the command succeeded, check the Boolean value in the `$?` variable. When the command succeeds, the value of `$?` is `0` (Bash) or `True` (PowerShell). When the command fails, the value of `$?` is non-zero (Bash) or `False` (PowerShell).

Bash

```
$ echo $?
0
```

PowerShell

```
PS C:\> $?
True
```

You can also use a directory listing command to see that the encrypt command created a new file, `hello.txt.encrypted`. Because the encrypt command did not specify a file name for the output, the AWS Encryption CLI wrote the output to a file with the same name as the input file plus a `.encrypted` suffix. To use a different suffix, or suppress the suffix, use the `--suffix` parameter.

The `hello.txt.encrypted` file contains an encrypted message that includes the ciphertext of the `hello.txt` file, an encrypted copy of the data key, and additional metadata, including the encryption context.

Bash

```
$  ls
hello.txt  hello.txt.encrypted
```

PowerShell

```
PS C:\> dir

    Directory: C:\TestCLI

Mode                LastWriteTime         Length Name
----                -------------         ------ ----
```

```
-a----        9/15/2017   5:57 PM             11 Hello.txt
-a----        9/17/2017   1:06 PM            585 Hello.txt.encrypted
```

Decrypting a file

This example uses the AWS Encryption CLI to decrypt the contents of the `Hello.txt.encrypted` file that was encrypted in the previous example.

The decrypt command uses the `--decrypt` parameter to indicate the operation and `--input` parameter to identify the file to decrypt. The value of the `--output` parameter is a dot that represents the current directory.

The `--wrapping-keys` parameter with a **key** attribute specifies the wrapping key used to decrypt the encrypted message. In decrypt commands with AWS KMS keys, the value of the key attribute must be a key ARN. The `--wrapping-keys` parameter is required in a decrypt command. If you are using AWS KMS keys, you can use the **key** attribute to specify AWS KMS keys for decrypting or the **discovery** attribute with a value of `true` (but not both). If you are using a custom master key provider, the **key** and **provider** attributes are required.

The `--commitment-policy` parameter is optional beginning in version 2.1.*x*, but it is recommended. Using it explicitly makes your intent clear, even if you specify the default value, `require-encrypt-require-decrypt`.

The `--encryption-context` parameter is optional in the decrypt command, even when an encryption context is provided in the encrypt command. In this case, the decrypt command uses the same encryption context that was provided in the encrypt command. Before decrypting, the AWS Encryption CLI verifies that the encryption context in the encrypted message includes a `purpose=test` pair. If it does not, the decrypt command fails.

The `--metadata-output` parameter specifies a file for metadata about the decryption operation. The value of the `--output` parameter, a dot (.), writes the output file to the current directory.

As a best practice, use the `--max-encrypted-data-keys` parameter to avoid decrypting a malformed message with an excessive number of encrypted data keys. Specify the expected number of encrypted data keys (one for each wrapping key used in encryption) or a reasonable maximum (such as 5). For details, see Limiting encrypted data keys.

The `--buffer` returns plaintext only after all input is processed, including verifying the digital signature if one is present.

Bash

```
\\ To run this example, replace the fictitious key ARN with a valid value.
$ keyArn=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

$ aws-encryption-cli --decrypt \
                     --input hello.txt.encrypted \
                     --wrapping-keys key=$keyArn \
                     --commitment-policy require-encrypt-require-decrypt \
                     --encryption-context purpose=test \
                     --metadata-output ~/metadata \
                     --max-encrypted-data-keys 1 \
                     --buffer \
                     --output .
```

PowerShell

```
\\ To run this example, replace the fictitious key ARN with a valid value.
PS C:\> $keyArn = 'arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'

PS C:\> aws-encryption-cli --decrypt `
                           --input Hello.txt.encrypted `
                           --wrapping-keys key=$keyArn `
                           --commitment-policy require-encrypt-require-decrypt `
                           --encryption-context purpose=test `
                           --metadata-output $home\Metadata.txt `
                           --max-encrypted-data-keys 1 `
                           --buffer `
                           --output .
```

When a decrypt command succeeds, it does not return any output. To determine whether the command succeeded, get the value of the `$?` variable. You can also use a directory listing command to see that the command created a new file with a `.decrypted` suffix. To see the plaintext content, use a command to get the file content, such as `cat` or Get-Content.

Bash

```
$  ls
hello.txt  hello.txt.encrypted  hello.txt.encrypted.decrypted
```

```
$  cat hello.txt.encrypted.decrypted
Hello World
```

PowerShell

```
PS C:\> dir

    Directory: C:\TestCLI

Mode                LastWriteTime         Length Name
----                -------------         ------ ----
-a----        9/17/2017   1:01 PM             11 Hello.txt
-a----        9/17/2017   1:06 PM            585 Hello.txt.encrypted
-a----        9/17/2017   1:08 PM             11 Hello.txt.encrypted.decrypted


PS C:\> Get-Content Hello.txt.encrypted.decrypted
Hello World
```

Encrypting all files in a directory

This example uses the AWS Encryption CLI to encrypt the contents of all of the files in a directory.

When a command affects multiple files, the AWS Encryption CLI processes each file individually. It gets the file contents, gets a unique data key for the file from the master key, encrypts the file contents under the data key, and writes the results to a new file in the output directory. As a result, you can decrypt the output files independently.

This listing of the `TestDir` directory shows the plaintext files that we want to encrypt.

Bash

```
$  ls testdir
cool-new-thing.py  hello.txt  employees.csv
```

PowerShell

```
PS C:\> dir C:\TestDir

    Directory: C:\TestDir
```

```
Mode                LastWriteTime         Length Name
----                -------------         ------ ----
-a----        9/12/2017   3:11 PM           2139 cool-new-thing.py
-a----        9/15/2017   5:57 PM             11 Hello.txt
-a----        9/17/2017   1:44 PM             46 Employees.csv
```

The first command saves the Amazon Resource Name (ARN) of an AWS KMS key in the `$keyArn` variable.

The second command encrypts the content of files in the `TestDir` directory and writes the files of encrypted content to the `TestEnc` directory. If the `TestEnc` directory doesn't exist, the command fails. Because the input location is a directory, the `--recursive` parameter is required.

The `--wrapping-keys` parameter, and its required **key** attribute, specify the wrapping key to use. The encrypt command includes an encryption context, `dept=IT`. When you specify an encryption context in a command that encrypts multiple files, the same encryption context is used for all of the files.

The command also has a `--metadata-output` parameter to tell the AWS Encryption CLI where to write the metadata about the encryption operations. The AWS Encryption CLI writes one metadata record for each file that was encrypted.

The `--commitment-policy` parameter is optional beginning in version 2.1.*x*, but it is recommended. If the command or script fails because it cannot decrypt a ciphertext, the explicit commitment policy setting might help you to detect the problem quickly.

When the command completes, the AWS Encryption CLI writes the encrypted files to the `TestEnc` directory, but it does not return any output.

The final command lists the files in the `TestEnc` directory. There is one output file of encrypted content for each input file of plaintext content. Because the command did not specify an alternate suffix, the encrypt command appended `.encrypted` to each of the input file names.

Bash

```
# To run this example, replace the fictitious key ARN with a valid master key
 identifier.
$  keyArn=arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab
```

```
$ aws-encryption-cli --encrypt \
                     --input testdir --recursive\
                     --wrapping-keys key=$keyArn \
                     --encryption-context dept=IT \
                     --commitment-policy require-encrypt-require-decrypt \
                     --metadata-output ~/metadata \
                     --output testenc

$ ls testenc
cool-new-thing.py.encrypted  employees.csv.encrypted  hello.txt.encrypted
```

PowerShell

```
# To run this example, replace the fictitious key ARN with a valid master key
 identifier.
PS C:\> $keyArn = arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

PS C:\> aws-encryption-cli --encrypt `
                           --input .\TestDir --recursive `
                           --wrapping-keys key=$keyArn `
                           --encryption-context dept=IT `
                           --commitment-policy require-encrypt-require-decrypt `
                           --metadata-output .\Metadata\Metadata.txt `
                           --output .\TestEnc

PS C:\> dir .\TestEnc

    Directory: C:\TestEnc

Mode                LastWriteTime         Length Name
----                -------------         ------ ----
-a----        9/17/2017   2:32 PM           2713 cool-new-thing.py.encrypted
-a----        9/17/2017   2:32 PM            620 Hello.txt.encrypted
-a----        9/17/2017   2:32 PM            585 Employees.csv.encrypted
```

Decrypting all files in a directory

This example decrypts all files in a directory. It starts with the files in the `TestEnc` directory that were encrypted in the previous example.

Bash

```
$  ls testenc
cool-new-thing.py.encrypted  hello.txt.encrypted  employees.csv.encrypted
```

PowerShell

```
PS C:\> dir C:\TestEnc

    Directory: C:\TestEnc

Mode                LastWriteTime         Length Name
----                -------------         ------ ----
-a----        9/17/2017   2:32 PM           2713 cool-new-thing.py.encrypted
-a----        9/17/2017   2:32 PM            620 Hello.txt.encrypted
-a----        9/17/2017   2:32 PM            585 Employees.csv.encrypted
```

This decrypt command decrypts all of the files in the TestEnc directory and writes the plaintext files to the TestDec directory. The `--wrapping-keys` parameter with a **key** attribute and a key ARN value tells the AWS Encryption CLI which AWS KMS keys to use to decrypt the files. The command uses the `--interactive` parameter to tell the AWS Encryption CLI to prompt you before overwriting a file with the same name.

This command also uses the encryption context that was provided when the files were encrypted. When decrypting multiple files, the AWS Encryption CLI checks the encryption context of every file. If the encryption context check on any file fails, the AWS Encryption CLI rejects the file, writes a warning, records the failure in the metadata, and then continues checking the remaining files. If the AWS Encryption CLI fails to decrypt a file for any other reason, the entire decrypt command fails immediately.

In this example, the encrypted messages in all of the input files contain the `dept=IT` encryption context element. However, if you were decrypting messages with different encryption contexts, you might still be able to verify part of the encryption context. For example, if some messages had an encryption context of `dept=finance` and others had `dept=IT`, you could verify that the encryption context always contains a `dept` name without specifying the value. If you wanted to be more specific, you could decrypt the files in separate commands.

The decrypt command does not return any output, but you can use a directory listing command to see that it created new files with the `.decrypted` suffix. To see the plaintext content, use a command to get the file content.

Bash

```
# To run this example, replace the fictitious key ARN with a valid master key
 identifier.
$ keyArn=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

$ aws-encryption-cli --decrypt \
                     --input testenc --recursive \
                     --wrapping-keys key=$keyArn \
                     --encryption-context dept=IT \
                     --commitment-policy require-encrypt-require-decrypt \
                     --metadata-output ~/metadata \
                     --max-encrypted-data-keys 1 \
                     --buffer \
                     --output testdec --interactive

$ ls testdec
cool-new-thing.py.encrypted.decrypted  hello.txt.encrypted.decrypted
 employees.csv.encrypted.decrypted
```

PowerShell

```
# To run this example, replace the fictitious key ARN with a valid master key
 identifier.
PS C:\> $keyArn = 'arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'

PS C:\> aws-encryption-cli --decrypt `
                           --input C:\TestEnc --recursive `
                           --wrapping-keys key=$keyArn `
                           --encryption-context dept=IT `
                           --commitment-policy require-encrypt-require-decrypt `
                           --metadata-output $home\Metadata.txt `
                           --max-encrypted-data-keys 1 `
                           --buffer `
                           --output C:\TestDec --interactive

PS C:\> dir .\TestDec
```

```
    Mode                LastWriteTime         Length Name
----                -------------         ------ ----
-a----        10/8/2017   4:57 PM           2139 cool-new-
thing.py.encrypted.decrypted
-a----        10/8/2017   4:57 PM             46 Employees.csv.encrypted.decrypted
-a----        10/8/2017   4:57 PM             11 Hello.txt.encrypted.decrypted
```

Encrypting and decrypting on the command line

These examples show you how to pipe input to commands (stdin) and write output to the command line (stdout). They explain how to represent stdin and stdout in a command and how to use the built-in Base64 encoding tools to prevent the shell from misinterpreting non-ASCII characters.

This example pipes a plaintext string to an encrypt command and saves the encrypted message in a variable. Then, it pipes the encrypted message in the variable to a decrypt command, which writes its output to the pipeline (stdout).

The example consists of three commands:

- The first command saves the key ARN of an AWS KMS key in the `$keyArn` variable.

  Bash

  ```
  $  keyArn=arn:aws:kms:us-
  west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab
  ```

  PowerShell

  ```
  PS C:\> $keyArn = 'arn:aws:kms:us-
  west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'
  ```

- The second command pipes the `Hello World` string to the encrypt command and saves the result in the `$encrypted` variable.

  The `--input` and `--output` parameters are required in all AWS Encryption CLI commands. To indicate that input is being piped to the command (stdin), use a hyphen (`-`) for the value of the

`--input` parameter. To send the output to the command line (stdout), use a hyphen for the value of the `--output` parameter.

The `--encode` parameter Base64-encodes the output before returning it. This prevents the shell from misinterpreting the non-ASCII characters in the encrypted message.

Because this command is just a proof of concept, we omit the encryption context and suppress the metadata (`-S`).

Bash

```
$ encrypted=$(echo 'Hello World' | aws-encryption-cli --encrypt -S \
                                                      --input - --output - --
encode \
                                                      --wrapping-keys key=
$keyArn )
```

PowerShell

```
PS C:\> $encrypted = 'Hello World' | aws-encryption-cli --encrypt -S `
                                                        --input - --output - --
encode `
                                                        --wrapping-keys key=
$keyArn
```

- The third command pipes the encrypted message in the `$encrypted` variable to the decrypt command.

  This decrypt command uses `--input -` to indicate that input is coming from the pipeline (stdin) and `--output -` to send the output to the pipeline (stdout). (The input parameter takes the location of the input, not the actual input bytes, so you cannot use the `$encrypted` variable as the value of the `--input` parameter.)

  This example uses the **discovery** attribute of the `--wrapping-keys` parameter to allow the AWS Encryption CLI to use any AWS KMS key to decrypt the data. It doesn't specify a commitment policy, so it uses the default value for version 2.1.*x* and later, `require-encrypt-require-decrypt`.

Because the output was encrypted and then encoded, the decrypt command uses the `--decode` parameter to decode Base64-encoded input before decrypting it. You can also use the `--decode` parameter to decode Base64-encoded input before encrypting it.

Again, the command omits the encryption context and suppresses the metadata (-S).

Bash

```
$  echo $encrypted | aws-encryption-cli --decrypt --wrapping-keys discovery=true
 --input - --output - --decode --buffer -S
Hello World
```

PowerShell

```
PS C:\> $encrypted | aws-encryption-cli --decrypt --wrapping-keys discovery=$true
 --input - --output - --decode --buffer -S
Hello World
```

You can also perform the encrypt and decrypt operations in a single command without the intervening variable.

As in the previous example, the `--input` and `--output` parameters have a `-` value and the command uses the `--encode` parameter to encode the output and the `--decode` parameter to decode the input.

Bash

```
$  keyArn=arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

$  echo 'Hello World' |
          aws-encryption-cli --encrypt --wrapping-keys key=$keyArn --input - --
output - --encode -S |
          aws-encryption-cli --decrypt --wrapping-keys discovery=true --input - --
output - --decode -S
Hello World
```

PowerShell

```
PS C:\> $keyArn = 'arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'

PS C:\> 'Hello World' |
               aws-encryption-cli --encrypt --wrapping-keys key=$keyArn --input - --
output - --encode -S |
               aws-encryption-cli --decrypt --wrapping-keys discovery=$true --input
 - --output - --decode -S
Hello World
```

Using multiple master keys

This example shows how to use multiple master keys when encrypting and decrypting data in the AWS Encryption CLI.

When you use multiple master keys to encrypt data, any one of the master keys can be used to decrypt the data. This strategy assures that you can decrypt the data even if one of the master keys is unavailable. If you are storing the encrypted data in multiple AWS Regions, this strategy lets you use a master key in the same Region to decrypt the data.

When you encrypt with multiple master keys, the first master key plays a special role. It generates the data key that is used to encrypt the data. The remaining master keys encrypt the plaintext data key. The resulting encrypted message includes the encrypted data and a collection of encrypted data keys, one for each master key. Although the first master key generated the data key, any of the master keys can decrypt one of the data keys, which can be used to decrypt the data.

Encrypting with three master keys

This example command uses three wrapping keys to encrypt the `Finance.log` file, one in each of three AWS Regions.

It writes the encrypted message to the `Archive` directory. The command uses the `--suffix` parameter with no value to suppress the suffix, so the input and output files names will be the same.

The command uses the `--wrapping-keys` parameter with three **key** attributes. You can also use multiple `--wrapping-keys` parameters in the same command.

To encrypt the log file, the AWS Encryption CLI asks the first wrapping key in the list, `$key1`, to generate the data key that it uses to encrypt the data. Then, it uses each of the other wrapping keys to encrypt a plaintext copy of the same data key. The encrypted message in the output file includes all three of the encrypted data keys.

Bash

```
$ key1=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab
$ key2=arn:aws:kms:us-east-2:111122223333:key/0987ab65-43cd-21ef-09ab-87654321cdef
$ key3=arn:aws:kms:ap-
southeast-1:111122223333:key/1a2b3c4d-5e6f-1a2b-3c4d-5e6f1a2b3c4d

$ aws-encryption-cli --encrypt --input /logs/finance.log \
                               --output /archive --suffix \
                               --encryption-context class=log \
                               --metadata-output ~/metadata \
                               --wrapping-keys key=$key1 key=$key2 key=$key3
```

PowerShell

```
PS C:\> $key1 = 'arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'
PS C:\> $key2 = 'arn:aws:kms:us-
east-2:111122223333:key/0987ab65-43cd-21ef-09ab-87654321cdef'
PS C:\> $key3 = 'arn:aws:kms:ap-
southeast-1:111122223333:key/1a2b3c4d-5e6f-1a2b-3c4d-5e6f1a2b3c4d'

PS C:\> aws-encryption-cli --encrypt --input D:\Logs\Finance.log `
                           --output D:\Archive --suffix `
                           --encryption-context class=log `
                           --metadata-output $home\Metadata.txt `
                           --wrapping-keys key=$key1 key=$key2 key=$key3
```

This command decrypts the encrypted copy of the `Finance.log` file and writes it to a `Finance.log.clear` file in the `Finance` directory. To decrypt data encrypted under three AWS KMS keys, you can specify the same three AWS KMS keys or any subset of them. This example specifies only one of the AWS KMS keys.

To tell the AWS Encryption CLI which AWS KMS keys to use to decrypt your data, use the **key** attribute of the `--wrapping-keys` parameter. When decrypting with AWS KMS keys, the value of the **key** attribute must be a key ARN.

You must have permission to call the Decrypt API on the AWS KMS keys you specify. For more information, see Authentication and Access Control for AWS KMS.

As a best practice, this examples use the `--max-encrypted-data-keys` parameter to avoid decrypting a malformed message with an excessive number of encrypted data keys. Even though this example uses only one wrapping key for decryption, the encrypted message has three (3) encrypted data keys; one for each of the three wrapping keys used when encrypting. Specify the expected number of encrypted data keys or a reasonable maximum value, such as 5. If you specify a maximum value less than 3, the command fails. For details, see Limiting encrypted data keys.

Bash

```
$ aws-encryption-cli --decrypt --input /archive/finance.log \
                     --wrapping-keys key=$key1 \
                     --output /finance --suffix '.clear' \
                     --metadata-output ~/metadata \
                     --max-encrypted-data-keys 3 \
                     --buffer \
                     --encryption-context class=log
```

PowerShell

```
PS C:\> aws-encryption-cli --decrypt `
                           --input D:\Archive\Finance.log `
                           --wrapping-keys key=$key1 `
                           --output D:\Finance --suffix '.clear' `
                           --metadata-output .\Metadata\Metadata.txt `
                           --max-encrypted-data-keys 3 `
                           --buffer `
                           --encryption-context class=log
```

Encrypting and decrypting in scripts

This example shows how to use the AWS Encryption CLI in scripts. You can write scripts that just encrypt and decrypt data, or scripts that encrypt or decrypt as part of a data management process.

In this example, the script gets a collection of log files, compresses them, encrypts them, and then copies the encrypted files to an Amazon S3 bucket. This script processes each file separately, so that you can decrypt and expand them independently.

When you compress and encrypt files, be sure to compress before you encrypt. Properly encrypted data is not compressible.

> **Warning**
>
> Be careful when compressing data that includes both secrets and data that might be controlled by a malicious actor. The final size of the compressed data might inadvertently reveal sensitive information about its contents.

Bash

```
# Continue running even if an operation fails.
set +e

dir=$1
encryptionContext=$2
s3bucket=$3
s3folder=$4
masterKeyProvider="aws-kms"
metadataOutput="/tmp/metadata-$(date +%s)"

compress(){
    gzip -qf $1
}

encrypt(){
    # -e encrypt
    # -i input
    # -o output
    # --metadata-output unique file for metadata
    # -m masterKey read from environment variable
    # -c encryption context read from the second argument.
    # -v be verbose
    aws-encryption-cli -e -i ${1} -o $(dirname ${1}) --metadata-output
 ${metadataOutput} -m key="${masterKey}" provider="${masterKeyProvider}" -c
 "${encryptionContext}" -v
}
```

```
s3put (){
    # copy file argument 1 to s3 location passed into the script.
    aws s3 cp ${1} ${s3bucket}/${s3folder}
}

# Validate all required arguments are present.
if [ "${dir}" ] && [ "${encryptionContext}" ] && [ "${s3bucket}" ] &&
 [ "${s3folder}" ] && [ "${masterKey}" ]; then

# Is $dir a valid directory?
test -d "${dir}"
if [ $? -ne 0 ]; then
    echo "Input is not a directory; exiting"
    exit 1
fi

# Iterate over all the files in the directory, except *gz and *encrypted (in case of
 a re-run).
for f in $(find ${dir} -type f \( -name "*" ! -name \*.gz ! -name \*encrypted \) );
 do
    echo "Working on $f"
    compress ${f}
    encrypt ${f}.gz
    rm -f ${f}.gz
    s3put ${f}.gz.encrypted
done;
else
    echo "Arguments: <Directory> <encryption context> <s3://bucketname> <s3 folder>"
    echo " and ENV var \$masterKey must be set"
    exit 255
fi
```

PowerShell

```
#Requires -Modules AWSPowerShell, Microsoft.PowerShell.Archive
Param
(
    [Parameter(Mandatory)]
    [ValidateScript({Test-Path $_})]
    [String[]]
    $FilePath,
```

```
    [Parameter()]
    [Switch]
    $Recurse,

    [Parameter(Mandatory=$true)]
    [String]
    $wrappingKeyID,

    [Parameter()]
    [String]
    $masterKeyProvider = 'aws-kms',

    [Parameter(Mandatory)]
    [ValidateScript({Test-Path $_})]
    [String]
    $ZipDirectory,

    [Parameter(Mandatory)]
    [ValidateScript({Test-Path $_})]
    [String]
    $EncryptDirectory,

    [Parameter()]
    [String]
    $EncryptionContext,

    [Parameter(Mandatory)]
    [ValidateScript({Test-Path $_})]
    [String]
    $MetadataDirectory,

    [Parameter(Mandatory)]
    [ValidateScript({Test-S3Bucket -BucketName $_})]
    [String]
    $S3Bucket,

    [Parameter()]
    [String]
    $S3BucketFolder
)

BEGIN {}
PROCESS {
```

```
    if ($files = dir $FilePath -Recurse:$Recurse)
    {

        # Step 1: Compress
        foreach ($file in $files)
        {
            $fileName = $file.Name
            try
            {
                Microsoft.PowerShell.Archive\Compress-Archive -Path $file.FullName -
DestinationPath $ZipDirectory\$filename.zip
            }
            catch
            {
                Write-Error "Zip failed on $file.FullName"
            }

            # Step 2: Encrypt
            if (-not (Test-Path "$ZipDirectory\$filename.zip"))
            {
                Write-Error "Cannot find zipped file: $ZipDirectory\$filename.zip"
            }
            else
            {
                # 2>&1 captures command output
                $err = (aws-encryption-cli -e -i "$ZipDirectory\$filename.zip" `
                                           -o $EncryptDirectory `
                                           -m key=$wrappingKeyID provider=
$masterKeyProvider `
                                           -c $EncryptionContext `
                                           --metadata-output $MetadataDirectory `
                                           -v) 2>&1

                # Check error status
                if ($? -eq $false)
                {
                    # Write the error
                    $err
                }
                elseif (Test-Path "$EncryptDirectory\$fileName.zip.encrypted")
                {
                    # Step 3: Write to S3 bucket
                    if ($S3BucketFolder)
                    {
```

```
                        Write-S3Object -BucketName $S3Bucket -File
 "$EncryptDirectory\$fileName.zip.encrypted" -Key "$S3BucketFolder/
$fileName.zip.encrypted"

                    }
                    else
                    {
                        Write-S3Object -BucketName $S3Bucket -File
 "$EncryptDirectory\$fileName.zip.encrypted"
                    }
                }
            }
        }
    }
}
```

Using data key caching

This example uses data key caching in a command that encrypts a large number of files.

By default, the AWS Encryption CLI (and other versions of the AWS Encryption SDK) generates a unique data key for each file that it encrypts. Although using a unique data key for each operation is a cryptographic best practice, limited reuse of data keys is acceptable for some situations. If you are considering data key caching, consult with a security engineer to understand the security requirements of your application and determine security thresholds that are right for you.

In this example, data key caching speeds up the encryption operation by reducing the frequency of requests to the master key provider.

The command in this example encrypts a large directory with multiple subdirectories that contain a total of approximately 800 small log files. The first command saves the ARN of the AWS KMS key in a `keyARN` variable. The second command encrypts all of the files in the input directory (recursively) and writes them to an archive directory. The command uses the `--suffix` parameter to specify the `.archive` suffix.

The `--caching` parameter enables data key caching. The **capacity** attribute, which limits the number of data keys in the cache, is set to 1, because serial file processing never uses more than one data key at a time. The **max_age** attribute, which determines how long the cached data key can used, is set to 10 seconds.

The optional **max_messages_encrypted** attribute is set to 10 messages, so a single data key is never used to encrypt more than 10 files. Limiting the number of files encrypted by each data key reduces the number of files that would be affected in the unlikely event that a data key was compromised.

To run this command on log files that your operating system generates, you might need administrator permissions (sudo in Linux; **Run as Administrator** in Windows).

Bash

```
$  keyArn=arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

$  aws-encryption-cli --encrypt \
                      --input /var/log/httpd --recursive \
                      --output ~/archive --suffix .archive \
                      --wrapping-keys key=$keyArn \
                      --encryption-context class=log \
                      --suppress-metadata \
                      --caching capacity=1 max_age=10 max_messages_encrypted=10
```

PowerShell

```
PS C:\> $keyARN = 'arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab'

PS C:\> aws-encryption-cli --encrypt `
                           --input C:\Windows\Logs --recursive `
                           --output $home\Archive --suffix '.archive' `
                           --wrapping-keys key=$keyARN `
                           --encryption-context class=log `
                           --suppress-metadata `
                           --caching capacity=1 max_age=10
 max_messages_encrypted=10
```

To test the effect of data key caching, this example uses the Measure-Command cmdlet in PowerShell. When you run this example without data key caching, it takes about 25 seconds to complete. This process generates a new data key for each file in the directory.

```
PS C:\> Measure-Command {aws-encryption-cli --encrypt `
```

```
                                                --input C:\Windows\Logs --recursive `
                                                --output $home\Archive  --suffix '.archive'
 `
                                                --wrapping-keys key=$keyARN `
                                                --encryption-context class=log `
                                                --suppress-metadata }


Days              : 0
Hours             : 0
Minutes           : 0
Seconds           : 25
Milliseconds      : 453
Ticks             : 254531202
TotalDays         : 0.000294596298611111
TotalHours        : 0.00707031116666667
TotalMinutes      : 0.42421867
TotalSeconds      : 25.4531202
TotalMilliseconds : 25453.1202
```

Data key caching makes the process quicker, even when you limit each data key to a maximum of 10 files. The command now takes less than 12 seconds to complete and reduces the number of calls to the master key provider to 1/10 of the original value.

```
PS C:\> Measure-Command {aws-encryption-cli --encrypt `
                                                --input C:\Windows\Logs --recursive `
                                                --output $home\Archive  --suffix '.archive'
 `
                                                --wrapping-keys key=$keyARN `
                                                --encryption-context class=log `
                                                --suppress-metadata `
                                                --caching capacity=1 max_age=10
 max_messages_encrypted=10}


Days              : 0
Hours             : 0
Minutes           : 0
Seconds           : 11
Milliseconds      : 813
Ticks             : 118132640
TotalDays         : 0.000136727592592593
TotalHours        : 0.00328146222222222
```

```
TotalMinutes      : 0.196887733333333
TotalSeconds      : 11.813264
TotalMilliseconds : 11813.264
```

If you eliminate the `max_messages_encrypted` restriction, all files are encrypted under the same data key. This change increases the risk of reusing data keys without making the process much faster. However, it reduces the number of calls to the master key provider to 1.

```
PS C:\> Measure-Command {aws-encryption-cli --encrypt `
                                            --input C:\Windows\Logs --recursive `
                                            --output $home\Archive  --suffix '.archive'
 `
                                            --wrapping-keys key=$keyARN `
                                            --encryption-context class=log `
                                            --suppress-metadata `
                                            --caching capacity=1 max_age=10}



Days              : 0
Hours             : 0
Minutes           : 0
Seconds           : 10
Milliseconds      : 252
Ticks             : 102523367
TotalDays         : 0.000118661304398148
TotalHours        : 0.00284787130555556
TotalMinutes      : 0.170872278333333
TotalSeconds      : 10.2523367
TotalMilliseconds : 10252.3367
```

AWS Encryption SDK CLI syntax and parameter reference

This topic provides syntax diagrams and brief parameter descriptions to help you use the AWS Encryption SDK Command Line Interface (CLI). For help with wrapping keys and other parameters, see How to use the AWS Encryption CLI. For examples, see Examples of the AWS Encryption CLI. For complete documentation, see Read the Docs.

Topics

- AWS Encryption CLI syntax
- AWS Encryption CLI command line parameters

- Advanced parameters

AWS Encryption CLI syntax

These AWS Encryption CLI syntax diagrams show the syntax for each task that you perform with the AWS Encryption CLI. They represent recommended syntax in AWS Encryption CLI version 2.1.*x* and later.

New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

> **Note**
>
> Unless noted in the parameter description, each parameter or attribute can be used only once in each command.
> If you use an attribute that a parameter does not support, the AWS Encryption CLI ignores that unsupported attribute without a warning or error.

Get help

To get the full AWS Encryption CLI syntax with parameter descriptions, use `--help` or `-h`.

```
aws-encryption-cli (--help | -h)
```

Get the version

To get the version number of your AWS Encryption CLI installation, use `--version`. Be sure to include the version when you ask questions, report problems, or share tips about using the AWS Encryption CLI.

```
aws-encryption-cli --version
```

Encrypt data

The following syntax diagram shows the parameters that an **encrypt** command uses.

```
aws-encryption-cli --encrypt
                   --input <input> [--recursive] [--decode]
                   --output <output> [--interactive] [--no-overwrite] [--suffix
 [<suffix>]] [--encode]
                   --wrapping-keys  [--wrapping-keys] ...
                       key=<keyID> [key=<keyID>] ...
                       [provider=<provider-name>] [region=<aws-region>]
 [profile=<aws-profile>]
                   --metadata-output <location> [--overwrite-metadata] | --suppress-
metadata]
                   [--commitment-policy <commitment-policy>]
                   [--encryption-context <encryption_context> [<encryption_context>
 ...]]
                   [--max-encrypted-data-keys <integer>]
                   [--algorithm <algorithm_suite>]
                   [--caching <attributes>]
                   [--frame-length <length>]
                   [-v | -vv | -vvv | -vvvv]
                   [--quiet]
```

Decrypt data

The following syntax diagram shows the parameters that a **decrypt** command uses.

In version 1.8.*x*, the `--wrapping-keys` parameter is optional when decrypting, but recommended. Beginning in version 2.1.*x*, the `--wrapping-keys` parameter is required when encrypting and decrypting. For AWS KMS keys, you can use the **key** attribute to specify wrapping keys (best practice) or set the **discovery** attribute to `true`, which doesn't limit the wrapping keys that the AWS Encryption CLI can use.

```
aws-encryption-cli --decrypt (or [--decrypt-unsigned])
                   --input <input> [--recursive] [--decode]
                   --output <output> [--interactive] [--no-overwrite]  [--suffix
 [<suffix>]] [--encode]
                   --wrapping-keys  [--wrapping-keys] ...
                       [key=<keyID>] [key=<keyID>] ...
                       [discovery={true|false}] [discovery-partition=<aws-partition-
name> discovery-account=<aws-account-ID> [discovery-account=<aws-account-ID>] ...]
                       [provider=<provider-name>] [region=<aws-region>]
 [profile=<aws-profile>]
                   --metadata-output <location> [--overwrite-metadata] | --suppress-
metadata]
```

```
                    [--commitment-policy <commitment-policy>]
                    [--encryption-context <encryption_context> [<encryption_context>
 ...]]
                    [--buffer]
                    [--max-encrypted-data-keys <integer>]
                    [--caching <attributes>]
                    [--max-length <length>]
                    [-v | -vv | -vvv | -vvvv]
                    [--quiet]
```

Use configuration files

You can refer to configuration files that contain parameters and their values. This is equivalent to typing the parameters and values in the command. For an example, see How to store parameters in a configuration file.

```
aws-encryption-cli @<configuration_file>

# In a PowerShell console, use a backtick to escape the @.
aws-encryption-cli `@<configuration_file>
```

AWS Encryption CLI command line parameters

This list provides a basic description of the AWS Encryption CLI command parameters. For a complete description, see the aws-encryption-sdk-cli documentation.

--encrypt (-e)

Encrypts the input data. Every command must have an `--encrypt`, or `--decrypt`, or `--decrypt-unsigned` parameter.

--decrypt (-d)

Decrypts the input data. Every command must have an `--encrypt`, `--decrypt`, or `--decrypt-unsigned` parameter.

--decrypt-unsigned [Introduced in versions 1.9.*x* and 2.2.*x*]

The `--decrypt-unsigned` parameter decrypts ciphertext and ensures that messages are unsigned before decryption. Use this parameter if you used the `--algorithm` parameter and

selected an algorithm suite without digital signing to encrypt data. If the ciphertext is signed, decryption fails.

You can use `--decrypt` or `--decrypt-unsigned` for decryption but not both.

--wrapping-keys (-w) [Introduced in version 1.8.*x*]

Specifies the wrapping keys (or *master keys*) used in encryption and decryption operations. You can use multiple `--wrapping-keys` parameters in each command.

Beginning in version 2.1.*x*, the `--wrapping-keys` parameter is required in encrypt and decrypt commands. In version 1.8.*x*, encrypt commands require either a `--wrapping-keys` or `--master-keys` parameter. In version 1.8.*x* decrypt commands, a `--wrapping-keys` parameter is optional but recommended.

When using a custom master key provider, encrypt and decrypt commands require **key** and **provider** attributes. When using AWS KMS keys, encrypt commands require a **key** attribute. Decrypt commands require a **key** attribute or a **discovery** attribute with a value of `true` (but not both). Using the **key** attribute when decrypting is an AWS Encryption SDK best practice. It is particularly important if you're decrypting batches of unfamiliar messages, such as those in an Amazon S3 bucket or an Amazon SQS queue.

