



AWS Whitepaper

# Best Practices for Deploying WorkSpaces



# Best Practices for Deploying WorkSpaces: AWS Whitepaper

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# Best Practices for Deploying Amazon WorkSpaces

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## Abstract

This whitepaper outlines a set of best practices for the deployment of WorkSpaces. The whitepaper covers network considerations, directory services and user authentication, security, and monitoring and logging.

This whitepaper also enables quick access to relevant information, and is intended for network engineers, directory engineers, or security engineers.

## Introduction

[Amazon WorkSpaces](#) is a managed desktop computing service in the cloud. Amazon WorkSpaces removes the burden of procuring or deploying hardware or installing complex software, and delivers a desktop experience with either a few clicks on the [AWS Management Console](#), using the Amazon Web Services (AWS) command line interface (CLI), or by using the application programming interface (API). With Amazon WorkSpaces, you can launch a Microsoft Windows or Amazon Linux desktop within minutes, which enables you to connect to and access your desktop software securely, reliably, and quickly from on-premises or from an external network. You can:

- Leverage your existing, on-premises Microsoft Active Directory (AD) by using [AWS Directory Service: Active Directory Connector](#) (AD Connector).
- Extend your directory to the AWS Cloud.
- Build a managed directory with [AWS Directory Service](#) Microsoft AD or Simple AD, to manage your users and WorkSpaces.
- Leverage your on-premises or cloud-hosted RADIUS server with AD Connector to provide multi-factor authentication (MFA) to your WorkSpaces.

You can automate the provisioning of Amazon WorkSpaces by using the CLI or API, which enables you to integrate Amazon WorkSpaces into your existing provisioning workflows.

For security, in addition to the integrated network encryption that the Amazon WorkSpaces service provides, you can also enable encryption at rest for your WorkSpaces. Refer to the [Encrypted WorkSpaces](#) section of this document.

You can deploy applications to your WorkSpaces by using your existing on-premises tools, such as Microsoft System Center Configuration Manager (SCCM), Puppet Enterprise, or Ansible.

The following sections provide details about Amazon WorkSpaces, explain how the service works, describe what you need to launch the service, and tells you what options and features are available for you to use.

# WorkSpaces requirements

The Amazon WorkSpaces service requires three components to deploy successfully:

- **WorkSpaces client application** — An Amazon WorkSpaces-supported client device. Refer to [Getting Started with Your Workspace](#).

You can also use Personal Computer over Internet Protocol (PCoIP) Zero Clients to connect to WorkSpaces. For a list of available devices, refer to [PCoIP Zero Clients for Amazon WorkSpaces](#).

- **A directory service to authenticate users and provide access to their Workspace** — Amazon WorkSpaces currently works with [AWS Directory Service](#) and Microsoft AD. You can use your on-premises AD server with AWS Directory Service to support your existing enterprise user credentials with Amazon WorkSpaces.
- **Amazon Virtual Private Cloud (Amazon VPC) in which to run your Amazon WorkSpaces** — You'll need a minimum of two subnets for an Amazon WorkSpaces deployment because each AWS Directory Service construct requires two subnets in a multi-AZ deployment.

# Network considerations

Each WorkSpace is associated with the specific Amazon VPC and AWS Directory Service construct that you used to create it. All AWS Directory Service constructs (Simple AD, AD Connector, and Microsoft AD) require two subnets to operate, each in different Availability Zones (AZs). Subnets are permanently affiliated with a Directory Service construct and can't be modified after it is created. Because of this, it's imperative that you determine the right subnet sizes before you create the Directory Services construct. Carefully consider the following before you create the subnets:

- How many WorkSpaces will you need over time?
- What is the expected growth?
- What types of users will you need to accommodate?
- How many AD domains will you connect?
- Where do your enterprise accounts reside?

Amazon recommends defining user groups, or personas, based on the type of access and the user authentication you require as part of your planning process. Answers to these questions are helpful when you need to limit access to certain applications or resources. Defined user personas can help you segment and restrict access using AWS Directory Service, network access control lists, routing tables, and VPC security groups. Each AWS Directory Service construct uses two subnets and applies the same settings to all WorkSpaces that launch from that construct. For example, you can use a security group that applies to all WorkSpaces attached to an AD Connector to specify whether MFA is required, or whether an end-user can have local administrator access on their WorkSpace.

## Note

Each AD Connector connects to your existing Enterprise Microsoft AD. To take advantage of this capability and specify an Organizational Unit (OU), you must construct your Directory Service to take your user personas into consideration.

