Implementation Guide

Network Orchestration for AWS Transit Gateway

Network Orchestration for AWS Transit Gateway: Implementation Guide

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Automate setting up and managing your transit networks with AWS Transit Gateway

The Network Orchestration for AWS Transit Gateway solution automates the process of setting up and managing transit networks in multi-account AWS environments. The solution creates a web user interface (UI) to help you control, audit, and approve or reject transit network changes. This solution supports both AWS Organizations and standalone AWS accounts, and you can use the solution to visualize your transit network across multiple AWS Regions. You can use this solution with the default deployment template or customize it to meet your specific use case.

You can use AWS Transit Gateway to attach Amazon Virtual Private Clouds (Amazon VPCs) in the same AWS Region, and to route traffic between them. With this solution, you can connect your VPCs across multiple accounts by tagging the VPCs. It also connects your transit gateway across multiple AWS Regions by tagging the transit gateway. You can set rules to automatically approve or reject, or manually approve, the network changes.

This implementation guide provides an overview of the Network Orchestration for AWS Transit Gateway solution, its reference architecture and components, considerations for planning the deployment, and configuration steps for deploying the solution to the Amazon Web Services (AWS) Cloud.

The intended audience for implementing this solution in their environment includes solution architects, networking professionals, business decision makers and cloud professionals. To deploy and use this solution, you should have an understanding of Amazon VPC, route tables, subnets, transit gateways, and network protocols. For additional training about these topics, see AWS Networking Basics, Understanding AWS Networking Gateways, and Advanced Architecting on AWS.

Use this navigation table to quickly find answers to these questions:

If you want to ...	Read ...
Know the cost for running this solution. The estimated cost for running this solution in the US East (N. Virginia) Region is USD $85.22 per month.	Cost

If you want to ...	Read ...
Understand the security considerations for this solution.	Security
Know how to plan for quotas for this solution.	Quotas
Know the supported AWS Regions for this solution.	Supported AWS Regions
View or download the AWS CloudForm ation template included in this solution to automatically deploy the infrastructure resources (the "stack") for this solution.	AWS CloudFormation template
Access the source code and optionally use the AWS Cloud Development Kit (AWS CDK) to deploy the solution.	GitHub repository

Features and benefits

This solution provides the following features:

Cross-account and cross-Region integration

This solution helps you automate the management of your networks across multiple AWS accounts and AWS Regions (through inter-Region peering). This helps reduce the time that you need to configure connectivity through your AWS environment.

Change management

For critical and sensitive environments, you can enable manual approval workflows through the web UI to accept or reject connectivity requests between your environments.

Tracking and auditing

Use the web UI to track or audit changes to your network environment, and to review approved or rejected requests.

Compliance

Use rules to automatically accept or reject network changes based on the organizational unit. For more information about approvals, see the Automated approval and Manual approval workflows.

Use cases

Network connectivity

To meet your workloads' requirements, this solution helps you attach VPCs with Transit Gateway by tagging the VPCs and subnets across multiple accounts. Based on the VPC and subnet tags, the solution automatically updates the subnet's associated route table with default routes to the transit gateway. It also creates association and enables propagation in the transit gateway route tables.

To connect your network across AWS Regions, this solution can create inter-Region transit gateway peering attachments.

Concepts and definitions

This section describes key concepts and defines terminology specific to this solution.

application

A logical group of AWS resources that you want to operate as a unit.

attachment

Connection from a resource to a transit gateway. For this solution, you can attach one or more VPCs to the transit gateway.

CloudFormation stack

Provisions the resources that are described in the templates.

CloudFormation template

Specifies the AWS resources included in this solution and their properties.

hub account

Central account where the solution is deployed and manages your central transit gateway. This is typically your network account.

network account

The networking account serves as the central hub for your network on AWS. You can manage your networking resources and route traffic between accounts in your environment, your on-premises, and egress/ingress traffic to the internet.

route table

A set of routing rules that controls the traffic leaving any subnet that's associated with the route table. This includes dynamic and static routes that decide the next hop based on the destination IP address of the packet.

state machine

A workflow for AWS Step Functions.

> **Note**
>
> For a general reference of AWS terms, see the AWS Glossary.

Architecture overview

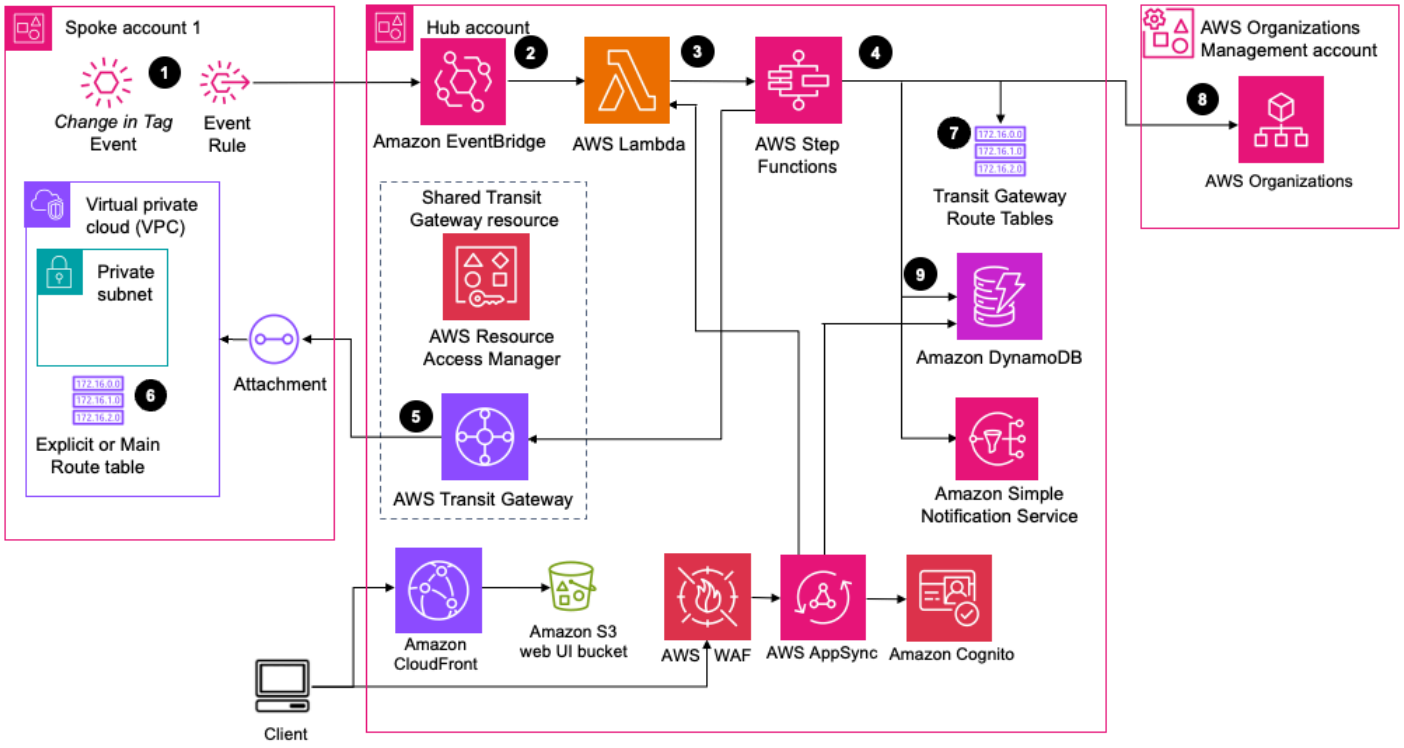
This section provides a reference implementation architecture diagram for the components deployed with this solution. This solution includes:

- A CloudFormation hub template (`aws-transit-network-orchestrator-hub.template`) that you deploy in the hub account. This template launches all the components necessary to automatically connect your VPCs to Transit Gateway. The template also deploys a web UI. For recommendations on choosing a hub account, refer to AWS accounts.
- A CloudFormation spoke template (`aws-transit-network-orchestrator-spoke.template`) to deploy in your spoke account(s).
- A CloudFormation organization role template (`aws-transit-network-orchestrator-organization-role.template`) to optionally deploy in your Organizations management account.

Architecture diagram

Deploying this solution with the default parameters deploys the following components in your AWS account.

Architecture diagram of AWS resources deployed to automate managing Transit Gateway attachments.



Note

CloudFormation resources are created from AWS Cloud Development Kit (AWS CDK) constructs.

1. This template deploys an Amazon EventBridge rule that monitors specific VPC and subnet tag changes.

   Note

   To identify the VPCs (spoke accounts) for the solution to manage, tag the VPCs and the selected subnets within those VPCs.

2. An EventBridge rule in the spoke account sends the tags to the EventBridge bus in the hub account.
3. The rules associated with the EventBridge bus invoke an AWS Lambda function to start the solution workflow. For more information about workflows, refer to Architecture details.

> **Note**
>
> Wait for the hub stack launch to complete before you launch spoke templates. The spoke accounts depend on the EventBridge bus that's created during the hub stack launch.

4. AWS Step Functions (solution state machine) processes network requests from the spoke accounts.
5. The state machine workflow attaches a VPC to the transit gateway.
6. The state machine workflow updates the VPC route table associated with the tagged subnet.
7. The state machine workflow updates the transit gateway route table with association and propagation changes.

> **Note**
>
> This workflow only updates the transit gateway route table defined in the VPC tags.

8. (Optional) The state machine workflow updates the attachment name with the VPC name and the Organizational Unit (OU) name for the spoke account (retrieved from the Org Management account).

> **Note**
>
> This occurs only if you provide your Organizations ARN for the **Account List or AWS Organizations ARN** template parameter. For more information, see Step 3: Launch the hub stack.

9. The solution updates Amazon DynamoDB with the information extracted from the event and resources created, updated, or deleted in the workflow.

Users can view tagging event details and the history of network requests from different accounts, and monitor their status in the web UI. Administrators can accept or reject requests when manual approval is required.

AWS Well-Architected design considerations

This solution uses the best practices from the AWS Well-Architected Framework which helps customers design and operate reliable, secure, efficient, and cost-effective workloads in the cloud.

This section describes how the design principles and best practices of the Well-Architected Framework benefit this solution.

Operational excellence

This section describes how the principles and best practices of the operational excellence pillar benefit this solution.