For an example showing how to use AWS KMS multi-Region keys as wrapping keys, see Using multi-Region AWS KMS keys.

Attributes: The value of the `--wrapping-keys` parameter consists of the following attributes. The format is `attribute_name=value`.

key

Identifies the wrapping key used in the operation. The format is a **key**=ID pair. You can specify multiple **key** attributes in each `--wrapping-keys` parameter value.

- **Encrypt commands**: All encrypt commands require the **key** attribute . When you use an AWS KMS key in an encrypt command, the value of the **key** attribute can be a key ID, key ARN, an alias name, or an alias ARN. For descriptions of the AWS KMS key identifiers, see Key identifiers in the *AWS Key Management Service Developer Guide*.
- **Decrypt commands**: When decrypting with AWS KMS keys, the `--wrapping-keys` parameter requires a **key** attribute with a key ARN value or a **discovery** attribute with a value of `true` (but not both). Using the **key** attribute is an AWS Encryption SDK best practice. When decrypting with a custom master key provider, the **key** attribute is required.

> **Note**
>
> To specify an AWS KMS wrapping key in a decrypt command, the value of the **key** attribute must be a key ARN. If you use a key ID, alias name, or alias ARN, the AWS Encryption CLI does not recognize the wrapping key.

You can specify multiple **key** attributes in each `--wrapping-keys` parameter value. However, any **provider**, **region**, and **profile** attributes in a `--wrapping-keys` parameter apply to all wrapping keys in that parameter value. To specify wrapping keys with different attribute values, use multiple `--wrapping-keys` parameters in the command.

discovery

Allows the AWS Encryption CLI to use any AWS KMS key to decrypt the message. The **discovery** value can be `true` or `false`. The default value is `false`. The **discovery** attribute is valid only in decrypt commands and only when the master key provider is AWS KMS.

When decrypting with AWS KMS keys, the `--wrapping-keys` parameter requires a **key** attribute or a **discovery** attribute with a value of `true` (but not both). If you use the **key** attribute, you can use a **discovery** attribute with a value of `false` to explicitly reject discovery.

- `False` (default) — When the **discovery** attribute isn't specified or its value is `false`, the AWS Encryption CLI decrypts the message using only the AWS KMS keys specified by the **key** attribute of the `--wrapping-keys` parameter. If you don't specify a **key** attribute when discovery is `false`, the decrypt command fails. This value supports an AWS Encryption CLI best practice.
- `True` — When the value of the **discovery** attribute is `true`, the AWS Encryption CLI gets the AWS KMS keys from metadata in the encrypted message, and uses those AWS KMS keys to decrypt the message. The **discovery** attribute with a value of `true` behaves like versions of the AWS Encryption CLI before version 1.8.*x* that didn't permit you to specify a wrapping key when decrypting. However, your intent to use any AWS KMS key is explicit. If you specify a **key** attribute when discovery is `true`, the decrypt command fails.

  The `true` value might cause the AWS Encryption CLI to use AWS KMS keys in different AWS accounts and Regions, or attempt to use AWS KMS keys that the user isn't authorized to use.

When **discovery** is `true`, it's a best practice to use the **discovery-partition** and **discovery-account** attributes to limit the AWS KMS keys used to those in the AWS accounts you specify.

discovery-account

Limits the AWS KMS keys used for decrypting to those in the specified AWS account. The only valid value for this attribute is an AWS account ID.

This attribute is optional and valid only in decrypt commands with AWS KMS keys where the **discovery** attribute is set to `true` and the **discovery-partition** attribute is specified.

Each **discovery-account** attribute takes just one AWS account ID, but you can specify multiple **discovery-account** attributes in the same `--wrapping-keys` parameter. All accounts specified in a given `--wrapping-keys` parameter must be in the specified AWS partition.

discovery-partition

Specifies the AWS partition for the accounts in the **discovery-account** attribute. Its value must be an AWS partition, such as `aws`, `aws-cn`, or `aws-gov-cloud`. For information, see Amazon Resource Names in the *AWS General Reference*.

This attribute is required when you use the **discovery-account** attribute. You can specify only one **discovery-partition** attribute in each `--wrapping keys` parameter. To specify AWS accounts in multiple partitions, use an additional `--wrapping-keys` parameter.

provider

Identifies the master key provider. The format is a **provider**=ID pair. The default value, **aws-kms**, represents AWS KMS. This attribute is required only when the master key provider is not AWS KMS.

region

Identifies the AWS Region of an AWS KMS key. This attribute is valid only for AWS KMS keys. It is used only when the **key** identifier does not specify a Region; otherwise, it is ignored. When it is used, it overrides the default Region in the AWS CLI named profile.

profile

Identifies an AWS CLI named profile. This attribute is valid only for AWS KMS keys. The Region in the profile is used only when the key identifier does not specify a Region and there is no **region** attribute in the command.

--input (-i)

Specifies the location of the data to encrypt or decrypt. This parameter is required. The value can be a path to a file or directory, or a file name pattern. If you are piping input to the command (stdin), use `-`.

If the input does not exist, the command completes successfully without error or warning.

--recursive (-r, -R)

Performs the operation on files in the input directory and its subdirectories. This parameter is required when the value of `--input` is a directory.

--decode

Decodes Base64-encoded input.

If you are decrypting a message that was encrypted and then encoded, you must decode the message before decrypting it. This parameter does that for you.

For example, if you used the `--encode` parameter in an encrypt command, use the `--decode` parameter in the corresponding decrypt command. You can also use this parameter to decode Base64-encoded input before you encrypt it.

--output (-o)

Specifies a destination for the output. This parameter is required. The value can be a file name, an existing directory, or `-`, which writes output to the command line (stdout).

If the specified output directory does not exist, the command fails. If the input contains subdirectories, the AWS Encryption CLI reproduces the subdirectories under the output directory that you specify.

By default, the AWS Encryption CLI overwrites files with the same name. To change that behavior, use the `--interactive` or `--no-overwrite` parameters. To suppress the overwrite warning, use the `--quiet` parameter.

> **Note**
>
> If a command that would overwrite an output file fails, the output file is deleted.

--interactive

Prompts before overwriting the file.

--no-overwrite

Does not overwrite files. Instead, if the output file exists, the AWS Encryption CLI skips the corresponding input.

--suffix

Specifies a custom file name suffix for files that the AWS Encryption CLI creates. To indicate no suffix, use the parameter with no value (`--suffix`).

By default, when the `--output` parameter does not specify a file name, the output file name has the same name as the input file name plus the suffix. The suffix for encrypt commands is `.encrypted`. The suffix for decrypt commands is `.decrypted`.

--encode

Applies Base64 (binary to text) encoding to the output. Encoding prevents the shell host program from misinterpreting non-ASCII characters in output text.

Use this parameter when writing encrypted output to stdout (`--output -`), especially in a PowerShell console, even when you are piping the output to another command or saving it in a variable.

--metadata-output

Specifies a location for metadata about the cryptographic operations. Enter a path and file name. If the directory does not exist, the command fails. To write the metadata to the command line (stdout), use `-`.

You cannot write command output (`--output`) and metadata output (`--metadata-output`) to stdout in the same command. Also, when the value of `--input` or `--output` is a directory (without file names), you cannot write the metadata output to the same directory or to any subdirectory of that directory.

If you specify an existing file, by default, the AWS Encryption CLI appends new metadata records to any content in the file. This feature lets you create a single file that contains the metadata for all of your cryptographic operations. To overwrite the content in an existing file, use the `--overwrite-metadata` parameter.

The AWS Encryption CLI returns a JSON-formatted metadata record for each encryption or decryption operation that the command performs. Each metadata record includes the full paths to the input and output file, the encryption context, the algorithm suite, and other valuable information that you can use to review the operation and verify that it meets your security standards.

--overwrite-metadata

Overwrites the content in the metadata output file. By default, the `--metadata-output` parameter appends metadata to any existing content in the file.

--suppress-metadata (-S)

Suppresses the metadata about the encryption or decryption operation.

--commitment-policy

Specifies the commitment policy for encrypt and decrypt commands. The commitment policy determines whether your message is encrypted and decrypted with the key commitment security feature.

The `--commitment-policy` parameter is introduced in version 1.8.*x*. It is valid in encrypt and decrypt commands.

In version 1.8.*x*, the AWS Encryption CLI uses the `forbid-encrypt-allow-decrypt` commitment policy for all encrypt and decrypt operations. When you use the `--wrapping-keys` parameter in an encrypt or decrypt command, a `--commitment-policy` parameter with the `forbid-encrypt-allow-decrypt` value is required. If you don't use the `--wrapping-keys` parameter, the `--commitment-policy` parameter is invalid. Setting a commitment policy explicitly prevents your commitment policy from changing automatically to `require-encrypt-require-decrypt` when you upgrade to version 2.1.*x*

Beginning in **version 2.1.*x***, all commitment policy values are supported. The `--commitment-policy` parameter is optional and the default value is `require-encrypt-require-decrypt`.

This parameter has the following values:

- `forbid-encrypt-allow-decrypt` — Cannot encrypt with key commitment. It can decrypt ciphertexts encrypted with or without key commitment.

  In version 1.8.*x*, this is the only valid value. The AWS Encryption CLI uses the `forbid-encrypt-allow-decrypt` commitment policy for all encrypt and decrypt operations.

- `require-encrypt-allow-decrypt` — Encrypts only with key commitment. Decrypts with and without key commitment. This value is introduced in version 2.1.*x*.
- `require-encrypt-require-decrypt` (default) — Encrypts and decrypts only with key commitment. This value is introduced in version 2.1.*x*. It is the default value in versions 2.1.*x* and later. With this value, the AWS Encryption CLI will not decrypt any ciphertext that was encrypted with earlier versions of the AWS Encryption SDK.

For detailed information about setting your commitment policy, see Migrating your AWS Encryption SDK.

--encryption-context (-c)

Specifies an encryption context for the operation. This parameter is not required, but it is recommended.

- In an `--encrypt` command, enter one or more `name=value` pairs. Use spaces to separate the pairs.
- In a `--decrypt` command, enter `name=value` pairs, `name` elements with no values, or both.

If the `name` or `value` in a `name=value` pair includes spaces or special characters, enclose the entire pair in quotation marks. For example, `--encryption-context "department=software development"`.

--buffer (-b) [Introduced in versions 1.9.*x* and 2.2.*x*]

Returns plaintext only after all input is processed, including verifying the digital signature if one is present.

--max-encrypted-data-keys [Introduced in versions 1.9.*x* and 2.2.*x*]

Specifies the maximum number of encrypted data keys in an encrypted message. This parameter is optional.

Valid values are 1 – 65,535. If you omit this parameter, the AWS Encryption CLI does not enforce any maximum. An encrypted message can hold up to 65,535 (2^16 - 1) encrypted data keys.

You can use this parameter in encrypt commands to prevent a malformed message. You can use it in decrypt commands to detect malicious messages and avoid decrypting messages with numerous encrypted data keys that you can't decrypt. For details and an example, see Limiting encrypted data keys.

--help (-h)

Prints usage and syntax at the command line.

--version

Gets the version of the AWS Encryption CLI.

-v | -vv | -vvv | -vvvv

Displays verbose information, warning, and debugging messages. The detail in the output increases with the number of `v`s in the parameter. The most detailed setting (`-vvvv`) returns debugging-level data from the AWS Encryption CLI and all of the components that it uses.

--quiet (-q)

Suppresses warning messages, such as the message that appears when you overwrite an output file.

--master-keys (-m) [Deprecated]

> **Note**
>
> The --master-keys parameter is deprecated in 1.8.*x* and removed in version 2.1.*x*. Instead, use the --wrapping-keys parameter.

Specifies the master keys used in encryption and decryption operations. You can use multiple master keys parameters in each command.

The `--master-keys` parameter is required in encrypt commands. It is required in decrypt commands only when you are using a custom (non-AWS KMS) master key provider.

Attributes: The value of the `--master-keys` parameter consists of the following attributes. The format is `attribute_name=value`.

key

Identifies the wrapping key used in the operation. The format is a **key**=ID pair. The **key** attribute is required in all encrypt commands.

When you use an AWS KMS key in an encrypt command, the value of the **key** attribute can be a key ID, key ARN, an alias name, or an alias ARN. For details about AWS KMS key identifiers, see Key identifiers in the *AWS Key Management Service Developer Guide*.

The **key** attribute is required in decrypt commands when the master key provider is not AWS KMS. The **key** attribute is not permitted in commands that decrypt data that was encrypted under an AWS KMS key.

You can specify multiple **key** attributes in each `--master-keys` parameter value. However, any **provider**, **region**, and **profile** attributes apply to all master keys in the parameter value. To specify master keys with different attribute values, use multiple `--master-keys` parameters in the command.

provider

Identifies the master key provider. The format is a **provider**=ID pair. The default value, **aws-kms**, represents AWS KMS. This attribute is required only when the master key provider is not AWS KMS.

region

Identifies the AWS Region of an AWS KMS key. This attribute is valid only for AWS KMS keys. It is used only when the **key** identifier does not specify a Region; otherwise, it is ignored. When it is used, it overrides the default Region in the AWS CLI named profile.

profile

Identifies an AWS CLI named profile. This attribute is valid only for AWS KMS keys. The Region in the profile is used only when the key identifier does not specify a Region and there is no **region** attribute in the command.

Advanced parameters

--algorithm

Specifies an alternate algorithm suite. This parameter is optional and valid only in encrypt commands.

If you omit this parameter, the AWS Encryption CLI uses one of the default algorithm suites for the AWS Encryption SDK introduced in version 1.8.*x*. Both default algorithms use AES-GCM with an HKDF, an ECDSA signature, and a 256-bit encryption key. One uses key commitment; one does not. The choice of default algorithm suite is determined by the commitment policy for the command.

The default algorithm suites are recommended for most encryption operations. For a list of valid values, see the values for the `algorithm` parameter in Read the Docs.

--frame-length

Creates output with specified frame length. This parameter is optional and valid only in encrypt commands.

Enter a value in bytes. Valid values are 0 and 1 – 2^31 - 1. A value of 0 indicates nonframed data. The default is 4096 (bytes).

> **Note**
>
> Whenever possible, use framed data. The AWS Encryption SDK supports nonframed data only for legacy use. Some language implementations of the AWS Encryption SDK can still generate nonframed ciphertext. All supported language implementations can decrypt framed and nonframed ciphertext.

--max-length

Indicates the maximum frame size (or maximum content length for nonframed messages) in bytes to read from encrypted messages. This parameter is optional and valid only in decrypt commands. It is designed to protect you from decrypting extremely large malicious ciphertext.

Enter a value in bytes. If you omit this parameter, the AWS Encryption SDK does not limit the frame size when decrypting.

--caching

Enables the data key caching feature, which reuses data keys, instead of generating a new data key for each input file. This parameter supports an advanced scenario. Be sure to read the Data Key Caching documentation before using this feature.

The `--caching` parameter has the following attributes.

capacity (required)

Determines the maximum number of entries in the cache.

The minimum value is 1. There is no maximum value.

max_age (required)

Determine how long cache entries are used, in seconds, beginning when they are added to the cache.

Enter a value greater than 0. There is no maximum value.

max_messages_encrypted (optional)

Determines the maximum number of messages that a cached entry can encrypt.

Valid values are 1 – 2^32. The default value is 2^32 (messages).

max_bytes_encrypted (optional)

Determines the maximum number of bytes that a cached entry can encrypt.

Valid values are 0 and 1 – 2^63 - 1. The default value is 2^63 - 1 (messages). A value of 0 lets you use data key caching only when you are encrypting empty message strings.

Versions of the AWS Encryption CLI

We recommend that you use the latest version of the AWS Encryption CLI.

> **Note**
>
> Versions of the AWS Encryption CLI earlier than 4.0.0 are in the end-of-support phase. You can safely update from version 2.1.*x* and later to the latest version of the AWS Encryption CLI without any code or data changes. However, new security features introduced in version 2.1.*x* are not backward-compatible. To update from version 1.7.*x* or earlier, you must first update to the latest 1.*x* version of the AWS Encryption CLI. For details, see Migrating your AWS Encryption SDK.
> New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

For information about significant versions of the AWS Encryption SDK, see Versions of the AWS Encryption SDK.

Which version do I use?

If you're new to the AWS Encryption CLI, use the latest version.

To decrypt data encrypted by a version of the AWS Encryption SDK earlier than version 1.7.*x*, migrate first to the latest version of the AWS Encryption CLI. Make all recommended changes before updating to version 2.1.*x* or later. For details, see Migrating your AWS Encryption SDK.

Learn more

- For detailed information about the changes and guidance for migrating to these new versions, see Migrating your AWS Encryption SDK.
- For descriptions of the new AWS Encryption CLI parameters and attributes, see AWS Encryption SDK CLI syntax and parameter reference.

The following lists describe the change to the AWS Encryption CLI in versions 1.8.*x* and 2.1.*x*.

Version 1.8.*x* changes to the AWS Encryption CLI

- Deprecates the `--master-keys` parameter. Instead, use the `--wrapping-keys` parameter.
- Adds the `--wrapping-keys` (`-w`) parameter. It supports all attributes of the `--master-keys` parameter. It also adds the following optional attributes, which are valid only when decrypting with AWS KMS keys.
  - **discovery**
  - **discovery-partition**
  - **discovery-account**

  For custom master key providers, `--encrypt` and `--decrypt` commands require either a `--wrapping-keys` parameter or a `--master-keys` parameter (but not both). Also, an `--encrypt` command with AWS KMS keys requires either a `--wrapping-keys` parameter or a `--master-keys` parameter (but not both).

  In a `--decrypt` command with AWS KMS keys, the `--wrapping-keys` parameter is optional, but recommended, because it is required in version 2.1.*x*. If you use it, you must specify either the **key** attribute or the **discovery** attribute with a value of `true` (but not both).
- Adds the `--commitment-policy` parameter. The only valid value is `forbid-encrypt-allow-decrypt`. The `forbid-encrypt-allow-decrypt` commitment policy is used in all encrypt and decrypt commands.

  In version 1.8.*x*, when you use the `--wrapping-keys` parameter, a `--commitment-policy` parameter with the `forbid-encrypt-allow-decrypt` value is required. Setting the value

explicitly prevents your commitment policy from changing automatically to `require-encrypt-require-decrypt` when you upgrade to version 2.1.*x*.

Version 2.1.*x* changes to the AWS Encryption CLI

- Removes the `--master-keys` parameter. Instead, use the `--wrapping-keys` parameter.
- The `--wrapping-keys` parameter is required in all encrypt and decrypt commands. You must specify either a **key** attribute or a **discovery** attribute with a value of `true` (but not both).
- The `--commitment-policy` parameter supports the following values. For details, see Setting your commitment policy.
  - `forbid-encrypt-allow-decrypt`
  - `require-encrypt-allow-decrypt`
  - `require-encrypt-require decrypt` (Default)
- The `--commitment-policy` parameter is optional in version 2.1.*x*. The default value is `require-encrypt-require-decrypt`.

Version 1.9.*x* and 2.2.*x* changes to the AWS Encryption CLI

- Adds the `--decrypt-unsigned` parameter. For details, see Version 2.2.*x*.
- Adds the `--buffer` parameter. For details, see Version 2.2.*x*.
- Adds the `--max-encrypted-data-keys` parameter. For details, see Limiting encrypted data keys.

Version 3.0.*x* changes to the AWS Encryption CLI

- Adds support for AWS KMS multi-Region keys. For details, see Using multi-Region AWS KMS keys.

Data key caching

Data key caching stores data keys and related cryptographic material in a cache. When you encrypt or decrypt data, the AWS Encryption SDK looks for a matching data key in the cache. If it finds a match, it uses the cached data key rather than generating a new one. Data key caching can improve performance, reduce cost, and help you stay within service limits as your application scales.

Your application can benefit from data key caching if:

- It can reuse data keys.
- It generates numerous data keys.
- Your cryptographic operations are unacceptably slow, expensive, limited, or resource-intensive.

Caching can reduce your use of cryptographic services, such as AWS Key Management Service (AWS KMS). If you are hitting your AWS KMS requests-per-second limit, caching can help. Your application can use cached keys to service some of your data key requests instead of calling AWS KMS. (You can also create a case in the AWS Support Center to raise the limit for your account.)

The AWS Encryption SDK helps you to create and manage your data key cache. It provides a local cache and a caching cryptographic materials manager (caching CMM) that interacts with the cache and enforces security thresholds that you set. Working together, these components help you to benefit from the efficiency of reusing data keys while maintaining the security of your system.

Data key caching is an optional feature of the AWS Encryption SDK that you should use cautiously. By default, the AWS Encryption SDK generates a new data key for every encryption operation. This technique supports cryptographic best practices, which discourage excessive reuse of data keys. In general, use data key caching only when it is required to meet your performance goals. Then, use the data key caching security thresholds to ensure that you use the minimum amount of caching required to meet your cost and performance goals.

Version 3.*x* of the AWS Encryption SDK for Java only supports the caching CMM with the legacy master key providers interface, not the keyring interface. However, version 4.*x* of the AWS Encryption SDK for .NET, version 3.*x* of the AWS Encryption SDK for Java, version 4.*x* of the AWS Encryption SDK for Python, version 1.*x* of the AWS Encryption SDK for Rust and version 0.1.*x* or later of the AWS Encryption SDK for Go support the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution. Content encrypted with the AWS KMS Hierarchical keyring can only be decrypted with the AWS KMS Hierarchical keyring.

For a detailed discussion of these security tradeoffs, see AWS Encryption SDK: How to Decide if Data Key Caching is Right for Your Application in the AWS Security Blog.

Topics

- How to use data key caching
- Setting cache security thresholds
- Data key caching details
- Data key caching example

How to use data key caching

This topic shows you how to use data key caching in your application. It takes you through the process step by step. Then, it combines the steps in a simple example that uses data key caching in an operation to encrypt a string.

The examples in this section show how to use version 2.0.*x* and later of the AWS Encryption SDK. For examples that use earlier versions, find your release in the Releases list of the GitHub repository for your programming language.

For complete and tested examples of using data key caching in the AWS Encryption SDK, see:

- C/C++: caching_cmm.cpp
- Java: SimpleDataKeyCachingExample.java
- JavaScript Browser: caching_cmm.ts
- JavaScript Node.js: caching_cmm.ts
- Python: data_key_caching_basic.py

The AWS Encryption SDK for .NET does not support data key caching.

Topics

- Using data key caching: Step-by-step
- Data key caching example: Encrypt a string

Using data key caching: Step-by-step

These step-by-step instructions show you how to create the components that you need to implement data key caching.

- Create a data key cache. In these examples, we use the local cache that the AWS Encryption SDK provides. We limit the cache to 10 data keys.

C

```
// Cache capacity (maximum number of entries) is required
size_t cache_capacity = 10;
struct aws_allocator *allocator = aws_default_allocator();

struct aws_cryptosdk_materials_cache *cache =
 aws_cryptosdk_materials_cache_local_new(allocator, cache_capacity);
```

Java

The following example uses version 2.*x* of the AWS Encryption SDK for Java. Version 3.*x* of the AWS Encryption SDK for Java deprecates the data key caching CMM. With version 3.*x*, you can also use the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.

```
// Cache capacity (maximum number of entries) is required
int MAX_CACHE_SIZE = 10;

CryptoMaterialsCache cache = new LocalCryptoMaterialsCache(MAX_CACHE_SIZE);
```

JavaScript Browser

```
const capacity = 10

const cache = getLocalCryptographicMaterialsCache(capacity)
```

JavaScript Node.js

```
const capacity = 10
```

```
const cache = getLocalCryptographicMaterialsCache(capacity)
```

Python

```
# Cache capacity (maximum number of entries) is required
MAX_CACHE_SIZE = 10

cache = aws_encryption_sdk.LocalCryptoMaterialsCache(MAX_CACHE_SIZE)
```

- Create a master key provider (Java and Python) or a keyring (C and JavaScript). These examples use an AWS Key Management Service (AWS KMS) master key provider or a compatible AWS KMS keyring.

C

```
// Create an AWS KMS keyring
//   The input is the Amazon Resource Name (ARN)
//   of an AWS KMS key

struct aws_cryptosdk_keyring *kms_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder().Build(kms_key_arn);
```

Java

The following example uses version 2.*x* of the AWS Encryption SDK for Java. Version 3.*x* of the AWS Encryption SDK for Java deprecates the data key caching CMM. With version 3.*x*, you can also use the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.

```
// Create an AWS KMS master key provider
//   The input is the Amazon Resource Name (ARN)
//   of an AWS KMS key

MasterKeyProvider<KmsMasterKey> keyProvider =
 KmsMasterKeyProvider.builder().buildStrict(kmsKeyArn);
```

JavaScript Browser

In the browser, you must inject your credentials securely. This example defines credentials in a webpack (kms.webpack.config) that resolves credentials at runtime. It creates an AWS KMS client provider instance from an AWS KMS client and the credentials. Then, when it creates the keyring, it passes the client provider to the constructor along with the AWS KMS key (`generatorKeyId`).

```
const { accessKeyId, secretAccessKey, sessionToken } = credentials

const clientProvider = getClient(KMS, {
    credentials: {
      accessKeyId,
      secretAccessKey,
      sessionToken
    }
  })

/*  Create an AWS KMS keyring
 *  You must configure the AWS KMS keyring with at least one AWS KMS key
 *  The input is the Amazon Resource Name (ARN)
 */ of an AWS KMS key

const keyring = new KmsKeyringBrowser({
    clientProvider,
    generatorKeyId,
    keyIds,
  })
```

JavaScript Node.js

```
/* Create an AWS KMS keyring
 *   The input is the Amazon Resource Name (ARN)
*/   of an AWS KMS key

const keyring = new KmsKeyringNode({ generatorKeyId })
```

Python

```
# Create an AWS KMS master key provider
#  The input is the Amazon Resource Name (ARN)
```

```
#  of an AWS KMS key

key_provider =
 aws_encryption_sdk.StrictAwsKmsMasterKeyProvider(key_ids=[kms_key_arn])
```

- Create a caching cryptographic materials manager (caching CMM).

  Associate your caching CMM with your cache and your master key provider or keyring. Then, set cache security thresholds on the caching CMM.

  C

  In the AWS Encryption SDK for C, you can create a caching CMM from an underlying CMM, such as the default CMM, or from a keyring. This example creates the caching CMM from a keyring.

  After you create the caching CMM, you can release your references to the keyring and the cache. For details, see the section called "Reference counting".

```
// Create the caching CMM
//   Set the partition ID to NULL.
//   Set the required maximum age value to 60 seconds.
struct aws_cryptosdk_cmm *caching_cmm =
 aws_cryptosdk_caching_cmm_new_from_keyring(allocator, cache, kms_keyring, NULL,
 60, AWS_TIMESTAMP_SECS);

// Add an optional message threshold
//   The cached data key will not be used for more than 10 messages.
aws_status = aws_cryptosdk_caching_cmm_set_limit_messages(caching_cmm, 10);

// Release your references to the cache and the keyring.
aws_cryptosdk_materials_cache_release(cache);
aws_cryptosdk_keyring_release(kms_keyring);
```

Java

The following example uses version 2.*x* of the AWS Encryption SDK for Java. Version 3.*x* of the AWS Encryption SDK for Java does not support data key caching, but it does support the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.

```
/*
 * Security thresholds
 *   Max entry age is required.
 *   Max messages (and max bytes) per entry are optional
 */
int MAX_ENTRY_AGE_SECONDS = 60;
int MAX_ENTRY_MSGS = 10;

//Create a caching CMM
CryptoMaterialsManager cachingCmm =
    CachingCryptoMaterialsManager.newBuilder().withMasterKeyProvider(keyProvider)
                                 .withCache(cache)
                                 .withMaxAge(MAX_ENTRY_AGE_SECONDS,
 TimeUnit.SECONDS)
                                 .withMessageUseLimit(MAX_ENTRY_MSGS)
                                 .build();
```

JavaScript Browser

```
/*
 * Security thresholds
 *   Max age (in milliseconds) is required.
 *   Max messages (and max bytes) per entry are optional.
 */
const maxAge = 1000 * 60
const maxMessagesEncrypted = 10

/* Create a caching CMM from a keyring  */
const cachingCmm = new WebCryptoCachingMaterialsManager({
  backingMaterials: keyring,
  cache,
  maxAge,
  maxMessagesEncrypted
})
```

JavaScript Node.js

```
/*
 * Security thresholds
 *   Max age (in milliseconds) is required.
 *   Max messages (and max bytes) per entry are optional.
 */
const maxAge = 1000 * 60
const maxMessagesEncrypted = 10

/* Create a caching CMM from a keyring  */
const cachingCmm = new NodeCachingMaterialsManager({
  backingMaterials: keyring,
  cache,
  maxAge,
  maxMessagesEncrypted
})
```

Python

```
# Security thresholds
#   Max entry age is required.
#   Max messages (and max bytes) per entry are optional
#
MAX_ENTRY_AGE_SECONDS = 60.0
MAX_ENTRY_MESSAGES = 10

# Create a caching CMM
caching_cmm = CachingCryptoMaterialsManager(
    master_key_provider=key_provider,
    cache=cache,
    max_age=MAX_ENTRY_AGE_SECONDS,
    max_messages_encrypted=MAX_ENTRY_MESSAGES
)
```

That's all you need to do. Then, let the AWS Encryption SDK manage the cache for you, or add your own cache management logic.

When you want to use data key caching in a call to encrypt or decrypt data, specify your caching CMM instead of a master key provider or other CMM.

> **Note**
>
> If you are encrypting data streams, or any data of unknown size, be sure to specify the data size in the request. The AWS Encryption SDK does not use data key caching when encrypting data of unknown size.

C

In the AWS Encryption SDK for C, you create a session with the caching CMM and then process the session.

By default, when the message size is unknown and unbounded, the AWS Encryption SDK does not cache data keys. To allow caching when you don't know the exact data size, use the `aws_cryptosdk_session_set_message_bound` method to set a maximum size for the message. Set the bound larger than the estimated message size. If the actual message size exceeds the bound, the encryption operation fails.

```
/* Create a session with the caching CMM. Set the session mode to encrypt. */
struct aws_cryptosdk_session *session =
 aws_cryptosdk_session_new_from_cmm_2(allocator, AWS_CRYPTOSDK_ENCRYPT,
 caching_cmm);

/* Set a message bound of 1000 bytes */
aws_status = aws_cryptosdk_session_set_message_bound(session, 1000);

/* Encrypt the message using the session with the caching CMM */
aws_status = aws_cryptosdk_session_process(
             session, output_buffer, output_capacity, &output_produced,
 input_buffer, input_len, &input_consumed);

/* Release your references to the caching CMM and the session. */
aws_cryptosdk_cmm_release(caching_cmm);
aws_cryptosdk_session_destroy(session);
```

Java

The following example uses version 2.*x* of the AWS Encryption SDK for Java. Version 3.*x* of the AWS Encryption SDK for Java deprecates the data key caching CMM. With version 3.*x*, you can also use the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.

```
// When the call to encryptData specifies a caching CMM,
// the encryption operation uses the data key cache
final AwsCrypto encryptionSdk = AwsCrypto.standard();
return encryptionSdk.encryptData(cachingCmm, plaintext_source).getResult();
```

JavaScript Browser

```
const { result } = await encrypt(cachingCmm, plaintext)
```

JavaScript Node.js

When you use the caching CMM in the AWS Encryption SDK for JavaScript for Node.js, the `encrypt` method requires the length of the plaintext. If you don't provide it, the data key is not cached. If you provide a length, but the plaintext data that you supply exceeds that length, the encrypt operation fails. If you don't know the exact length of the plaintext, such as when you're streaming data, provide the largest expected value.

```
const { result } = await encrypt(cachingCmm, plaintext, { plaintextLength:
 plaintext.length })
```

Python

```
# Set up an encryption client
client = aws_encryption_sdk.EncryptionSDKClient()

# When the call to encrypt specifies a caching CMM,
# the encryption operation uses the data key cache
#
encrypted_message, header = client.encrypt(
    source=plaintext_source,
    materials_manager=caching_cmm
)
```

Data key caching example: Encrypt a string

This simple code example uses data key caching when encrypting a string. It combines the code from the step-by-step procedure into test code that you can run.

The example creates a local cache and a master key provider or keyring for an AWS KMS key. Then, it uses the local cache and master key provider or keyring to create a caching CMM with

appropriate security thresholds. In Java and Python, the encryption request specifies the caching CMM, the plaintext data to encrypt, and an encryption context. In C, the caching CMM is specified in the session, and the session is provided to the encryption request.

To run these examples, you need to supply the Amazon Resource Name (ARN) of an AWS KMS key. Be sure that you have permission to use the AWS KMS key to generate a data key.

For more detailed, real-world examples of creating and using a data key cache, see Data key caching example code.