## VPC design

This section describes best practices for sizing your VPC and subnets, traffic flow, and implications for directory services design.

Here are a few things to consider when designing the VPC, subnets, security groups, routing policies, and network access control lists (ACLs) for your Amazon WorkSpaces so that you can build your WorkSpaces environment for scale, security, and ease of management:

- **VPC** — We recommend using a separate VPC specifically for your WorkSpaces deployment. With a separate VPC, you can specify the necessary governance and security guardrails for your WorkSpaces by creating traffic separation.
- **Directory Services** — Each Directory Service construct requires a pair of subnets that provides a highly available directory service split between AZs.
- **Subnet size** — WorkSpaces deployments are tied to a directory construct and reside in the same VPC as your chosen Directory Service, but they can be in different VPC subnets. A few considerations:
  - Subnet sizes are permanent and cannot change. You should leave ample room for future growth.
  - You can specify a default security group for your chosen Directory Service. The security group applies to all WorkSpaces that are associated with the specific Directory Service construct.
  - You can have multiple instances of Directory Service use the same subnet.

Consider future plans when you design your VPC. For example, you might want to add management components, such as an antivirus server, a patch management server, or an AD or RADIUS MFA server. It's worth planning for additional available IP addresses in your VPC design to accommodate such requirements.

For in-depth guidance and considerations for VPC design and subnet sizing, refer to the re:Invent presentation [How Amazon.com is Moving to Amazon WorkSpaces](#).

## Network interfaces

Each WorkSpaces has two elastic network interfaces (ENIs), a management network interface (eth0), and a primary network interface (eth1). AWS uses the management network interface to

manage the WorkSpace — it's the interface on which your client connection terminates. AWS uses a private IP address range for this interface. For network routing to work properly, you can't use this private address space on any network that can communicate with your WorkSpaces VPC.

For a list of the private IP ranges that are used on a per Region basis, refer to [Amazon WorkSpaces Details](#).

### Note

Amazon WorkSpaces and their associated management network interfaces do not reside in your VPC, and you cannot view the management network interface or the Amazon Elastic Compute Cloud (Amazon EC2) instance ID in your AWS Management Console (refer to [Figure 5](#), [Figure 6](#), and [Figure 7](#)). However, you can view and modify the security group settings of your primary network interface (eth1) in the console. The primary network interface of each WorkSpace does count toward your ENI Amazon EC2 resource quotas. For large deployments of Amazon WorkSpaces, you need to open a support ticket via the AWS Management Console to increase your ENI quotas.

## Traffic flow

You can break down Amazon WorkSpaces traffic into two main components:

- The traffic between the client device and the Amazon WorkSpaces service.
- The traffic between the Amazon WorkSpaces service and customer network traffic.

The next section discusses both of these components.