- The solution pushes metrics to CloudWatch to provide observability into the infrastructure, including Lambda functions, Step Functions, Amazon API Gateway, Amazon Simple Storage Service (Amazon S3) buckets, and the rest of the solution components.
- AWS X-Ray traces are enabled for Step Functions and AWS AppSync. This helps you visualize the components of the state machine and analyze user requests as they travel through your AWS AppSync APIs to the underlying services, identify performance bottlenecks, and troubleshoot requests that resulted in an error.

Security

This section describes how the principles and best practices of the security pillar benefit this solution.

- The web UI users are authenticated and authorized with Amazon Cognito.
- All inter-service communications use AWS Identity and Access Management (IAM) roles.
- All multi-account communications use IAM roles.
- All IAM roles used by the solution follow least-privilege access. In other words, they only contain minimum permissions required so that the service can function properly.
- The access token obtained from Amazon Cognito is used to authorize application programming interface (API) calls.
- All data storage, such as S3 buckets and DynamoDB tables, have encryption at rest.
- AWS WAF protects the web UI and APIs from attacks using solution-configured web access control lists (ACLs).

The solution creates CloudFront distribution with the Default CloudFront SSL Certificate which allows TLS 1.1 and TLS 1.0. We recommend using Custom SSL Certificate with TLSv1.2_2021 security policy to disallow insecure protocols and cipher suites.

Reliability

This section describes how the principles and best practices of the reliability pillar benefit this solution.

- The solution uses serverless AWS services wherever possible (such as Lambda, AWS AppSync, Amazon S3, and Step Functions) to ensure high availability and recovery from service failure.
- AWS protects the solution against definition errors of state machines leveraged by Step Functions by running automated tests on the solution.
- Data processing uses Lambda functions. The solution stores data in DynamoDB and Amazon S3, so it persists in multiple Availability Zones by default.

Performance efficiency

This section describes how the principles and best practices of the performance efficiency pillar benefit this solution.

- The solution uses serverless architecture. For additional details, refer to Reliability.
- The solution uses `error handling` in Step Functions to run concurrent state machine executions that add or remove multiple subnets in the `VPC-TGW` attachment. This allows you to create VPC and related resources in parallel using CloudFormation stack.
- You can launch the solution in any AWS Region that supports the AWS services used in this solution (such as Lambda, API Gateway, Amazon S3, Step Functions, Amazon Cognito, Amazon CloudFront, and AWS WAF). You can also choose not to deploy the web UI if CloudFront and Amazon Cognito aren't supported in the Region. Refer to Supported AWS Regions.
- AWS automatically tests and deploys the solution daily. Our solution architects and subject matter experts review the solution for areas to experiment and improve.

Cost optimization

This section describes how the principles and best practices of the cost optimization pillar benefit this solution.

- The solution uses serverless architecture (for example, Step Functions and DynamoDB) to minimize the cost of unused compute infrastructure, and customers pay only for what they use.
- The compute layer defaults to Lambda, which uses a pay-per-use model.

Sustainability

This section describes how the principles and best practices of the sustainability pillar benefit this solution.

- The solution uses managed and serverless services to minimize the environmental impact of the backend services.
- The solution's serverless design is aimed at reducing carbon footprint compared to the footprint of continually operating on-premises servers.
- The web UI allows users to select scan parameters to perform selective scans in specific AWS accounts, Regions, and services.

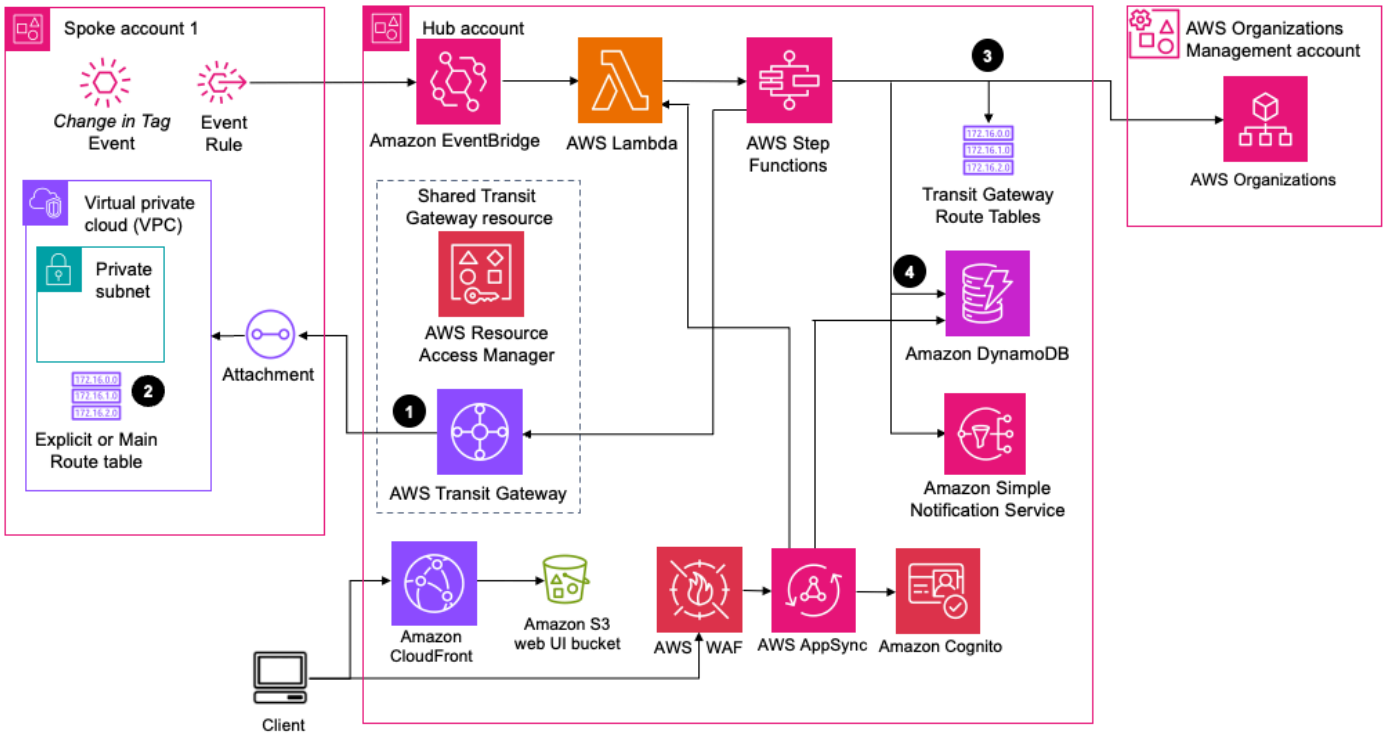
Architecture details

This section describes the components and AWS services that make up this solution and the architecture details on how these components work together.

Automated approval

By default, the solution approves network requests from spoke accounts automatically. This section provides detail about this workflow.

Architecture diagram of AWS resources deployed to approve network requests automatically.



1. Depending on the event, the state machine can perform the following actions:
   - Create, update, or delete transit gateway attachments to the VPC
   - Create or update transit gateway route table associations
   - Enable or disable transit gateway route table propagations
2. The state machine creates routes in the VPC route tables associated with the subnets that you tagged, with the following exceptions (see Step 5. Add tags for more information):

- If there is no explicit route table associated with the subnet, the solution updates the main route table instead.
- If you tag a second subnet in the same Availability Zone, you must use the `route-to-tgw` tag key to only add the route and skip adding the subnet in the attachment.

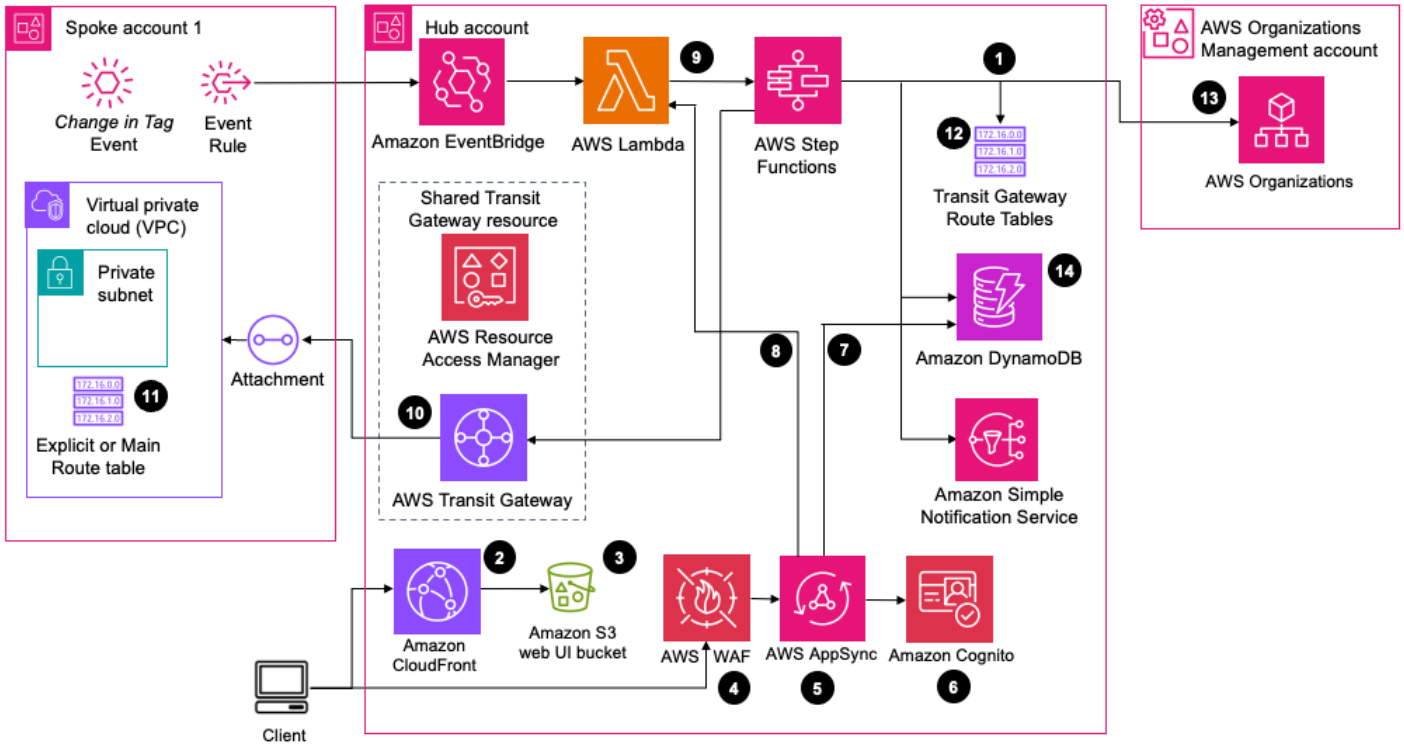
3. The state machine then adds a new status tag to the VPC or the subnet with the status of the request.
4. The state machine updates the DynamoDB table to activate the network administrator to audit the network change history. The changes in DynamoDB are automatically reflected in the web UI dashboard. Administrators and users can sign in to the web UI to review the history of all changes that occurred in the network.