C

```
/*
 * Copyright 2019 Amazon.com, Inc. or its affiliates. All Rights Reserved.
 *
 * Licensed under the Apache License, Version 2.0 (the "License"). You may not use
 * this file except in compliance with the License. A copy of the License is
 * located at
 *
 *     http://aws.amazon.com/apache2.0/
 *
 * or in the "license" file accompanying this file. This file is distributed on an
 * "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or
 * implied. See the License for the specific language governing permissions and
 * limitations under the License.
 */

#include <aws/cryptosdk/cache.h>
#include <aws/cryptosdk/cpp/kms_keyring.h>
#include <aws/cryptosdk/session.h>

void encrypt_with_caching(
    uint8_t *ciphertext,     // output will go here (assumes ciphertext_capacity
 bytes already allocated)
    size_t *ciphertext_len,  // length of output will go here
    size_t ciphertext_capacity,
    const char *kms_key_arn,
    int max_entry_age,
    int cache_capacity) {
    const uint64_t MAX_ENTRY_MSGS = 100;

    struct aws_allocator *allocator = aws_default_allocator();
```

```
   // Load error strings for debugging
   aws_cryptosdk_load_error_strings();

   // Create a keyring
   struct aws_cryptosdk_keyring *kms_keyring =
Aws::Cryptosdk::KmsKeyring::Builder().Build(kms_key_arn);

   // Create a cache
   struct aws_cryptosdk_materials_cache *cache =
aws_cryptosdk_materials_cache_local_new(allocator, cache_capacity);

   // Create a caching CMM
   struct aws_cryptosdk_cmm *caching_cmm =
aws_cryptosdk_caching_cmm_new_from_keyring(
       allocator, cache, kms_keyring, NULL, max_entry_age, AWS_TIMESTAMP_SECS);
   if (!caching_cmm) abort();

   if (aws_cryptosdk_caching_cmm_set_limit_messages(caching_cmm, MAX_ENTRY_MSGS))
abort();

   // Create a session
   struct aws_cryptosdk_session *session =
       aws_cryptosdk_session_new_from_cmm_2(allocator, AWS_CRYPTOSDK_ENCRYPT,
caching_cmm);
   if (!session) abort();

   // Encryption context
   struct aws_hash_table *enc_ctx =
aws_cryptosdk_session_get_enc_ctx_ptr_mut(session);
   if (!enc_ctx) abort();
   AWS_STATIC_STRING_FROM_LITERAL(enc_ctx_key, "purpose");
   AWS_STATIC_STRING_FROM_LITERAL(enc_ctx_value, "test");
   if (aws_hash_table_put(enc_ctx, enc_ctx_key, (void *)enc_ctx_value, NULL))
abort();

   // Plaintext data to be encrypted
   const char *my_data = "My plaintext data";
   size_t my_data_len  = strlen(my_data);
   if (aws_cryptosdk_session_set_message_size(session, my_data_len)) abort();

   // When the session uses a caching CMM, the encryption operation uses the data
key cache
   // specified in the caching CMM.
   size_t bytes_read;
```

```
    if (aws_cryptosdk_session_process(
            session,
            ciphertext,
            ciphertext_capacity,
            ciphertext_len,
            (const uint8_t *)my_data,
            my_data_len,
            &bytes_read))
        abort();
    if (!aws_cryptosdk_session_is_done(session) || bytes_read != my_data_len)
 abort();

    aws_cryptosdk_session_destroy(session);
    aws_cryptosdk_cmm_release(caching_cmm);
    aws_cryptosdk_materials_cache_release(cache);
    aws_cryptosdk_keyring_release(kms_keyring);
}
```

Java

The following example uses version 2.*x* of the AWS Encryption SDK for Java. Version 3.*x* of the AWS Encryption SDK for Java deprecates the data key caching CMM. With version 3.*x*, you can also use the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.

```
// Copyright Amazon.com Inc. or its affiliates. All Rights Reserved.
// SPDX-License-Identifier: Apache-2.0

package com.amazonaws.crypto.examples;

import com.amazonaws.encryptionsdk.AwsCrypto;
import com.amazonaws.encryptionsdk.CryptoMaterialsManager;
import com.amazonaws.encryptionsdk.MasterKeyProvider;
import com.amazonaws.encryptionsdk.caching.CachingCryptoMaterialsManager;
import com.amazonaws.encryptionsdk.caching.CryptoMaterialsCache;
import com.amazonaws.encryptionsdk.caching.LocalCryptoMaterialsCache;
import com.amazonaws.encryptionsdk.kmssdkv2.KmsMasterKey;
import com.amazonaws.encryptionsdk.kmssdkv2.KmsMasterKeyProvider;
import java.nio.charset.StandardCharsets;
import java.util.Collections;
import java.util.Map;
import java.util.concurrent.TimeUnit;
```

```
/**
 * <p>
 * Encrypts a string using an &KMS; key and data key caching
 *
 * <p>
 * Arguments:
 * <ol>
 * <li>KMS Key ARN: To find the Amazon Resource Name of your &KMS; key,
 *     see 'Find the key ID and ARN' at https://docs.aws.amazon.com/kms/latest/
developerguide/find-cmk-id-arn.html
 * <li>Max entry age: Maximum time (in seconds) that a cached entry can be used
 * <li>Cache capacity: Maximum number of entries in the cache
 * </ol>
 */
public class SimpleDataKeyCachingExample {

    /*
     * Security thresholds
     *   Max entry age is required.
     *   Max messages (and max bytes) per data key are optional
     */
    private static final int MAX_ENTRY_MSGS = 100;

    public static byte[] encryptWithCaching(String kmsKeyArn, int maxEntryAge, int
 cacheCapacity) {
        // Plaintext data to be encrypted
        byte[] myData = "My plaintext data".getBytes(StandardCharsets.UTF_8);

        // Encryption context
        // Most encrypted data should have an associated encryption context
        // to protect integrity. This sample uses placeholder values.
        // For more information see:
        // blogs.aws.amazon.com/security/post/Tx2LZ6WBJJANTNW/How-to-Protect-the-
Integrity-of-Your-Encrypted-Data-by-Using-AWS-Key-Management
        final Map<String, String> encryptionContext =
 Collections.singletonMap("purpose", "test");

        // Create a master key provider
        MasterKeyProvider<KmsMasterKey> keyProvider =
 KmsMasterKeyProvider.builder()
            .buildStrict(kmsKeyArn);

        // Create a cache
        CryptoMaterialsCache cache = new LocalCryptoMaterialsCache(cacheCapacity);
```

```
        // Create a caching CMM
        CryptoMaterialsManager cachingCmm =

 CachingCryptoMaterialsManager.newBuilder().withMasterKeyProvider(keyProvider)
                .withCache(cache)
                .withMaxAge(maxEntryAge, TimeUnit.SECONDS)
                .withMessageUseLimit(MAX_ENTRY_MSGS)
                .build();

        // When the call to encryptData specifies a caching CMM,
        // the encryption operation uses the data key cache
        final AwsCrypto encryptionSdk = AwsCrypto.standard();
        return encryptionSdk.encryptData(cachingCmm, myData,
 encryptionContext).getResult();
    }
}
```

JavaScript Browser

```
// Copyright Amazon.com Inc. or its affiliates. All Rights Reserved.
// SPDX-License-Identifier: Apache-2.0

/* This is a simple example of using a caching CMM with a KMS keyring
 * to encrypt and decrypt using the AWS Encryption SDK for Javascript in a browser.
 */

import {
  KmsKeyringBrowser,
  KMS,
  getClient,
  buildClient,
  CommitmentPolicy,
  WebCryptoCachingMaterialsManager,
  getLocalCryptographicMaterialsCache,
} from '@aws-crypto/client-browser'
import { toBase64 } from '@aws-sdk/util-base64-browser'

/* This builds the client with the REQUIRE_ENCRYPT_REQUIRE_DECRYPT commitment
 policy,
 * which enforces that this client only encrypts using committing algorithm suites
 * and enforces that this client
 * will only decrypt encrypted messages
```

```
 * that were created with a committing algorithm suite.
 * This is the default commitment policy
 * if you build the client with `buildClient()`.
 */
const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

/* This is injected by webpack.
 * The webpack.DefinePlugin or @aws-sdk/karma-credential-loader will replace the
 values when bundling.
 * The credential values are pulled from @aws-sdk/credential-provider-node
 * Use any method you like to get credentials into the browser.
 * See kms.webpack.config
 */
declare const credentials: {
  accessKeyId: string
  secretAccessKey: string
  sessionToken: string
}

/* This is done to facilitate testing. */
export async function testCachingCMMExample() {
  /* This example uses an &KMS; keyring. The generator key in a &KMS; keyring
 generates and encrypts the data key.
   * The caller needs kms:GenerateDataKey permission on the &KMS; key in
 generatorKeyId.
   */
  const generatorKeyId =
    'arn:aws:kms:us-west-2:658956600833:alias/EncryptDecrypt'

  /* Adding additional KMS keys that can decrypt.
   * The caller must have kms:Encrypt permission for every &KMS; key in keyIds.
   * You might list several keys in different AWS Regions.
   * This allows you to decrypt the data in any of the represented Regions.
   * In this example, the generator key
   * and the additional key are actually the same &KMS; key.
   * In `generatorId`, this &KMS; key is identified by its alias ARN.
   * In `keyIds`, this &KMS; key is identified by its key ARN.
   * In practice, you would specify different &KMS; keys,
   * or omit the `keyIds` parameter.
   * This is *only* to demonstrate how the &KMS; key ARNs are configured.
   */
  const keyIds = [
```

```
    'arn:aws:kms:us-west-2:658956600833:key/b3537ef1-d8dc-4780-9f5a-55776cbb2f7f',
  ]

  /* Need a client provider that will inject correct credentials.
   * The credentials here are injected by webpack from your environment bundle is
created
   * The credential values are pulled using @aws-sdk/credential-provider-node.
   * See kms.webpack.config
   * You should inject your credential into the browser in a secure manner
   * that works with your application.
   */
  const { accessKeyId, secretAccessKey, sessionToken } = credentials

  /* getClient takes a KMS client constructor
   * and optional configuration values.
   * The credentials can be injected here,
   * because browsers do not have a standard credential discovery process the way
Node.js does.
   */
  const clientProvider = getClient(KMS, {
    credentials: {
      accessKeyId,
      secretAccessKey,
      sessionToken,
    },
  })

  /* You must configure the KMS keyring with your &KMS; keys */
  const keyring = new KmsKeyringBrowser({
    clientProvider,
    generatorKeyId,
    keyIds,
  })

  /* Create a cache to hold the data keys (and related cryptographic material).
   * This example uses the local cache provided by the Encryption SDK.
   * The `capacity` value represents the maximum number of entries
   * that the cache can hold.
   * To make room for an additional entry,
   * the cache evicts the oldest cached entry.
   * Both encrypt and decrypt requests count independently towards this threshold.
   * Entries that exceed any cache threshold are actively removed from the cache.
   * By default, the SDK checks one item in the cache every 60 seconds (60,000
milliseconds).
```

```
  * To change this frequency, pass in a `proactiveFrequency` value
  * as the second parameter. This value is in milliseconds.
  */
 const capacity = 100
 const cache = getLocalCryptographicMaterialsCache(capacity)

 /* The partition name lets multiple caching CMMs share the same local
cryptographic cache.
  * By default, the entries for each CMM are cached separately. However, if you
want these CMMs to share the cache,
  * use the same partition name for both caching CMMs.
  * If you don't supply a partition name, the Encryption SDK generates a random
name for each caching CMM.
  * As a result, sharing elements in the cache MUST be an intentional operation.
  */
 const partition = 'local partition name'

 /* maxAge is the time in milliseconds that an entry will be cached.
  * Elements are actively removed from the cache.
  */
 const maxAge = 1000 * 60

 /* The maximum number of bytes that will be encrypted under a single data key.
  * This value is optional,
  * but you should configure the lowest practical value.
  */
 const maxBytesEncrypted = 100

 /* The maximum number of messages that will be encrypted under a single data key.
  * This value is optional,
  * but you should configure the lowest practical value.
  */
 const maxMessagesEncrypted = 10

 const cachingCMM = new WebCryptoCachingMaterialsManager({
   backingMaterials: keyring,
   cache,
   partition,
   maxAge,
   maxBytesEncrypted,
   maxMessagesEncrypted,
 })

 /* Encryption context is a *very* powerful tool for controlling
```

```
   * and managing access.
   * When you pass an encryption context to the encrypt function,
   * the encryption context is cryptographically bound to the ciphertext.
   * If you don't pass in the same encryption context when decrypting,
   * the decrypt function fails.
   * The encryption context is ***not*** secret!
   * Encrypted data is opaque.
   * You can use an encryption context to assert things about the encrypted data.
   * The encryption context helps you to determine
   * whether the ciphertext you retrieved is the ciphertext you expect to decrypt.
   * For example, if you are are only expecting data from 'us-west-2',
   * the appearance of a different AWS Region in the encryption context can indicate
 malicious interference.
   * See: https://docs.aws.amazon.com/encryption-sdk/latest/developer-guide/
concepts.html#encryption-context
   *
   * Also, cached data keys are reused ***only*** when the encryption contexts
 passed into the functions are an exact case-sensitive match.
   * See: https://docs.aws.amazon.com/encryption-sdk/latest/developer-guide/data-
caching-details.html#caching-encryption-context
   */
  const encryptionContext = {
    stage: 'demo',
    purpose: 'simple demonstration app',
    origin: 'us-west-2',
  }

  /* Find data to encrypt. */
  const plainText = new Uint8Array([1, 2, 3, 4, 5])

  /* Encrypt the data.
   * The caching CMM only reuses data keys
   * when it know the length (or an estimate) of the plaintext.
   * However, in the browser,
   * you must provide all of the plaintext to the encrypt function.
   * Therefore, the encrypt function in the browser knows the length of the
 plaintext
   * and does not accept a plaintextLength option.
   */
  const { result } = await encrypt(cachingCMM, plainText, { encryptionContext })

  /* Log the plain text
   * only for testing and to show that it works.
   */
```

```
 console.log('plainText:', plainText)
 document.write('</br>plainText:' + plainText + '</br>')

 /* Log the base64-encoded result
  * so that you can try decrypting it with another AWS Encryption SDK
implementation.
  */
 const resultBase64 = toBase64(result)
 console.log(resultBase64)
 document.write(resultBase64)

 /* Decrypt the data.
  * NOTE: This decrypt request will not use the data key
  * that was cached during the encrypt operation.
  * Data keys for encrypt and decrypt operations are cached separately.
  */
 const { plaintext, messageHeader } = await decrypt(cachingCMM, result)

 /* Grab the encryption context so you can verify it. */
 const { encryptionContext: decryptedContext } = messageHeader

 /* Verify the encryption context.
  * If you use an algorithm suite with signing,
  * the Encryption SDK adds a name-value pair to the encryption context that
contains the public key.
  * Because the encryption context might contain additional key-value pairs,
  * do not include a test that requires that all key-value pairs match.
  * Instead, verify that the key-value pairs that you supplied to the `encrypt`
function are included in the encryption context that the `decrypt` function
returns.
  */
 Object.entries(encryptionContext).forEach(([key, value]) => {
   if (decryptedContext[key] !== value)
     throw new Error('Encryption Context does not match expected values')
 })

 /* Log the clear message
  * only for testing and to show that it works.
  */
 document.write('</br>Decrypted:' + plaintext)
 console.log(plaintext)

 /* Return the values to make testing easy. */
 return { plainText, plaintext }
```

```
}
```

JavaScript Node.js

```
// Copyright Amazon.com Inc. or its affiliates. All Rights Reserved.
// SPDX-License-Identifier: Apache-2.0

import {
  KmsKeyringNode,
  buildClient,
  CommitmentPolicy,
  NodeCachingMaterialsManager,
  getLocalCryptographicMaterialsCache,
} from '@aws-crypto/client-node'

/* This builds the client with the REQUIRE_ENCRYPT_REQUIRE_DECRYPT commitment
 policy,
 * which enforces that this client only encrypts using committing algorithm suites
 * and enforces that this client
 * will only decrypt encrypted messages
 * that were created with a committing algorithm suite.
 * This is the default commitment policy
 * if you build the client with `buildClient()`.
 */
const { encrypt, decrypt } = buildClient(
  CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT
)

export async function cachingCMMNodeSimpleTest() {
  /* An &KMS; key is required to generate the data key.
   * You need kms:GenerateDataKey permission on the &KMS; key in generatorKeyId.
   */
  const generatorKeyId =
    'arn:aws:kms:us-west-2:658956600833:alias/EncryptDecrypt'

  /* Adding alternate &KMS; keys that can decrypt.
   * Access to kms:Encrypt is required for every &KMS; key in keyIds.
   * You might list several keys in different AWS Regions.
   * This allows you to decrypt the data in any of the represented Regions.
   * In this example, the generator key
   * and the additional key are actually the same &KMS; key.
   * In `generatorId`, this &KMS; key is identified by its alias ARN.
   * In `keyIds`, this &KMS; key is identified by its key ARN.
```

```
  * In practice, you would specify different &KMS; keys,
  * or omit the `keyIds` parameter.
  * This is *only* to demonstrate how the &KMS; key ARNs are configured.
  */
 const keyIds = [
   'arn:aws:kms:us-west-2:658956600833:key/b3537ef1-d8dc-4780-9f5a-55776cbb2f7f',
 ]

 /* The &KMS; keyring must be configured with the desired &KMS; keys
  * This example passes the keyring to the caching CMM
  * instead of using it directly.
  */
 const keyring = new KmsKeyringNode({ generatorKeyId, keyIds })

 /* Create a cache to hold the data keys (and related cryptographic material).
  * This example uses the local cache provided by the Encryption SDK.
  * The `capacity` value represents the maximum number of entries
  * that the cache can hold.
  * To make room for an additional entry,
  * the cache evicts the oldest cached entry.
  * Both encrypt and decrypt requests count independently towards this threshold.
  * Entries that exceed any cache threshold are actively removed from the cache.
  * By default, the SDK checks one item in the cache every 60 seconds (60,000
milliseconds).
  * To change this frequency, pass in a `proactiveFrequency` value
  * as the second parameter. This value is in milliseconds.
  */
 const capacity = 100
 const cache = getLocalCryptographicMaterialsCache(capacity)

 /* The partition name lets multiple caching CMMs share the same local
cryptographic cache.
  * By default, the entries for each CMM are cached separately. However, if you
want these CMMs to share the cache,
  * use the same partition name for both caching CMMs.
  * If you don't supply a partition name, the Encryption SDK generates a random
name for each caching CMM.
  * As a result, sharing elements in the cache MUST be an intentional operation.
  */
 const partition = 'local partition name'

 /* maxAge is the time in milliseconds that an entry will be cached.
  * Elements are actively removed from the cache.
  */
```

```
  const maxAge = 1000 * 60

  /* The maximum amount of bytes that will be encrypted under a single data key.
   * This value is optional,
   * but you should configure the lowest value possible.
   */
  const maxBytesEncrypted = 100

  /* The maximum number of messages that will be encrypted under a single data key.
   * This value is optional,
   * but you should configure the lowest value possible.
   */
  const maxMessagesEncrypted = 10

  const cachingCMM = new NodeCachingMaterialsManager({
    backingMaterials: keyring,
    cache,
    partition,
    maxAge,
    maxBytesEncrypted,
    maxMessagesEncrypted,
  })

  /* Encryption context is a *very* powerful tool for controlling
   * and managing access.
   * When you pass an encryption context to the encrypt function,
   * the encryption context is cryptographically bound to the ciphertext.
   * If you don't pass in the same encryption context when decrypting,
   * the decrypt function fails.
   * The encryption context is ***not*** secret!
   * Encrypted data is opaque.
   * You can use an encryption context to assert things about the encrypted data.
   * The encryption context helps you to determine
   * whether the ciphertext you retrieved is the ciphertext you expect to decrypt.
   * For example, if you are are only expecting data from 'us-west-2',
   * the appearance of a different AWS Region in the encryption context can indicate
 malicious interference.
   * See: https://docs.aws.amazon.com/encryption-sdk/latest/developer-guide/
concepts.html#encryption-context
   *
   * Also, cached data keys are reused ***only*** when the encryption contexts
 passed into the functions are an exact case-sensitive match.
   * See: https://docs.aws.amazon.com/encryption-sdk/latest/developer-guide/data-
caching-details.html#caching-encryption-context
```

```
   */
  const encryptionContext = {
    stage: 'demo',
    purpose: 'simple demonstration app',
    origin: 'us-west-2',
  }

  /* Find data to encrypt.  A simple string. */
  const cleartext = 'asdf'

  /* Encrypt the data.
   * The caching CMM only reuses data keys
   * when it know the length (or an estimate) of the plaintext.
   * If you do not know the length,
   * because the data is a stream
   * provide an estimate of the largest expected value.
   *
   * If your estimate is smaller than the actual plaintext length
   * the AWS Encryption SDK will throw an exception.
   *
   * If the plaintext is not a stream,
   * the AWS Encryption SDK uses the actual plaintext length
   * instead of any length you provide.
   */
  const { result } = await encrypt(cachingCMM, cleartext, {
    encryptionContext,
    plaintextLength: 4,
  })

  /* Decrypt the data.
   * NOTE: This decrypt request will not use the data key
   * that was cached during the encrypt operation.
   * Data keys for encrypt and decrypt operations are cached separately.
   */
  const { plaintext, messageHeader } = await decrypt(cachingCMM, result)

  /* Grab the encryption context so you can verify it. */
  const { encryptionContext: decryptedContext } = messageHeader

  /* Verify the encryption context.
   * If you use an algorithm suite with signing,
   * the Encryption SDK adds a name-value pair to the encryption context that
 contains the public key.
   * Because the encryption context might contain additional key-value pairs,
```

```
   * do not include a test that requires that all key-value pairs match.
   * Instead, verify that the key-value pairs that you supplied to the `encrypt`
 function are included in the encryption context that the `decrypt` function
 returns.
   */
  Object.entries(encryptionContext).forEach(([key, value]) => {
    if (decryptedContext[key] !== value)
      throw new Error('Encryption Context does not match expected values')
  })

  /* Return the values so the code can be tested. */
  return { plaintext, result, cleartext, messageHeader }
}
```

Python

```
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#
# Licensed under the Apache License, Version 2.0 (the "License"). You
# may not use this file except in compliance with the License. A copy of
# the License is located at
#
# http://aws.amazon.com/apache2.0/
#
# or in the "license" file accompanying this file. This file is
# distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF
# ANY KIND, either express or implied. See the License for the specific
# language governing permissions and limitations under the License.
"""Example of encryption with data key caching."""
import aws_encryption_sdk
from aws_encryption_sdk import CommitmentPolicy


def encrypt_with_caching(kms_key_arn, max_age_in_cache, cache_capacity):
    """Encrypts a string using an &KMS; key and data key caching.

    :param str kms_key_arn: Amazon Resource Name (ARN) of the &KMS; key
    :param float max_age_in_cache: Maximum time in seconds that a cached entry can
 be used
    :param int cache_capacity: Maximum number of entries to retain in cache at once
    """
    # Data to be encrypted
    my_data = "My plaintext data"
```

```
    # Security thresholds
    #   Max messages (or max bytes per) data key are optional
    MAX_ENTRY_MESSAGES = 100

    # Create an encryption context
    encryption_context = {"purpose": "test"}

    # Set up an encryption client with an explicit commitment policy. Note that if
you do not explicitly choose a
    # commitment policy, REQUIRE_ENCRYPT_REQUIRE_DECRYPT is used by default.
    client =
aws_encryption_sdk.EncryptionSDKClient(commitment_policy=CommitmentPolicy.REQUIRE_ENCRYPT_R

    # Create a master key provider for the &KMS; key
    key_provider =
aws_encryption_sdk.StrictAwsKmsMasterKeyProvider(key_ids=[kms_key_arn])

    # Create a local cache
    cache = aws_encryption_sdk.LocalCryptoMaterialsCache(cache_capacity)

    # Create a caching CMM
    caching_cmm = aws_encryption_sdk.CachingCryptoMaterialsManager(
        master_key_provider=key_provider,
        cache=cache,
        max_age=max_age_in_cache,
        max_messages_encrypted=MAX_ENTRY_MESSAGES,
    )

    # When the call to encrypt data specifies a caching CMM,
    # the encryption operation uses the data key cache specified
    # in the caching CMM
    encrypted_message, _header = client.encrypt(
        source=my_data, materials_manager=caching_cmm,
encryption_context=encryption_context
    )

    return encrypted_message
```

Setting cache security thresholds

When you implement data key caching, you need to configure the security thresholds that the caching CMM enforces.

The security thresholds help you to limit how long each cached data key is used and how much data is protected under each data key. The caching CMM returns cached data keys only when the cache entry conforms to all of the security thresholds. If the cache entry exceeds any threshold, the entry is not used for the current operation and it is evicted from the cache as soon as possible. The first use of each data key (before caching) is exempt from these thresholds.

As a rule, use the minimum amount of caching that is required to meet your cost and performance goals.

The AWS Encryption SDK only caches data keys that are encrypted by using a key derivation function. Also, it establishes upper limits for some of the threshold values. These restrictions ensure that data keys are not reused beyond their cryptographic limits. However, because your plaintext data keys are cached (in memory, by default), try to minimize the time that the keys are saved . Also, try to limit the data that might be exposed if a key is compromised.

For examples of setting cache security thresholds, see AWS Encryption SDK: How to Decide if Data Key Caching is Right for Your Application in the AWS Security Blog.

> **Note**
>
> The caching CMM enforces all of the following thresholds. If you do not specify an optional value, the caching CMM uses the default value.
> To disable data key caching temporarily, the Java and Python implementations of the AWS Encryption SDK provide a *null cryptographic materials cache* (null cache). The null cache returns a miss for every GET request and does not respond to PUT requests. We recommend that you use the null cache instead of setting the cache capacity or security thresholds to 0. For more information, see the null cache in Java and Python.

Maximum age (required)

Determines how long a cached entry can be used, beginning when it was added. This value is required. Enter a value greater than 0. The AWS Encryption SDK does not limit the maximum age value.

All language implementations of the AWS Encryption SDK define the maximum age in seconds, except for the AWS Encryption SDK for JavaScript, which uses milliseconds.

Use the shortest interval that still allows your application to benefit from the cache. You can use the maximum age threshold like a key rotation policy. Use it to limit reuse of data keys, minimize exposure of cryptographic materials, and evict data keys whose policies might have changed while they were cached.

Maximum messages encrypted (optional)

Specifies the maximum number of messages that a cached data key can encrypt. This value is optional. Enter a value between 1 and 2^32 messages. The default value is 2^32 messages.

Set the number of messages protected by each cached key to be large enough to get value from reuse, but small enough to limit the number of messages that might be exposed if a key is compromised.

Maximum bytes encrypted (optional)

Specifies the maximum number of bytes that a cached data key can encrypt. This value is optional. Enter a value between 0 and 2^63 - 1. The default value is 2^63 - 1. A value of 0 lets you use data key caching only when you are encrypting empty message strings.

The bytes in the current request are included when evaluating this threshold. If the bytes processed, plus current bytes, exceed the threshold, the cached data key is evicted from the cache, even though it might have been used on a smaller request.

Data key caching details

Most applications can use the default implementation of data key caching without writing custom code. This section describes the default implementation and some details about options.

Topics

- How data key caching works
- Creating a cryptographic materials cache
- Creating a caching cryptographic materials manager
- What is in a data key cache entry?
- Encryption context: How to select cache entries

- Is my application using cached data keys?

How data key caching works

When you use data key caching in a request to encrypt or decrypt data, the AWS Encryption SDK first searches the cache for a data key that matches the request. If it finds a valid match, it uses the cached data key to encrypt the data. Otherwise, it generates a new data key, just as it would without the cache.

Data key caching is not used for data of unknown size, such as streamed data. This allows the caching CMM to properly enforce the maximum bytes threshold. To avoid this behavior, add the message size to the encryption request.

In addition to a cache, data key caching uses a caching cryptographic materials manager (caching CMM). The caching CMM is a specialized cryptographic materials manager (CMM) that interacts with a cache and an underlying CMM. (When you specify a master key provider or keyring, the AWS Encryption SDK creates a default CMM for you.) The caching CMM caches the data keys that its underlying CMM returns. The caching CMM also enforces cache security thresholds that you set.

To prevent the wrong data key from being selected from the cache, all compatible caching CMMs require that the following properties of the cached cryptographic materials match the materials request.

- Algorithm suite
- Encryption context (even when empty)
- Partition name (a string that identifies the caching CMM)
- (Decryption only) Encrypted data keys

> **Note**
>
> The AWS Encryption SDK caches data keys only when the algorithm suite uses a key derivation function.

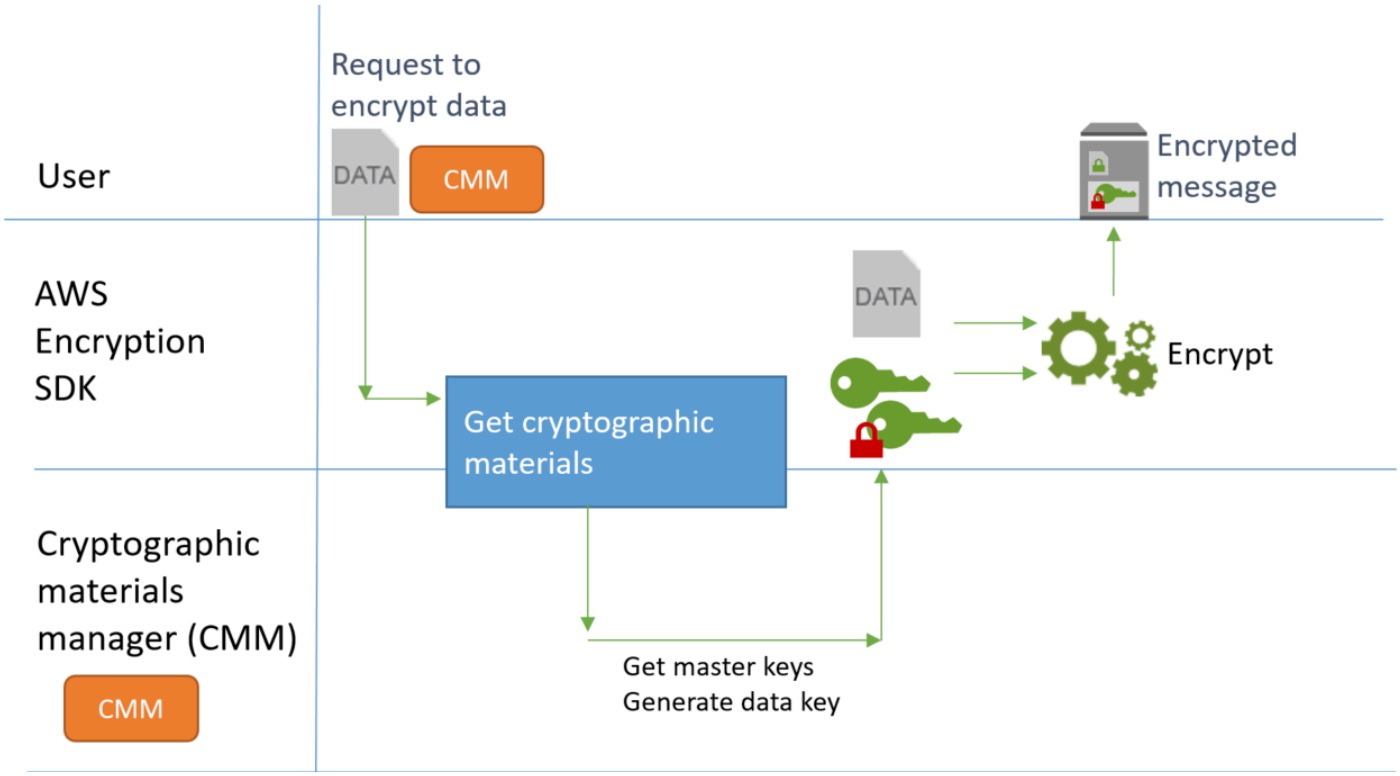
The following workflows show how a request to encrypt data is processed with and without data key caching. They show how the caching components that you create, including the cache and the caching CMM, are used in the process.

Encrypt data without caching

To get encryption materials without caching:

1. An application asks the AWS Encryption SDK to encrypt data.

   The request specifies a master key provider or keyring. The AWS Encryption SDK creates a default CMM that interacts with your master key provider or keyring.
2. The AWS Encryption SDK asks the CMM for encryption materials (get cryptographic materials).
3. The CMM asks its keyring (C and JavaScript) or master key provider (Java and Python) for cryptographic materials. This might involve a call to a cryptographic service, such as AWS Key Management Service (AWS KMS). The CMM returns the encryption materials to the AWS Encryption SDK.
4. The AWS Encryption SDK uses the plaintext data key to encrypt the data. It stores the encrypted data and encrypted data keys in an encrypted message, which it returns to the user.



Encrypt data with caching

To get encryption materials with data key caching:

1. An application asks the AWS Encryption SDK to encrypt data.

   The request specifies a caching cryptographic materials manager (caching CMM) that is associated with a underlying cryptographic materials manager (CMM). When you specify a master key provider or keyring, the AWS Encryption SDK creates a default CMM for you.

2. The SDK asks the specified caching CMM for encryption materials.
3. The caching CMM requests encryption materials from the cache.
   a. If the cache finds a match, it updates the age and use values of the matched cache entry, and returns the cached encryption materials to the caching CMM.

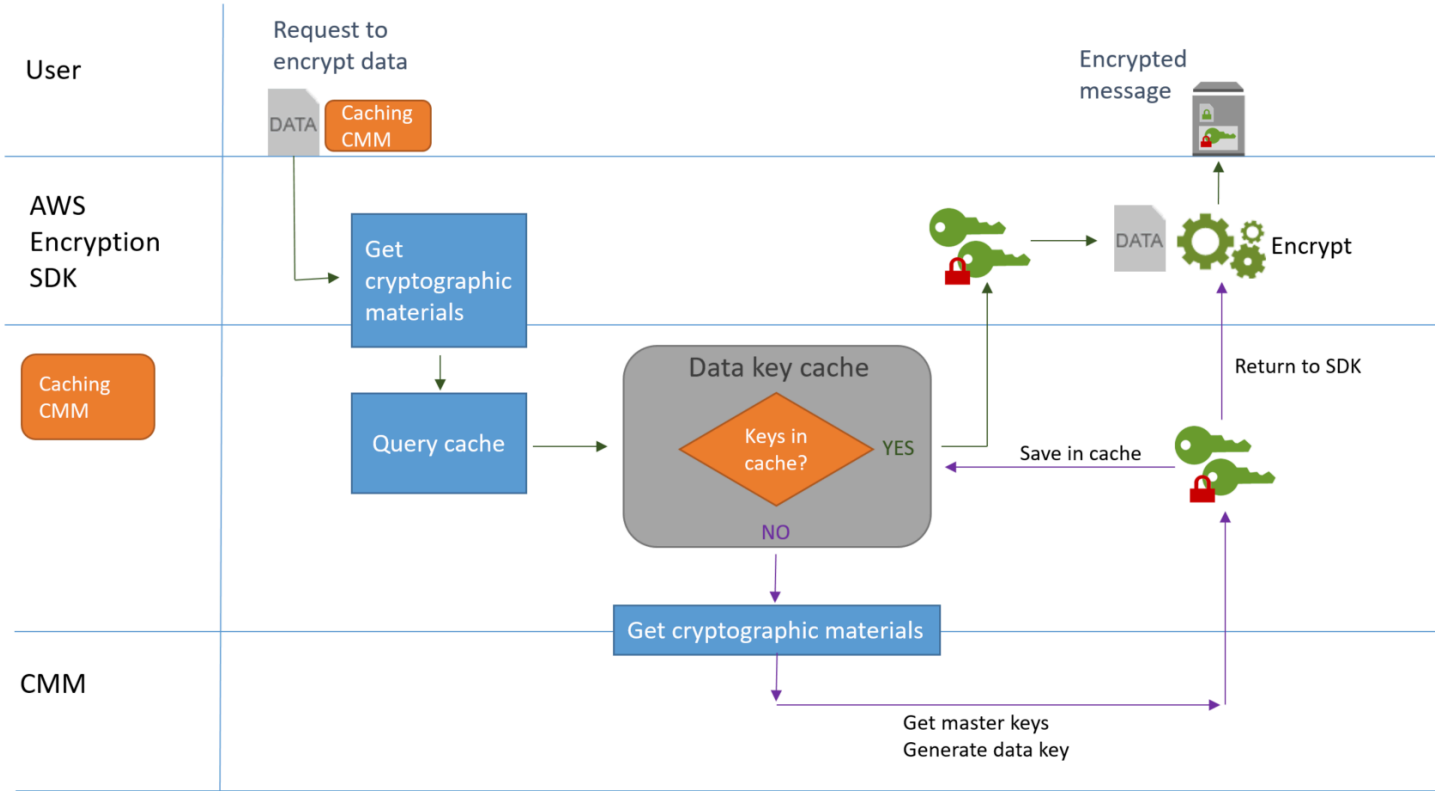
      If the cache entry conforms to its security thresholds, the caching CMM returns it to the SDK. Otherwise, it tells the cache to evict the entry and proceeds as though there was no match.

   b. If the cache cannot find a valid match, the caching CMM asks its underlying CMM to generate a new data key.

      The underlying CMM gets the cryptographic materials from its keyring (C and JavaScript) or master key provider (Java and Python). This might involve a call to a service, such as AWS Key Management Service. The underlying CMM returns the plaintext and encrypted copies of the data key to the caching CMM.

      The caching CMM saves the new encryption materials in the cache.

4. The caching CMM returns the encryption materials to the AWS Encryption SDK.
5. The AWS Encryption SDK uses the plaintext data key to encrypt the data. It stores the encrypted data and encrypted data keys in an encrypted message, which it returns to the user.



Creating a cryptographic materials cache

The AWS Encryption SDK defines the requirements for a cryptographic materials cache used in data key caching. It also provides a local cache, which is a configurable, in-memory, least recently used (LRU) cache. To create an instance of the local cache, use the `LocalCryptoMaterialsCache` constructor in Java and Python, the getLocalCryptographicMaterialsCache function in JavaScript, or the `aws_cryptosdk_materials_cache_local_new` constructor in C.