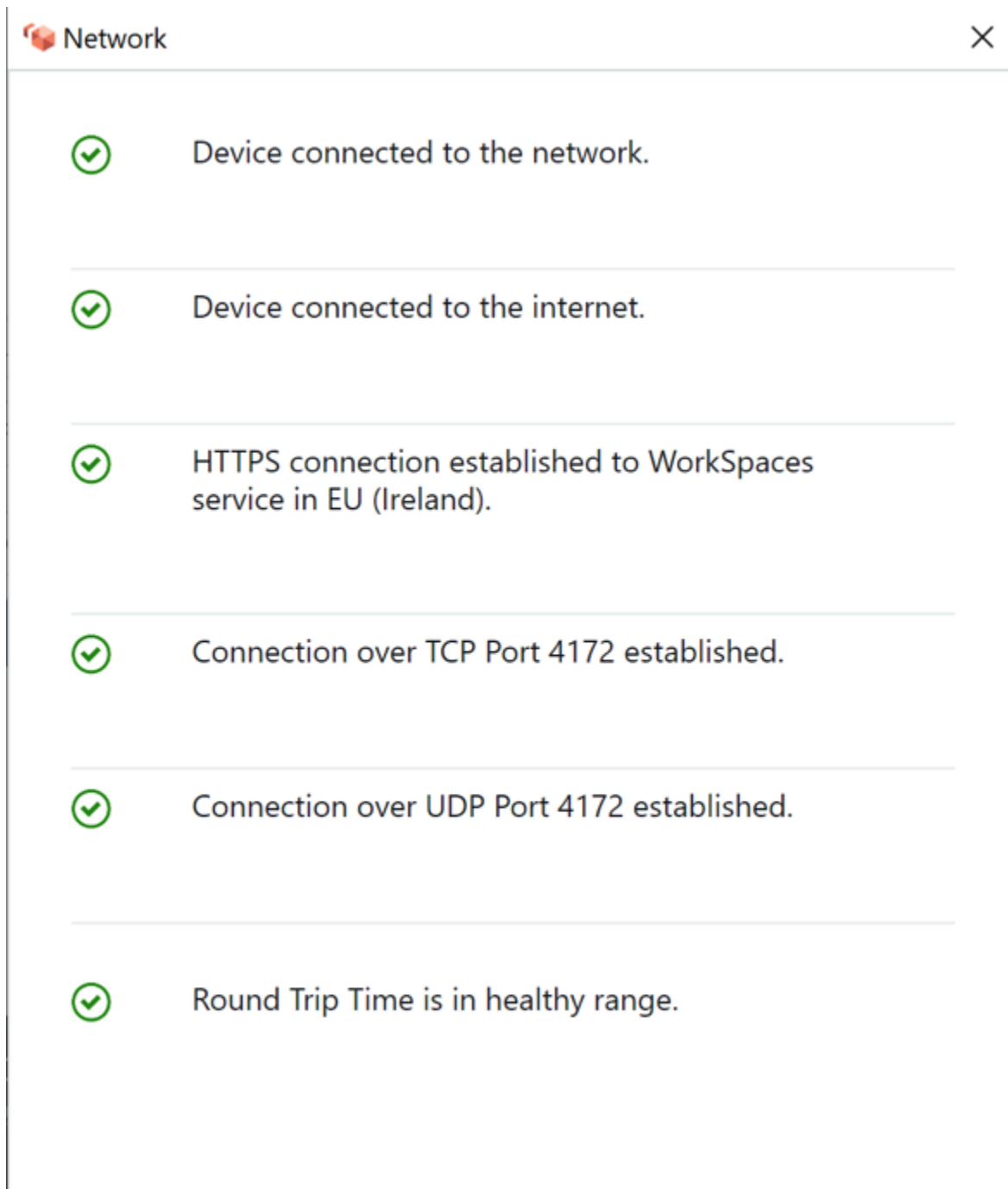
## Client device to WorkSpace

Regardless of its location (on-premises or remote), the device running the Amazon WorkSpaces client uses the same two ports for connectivity to the Amazon WorkSpaces service. The client uses port 443 (HTTPS port) for all authentication and session-related information, and port 4172 (PCoIP port), with both Transmission Control Protocol (TCP) and User Datagram Protocol (UDP), for pixel streaming to a given WorkSpace and network health checks. Traffic on both ports is encrypted. Port 443 traffic is used for authentication and session information and uses TLS for encrypting the traffic. Pixel streaming traffic uses AES-256-bit encryption for communication between the client

and `eth0` of the WorkSpace, via the streaming gateway. More information can be found in the [Security](#) section of this document.

We publish per-region IP ranges of our PCoIP streaming gateways and network health check endpoints. You can limit outbound traffic on port 4172 from your corporate network to the AWS streaming gateway and network health check endpoints by allowing only outbound traffic on port 4172 to the specific AWS Regions in which you're using Amazon WorkSpaces. For the IP ranges and network health check endpoints, refer to [Amazon WorkSpaces PCoIP Gateway IP Ranges](#).

The Amazon WorkSpaces client has a built-in network status check. This utility shows users whether their network can support a connection by way of a status indicator on the bottom right of the application. The following figure shows a more detailed view of the network status can be accessed by choosing **Network** on the top-right side of the client.



*Figure 1: WorkSpaces Client: network check*

A user initiates a connection from their client to the Amazon WorkSpaces service by supplying their login information for the directory used by the Directory Service construct, typically their corporate directory. The login information is sent via HTTPS to the authentication gateways of the Amazon WorkSpaces service in the Region where the Workspace is located. The authentication gateway

of the Amazon WorkSpaces service then forwards the traffic to the specific AWS Directory Service construct associated with your WorkSpace.

For example, when using the AD Connector, the AD Connector forwards the authentication request directly to your AD service, which could be on-premises or in an AWS VPC. For more information, refer to the [AD DS Deployment Scenarios](#) section of this document. The AD Connector does not store any authentication information, and it acts as a stateless proxy. As a result, it's imperative that the AD Connector has connectivity to an AD server. The AD Connector determines which AD server to connect to by using the DNS servers that you define when you create the AD Connector.