Manual approval

You can choose to manually approve network requests from spoke accounts, instead of automated approval. This section provides detail about this workflow.

> **Important**
>
> If you don't deploy the UI, you can't approve or reject a network change. All the network changes will be auto-approved. You can use the compliance rules to automatically approve and reject network changes.

Architecture diagram of AWS resources deployed to support manual approval of network requests.



1. If you set the **ApprovalRequired** tag key to `Yes` or `Conditional` in the **Transit gateway route table** parameter, the state machine skips changes depending on the rules set under the `Conditional` setting. To set up this flag, refer to Transit Gateway route table tags.
2. The administrator signs in to the web UI, and the Amazon Cognito user pool authenticates each user. CloudFront delivers the web UI content from an S3 bucket.
3. The S3 bucket hosts the web UI.
4. The web UI gets a token from Amazon Cognito and sends a request to AWS AppSync. AWS WAF protects the APIs from security events. This solution configures a set of rules called a web ACL. The web ACL allows, blocks, or counts web requests based on configurable, user-defined web security rules and conditions.
5. AWS AppSync provides the solution's API layer using GraphQL.
6. Amazon Cognito authenticates the token in the header of the API requests.
7. An AWS AppSync resolver updates the DynamoDB table with the processing status.
8. An AWS AppSync resolver invokes a Lambda function that validates the event.
9. A Lambda function starts a new state machine execution.
10. The state machine workflow attaches a VPC to the transit gateway.
11. The state machine workflow updates the VPC route table associated with the tagged subnet.

12. The state machine workflow updates the transit gateway route table with association and propagation changes.

> **Note**
>
> This workflow only updates the transit gateway route table defined in the VPC tags.

13. (Optional) The state machine workflow updates the attachment name with the VPC name and the Organizational Unit (OU) name for the spoke account (retrieved from the Org Management account).

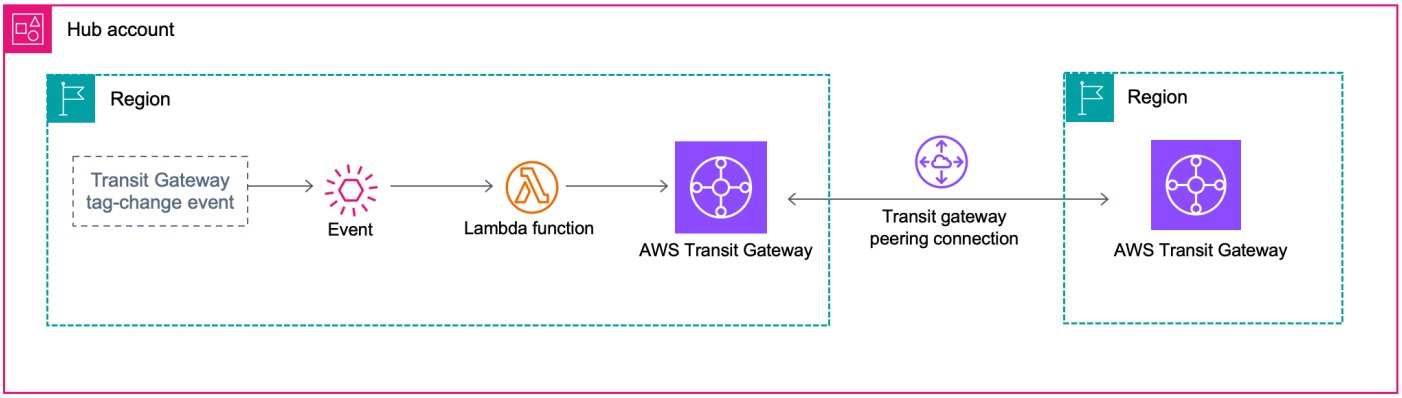
> **Note**
>
> This occurs only if you provide your Organizations ARN for the **Account List or AWS Organizations ARN** template parameter. For more information, see Step 3: Launch the hub stack.

14. The solution updates the DynamoDB with the information extracted from the event and resources created, updated, or deleted in the workflow. The changes in DynamoDB are automatically reflected in the web UI dashboard. Administrators and users can sign in to the web UI to review the history of all changes that occurred in the network.

Transit Gateway inter-Region peering

You can use Transit Gateway peering to directly route traffic between two transit gateways in the same AWS Region or across Regions. This section provides information about how this solution supports peering.

Architecture diagram of AWS resources deployed to support Transit Gateway inter-Region peering.



1. When you tag the transit gateway, an EventBridge event initiates. The target for this event is the transit gateway peering attachment Lambda function in the hub account.
2. The `tgw-peering` Lambda function creates the peering attachment between the transit gateways based on the tag key and value. The peering attachment state transitions from `InitializingRequest` to `PendingAcceptance`.
3. The Lambda function accepts the peering attachment request in the remote Region.
4. The solution sets the peering attachment state to `Available`.

AWS services in this solution

AWS service	Description
AWS Transit Gateway	**Core.** Deploys a transit gateway that connects VPCs through a central hub.
AWS Lambda	**Core.** Deploys multiple Lambda functions to support core microservices and create transit gateway attachments.
AWS Step Functions	**Core.** Deploys a state machine to orchestrate the subnet and VPC tagging events and create transit gateway attachments.

AWS service	Description
Amazon DynamoDB	**Core.** Deploys a DynamoDB table for VPC and transit gateway attachments, and for transit gateway peering attachments.
Amazon EventBridge	**Core.** Deploys an event bus and event rules to connect components of the solution.
AWS X-Ray	**Supporting.** Deploys traces for API Gateway and Step Functions, allowing you to investiga te root causes of failures.
Amazon SNS	**Optional.** Deploys a topic that sends an email notification with the optional web UI URL.
Amazon Cognito	**Optional.** Deploys a user pool that supports identity authentication for the optional web UI.
AWS AppSync	**Optional.** Deploys AWS AppSync schema and resolvers for the DynamoDB table and Lambda functions. Using resolvers, AWS AppSync translates GraphQL requests and fetches information from DynamoDB.
Amazon S3	**Optional.** Deploys Amazon S3 buckets to host the web UI assets.
AWS WAF	**Optional.** Deploys AWS WAF web access control list (ACL) to protect AWS AppSync from common security events, such as SQL injection and cross-site scripting (XSS).
Amazon CloudFront	**Optional.** Deploys CloudFront with an Amazon S3 bucket as the origin. This restricts access to the Amazon S3 bucket so that it's not publicly accessible and prevents direct access from the bucket.

Plan your deployment

This section describes the cost, architecture, network security, and other considerations before deploying the solution.

Cost

You are responsible for the cost of the AWS services used while running this solution. As of this revision, the cost for running this solution with the default settings in the US East (N. Virginia) Region is approximately **$85.22 a month**. These costs are for the resources shown in the Sample cost table.

See the pricing webpage for each AWS service used in this solution.

We recommend creating a budget through AWS Cost Explorer to help manage costs. Prices are subject to change. For full details, see the pricing webpage for each AWS service used in this solution.

Sample cost table

The following table provides a sample cost breakdown for deploying this solution with the default parameters in the US East (N. Virginia) Region for one month. This cost estimate assumes the following:

- The solution manages two VPCs attached to one transit gateway, with each VPC containing two subnets in different Availability Zones.
- The solution makes automated queries to DynamoDB from an actively running web UI every five minutes. This estimate does not include manual queries.
- One GB of data a month travels between the two VPCs through the transit gateway.
- The number of requests to the GraphQL API is 10,000 a month.

AWS service	Dimensions	Cost [USD]
Variable Costs		
Transit Gateway	Hourly charge (containing two VPC attachments)	$72.00

AWS service	Dimensions	Cost [USD]
Transit Gateway	Data processing charge (data transfer of 1 GB from two attached VPCs)	$0.60
Transit Gateway	Data processing and outbound inter-Region transfer charge (data transfer of 1 GB between two inter-Region peered transit gateways)	$0.40
Amazon DynamoDB	Includes automated queries only	$3.27
AWS AppSync	Includes auto approval workflow only	$1.23
Fixed Costs		
Amazon EventBridge		< $ 0.01
AWS WAF		$ 7.61
AWS X-Ray	100,000 Traces recorded for 2 services (Step Functions and AppSync) with default 5% sampling rate	< $ 0.10
	Total:	~ $85.22 / month

Security

When you build systems on AWS infrastructure, security responsibilities are shared between you and AWS. This shared responsibility model reduces your operational burden because AWS operates, manages, and controls the components including the host operating system, the virtualization

layer, and the physical security of the facilities in which the services operate. For more information about AWS security, visit AWS Cloud Security.

IAM roles

IAM roles allow customers to assign granular access policies and permissions to services and users on AWS. This solution creates IAM roles and sets permissions in the respective accounts. This allows the solution to assume a defined role in the spoke and management account to make changes when necessary. The hub account assumes role in the Management account and spoke accounts.

AWS WAF

AWS WAF is a web application firewall that helps protect web applications and APIs from attacks. It allows you to configure a web ACL that allows, blocks, or counts web requests based on configurable web security rules and conditions that you define. For more information, refer to How AWS WAF Works.

You can use AWS WAF to protect AWS AppSync from common security events, such as SQL injection and XSS. These types of security events could affect API availability and performance, compromise security, or consume excessive resources. For example, you can create rules to allow or block requests from specified IP address ranges, requests from Classless Inter-Domain Routing (CIDR) blocks, requests that originate from a specific country or Region, requests that contain malicious SQL code, or requests that contain malicious script.

Amazon CloudFront

This solution deploys a static website hosted in an S3 bucket. To help reduce latency and improve security, this solution includes an Amazon CloudFront distribution with an origin access identity. This identity is a CloudFront user that helps provide public access to the solution's website bucket contents. For more information, refer to Restricting access to an Amazon S3 origin.

Amazon Cognito

This solution creates Amazon Cognito user accounts for signing in to the web UI. The solution also grants the administrator and the read-only users with the appropriate permissions to control user access to data.