The local cache includes logic for basic cache management, including adding, evicting, and matching cached entries, and maintaining the cache. You don't need to write any custom cache management logic. You can use the local cache as is, customize it, or substitute any compatible cache.

When you create a local cache, you set its *capacity*, that is, the maximum number of entries that the cache can hold. This setting helps you to design an efficient cache with limited data key reuse.

The AWS Encryption SDK for Java and the AWS Encryption SDK for Python also provide a *null cryptographic materials cache* (NullCryptoMaterialsCache). The NullCryptoMaterialsCache returns a miss for all GET operations and does not respond to PUT operations. You can use the

NullCryptoMaterialsCache in testing or to temporarily disable caching in an application that includes caching code.

In the AWS Encryption SDK, each cryptographic materials cache is associated with a caching cryptographic materials manager (caching CMM). The caching CMM gets data keys from the cache, puts data keys in the cache, and enforces security thresholds that you set. When you create a caching CMM, you specify the cache that it uses and the underlying CMM or master key provider that generates the data keys that it caches.

Creating a caching cryptographic materials manager

To enable data key caching, you create a cache and a *caching cryptographic materials manager* (caching CMM). Then, in your requests to encrypt or decrypt data, you specify a caching CMM, instead of a standard cryptographic materials manager (CMM), or master key provider or keyring.

There are two types of CMMs. Both get data keys (and related cryptographic material), but in different ways, as follows:

- A CMM is associated with a keyring (C or JavaScript) or a master key provider (Java and Python). When the SDK asks the CMM for encryption or decryption materials, the CMM gets the materials from its keyring or master key provider. In Java and Python, the CMM uses the master keys to generate, encrypt, or decrypt the data keys. In C and JavaScript, the keyring generates, encrypts, and returns the cryptographic materials.
- A caching CMM is associated with one cache, such as a local cache, and an underlying CMM. When the SDK asks the caching CMM for cryptographic materials, the caching CMM tries to get them from the cache. If it cannot find a match, the caching CMM asks its underlying CMM for the materials. Then, it caches the new cryptographic materials before returning them to the caller.

The caching CMM also enforces security thresholds that you set for each cache entry. Because the security thresholds are set in and enforced by the caching CMM, you can use any compatible cache, even if the cache is not designed for sensitive material.

What is in a data key cache entry?

Data key caching stores data keys and related cryptographic materials in a cache. Each entry includes the elements listed below. You might find this information useful when you're deciding whether to use the data key caching feature, and when you're setting security thresholds on a caching cryptographic materials manager (caching CMM).

Cached Entries for Encryption Requests

The entries that are added to a data key cache as a result of a encryption operation include the following elements:

- Plaintext data key
- Encrypted data keys (one or more)
- Encryption context
- Message signing key (if one is used)
- Algorithm suite
- Metadata, including usage counters for enforcing security thresholds

Cached Entries for Decryption Requests

The entries that are added to a data key cache as a result of a decryption operation include the following elements:

- Plaintext data key
- Signature verification key (if one is used)
- Metadata, including usage counters for enforcing security thresholds

Encryption context: How to select cache entries

You can specify an encryption context in any request to encrypt data. However, the encryption context plays a special role in data key caching. It lets you create subgroups of data keys in your cache, even when the data keys originate from the same caching CMM.

An encryption context is a set of key-value pairs that contain arbitrary nonsecret data. During encryption, the encryption context is cryptographically bound to the encrypted data so that the same encryption context is required to decrypt the data. In the AWS Encryption SDK, the encryption context is stored in the encrypted message with the encrypted data and data keys.

When you use a data key cache, you can also use the encryption context to select particular cached data keys for your encryption operations. The encryption context is saved in the cache entry with the data key (it's part of the cache entry ID). Cached data keys are reused only when their encryption contexts match. If you want to reuse certain data keys for an encryption request,

specify the same encryption context. If you want to avoid those data keys, specify a different encryption context.

The encryption context is always optional, but recommended. If you don't specify an encryption context in your request, an empty encryption context is included in the cache entry identifier and matched to each request.

Is my application using cached data keys?

Data key caching is an optimization strategy that is very effective for certain applications and workloads. However, because it entails some risk, it's important to determine how effective it is likely to be for your situation, and then decide whether the benefits outweigh the risks.

Because data key caching reuses data keys, the most obvious effect is reducing the number of calls to generate new data keys. When data key caching is implemented, the AWS Encryption SDK calls the AWS KMS `GenerateDataKey` operation only to create the initial data key and when the cache misses. But, caching improves performance perceptibly only in applications that generate numerous data keys with the same characteristics, including the same encryption context and algorithm suite.

To determine whether your implementation of the AWS Encryption SDK is actually using data keys from the cache, try the following techniques.

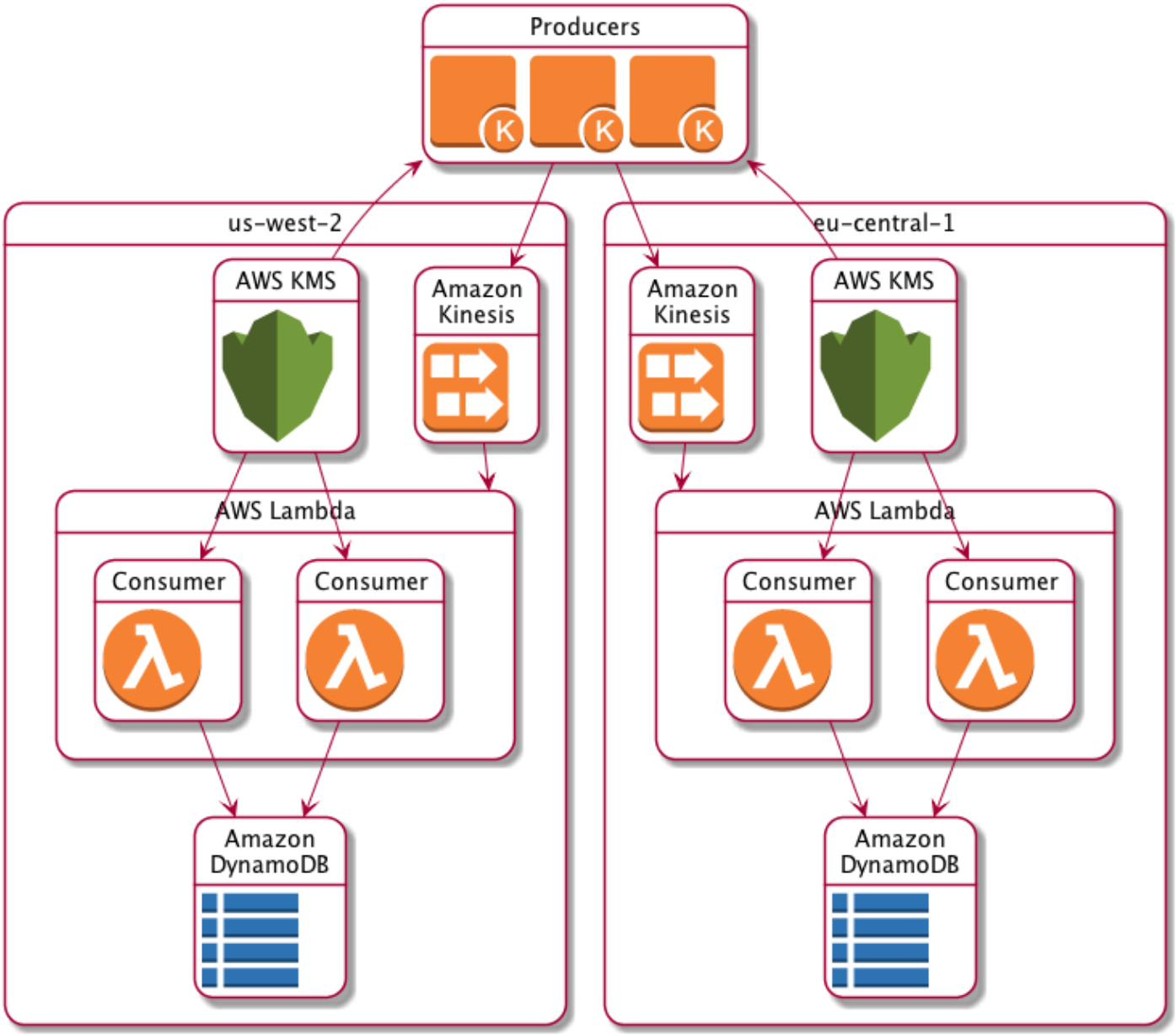
- In the logs of your master key infrastructure, check the frequency of calls to create new data keys. When data key caching is effective, the number of calls to create new keys should drop perceptibly. For example, if you are using a AWS KMS master key provider or keyring, search the CloudTrail logs for GenerateDataKey calls.
- Compare the encrypted messages that the AWS Encryption SDK returns in response to different encrypt requests. For example, if you are using the AWS Encryption SDK for Java, compare the ParsedCiphertext object from different encrypt calls. In the AWS Encryption SDK for JavaScript, compare the contents of the `encryptedDataKeys` property of the MessageHeader. When data keys are reused, the encrypted data keys in the encrypted message are identical.

Data key caching example

This example uses data key caching with a local cache to speed up an application in which data generated by multiple devices is encrypted and stored in different Regions.

In this scenario, multiple data producers generate data, encrypt it, and write to a Kinesis stream in each Region. AWS Lambda functions (consumers) decrypt the streams and write plaintext data to a DynamoDB table in the Region. Data producers and consumers use the AWS Encryption SDK and an AWS KMS master key provider. To reduce calls to KMS, each producer and consumer has their own local cache.

You can find the source code for these examples in Java and Python. The sample also includes a AWS CloudFormation template that defines the resources for the samples.



Local cache results

The following table shows that a local cache reduces the total calls to KMS (per second per Region) in this example to 1% of its original value.

Producer requests

	Requests per second per client			Clients per region	Average requests per second per region
	Generate data key (us-west-2)	Encrypt data key (eu-central-1)	Total (per region)		
No cache	1	1	1	500	500
Local cache	1 rps / 100 uses	1 rps / 100 uses	1 rps / 100 uses	500	5

Consumer requests

	Requests per second per client			Client per region	Average requests per second per region
	Decrypt data key	Producers	Total		
No cache	1 rps per producer	500	500	2	1,000
Local cache	1 rps per producer / 100 uses	500	5	2	10

Data key caching example code

This code sample creates a simple implementation of data key caching with a local cache in Java and Python. The code creates two instances of a local cache: one for data producers that are encrypting data and another for data consumers (AWS Lambda functions) that are decrypting data.

For details about the implementation of data key caching in each language, see the Javadoc and Python documentation for the AWS Encryption SDK.

Data key caching is available for all programming languages that the AWS Encryption SDK supports.

For complete and tested examples of using data key caching in the AWS Encryption SDK, see:

- C/C++: caching_cmm.cpp
- Java: SimpleDataKeyCachingExample.java
- JavaScript Browser: caching_cmm.ts
- JavaScript Node.js: caching_cmm.ts
- Python: data_key_caching_basic.py

Producer

The producer gets a map, converts it to JSON, uses the AWS Encryption SDK to encrypt it, and pushes the ciphertext record to a Kinesis stream in each AWS Region.

The code defines a caching cryptographic materials manager (caching CMM) and associates it with a local cache and an underlying AWS KMS master key provider. The caching CMM caches the data keys (and related cryptographic materials) from the master key provider. It also interacts with the cache on behalf of the SDK and enforces security thresholds that you set.

Because the call to the encrypt method specifies a caching CMM, instead of a regular cryptographic materials manager (CMM) or master key provider, the encryption will use data key caching.

Java

The following example uses version 2.*x* of the AWS Encryption SDK for Java. Version 3.*x* of the AWS Encryption SDK for Java deprecates the data key caching CMM. With version 3.*x*, you can also use the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.

```
/*
 * Copyright 2017 Amazon.com, Inc. or its affiliates. All Rights Reserved.
 *
 * Licensed under the Apache License, Version 2.0 (the "License"). You may not use
 this file except
 * in compliance with the License. A copy of the License is located at
```

```
 *
 * http://aws.amazon.com/apache2.0
 *
 * or in the "license" file accompanying this file. This file is distributed on an
 "AS IS" BASIS,
 * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied. See the
 License for the
 * specific language governing permissions and limitations under the License.
 */
package com.amazonaws.crypto.examples.kinesisdatakeycaching;

import com.amazonaws.encryptionsdk.AwsCrypto;
import com.amazonaws.encryptionsdk.CommitmentPolicy;
import com.amazonaws.encryptionsdk.CryptoResult;
import com.amazonaws.encryptionsdk.MasterKeyProvider;
import com.amazonaws.encryptionsdk.caching.CachingCryptoMaterialsManager;
import com.amazonaws.encryptionsdk.caching.LocalCryptoMaterialsCache;
import com.amazonaws.encryptionsdk.kmssdkv2.KmsMasterKey;
import com.amazonaws.encryptionsdk.kmssdkv2.KmsMasterKeyProvider;
import com.amazonaws.encryptionsdk.multi.MultipleProviderFactory;
import com.amazonaws.util.json.Jackson;
import java.util.ArrayList;
import java.util.HashMap;
import java.util.List;
import java.util.Map;
import java.util.UUID;
import java.util.concurrent.TimeUnit;
import software.amazon.awssdk.auth.credentials.AwsCredentialsProvider;
import software.amazon.awssdk.auth.credentials.DefaultCredentialsProvider;
import software.amazon.awssdk.core.SdkBytes;
import software.amazon.awssdk.regions.Region;
import software.amazon.awssdk.services.kinesis.KinesisClient;
import software.amazon.awssdk.services.kms.KmsClient;

/**
 * Pushes data to Kinesis Streams in multiple Regions.
 */
public class MultiRegionRecordPusher {

    private static final long MAX_ENTRY_AGE_MILLISECONDS = 300000;
    private static final long MAX_ENTRY_USES = 100;
    private static final int MAX_CACHE_ENTRIES = 100;
    private final String streamName_;
    private final ArrayList<KinesisClient> kinesisClients_;
```

```
   private final CachingCryptoMaterialsManager cachingMaterialsManager_;
   private final AwsCrypto crypto_;

   /**
    * Creates an instance of this object with Kinesis clients for all target
Regions and a cached
    * key provider containing KMS master keys in all target Regions.
    */
   public MultiRegionRecordPusher(final Region[] regions, final String
kmsAliasName,
       final String streamName) {
       streamName_ = streamName;
       crypto_ = AwsCrypto.builder()
           .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
           .build();
       kinesisClients_ = new ArrayList<>();

       AwsCredentialsProvider credentialsProvider =
DefaultCredentialsProvider.builder().build();

       // Build KmsMasterKey and AmazonKinesisClient objects for each target region
       List<KmsMasterKey> masterKeys = new ArrayList<>();
       for (Region region : regions) {
           kinesisClients_.add(KinesisClient.builder()
               .credentialsProvider(credentialsProvider)
               .region(region)
               .build());

           KmsMasterKey regionMasterKey = KmsMasterKeyProvider.builder()
               .defaultRegion(region)
               .builderSupplier(() ->
KmsClient.builder().credentialsProvider(credentialsProvider))
               .buildStrict(kmsAliasName)
               .getMasterKey(kmsAliasName);

           masterKeys.add(regionMasterKey);
       }

       // Collect KmsMasterKey objects into single provider and add cache
       MasterKeyProvider<?> masterKeyProvider =
MultipleProviderFactory.buildMultiProvider(
           KmsMasterKey.class,
           masterKeys
       );
```

```
        cachingMaterialsManager_ = CachingCryptoMaterialsManager.newBuilder()
            .withMasterKeyProvider(masterKeyProvider)
            .withCache(new LocalCryptoMaterialsCache(MAX_CACHE_ENTRIES))
            .withMaxAge(MAX_ENTRY_AGE_MILLISECONDS, TimeUnit.MILLISECONDS)
            .withMessageUseLimit(MAX_ENTRY_USES)
            .build();
    }

    /**
     * JSON serializes and encrypts the received record data and pushes it to all
 target streams.
     */
    public void putRecord(final Map<Object, Object> data) {
        String partitionKey = UUID.randomUUID().toString();
        Map<String, String> encryptionContext = new HashMap<>();
        encryptionContext.put("stream", streamName_);

        // JSON serialize data
        String jsonData = Jackson.toJsonString(data);

        // Encrypt data
        CryptoResult<byte[], ?> result = crypto_.encryptData(
            cachingMaterialsManager_,
            jsonData.getBytes(),
            encryptionContext
        );
        byte[] encryptedData = result.getResult();

        // Put records to Kinesis stream in all Regions
        for (KinesisClient regionalKinesisClient : kinesisClients_) {
            regionalKinesisClient.putRecord(builder ->
                builder.streamName(streamName_)
                    .data(SdkBytes.fromByteArray(encryptedData))
                    .partitionKey(partitionKey));
        }
    }
}
```

Python

```
"""
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```

```
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specific language governing permissions and limitations under the License.
"""
import json
import uuid

from aws_encryption_sdk import EncryptionSDKClient, StrictAwsKmsMasterKeyProvider,
 CachingCryptoMaterialsManager, LocalCryptoMaterialsCache, CommitmentPolicy
from aws_encryption_sdk.key_providers.kms import KMSMasterKey
import boto3


class MultiRegionRecordPusher(object):
    """Pushes data to Kinesis Streams in multiple Regions."""
    CACHE_CAPACITY = 100
    MAX_ENTRY_AGE_SECONDS = 300.0
    MAX_ENTRY_MESSAGES_ENCRYPTED = 100

    def __init__(self, regions, kms_alias_name, stream_name):
        self._kinesis_clients = []
        self._stream_name = stream_name

        # Set up EncryptionSDKClient
        _client =
 EncryptionSDKClient(CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT)

        # Set up KMSMasterKeyProvider with cache
        _key_provider = StrictAwsKmsMasterKeyProvider(kms_alias_name)

        # Add MasterKey and Kinesis client for each Region
        for region in regions:
            self._kinesis_clients.append(boto3.client('kinesis',
 region_name=region))
            regional_master_key = KMSMasterKey(
```

```
                client=boto3.client('kms', region_name=region),
                key_id=kms_alias_name
            )
            _key_provider.add_master_key_provider(regional_master_key)

        cache = LocalCryptoMaterialsCache(capacity=self.CACHE_CAPACITY)
        self._materials_manager = CachingCryptoMaterialsManager(
            master_key_provider=_key_provider,
            cache=cache,
            max_age=self.MAX_ENTRY_AGE_SECONDS,
            max_messages_encrypted=self.MAX_ENTRY_MESSAGES_ENCRYPTED
        )

    def put_record(self, record_data):
        """JSON serializes and encrypts the received record data and pushes it to
all target streams.

        :param dict record_data: Data to write to stream
        """
        # Kinesis partition key to randomize write load across stream shards
        partition_key = uuid.uuid4().hex

        encryption_context = {'stream': self._stream_name}

        # JSON serialize data
        json_data = json.dumps(record_data)

        # Encrypt data
        encrypted_data, _header = _client.encrypt(
            source=json_data,
            materials_manager=self._materials_manager,
            encryption_context=encryption_context
        )

        # Put records to Kinesis stream in all Regions
        for client in self._kinesis_clients:
            client.put_record(
                StreamName=self._stream_name,
                Data=encrypted_data,
                PartitionKey=partition_key
            )
```

Consumer

The data consumer is an AWS Lambda function that is triggered by Kinesis events. It decrypts and deserializes each record, and writes the plaintext record to an Amazon DynamoDB table in the same Region.

Like the producer code, the consumer code enables data key caching by using a caching cryptographic materials manager (caching CMM) in calls to the decrypt method.

The Java code builds a master key provider in *strict mode* with a specified AWS KMS key. Strict mode isn't required when decrypting, but it's a best practice. The Python code uses *discovery mode*, which lets the AWS Encryption SDK use any wrapping key that encrypted a data key to decrypt it.

Java

The following example uses version 2.*x* of the AWS Encryption SDK for Java. Version 3.*x* of the AWS Encryption SDK for Java deprecates the data key caching CMM. With version 3.*x*, you can also use the AWS KMS Hierarchical keyring, an alternative cryptographic materials caching solution.

This code creates a master key provider for decrypting in strict mode. The AWS Encryption SDK can use only the AWS KMS keys you specify to decrypt your message.

```
/*
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 "AS IS" BASIS,
 * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied. See the
 License for the
 * specific language governing permissions and limitations under the License.
 */
package com.amazonaws.crypto.examples.kinesisdatakeycaching;

import com.amazonaws.encryptionsdk.AwsCrypto;
import com.amazonaws.encryptionsdk.CommitmentPolicy;
```

```
import com.amazonaws.encryptionsdk.CryptoResult;
import com.amazonaws.encryptionsdk.caching.CachingCryptoMaterialsManager;
import com.amazonaws.encryptionsdk.caching.LocalCryptoMaterialsCache;
import com.amazonaws.encryptionsdk.kmssdkv2.KmsMasterKeyProvider;
import com.amazonaws.services.lambda.runtime.Context;
import com.amazonaws.services.lambda.runtime.events.KinesisEvent;
import com.amazonaws.services.lambda.runtime.events.KinesisEvent.KinesisEventRecord;
import com.amazonaws.util.BinaryUtils;
import java.io.UnsupportedEncodingException;
import java.nio.ByteBuffer;
import java.nio.charset.StandardCharsets;
import java.util.concurrent.TimeUnit;
import software.amazon.awssdk.enhanced.dynamodb.DynamoDbEnhancedClient;
import software.amazon.awssdk.enhanced.dynamodb.DynamoDbTable;
import software.amazon.awssdk.enhanced.dynamodb.TableSchema;

/**
 * Decrypts all incoming Kinesis records and writes records to DynamoDB.
 */
public class LambdaDecryptAndWrite {

    private static final long MAX_ENTRY_AGE_MILLISECONDS = 600000;
    private static final int MAX_CACHE_ENTRIES = 100;
    private final CachingCryptoMaterialsManager cachingMaterialsManager_;
    private final AwsCrypto crypto_;
    private final DynamoDbTable<Item> table_;

    /**
     * Because the cache is used only for decryption, the code doesn't set the max
 bytes or max
     * message security thresholds that are enforced only on on data keys used for
 encryption.
     */
    public LambdaDecryptAndWrite() {
        String kmsKeyArn = System.getenv("CMK_ARN");
        cachingMaterialsManager_ = CachingCryptoMaterialsManager.newBuilder()

 .withMasterKeyProvider(KmsMasterKeyProvider.builder().buildStrict(kmsKeyArn))
            .withCache(new LocalCryptoMaterialsCache(MAX_CACHE_ENTRIES))
            .withMaxAge(MAX_ENTRY_AGE_MILLISECONDS, TimeUnit.MILLISECONDS)
            .build();

        crypto_ = AwsCrypto.builder()
            .withCommitmentPolicy(CommitmentPolicy.RequireEncryptRequireDecrypt)
```

```
            .build();

        String tableName = System.getenv("TABLE_NAME");
        DynamoDbEnhancedClient dynamodb = DynamoDbEnhancedClient.builder().build();
        table_ = dynamodb.table(tableName, TableSchema.fromClass(Item.class));
    }

    /**
     * @param event
     * @param context
     */
    public void handleRequest(KinesisEvent event, Context context)
        throws UnsupportedEncodingException {
        for (KinesisEventRecord record : event.getRecords()) {
            ByteBuffer ciphertextBuffer = record.getKinesis().getData();
            byte[] ciphertext = BinaryUtils.copyAllBytesFrom(ciphertextBuffer);

            // Decrypt and unpack record
            CryptoResult<byte[], ?> plaintextResult =
 crypto_.decryptData(cachingMaterialsManager_,
                ciphertext);

            // Verify the encryption context value
            String streamArn = record.getEventSourceARN();
            String streamName = streamArn.substring(streamArn.indexOf("/") + 1);
            if (!
streamName.equals(plaintextResult.getEncryptionContext().get("stream"))) {
                throw new IllegalStateException("Wrong Encryption Context!");
            }

            // Write record to DynamoDB
            String jsonItem = new String(plaintextResult.getResult(),
 StandardCharsets.UTF_8);
            System.out.println(jsonItem);
            table_.putItem(Item.fromJSON(jsonItem));
        }
    }

    private static class Item {

        static Item fromJSON(String jsonText) {
            // Parse JSON and create new Item
            return new Item();
        }
```

```
    }
}
```

Python

This Python code decrypts with a master key provider in discovery mode. It lets the AWS Encryption SDK use any wrapping key that encrypted a data key to decrypt it. Strict mode, in which you specify the wrapping keys that can be used for decryption, is a best practice.

```
"""
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specific language governing permissions and limitations under the License.
"""
import base64
import json
import logging
import os

from aws_encryption_sdk import EncryptionSDKClient,
 DiscoveryAwsKmsMasterKeyProvider, CachingCryptoMaterialsManager,
 LocalCryptoMaterialsCache, CommitmentPolicy
import boto3

_LOGGER = logging.getLogger(__name__)
_is_setup = False
CACHE_CAPACITY = 100
MAX_ENTRY_AGE_SECONDS = 600.0

def setup():
    """Sets up clients that should persist across Lambda invocations."""
    global encryption_sdk_client
```

```
    encryption_sdk_client =
 EncryptionSDKClient(CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT)

    global materials_manager
    key_provider = DiscoveryAwsKmsMasterKeyProvider()
    cache = LocalCryptoMaterialsCache(capacity=CACHE_CAPACITY)

    #  Because the cache is used only for decryption, the code doesn't set
    #   the max bytes or max message security thresholds that are enforced
    #   only on on data keys used for encryption.
    materials_manager = CachingCryptoMaterialsManager(
        master_key_provider=key_provider,
        cache=cache,
        max_age=MAX_ENTRY_AGE_SECONDS
    )
    global table
    table_name = os.environ.get('TABLE_NAME')
    table = boto3.resource('dynamodb').Table(table_name)
    global _is_setup
    _is_setup = True


def lambda_handler(event, context):
    """Decrypts all incoming Kinesis records and writes records to DynamoDB."""
    _LOGGER.debug('New event:')
    _LOGGER.debug(event)
    if not _is_setup:
        setup()
    with table.batch_writer() as batch:
        for record in event.get('Records', []):
            # Record data base64-encoded by Kinesis
            ciphertext = base64.b64decode(record['kinesis']['data'])

            # Decrypt and unpack record
            plaintext, header = encryption_sdk_client.decrypt(
                source=ciphertext,
                materials_manager=materials_manager
            )
            item = json.loads(plaintext)

            # Verify the encryption context value
            stream_name = record['eventSourceARN'].split('/', 1)[1]
            if stream_name != header.encryption_context['stream']:
                raise ValueError('Wrong Encryption Context!')
```

```
            # Write record to DynamoDB
            batch.put_item(Item=item)
```

Data key caching example: AWS CloudFormation template

This AWS CloudFormation template sets up all the necessary AWS resources to reproduce the data key caching example.

JSON

```
{
    "Parameters": {
        "SourceCodeBucket": {
            "Type": "String",
            "Description": "S3 bucket containing Lambda source code zip files"
        },
        "PythonLambdaS3Key": {
            "Type": "String",
            "Description": "S3 key containing Python Lambda source code zip file"
        },
        "PythonLambdaObjectVersionId": {
            "Type": "String",
            "Description": "S3 version id for S3 key containing Python Lambda source
 code zip file"
        },
        "JavaLambdaS3Key": {
            "Type": "String",
            "Description": "S3 key containing Python Lambda source code zip file"
        },
        "JavaLambdaObjectVersionId": {
            "Type": "String",
            "Description": "S3 version id for S3 key containing Python Lambda source
 code zip file"
        },
        "KeyAliasSuffix": {
            "Type": "String",
            "Description": "Suffix to use for KMS key Alias (ie: alias/
<KeyAliasSuffix>)"
        },
        "StreamName": {
```

```
            "Type": "String",
            "Description": "Name to use for Kinesis Stream"
        }
    },
    "Resources": {
        "InputStream": {
            "Type": "AWS::Kinesis::Stream",
            "Properties": {
                "Name": {
                    "Ref": "StreamName"
                },
                "ShardCount": 2
            }
        },
        "PythonLambdaOutputTable": {
            "Type": "AWS::DynamoDB::Table",
            "Properties": {
                "AttributeDefinitions": [
                    {
                        "AttributeName": "id",
                        "AttributeType": "S"
                    }
                ],
                "KeySchema": [
                    {
                        "AttributeName": "id",
                        "KeyType": "HASH"
                    }
                ],
                "ProvisionedThroughput": {
                    "ReadCapacityUnits": 1,
                    "WriteCapacityUnits": 1
                }
            }
        },
        "PythonLambdaRole": {
            "Type": "AWS::IAM::Role",
            "Properties": {
                "AssumeRolePolicyDocument": {
                    "Version": "2012-10-17",
                    "Statement": [
                        {
                            "Effect": "Allow",
                            "Principal": {
```

```
                                "Service": "lambda.amazonaws.com"
                            },
                            "Action": "sts:AssumeRole"
                        }
                    ]
                },
                "ManagedPolicyArns": [
                    "arn:aws:iam::aws:policy/service-role/
AWSLambdaBasicExecutionRole"
                ],
                "Policies": [
                    {
                        "PolicyName": "PythonLambdaAccess",
                        "PolicyDocument": {
                            "Version": "2012-10-17",
                            "Statement": [
                                {
                                    "Effect": "Allow",
                                    "Action": [
                                        "dynamodb:DescribeTable",
                                        "dynamodb:BatchWriteItem"
                                    ],
                                    "Resource": {
                                        "Fn::Sub": "arn:aws:dynamodb:${AWS::Region}:
${AWS::AccountId}:table/${PythonLambdaOutputTable}"
                                    }
                                },
                                {
                                    "Effect": "Allow",
                                    "Action": [
                                        "dynamodb:PutItem"
                                    ],
                                    "Resource": {
                                        "Fn::Sub": "arn:aws:dynamodb:${AWS::Region}:
${AWS::AccountId}:table/${PythonLambdaOutputTable}*"
                                    }
                                },
                                {
                                    "Effect": "Allow",
                                    "Action": [
                                        "kinesis:GetRecords",
                                        "kinesis:GetShardIterator",
                                        "kinesis:DescribeStream",
                                        "kinesis:ListStreams"
```

```
                                    ],
                                    "Resource": {
                                        "Fn::Sub": "arn:aws:kinesis:${AWS::Region}:
${AWS::AccountId}:stream/${InputStream}"
                                    }
                                }
                            ]
                        }
                    }
                ]
            }
        },
        "PythonLambdaFunction": {
            "Type": "AWS::Lambda::Function",
            "Properties": {
                "Description": "Python consumer",
                "Runtime": "python2.7",
                "MemorySize": 512,
                "Timeout": 90,
                "Role": {
                    "Fn::GetAtt": [
                        "PythonLambdaRole",
                        "Arn"
                    ]
                },
                "Handler":
 "aws_crypto_examples.kinesis_datakey_caching.consumer.lambda_handler",
                "Code": {
                    "S3Bucket": {
                        "Ref": "SourceCodeBucket"
                    },
                    "S3Key": {
                        "Ref": "PythonLambdaS3Key"
                    },
                    "S3ObjectVersion": {
                        "Ref": "PythonLambdaObjectVersionId"
                    }
                },
                "Environment": {
                    "Variables": {
                        "TABLE_NAME": {
                            "Ref": "PythonLambdaOutputTable"
                        }
                    }
```

```
                }
            }
        },
        "PythonLambdaSourceMapping": {
            "Type": "AWS::Lambda::EventSourceMapping",
            "Properties": {
                "BatchSize": 1,
                "Enabled": true,
                "EventSourceArn": {
                    "Fn::Sub": "arn:aws:kinesis:${AWS::Region}:
${AWS::AccountId}:stream/${InputStream}"
                },
                "FunctionName": {
                    "Ref": "PythonLambdaFunction"
                },
                "StartingPosition": "TRIM_HORIZON"
            }
        },
        "JavaLambdaOutputTable": {
            "Type": "AWS::DynamoDB::Table",
            "Properties": {
                "AttributeDefinitions": [
                    {
                        "AttributeName": "id",
                        "AttributeType": "S"
                    }
                ],
                "KeySchema": [
                    {
                        "AttributeName": "id",
                        "KeyType": "HASH"
                    }
                ],
                "ProvisionedThroughput": {
                    "ReadCapacityUnits": 1,
                    "WriteCapacityUnits": 1
                }
            }
        },
        "JavaLambdaRole": {
            "Type": "AWS::IAM::Role",
            "Properties": {
                "AssumeRolePolicyDocument": {
                    "Version": "2012-10-17",
```

```
                    "Statement": [
                        {
                            "Effect": "Allow",
                            "Principal": {
                                "Service": "lambda.amazonaws.com"
                            },
                            "Action": "sts:AssumeRole"
                        }
                    ]
                },
                "ManagedPolicyArns": [
                    "arn:aws:iam::aws:policy/service-role/
AWSLambdaBasicExecutionRole"
                ],
                "Policies": [
                    {
                        "PolicyName": "JavaLambdaAccess",
                        "PolicyDocument": {
                            "Version": "2012-10-17",
                            "Statement": [
                                {
                                    "Effect": "Allow",
                                    "Action": [
                                        "dynamodb:DescribeTable",
                                        "dynamodb:BatchWriteItem"
                                    ],
                                    "Resource": {
                                        "Fn::Sub": "arn:aws:dynamodb:${AWS::Region}:
${AWS::AccountId}:table/${JavaLambdaOutputTable}"
                                    }
                                },
                                {
                                    "Effect": "Allow",
                                    "Action": [
                                        "dynamodb:PutItem"
                                    ],
                                    "Resource": {
                                        "Fn::Sub": "arn:aws:dynamodb:${AWS::Region}:
${AWS::AccountId}:table/${JavaLambdaOutputTable}*"
                                    }
                                },
                                {
                                    "Effect": "Allow",
                                    "Action": [
```

```
                                        "kinesis:GetRecords",
                                        "kinesis:GetShardIterator",
                                        "kinesis:DescribeStream",
                                        "kinesis:ListStreams"
                                    ],
                                    "Resource": {
                                        "Fn::Sub": "arn:aws:kinesis:${AWS::Region}:
${AWS::AccountId}:stream/${InputStream}"
                                    }
                                }
                            ]
                        }
                    }
                ]
            }
        },
        "JavaLambdaFunction": {
            "Type": "AWS::Lambda::Function",
            "Properties": {
                "Description": "Java consumer",
                "Runtime": "java8",
                "MemorySize": 512,
                "Timeout": 90,
                "Role": {
                    "Fn::GetAtt": [
                        "JavaLambdaRole",
                        "Arn"
                    ]
                },
                "Handler":
 "com.amazonaws.crypto.examples.kinesisdatakeycaching.LambdaDecryptAndWrite::handleRequest",
                "Code": {
                    "S3Bucket": {
                        "Ref": "SourceCodeBucket"
                    },
                    "S3Key": {
                        "Ref": "JavaLambdaS3Key"
                    },
                    "S3ObjectVersion": {
                        "Ref": "JavaLambdaObjectVersionId"
                    }
                },
                "Environment": {
                    "Variables": {
```