If you're using an AD Connector and you have MFA enabled on the directory, the MFA token is checked before the directory service authentication. Should the MFA validation fail, the user's login information is not forwarded to your AWS Directory Service.

Once a user is authenticated, the streaming traffic starts by using port 4172 (PCoIP port) through the AWS streaming gateway to the WorkSpace. Session-related information is still exchanged via HTTPS throughout the session. The streaming traffic uses the first ENI on the WorkSpace (eth0 on the WorkSpace) that is not connected to your VPC. The network connection from the streaming gateway to the ENI is managed by AWS. In the event of a connection failure from the streaming gateways to the WorkSpaces streaming ENI, a CloudWatch event is generated. For more information, refer to the [Monitoring or Logging Using Amazon CloudWatch](#) section of this document.

The amount of data sent between the Amazon WorkSpaces service and the client depends on the level of pixel activity. To ensure an optimal experience for users, we recommend that the round-trip time (RTT) between the WorkSpaces client and the AWS Region where your WorkSpaces are located is less than 100 milliseconds (ms). Typically, this means your WorkSpaces client is located less than two thousand miles from the Region in which the WorkSpace is being hosted. The [Connection Health Check](#) webpage can help you determine the most optimal AWS Region to connect to the Amazon WorkSpaces service.

## Amazon WorkSpaces Service to VPC

After a connection is authenticated from a client to a WorkSpace and streaming traffic is initiated, your WorkSpaces client will display either a Windows or Linux desktop (your Amazon WorkSpace) that is connected to your virtual private cloud (VPC), and your network should show that you have established that connection. The WorkSpace's primary Elastic Network Interface (ENI), identified as eth1, will have an IP address assigned to it from the Dynamic Host Configuration Protocol (DHCP)

service that is provided by your VPC, typically from the same subnets as your AWS Directory Service. The IP address stays with the WorkSpace for the duration of the life of the WorkSpace. The ENI in your VPC has access to any resource in the VPC, and to any network you have connected to your VPC (via a VPC peering, an AWS Direct Connect connection, or VPN connection).

ENI access to your network resources is determined by the route table of the subnet and default security group that your AWS Directory Service configures for each WorkSpace, as well any additional security groups that you assign to the ENI. You can add security groups to the ENI facing your VPC at any time by using the AWS Management Console or AWS CLI. (For more information on security groups, refer to [Security Groups for Your WorkSpaces](#).) In addition to security groups, you can use your preferred host-based firewall on a given WorkSpace to limit network access to resources within the VPC.

It is recommended to create your DHCP options set with the DNS Server IP(s) and fully qualified domain names that are authoritative to your Active Directory specific to your environment, then assign those [custom created DHCP options set to the Amazon VPC](#) used by Amazon WorkSpaces. By default, [Amazon Virtual Private Cloud](#) (Amazon VPC) uses AWS DNS instead of your directory service DNS. Using a DHCP options set will ensure proper DNS name resolution and consistent configuration of your internal DNS name servers for not only your WorkSpaces, but any supporting workload(s) or instance(s) you may have planned for your deployment.

When DHCP Options are applied, there are two important differences in how they will be applied to WorkSpaces in comparison to how they are applied with traditional EC2 instances:

- The first difference is how DHCP Option DNS suffixes will be applied. Each WorkSpace has DNS settings configured for its network adapter with the *Append primary and connection specific DNS suffixes* and *Append parent suffixes of the primary DNS suffix* options enabled. The configuration will be updated with the DNS suffix configured within the AWS Directory Service you registered and associated with the WorkSpace by default. Also, if the DNS suffix configured within the DHCP Options Set used is different, it will be added and applied to any associated WorkSpaces.
- The second difference is that the configured DHCP Option DNS IPs will **not** be applied to the WorkSpace due to the Amazon WorkSpaces service prioritizing the Domain Controllers IP addresses of the configured directory.

Alternatively, you can configure a Route 53 private hosted zone to support a hybrid or split DNS environment and obtain proper DNS resolution for your Amazon WorkSpaces environment. For more information, refer to [Hybrid Cloud DNS Options for VPC](#) and [AWS Hybrid DNS with Active Directory](#).