Important

If you connect an external identity provider through SAML, every user from your identity provider will have read access to the web UI. To prevent giving read access to all users by default, modify the `cognito-trigger` Lambda function deployed by this solution. For more information, see Configuring Lambda function options.

Supported AWS Regions

This solution uses the AWS services that aren't currently available in all AWS Regions. You must launch this solution in an AWS Region where these services available. For the most current availability of AWS services by Region, see the AWS Regional Services List.

This solution is available in the following AWS Regions:

Region name	
US East (Ohio)	Canada (Central)
US East (N. Virginia)	China (Beijing)
US West (Northern California)	China (Ningxia)
US West (Oregon)	Europe (Frankfurt)
Asia Pacific (Mumbai)	Europe (Ireland)
Asia Pacific (Seoul)	Europe (London)
Asia Pacific (Singapore)	Europe (Paris)
Asia Pacific (Sydney)	Europe (Stockholm)
Asia Pacific (Tokyo)	South America (Sao Paulo)

AWS accounts for multi-account environments

To deploy a multi-account environment, we recommend the following AWS account guidelines for each stack:

- **Hub stack** - Deploy to a member account in your AWS Organization, preferably where you have an existing transit gateway or plan to create a new one, or in a dedicated network account where you plan to create a new transit gateway. It can't be the Organizations management account.
- **Spoke stack** - Deploy to all the member accounts in your AWS Organization that have a VPC that you plan to attach to the transit gateway hub account. You must deploy it in the hub account if you want to attach VPCs in the hub account.
- **Organization role stack** - Optionally deploy in the Organizations management account to allow the solution to add Organizational Unit paths in the attachment name to help you identify the VPC location.

Quotas

Service quotas, also referred to as limits, are the maximum number of service resources or operations for your AWS account.

Quotas for AWS services in this solution

Make sure you have sufficient quota for each of the services implemented in this solution. For more information, refer to AWS service quotas.

Select one of the following links to go to the page for that service. To see the service quotas for all AWS services in the documentation without switching pages, view the information in the Service endpoints and quotas page in the *AWS General Reference guide* PDF instead.

Transit Gateway	AWS X-Ray
Lambda	Amazon SNS
Step Functions	Amazon Cognito
DynamoDB	AWS AppSync
EventBridge	Amazon S3

AWS WAF	CloudFront

CloudFormation quotas

Your AWS account has CloudFormation quotas that you must be aware of when launching the stacks for this solution. By understanding these quotas, you can avoid limitation errors that can prevent you from deploying this solution successfully. For more information, refer to AWS CloudFormation quotas in the *AWS CloudFormation Users Guide*.

Lambda quotas

In the hub account, the state machine invokes Lambda functions to run the scan in parallel depending on the VPCs and subnets tagged across multiple accounts in your organization. Review and increase your Lambda invocation limit to avoid throttling.

Transit Gateway quotas

The solution creates a new transit gateway for each hub stack deployment unless you provide an existing transit gateway in the hub template parameter **(Optional) Do you wish to use an existing transit gateway? If yes, you must provide the transit gateway id below.** Your account has a default Transit Gateway quota of five.

AWS Transit Gateway Network Manager quotas

The solution creates a new global network for each hub stack deployment unless you provide an existing global network ID in the hub template parameter **(Optional) Do you wish to use an existing global network? If yes, you must provide the global network id below.** Your account has default global network quota of five. Only one global network is recommended for all the other deployments in different AWS Regions in the hub account. Provide the global network ID created by the first deployment in the other deployments in different AWS Regions.

Deploy the solution

This solution uses CloudFormation templates and stacks to automate its deployment. The CloudFormation templates specify the AWS resources included in this solution and their properties. The CloudFormation stack provisions the resources that are described in the templates.

> **Note**
>
> If you have previously deployed this solution, see Update the solution for update instructions.

Prerequisites

You must meet the following prerequisites before launching the stacks.

If your accounts are part of Organizations, you must first manually activate AWS RAM in the Organizations console and obtain the Organizations management account ID and organization ID before deploying the solution templates.

Activate AWS RAM for Organizations accounts

Use the following procedure to activate AWS RAM using the AWS Organizations console.

1. Sign in to the AWS Organizations console.
2. In the navigation pane, select **Settings**.
3. Navigate to **AWS RAM**, and select **Enable access**.

Use the following procedure to activate the sharing option in the AWS RAM console.

1. Sign in to the AWS RAM console.
2. In the navigation pane, select **Settings**.
3. Choose *Enable sharing***with AWS Organizations**.
4. Choose **Save settings**.

Identify the Organizations ARN

To use this solution with accounts connected to AWS Organizations, you must specify the AWS Organizations ARN when you launch the hub template. The ARN value consists of the AWS Organizations management account ID and the organization ID. You can build the ARN string manually if you have access to the AWS Organizations management account ID and the organization ID, or you can use the AWS Command Line Interface (AWS CLI) to query the Organization ARN.

> **Note**
>
> If you don't have access to the management account ID and the Organization ID, contact your organization's management account administrator.

Use the following procedure to build the Organizations ARN manually after you have the Organizations management account ID and the organization ID.

1. Sign in to the AWS Organizations console from your organization's management account.
2. Select **AWS accounts** from the navigation menu.
3. Identify the management account and record the **Account ID**.
4. Select **Settings** from the navigation menu.
5. Record the entry for **Organization ID**.
6. Use the following sample to manually build the Organization ARN. Replace the placeholders with your management account and organization IDs.

```
arn:<AWS_PARTITION>:organizations::<ORG_MANAGEMENT_ACCOUNT_ID>:organization/<ORG-ID>
```

To use the AWS CLI to query the ARN, use the describe-organization API call. To set up AWS CLI, refer to Configuring the AWS CLI in the *AWS Command Line Interface_User Guide*.

Deployment process overview

Follow the step-by-step instructions in this section to configure and deploy the solution into your account.

Important

This solution includes an option to send anonymized operational metrics to AWS. We use this data to better understand how customers use this solution and related services and products. AWS owns the data gathered though this survey. Data collection is subject to the AWS Privacy Notice.

To opt out of this feature, download the template, modify the AWS CloudFormation mapping section, and then use the AWS CloudFormation console to upload your updated template and deploy the solution. For more information, see the Anonymized data collection section of this guide.

Before you launch the solution, review the cost, architecture, security, and other considerations discussed earlier in this guide. Follow the step-by-step instructions in this section to configure and deploy the solution into your account.

Time to deploy: Approximately 25 minutes

Step 1. (Optional) Launch the organization role stack

- Launch the CloudFormation template in your Organizations management account.
- Enter values for the required **HubAccount** parameter.

Step 2. (Optional) Launch the service- linked role for AWS RAM hub stack

Note

If the `AWSServiceRoleForResourceAccessManager` role already exists, skip this step.

- Launch the CloudFormation template in your hub account.

Step 3. Launch the hub stack

- Launch the CloudFormation template in your hub account.
- Enter values for the required **Account List or AWS Organizations ARN** parameter.
- If deploying the web UI, enter values for the following parameters: **Allowed Listed Ranges**, **Console Login Information Email**, and **Cognito Domain Prefix**.

- Review the other template parameters and adjust, if necessary.

Step 4. Launch the spoke stack(s)

- Launch the CloudFormation template into your spoke account(s).
- Enter a value for the required **Network (Hub) Account** parameter.

Step 5. Add tags

- Add the required tags to the spoke VPCs and subnets.
- Validate and view transit gateway attachments.

AWS CloudFormation templates

This solution uses CloudFormation to automate its deployment in the AWS Cloud. It includes the following AWS CloudFormation templates, which you can download before deployment.

> **Note**
>
> AWS CloudFormation resources are created from AWS CDK constructs.

View template

network-orchestration-hub.template - Use this template to launch the solution and all associated components in your AWS network hub account. The default configuration deploys the following:

- One transit gateway
- Four transit gateway route tables
- One global network in Transit Gateway network manager
- Step Functions (to orchestrate VPC and transit gateway attachments)
- One AWS Resource Access Manager (AWS RAM) resource share
- One optional web UI with the following resources:
  - One DynamoDB table
  - EventBridge event bus and rules

  - IAM roles
- One optional web UI for network management with the following resources:
  - One Amazon SNS topic
  - AWS AppSync API with WAF
  - One Amazon Cognito user pool
  - One CloudFront distribution with a CloudFront function
  - Amazon S3 buckets

View template

network-orchestration-hub-service-linked-roles.template - Optionally use this template to launch the service-linked role for AWS RAM in your hub account. This stack is optional because it fails if the `AWSServiceRoleForResourceAccessManager` role already exists in the hub account.

View template

network-orchestration-spoke.template - Use this template to launch the solution and all associated components in your spoke account(s). The default configuration deploys EventBridge rules and IAM roles.

View template

network-orchestration-spoke-service-linked-roles.template - The template gets deployed as a nested stack by the spoke template if the service linked role `AWSServiceRoleForVPCTransitGateway` does not exist in the account.

View template

network-orchestration-organization-role.template - Use this template to create an IAM role in the Organizations management account. The hub account requires this role to create easily-identifiable names for the transit gateway attachments, using a combination of OU path and VPC name.

Step 1: Launch the organization role stack (optional)

Follow the step-by-step instructions in this section to configure and deploy the organization role stack into your Organizations management account. This optional step helps you add a OU path and VPC name in the attachment tags for tracking and auditing.

1. Sign in to your AWS Organizations management account using the AWS Management Console and select the button to launch the `network-orchestration-organization-role.template` AWS CloudFormation template.

2. Launch this template in the same Region as you plan to launch the hub and spoke templates. The organization role template launches in the US East (N. Virginia) Region by default.
3. On the **Create stack** page, verify that the correct template URL shows in the **Amazon S3 URL** text box and choose **Next**.
4. On the **Specify stack details** page, assign a name to your solution stack. For information about naming character limitations, see IAM and AWS STS quotas in the *AWS Identity and Access Management User Guide*.
5. For **Parameters**, review the parameters for the template and modify them as necessary. This stack uses the following default values.

Parameter	Default	Description
HubAccount	*<Requires input>*	The account ID for the hub account.

6. Choose **Next**.
7. On the **Configure stack options** page, choose **Next**.
8. On the **Review and create** page, review and confirm the settings. Choose the box acknowledging that the template creates IAM resources.
9. Choose **Submit** to deploy the stack.