```
                        "TABLE_NAME": {
                            "Ref": "JavaLambdaOutputTable"
                        },
                        "CMK_ARN": {
                            "Fn::GetAtt": [
                                "RegionKinesisCMK",
                                "Arn"
                            ]
                        }
                    }
                }
            }
        },
        "JavaLambdaSourceMapping": {
            "Type": "AWS::Lambda::EventSourceMapping",
            "Properties": {
                "BatchSize": 1,
                "Enabled": true,
                "EventSourceArn": {
                    "Fn::Sub": "arn:aws:kinesis:${AWS::Region}:
${AWS::AccountId}:stream/${InputStream}"
                },
                "FunctionName": {
                    "Ref": "JavaLambdaFunction"
                },
                "StartingPosition": "TRIM_HORIZON"
            }
        },
        "RegionKinesisCMK": {
            "Type": "AWS::KMS::Key",
            "Properties": {
                "Description": "Used to encrypt data passing through Kinesis Stream
 in this region",
                "Enabled": true,
                "KeyPolicy": {
                    "Version": "2012-10-17",
                    "Statement": [
                        {
                            "Effect": "Allow",
                            "Principal": {
                                "AWS": {
                                    "Fn::Sub": "arn:aws:iam::${AWS::AccountId}:root"
                                }
                            },
```

```
                            "Action": [
                                "kms:Encrypt",
                                "kms:GenerateDataKey",
                                "kms:CreateAlias",
                                "kms:DeleteAlias",
                                "kms:DescribeKey",
                                "kms:DisableKey",
                                "kms:EnableKey",
                                "kms:PutKeyPolicy",
                                "kms:ScheduleKeyDeletion",
                                "kms:UpdateAlias",
                                "kms:UpdateKeyDescription"
                            ],
                            "Resource": "*"
                        },
                        {
                            "Effect": "Allow",
                            "Principal": {
                                "AWS": [
                                    {
                                        "Fn::GetAtt": [
                                            "PythonLambdaRole",
                                            "Arn"
                                        ]
                                    },
                                    {
                                        "Fn::GetAtt": [
                                            "JavaLambdaRole",
                                            "Arn"
                                        ]
                                    }
                                ]
                            },
                            "Action": "kms:Decrypt",
                            "Resource": "*"
                        }
                    ]
                }
            }
        },
        "RegionKinesisCMKAlias": {
            "Type": "AWS::KMS::Alias",
            "Properties": {
                "AliasName": {
```

```
                    "Fn::Sub": "alias/${KeyAliasSuffix}"
                },
                "TargetKeyId": {
                    "Ref": "RegionKinesisCMK"
                }
            }
        }
    }
}
```

YAML

```
Parameters:
    SourceCodeBucket:
        Type: String
        Description: S3 bucket containing Lambda source code zip files
    PythonLambdaS3Key:
        Type: String
        Description: S3 key containing Python Lambda source code zip file
    PythonLambdaObjectVersionId:
        Type: String
        Description: S3 version id for S3 key containing Python Lambda source code
 zip file
    JavaLambdaS3Key:
        Type: String
        Description: S3 key containing Python Lambda source code zip file
    JavaLambdaObjectVersionId:
        Type: String
        Description: S3 version id for S3 key containing Python Lambda source code
 zip file
    KeyAliasSuffix:
        Type: String
        Description: 'Suffix to use for KMS CMK Alias (ie: alias/<KeyAliasSuffix>)'
    StreamName:
        Type: String
        Description: Name to use for Kinesis Stream
Resources:
    InputStream:
        Type: AWS::Kinesis::Stream
        Properties:
            Name: !Ref StreamName
            ShardCount: 2
    PythonLambdaOutputTable:
```

```
        Type: AWS::DynamoDB::Table
        Properties:
            AttributeDefinitions:
                -
                    AttributeName: id
                    AttributeType: S
            KeySchema:
                -
                    AttributeName: id
                    KeyType: HASH
            ProvisionedThroughput:
                ReadCapacityUnits: 1
                WriteCapacityUnits: 1
    PythonLambdaRole:
        Type: AWS::IAM::Role
        Properties:
            AssumeRolePolicyDocument:
                Version: 2012-10-17
                Statement:
                    -
                        Effect: Allow
                        Principal:
                            Service: lambda.amazonaws.com
                        Action: sts:AssumeRole
            ManagedPolicyArns:
                - arn:aws:iam::aws:policy/service-role/AWSLambdaBasicExecutionRole
            Policies:
                -
                    PolicyName: PythonLambdaAccess
                    PolicyDocument:
                        Version: 2012-10-17
                        Statement:
                            -
                                Effect: Allow
                                Action:
                                    - dynamodb:DescribeTable
                                    - dynamodb:BatchWriteItem
                                Resource: !Sub arn:aws:dynamodb:${AWS::Region}:
${AWS::AccountId}:table/${PythonLambdaOutputTable}
                            -
                                Effect: Allow
                                Action:
                                    - dynamodb:PutItem
```

```
                                Resource: !Sub arn:aws:dynamodb:${AWS::Region}:
${AWS::AccountId}:table/${PythonLambdaOutputTable}*
                            -
                                Effect: Allow
                                Action:
                                    - kinesis:GetRecords
                                    - kinesis:GetShardIterator
                                    - kinesis:DescribeStream
                                    - kinesis:ListStreams
                                Resource: !Sub arn:aws:kinesis:${AWS::Region}:
${AWS::AccountId}:stream/${InputStream}
    PythonLambdaFunction:
        Type: AWS::Lambda::Function
        Properties:
            Description: Python consumer
            Runtime: python2.7
            MemorySize: 512
            Timeout: 90
            Role: !GetAtt PythonLambdaRole.Arn
            Handler:
 aws_crypto_examples.kinesis_datakey_caching.consumer.lambda_handler
            Code:
                S3Bucket: !Ref SourceCodeBucket
                S3Key: !Ref PythonLambdaS3Key
                S3ObjectVersion: !Ref PythonLambdaObjectVersionId
            Environment:
                Variables:
                    TABLE_NAME: !Ref PythonLambdaOutputTable
    PythonLambdaSourceMapping:
        Type: AWS::Lambda::EventSourceMapping
        Properties:
            BatchSize: 1
            Enabled: true
            EventSourceArn: !Sub arn:aws:kinesis:${AWS::Region}:
${AWS::AccountId}:stream/${InputStream}
            FunctionName: !Ref PythonLambdaFunction
            StartingPosition: TRIM_HORIZON
    JavaLambdaOutputTable:
        Type: AWS::DynamoDB::Table
        Properties:
            AttributeDefinitions:
                -
                    AttributeName: id
                    AttributeType: S
```

```
            KeySchema:
                -
                    AttributeName: id
                    KeType: HASH
            ProvisionedThroughput:
                ReadCapacityUnits: 1
                WriteCapacityUnits: 1
    JavaLambdaRole:
        Type: AWS::IAM::Role
        Properties:
            AssumeRolePolicyDocument:
                Version: 2012-10-17
                Statement:
                    -
                        Effect: Allow
                        Principal:
                            Service: lambda.amazonaws.com
                        Action: sts:AssumeRole
            ManagedPolicyArns:
                - arn:aws:iam::aws:policy/service-role/AWSLambdaBasicExecutionRole
            Policies:
                -
                    PolicyName: JavaLambdaAccess
                    PolicyDocument:
                        Version: 2012-10-17
                        Statement:
                            -
                                Effect: Allow
                                Action:
                                    - dynamodb:DescribeTable
                                    - dynamodb:BatchWriteItem
                                Resource: !Sub arn:aws:dynamodb:${AWS::Region}:
${AWS::AccountId}:table/${JavaLambdaOutputTable}
                            -
                                Effect: Allow
                                Action:
                                    - dynamodb:PutItem
                                Resource: !Sub arn:aws:dynamodb:${AWS::Region}:
${AWS::AccountId}:table/${JavaLambdaOutputTable}*
                            -
                                Effect: Allow
                                Action:
                                    - kinesis:GetRecords
                                    - kinesis:GetShardIterator
```

```
                                    - kinesis:DescribeStream
                                    - kinesis:ListStreams
                                Resource: !Sub arn:aws:kinesis:${AWS::Region}:
${AWS::AccountId}:stream/${InputStream}
    JavaLambdaFunction:
        Type: AWS::Lambda::Function
        Properties:
            Description: Java consumer
            Runtime: java8
            MemorySize: 512
            Timeout: 90
            Role: !GetAtt JavaLambdaRole.Arn
            Handler:
 com.amazonaws.crypto.examples.kinesisdatakeycaching.LambdaDecryptAndWrite::handleRequest
            Code:
                S3Bucket: !Ref SourceCodeBucket
                S3Key: !Ref JavaLambdaS3Key
                S3ObjectVersion: !Ref JavaLambdaObjectVersionId
            Environment:
                Variables:
                    TABLE_NAME: !Ref JavaLambdaOutputTable
                    CMK_ARN: !GetAtt RegionKinesisCMK.Arn
    JavaLambdaSourceMapping:
        Type: AWS::Lambda::EventSourceMapping
        Properties:
            BatchSize: 1
            Enabled: true
            EventSourceArn: !Sub arn:aws:kinesis:${AWS::Region}:
${AWS::AccountId}:stream/${InputStream}
            FunctionName: !Ref JavaLambdaFunction
            StartingPosition: TRIM_HORIZON
    RegionKinesisCMK:
        Type: AWS::KMS::Key
        Properties:
            Description: Used to encrypt data passing through Kinesis Stream in this
 region
            Enabled: true
            KeyPolicy:
                Version: 2012-10-17
                Statement:
                    -
                        Effect: Allow
                        Principal:
                            AWS: !Sub arn:aws:iam::${AWS::AccountId}:root
```

```
                        Action:
                            # Data plane actions
                            - kms:Encrypt
                            - kms:GenerateDataKey
                            # Control plane actions
                            - kms:CreateAlias
                            - kms:DeleteAlias
                            - kms:DescribeKey
                            - kms:DisableKey
                            - kms:EnableKey
                            - kms:PutKeyPolicy
                            - kms:ScheduleKeyDeletion
                            - kms:UpdateAlias
                            - kms:UpdateKeyDescription
                        Resource: '*'
                    -
                        Effect: Allow
                        Principal:
                            AWS:
                                - !GetAtt PythonLambdaRole.Arn
                                - !GetAtt JavaLambdaRole.Arn
                        Action: kms:Decrypt
                        Resource: '*'
    RegionKinesisCMKAlias:
        Type: AWS::KMS::Alias
        Properties:
            AliasName: !Sub alias/${KeyAliasSuffix}
            TargetKeyId: !Ref RegionKinesisCMK
```

Versions of the AWS Encryption SDK

The AWS Encryption SDK language implementations use semantic versioning to make it easier for you to identify the magnitude of changes in each release. A change in the major version number, such as 1.*x*.*x* to 2.*x*.*x*, indicates a breaking change that is likely to require code changes and a planned deployment. Breaking changes in a new version might not impact every use case, review the release notes to see if you're impacted. A change in a minor version, such as *x*.1.*x* to *x*.2.*x*, is always backward compatible, but might include deprecated elements.

Whenever possible, use the latest version of the AWS Encryption SDK in your chosen programming language. The maintenance and support policy for each version differs between programming language implementations. For details about the supported versions in your preferred programming language, see the `SUPPORT_POLICY.rst` file in its GitHub repository.

When upgrades include new features that require special configuration to avoid encryption or decryption error, we provide an intermediate version and detailed instructions for using it. For example, versions 1.7.*x* and 1.8.*x* are designed to be transitional versions that help you upgrade from versions earlier than 1.7.*x* to versions 2.0.*x* and later. For details, see Migrating your AWS Encryption SDK.

> **Note**
>
> The *x* in a version number represents any patch of the major and minor version. For example, version 1.7.*x* represents all versions that begin with 1.7, including 1.7.1 and 1.7.9. New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

The following tables provide an overview of the major differences between supported versions of the AWS Encryption SDK for each programming language.

C

For a detailed description of all changes, see the CHANGELOG.md in the aws-encryption-sdk-c repository on GitHub.

Major version	Details		SDK major version life-cycle phase
1.x	1.0	Initial release.	End-of-Support phase
	1.7	Updates to the AWS Encryption SDK that help users of earlier versions upgrade to versions 2.0.*x* and later. For more information, see version 1.7.*x*.	
2.x	2.0	Updates to the AWS Encryption SDK. For more information, see version 2.0.*x*.	General Availability (GA)
	2.2	Improvements to the message decryption process.	
	2.3	Adds support for AWS KMS multi-Region keys.	

C# / .NET

For a detailed description of all changes, see the CHANGELOG.md in the `aws-encryption-sdk-net` repository on GitHub.

Major version	Details		SDK major version life-cycle phase
3.x	3.0	Initial release.	General Availability (GA)

			Version 3.x of the AWS Encryption SDK for .NET will enter maintenance mode on May, 13 2024.
4.x	4.0	Adds support for the AWS KMS Hierarchical keyring, the required encryption context CMM, and asymmetric RSA AWS KMS keyrings.	General Availability (GA)

Command line interface (CLI)

For a detailed description of all changes, see Versions of the AWS Encryption CLI and the CHANGELOG.rst in the aws-encryption-sdk-cli repository on GitHub.

Major version	Details		SDK major version life-cycle phase
1.x	1.0	Initial release.	End-of-Support phase
	1.7	Updates to the AWS Encryption SDK that help users of earlier versions upgrade to versions 2.0.*x* and later. For more information, see version 1.7.*x*.	
2.x	2.0	Updates to the AWS Encryption SDK. For more information, see version 2.0.*x*.	End-of-Support phase

	2.1	Removes the `--discovery` parameter and replaces it with the `discovery` attribute of the `--wrapping-keys` parameter. Version 2.1.0 of the AWS Encryption CLI is equivalent to version 2.0 in other programming languages.	
	2.2	Improvements to the message decryption process.	
3.x	3.0	Adds support for AWS KMS multi-Region keys.	End-of-Support phase
4.x	4.0	The AWS Encryption CLI no longer supports Python 2 or Python 3.4. As of major version 4.*x* of the AWS Encryption CLI, only Python 3.5 or later is supported.	General Availability (GA)

	4.1	The AWS Encryption CLI no longer supports Python 3.5. As of version 4.1.*x* of the AWS Encryption CLI, only Python 3.6 or later is supported.
	4.2	The AWS Encryption CLI no longer supports Python 3.6. As of version 4.2.*x* of the AWS Encryption CLI, only Python 3.7 or later is supported.

Java

For a detailed description of all changes, see the CHANGELOG.rst in the aws-encryption-sdk-java repository on GitHub.

Major version	Details		SDK major version life-cycle phase
1.x	1.0	Initial release.	End-of-Support phase
	1.3	Adds support for cryptographic materials manager and data key caching. Moved to deterministic IV generation.	
	1.6.1	Deprecates `AwsCrypto.encryptString()` and	

		`AwsCrypto.decryptString()` and replaces them with `AwsCrypto.encryptData()` and `AwsCrypto.decryptData()`.	
	1.7	Updates to the AWS Encryption SDK that help users of earlier versions upgrade to versions 2.0.*x* and later. For more information, see version 1.7.*x*.	
2.x	2.0	Updates to the AWS Encryption SDK. For more information, see version 2.0.*x*.	General Availability (GA) Version 2.x of the AWS Encryption SDK for Java will enter maintenance mode in 2024.
	2.2	Improvements to the message decryption process.	
	2.3	Adds support for AWS KMS multi-Region keys.	
	2.4	Adds support for AWS SDK for Java 2.x.	

3.x	3.0	Integrates the AWS Encryption SDK for Java with the Material Providers Library (MPL). Adds support for symmetric and asymmetric RSA AWS KMS keyrings, AWS KMS ECDH keyrings, AWS KMS Hierarchical keyrings, Raw AES keyrings, Raw RSA keyrings, Raw ECDH keyrings, Multi-keyrings, and the required encryption context CMM.	General Availability (GA)

Go

For a detailed description of all changes, see the CHANGELOG.md in the Go directory of the aws-encryption-sdk repository on GitHub.

Major version	Details		SDK major version life-cycle phase
0.1.*x*	0.1.0	Initial release.	General Availability (GA)

JavaScript

For a detailed description of all changes, see the CHANGELOG.md in the aws-encryption-sdk-javascript repository on GitHub.

Major version	Details		SDK major version life-cycle phase
1.x	1.0	Initial release.	End-of-Support phase
	1.7	Updates to the AWS Encryption SDK that help users of earlier versions upgrade to versions 2.0.*x* and later. For more information, see version 1.7.*x*.	
2.x	2.0	Updates to the AWS Encryption SDK. For more information, see version 2.0.*x*.	End-of-Support phase
	2.2	Improvements to the message decryption process.	
	2.3	Adds support for AWS KMS multi-Region keys.	
3.x	3.0	Removes CI coverage for Node 10. Upgrades dependencies to no longer support Node 8 and Node 10.	Maintenance Support for version 3.x of the AWS Encryption SDK for JavaScript will end on January 17, 2024.
4.x	4.0	Requires version 3 of the AWS Encryption SDK for JavaScript's	General Availability (GA)

		`kms-client` to use the AWS KMS keyring.	

Python

For a detailed description of all changes, see the CHANGELOG.rst in the aws-encryption-sdk-python repository on GitHub.

Major version	Details		SDK major version life-cycle phase
1.x	1.0	Initial release.	End-of-Support phase
	1.3	Adds support for cryptographic materials manager and data key caching. Moved to determini stic IV generation.	
	1.7	Updates to the AWS Encryption SDK that help users of earlier versions upgrade to versions 2.0.*x* and later. For more information, see version 1.7.*x*.	
2.x	2.0	Updates to the AWS Encryption SDK. For more information, see version 2.0.*x*.	End-of-Support phase
	2.2	Improvements to the message decryption process.	

	2.3	Adds support for AWS KMS multi-Region keys.	
3.x	3.0	The AWS Encryption SDK for Python no longer supports Python 2 or Python 3.4. As of major version 3.*x* of the AWS Encryption SDK for Python, only Python 3.5 or later is supported.	General Availability (GA)
4.x	4.0	Integrates the AWS Encryption SDK for Python with the Material Providers Library (MPL).	General Availability (GA)

Rust

For a detailed description of all changes, see the CHANGELOG.md in the Rust directory of the aws-encryption-sdk repository on GitHub.

Major version	Details		SDK major version life-cycle phase
1.x	1.0	Initial release.	General Availability (GA)

Version details

The following list describes the major differences between supported versions of the AWS Encryption SDK.

Topics

- Versions earlier than 1.7.x
- Version 1.7.x
- Version 2.0.x
- Version 2.2.x
- Version 2.3.x

Versions earlier than 1.7.*x*

> **Note**
>
> All 1.*x*.*x* versions of the AWS Encryption SDK are in the end-of-support phase. Upgrade to the latest available version of the AWS Encryption SDK for your programming language as soon as is practical. To upgrade from an AWS Encryption SDK version earlier than 1.7.*x*, you must first upgrade to 1.7.*x*. For details, see Migrating your AWS Encryption SDK.

Versions of the AWS Encryption SDK earlier than 1.7.*x* provide important security features, including encryption with the Advanced Encryption Standard algorithm in Galois/Counter Mode (AES-GCM), an HMAC-based extract-and-expand key derivation function (HKDF), signing, and a 256-bit encryption key. However, these versions don't support best practices that we recommend, including key commitment.

Version 1.7.*x*

> **Note**
>
> All 1.*x*.*x* versions of the AWS Encryption SDK are in the end-of-support phase.

Version 1.7.*x* is designed to help users of earlier versions of the AWS Encryption SDK to upgrade to versions 2.0.*x* and later. If you are new to the AWS Encryption SDK, you can skip this version and begin with the latest available version in your programming language.

Version 1.7.*x* is fully backward compatible; it does not introduce any breaking changes or change the behavior of the AWS Encryption SDK. It's also forwards compatible; it allows you to update your code so it's compatible with version 2.0.*x*. It includes new features, but doesn't fully enable

them. And it requires configuration values that prevent you from immediately adopting all new features until you are ready.

Version 1.7.*x* includes the following changes:

AWS KMS master key provider updates (required)

Version 1.7.*x* introduces new constructors to the AWS Encryption SDK for Java and AWS Encryption SDK for Python that explicitly create AWS KMS master key providers in either *strict* or *discovery* mode. This version adds similar changes to the AWS Encryption SDK command-line interface (CLI). For details, see Updating AWS KMS master key providers.

- In *strict mode*, AWS KMS master key providers require a list of wrapping keys, and they encrypt and decrypt with only the wrapping keys you specify. This is an AWS Encryption SDK best practice that assures that you are using the wrapping keys you intend to use.
- In *discovery mode*, AWS KMS master key providers do not take any wrapping keys. You cannot use them for encrypting. When decrypting, they can use any wrapping key to decrypt an encrypted data key. However, you can limit the wrapping keys used for decryption to those in particular AWS accounts. Account filtering is optional, but it's a best practice that we recommend.

The constructors that create earlier versions of AWS KMS master key providers are deprecated in version 1.7.*x* and removed in version 2.0.*x*. These constructors instantiate master key providers that encrypt using the wrapping keys you specify. However, they decrypt encrypted data keys using the wrapping key that encrypted them, without regard to the specified wrapping keys. Users might unintentionally decrypt messages with wrapping keys they don't intend to use, including AWS KMS keys in other AWS accounts and Regions.

There are no changes to constructors for AWS KMS master keys. When encrypting and decrypting, AWS KMS master keys use only the AWS KMS key that you specify.

AWS KMS keyring updates (optional)

Version 1.7.*x* adds a new filter to the AWS Encryption SDK for C and AWS Encryption SDK for JavaScript implementations that limits AWS KMS discovery keyrings to particular AWS accounts. This new account filter is optional, but it's a best practice that we recommend. For details, see Updating AWS KMS keyrings.

There are no changes to constructors for AWS KMS keyrings. Standard AWS KMS keyrings behave like master key providers in strict mode. AWS KMS discovery keyrings are created explicitly in discovery mode.

Passing a key ID to AWS KMS Decrypt

Beginning in version 1.7.*x*, when decrypting encrypted data keys, the AWS Encryption SDK always specifies an AWS KMS key in its calls to the AWS KMS Decrypt operation. The AWS Encryption SDK gets the key ID value for the AWS KMS key from the metadata in each encrypted data key. This feature doesn't require any code changes.

Specifying the key ID of the AWS KMS key is not required to decrypt ciphertext that was encrypted under a symmetric encryption KMS key, but it is an AWS KMS best practice. Like specifying wrapping keys in your key provider, this practice assures that AWS KMS only decrypts using the wrapping key you intend to use.

Decrypt ciphertext with key commitment

Version 1.7.*x* can decrypt ciphertext that was encrypted with or without key commitment. However, it cannot encrypt ciphertext with key commitment. This property allows you to fully deploy applications that can decrypt ciphertext encrypted with key commitment before they ever encounter any such ciphertext. Because this version decrypts messages that are encrypted without key commitment, you don't need to re-encrypt any ciphertext.

To implement this behavior, version 1.7.*x* includes a new commitment policy configuration setting that determines whether the AWS Encryption SDK can encrypt or decrypt with key commitment. In version 1.7.*x*, the only valid value for the commitment policy, `ForbidEncryptAllowDecrypt`, is used in all encrypt and decrypt operations. This value prevents the AWS Encryption SDK from encrypting with either of the new algorithm suites that include key commitment. It allows the AWS Encryption SDK to decrypt ciphertext with and without key commitment.

Although there is only one valid commitment policy value in version 1.7.*x*, we require that you can set this value explicitly when you use the new APIs introduced in this release. Setting the value explicitly prevents your commitment policy from changing automatically to `require-encrypt-require-decrypt` when you upgrade to version 2.1.*x*. Instead, you can migrate your commitment policy in stages.

Algorithm suites with key commitment

Version 1.7.*x* includes two new algorithm suites that support key commitment. One includes signing; the other does not. Like earlier supported algorithm suites, both of these new algorithm suites include encryption with AES-GCM, a 256-bit encryption key, and an HMAC-based extract-and-expand key derivation function (HKDF).

However, the default algorithm suite used for encryption does not change. These algorithm suites are added to version 1.7.*x* to prepare your application to use them in versions 2.0.*x* and later.

CMM implementation changes

Version 1.7.*x* introduces changes to the Default cryptographic materials manager (CMM) interface to support key commitment. This change affects you only if you have written a custom CMM. For details, see the API documentation or GitHub repository for your programming language.

Version 2.0.*x*

Version 2.0.*x* supports new security features offered in the AWS Encryption SDK, including specified wrapping keys and key commitment. To support these features, version 2.0.*x* includes breaking changes for earlier versions of the AWS Encryption SDK. You can prepare for these changes by deploying version 1.7.*x*. Version 2.0.*x* includes all of the new features introduced in version 1.7.*x* with the following additions and changes.

> **Note**
>
> Version 2.*x*.*x* of the AWS Encryption SDK for Python, AWS Encryption SDK for JavaScript, and the AWS Encryption CLI are in the end-of-support phase.
> For information about support and maintenance of this AWS Encryption SDK version in your preferred programming language, see the `SUPPORT_POLICY.rst` file in its GitHub repository.

AWS KMS master key providers

The original AWS KMS master key provider constructors that were deprecated in version 1.7.*x* are removed in version 2.0.*x*. You must explicitly construct AWS KMS master key providers in strict mode or discovery mode.

Encrypt and decrypt ciphertext with key commitment

Version 2.0.*x* can encrypt and decrypt ciphertext with or without key commitment. Its behavior is determined by the commitment policy setting. By default, it always encrypts with key commitment and only decrypts ciphertext encrypted with key commitment. Unless you change

the commitment policy, the AWS Encryption SDK will not decrypt ciphertexts encrypted by any earlier version of the AWS Encryption SDK, including version 1.7.*x*.

> **Important**
>
> By default, version 2.0.*x* will not decrypt any ciphertext that was encrypted without key commitment. If your application might encounter a ciphertext that was encrypted without key commitment, set a commitment policy value with `AllowDecrypt`.

In version 2.0.*x*, the commitment policy setting has three valid values:

- `ForbidEncryptAllowDecrypt` — The AWS Encryption SDK cannot encrypt with key commitment. It can decrypt ciphertexts encrypted with or without key commitment.
- `RequireEncryptAllowDecrypt` — The AWS Encryption SDK must encrypt with key commitment. It can decrypt ciphertexts encrypted with or without key commitment.
- `RequireEncryptRequireDecrypt` (default) — The AWS Encryption SDK must encrypt with key commitment. It only decrypts ciphertexts with key commitment.

If you are migrating from an earlier version of the AWS Encryption SDK to version 2.0.*x*, set the commitment policy to a value that assures that you can decrypt all existing ciphertexts that your application might encounter. You are likely to adjust this setting over time.

Version 2.2.*x*

Adds support for digital signatures and limiting encrypted data keys.

> **Note**
>
> Version 2.*x.x* of the AWS Encryption SDK for Python, AWS Encryption SDK for JavaScript, and the AWS Encryption CLI are in the end-of-support phase.
> For information about support and maintenance of this AWS Encryption SDK version in your preferred programming language, see the `SUPPORT_POLICY.rst` file in its GitHub repository.

Digital signatures

To improve handling of digital signatures when decrypting, the AWS Encryption SDK includes the following features:

- *Non-streaming mode* — returns plaintext only after processing all input, including verifying the digital signature if present. This feature prevents you from using plaintext before verifying the digital signature. Use this feature whenever you decrypt data encrypted with digital signatures (the default algorithm suite). For example, because the AWS Encryption CLI always processes data in streaming mode, use the `- -buffer` parameter when decrypting ciphertext with digital signatures.
- *Unsigned-only decryption mode* — this feature only decrypts unsigned ciphertext. If decryption encounters a digital signature in the ciphertext, the operation fails. Use this feature to avoid unintentionally processing plaintext from signed messages before verifying the signature.

Limiting encrypted data keys

You can limit the number of encrypted data keys in an encrypted message. This feature can help you detect a misconfigured master key provider or keyring when encrypting, or identify a malicious ciphertext when decrypting.

You should limit encrypted data keys when you decrypt messages from an untrusted source. It prevents unnecessary, expensive, and potentially exhaustive calls to your key infrastructure.

Version 2.3.*x*

Adds support for AWS KMS multi-Region keys. For details, see Using multi-Region AWS KMS keys.

> **Note**
>
> The AWS Encryption CLI supports multi-Region keys beginning in version 3.0.*x*.
> Version 2.*x*.*x* of the AWS Encryption SDK for Python, AWS Encryption SDK for JavaScript, and the AWS Encryption CLI are in the end-of-support phase.
> For information about support and maintenance of this AWS Encryption SDK version in your preferred programming language, see the `SUPPORT_POLICY.rst` file in its GitHub repository.

Migrating your AWS Encryption SDK

The AWS Encryption SDK supports multiple interoperable programming language implementations, each of which is developed in an open-source repository on GitHub. As a best practice, we recommend that you use the latest version of the AWS Encryption SDK for each language.

You can safely upgrade from version 2.0.*x* or later of AWS Encryption SDK to the latest version. However, the 2.0.*x* version of the AWS Encryption SDK introduces significant new security features, some of which are breaking changes. To upgrade from versions earlier than 1.7.*x* to versions 2.0.*x* and later, you must first upgrade to the latest 1.*x* version. The topics in this section are designed to help you understand the changes, select the correct version for your application, and migrate safely and successfully to the newest versions of the AWS Encryption SDK.

For information about significant versions of the AWS Encryption SDK, see Versions of the AWS Encryption SDK.

Important

Do not upgrade directly from a version earlier than 1.7.*x* to version 2.0.*x* or later without first upgrading to the latest 1.*x* version. If you upgrade directly to version 2.0.*x* or later and enable all new features immediately, the AWS Encryption SDK won't be able to decrypt ciphertext encrypted under older versions of the AWS Encryption SDK.

Note

The earliest version of the AWS Encryption SDK for .NET is version 3.0.*x*. All versions of the AWS Encryption SDK for .NET support the security best practices introduced in 2.0.*x* of the AWS Encryption SDK. You can safely upgrade to the latest version without any code or data changes.

AWS Encryption CLI: When reading this migration guide, use the 1.7.*x* migration instructions for AWS Encryption CLI 1.8.*x* and use the 2.0.*x* migration instructions for AWS Encryption CLI 2.1.*x*. For details, see Versions of the AWS Encryption CLI.

New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS

Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

New users

If you're new to the AWS Encryption SDK, install the latest version of the AWS Encryption SDK for your programming language. The default values enable all security features of the AWS Encryption SDK, including encryption with signing, key derivation, and key commitment. of the AWS Encryption SDK

Current users

We recommend that you upgrade from your current version to the latest available version as soon as possible. All 1.*x* versions of the AWS Encryption SDK are in the end-of-support phase, as are later versions in some programming languages. For details about the support and maintenance status of the AWS Encryption SDK in your programming language, see Support and maintenance.

AWS Encryption SDK versions 2.0.*x* and later provide new security features to help protect your data. However, AWS Encryption SDK version 2.0.*x* includes breaking changes that are not backwards compatible. To assure a safe transition, begin by migrating from your current version to the latest 1.*x* in your programming language. When your latest 1.*x* version is fully deployed and operating successfully, you can safely migrate to versions 2.0.*x* and later. This two-step process is critical especially for distributed applications.

For more information about the AWS Encryption SDK security features that underlie these changes, see Improved client-side encryption: Explicit KeyIds and key commitment in the *AWS Security Blog*.

Looking for help with using the AWS Encryption SDK for Java with the AWS SDK for Java 2.x? See Prerequisites.

Topics

- How to migrate and deploy the AWS Encryption SDK
- Updating AWS KMS master key providers
- Updating AWS KMS keyrings
- Setting your commitment policy

- Troubleshooting migration to the latest versions

How to migrate and deploy the AWS Encryption SDK

When migrating from an AWS Encryption SDK version earlier than 1.7.*x* to version 2.0.*x* or later, you must transition safely to encrypting with key commitment. Otherwise, your application will encounter ciphertexts that it cannot decrypt. If you are using AWS KMS master key providers, you must update to new constructors that create master key providers in strict mode or discovery mode.

> **Note**
>
> This topic is designed for users migrating from earlier versions of the AWS Encryption SDK to version 2.0.*x* or later. If you are new to the AWS Encryption SDK, you can begin using the latest available version immediately with the default settings.

To avoid a critical situation in which you cannot decrypt ciphertext that you need to read, we recommend that you migrate and deploy in multiple distinct stages. Verify that each stage is complete and fully deployed before starting the next stage. This is particularly important for distributed applications with multiple hosts.

Stage 1: Update your application to the latest 1.*x* version

Update to the latest 1.*x* version for your programming language. Test carefully, deploy your changes, and confirm that the update has propagated to all destination hosts before starting stage 2.

> **Important**
>
> Verify that your latest 1.*x* version is version 1.7.*x* or later of the AWS Encryption SDK.

The latest 1.*x* versions of the AWS Encryption SDK are backward compatible with legacy versions of the AWS Encryption SDK and forward compatible with versions 2.0.*x* and later. They include the new features that are present in version 2.0.*x*, but include safe defaults designed for this migration. They allow you to upgrade your AWS KMS master key providers, if necessary, and to fully deploy with algorithm suites that can decrypt ciphertext with key commitment.

- Replace deprecated elements, including constructors for legacy AWS KMS master key providers. In Python, be sure to turn on deprecation warnings. Code elements that are deprecated in the latest 1.*x* versions are removed from versions 2.0.*x* and later.
- Explicitly set your commitment policy to `ForbidEncryptAllowDecrypt`. Although this is the only valid value in the latest 1.*x* versions, this setting is required when you use the APIs introduced in this release. It prevents your application from rejecting ciphertext encrypted without key commitment when you migrate to version 2.0.*x* and later. For details, see the section called "Setting your commitment policy".
- If you use AWS KMS master key providers, you must update your legacy master key providers to master key providers that support *strict mode* and *discovery mode*. This update is required for the AWS Encryption SDK for Java, AWS Encryption SDK for Python, and the AWS Encryption CLI. If you use master key providers in discovery mode, we recommend that you implement the discovery filter that limits the wrapping keys used to those in particular AWS accounts. This update is optional, but it's a best practice that we recommend. For details, see Updating AWS KMS master key providers.
- If you use AWS KMS discovery keyrings, we recommend that you include a discovery filter that limits the wrapping keys used in decryption to those in particular AWS accounts. This update is optional, but it's a best practice that we recommend. For details, see Updating AWS KMS keyrings.

Stage 2: Update your application to the latest version

After deploying the latest 1.*x* version successfully to all hosts, you can upgrade to versions 2.0.*x* and later. Version 2.0.*x* includes breaking changes for all earlier versions of the AWS Encryption SDK. However, if you make the code changes recommended in Stage 1, you can avoid errors when you migrate to the latest version.

Before you update to the latest version, verify that your commitment policy is consistently set to `ForbidEncryptAllowDecrypt`. Then, depending on your data configuration, you can migrate at your own pace to `RequireEncryptAllowDecrypt` and then to the default setting, `RequireEncryptRequireDecrypt`. We recommend a series of transition steps like the following pattern.

1. Begin with your commitment policy set to `ForbidEncryptAllowDecrypt`. The AWS Encryption SDK can decrypt messages with key commitment, but it doesn't yet encrypt with key commitment.

2. When you are ready, update your commitment policy to `RequireEncryptAllowDecrypt`. The AWS Encryption SDK begins to encrypt your data with key commitment. It can decrypt ciphertext with and without key commitment.

   Before updating your commitment policy to `RequireEncryptAllowDecrypt`, verify that your latest 1.*x* version is deployed to all hosts, including hosts of any applications that decrypt the ciphertext you produce. Versions of the AWS Encryption SDK prior to version 1.7.*x* cannot decrypt messages encrypted with key commitment.

   This is also a good time to add metrics to your application to measure whether you are still processing ciphertext without key commitment. This will help you determine when it's safe to update your commitment policy setting to `RequireEncryptRequireDecrypt`. For some applications, such as those that encrypt messages in an Amazon SQS queue, this might mean waiting long enough that all ciphertext encrypted under old versions have been re-encrypted or deleted. For other applications, such as encrypted S3 objects, you might need to download, re-encrypt, and re-upload all objects.
3. When you are certain that you don't have any messages encrypted without key commitment, you can update your commitment policy to `RequireEncryptRequireDecrypt`. This value assures that your data is always encrypted and decrypted with key commitment. This setting is the default, so you aren't required to set it explicitly, but we recommend it. An explicit setting will aid debugging and any potential rollbacks that might be required if your application encounters ciphertext encrypted without key commitment.

Updating AWS KMS master key providers

To migrate to the latest 1.*x* version of the AWS Encryption SDK, and then to version 2.0.*x* or later, you must replace legacy AWS KMS master key providers with master key providers created explicitly in *strict mode* or *discovery mode*. Legacy master key providers are deprecated in version 1.7.*x* and removed in version 2.0.*x*. This change is required for applications and scripts that use the AWS Encryption SDK for Java, AWS Encryption SDK for Python, and the AWS Encryption CLI. The examples in this section will show you how to update your code.

> **Note**
>
> In Python, turn on deprecation warnings. This will help you identify the parts of your code that you need to update.

If you are using an AWS KMS master key (not a master key provider), you can skip this step. AWS KMS master keys are not deprecated or removed. They encrypt and decrypt only with the wrapping keys that you specify.

The examples in this section focus on the elements of your code that you need to change. For a complete example of the updated code, see the Examples section of the GitHub repository for your programming language. Also, these examples typically use key ARNs to represent AWS KMS keys. When you create a master key provider for encrypting, you can use any valid AWS KMS key identifier to represent an AWS KMS key . When you create a master key provider for decrypting, you must use a key ARN.

Learn more about migration

For all AWS Encryption SDK users, learn about setting your commitment policy in the section called "Setting your commitment policy".

For AWS Encryption SDK for C and AWS Encryption SDK for JavaScript users, learn about an optional update to keyrings in Updating AWS KMS keyrings.

Topics

- Migrating to strict mode
- Migrating to discovery mode

Migrating to strict mode

After updating to the latest 1.*x* version of the AWS Encryption SDK, replace your legacy master key providers with master key providers in strict mode. In strict mode, you must specify the wrapping keys to use when encrypting and decrypting. The AWS Encryption SDK uses only the wrapping keys you specify. Deprecated master key providers can decrypt data using any AWS KMS key that encrypted a data key, including AWS KMS keys in different AWS accounts and Regions.

Master key providers in strict mode are introduced in the AWS Encryption SDK version 1.7.*x*. They replace legacy master key providers, which are deprecated in 1.7.*x* and removed in 2.0.*x*. Using master key providers in strict mode is an AWS Encryption SDK best practice.

The following code creates a master key provider in strict mode that you can use for encrypting and decrypting.

Java

This example represents code in an application that uses the version 1.6.2 or earlier of the AWS Encryption SDK for Java.

This code uses the `KmsMasterKeyProvider.builder()` method to instantiate an AWS KMS master key provider that uses one AWS KMS key as a wrapping key.