**Note**

Each WorkSpace must refresh the IP table when applying a new or different DHCP option set to the VPC. To refresh, you can run `ipconfig /renew` or reboot any WorkSpace(s) in the VPC configured with your updated DHCP options set. If you are using AD Connector, and update the IP addresses of your connected IP addresses/domain controllers, you must then update the Skylight DomainJoinDNS registry key on your WorkSpaces. It's recommended to do this via a GPO. The path to this registry key is `HKLM:\SOFTWARE\Amazon\Skylight`. The value of this REG\_SZ is not updated if the AD Connector's DNS settings are modified, and VPC DHCP Option Sets will not update this key either.

The figure in the [AD DS Deployment Scenarios](#) section of this whitepaper shows the traffic flow described.

As explained previously, the Amazon WorkSpaces service prioritizes the Domain Controller IP addresses of the configured Directory for DNS resolution, and ignores the DNS servers configured in your DHCP options set. If you need to have more granular control over your DNS server settings for your Amazon WorkSpaces, you can use the instructions to update DNS servers for Amazon WorkSpaces in the [Update DNS servers for Amazon WorkSpaces](#) guide of the *Amazon WorkSpaces Administration Guide*.

If your WorkSpaces need to resolve other services in AWS, and if you're using the [default DHCP options set](#) with your VPC, your Domain Controller DNS service in this VPC must therefore be configured to use DNS forwarding, pointing to the [Amazon DNS server](#) with the IP address at the base of your VPC CIDR plus two; that is, if your VPC CIDR is 10.0.0.0/24, you configure DNS forwarding to use the standard Route 53 DNS Resolver at 10.0.0.2.

In case your WorkSpaces require DNS resolution of resources on your on-premises network, you may use a [Route 53 Resolver Outbound Endpoint](#), create a Route 53 Forwarding rule, and associate this rule with the VPCs requiring this DNS resolution. If you have configured the forwarding on your Domain Controller DNS service to the default Route 53 DNS Resolver of your VPC as explained in the previous paragraph, the DNS resolution process can be found in the [Resolving DNS queries between VPCs and your network](#) guide of the *Amazon Route 53 Developer Guide*.

If you are using the default DHCP options set, and you require other hosts in your VPCs that are not part of your Active Directory domain to be able to resolve hostnames in your Active Directory namespace, you can use this Route 53 Resolver Outbound Endpoint, and add another Route 53



for your AWS Managed Microsoft AD domain `example.aws` to your Active Directory DNS service in the Shared Services VPC.

With this architecture, your Amazon WorkSpaces will be able to resolve DNS queries for the following:

- Your AWS Managed Microsoft AD domain `example.aws`.
- EC2 instances in the domain configured with your default DHCP options set (for example, `host1.eu-west-1.compute.internal`) as well as other AWS services or endpoints.
- Hosts and services in your on-premises domain, such as `host3.example.com`.
- The other EC2 workloads in the Shared Services VPC (`host1.eu-west-1.compute.internal`) and in the WorkSpaces VPC (`host2.eu-west-1.compute.internal`) can do the same DNS resolutions as your WorkSpaces, as long as the Route 53 Forwarding rules are associated with both VPCs. DNS resolution for the `example.aws` domain will in this case go via the default Route 53 DNS Resolver at the VPC CIDR base IP address +2, which per configured and associated Route 53 Forwarding rules will forward them via the Route 53 Resolver Outbound Endpoint to the WorkSpaces Active Directory DNS service.
- Finally, an on-premises client can also do the same DNS resolution, since the on-premises DNS Server is configured with conditional forwarders for the `example.aws` and `eu-west-1.compute.internal` domains, forwarding DNS queries for these domains to the Route 53 Resolver Inbound Endpoint IP addresses.

## Example of a typical configuration

Let's consider a scenario where you have two types of users and your AWS Directory Service uses a centralized AD for user authentication:

- **Workers who need full access from anywhere** (for example, full-time employees) — These users will have full access to the internet and the internal network, and they will pass through a firewall from the VPC to the on-premises network.
- **Workers who should have only restricted access from inside the corporate network** (for example, contractors and consultants) — These users have restricted internet access through a proxy server to specific websites in the VPC, and will have limited network access in the VPC and to the on-premises network.

You'd like to give full-time employees the ability to have local administrator access on their WorkSpace to install software, and you would like to enforce two-factor authentication with MFA. You also want to allow full-time employees to access the internet without restrictions from their WorkSpace.

For contractors, you want to block local administrator access so that they can only use specific pre-installed applications. You want to apply restrictive network access controls using security groups for these WorkSpaces. You need to open ports 80 and 443 to specific internal websites only, and you want to entirely block their access to the internet.