You can view the status of the stack in the AWS CloudFormation console in the **Status** column. You should see a status of **CREATE_COMPLETE** in approximately three to four minutes.

Note

After the stack deploys, record the ARN for the role from the **Outputs** tab of the stack. You need this ARN as input for the **Account List or AWS Organizations ARN** parameter in the hub template.

Step 2: (Optional) Launch the service-linked role for AWS RAM hub stack

Follow the step-by-step instructions in this section to configure and deploy the optional service-linked role for AWS RAM hub stack into your hub account.

Important

This stack deploys the service-linked role for AWS RAM. AWS RAM uses the service-linked role named `AWSServiceRoleForResourceAccessManager` when you enable sharing with AWS Organizations. This role grants permissions to the AWS RAM service to view organization details, such as the list of member accounts and which organizational units each account is in.
This stack is optional because it fails if the role already exists in the hub account. You can validate if this roles exists by signing in to the IAM console, selecting **Roles** from the navigation menu, and entering `AWSServiceRoleForResourceAccessManager` in the search box. If this role already exists, skip this step.
The stack deployment will fail with following details in the CloudFormation events if it already exists.
Error Code: `AlreadyExists`
Message: `Service role name AWSServiceRoleForResourceAccessManager has been taken in this account.`

1. Sign in to the AWS Management Console with your AWS network hub account and select the button to launch the `network-orchestration-hub-service-linked-roles.template` CloudFormation template.

2. Launch this template in the same Region as the hub template. The template launches in the US East (N. Virginia) Region by default.
3. On the **Create stack** page, verify that the correct template URL shows in the **Amazon S3 URL** text box and choose **Next**.
4. On the **Specify stack details** page, assign a name to your solution stack. For information about naming character limitations, see IAM and AWS STS quotas in the *AWS Identity and Access Management User Guide*.
5. Choose **Next**.
6. On the **Configure stack options** page, choose **Next**.
7. On the **Review and create** page, review and confirm the settings. Choose the box acknowledging that the template creates IAM resources.
8. Choose **Submit** to deploy the stack.

You can view the status of the stack in the AWS CloudFormation console in the **Status** column. You should see a status of **CREATE_COMPLETE** in approximately three to four minutes.

Step 3: Launch the hub stack

Follow the step-by-step instructions in this section to configure and deploy the hub stack into your hub account.

1. Sign in to the AWS Management Console with your AWS network hub account and select the button to launch the `network-orchestration-hub.template` CloudFormation template. +{

2. The template launches in the US East (N. Virginia) Region by default. To launch this solution in a different AWS Region, use the Region selector in the console navigation bar. See Supported AWS Regions for more information on selecting a Region.
3. On the **Create stack** page, verify that the correct template URL shows in the **Amazon S3 URL** text box and choose **Next**.
4. On the **Specify stack details** page, assign a name to your solution stack. For information about naming character limitations, see IAM and AWS STS quotas in the *AWS Identity and Access Management User Guide*.

For **Parameters**, review the parameters for the template and modify them as necessary. This stack uses the following default values.

Parameter	Default	Description
Account Structure Settings		
Principal Type	`AWS Organization ARN`	Choose whether to use the default Organization ARN or a list of accounts. For guidance, refer to AWS accounts.
Account List or AWS Organizations ARN	*`<Requires input>`*	To use Organizations, enter the Organization ARN to share the transit gateway with the principals. For example: `arn:<AWS_PARTITION>:organizations::<ORG_MANAGEMENT_ACCOUNT_ID>:organization/<ORG-ID>` For additional guidance to identify the ARN value, refer to Identify the Organizations ARN. To use an account list, enter a comma-separated list of AWS account numbers. For example, `123456789012` .

Parameter	Default	Description
Allow External Principals	`Yes`	Choose whether to enable or disable sharing the transit gateway with principal s outside the organizat ion. NOTE: You must set this parameter to `Yes` if you're using the `List of Accounts` value for the **Principal Type** parameter.
(Optional) IAM Role ARN of Management Account	*<Optional input>*	To tag attachments with the account name and OU path, provide the ARN for the role in the management account which can be assumed by the hub account. Leave this value blank if you're deploying this solution in your managemen t account.
Web UI Settings		
Web User Interface	`Yes`	Option to deploy web UI to manage and audit the changes in the network. Select `No` to skip creation of the Console bucket, CloudFront, Amazon Cognito user pool, AWS WAF, and other support resources. NOTE: If you select `No` for this parameter, skip the remaining parameters in the **Web UI Settings** section.

Parameter	Default	Description
Allow Listed Ranges	`0.0.0.0/1,128.0.0.0/1`	Comma-separated list of CIDR ranges allowed to access GraphQL API. Default allows the entire internet.
Cognito Domain Prefix	*<Requires input>*	The prefix to the Cognito hosted domain name that will be associated with the user pool. Must be unique per AWS Region and must not contain reserved word 'cognito'.
Console Login Information Email	*<Requires input>*	The email address of the administrator user for the web UI. After launch, the solution sends an email to this address with a temporary password for the web UI.
Admin Username	`adminuser`	The username for network administrators with full read and write permissions to the web UI.
Read-Only Username	`readonlyuser`	The username for users with read-only permission to the web UI.

Parameter	Default	Description
Set MFA for Cognito to '`ON' or '`OPTIONAL'	`OPTIONAL`	`ON` - Amazon Cognito users will need to set up multi-factor authentication (MFA) on first login. `OPTIONAL` - Amazon Cognito users may opt to set up MFA.
SAML Provider Name	*<Optional input>*	If you want to connect an external identity provider, specify a name that appears on the UI.
SAML Provider Metadata URL	*<Optional input>*	If you want to connect an external identity provider, enter the URL to the metadata file of your SAML-based identity provider. The URL must begin with `https://`.
Transit Gateway Settings		

Parameter	Default	Description
(Optional) Do you wish to use an existing transit gateway? If yes, you must provide the transit gateway id below.	*<Optional input>*	The existing transit gateway ID in the current Region. For example, `tgw-a1b2c3d4e5` . If you don't provide a value, the solution creates a new transit gateway. If you do provide a value, the solution uses your existing transit gateway. You must ensure that: • The existing transit gateway has enabled the `AutoAcceptSharedAttachments` flag. The solution doesn't create additional transit gateway route tables for you. For more information, see Create a transit gateway. • The existing transit gateway isn't already registered with an existing global network ID provided in the parameter **(Optional) Do you wish to use an existing global network? If yes, you must provide the global network id below.** If you're updating the solution, provide a value.

Parameter	Default	Description
(Optional) Do you wish to register the transit gateway with a global network?	`Yes`	Choose whether to register the transit gateway with the global network. NOTE: You must set this parameter to No if either of the following is true: **The transit gateway managed by the solution is already registered with an existing global network.** The global network is not available in your selected AWS Region. Refer to Region availability in the *AWS Global Networks for Transit Gateways User Guide*.

Parameter	Default	Description
(Optional) Do you wish to use an existing global network? If yes, you must provide the global network id below.	*<Optional input>*	You can skip this section if you chose No for the previous parameter. The existing global network ID. To register the transit gateway ID (see previous parameter), provide an existing global network ID. For example, `global-network-012312312312 31231` . If you don't provide a value, the solution creates a new global network. If you do provide a value, ensure that the existing transit gateway provided in the **(Optional) Do you wish to use an existing transit gateway? If yes, you must provide the transit gateway id below.** parameter isn't already registered with the existing global network ID.NOTE: If you use this solution in more than one Region, we recommended using the global network created by the first solution deployment to register all the transit gateways deployed by the solution

Parameter	Default	Description
		in all the Regions with the same global network.
VPC Route Table Settings		
Choose the type of destination for target Transit Gateway	`All-traffic (0/0)`	Specify the default route setting for the route table associated with the tagged subnets. Choose from `All-traffic (0/0)` , `RFC-1918 (10/8, 172.16/12, 192.168/16)` , `Custom-Destinations` , or `Configure-Manually` . NOTE: If the route already exists, the solution will not overwrite it.
If selected '`Custom-Destinations', provide a comma separated list of CIDR Blocks.	*<Optional Input>*	Option to provide CIDR block(s). For example, `192.168.1.0/24, 192.168.2.0/24` . NOTE: Optional if providing prefix list ID(s).
If selected '`Custom-Destinations', provide a comma separated list of Customer-managed Prefix List IDs.	*<Optional input>*	Option to provide customer-managed prefix list ID(s). For example, `pl-abcd1234, pl-efgh5678` . NOTE: Optional if providing CIDR block(s).
Tag Settings		

Parameter	Default	Description
Tag key for subnets - Adds subnet to VPC attachment and add routes to route table associated with the tagged subnet.	`Attach-to-tgw`	Specify a custom tag key name to initiate the transit gateway attachment workflow. NOTE: After initial deployment, don't change this solution's default parameter. If you change this parameter after deployment, you must manually update the tags on your VPCs.
Tag key for subnets - Only adds routes to route table associated with the tagged subnet.	`Route-to-tgw`	Specify a custom tag key name to skip the transit gateway attachment workflow and only update route table associated with the subnet being tagged.
Tag key for TGW Route Table Association with TGW Attachment	`Associate-with`	Specify a custom tag key name to initiate the transit gateway route table association with the transit gateway attachment workflow. NOTE: After initial deployment, don't change this solution's default parameter. If you change this parameter after deployment, you must manually update the tags on your VPCs.

Parameter	Default	Description
Tag key for Route Propagation to TGW Route Table(s)	`Propagate-to`	Specify a custom tag key name to initiate the route propagation to the transit gateway route table(s) workflow. NOTE: After initial deployment, don't change this solution's default parameter. If you change this parameter after deployment, you must manually update the tags on your VPCs.
(Optional) Comma separated list of VPC tag keys to copy from VPC to TGW Attachments	`Associate-with,Propagate-to`	Comma-separated list of tag keys (don't include `Name`). If the VPC has these tag keys, the tag key and value are copied to the created TGW attachment(s).
Transit Gateway Peering Tag	`TgwPeer`	Transit Gateway tag to monitor for peering connections. The tag value must follow the format `tgw-id_aws-region/tgw-id_aws-region`. For example, use `tgw-12345678_us-east-1/tgw-567890123_us-east-2` to create peering attachments with the two peers. You can update the value at any time.
Notification Settings		

Parameter	Default	Description
Receive Approval Notifications	No	Choose whether to receive approval notifications.
Approval Notification Email	*<Optional input>*	The email address for approval notifications. To use this parameter, you must set the **Receive Approval Notifications** parameter to `Yes`.