```
// Create a master key provider
// Replace the example key ARN with a valid one
String awsKmsKey = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

KmsMasterKeyProvider masterKeyProvider = KmsMasterKeyProvider.builder()
    .withKeysForEncryption(awsKmsKey)
    .build();
```

This example represents code in an application that uses version 1.7.*x* or later of the AWS Encryption SDK for Java . For a complete example, see BasicEncryptionExample.java.

The `Builder.build()` and `Builder.withKeysForEncryption()` methods used in the previous example are deprecated in version 1.7.*x* and are removed from version 2.0.*x*.

To update to a strict mode master key provider, this code replaces calls to deprecated methods with a call to the new `Builder.buildStrict()` method. This example specifies one AWS KMS key as the wrapping key, but the `Builder.buildStrict()` method can take a list of multiple AWS KMS keys.

```
// Create a master key provider in strict mode
// Replace the example key ARN with a valid one from your AWS account.
String awsKmsKey = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

KmsMasterKeyProvider masterKeyProvider = KmsMasterKeyProvider.builder()
    .buildStrict(awsKmsKey);
```

Python

This example represents code in an application that uses version 1.4.1 of the AWS Encryption SDK for Python. This code uses `KMSMasterKeyProvider`, which is deprecated in version 1.7.*x* and removed from version 2.0.*x*. When decrypting, it uses any AWS KMS key that encrypted a data key without regard to the AWS KMS keys you specify.

Note that `KMSMasterKey` is not deprecated or removed. When encrypting and decrypting, it uses only the AWS KMS key you specify.

```
# Create a master key provider
# Replace the example key ARN with a valid one
key_1 = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab"
key_2 = "arn:aws:kms:us-west-2:111122223333:key/0987dcba-09fe-87dc-65ba-
ab0987654321"

aws_kms_master_key_provider = KMSMasterKeyProvider(
   key_ids=[key_1, key_2]
)
```

This example represents code in an application that uses version 1.7.*x* of the AWS Encryption SDK for Python. For a complete example, see basic_encryption.py.

To update to a strict mode master key provider, this code replaces the call to `KMSMasterKeyProvider()` with a call to `StrictAwsKmsMasterKeyProvider()`.

```
# Create a master key provider in strict mode
# Replace the example key ARNs with valid values from your AWS account
key_1 = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab"
key_2 = "arn:aws:kms:us-west-2:111122223333:key/0987dcba-09fe-87dc-65ba-
ab0987654321"

aws_kms_master_key_provider = StrictAwsKmsMasterKeyProvider(
    key_ids=[key_1, key_2]
)
```

AWS Encryption CLI

This example shows how to encrypt and decrypt using the AWS Encryption CLI version 1.1.7 or earlier.

In version 1.1.7 and earlier, when encrypting, you specify one or more master keys (or *wrapping keys*), such as an AWS KMS key. When decrypting, you can't specify any wrapping keys unless you are using a custom master key provider. The AWS Encryption CLI can use any wrapping key that encrypted a data key.

```
\\ Replace the example key ARN with a valid one
```

```
$ keyArn=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

\\ Encrypt your plaintext data
$ aws-encryption-cli --encrypt \
                     --input hello.txt \
                     --master-keys key=$keyArn \
                     --metadata-output ~/metadata \
                     --encryption-context purpose=test \
                     --output .

\\ Decrypt your ciphertext
$ aws-encryption-cli --decrypt \
                     --input hello.txt.encrypted \
                     --encryption-context purpose=test \
                     --metadata-output ~/metadata \
                     --output .
```

This example shows how to encrypt and decrypt using the AWS Encryption CLI version 1.7.*x* or later. For complete examples, see Examples of the AWS Encryption CLI.

The `--master-keys` parameter is deprecated in version 1.7.*x* and removed in version 2.0.*x*. It's replaced the by `--wrapping-keys` parameter, which is required in encrypt and decrypt commands. This parameter supports strict mode and discovery mode. Strict mode is an AWS Encryption SDK best practice that assures that you use the wrapping key that you intend.

To upgrade to *strict mode*, use the **key** attribute of the `--wrapping-keys` parameter to specify a wrapping key when encrypting and decrypting.

```
\\ Replace the example key ARN with a valid value
$ keyArn=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

\\ Encrypt your plaintext data
$ aws-encryption-cli --encrypt \
                     --input hello.txt \
                     --wrapping-keys key=$keyArn \
                     --metadata-output ~/metadata \
                     --encryption-context purpose=test \
                     --output .

\\ Decrypt your ciphertext
$ aws-encryption-cli --decrypt \
                     --input hello.txt.encrypted \
                     --wrapping-keys key=$keyArn \
```

```
                        --encryption-context purpose=test \
                        --metadata-output ~/metadata \
                        --output .
```

Migrating to discovery mode

Beginning in version 1.7.*x*, it's an AWS Encryption SDK best practice to use *strict mode* for AWS KMS master key providers, that is, to specify wrapping keys when encrypting and decrypting. You must always specify wrapping keys when encrypting. But there are situations in which specifying the key ARNs of AWS KMS keys for decrypting is impractical. For example, if you're using aliases to identify AWS KMS keys when encrypting, you lose the benefit of aliases if you have to list key ARNs when decrypting. Also, because master key providers in discovery mode behave like the original master key providers, you might use them temporarily as part of your migration strategy, and then upgrade to master key providers in strict mode later.

In cases like this, you can use master key providers in *discovery mode*. These master key providers don't let you specify wrapping keys, so you cannot use them for encrypting. When decrypting, they can use any wrapping key that encrypted a data key. But unlike legacy master key providers, which behave the same way, you create them in discovery mode explicitly. When using master key providers in discovery mode, you can limit the wrapping keys that can be used to those in particular AWS accounts. This discovery filter is optional, but it's a best practice that we recommend. For information about AWS partitions and accounts, see Amazon Resource Names in the *AWS General Reference*.

The following examples create an AWS KMS master key provider in strict mode for encrypting and an AWS KMS master key provider in discovery mode for decrypting. The master key provider in discovery mode uses a discovery filter to limit the wrapping keys used for decrypting to the `aws` partition and to particular example AWS accounts. Although the account filter is not necessary in this very simple example, it's a best practice that is very beneficial when one application encrypts data and a different application decrypts the data.

Java

This example represents code in an application that uses version 1.7.*x* or later of the AWS Encryption SDK for Java. For a complete example, see DiscoveryDecryptionExample.java.

To instantiate a master key provider in strict mode for encrypting, this example uses the `Builder.buildStrict()` method. To instantiate a master key provider in

discovery mode for decrypting, it uses the `Builder.buildDiscovery()` method. The `Builder.buildDiscovery()` method takes a `DiscoveryFilter` that limits the AWS Encryption SDK to AWS KMS keys in the specified AWS partition and accounts.

```
// Create a master key provider in strict mode for encrypting
// Replace the example alias ARN with a valid one from your AWS account.
String awsKmsKey = "arn:aws:kms:us-west-2:111122223333:alias/ExampleAlias";

KmsMasterKeyProvider encryptingKeyProvider = KmsMasterKeyProvider.builder()
    .buildStrict(awsKmsKey);

// Create a master key provider in discovery mode for decrypting
// Replace the example account IDs with valid values.
DiscoveryFilter accounts = new DiscoveryFilter("aws", Arrays.asList("111122223333",
 "444455556666"));

KmsMasterKeyProvider decryptingKeyProvider = KmsMasterKeyProvider.builder()
    .buildDiscovery(accounts);
```

Python

This example represents code in an application that uses version 1.7.*x* or later of the AWS Encryption SDK for Python . For a complete example, see discovery_kms_provider.py.

To create a master key provider in strict mode for encrypting, this example uses `StrictAwsKmsMasterKeyProvider`. To create a master key provider in discovery mode for decrypting, it uses `DiscoveryAwsKmsMasterKeyProvider` with a `DiscoveryFilter` that limits the AWS Encryption SDK to AWS KMS keys in the specified AWS partition and accounts.

```
# Create a master key provider in strict mode
# Replace the example key ARN and alias ARNs with valid values from your AWS
 account.
key_1 = "arn:aws:kms:us-west-2:111122223333:alias/ExampleAlias"
key_2 = "arn:aws:kms:us-
west-2:444455556666:key/1a2b3c4d-5e6f-1a2b-3c4d-5e6f1a2b3c4d"

aws_kms_master_key_provider = StrictAwsKmsMasterKeyProvider(
    key_ids=[key_1, key_2]
)

# Create a master key provider in discovery mode for decrypting
# Replace the example account IDs with valid values
```

```
accounts = DiscoveryFilter(
    partition="aws",
    account_ids=["111122223333", "444455556666"]
)
aws_kms_master_key_provider = DiscoveryAwsKmsMasterKeyProvider(
        discovery_filter=accounts
)
```

AWS Encryption CLI

This example shows how to encrypt and decrypt using the AWS Encryption CLI version 1.7.*x* or later. Beginning in version 1.7.*x*, the `--wrapping-keys` parameter is required when encrypting and decrypting. The `--wrapping-keys` parameter supports strict mode and discovery mode. For complete examples, see the section called "Examples".

When encrypting, this example specifies a wrapping key, which is required. When decrypting, it explicitly chooses *discovery mode* by using the `discovery` attribute of the `--wrapping-keys` parameter with a value of `true`.

To limit the wrapping keys that the AWS Encryption SDK can use in discovery mode to those in particular AWS accounts, this example uses the `discovery-partition` and `discovery-account` attributes of the `--wrapping-keys` parameter. These optional attributes are valid only when the `discovery` attribute is set to `true`. You must use the `discovery-partition` and `discovery-account` attributes together; neither is valid alone.

```
\\ Replace the example key ARN with a valid value
$ keyAlias=arn:aws:kms:us-west-2:111122223333:alias/ExampleAlias

\\ Encrypt your plaintext data
$ aws-encryption-cli --encrypt \
                     --input hello.txt \
                     --wrapping-keys key=$keyAlias \
                     --metadata-output ~/metadata \
                     --encryption-context purpose=test \
                     --output .

\\ Decrypt your ciphertext
\\ Replace the example account IDs with valid values
$ aws-encryption-cli --decrypt \
                     --input hello.txt.encrypted \
                     --wrapping-keys discovery=true \
                                     discovery-partition=aws \
```

```
                                        discovery-account=111122223333 \
                                        discovery-account=444455556666 \
                        --encryption-context purpose=test \
                        --metadata-output ~/metadata \
                        --output .
```

Updating AWS KMS keyrings

The AWS KMS keyrings in the AWS Encryption SDK for C, the AWS Encryption SDK for .NET, and the AWS Encryption SDK for JavaScript support best practices by allowing you to specify wrapping keys when encrypting and decrypting. If you create an AWS KMS discovery keyring, you do so explicitly.

> **Note**
>
> The earliest version of the AWS Encryption SDK for .NET is version 3.0.*x*. All versions of the AWS Encryption SDK for .NET support the security best practices introduced in 2.0.*x* of the AWS Encryption SDK. You can safely upgrade to the latest version without any code or data changes.

When you update to the latest 1.*x* version of the AWS Encryption SDK, you can use a discovery filter to limit the wrapping keys that an AWS KMS discovery keyring or AWS KMS regional discovery keyring uses when decrypting to those in particular AWS accounts. Filtering a discovery keyring is an AWS Encryption SDK best practice.

The examples in this section will show you how to add the discovery filter to an AWS KMS regional discovery keyring.

Learn more about migration

For all AWS Encryption SDK users, learn about setting your commitment policy in the section called "Setting your commitment policy".

For AWS Encryption SDK for Java, AWS Encryption SDK for Python, and AWS Encryption CLI users, learn about a required update to master key providers in the section called "Updating AWS KMS master key providers".

You might have code like the following in your application. This example creates an AWS KMS regional discovery keyring that can only use wrapping keys in the US West (Oregon) (us-west-2) Region. This example represents code in AWS Encryption SDK versions earlier than 1.7.*x*. However, it is still valid in versions 1.7.*x* and later.

C

```
struct aws_cryptosdk_keyring *kms_regional_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder()
       .WithKmsClient(create_kms_client(Aws::Region::US_WEST_2)).BuildDiscovery());
```

JavaScript Browser

```
const clientProvider = getClient(KMS, { credentials })

const discovery = true
const clientProvider = limitRegions(['us-west-2'], getKmsClient)
const keyring = new KmsKeyringBrowser({ clientProvider, discovery })
```

JavaScript Node.js

```
const discovery = true
const clientProvider = limitRegions(['us-west-2'], getKmsClient)
const keyring = new KmsKeyringNode({ clientProvider, discovery })
```

Beginning in version 1.7.*x*, you can add a discovery filter to any AWS KMS discovery keyring. This discovery filter limits the AWS KMS keys that the AWS Encryption SDK can use for decryption to those in the specified partition and accounts. Before using this code, change the partition, if necessary, and replace the example account IDs with valid ones.

C

For a complete example, see kms_discovery.cpp.

```
std::shared_ptr<KmsKeyring::DiscoveryFilter> discovery_filter(
    KmsKeyring::DiscoveryFilter::Builder("aws")
        .AddAccount("111122223333")
        .AddAccount("444455556666")
        .Build());
```

```
struct aws_cryptosdk_keyring *kms_regional_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder()

 .WithKmsClient(create_kms_client(Aws::Region::US_WEST_2)).BuildDiscovery(discovery_filter))
```

JavaScript Browser

```
const clientProvider = getClient(KMS, { credentials })

const discovery = true
const clientProvider = limitRegions(['us-west-2'], getKmsClient)
const keyring = new KmsKeyringBrowser(clientProvider, {
    discovery,
    discoveryFilter: { accountIDs: ['111122223333', '444455556666'], partition:
 'aws' }
})
```

JavaScript Node.js

For a complete example, see kms_filtered_discovery.ts.

```
const discovery = true
const clientProvider = limitRegions(['us-west-2'], getKmsClient)
const keyring = new KmsKeyringNode({
    clientProvider,
    discovery,
    discoveryFilter: { accountIDs: ['111122223333', '444455556666'], partition:
 'aws' }
})
```

Setting your commitment policy

Key commitment assures that your encrypted data always decrypts to the same plaintext. To provide this security property, beginning in version 1.7.*x*, the AWS Encryption SDK uses new algorithm suites with key commitment. To determine whether your data is encrypted and decrypted with key commitment, use the commitment policy configuration setting. Encrypting and decrypting data with key commitment is an AWS Encryption SDK best practice.

Setting a commitment policy is an important part of the second step in the migration process — migrating from the latest 1.*x* versions of the AWS Encryption SDK to versions 2.0.*x* and later.

After setting and changing your commitment policy, be sure to test your application thoroughly before deploying it in production. For migration guidance, see How to migrate and deploy the AWS Encryption SDK.

The commitment policy setting has three valid values in versions 2.0.*x* and later. In the latest 1.*x* versions (beginning with version 1.7.*x*), only `ForbidEncryptAllowDecrypt` is valid.

- `ForbidEncryptAllowDecrypt` — The AWS Encryption SDK cannot encrypt with key commitment. It can decrypt ciphertexts encrypted with or without key commitment.

  In the latest 1.*x* versions, this is the only valid value. It ensures that you don't encrypt with key commitment until you are fully prepared to decrypt with key commitment. Setting the value explicitly prevents your commitment policy from changing automatically to `require-encrypt-require-decrypt` when you upgrade to versions 2.0.*x* or later. Instead, you can migrate your commitment policy in stages.
- `RequireEncryptAllowDecrypt` — The AWS Encryption SDK always encrypts with key commitment. It can decrypt ciphertexts encrypted with or without key commitment. This value is added in version 2.0.*x*.
- `RequireEncryptRequireDecrypt` — The AWS Encryption SDK always encrypts and decrypts with key commitment. This value is added in version 2.0.*x*. It is the default value in versions 2.0.*x* and later.

In the latest 1.*x* versions, the only valid commitment policy value is `ForbidEncryptAllowDecrypt`. After you migrate to version 2.0.*x* or later, you can change your commitment policy in stages as you are ready. Don't update your commitment policy to `RequireEncryptRequireDecrypt` until you are certain that you don't have any messages encrypted without key commitment.

These examples show you how to set your commitment policy in the latest 1.*x* versions and in versions 2.0.*x* and later. The technique depends on your programming language.

Learn more about migration

For AWS Encryption SDK for Java, AWS Encryption SDK for Python, and the AWS Encryption CLI, learn about required changes to master key providers in the section called “Updating AWS KMS master key providers”.

For AWS Encryption SDK for C and AWS Encryption SDK for JavaScript, learn about an optional update to keyrings in Updating AWS KMS keyrings.

How to set your commitment policy

The technique that you use to set your commitment policy differs slightly with each language implementation. These examples show you how to do it. Before changing your commitment policy, review the multi-stage approach in How to migrate and deploy.

C

Beginning in version 1.7.*x* of the AWS Encryption SDK for C, you use the `aws_cryptosdk_session_set_commitment_policy` function to set the commitment policy on your encrypt and decrypt sessions. The commitment policy that you set applies to all encrypt and decrypt operations called on that session.

The `aws_cryptosdk_session_new_from_keyring` and `aws_cryptosdk_session_new_from_cmm` functions are deprecated in version 1.7.*x* and removed in version 2.0.*x*. These functions are replaced by `aws_cryptosdk_session_new_from_keyring_2` and `aws_cryptosdk_session_new_from_cmm_2` functions that return a session.

When you use the `aws_cryptosdk_session_new_from_keyring_2` and `aws_cryptosdk_session_new_from_cmm_2` in the latest 1.*x* versions, you are required to call the `aws_cryptosdk_session_set_commitment_policy` function with the `COMMITMENT_POLICY_FORBID_ENCRYPT_ALLOW_DECRYPT` commitment policy value. In versions 2.0.*x* and later, calling this function is optional and it takes all valid values. The default commitment policy for versions 2.0.*x* and later is `COMMITMENT_POLICY_REQUIRE_ENCRYPT_REQUIRE_DECRYPT`.

For a complete example, see string.cpp.

```
/* Load error strings for debugging */
aws_cryptosdk_load_error_strings();

/* Create an AWS KMS keyring */
const char * key_arn = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";
struct aws_cryptosdk_keyring *kms_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder().Build(key_arn);

/* Create an encrypt session with a CommitmentPolicy setting */
struct aws_cryptosdk_session *encrypt_session =
 aws_cryptosdk_session_new_from_keyring_2(
```

```
    alloc, AWS_CRYPTOSDK_ENCRYPT, kms_keyring);

aws_cryptosdk_keyring_release(kms_keyring);
aws_cryptosdk_session_set_commitment_policy(encrypt_session,
    COMMITMENT_POLICY_FORBID_ENCRYPT_ALLOW_DECRYPT);

...
/* Encrypt your data */

size_t plaintext_consumed_output;
aws_cryptosdk_session_process(encrypt_session,
                              ciphertext_output,
                              ciphertext_buf_sz_output,
                              ciphertext_len_output,
                              plaintext_input,
                              plaintext_len_input,
                              &plaintext_consumed_output)
...

/* Create a decrypt session with a CommitmentPolicy setting */

struct aws_cryptosdk_keyring *kms_keyring =
 Aws::Cryptosdk::KmsKeyring::Builder().Build(key_arn);
struct aws_cryptosdk_session *decrypt_session =
 *aws_cryptosdk_session_new_from_keyring_2(
        alloc, AWS_CRYPTOSDK_DECRYPT, kms_keyring);
aws_cryptosdk_keyring_release(kms_keyring);
aws_cryptosdk_session_set_commitment_policy(decrypt_session,
        COMMITMENT_POLICY_FORBID_ENCRYPT_ALLOW_DECRYPT);

/* Decrypt your ciphertext */
size_t ciphertext_consumed_output;
aws_cryptosdk_session_process(decrypt_session,
                              plaintext_output,
                              plaintext_buf_sz_output,
                              plaintext_len_output,
                              ciphertext_input,
                              ciphertext_len_input,
                              &ciphertext_consumed_output)
```

C# / .NET

The `require-encrypt-require-decrypt` value is the default commitment policy in all versions of the AWS Encryption SDK for .NET. You can set it explicitly as a best practice,

but it's not required. However, if you are using the AWS Encryption SDK for .NET to decrypt ciphertext that was encrypted by another language implementation of the AWS Encryption SDK without key commitment, you need to change the commitment policy value to `REQUIRE_ENCRYPT_ALLOW_DECRYPT` or `FORBID_ENCRYPT_ALLOW_DECRYPT`. Otherwise, attempts to decrypt the ciphertext will fail.

In the AWS Encryption SDK for .NET, you set the commitment policy on an instance of the AWS Encryption SDK. Instantiate an `AwsEncryptionSdkConfig` object with a `CommitmentPolicy` parameter, and use the configuration object to create the AWS Encryption SDK instance. Then, call the `Encrypt()` and `Decrypt()` methods of the configured AWS Encryption SDK instance.

This example sets the commitment policy to `require-encrypt-allow-decrypt`.

```
// Instantiate the material providers
var materialProviders =

 AwsCryptographicMaterialProvidersFactory.CreateDefaultAwsCryptographicMaterialProviders();

// Configure the commitment policy on the AWS Encryption SDK instance
var config = new AwsEncryptionSdkConfig
{
    CommitmentPolicy = CommitmentPolicy.REQUIRE_ENCRYPT_ALLOW_DECRYPT
};
var encryptionSdk = AwsEncryptionSdkFactory.CreateAwsEncryptionSdk(config);

string keyArn = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";

var encryptionContext = new Dictionary<string, string>()
{
    {"purpose", "test"}encryptionSdk
};

var createKeyringInput = new CreateAwsKmsKeyringInput
{
    KmsClient = new AmazonKeyManagementServiceClient(),
    KmsKeyId = keyArn
};
var keyring = materialProviders.CreateAwsKmsKeyring(createKeyringInput);

// Encrypt your plaintext data
var encryptInput = new EncryptInput
```

```
{
    Plaintext = plaintext,
    Keyring = keyring,
    EncryptionContext = encryptionContext
};
var encryptOutput = encryptionSdk.Encrypt(encryptInput);

// Decrypt your ciphertext
var decryptInput = new DecryptInput
{
    Ciphertext = ciphertext,
    Keyring = keyring
};
var decryptOutput = encryptionSdk.Decrypt(decryptInput);
```

AWS Encryption CLI

To set a commitment policy in the AWS Encryption CLI, use the `--commitment-policy` parameter. This parameter is introduced in version 1.8.*x*.

In the latest 1.*x* version, when you use the `--wrapping-keys` parameter in an `--encrypt` or `--decrypt` command, a `--commitment-policy` parameter with the `forbid-encrypt-allow-decrypt` value is required. Otherwise, the `--commitment-policy` parameter is invalid.

In versions 2.1.*x* and later, the `--commitment-policy` parameter is optional and defaults to the `require-encrypt-require-decrypt` value, which won't encrypt or decrypt any ciphertext encrypted without key commitment. However, we recommend that you set the commitment policy explicitly in all encrypt and decrypt calls to help with maintenance and troubleshooting.

This example sets the commitment policy. It also uses the `--wrapping-keys` parameter that replaces the `--master-keys` parameter beginning in version 1.8.*x*. For details, see the section called "Updating AWS KMS master key providers". For complete examples, see Examples of the AWS Encryption CLI.

```
\\ To run this example, replace the fictitious key ARN with a valid value.
$ keyArn=arn:aws:kms:us-west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab

\\ Encrypt your plaintext data - no change to algorithm suite used
$ aws-encryption-cli --encrypt \
                     --input hello.txt \
```

```
                      --wrapping-keys key=$keyArn \
                      --commitment-policy forbid-encrypt-allow-decrypt \
                      --metadata-output ~/metadata \
                      --encryption-context purpose=test \
                      --output .

\\ Decrypt your ciphertext - supports key commitment on 1.7 and later
$ aws-encryption-cli --decrypt \
                      --input hello.txt.encrypted \
                      --wrapping-keys key=$keyArn \
                      --commitment-policy forbid-encrypt-allow-decrypt \
                      --encryption-context purpose=test \
                      --metadata-output ~/metadata \
                      --output .
```

Java

Beginning in version 1.7.*x* of the AWS Encryption SDK for Java, you set the commitment policy on your instance of `AwsCrypto`, the object that represents the AWS Encryption SDK client. This commitment policy setting applies to all encrypt and decrypt operations called on that client.

The `AwsCrypto()` constructor is deprecated in the latest 1.*x* versions of the AWS Encryption SDK for Java and is removed in version 2.0.*x*. It's replaced by a new `Builder` class, a `Builder.withCommitmentPolicy()` method, and the `CommitmentPolicy` enumerated type.

In the latest 1.*x* versions, the `Builder` class requires the `Builder.withCommitmentPolicy()` method and the `CommitmentPolicy.ForbidEncryptAllowDecrypt` argument. Beginning in version 2.0.*x*, the `Builder.withCommitmentPolicy()` method is optional; the default value is `CommitmentPolicy.RequireEncryptRequireDecrypt`.

For a complete example, see SetCommitmentPolicyExample.java.

```
// Instantiate the client
final AwsCrypto crypto = AwsCrypto.builder()
    .withCommitmentPolicy(CommitmentPolicy.ForbidEncryptAllowDecrypt)
    .build();

// Create a master key provider in strict mode
String awsKmsKey = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab";
```

```
KmsMasterKeyProvider masterKeyProvider = KmsMasterKeyProvider.builder()
    .buildStrict(awsKmsKey);

// Encrypt your plaintext data
CryptoResult<byte[], KmsMasterKey> encryptResult = crypto.encryptData(
    masterKeyProvider,
    sourcePlaintext,
    encryptionContext);
byte[] ciphertext = encryptResult.getResult();

// Decrypt your ciphertext
CryptoResult<byte[], KmsMasterKey> decryptResult = crypto.decryptData(
        masterKeyProvider,
        ciphertext);
byte[] decrypted = decryptResult.getResult();
```

JavaScript

Beginning in version 1.7.*x* of the AWS Encryption SDK for JavaScript, you can set the commitment policy when you call the new `buildClient` function that instantiates an AWS Encryption SDK client. The `buildClient` function takes an enumerated value that represents your commitment policy. It returns updated `encrypt` and `decrypt` functions that enforce your commitment policy when you encrypt and decrypt.

In the latest 1.*x* versions, the `buildClient` function requires the `CommitmentPolicy.FORBID_ENCRYPT_ALLOW_DECRYPT` argument. Beginning in version 2.0.*x*, the commitment policy argument is optional and the default value is `CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT`.

The code for Node.js and the browser are identical for this purpose, except that browser needs a statement to set credentials.

The following example encrypts data with an AWS KMS keyring. The new `buildClient` function sets the commitment policy to `FORBID_ENCRYPT_ALLOW_DECRYPT`, the default value in the latest 1.*x* versins. The upgraded `encrypt` and `decrypt` functions that `buildClient` returns enforce the commitment policy you set.

```
import { buildClient } from '@aws-crypto/client-node'
const { encrypt, decrypt } =
 buildClient(CommitmentPolicy.FORBID_ENCRYPT_ALLOW_DECRYPT)
```

```
// Create an AWS KMS keyring
const generatorKeyId = 'arn:aws:kms:us-west-2:111122223333:alias/ExampleAlias'
const keyIds = ['arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab']
const keyring = new KmsKeyringNode({ generatorKeyId, keyIds })

// Encrypt your plaintext data
const { ciphertext } = await encrypt(keyring, plaintext, { encryptionContext:
 context })

// Decrypt your ciphertext
const { decrypted, messageHeader } = await decrypt(keyring, ciphertext)
```

Python

Beginning in version 1.7.*x* of the AWS Encryption SDK for Python, you set the commitment policy on your instance of `EncryptionSDKClient`, a new object that represents the AWS Encryption SDK client. The commitment policy that you set applies to all `encrypt` and `decrypt` calls that use that instance of the client.

In the latest 1.*x* versions, the `EncryptionSDKClient` constructor requires the `CommitmentPolicy.FORBID_ENCRYPT_ALLOW_DECRYPT` enumerated value. Beginning in version 2.0.*x*, the commitment policy argument is optional and the default value is `CommitmentPolicy.REQUIRE_ENCRYPT_REQUIRE_DECRYPT`.

This example uses the new `EncryptionSDKClient` constructor and sets the commitment policy to the 1.7.*x* default value. The constructor instantiates a client that represents the AWS Encryption SDK. When you call the `encrypt`, `decrypt`, or `stream` methods on this client, they enforce the commitment policy that you set. This example also uses the new constructor for the `StrictAwsKmsMasterKeyProvider` class, which specifies AWS KMS keys when encrypting and decrypting.

For a complete example, see set_commitment.py.

```
# Instantiate the client
client =
 aws_encryption_sdk.EncryptionSDKClient(commitment_policy=CommitmentPolicy.FORBID_ENCRYPT_AL

// Create a master key provider in strict mode
aws_kms_key = "arn:aws:kms:us-
west-2:111122223333:key/1234abcd-12ab-34cd-56ef-1234567890ab"
aws_kms_strict_master_key_provider = StrictAwsKmsMasterKeyProvider(
```

```
        key_ids=[aws_kms_key]
)

# Encrypt your plaintext data
ciphertext, encrypt_header = client.encrypt(
        source=source_plaintext,
        encryption_context=encryption_context,
        master_key_provider=aws_kms_strict_master_key_provider
)

# Decrypt your ciphertext
decrypted, decrypt_header = client.decrypt(
        source=ciphertext,
        master_key_provider=aws_kms_strict_master_key_provider
)
```

Rust

The `require-encrypt-require-decrypt` value is the default commitment policy in all versions of the AWS Encryption SDK for Rust. You can set it explicitly as a best practice, but it's not required. However, if you are using the AWS Encryption SDK for Rust to decrypt ciphertext that was encrypted by another language implementation of the AWS Encryption SDK without key commitment, you need to change the commitment policy value to `REQUIRE_ENCRYPT_ALLOW_DECRYPT` or `FORBID_ENCRYPT_ALLOW_DECRYPT`. Otherwise, attempts to decrypt the ciphertext will fail.

In the AWS Encryption SDK for Rust, you set the commitment policy on an instance of the AWS Encryption SDK. Instantiate an `AwsEncryptionSdkConfig` object with a `comitment_policy` parameter, and use the configuration object to create the AWS Encryption SDK instance. Then, call the `Encrypt()` and `Decrypt()` methods of the configured AWS Encryption SDK instance.

This example sets the commitment policy to `forbid-encrypt-allow-decrypt`.