In this scenario, there are two completely different types of user personas with different requirements for network and desktop access. It's a best practice to manage and configure their WorkSpaces differently. You will need to create two AD Connectors, one for each user persona. Each AD Connector requires two subnets that have enough IP addresses available to meet your WorkSpaces usage growth estimates.

#### Note

Each AWS VPC subnet consumes five IP addresses (the first four and the last IP address) for management purposes, and each AD Connector consumes one IP address in each subnet in which it persists.

Further considerations for this scenario are as follows:

- AWS VPC subnets should be private subnets, so that traffic, such as internet access, can be controlled through either a Network Address Translation (NAT) Gateway, Proxy-NAT server in the cloud, or routed back through your on-premises traffic management system.
- A firewall is in place for all VPC traffic bound for the on-premises network.
- Microsoft AD server and the MFA RADIUS servers are either on-premises (refer to [Scenario 1: Using AD Connector to Proxy Authentication to On-Premises AD DS](#) in this document) or part of the AWS Cloud implementation (refer to [Scenario 2](#) and [Scenario 3](#), AD DS Deployment Scenarios, in this document).

Given that all WorkSpaces are granted some form of internet access, and given that they are hosted in a private subnet, you also must create public subnets that can access the internet through an internet gateway. You need a NAT gateway for the full-time employees, allowing them to access the internet, and a Proxy-NAT server for the consultants and contractors, to limit their

access to specific internal websites. To plan for failure, design for high availability, and limit cross-AZ traffic charges, you should have two NAT gateways and NAT or proxy servers in two different subnets in a multi-AZ deployment. The two AZs that you select as public subnets will match the two AZs that you use for your WorkSpaces subnets, in regions that have more than two zones. You can route all traffic from each WorkSpaces AZ to the corresponding public subnet to limit cross-AZ traffic charges and provide easier management. The following figure shows the VPC configuration.