5. Choose **Next**.
6. On the **Configure stack options** page, choose **Next**.
7. On the **Review and create** page, review and confirm the settings. Choose the box acknowledging that the template creates IAM resources.
8. Choose **Submit** to deploy the stack.

You can view the status of the stack in the AWS CloudFormation console in the **Status** column. You should see a status of **CREATE_COMPLETE** in approximately 25 minutes.

After the stack is created, you receive two emails that contain temporary passwords for the read-only user and the admin user. If you enabled approval notification, Amazon SNS sends a subscription confirmation email with a link to the solution's web UI. You can also find the link to the web UI in the CloudFormation stack **Outputs** tab. The link is the **Value** of the **Console URL**. The system-generated password must be changed the first time you sign in.

> **Note**
>
> The temporary account expires if you don't sign in within seven days. Your new password must be at least 10 characters long.

Step 4: Launch the spoke stack(s)

Follow the step-by-step instructions in this section to configure and deploy the spoke stack(s) into your account(s).

> **Note**
>
> You must wait for the hub stack deployment to complete before you launch the spoke templates. The spoke templates depend on the EventBridge rule created during the hub stack launch. Additionally, deploy all templates in the same Region.

1. Sign in to your AWS spoke account using the AWS Management Console and select the button to launch the `network-orchestration-spoke.template` CloudFormation template.

   Launch solution

2. Launch this template in the same Region as the hub template. The template launches in the US East (N. Virginia) Region by default.
3. On the **Create stack** page, verify that the correct template URL shows in the **Amazon S3 URL** text box and choose **Next**.
4. On the **Specify stack details** page, assign a name to your solution stack For information about naming character limitations, see IAM and AWS STS quotas in the *AWS Identity and Access Management User Guide*.
5. For **Parameters**, review the parameters for the template and modify them as necessary. This stack uses the following default values.

Parameter	Default	Description
Account ID of the network account where Transit Gateway resides.		
Network (Hub) Account	*<Requires input>*	The account ID for the hub account.

6. Choose **Next**.
7. On the **Configure stack options** page, choose **Next**.
8. On the **Review and create** page, review and confirm the settings. Choose the box acknowledging that the template creates IAM resources.
9. Choose **Submit** to deploy the stack.

You can view the status of the stack in the AWS CloudFormation console in the **Status** column. You should see a status of **CREATE_COMPLETE** in approximately three to four minutes.

Step 5: Add tags

Follow the step-by-step instructions in this section to add tags to your VPCs and subnets to create or update transit gateway attachments to the VPC or to your transit gateway to create transit gateway peering attachments. Changing tag keys and values (if applicable) results in identifying the transit gateway route tables to create associations and enable propagations. Deleting the tags results in deleting the resources created when the tag was added.

For a real-world scenario on how to configure tag values with this solution, refer to Implementing Serverless Transit Network Orchestrator (STNO) in AWS Control Tower. For information on using Organizations tag policies with this solution, refer to Enforce compliance using AWS Organizations tag policies with Serverless Transit Network Orchestrator (STNO).

Transit gateway attachments to a VPC

This section provides instructions for attaching VPCs to your transit gateway.

Add tags to VPCs

Follow the step-by-step instructions in this section to add tags to your VPCs.

1. Sign in to your spoke account.
2. Navigate to the Amazon VPC console.
3. Choose **VPCs**.
4. Select **Tags** and choose **Manage tags**.
5. Choose **Add new tag**.
6. Add the key-value pairs listed in VPC tags.

> **Note**
>
> If you're using custom names for your transit gateway route tables, the values of the tags you assign need to match the names of the route tables associated with the transit gateway you're connecting to.

Add tags to subnets

Follow the step-by-step instructions in this section to add tags to your subnets.

1. Sign in to your spoke account.
2. Navigate to Subnets within the Amazon VPC console.
3. Select the subnet that you want to attach to the transit gateway.
4. Select **Tags** and choose **Manage tags**.
5. Choose **Add new tag**.
6. Add keys (without values) listed in Subnet tags.

Add transit gateway attachments

Tags identify applicable resources, such as VPCs and subnets, in your spoke accounts. Tags allow create, read, update, and delete (CRUD) operations to run on the transit gateway route table associations and propagation.

> **Note**
>
> Verify that you have the appropriate access privileges to tag VPCs in spoke accounts, or identify the appropriate administrator in your organization.

VPC tags

For this solution to manage the VPC, the VPC in the spoke account must be tagged with both the **Associate-with** and **Propagate-to** keys. You must also add or remove both keys at the same time. By default, the tags are configured for automatic approval.

Key	Value	Description
Associate-with	*<Requires input>*	The default key is `Associate-with` . The value can be one of the default route table names (`Flat`, `Isolated`, `Infrastructure` , or `On-premises`) or a custom key.

Key	Value	Description
		You can change the name of the key in the template during initial configuration, but you must use the same key name when you tag the VPC. **Type:** String For sample route table options, refer to Custom route tables.
Propagate-to	*<Requires input>*	The default key is `Propagate-to` . The value can be one or more default route table names (`Flat`, `Isolated`, `Infrastructure` , or `On-premises`) or a key(s) that you created. You can change the name of the key in the template during initial configuration, but you must use the same key name when you tag the VPC. **Type:** CommaDelimitedList For sample route table options, refer to Custom route tables.

Subnet tags

> **Note**
>
> For a transit gateway attachment to a VPC, you can add only one subnet per Availability Zone. You can't attach a second subnet in the same Availability Zone to the transit gateway. Starting in version 3.3.0 of this solution, we support a new tag key **Route-to-tgw** that skips adding the subnet in the transit gateway attachment and only updates the associated route table with the default route.

Key	Value	Description
Attach-to-tgw	*<Leave blank>*	The default key is `Attach-to-tgw .` **Important** Don't enter a value. You can change the name of the key in the template during initial configuration, but you must use the same key name when you tag the subnet. If there isn't an explicit route table associated with the subnet, the solution updates the main route table with the default route.
Route-to-tgw	*<Leave blank>*	The default key is `Route-to-tgw .`

Key	Value	Description
		Important Don't enter a value. You can change the name of the key in the template during initial configuration, but you must use the same key name when you tag the subnet. If there isn't an explicit route table associated with the subnet, the solution updates the main route table with the default route.

Transit gateway peering attachments

This section provides instructions for creating transit gateway peering attachments.

See Add or edit tags for a transit gateway for instructions on adding and editing tags.

Add tags to transit gateway

Key	Value	Description
TgwPeer	*<tgw-id_aws_region>*	The default key prefix is `TgwPeer`. The default delimiter in the tag value to list multiple transit gateway per region is `slash(/)`.

Key	Value	Description
		You must provide a valid Region name where the remote transit gateway exists. The value must be the remote transit gateway ID that exists in the `<aws_region>` that you provided in the key. For example, if you create a peering attachment with a transit gateway (`tgw-2222`) in the U.S. East (Ohio) Region (`us-east-2`), the tag key would be `TgwPeer` and the value would be `tgw-2222_us-east-2`. You can peer with a second transit gateway in the same Region by using the same delimiter to add another suffix the tag key. In this case, the tag key would be `TgwPeer` and the value must be `tgw-2222_us-east-2/tgw-3333_us-east-1`. You can change the Transit Gateway Peering Tag add reference to the CFN parameter used in the key in the template during initial configuration, but you must use the same key name when you tag the transit gateway.

Key	Value	Description
		Note Changing the value doesn't update the attachment. You must delete the tag and recreate it with a new value, then recreate the peering attachment.

Important

To route traffic between peered transit gateways, you must add a static route to the selected transit gateway route table that points to the transit gateway peering attachment. After you create the route, associate the same transit gateway route table with the transit gateway peering attachment. Refer to Create a static route for more information.

Custom compliance for network changes

This section provides instructions for custom compliance.

Add tags to transit gateway route table

Each transit gateway route table is tagged with an **ApprovalRequired** tag key with a default value of No. You can set the value to:

- `Yes` to enforce manual approval
- `Conditional` and add custom rules for compliance

Key	Value	Description
ApprovalRequired	`No`	The default value is No. This default setting allows any auto-approved or manually approved association and propagation changes.
ApprovalRequired	`Yes`	This setting enforces the manually approved workflow for any change in the association and propagation changes.
ApprovalRequired	`Conditional`	You can use this setting to automate approving or rejecting requests separately for associations and propagations. You can also optionally define rules based on the requesting account's OU.

Custom compliance rules

Administrators can change from the default automatic approval setup to manual approval by changing the **ApprovalRequired** tag value for every transit gateway route table individually.

See View transit gateway route tables for instuctions on viewing your transit gateway route tables and updating tags.

The following tag keys and values are required with at least one rule if the **ApprovalRequired** is set to `Conditional`.

Key	Value	Description
ApprovalRule-Default-Association	`Reject |Accept | ApprovalRequired`	Default approval action for `Associate-with` route

Key	Value	Description
		tables if none of the custom rules match. Enter `Reject`, `Accept`, or `ApprovalRequired` to match your desired action.
ApprovalRule-Default-Propagation	`Reject |Accept | ApprovalRequired`	Default approval action for `Propagate-to` route tables if none of the custom rules match. Enter `Reject`, `Accept`, or `ApprovalRequired` to match your desired action.
ApprovalRule-*<NN>*-InOUs | ApprovalRule-*<NN>*-NotInOUs	`Root/OUName1, Root/OUName2`	A comma-separated list of OU paths starting with `Root/`. If you enter the key with the `InOUs` string, the rule checks if the account is in one of these OUs. If you enter the key with the `NotInOUs` string, the rule checks if the account isn't in any of the specified OUs. **Note** *<NN>* denotes a two-digit number `01-99`. Review service quotas for the tags for each resource in your account.

Key	Value	Description
ApprovalRule--*<NN>*-Association	`Reject | Accept | ApprovalRequired`	The approval action to take for a VPC that associates with this route table if the `ApprovalRule-` *<NN>*`-InOUs` or `ApprovalRule-` *<NN>*`-NotInOUs` check matches. Enter `Reject`, `Accept`, or `ApprovalRequired` to match your desired action. **Note** *<NN>* denotes a two-digit number `01-99`. Review service quotas for the tags for each resource in your account.