```
// Configure the commitment policy on the AWS Encryption SDK instance
let esdk_config = AwsEncryptionSdkConfig::builder()
                    .commitment_policy(ForbidEncryptAllowDecrypt)
                    .build()?;
let esdk_client = esdk_client::Client::from_conf(esdk_config)?;

// Create an AWS KMS client
let sdk_config =
 aws_config::load_defaults(aws_config::BehaviorVersion::latest()).await;
```

```
let kms_client = aws_sdk_kms::Client::new(&sdk_config);

// Create your encryption context
let encryption_context = HashMap::from([
    ("encryption".to_string(), "context".to_string()),
    ("is not".to_string(), "secret".to_string()),
    ("but adds".to_string(), "useful metadata".to_string()),
    ("that can help you".to_string(), "be confident that".to_string()),
    ("the data you are handling".to_string(), "is what you think it
 is".to_string()),
]);

// Instantiate the material providers library
let mpl_config = MaterialProvidersConfig::builder().build()?;
let mpl = mpl_client::Client::from_conf(mpl_config)?;

// Create an AWS KMS keyring
let kms_keyring = mpl
    .create_aws_kms_keyring()
    .kms_key_id(kms_key_id)
    .kms_client(kms_client)
    .send()
    .await?;

// Encrypt your plaintext data
let plaintext = example_data.as_bytes();

let encryption_response = esdk_client.encrypt()
    .plaintext(plaintext)
    .keyring(kms_keyring.clone())
    .encryption_context(encryption_context.clone())
    .send()
    .await?;

// Decrypt your ciphertext
let decryption_response = esdk_client.decrypt()
    .ciphertext(ciphertext)
    .keyring(kms_keyring)
    // Provide the encryption context that was supplied to the encrypt method
    .encryption_context(encryption_context)
    .send()
    .await?;
```

Go

```
import (
    "context"

 mpl "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygenerated"
 mpltypes "aws/aws-cryptographic-material-providers-library/releases/go/mpl/
awscryptographymaterialproviderssmithygeneratedtypes"
 client "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygenerated"
 esdktypes "github.com/aws/aws-encryption-sdk/
awscryptographyencryptionsdksmithygeneratedtypes"
    "github.com/aws/aws-sdk-go-v2/config"
    "github.com/aws/aws-sdk-go-v2/service/kms"
)

// Instantiate the AWS Encryption SDK client
commitPolicyForbidEncryptAllowDecrypt :=
 mpltypes.ESDKCommitmentPolicyForbidEncryptAllowDecrypt
encryptionClient, err :=
 client.NewClient(esdktypes.AwsEncryptionSdkConfig{CommitmentPolicy:
 &commitPolicyForbidEncryptAllowDecrypt})
if err != nil {
    panic(err)
}

// Create an AWS KMS client
cfg, err := config.LoadDefaultConfig(context.TODO())
if err != nil {
    panic(err)
}
kmsClient := kms.NewFromConfig(cfg, func(o *kms.Options) {
    o.Region = KmsKeyRegion
})

// Optional: Create an encryption context
encryptionContext := map[string]string{
    "encryption":                "context",
    "is not":                    "secret",
    "but adds":                  "useful metadata",
    "that can help you":         "be confident that",
    "the data you are handling": "is what you think it is",
}
```

```
// Instantiate the material providers library
matProv, err := mpl.NewClient(mpltypes.MaterialProvidersConfig{})
if err != nil {
    panic(err)
}

// Create an AWS KMS keyring
awsKmsKeyringInput := mpltypes.CreateAwsKmsKeyringInput{
    KmsClient: kmsClient,
    KmsKeyId:  kmsKeyId,
}
awsKmsKeyring, err := matProv.CreateAwsKmsKeyring(context.Background(),
 awsKmsKeyringInput)
if err != nil {
    panic(err)
}

// Encrypt your plaintext data
res, err := forbidEncryptClient.Encrypt(context.Background(),
 esdktypes.EncryptInput{
    Plaintext:         []byte(exampleText),
    EncryptionContext: encryptionContext,
    Keyring:           awsKmsKeyring,
})
if err != nil {
    panic(err)
}

// Decrypt your ciphertext
decryptOutput, err := forbidEncryptClient.Decrypt(context.Background(),
 esdktypes.DecryptInput{
    Ciphertext:        res.Ciphertext,
    EncryptionContext: encryptionContext,
    Keyring:           awsKmsKeyring,
})
if err != nil {
    panic(err)
}
```

Troubleshooting migration to the latest versions

Before updating your application to version 2.0.*x* or later of the AWS Encryption SDK, update to the latest 1.*x* version of the AWS Encryption SDK and deploy it completely. That will help you avoid most errors you might encounter when updating to versions 2.0.*x* and later. For detailed guidance, including examples, see Migrating your AWS Encryption SDK.

> **Important**
>
> Verify that your latest 1.*x* version is version 1.7.*x* or later of the AWS Encryption SDK.

> **Note**
>
> **AWS Encryption CLI**: References in this guide to version 1.7.*x* of the AWS Encryption SDK apply to version 1.8.*x* of the AWS Encryption CLI. References in this guide to version 2.0.*x* of the AWS Encryption SDK apply to 2.1.*x* of the AWS Encryption CLI.
> New security features were originally released in AWS Encryption CLI versions 1.7.*x* and 2.0.*x*. However, AWS Encryption CLI version 1.8.*x* replaces version 1.7.*x* and AWS Encryption CLI 2.1.*x* replaces 2.0.*x*. For details, see the relevant security advisory in the aws-encryption-sdk-cli repository on GitHub.

This topic is designed to help you recognize and resolve the most common errors you might encounter.

Topics

- Deprecated or removed objects
- Configuration conflict: Commitment policy and algorithm suite
- Configuration conflict: Commitment policy and ciphertext
- Key commitment validation failed
- Other encryption failures
- Other decryption failures
- Rollback considerations

Deprecated or removed objects

Version 2.0.*x* includes several breaking changes, including removing legacy constructors, methods, functions, and classes that were deprecated in version 1.7.*x*. To avoid compiler errors, import errors, syntax errors, and symbol not found errors (depending on your programming language), upgrade first to the latest 1.*x* version of the AWS Encryption SDK for your programming language. (This must be version 1.7.*x* or later.) While using the latest 1.*x* version, you can begin using the replacement elements before the original symbols are removed.

If you need to upgrade to version 2.0.*x* or later immediately, consult the changelog for your programming language, and replace the legacy symbols with the symbols the changelog recommends.

Configuration conflict: Commitment policy and algorithm suite

If you specify an algorithm suite that conflicts with your commitment policy, the call to encrypt fails with a *Configuration conflict* error.

To avoid this type of error, don't specify an algorithm suite. By default, the AWS Encryption SDK chooses the most secure algorithm that is compatible with your commitment policy. However, if you must specify an algorithm suite, such as one without signing, be sure to choose an algorithm suite that is compatible with your commitment policy.

Commitment policy	Compatible algorithm suites
ForbidEncryptAllowDecrypt	Any algorithm suite *without* key commitment, such as: `AES_256_GCM_IV12_TAG16_HKDF_SHA384_ECDSA_P384` (03 78) (with signing) `AES_256_GCM_IV12_TAG16_HKDF_SHA256` (01 78) (without signing)
RequireEncryptAllowDecrypt RequireEncryptRequireDecrypt	Any algorithm suite *with* key commitment, such as: `AES_256_GCM_HKDF_SHA512_COMMIT_KEY_ECDSA_P384` (05 78) (with signing)

Commitment policy	Compatible algorithm suites
	`AES_256_GCM_HKDF_SHA512_COMMIT_KEY` (04 78) (without signing)

If you encounter this error when you have not specified an algorithm suite, the conflicting algorithm suite might have been chosen by your cryptographic materials manager (CMM). The Default CMM won't select a conflicting algorithm suite, but a custom CMM might. For help, consult the documentation for your custom CMM.

Configuration conflict: Commitment policy and ciphertext

The `RequireEncryptRequireDecrypt` commitment policy does not permit the AWS Encryption SDK to decrypt a message that was encrypted without key commitment. If you ask the AWS Encryption SDK to decrypt a message without key commitment, it returns a *Configuration conflict* error.

To avoid this error, before setting the `RequireEncryptRequireDecrypt` commitment policy, be sure that all ciphertexts encrypted without key commitment are decrypted and re-encrypted with key commitment, or handled by a different application. If you encounter this error, you can return an error for the conflicting ciphertext or change your commitment policy temporarily to `RequireEncryptAllowDecrypt`.

If you are encountering this error because you upgraded to version 2.0.*x* or later from a version earlier than 1.7.*x* without first upgrading to the latest 1.*x* version (version 1.7.*x* or later), consider rolling back to the latest 1.*x* version and deploying that version to all hosts before upgrading to version 2.0.*x* or later. For help, see How to migrate and deploy the AWS Encryption SDK.

Key commitment validation failed

When you decrypt messages that are encrypted with key commitment, you might get a *Key commitment validation failed* error message. This indicates that the decrypt call failed because a data key in an encrypted message is not identical to the unique data key for the message. By validating the data key during decryption, key commitment protects you from decrypting a message that might result in more than one plaintext.

This error indicates that the encrypted message that you were trying to decrypt was not returned by the AWS Encryption SDK. It might be a manually crafted message or the result of data

corruption. If you encounter this error, your application can reject the message and continue, or stop processing new messages.

Other encryption failures

Encryption can fail for multiple reasons. You cannot use an AWS KMS discovery keyring or a master key provider in discovery mode to encrypt a message.

Be sure that you specify a keyring or master key provider with wrapping keys that you have permission to use for encryption. For help with permissions on AWS KMS keys, see Viewing a key policy and Determining access to an AWS KMS key in the *AWS Key Management Service Developer Guide*.

Other decryption failures

If your attempt to decrypt an encrypted message fails, it means that the AWS Encryption SDK could not (or would not) decrypt any of the encrypted data keys in the message.

If you used a keyring or master key provider that specifies wrapping keys, the AWS Encryption SDK uses only the wrapping keys you specify. Verify that you are using the wrapping keys that you intend and that you have `kms:Decrypt` permission on at least one of the wrapping keys. If you are using AWS KMS keys, as a fallback, you can try decrypting the message with an AWS KMS discovery keyring or a master key provider in discovery mode. If the operation succeeds, before returning the plaintext, verify that the key used to decrypt the message is one that you trust.

Rollback considerations

If your application is failing to encrypt or decrypt data, you can usually resolve the problem by updating the code symbols, keyrings, master key providers, or commitment policy. However, in some cases, you might decide that it's best to roll back your application to a previous version of the AWS Encryption SDK.

If you must roll back, do so with caution. Versions of the AWS Encryption SDK prior to 1.7.*x* cannot decrypt ciphertext encrypted with key commitment.

- Rolling back from the latest 1.*x* version to a previous version of the AWS Encryption SDK is generally safe. You might have to undo changes you made to your code to use symbols and objects that are not supported in previous versions.
- Once you have begun encrypting with key commitment (setting your commitment policy to `RequireEncryptAllowDecrypt`) in version 2.0.*x* or later, you can roll back to version 1.7.*x*,

but not to any earlier version. Versions of the AWS Encryption SDK prior to 1.7.*x* cannot decrypt ciphertext encrypted with key commitment.

If you accidentally enable encrypting with key commitment before all hosts can decrypt with key commitment, it might be best to continue with the roll out rather than to roll back. If messages are transient or can be safely dropped, then you might consider a rollback with loss of messages. If a rollback is required, you might consider writing a tool that decrypts and re-encrypts all messages.

Frequently asked questions

Frequently asked questions

- How is the AWS Encryption SDK different from the AWS SDKs?
- How is the AWS Encryption SDK different from the Amazon S3 encryption client?
- Which cryptographic algorithms are supported by the AWS Encryption SDK, and which one is the default?
- How is the initialization vector (IV) generated and where is it stored?
- How is each data key generated, encrypted, and decrypted?
- How do I keep track of the data keys that were used to encrypt my data?
- How does the AWS Encryption SDK store encrypted data keys with their encrypted data?
- How much overhead does the AWS Encryption SDK message format add to my encrypted data?
- Can I use my own master key provider?
- Can I encrypt data under more than one wrapping key?
- Which data types can I encrypt with the AWS Encryption SDK?
- How does the AWS Encryption SDK encrypt and decrypt input/output (I/O) streams?

How is the AWS Encryption SDK different from the AWS SDKs?

The AWS SDKs provide libraries for interacting with Amazon Web Services (AWS), including AWS Key Management Service (AWS KMS). Some of the language implementations of the AWS Encryption SDK, such as the AWS Encryption SDK for .NET, always require the AWS SDK in the same programming language. Other language implementations require the corresponding AWS SDK only when you use AWS KMS keys in your keyrings or master key providers. For details, see the topic about your programming language in AWS Encryption SDK programming languages.

You can use the AWS SDKs to interact with AWS KMS, including encrypting and decrypting small amounts of data (up to 4,096 bytes with a symmetric encryption key) and generating data keys for client-side encryption. However, when you generate a data key, you must manage the entire encryption and decryption process, includluding encrypting your data with the data key outside of AWS KMS, safely discarding the plaintext data key, storing the encrypted data key, and then decrypting the data key and decrypting your data. The AWS Encryption SDK handles this process for you.

The AWS Encryption SDK provides a library that encrypts and decrypts data using industry standards and best practices. It generates the data key, encrypts it under the wrapping keys you specify, and returns an *encrypted message*, a portable data object that includes the encrypted data and the encrypted data keys you need to decrypt it. When it's time to decrypt, you pass in the encrypted message and at least one of the wrapping keys (optional), and the AWS Encryption SDK returns your plaintext data.

You can use AWS KMS keys as wrapping keys in the AWS Encryption SDK, but it is not required. You can use encryption keys that you generate and those from your key manager or on-premises hardware security module. You can use the AWS Encryption SDK even if you don't have an AWS account.

How is the AWS Encryption SDK different from the Amazon S3 encryption client?

The Amazon S3 encryption client in the AWS SDKs provides encryption and decryption for data that you store in Amazon Simple Storage Service (Amazon S3). These clients are tightly coupled to Amazon S3 and are intended for use only with data stored there.

The AWS Encryption SDK provides encryption and decryption for data that you can store anywhere. The AWS Encryption SDK and the Amazon S3 encryption client are not compatible because they produce ciphertexts with different data formats.

Which cryptographic algorithms are supported by the AWS Encryption SDK, and which one is the default?

The AWS Encryption SDK uses the Advanced Encryption Standard (AES) symmetric algorithm in Galois/Counter Mode (GCM), known as AES-GCM, to encrypt your data. It lets you choose from several symmetric and asymmetric algorithms to encrypt the data keys that encrypt your data.

For AES-GCM, the default algorithm suite is AES-GCM with a 256-bit key, key derivation (HKDF), digital signatures, and key commitment. AWS Encryption SDK also supports 192-bit, and 128-bit encryption keys and encryption algorithms without digital signatures and key commitment.

In all cases, the length of the initialization vector (IV) is 12 bytes; the length of the authentication tag is 16 bytes. By default, the SDK uses the data key as an input to the HMAC-based extract-and-expand key derivation function (HKDF) to derive the AES-GCM encryption key, and also adds an Elliptic Curve Digital Signature Algorithm (ECDSA) signature.

For information about choosing which algorithm to use, see Supported algorithm suites.

For implementation details about the supported algorithms, see Algorithms reference.

How is the initialization vector (IV) generated and where is it stored?

The AWS Encryption SDK uses a deterministic method to construct a different IV value for each frame. This procedure guarantees that IVs are never repeated within a message. (Prior to version 1.3.0 of the AWS Encryption SDK for Java and the AWS Encryption SDK for Python, the AWS Encryption SDK randomly generated a unique IV value for each frame.)

The IV is stored in the encrypted message that the AWS Encryption SDK returns. For more information, see the AWS Encryption SDK message format reference.

How is each data key generated, encrypted, and decrypted?

The method depends on the keyring or master key provider you use.

The AWS KMS keyrings and master key providers in the AWS Encryption SDK use the AWS KMS GenerateDataKey API operation to generate each data key and encrypt it under its wrapping key. To encrypt copies of the data key under additional KMS keys, they use the AWS KMS Encrypt operation. To decrypt the data keys, they use the AWS KMS Decrypt operation. For details, see AWS KMS keyring in the AWS Encryption SDK Specification in GitHub.

Other keyrings generate the data key, encrypt, and decrypt using best practice methods for each programming language. For details, see the specification of the keyring or master key provider in the Framework section of the AWS Encryption SDK Specification in GitHub.

How do I keep track of the data keys that were used to encrypt my data?

The AWS Encryption SDK does this for you. When you encrypt data, the SDK encrypts the data key and stores the encrypted key along with the encrypted data in the encrypted message that it returns. When you decrypt data, the AWS Encryption SDK extracts the encrypted data key from the encrypted message, decrypts it, and then uses it to decrypt the data.

How does the AWS Encryption SDK store encrypted data keys with their encrypted data?

The encryption operations in the AWS Encryption SDK return an encrypted message, a single data structure that contains the encrypted data and its encrypted data keys. The message format consists of at least two parts: a *header* and a *body*. The message header contains the encrypted data keys and information about how the message body is formed. The message body contains the encrypted data. If the algorithm suite includes a digital signature, the message format includes a *footer* that contains the signature. For more information, see AWS Encryption SDK message format reference.

How much overhead does the AWS Encryption SDK message format add to my encrypted data?

The amount of overhead added by the AWS Encryption SDK depends on several factors, including the following:

- The size of the plaintext data
- Which of the supported algorithms is used
- Whether additional authenticated data (AAD) is provided, and the length of that AAD
- The number and type of wrapping keys or master keys
- The frame size (when framed data is used)

When you use the AWS Encryption SDK with its default configuration (one AWS KMS key as the wrapping key (or master key), no AAD, nonframed data, and an encryption algorithm with signing), the overhead is approximately 600 bytes. In general, you can reasonably assume that the AWS Encryption SDK adds overhead of 1 KB or less, not including the provided AAD. For more information, see AWS Encryption SDK message format reference.

Can I use my own master key provider?

Yes. The implementation details vary depending on which of th the supported programming languages you use. However, all supported languages allow you to define custom cryptographic materials managers (CMMs)Ms), master key providers, keyrings, master keys, and wrapping keys.

Can I encrypt data under more than one wrapping key?

Yes. You can encrypt the data key with additional wrapping keys (or master keys) to add redundancy when the key is in a different region or is unavailable for decryption.

To encrypt data under multiple wrapping keys, create a keyring or master key provider with multiple wrapping keys. When working with keyrings, you can create a single keyring with multiple wrapping keys or a multi-keyring.

When you encrypt data with multiple wrapping keys, the AWS Encryption SDK uses one wrapping key to generate a plaintext data key. The data key is unique and mathematically unrelated to the wrapping key. The operation returns the plaintext data key and a copy of the data key encrypted by the wrapping key. Then the encryption method, encrypts the data key with the other wrapping keys. The resulting encrypted message includes the encrypted data and one encrypted data key for each wrapping key.

The encryptypted message can be decrypted by using any one of the wrapping keys used in the encryption operation. The AWS Encryption SDK uses a wrapping key to decrypt an encrypted data key. Then, it uses the plaintext data key to decrypt the data.

Which data types can I encrypt with the AWS Encryption SDK?

Most programming language implementations of the AWS Encryption SDK can encrypt raw bytes (byte arrays), I/O streams (byte streams), and strings. The AWS Encryption SDK for .NET does not support I/O streams. We provide example code for each of the supported programming languages.

How does the AWS Encryption SDK encrypt and decrypt input/output (I/O) streams?

The AWS Encryption SDK creates an encrypting or decrypting stream that wraps an underlying I/O stream. The encrypting or decrypting stream performs a cryptographic operation on a read or write call. For example, it can read plaintext data on the underlying stream and encrypt it before returning the result. Or it can read ciphertext from an underlying stream and decrypt it before returning the result. We provide example code for encrypting and decrypting streams for each of the supported programming languages that supports streaming.

The AWS Encryption SDK for .NET does not support I/O streams.

AWS Encryption SDK reference

The information on this page is a reference for building your own encryption library that is compatible with the AWS Encryption SDK. If you are not building your own compatible encryption library, you likely do not need this information.

To use the AWS Encryption SDK in one of the supported programming languages, see Programming languages.

For the specification that defines the elements of a proper AWS Encryption SDK implement ation, see the AWS Encryption SDK Specification in GitHub.

The AWS Encryption SDK uses the supported algorithms to return a single data structure or *message* that contains encrypted data and the corresponding encrypted data keys. The following topics explain the algorithms and the data structure. Use this information to build libraries that can read and write ciphertexts that are compatible with this SDK.

Topics

- AWS Encryption SDK message format reference
- AWS Encryption SDK message format examples
- Body additional authenticated data (AAD) reference for the AWS Encryption SDK
- AWS Encryption SDK algorithms reference
- AWS Encryption SDK initialization vector reference
- AWS KMS Hierarchical keyring technical details

AWS Encryption SDK message format reference

The information on this page is a reference for building your own encryption library that is compatible with the AWS Encryption SDK. If you are not building your own compatible encryption library, you likely do not need this information.

To use the AWS Encryption SDK in one of the supported programming languages, see Programming languages.

For the specification that defines the elements of a proper AWS Encryption SDK implementation, see the AWS Encryption SDK Specification in GitHub.

The encryption operations in the AWS Encryption SDK return a single data structure or encrypted message that contains the encrypted data (ciphertext) and all encrypted data keys. To understand this data structure, or to build libraries that read and write it, you need to understand the message format.

The message format consists of at least two parts: a *header* and a *body*. In some cases, the message format consists of a third part, a *footer*. The message format defines an ordered sequence of bytes in network byte order, also called big-endian format. The message format begins with the header, followed by the body, followed by the footer (when there is one).

The algorithms suites supported by the AWS Encryption SDK use one of two message format versions. Algorithm suites without key commitment use message format version 1. Algorithm suites with key commitment use message format version 2.

Topics

- Header structure
- Body structure
- Footer structure

Header structure

The message header contains the encrypted data key and information about how the message body is formed. The following table describes the fields that form the header in message format versions 1 and 2. The bytes are appended in the order shown.

The **Not present** value indicates that the field doesn't exist in that version of the message format. **Bold text** indicates values that are different in each version.

> **Note**
>
> You might need to scroll horizontally or vertically to see all of the data in this table.

Header Structure

Field	Message format version 1 Length (bytes)	Message format version 2 Length (bytes)
Version	1	1
Type	**1**	**Not present**
Algorithm ID	2	2
Message ID	**16**	**32**
AAD Length	2 When the encryption context is empty, the value of the 2-byte AAD Length field is 0.	2 When the encryption context is empty, the value of the 2-byte AAD Length field is 0.
AAD	Variable. The length of this field appears in the previous 2 bytes (AAD Length field). When the encryption context is empty, there is no AAD field in the header.	Variable. The length of this field appears in the previous 2 bytes (AAD Length field). When the encryption context is empty, there is no AAD field in the header.
Encrypted Data Key Count	2	2
Encrypted Data Key(s)	Variable. Determined by the number of encrypted data keys and the length of each.	Variable. Determined by the number of encrypted data keys and the length of each.
Content Type	1	1
Reserved	**4**	**Not present**
IV Length	**1**	**Not present**
Frame Length	4	4

Field	Message format version 1 Length (bytes)	Message format version 2 Length (bytes)
Algorithm Suite Data	**Not present**	**Variable.** Determined by the algorithm that generated the message.
Header Authentication	Variable. Determined by the algorithm that generated the message.	Variable. Determined by the algorithm that generated the message.

Version

The version of this message format. The version is either 1 or 2 encoded as the byte `01` or `02` in hexadecimal notation

Type

The type of this message format. The type indicates the kind of structure. The only supported type is described as *customer authenticated encrypted data*. Its type value is 128, encoded as byte `80` in hexadecimal notation.

This field is not present in message format version 2.

Algorithm ID

An identifier for the algorithm used. It is a 2-byte value interpreted as a 16-bit unsigned integer. For more information about the algorithms, see AWS Encryption SDK algorithms reference.

Message ID

A randomly generated value that identifies the message. The Message ID:

- Uniquely identifies the encrypted message.
- Weakly binds the message header to the message body.
- Provides a mechanism to securely reuse a data key with multiple encrypted messages.
- Protects against accidental reuse of a data key or the wearing out of keys in the AWS Encryption SDK.

This value is 128 bits in message format version 1 and 256 bits in version 2.

AAD Length

The length of the additional authenticated data (AAD). It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of bytes that contain the AAD.

When the encryption context is empty, the value of the AAD Length field is 0.

AAD

The additional authenticated data. The AAD is an encoding of the encryption context, an array of key-value pairs where each key and value is a string of UTF-8 encoded characters. The encryption context is converted to a sequence of bytes and used for the AAD value. When the encryption context is empty, there is no AAD field in the header.

When the algorithms with signing are used, the encryption context must contain the key-value pair `{'aws-crypto-public-key', Qtxt}`. Qtxt represents the elliptic curve point Q compressed according to SEC 1 version 2.0 and then base64-encoded. The encryption context can contain additional values, but the maximum length of the constructed AAD is 2^16 - 1 bytes.

The following table describes the fields that form the AAD. Key-value pairs are sorted, by key, in ascending order according to UTF-8 character code. The bytes are appended in the order shown.

AAD Structure

Field	Length (bytes)
Key-Value Pair Count	2
Key Length	2
Key	Variable. Equal to the value specified in the previous 2 bytes (Key Length).
Value Length	2
Value	Variable. Equal to the value specified in the previous 2 bytes (Value Length).

Key-Value Pair Count

The number of key-value pairs in the AAD. It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of key-value pairs in the AAD. The maximum number of key-value pairs in the AAD is 2^16 - 1.

When there is no encryption context or the encryption context is empty, this field is not present in the AAD structure.

Key Length

The length of the key for the key-value pair. It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of bytes that contain the key.

Key

The key for the key-value pair. It is a sequence of UTF-8 encoded bytes.

Value Length

The length of the value for the key-value pair. It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of bytes that contain the value.

Value

The value for the key-value pair. It is a sequence of UTF-8 encoded bytes.

Encrypted Data Key Count

The number of encrypted data keys. It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of encrypted data keys. The maximum number of encrypted data keys in each message is 65,535 (2^16 - 1).

Encrypted Data Key(s)

A sequence of encrypted data keys. The length of the sequence is determined by the number of encrypted data keys and the length of each. The sequence contains at least one encrypted data key.

The following table describes the fields that form each encrypted data key. The bytes are appended in the order shown.

Encrypted Data Key Structure

Field	Length (bytes)
Key Provider ID Length	2
Key Provider ID	Variable. Equal to the value specified in the previous 2 bytes (Key Provider ID Length).
Key Provider Information Length	2
Key Provider Information	Variable. Equal to the value specified in the previous 2 bytes (Key Provider Information Length).
Encrypted Data Key Length	2
Encrypted Data Key	Variable. Equal to the value specified in the previous 2 bytes (Encrypted Data Key Length).

Key Provider ID Length

The length of the key provider identifier. It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of bytes that contain the key provider ID.

Key Provider ID

The key provider identifier. It is used to indicate the provider of the encrypted data key and intended to be extensible.

Key Provider Information Length

The length of the key provider information. It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of bytes that contain the key provider information.

Key Provider Information

The key provider information. It is determined by the key provider.

When AWS KMS is the master key provider or you are using an AWS KMS keyring, this value contains the Amazon Resource Name (ARN) of the AWS KMS key.

Encrypted Data Key Length

The length of the encrypted data key. It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of bytes that contain the encrypted data key.

Encrypted Data Key

The encrypted data key. It is the data encryption key encrypted by the key provider.

Content Type

The type of encrypted data, either nonframed or framed.

> **Note**
>
> Whenever possible, use framed data. The AWS Encryption SDK supports nonframed data only for legacy use. Some language implementations of the AWS Encryption SDK can still generate nonframed ciphertext. All supported language implementations can decrypt framed and nonframed ciphertext.

Framed data is divided into equal-length parts; each part is encrypted separately. Framed content is type 2, encoded as the byte `02` in hexadecimal notation.

Nonframed data is not divided; it is a single encrypted blob. Non-framed content is type 1, encoded as the byte `01` in hexadecimal notation.

Reserved

A reserved sequence of 4 bytes. This value must be 0. It is encoded as the bytes `00 00 00 00` in hexadecimal notation (that is, a 4-byte sequence of a 32-bit integer value equal to 0).

This field is not present in message format version 2.

IV Length

The length of the initialization vector (IV). It is a 1-byte value interpreted as an 8-bit unsigned integer that specifies the number of bytes that contain the IV. This value is determined by the IV bytes value of the algorithm that generated the message.

This field is not present in message format version 2, which only supports algorithm suites that use deterministic IV values in the message header.

Frame Length

The length of each frame of framed data. It is a 4-byte value interpreted as a 32-bit unsigned integer that specifies the number of bytes in each frame. When the data is nonframed, that is, when the value of the `Content Type` field is 1, this value must be 0.

> **Note**
>
> Whenever possible, use framed data. The AWS Encryption SDK supports nonframed data only for legacy use. Some language implementations of the AWS Encryption SDK can still generate nonframed ciphertext. All supported language implementations can decrypt framed and nonframed ciphertext.

Algorithm Suite Data

Supplementary data needed by the algorithm that generated the message. The length and contents are determined by the algorithm. Its length might be 0.

This field is not present in message format version 1.

Header Authentication

The header authentication is determined by the algorithm that generated the message. The header authentication is calculated over the entire header. It consists of an IV and an authentication tag. The bytes are appended in the order shown.

Header Authentication Structure

Field	Length in version 1.0 (bytes)	Length in version 2.0 (bytes)
IV	Variable. Determined by the IV bytes value of the algorithm that generated the message.	N/A
Authentication Tag	Variable. Determined by the authentication tag bytes value of the algorithm that generated the message.	Variable. Determined by the authentication tag bytes value of the algorithm that generated the message.

IV

The initialization vector (IV) used to calculate the header authentication tag.

This field is not present in the header of message format version 2. Message format version 2 only supports algorithm suites that use deterministic IV values in the message header.

Authentication Tag

The authentication value for the header. It is used to authenticate the entire contents of the header.

Body structure

The message body contains the encrypted data, called the *ciphertext*. The structure of the body depends on the content type (nonframed or framed). The following sections describe the format of the message body for each content type. The message body structure is the same in message format versions 1 and 2.

Topics

- Non-framed data
- Framed data

Non-framed data

Non-framed data is encrypted in a single blob with a unique IV and body AAD.

> **Note**
>
> Whenever possible, use framed data. The AWS Encryption SDK supports nonframed data only for legacy use. Some language implementations of the AWS Encryption SDK can still generate nonframed ciphertext. All supported language implementations can decrypt framed and nonframed ciphertext.

The following table describes the fields that form nonframed data. The bytes are appended in the order shown.

Non-Framed Body Structure

Field	Length, in bytes
IV	Variable. Equal to the value specified in the IV Length byte of the header.
Encrypted Content Length	8
Encrypted Content	Variable. Equal to the value specified in the previous 8 bytes (Encrypted Content Length).
Authentication Tag	Variable. Determined by the algorithm implementation used.

IV

The initialization vector (IV) to use with the encryption algorithm.

Encrypted Content Length

The length of the encrypted content, or *ciphertext*. It is an 8-byte value interpreted as a 64-bit unsigned integer that specifies the number of bytes that contain the encrypted content.

Technically, the maximum allowed value is 2^63 - 1, or 8 exbibytes (8 EiB). However, in practice the maximum value is 2^36 - 32, or 64 gibibytes (64 GiB), due to restrictions imposed by the implemented algorithms.

> **Note**
>
> The Java implementation of this SDK further restricts this value to 2^31 - 1, or 2 gibibytes (2 GiB), due to restrictions in the language.

Encrypted Content

The encrypted content (ciphertext) as returned by the encryption algorithm.

Authentication Tag

The authentication value for the body. It is used to authenticate the message body.

Framed data

In framed data, the plaintext data is divided into equal-length parts called *frames*. The AWS Encryption SDK encrypts each frame separately with a unique IV and body AAD.

> **Note**
>
> Whenever possible, use framed data. The AWS Encryption SDK supports nonframed data only for legacy use. Some language implementations of the AWS Encryption SDK can still generate nonframed ciphertext. All supported language implementations can decrypt framed and nonframed ciphertext.

The frame length, which is the length of the encrypted content in the frame, can be different for each message. The maximum number of bytes in a frame is 2^32 - 1. The maximum number of frames in a message is 2^32 - 1.

There are two types of frames: *regular* and *final*. Every message must consist of or include a final frame.

All regular frames in a message have the same frame length. The final frame can have a different frame length.

The composition of frames in framed data varies with the length of the encrypted content.

- **Equal to the frame length** — When the encrypted content length is the same as the frame length of the regular frames, the message can consist of a regular frame that contains the data, followed by a final frame of zero (0) length. Or, the message can consist only of a final frame that contains the data. In this case, the final frame has the same frame length as the regular frames.
- **Multiple of the frame length** — When the encrypted content length is an exact multiple of the frame length of the regular frames, the message can end in a regular frame that contains the data, followed by a final frame of zero (0) length. Or, the message can end in a final frame that contains the data. In this case, the final frame has the same frame length as the regular frames.
- **Not a multiple of the frame length** — When the encrypted content length is not an exact multiple of the frame length of the regular frames, the final frame contains the remaining data. The frame length of the final frame is less than the frame length of the regular frames.

- **Less than the frame length** — When the encrypted content length is less than the frame length of the regular frames, the message consists of a final frame that contains all of the data. The frame length of the final frame is less than the frame length of the regular frames.

The following tables describe the fields that form the frames. The bytes are appended in the order shown.

Framed Body Structure, Regular Frame

Field	Length, in bytes
Sequence Number	4
IV	Variable. Equal to the value specified in the IV Length byte of the header.
Encrypted Content	Variable. Equal to the value specified in the Frame Length of the header.
Authentication Tag	Variable. Determined by the algorithm used, as specified in the Algorithm ID of the header.

Sequence Number

The frame sequence number. It is an incremental counter number for the frame. It is a 4-byte value interpreted as a 32-bit unsigned integer.

Framed data must start at sequence number 1. Subsequent frames must be in order and must contain an increment of 1 of the previous frame. Otherwise, the decryption process stops and reports an error.

IV

The initialization vector (IV) for the frame. The SDK uses a deterministic method to construct a different IV for each frame in the message. Its length is specified by the algorithm suite used.

Encrypted Content

The encrypted content (ciphertext) for the frame, as returned by the encryption algorithm.

Authentication Tag

The authentication value for the frame. It is used to authenticate the entire frame.

Framed Body Structure, Final Frame

Field	Length, in bytes
Sequence Number End	4
Sequence Number	4
IV	Variable. Equal to the value specified in the IV Length byte of the header.
Encrypted Content Length	4
Encrypted Content	Variable. Equal to the value specified in the previous 4 bytes (Encrypted Content Length).
Authentication Tag	Variable. Determined by the algorithm used, as specified in the Algorithm ID of the header.

Sequence Number End

An indicator for the final frame. The value is encoded as the 4 bytes `FF FF FF FF` in hexadecimal notation.

Sequence Number

The frame sequence number. It is an incremental counter number for the frame. It is a 4-byte value interpreted as a 32-bit unsigned integer.

Framed data must start at sequence number 1. Subsequent frames must be in order and must contain an increment of 1 of the previous frame. Otherwise, the decryption process stops and reports an error.

IV

The initialization vector (IV) for the frame. The SDK uses a deterministic method to construct a different IV for each frame in the message. The length of the IV length is specified by the algorithm suite.

Encrypted Content Length

The length of the encrypted content. It is a 4-byte value interpreted as a 32-bit unsigned integer that specifies the number of bytes that contain the encrypted content for the frame.

Encrypted Content

The encrypted content (ciphertext) for the frame, as returned by the encryption algorithm.

Authentication Tag

The authentication value for the frame. It is used to authenticate the entire frame.

Footer structure

When the algorithms with signing are used, the message format contains a footer. The message footer contains a digital signature calculated over the message header and body. The following table describes the fields that form the footer. The bytes are appended in the order shown. The message footer structure is the same in message format versions 1 and 2.

Footer Structure

Field	Length, in bytes
Signature Length	2
Signature	Variable. Equal to the value specified in the previous 2 bytes (Signature Length).

Signature Length

The length of the signature. It is a 2-byte value interpreted as a 16-bit unsigned integer that specifies the number of bytes that contain the signature.

Signature

The signature.

AWS Encryption SDK message format examples

The information on this page is a reference for building your own encryption library that is compatible with the AWS Encryption SDK. If you are not building your own compatible encryption library, you likely do not need this information.

To use the AWS Encryption SDK in one of the supported programming languages, see Programming languages.

For the specification that defines the elements of a proper AWS Encryption SDK implement ation, see the AWS Encryption SDK Specification in GitHub.

The following topics show examples of the AWS Encryption SDK message format. Each example shows the raw bytes, in hexadecimal notation, followed by a description of what those bytes represent.

Topics

- Framed data (message format version 1)
- Framed data (message format version 2)
- Non-framed data (message format version 1)

Framed data (message format version 1)

The following example shows the message format for framed data in message format version 1.