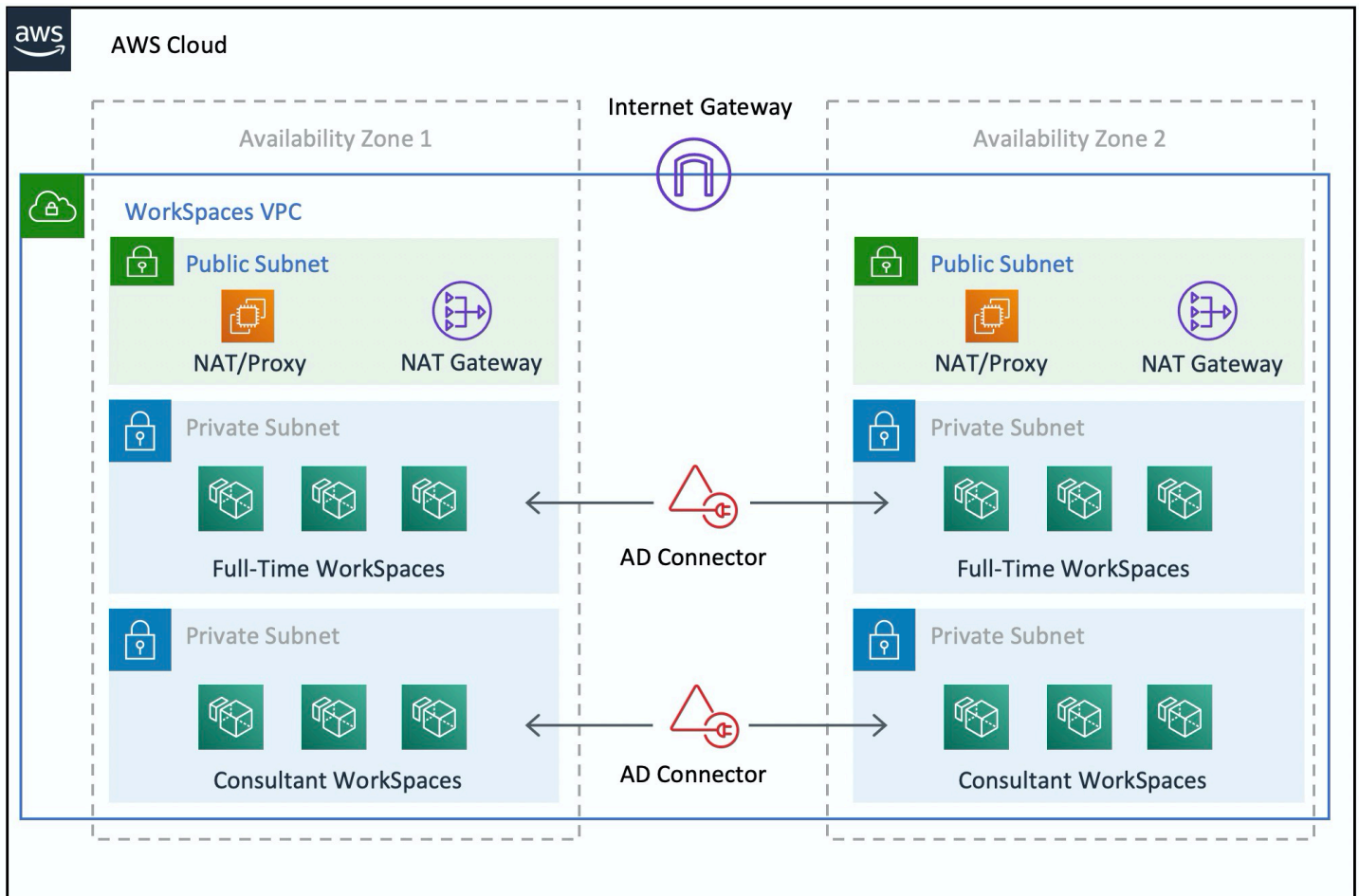


Figure 3: High-level VPC design

The following information describes how to configure the two different WorkSpaces types:

### To configure WorkSpaces for full-time employees:

1. In the Amazon WorkSpaces Management Console, choose the **Directories** option on the menu bar.
2. Choose the directory that hosts your full-time employees.
3. Choose Local Administrator Setting.

By enabling this option, any newly created WorkSpace will have local administrator privileges. To grant internet access, configure NAT for outbound internet access from your VPC. To enable MFA, you need to specify a RADIUS server, server IPs, ports, and a pre-shared key.

For full-time employees' WorkSpaces, inbound traffic to the WorkSpace can be limited to Remote Desktop Protocol (RDP) from the Helpdesk subnet by applying a default security group via the AD Connector settings.

### To configure WorkSpaces for contractors and consultants:

1. In the Amazon WorkSpaces Management Console, disable **Internet Access** and the **Local Administrator** setting.
2. Add a security group under the **Security Group** settings section to enforce a security group for all new WorkSpaces created under that directory.

For consultants' WorkSpaces, limit outbound and inbound traffic to the WorkSpaces by applying a default Security group via the AD Connector settings to all WorkSpaces associated with the AD Connector. The security group prevents outbound access from the WorkSpaces to anything other than HTTP and HTTPS traffic, and inbound traffic to RDP from the Helpdesk subnet in the on-premises network.

#### Note

The security group applies only to the ENI that is in the VPC (eth1 on the WorkSpace), and access to the WorkSpace from the WorkSpaces client is not restricted as a result of a security group. The following figure shows the final WorkSpaces VPC design.