Key	Value	Description
ApprovalRule--*<NN>*-Propagation	`Reject |Accept | ApprovalRequired`	The approval action to take for a VPC that propagates to this route table if the `ApprovalRule-` *<NN>*`-InOUs` or `ApprovalRule-` *<NN>*`-NotInOUs` check matches. Enter `Reject`, `Accept`, or `ApprovalRequired` to match your desired action. **Note** *<NN>* denotes a two-digit number `01-99`. Review service quotas for the tags for each resource in your account.

Note

If you don't provide a value for the **ApprovalRule** keys, the default value is ApprovalRequired_._

Example: Infrastructure route table rules using OU membership

If your VPCs provide organization-wide shared services, such as Microsoft Active Directory and patching servers, and are limited to AWS accounts in the Infrastructure or Security OU, you can use the following rules to ensure that only VPCs in those OUs associate with the Infrastructure route table without approval. This prevents workload VPCs accidentally associating with the Infrastructure route table, which could inadvertently expose them to the entire organization.

This example also demonstrates how you can prevent VPCs in Sandbox OUs from accessing the organizational shared services. Together, the following rules auto-reject associations or propagations from Sandbox VPCs for the Infrastructure route table.

Infrastructure Route Table Tag Key	Value
Name	`Infrastructure`
ApprovalRequired	`Conditional`
ApprovalRule-Default-Association	`ApprovalRequired`
ApprovalRule-Default-Propagation	`ApprovalRequired`
ApprovalRule-01-InOUs	`Root/Infrastructure/, Root/Security/`
ApprovalRule-01-Association	`Accept`
ApprovalRule-01-Propagation	`Accept`
ApprovalRule-02-InOUs	`Root/Sandbox/`
ApprovalRule-02-Association	`Reject`
ApprovalRule-02-Propagation	`Reject`

Update the solution

If you have previously deployed the solution, follow these procedures to update the stacks to get the latest version of the solution's framework.

> **Important**
>
> To successfully update the hub stack from an earlier version of this solution to version 3.3.0 or later, provide input for the two required parameters for the hub stack: **Cognito Domain Prefix** and **Allow Listed Ranges**.

Update the organization role stack (optional)

Follow the step-by-step instructions in this section to update the organization role stack for your Organizations management account.

1. Sign in to the AWS CloudFormation console, select your existing Network Orchestration for AWS Transit Gateway CloudFormation stack, and select **Update**.

   > **Note**
   >
   > This solution was previously called Serverless Transit Network Orchestrator.

2. Select **Replace current template**.
3. Under **Specify template**:
   a. Select **Amazon S3 URL**.
   b. Copy the link of the `network-orchestration-organization-role.template` CloudFormation template.
   c. Paste the link in the **Amazon S3 URL** box.
   d. Verify that the correct template URL shows in the **Amazon S3 URL** text box, and choose **Next**. Choose **Next** again.
4. Under **Parameters**, review the parameters for the template and modify them as necessary. For details about the parameters, see Step 1: Launch the organization role stack (optional).
5. Choose **Next**.
6. On the **Configure stack options** page, choose **Next**.

7. On the **Review** page, review and confirm the settings. Choose the box acknowledging that the template creates IAM resources.
8. Choose **View change set** and verify the changes.
9. Choose **Update stack** to deploy the stack.

You can view the status of the stack in the AWS CloudFormation console in the **Status** column. You should receive a UPDATE_COMPLETE status in approximately three to four minutes.

Update the hub stack(s)

Follow the step-by-step instructions in this section to update the hub stack(s).

Hub stack

> **Important**
>
> To mitigate the `AlreadyExists` error code for the service-linked role (**AWSServiceRoleForResourceAccessManager**) in the hub stack, we moved the role to a separate stack for v3.3.1 of this solution. This way, you can upgrade the hub stack in multiple Regions. You must deploy the service-linked role for AWS RAM hub stack *after* updating the hub stack.

Follow the step-by-step instructions in this section to update the hub stack.

1. Sign in to the AWS CloudFormation console, select your existing Network Orchestration for AWS Transit Gateway CloudFormation stack, and select **Update**.

   > **Note**
   >
   > This solution was previously called Serverless Transit Network Orchestrator.

2. Select **Replace current template**.
3. Under **Specify template**:
   a. Select **Amazon S3 URL**.
   b. Copy the link of the `network-orchestration-hub.template` CloudFormation template.
   c. Paste the link in the **Amazon S3 URL** box.

d. Verify that the correct template URL shows in the **Amazon S3 URL** text box, and choose **Next**. Choose **Next** again.

4. Under **Parameters**, review the parameters for the template and modify them as necessary. For details about the parameters, see Step 3: Launch the hub stack (optional).

> **Important**
>
> To successfully upgrade from an earlier version of this solution to version 3.3.0 or later, provide input for the two required parameters for the hub stack: **Cognito Domain Prefix** and **Allow Listed Ranges**.

5. Choose **Next**.
6. On the **Configure stack options** page, choose **Next**.
7. On the **Review** page, review and confirm the settings. Choose the box acknowledging that the template creates IAM resources.
8. Choose **View change set** and verify the changes.
9. Choose **Update stack** to deploy the stack.

You can view the status of the stack in the AWS CloudFormation console in the **Status** column. You should receive a UPDATE_COMPLETE status in approximately 25 minutes.

Service-linked role for AWS RAM hub stack

The hub stack deletes the **AWSServiceRoleForResourceAccessManager** service-linked role. Re-deploy the service-linked role using Step 2 of **Deploy the solution**.

Update the spoke stack(s)

Follow the step-by-step instructions in this section to update the spoke stacks.

Spoke stack

> **Important**
>
> To mitigate the `AlreadyExists` error code for the service-linked role (**AWSServiceRoleForVPCTransitGateway**) in the spoke stack, we moved the role to a

separate stack. This way, you can upgrade the spoke stack in multiple Regions. You must deploy the service-linked role stack *after* updating the spoke stack.

Follow the step-by-step instructions in this section to update the spoke stack(s) for your spoke account(s).

1. Sign in to the AWS CloudFormation console, select your existing Network Orchestration for AWS Transit Gateway CloudFormation stack, and select **Update**.

   > **Note**
   >
   > This solution was previously called Serverless Transit Network Orchestrator.

2. Select **Replace current template**.
3. Under **Specify template**:
   a. Select **Amazon S3 URL**.
   b. Copy the link of the `network-orchestration-spoke.template` CloudFormation template.
   c. Paste the link in the **Amazon S3 URL** box.
   d. Verify that the correct template URL shows in the **Amazon S3 URL** text box, and choose **Next**. Choose **Next** again.
4. Under **Parameters**, review the parameters for the template and modify them as necessary. For details about the parameters, see Step 4: Launch the spoke stack(s).
5. Choose **Next**.
6. On the **Configure stack options** page, choose **Next**.
7. On the **Review** page, review and confirm the settings. Choose the box acknowledging that the template creates IAM resources.
8. Choose **View change set** and verify the changes.
9. Choose **Update stack** to deploy the stack.

You can view the status of the stack in the AWS CloudFormation console in the **Status** column. You should receive a UPDATE_COMPLETE status in approximately three to four.

Service-linked role for Transit Gateway spoke stack

The spoke stack attempts to delete the **AWSServiceRoleForVPCTransitGateway** service-linked role. If there are existing transit gateway attachments, the following events occur while updating the spoke stack:

- The role deletion fails
- You receive `AlreadyExists` error code

Uninstall the solution

You can uninstall the solution from the AWS Management Console or by using the AWS CLI. You must manually delete the transit gateway, Amazon S3 buckets, and global network created by this solution. AWS solutions don't automatically delete these resources, in case you have stored data that you want to retain.

Using the AWS Management Console

1. Sign in to the AWS CloudFormation console.
2. On the **Stacks** page, select this solution's installation stack.
3. Choose **Delete**.

Using AWS Command Line Interface

Determine whether the AWS CLI is available in your environment. For installation instructions, see What is the AWS Command Line Interface? in the *AWS CLI User Guide*. After confirming that the AWS CLI is available, run the following command.

```
$ aws cloudformation delete-stack --stack-name <installation-stack-name>
```

Manually delete resources

We configured this solution to retain solution-specific resources to prevent accidental data loss if you decide to delete the CloudFormation stack. After uninstalling the solution, you can manually delete these resources if you don't need to retain the data. Refer to these guides to delete the following resources:

- Delete a transit gateway
- Delete Amazon S3 buckets
- Delete an AWS Network Manager global network

Use the solution

This section provides a user guide for the solution's web UI and instructions to using and customizing route tables.

Use the web UI

> **Important**
>
> If you don't deploy the UI, you can't approve or reject a network change. All the network changes will be auto-approved. You can use the compliance rules to auto-approve and auto-reject network changes.

Sign in to the web UI

After the hub stack is successfully deployed, you receive two emails containing a link to the web UI and sign-in credentials. By default, the solution creates one Amazon Cognito `adminuser` (in the admin group) and one Amazon Cognito `readonlyuser` (in the read-only group). For more information, refer to Managing and searching for user accounts in the *Amazon Cognito Developer Guide*.

> **Note**
>
> If you configured an external SAML-based identity provider in step 3 (**SAML Provider Name** parameter), instead of signing in with sign-in credentials, you can choose the button that redirects to your identity provider's sign in page. On the first sign in, the solution automatically adds every user to the **ReadOnlyUserGroup** and thereby grants them read access to the web UI. After a user signs in with read access, you can assign them to the **AdminGroup** with Amazon Cognito if needed. For more information, see Adding groups to a user pool in the *Amazon Cognito Developer Guide*.

Follow the step-by-step instructions in this section to sign in to the web UI.

1. Choose the link to open the web UI.

2. Enter the provided user credentials to sign in. You must change the system-generated password the first time that you sign in.

> **Note**
>
> The temporary account expires if you don't sign in within seven days. Your new password must be at least ten characters long.

Manage network activities

You can use the web UI to access the dashboard to view network changes, access action items to view, approve or reject network requests when manual approval is required, and view the history of all changes made within the solution.

> **Note**
>
> Information and history for a VPC are set to expire based on the time you specify in the hub template at stack launch. The default time is 90 days. Expired requests are automatically deleted from DynamoDB within 48 hours and are not shown in the web UI after deletion.

Access the dashboard

The **Dashboard** tab displays fields containing information about network changes stored in DynamoDB such as **VPC ID**, **VPC CIDR**, **Status**, **Association Route Table**, **Propagation Route Tables**, **Spoke Account**, **Subnet ID**, **Availability Zone**, and other relevant information. You can sort by these fields. You can also view the **Status** of each network change, including whether it was approved, rejected, auto-approved, or auto-rejected.