```
+--------+
| Header |
+--------+
01                                      Version (1.0)
80                                      Type (128, customer authenticated encrypted
 data)
0378                                    Algorithm ID (see Algorithms reference)
6E7C0FBD 4DF4A999 717C22A2 DDFE1A27     Message ID (random 128-bit value)
008E                                    AAD Length (142)
0004                                    AAD Key-Value Pair Count (4)
0005                                    AAD Key-Value Pair 1, Key Length (5)
30746869 73                             AAD Key-Value Pair 1, Key ("0This")
0002                                    AAD Key-Value Pair 1, Value Length (2)
```

```
6973                                        AAD Key-Value Pair 1, Value ("is")
0003                                        AAD Key-Value Pair 2, Key Length (3)
31616E                                      AAD Key-Value Pair 2, Key ("1an")
000A                                        AAD Key-Value Pair 2, Value Length (10)
656E6372 79774690 6F6E                      AAD Key-Value Pair 2, Value ("encryption")
0008                                        AAD Key-Value Pair 3, Key Length (8)
32636F6E 74657874                           AAD Key-Value Pair 3, Key ("2context")
0007                                        AAD Key-Value Pair 3, Value Length (7)
6578616D 706C65                             AAD Key-Value Pair 3, Value ("example")
0015                                        AAD Key-Value Pair 4, Key Length (21)
6177732D 63727970 746F2D70 75626C69         AAD Key-Value Pair 4, Key ("aws-crypto-
public-key")
632D6B65 79
0044                                        AAD Key-Value Pair 4, Value Length (68)
416A4173 7569326F 7430364C 4B77715A         AAD Key-Value Pair 4, Value
 ("AjAsui2ot06LKwqZXDJnU/Aqc2vD+0OkpOZ1cc8Tg2qd7rs5aLTg7lvfUEW/86+/5w==")
58444A6E 552F4171 63327644 2B304F6B
704F5A31 63633854 67327164 37727335
614C5467 376C7666 5545572F 38362B2F
35773D3D
0002                                        EncryptedDataKeyCount (2)
0007                                        Encrypted Data Key 1, Key Provider ID Length
 (7)
6177732D 6B6D73                             Encrypted Data Key 1, Key Provider ID ("aws-
kms")
004B                                        Encrypted Data Key 1, Key Provider
 Information Length (75)
61726E3A 6177733A 6B6D733A 75732D77         Encrypted Data Key 1, Key Provider
 Information ("arn:aws:kms:us-west-2:111122223333:key/715c0818-5825-4245-
a755-138a6d9a11e6")
6573742D 323A3131 31313232 32323333
33333A6B 65792F37 31356330 3831382D
35383235 2D343234 352D6137 35352D31
33386136 64396131 316536
00A7                                        Encrypted Data Key 1, Encrypted Data Key
 Length (167)
01010200 7857A1C1 F7370545 4ECA7C83         Encrypted Data Key 1, Encrypted Data Key
956C4702 23DCE8D7 16C59679 973E3CED
02A4EF29 7F000000 7E307C06 092A8648
86F70D01 0706A06F 306D0201 00306806
092A8648 86F70D01 0701301E 06096086
48016503 04012E30 11040C3F F02C897B
7A12EB19 8BF2D802 0110803B 24003D1F
A5474FBC 392360B5 CB9997E0 6A17DE4C
```

```
A6BD7332 6BF86DAB 60D8CCB8 8295DBE9
4707E356 ADA3735A 7C52D778 B3135A47
9F224BF9 E67E87
0007                                    Encrypted Data Key 2, Key Provider ID Length
 (7)
6177732D 6B6D73                         Encrypted Data Key 2, Key Provider ID ("aws-
kms")
004E                                    Encrypted Data Key 2, Key Provider
 Information Length (78)
61726E3A 6177733A 6B6D733A 63612D63     Encrypted Data Key 2, Key Provider
 Information ("arn:aws:kms:ca-central-1:111122223333:key/9b13ca4b-afcc-46a8-aa47-
be3435b423ff")
656E7472 616C2D31 3A313131 31323232
32333333 333A6B65 792F3962 31336361
34622D61 6663632D 34366138 2D616134
372D6265 33343335 62343233 6666
00A7                                    Encrypted Data Key 2, Encrypted Data Key
 Length (167)
01010200 78FAFFFB D6DE06AF AC72F79B     Encrypted Data Key 2, Encrypted Data Key
0E57BD87 3F60F4E6 FD196144 5A002C94
AF787150 69000000 7E307C06 092A8648
86F70D01 0706A06F 306D0201 00306806
092A8648 86F70D01 0701301E 06096086
48016503 04012E30 11040C36 CD985E12
D218B674 5BBC6102 0110803B 0320E3CD
E470AA27 DEAB660B 3E0CE8E0 8B1A89E4
57DCC69B AAB1294F 21202C01 9A50D323
72EBAAFD E24E3ED8 7168E0FA DB40508F
556FBD58 9E621C
02                                      Content Type (2, framed data)
00000000                                Reserved
0C                                      IV Length (12)
00000100                                Frame Length (256)
4ECBD5C0 9899CA65 923D2347              IV
0B896144 0CA27950 CA571201 4DA58029     Authentication Tag
+------+
| Body |
+------+
00000001                                Frame 1, Sequence Number (1)
6BD3FE9C ADBCB213 5B89E8F1              Frame 1, IV
1F6471E0 A51AF310 10FA9EF6 F0C76EDF     Frame 1, Encrypted Content
F5AFA33C 7D2E8C6C 9C5D5175 A212AF8E
FBD9A0C3 C6E3FB59 C125DBF2 89AC7939
BDEE43A8 0F00F49E ACBBD8B2 1C785089
```

```
A90DB923 699A1495 C3B31B50 0A48A830
201E3AD9 1EA6DA14 7F6496DB 6BC104A4
DEB7F372 375ECB28 9BF84B6D 2863889F
CB80A167 9C361C4B 5EC07438 7A4822B4
A7D9D2CC 5150D414 AF75F509 FCE118BD
6D1E798B AEBA4CDB AD009E5F 1A571B77
0041BC78 3E5F2F41 8AF157FD 461E959A
BB732F27 D83DC36D CC9EBC05 00D87803
57F2BB80 066971C2 DEEA062F 4F36255D
E866C042 E1382369 12E9926B BA40E2FC
A820055F FB47E428 41876F14 3B6261D9
5262DB34 59F5D37E 76E46522 E8213640
04EE3CC5 379732B5 F56751FA 8E5F26AD        Frame 1, Authentication Tag
00000002                                    Frame 2, Sequence Number (2)
F1140984 FF25F943 959BE514                  Frame 2, IV
216C7C6A 2234F395 F0D2D9B9 304670BF        Frame 2, Encrypted Content
A1042608 8A8BCB3F B58CF384 D72EC004
A41455B4 9A78BAC9 36E54E68 2709B7BD
A884C1E1 705FF696 E540D297 446A8285
23DFEE28 E74B225A 732F2C0C 27C6BDA2
7597C901 65EF3502 546575D4 6D5EBF22
1FF787AB 2E38FD77 125D129C 43D44B96
778D7CEE 3C36625F FF3A985C 76F7D320
ED70B1F3 79729B47 E7D9B5FC 02FCE9F5
C8760D55 7779520A 81D54F9B EC45219D
95941F7E 5CBAEAC8 CEC13B62 1464757D
AC65B6EF 08262D74 44670624 A3657F7F
2A57F1FD E7060503 AC37E197 2F297A84
DF1172C2 FA63CF54 E6E2B9B6 A86F582B
3B16F868 1BBC5E4D 0B6919B3 08D5ABCF
FECDC4A4 8577F08B 99D766A1 E5545670
A61F0A3B A3E45A84 4D151493 63ECA38F        Frame 2, Authentication Tag
FFFFFFFF                                    Final Frame, Sequence Number End
00000003                                    Final Frame, Sequence Number (3)
35F74F11 25410F01 DD9E04BF                  Final Frame, IV
0000008E                                    Final Frame, Encrypted Content Length (142)
F7A53D37 2F467237 6FBD0B57 D1DFE830        Final Frame, Encrypted Content
B965AD1F A910AA5F 5EFFFFF4 BC7D431C
BA9FA7C4 B25AF82E 64A04E3A A0915526
88859500 7096FABB 3ACAD32A 75CFED0C
4A4E52A3 8E41484D 270B7A0F ED61810C
3A043180 DF25E5C5 3676E449 0986557F
C051AD55 A437F6BC 139E9E55 6199FD60
6ADC017D BA41CDA4 C9F17A83 3823F9EC
```

```
B66B6A5A 80FDB433 8A48D6A4 21CB
811234FD 8D589683 51F6F39A 040B3E3B        Final Frame, Authentication Tag
+--------+
| Footer |
+--------+
0066                                       Signature Length (102)
30640230 085C1D3C 63424E15 B2244448        Signature
639AED00 F7624854 F8CF2203 D7198A28
758B309F 5EFD9D5D 2E07AD0B 467B8317
5208B133 02301DF7 2DFC877A 66838028
3C6A7D5E 4F8B894E 83D98E7C E350F424
7E06808D 0FE79002 E24422B9 98A0D130
A13762FF 844D
```

Framed data (message format version 2)

The following example shows the message format for framed data in message format version 2.

```
+--------+
| Header |
+--------+
02                                         Version (2.0)
0578                                       Algorithm ID (see Algorithms reference)
122747eb 21dfe39b 38631c61 7fad7340
cc621a30 32a11cc3 216d0204 fd148459        Message ID (random 256-bit value)
008e                                       AAD Length (142)
0004                                       AAD Key-Value Pair Count (4)
0005                                       AAD Key-Value Pair 1, Key Length (5)
30546869 73                                AAD Key-Value Pair 1, Key ("0This")
0002                                       AAD Key-Value Pair 1, Value Length (2)
6973                                       AAD Key-Value Pair 1, Value ("is")
0003                                       AAD Key-Value Pair 2, Key Length (3)
31616e                                     AAD Key-Value Pair 2, Key ("1an")
000a                                       AAD Key-Value Pair 2, Value Length (10)
656e6372 79707469 6f6e                     AAD Key-Value Pair 2, Value ("encryption")
0008                                       AAD Key-Value Pair 3, Key Length (8)
32636f6e 74657874                          AAD Key-Value Pair 3, Key ("2context")
0007                                       AAD Key-Value Pair 3, Value Length (7)
6578616d 706c65                            AAD Key-Value Pair 3, Value ("example")
0015                                       AAD Key-Value Pair 4, Key Length (21)
6177732d 63727970 746f2d70 75626c69        AAD Key-Value Pair 4, Key ("aws-crypto-
public-key")
632d6b65 79
```

```
0044                                    AAD Key-Value Pair 4, Value Length (68)
41746733 72703845 41345161 36706669     AAD Key-Value Pair 4, Value
 ("QXRnM3JwOEVBNFFhNnBmaTk3MUlTNTk3NHpOMnlZWE5vSmtwRHFPc0dIYkVaVDRqME5OMlFkRStmbTFVY01WdThnPT0=
39373149 53353937 347a4e32 7959584e
6f4a6b70 44714f73 47486245 5a54346a
304e4e32 5164452b 666d3155 634d5675
38673d3d
0001                                    Encrypted Data Key Count (1)
0007                                    Encrypted Data Key 1, Key Provider ID Length
 (7)
6177732d 6b6d73                         Encrypted Data Key 1, Key Provider ID ("aws-
kms")
004b                                    Encrypted Data Key 1, Key Provider
 Information Length (75)
61726e3a 6177733a 6b6d733a 75732d77     Encrypted Data Key 1, Key
 Provider Information ("arn:aws:kms:us-west-2:658956600833:key/b3537ef1-
d8dc-4780-9f5a-55776cbb2f7f")
6573742d 323a3635 38393536 36303038
33333a6b 65792f62 33353337 6566312d
64386463 2d343738 302d3966 35612d35
35373736 63626232 663766
00a7                                    Encrypted Data Key 1, Encrypted Data Key
 Length (167)
01010100 7840f38c 275e3109 7416c107     Encrypted Data Key 1, Encrypted Data Key
29515057 1964ada3 ef1c21e9 4c8ba0bd
bc9d0fb4 14000000 7e307c06 092a8648
86f70d01 0706a06f 306d0201 00306806
092a8648 86f70d01 0701301e 06096086
48016503 04012e30 11040c39 32d75294
06063803 f8460802 0110803b 2a46bc23
413196d2 903bf1d7 3ed98fc8 a94ac6ed
e00ee216 74ec1349 12777577 7fa052a5
ba62e9e4 f2ac8df6 bcb1758f 2ce0fb21
cc9ee5c9 7203bb
02                                      Content Type (2, framed data)
00001000                                Frame Length (4096)
05cd035b 29d5499d 4587570b 87502afe     Algorithm Suite Data (key commitment)
634f7b2c c3df2aa9 88a10105 4a2c7687
76cb339f 2536741f 59a1c202 4f2594ab     Authentication Tag
+------+
| Body |
+------+
ffffffff                                Final Frame, Sequence Number End
00000001                                Final Frame, Sequence Number (1)
```

```
00000000 00000000 00000001                  Final Frame, IV
00000009                                    Final Frame, Encrypted Content Length (9)
fa6e39c6 02927399 3e                        Final Frame, Encrypted Content
f683a564 405d68db eeb0656c d57c9eb0         Final Frame, Authentication Tag
+--------+
| Footer |
+--------+
0067                                        Signature Length (103)
30650230 2a1647ad 98867925 c1712e8f         Signature
ade70b3f 2a2bc3b8 50eb91ef 56cfdd18
967d91d8 42d92baf 357bba48 f636c7a0
869cade2 023100aa ae12d08f 8a0afe85
e5054803 110c9ed8 11b2e08a c4a052a9
074217ea 3b01b660 534ac921 bf091d12
3657e2b0 9368bd
```

Non-framed data (message format version 1)

The following example shows the message format for nonframed data.

> **Note**
>
> Whenever possible, use framed data. The AWS Encryption SDK supports nonframed data only for legacy use. Some language implementations of the AWS Encryption SDK can still generate nonframed ciphertext. All supported language implementations can decrypt framed and nonframed ciphertext.

```
+--------+
| Header |
+--------+
01                                          Version (1.0)
80                                          Type (128, customer authenticated encrypted
 data)
0378                                        Algorithm ID (see Algorithms reference)
B8929B01 753D4A45 C0217F39 404F70FF         Message ID (random 128-bit value)
008E                                        AAD Length (142)
0004                                        AAD Key-Value Pair Count (4)
0005                                        AAD Key-Value Pair 1, Key Length (5)
30746869 73                                 AAD Key-Value Pair 1, Key ("0This")
0002                                        AAD Key-Value Pair 1, Value Length (2)
```

```
6973                                        AAD Key-Value Pair 1, Value ("is")
0003                                        AAD Key-Value Pair 2, Key Length (3)
31616E                                      AAD Key-Value Pair 2, Key ("1an")
000A                                        AAD Key-Value Pair 2, Value Length (10)
656E6372 79774690 6F6E                      AAD Key-Value Pair 2, Value ("encryption")
0008                                        AAD Key-Value Pair 3, Key Length (8)
32636F6E 74657874                           AAD Key-Value Pair 3, Key ("2context")
0007                                        AAD Key-Value Pair 3, Value Length (7)
6578616D 706C65                             AAD Key-Value Pair 3, Value ("example")
0015                                        AAD Key-Value Pair 4, Key Length (21)
6177732D 63727970 746F2D70 75626C69         AAD Key-Value Pair 4, Key ("aws-crypto-
public-key")
632D6B65 79
0044                                        AAD Key-Value Pair 4, Value Length (68)
41734738 67473949 6E4C5075 3136594B         AAD Key-Value Pair 4, Value
 ("AsG8gG9InLPu16YKlqXTOD+nykG8YqHAhqecj8aXfD2e5B4gtVE73dZkyClA+rAMOQ==")
6C715854 4F442B6E 796B4738 59714841
68716563 6A386158 66443265 35423467
74564537 33645A6B 79436C41 2B72414D
4F513D3D
0002                                        Encrypted Data Key Count (2)
0007                                        Encrypted Data Key 1, Key Provider ID Length
 (7)
6177732D 6B6D73                             Encrypted Data Key 1, Key Provider ID ("aws-
kms")
004B                                        Encrypted Data Key 1, Key Provider
 Information Length (75)
61726E3A 6177733A 6B6D733A 75732D77         Encrypted Data Key 1, Key Provider
 Information ("arn:aws:kms:us-west-2:111122223333:key/715c0818-5825-4245-
a755-138a6d9a11e6")
6573742D 323A3131 31313232 32323333
33333A6B 65792F37 31356330 3831382D
35383235 2D343234 352D6137 35352D31
33386136 64396131 316536
00A7                                        Encrypted Data Key 1, Encrypted Data Key
 Length (167)
01010200 7857A1C1 F7370545 4ECA7C83         Encrypted Data Key 1, Encrypted Data Key
956C4702 23DCE8D7 16C59679 973E3CED
02A4EF29 7F000000 7E307C06 092A8648
86F70D01 0706A06F 306D0201 00306806
092A8648 86F70D01 0701301E 06096086
48016503 04012E30 11040C28 4116449A
0F2A0383 659EF802 0110803B B23A8133
3A33605C 48840656 C38BCB1F 9CCE7369
```

```
E9A33EBE 33F46461 0591FECA 947262F3
418E1151 21311A75 E575ECC5 61A286E0
3E2DEBD5 CB005D
0007                                    Encrypted Data Key 2, Key Provider ID Length
 (7)
6177732D 6B6D73                         Encrypted Data Key 2, Key Provider ID ("aws-
kms")
004E                                    Encrypted Data Key 2, Key Provider
 Information Length (78)
61726E3A 6177733A 6B6D733A 63612D63     Encrypted Data Key 2, Key Provider
 Information ("arn:aws:kms:ca-central-1:111122223333:key/9b13ca4b-afcc-46a8-aa47-
be3435b423ff")
656E7472 616C2D31 3A313131 31323232
32333333 333A6B65 792F3962 31336361
34622D61 6663632D 34366138 2D616134
372D6265 33343335 62343233 6666
00A7                                    Encrypted Data Key 2, Encrypted Data Key
 Length (167)
01010200 78FAFFFB D6DE06AF AC72F79B     Encrypted Data Key 2, Encrypted Data Key
0E57BD87 3F60F4E6 FD196144 5A002C94
AF787150 69000000 7E307C06 092A8648
86F70D01 0706A06F 306D0201 00306806
092A8648 86F70D01 0701301E 06096086
48016503 04012E30 11040CB2 A820D0CC
76616EF2 A6B30D02 0110803B 8073D0F1
FDD01BD9 B0979082 099FDBFC F7B13548
3CC686D7 F3CF7C7A CCC52639 122A1495
71F18A46 80E2C43F A34C0E58 11D05114
2A363C2A E11397
01                                      Content Type (1, nonframed data)
00000000                                Reserved
0C                                      IV Length (12)
00000000                                Frame Length (0, nonframed data)
734C1BBE 032F7025 84CDA9D0              IV
2C82BB23 4CBF4AAB 8F5C6002 622E886C     Authentication Tag
+------+
| Body |
+------+
D39DD3E5 915E0201 77A4AB11              IV
00000000 0000028E                       Encrypted Content Length (654)
E8B6F955 B5F22FE4 FD890224 4E1D5155     Encrypted Content
5871BA4C 93F78436 1085E4F8 D61ECE28
59455BD8 D76479DF C28D2E0B BDB3D5D3
E4159DFE C8A944B6 685643FC EA24122B
```

```
6766ECD5 E3F54653 DF205D30 0081D2D8
55FCDA5B 9F5318BC F4265B06 2FE7C741
C7D75BCC 10F05EA5 0E2F2F40 47A60344
ECE10AA7 559AF633 9DE2C21B 12AC8087
95FE9C58 C65329D1 377C4CD7 EA103EC1
31E4F48A 9B1CC047 EE5A0719 704211E5
B48A2068 8060DF60 B492A737 21B0DB21
C9B21A10 371E6179 78FAFB0B BAAEC3F4
9D86E334 701E1442 EA5DA288 64485077
54C0C231 AD43571A B9071925 609A4E59
B8178484 7EB73A4F AAE46B26 F5B374B8
12B0000C 8429F504 936B2492 AAF47E94
A5BA804F 7F190927 5D2DF651 B59D4C2F
A15D0551 DAEBA4AF 2060D0D5 CB1DA4E6
5E2034DB 4D19E7CD EEA6CF7E 549C86AC
46B2C979 AB84EE12 202FD6DF E7E3C09F
C2394012 AF20A97E 369BCBDA 62459D3E
C6FFB914 FEFD4DE5 88F5AFE1 98488557
1BABBAE4 BE55325E 4FB7E602 C1C04BEE
F3CB6B86 71666C06 6BF74E1B 0F881F31
B731839B CF711F6A 84CA95F5 958D3B44
E3862DF6 338E02B5 C345CFF8 A31D54F3
6920AA76 0BF8E903 552C5A04 917CCD11
D4E5DF5C 491EE86B 20C33FE1 5D21F0AD
6932E67C C64B3A26 B8988B25 CFA33E2B
63490741 3AB79D60 D8AEFBE9 2F48E25A
978A019C FE49EE0A 0E96BF0D D6074DDB
66DFF333 0E10226F 0A1B219C BE54E4C2
2C15100C 6A2AA3F1 88251874 FDC94F6B
9247EF61 3E7B7E0D 29F3AD89 FA14A29C
76E08E9B 9ADCDF8C C886D4FD A69F6CB4
E24FDE26 3044C856 BF08F051 1ADAD329
C4A46A1E B5AB72FE 096041F1 F3F3571B
2EAFD9CB B9EB8B83 AE05885A 8F2D2793
1E3305D9 0C9E2294 E8AD7E3B 8E4DEC96
6276C5F1 A3B7E51E 422D365D E4C0259C
50715406 822D1682 80B0F2E5 5C94
65B2E942 24BEEA6E A513F918 CCEC1DE3      Authentication Tag
+--------+
| Footer |
+--------+
0067                                     Signature Length (103)
30650230 7229DDF5 B86A5B64 54E4D627      Signature
CBE194F1 1CC0F8CF D27B7F8B F50658C0
```

```
BE84B355 3CED1721 A0BE2A1B 8E3F449E
1BEB8281 023100B2 0CB323EF 58A4ACE3
1559963B 889F72C3 B15D1700 5FB26E61
331F3614 BC407CEE B86A66FA CBF74D9E
34CB7E4B 363A38
```

Body additional authenticated data (AAD) reference for the AWS Encryption SDK

The information on this page is a reference for building your own encryption library that is compatible with the AWS Encryption SDK. If you are not building your own compatible encryption library, you likely do not need this information.

To use the AWS Encryption SDK in one of the supported programming languages, see Programming languages.

For the specification that defines the elements of a proper AWS Encryption SDK implement ation, see the AWS Encryption SDK Specification in GitHub.

You must provide additional authenticated data (AAD) to the AES-GCM algorithm for each cryptographic operation. This is true for both framed and nonframed body data. For more information about AAD and how it is used in Galois/Counter Mode (GCM), see Recommendations for Block Cipher Modes of Operations: Galois/Counter Mode (GCM) and GMAC.

The following table describes the fields that form the body AAD. The bytes are appended in the order shown.

Body AAD Structure

Field	Length, in bytes
Message ID	16
Body AAD Content	Variable. See **Body AAD Content** in the following list.
Sequence Number	4

Field	Length, in bytes
Content Length	8

Message ID

The same Message ID value set in the message header.

Body AAD Content

A UTF-8 encoded value determined by the type of body data used.

For nonframed data, use the value `AWSKMSEncryptionClient Single Block`.

For regular frames in framed data, use the value `AWSKMSEncryptionClient Frame`.

For the final frame in framed data, use the value `AWSKMSEncryptionClient Final Frame`.

Sequence Number

A 4-byte value interpreted as a 32-bit unsigned integer.

For framed data, this is the frame sequence number.

For nonframed data, use the value 1, encoded as the 4 bytes `00 00 00 01` in hexadecimal notation.

Content Length

The length, in bytes, of the plaintext data provided to the algorithm for encryption. It is an 8-byte value interpreted as a 64-bit unsigned integer.

AWS Encryption SDK algorithms reference

The information on this page is a reference for building your own encryption library that is compatible with the AWS Encryption SDK. If you are not building your own compatible encryption library, you likely do not need this information.

To use the AWS Encryption SDK in one of the supported programming languages, see Programming languages.

For the specification that defines the elements of a proper AWS Encryption SDK implementation, see the AWS Encryption SDK Specification in GitHub.

If you are building your own library that can read and write ciphertexts that are compatible with the AWS Encryption SDK, you'll need to understand how the AWS Encryption SDK implements the supported algorithm suites to encrypt raw data.

The AWS Encryption SDK supports the following algorithm suites. All AES-GCM algorithm suites have a 12-byte initialization vector and a 16-byte AES-GCM authentication tag. The default algorithm suite varies with the AWS Encryption SDK version and the selected key commitment policy. For details, see Commitment policy and algorithm suite.

AWS Encryption SDK Algorithm Suites

Algorithm ID	Message format version	Encryption algorithm	Data key length (bits)	Key derivation algorithm	Signature algorithm	Key commitment algorithm	Algorithm suite data length (bytes)
`05 78`	0x02	AES-GCM	256	HKDF with SHA-512	ECDSA with P-384 and SHA-384	HKDF with SHA-512	32 (key commitment)
`04 78`	0x02	AES-GCM	256	HKDF with SHA-512	None	HKDF with SHA-512	32 (key commitment)
`03 78`	0x01	AES-GCM	256	HKDF with SHA-384	ECDSA with P-384 and SHA-384	None	N/A

Algorithm ID	Message format version	Encryption algorithm	Data key length (bits)	Key derivation algorithm	Signature algorithm	Key commitment algorithm	Algorithm suite data length (bytes)
03 46	0x01	AES-GCM	192	HKDF with SHA-384	ECDSA with P-384 and SHA-384	None	N/A
02 14	0x01	AES-GCM	128	HKDF with SHA-256	ECDSA with P-256 and SHA-256	None	N/A
01 78	0x01	AES-GCM	256	HKDF with SHA-256	None	None	N/A
01 46	0x01	AES-GCM	192	HKDF with SHA-256	None	None	N/A
01 14	0x01	AES-GCM	128	HKDF with SHA-256	None	None	N/A
00 78	0x01	AES-GCM	256	None	None	None	N/A
00 46	0x01	AES-GCM	192	None	None	None	N/A
00 14	0x01	AES-GCM	128	None	None	None	N/A

Algorithm ID

A 2-byte hexadecimal value that uniquely identifies an algorithm implementation. This value is stored in the message header of the ciphertext.

Message format version

The version of the message format. Algorithm suites with key commitment use message format version 2 (0x02). Algorithm suites without key commitment use message format version 1 (0x01).

Algorithm suite data length

The length in bytes of data specific to the algorithm suite. This field is supported only in message format version 2 (0x02). In message format version 2 (0x02), this data appears in the `Algorithm suite data` field of the message header. Algorithm suites that support key commitment use 32 bytes for the key commitment string. For more information, see **Key commitment algorithm** in this list.

Data key length

The length of the data key in bits. The AWS Encryption SDK supports 256-bit, 192-bit, and 128-bit keys. The data key is generated by a keyring or master key.

In some implementations, this data key is used as input to an HMAC-based extract-and-expand key derivation function (HKDF). The output of the HKDF is used as the data encryption key in the encryption algorithm. For more information, see **Key derivation algorithm** in this list.

Encryption algorithm

The name and mode of the encryption algorithm used. Algorithm suites in the AWS Encryption SDK use the Advanced Encryption Standard (AES) encryption algorithm with Galois/Counter Mode (GCM).

Key commitment algorithm

The algorithm used to calculate the key commitment string. The output is stored in the `Algorithm suite data` field of the message header and is used to validate the data key for key commitment.

For a technical explanation of adding key commitment to an algorithm suite, see Key Committing AEADs in Cryptology ePrint Archive.

Key derivation algorithm

The HMAC-based extract-and-expand key derivation function (HKDF) used to derive the data encryption key. The AWS Encryption SDK uses the HKDF defined in RFC 5869.

Algorithm suites without key commitment (algorithm ID `01xx` – `03xx`)

- The hash function used is either SHA-384 or SHA-256, depending on the algorithm suite.
- For the extract step:
  - No salt is used. Per the RFC, the salt is set to a string of zeros. The string length is equal to the length of the hash function output, which is 48 bytes for SHA-384 and 32 bytes for SHA-256.
  - The input keying material is the data key from the keyring or master key provider.
- For the expand step:
  - The input pseudorandom key is the output from the extract step.
  - The input info is a concatenation of the algorithm ID and message ID (in that order).
  - The length of the output keying material is the **Data key length**. This output is used as the data encryption key in the encryption algorithm.

Algorithm suites with key commitment (algorithm ID `04xx` and `05xx`)

- The hash function used is SHA-512.
- For the extract step:
  - The salt is a 256-bit cryptographic random value. In message format version 2 (0x02), this value is stored in the `MessageID` field.
  - The initial keying material is the data key from the keyring or master key provider.
- For the expand step:
  - The input pseudorandom key is the output from the extract step.
  - The key label is the UTF-8-encoded bytes of the `DERIVEKEY` string in big endian byte order.
  - The input info is a concatenation of the algorithm ID and the key label (in that order).
  - The length of the output keying material is the **Data key length**. This output is used as the data encryption key in the encryption algorithm.

Message format version

The version of the message format used with the algorithm suite. For details, see Message format reference.

Signature algorithm

The signature algorithm that is used to generate a digital signature over the ciphertext header and body. The AWS Encryption SDK uses the Elliptic Curve Digital Signature Algorithm (ECDSA) with the following specifics:

- The elliptic curve used is either the P-384 or P-256 curve, as specified by the algorithm ID. These curves are defined in Digital Signature Standard (DSS) (FIPS PUB 186-4).
- The hash function used is SHA-384 (with the P-384 curve) or SHA-256 (with the P-256 curve).

AWS Encryption SDK initialization vector reference

The information on this page is a reference for building your own encryption library that is compatible with the AWS Encryption SDK. If you are not building your own compatible encryption library, you likely do not need this information.

To use the AWS Encryption SDK in one of the supported programming languages, see Programming languages.

For the specification that defines the elements of a proper AWS Encryption SDK implement ation, see the AWS Encryption SDK Specification in GitHub.

The AWS Encryption SDK supplies the initialization vectors (IVs) that are required by all supported algorithm suites. The SDK uses frame sequence numbers to construct an IV so that no two frames in the same message can have the same IV.

Each 96-bit (12-byte) IV is constructed from two big-endian byte arrays concatenated in the following order:

- 64 bits: 0 (reserved for future use)
- 32 bits: Frame sequence number. For the header authentication tag, this value is all zeroes.

Before the introduction of data key caching, the AWS Encryption SDK always used a new data key to encrypt each message, and it generated all IVs randomly. Randomly generated IVs were cryptographically safe because data keys were never reused. When the SDK introduced data key caching, which intentionally reuses data keys, we changed the way the SDK generates IVs.

Using deterministic IVs that cannot repeat within a message significantly increases the number of invocations that can safely be executed under a single data key. In addition, data keys that are cached always use an algorithm suite with a key derivation function. Using a deterministic IV with a pseudo-random key derivation function to derive encryption keys from a data key allows the AWS Encryption SDK to encrypt 2^32 messages without exceeding cryptographic bounds.

AWS KMS Hierarchical keyring technical details

The AWS KMS Hierarchical keyring uses a unqiue data key to encrypt each message and encrypts each data key with a unique wrapping key derived from an active branch key. It uses a key derivation in counter mode with a pseudorandom function with HMAC SHA-256 to derive the 32 byte wrapping key with the following inputs.

- A 16 byte random salt
- The active branch key
- The UTF-8 encoded value for the key provider identifier "aws-kms-hierarchy"

The Hierarchical keyring uses the derived wrapping key to encrypt a copy of the plaintext data key using AES-GCM-256 with a 16 byte authentication tag and the following inputs.

- The derived wrapping key is used as the AES-GCM cipher key
- The data key is used as the AES-GCM message
- A 12 byte random initialization vector (IV) is used as the AES-GCM IV
- Additional authenticated data (AAD) containing the following serialized values.

Value	Length in bytes	Interpreted as
"aws-kms-hierarchy"	17	UTF-8 encoded
The branch key identifier	Variable	UTF-8 encoded
The branch key version	16	UTF-8 encoded
Encryption context	Variable	UTF-8 encoded key value pairs

Document history for the AWS Encryption SDK Developer Guide

This topic describes significant updates to the *AWS Encryption SDK Developer Guide*.

Topics

- Recent updates
- Earlier updates

Recent updates

The following table describes significant changes to this documentation since November 2017. In addition to major changes listed here, we also update the documentation frequently to improve the descriptions and examples, and to address the feedback that you send to us. To be notified about significant changes, subscribe to the RSS feed.

Change	Description	Date
General availability	Added documentation for the AWS KMS ECDH keyring and Raw ECDH keyring.	June 17, 2024
AWS Encryption SDK for Java version 3.x	Integrates the AWS Encryption SDK for Java with the material providers library. Adds support for keyrings and the required encryption context CMM.	December 6, 2023
AWS Encryption SDK for .NET version 4.x	Adds support for the AWS KMS Hierarchical keyring, the required encryption context CMM, and asymmetric RSA AWS KMS keyrings.	October 12, 2023

General availability	Introducing support for the AWS Encryption SDK for .NET.	May 17, 2022
Documentation change	Replace the AWS Key Management Service term *customer master key (CMK)* with *AWS KMS key* and *KMS key*.	August 30, 2021
General availability	Added support for AWS Key Management Service.(AWS KMS) multi-Region keys. Multi-Region keys are AWS KMS keys in different AWS Regions that can be used interchangeably because they have the same key ID and key material.	June 8, 2021
General availability	Added and updated documentation about the improved message decryption process.	May 11, 2021
General availability	Added and updated documentation for the general availability release of AWS Encryption CLI version 1.8.*x* to replace AWS Encryption CLI version 1.7.*x*, and AWS Encryption CLI 2.1.*x* to replace AWS Encryption CLI 2.0.*x*.	October 27, 2020

General availability	Added and updated documentation for the general availability release of the AWS Encryption SDK versions 1.7.*x* and 2.0.*x*, including a best practices guide, a migration guide, updated concepts, updated programming language topics, an updated algorithm suites reference, an updated message format reference, and a new message format example.	September 24, 2020
General availability	Added and updated documentation for the general availability release of the AWS Encryption SDK for JavaScript.	October 1, 2019
Preview release	Added and updated documentation of the public beta release of the AWS Encryption SDK for JavaScript.	June 21, 2019
General availability	Added and updated documentation for the general availability release of the AWS Encryption SDK for C.	May 16, 2019
Preview release	Added documentation of the preview release of the AWS Encryption SDK for C.	February 5, 2019

New release	Added documentation of the command line interface for the AWS Encryption SDK.	November 20, 2017

Earlier updates

The following table describes significant changes to the *AWS Encryption SDK Developer Guide* before November 2017.

Change	Description	Date
New release	Added the *Data key caching* chapter for the new feature. Added the the section called "Initialization vector reference" topic that explains that the SDK changed from generatin g random IVs to constructing deterministic IVs. Added the the section called "Concepts" topic to explain concepts, including the new cryptographic materials manager.	July 31, 2017
Update	Expanded the Message format reference documenta tion into a new AWS Encryption SDK reference section. Added a section about the AWS Encryption SDK Supported algorithm suites.	March 21, 2017

Change	Description	Date
New release	The AWS Encryption SDK now supports the Python programming language, in addition to Java.	March 21, 2017
Initial release	Initial release of the AWS Encryption SDK and this documentation.	March 22, 2016