Access action items

The **Action Items** tab displays the requests that require manual approval. If you chose to automatically approve requests, this tab will be empty. For manual approvals, each request contains the same fields as those in the **Dashboard** tab. Requests can have the following status: `requested`, `processing`, or `failed`. The reason for the failure displays in the comment column.

Approve or reject requests

When you enable manual approval for requests, the administrator approves or rejects the request using the web UI. Only users in the admin group can approve or reject requests. Users from the read only group can only view requests. When an administrator approves or rejects the request, the status is set to `processing`.

When a request is `processing`, users can't take further action from the web UI. The web UI calls a Lambda function, which initiates the solution state machine to process the request. After the process completes, state machine updates the request status, and the web UI reflects the new status.

View history of a request

To view the history of a request, select the request from either the **Dashboard** or **Action Items** tab and then choose **View History**.

Using and customizing route tables

This section provides a user guide for solution transit gateway route tables.

Default route tables

This solution creates the following default transit gateway route tables: `Flat`, `Isolated`, `Infrastructure`, and `On-premises`. Each route table and suggested propagations include a policy for common use cases.

- **Flat*route table** - VPCs associated with the `Flat` policy can reach other VPCs associated with the `Flat`, `SharedServices`, or `Hybrid` policies. The `Flat` policy enables a VPC to have connectivity to many other VPCs.
- **Isolated route table** - VPCs associated with the `Isolated policy` can reach VPCs with the `SharedServices` and `Hybrid` policies. VPCs in the `Isolated` policy can't use Transit Gateway to connect to other VPCs in the `Isolated` policy. This policy is for VPCs that don't communicate with each other.
- **Infrastructure route table** - VPCs associated with the `SharedServices` policy can reach other VPCs associated with the `Isolated`, `Flat`, or `Hybrid` policies. The `SharedServices` policy is used for VPCs that many other VPCs may rely on, such as shared authentication, shared tooling, or orchestration tools.

- **On-premises route table -** This route table is used for connecting to on-premises through either AWS Virtual Private Network (AWS VPN) or AWS Direct Connect. Associate your on-premises connections to the `On-premises` route table.

Policy types	Associate with (route table name)	Propagate to (list of route table names)
`Flat` (east-west traffic)	`Flat`	`Flat, On-premises, Infrastructure`
`Isolated` (north-south traffic)	`Isolated`	`On-premises, Infrastructure`
`SharedServices`	`Infrastructure`	`Flat, On-premises, Isolated`
`Hybrid`	`On-premises`	`Flat, Infrastructure, Isolated`

Note

In this implementation guide, a policy is defined by both an association to a single transit gateway route table, and the transit gateway route table propagation. To implement these concepts, you must tag both the association and propagation on each spoke VPC according to the intended design. This is because the policies aren't centrally managed. Inconsistent tagging can create a drift between the desired policy and what is configured.
You can use the **ApprovalRequired** tag on route tables that need manual control. By default, we set up this solution for automatic approval, but you can change this tag to set up manual approval. See Transit gateway route table tags for more information about the **ApprovalRequired** tag.
For more information, refer to On-premises connectivity.

Custom route tables

If the default policies don't meet your requirements, you can create your own transit gateway route table configurations.

> **Note**
>
> You don't need a separate route table for each VPC to achieve segmentation. Segmentation is accomplished by controlling the propagation. For example, an `Isolated` route table doesn't propagate to itself and, as a result, nothing associated with an `Isolated` route table is able to reach other `Isolated` resources through the transit gateway.

The administrator can create new transit gateway route tables in the Amazon VPC console in the hub account. The combination of route tables and propagation provided with the transit gateway allows for a variety of connection policies.

Example 1: Create a new custom route table

The following sample table and steps provide a guide for setting your routing policies. For this example, you implement a `Development` policy and route table. This policy and route table allow developers to create VPCs that don't have access to sensitive resources in the `Isolated` or `Infrastructure` route tables. You create a new transit gateway route table that propagates to the `Flat`, `On-premises`, and `Development` route tables.

Policy types	Associate with (route table name)	Propagate to (list of route table names)
`Flat` (east-west traffic)	`Flat`	`Flat, On-premises, Infrastructure, Development`
`Isolated` (north-south traffic)	`Isolated`	`On-premises, Infrastructure`
`SharedServices`	`Infrastructure`	`Flat, On-premises, Isolated`

Policy types	Associate with (route table name)	Propagate to (list of route table names)
Hybrid	`On-premises`	`Flat, Infrastructure, Isolated, Development`
Development	`Development`	`Development, Flat, On-premises`

Create the route table

1. In the hub account, sign in to the Amazon VPC console.
2. In the navigation pane, choose **Transit gateway route tables**.
3. Choose **Create transit gateway route table**.
4. For **Name tag**, enter a name for the route table. For this example, enter `Development`.
5. For **Transit gateway ID**, select the appropriate transit gateway.
6. Choose **Create transit gateway route table**. You will receive a confirmation message.
7. Select **Close**.
8. Optional: If you want changes to this route table to be manually approved:
   a. Select the newly created route table from the list in step 2.
   b. Choose the **Tags** tab.
   c. Choose **Add/Edit** tags and then choose **Create tag**.
   d. In the **Key** field, enter `ApprovalRequired` and in the **Value** field, enter `Yes`.
   e. Choose **Save**.

Determine the access model

After the new route table is created, determine the access model. For two transit gateway attachments to communicate, each of their associated route tables must have each other's routes.

1. Determine where your new route table should propagate routes, defined by the other transit gateway route tables. For example, should the `Infrastructure` route table be propagated from your new `Development` route table?

2. Check that the other route tables are reciprocating the propagation for two-way communication. For example, you may want to propagate `Infrastructure`, `Flat`, and `On-premises` route table to your new `Development` route table.

> **Note**
>
> If your custom route table requires access to VPCs that have already been attached, you must change the **Propagate-to** tag for each spoke VPC to include your new route table.

Associate VPCs

To associate a new VPC to this route table:

1. Tag the new VPC with the **Associate-with** key and reference the new route table name in the value. See Step 5: Add tags for detailed tagging instructions. For example:

```
Associate-with: <ExampleRouteTable>
```

2. Tag the new VPC with the **Propagate-to** key and reference the route tables you want to propagate to from the previous step. For example:

```
Propagate-to: Infrastructure, Flat, Hybrid
```

3. Tag one subnet in each Availability Zone. For example:

```
Attach-to-tgw: <leave blank>
```

> **Note**
>
> If you configured manual approval, you might need to sign in to the web UI to approve the change. If that is the case, you will receive an email with the request that contains the link to the web UI.

To confirm the attachment, look for attachments on the transit gateway in the VPC management console, in the web UI, or in the state machine history.

For more information about transit gateway route tables, refer to Transit gateway route tables.

Example 2: Modify policies

If you don't need the provided `Flat` policy, you can modify the existing `Flat` policy to meet your custom requirements. Turn off propagation to the `Infrastructure` route table and remove the `Flat` propagation from the `Infrastructure` route table.

On-premises connectivity

This solution builds a base network, giving you automation to attach VPCs to a transit gateway. You can extend your on-premises network by creating transit gateway route tables using the web UI, creating VPN attachments, or attaching a transit gateway to an AWS Direct Connect gateway.

For instructions on how to manually attach a VPN to the transit gateway for on-premises connectivity, see Transit gateway VPN attachments.

For instructions on how to manually attach Direct Connect to the transit gateway for on-premises connectivity, refer to Transit gateway attachments to a Direct Connect gateway.

Developer guide

This section provides the source code for the solution.

Source code

This solution is coded in Python and the web UI is coded in ReactJS.

Visit our GitHub repository to download the source files for this solution and to share your customizations with others.

The AWS CDK generates the solution templates. See the README.md file for additional information.

Reference

This section includes information about an optional feature for collecting unique metrics for this solution and a list of builders who contributed to this solution.

Anonymized data collection

This solution includes an option to send anonymized operational metrics to AWS. We use this data to better understand how customers use this solution and related services and products. When invoked, the following information is collected and sent to AWS:

- **Solution ID** - The AWS solution identifier
- **Unique ID (UUID)** - Randomly generated, unique identifier for each deployment of this solution
- **Timestamp** - Data-collection timestamp
- **Deployment Data**:
  - **PrincipalType** - `"AWS Organization ARN" | "List of Accounts"`
  - **ApprovalNotification** - `"Yes" | "No"`
  - **AuditTrailRetentionPeriod** - `"90" (default)`
  - **DefaultRoute** - ` "All-Traffic (0/0)" | "RFC-1918 (10/8, 172.16/12, 192.168/16)" | "Custom-Destinations" | "Configure-Manually"`
  - **CreatedNewTransitGateway** - `"Yes" | "No"`
  - **DeployWebUI** - `"Yes" | "No"`
- **Tag Change Data**:
  - **Action** - `"CreateTgwVpcAttachment" | "DeleteTgwVpcAttachment" | "AddSubnet" | "RemoveSubnet"`
  - **Status** - `"auto-approved" | "auto-rejected"`
  - **AdminAction** - `"not-applicable" | "accept" | "reject"`
  - **ApprovalRequired** - `"yes" | "no"`
  - **TagEventSource** - `"Subnet" | "vpc"`
  - **RouteTableType** - `"explicit" | "main"`
  - **Region** - *<region-name>*
  - **SolutionVersion** - *<version-number>*

AWS owns the data gathered through this survey. Data collection is subject to the AWS Privacy Notice.

To opt out of this feature, complete the following steps before launching the CloudFormation hub template.

1. Download the `network-orchestration-hub.template` CloudFormation template to your local hard drive.
2. Open the CloudFormation hub template with a text editor.
3. Modify the CloudFormation hub template mapping sections from:

```
AnonymizedData:
 SendAnonymizedData:
 Data: Yes
```

   to:

```
AnonymizedData:
 SendAnonymizedData:
 Data: No
```

4. Sign in to the AWS CloudFormation console.
5. Select **Create stack**.
6. On the **Create stack page**, **Specify template section**, select **Upload a template file**.
7. Under **Upload a template file**, choose **Choose file** and select the edited hub template from your local drive.
8. Choose **Next** and follow the steps in Step 3: Launch the hub stack in the Deploy the solution section of this guide.

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Revisions

Check the CHANGELOG.md file in the GitHub repository to see all notable changes and updates to the software. The changelog provides a clear record of improvements and fixes for each version.

Notices

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