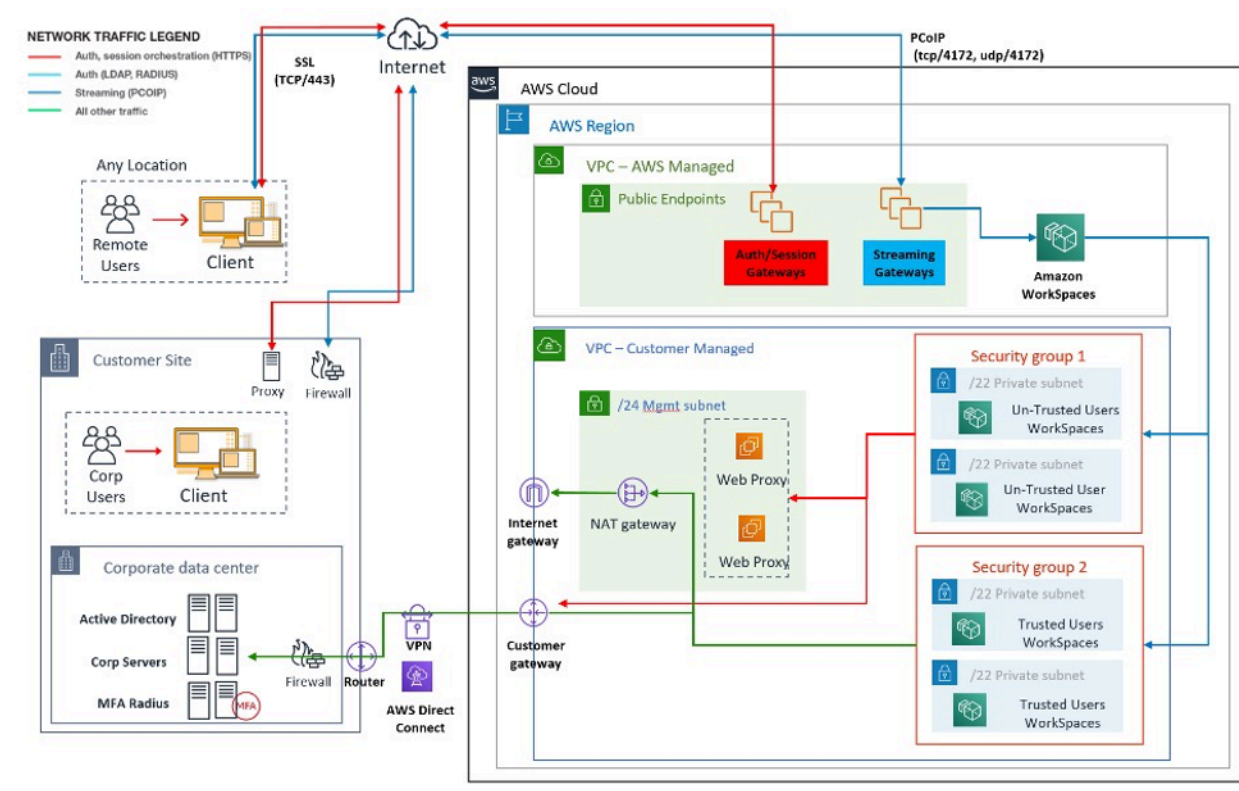


Figure 4: WorkSpaces design with user personas

## AWS Directory Service

As mentioned in the introduction, AWS Directory Service is a core component of Amazon WorkSpaces. With AWS Directory Service, you can create three types of directories with Amazon WorkSpaces:

- [AWS Managed Microsoft AD](#) is a managed Microsoft AD, powered by Windows Server 2012 R2. AWS Managed Microsoft AD is available in Standard or Enterprise Edition.
- [Simple AD](#) is standalone, Microsoft AD-compatible, managed directory service powered by Samba 4.
- [AD Connector](#) is a directory proxy for redirecting authentication requests and user or group lookups to your existing on-premises Microsoft AD.

The following section describes communication flows for authentication between the Amazon WorkSpaces brokerage service and AWS Directory Service, best practices for implementing WorkSpaces with AWS Directory Service, and advanced concepts, such as MFA. It also discusses infrastructure architecture concepts for Amazon WorkSpaces at scale, requirements on Amazon

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## VPC, and AWS Directory Service, including integration with on-premises Microsoft AD Domain Services (AD DS).

# AD DS deployment scenarios

Backing Amazon WorkSpaces is the AWS Directory Service, and the proper design and deployment of the directory service is critical. The following six scenarios build on the [Active Directory Domain Services in the AWS Quick Start guide](#), and describe the best practice deployment options for AD DS when used with Amazon WorkSpaces. The [Design Considerations](#) section of this document details the specific requirements and best practices of using AD Connector for WorkSpaces, which is an integral part of the overall WorkSpaces design concept.

- **Scenario 1: Using AD Connector to proxy authentication to on-premises AD DS** — In this scenario, network connectivity (VPN/Direct Connect) is in place to the customer, with all authentication proxied via AWS Directory Service (AD Connector) to the customer on-premises AD DS.
- **Scenario 2: Extending on-premises AD DS into AWS (Replica)** — This scenario is similar to scenario 1, but here a replica of the customer AD DS is deployed on AWS in combination with AD Connector, reducing latency of authentication/query requests to AD DS and the AD DS global catalog.
- **Scenario 3: Standalone isolated deployment using AWS Directory Service in the AWS Cloud** — This is an isolated scenario and doesn't include connectivity back to the customer for authentication. This approach uses AWS Directory Service (Microsoft AD) and AD Connector. Although this scenario doesn't rely on connectivity to the customer for authentication, it does make provision for application traffic where required over VPN or Direct Connect.
- **Scenario 4: AWS Microsoft AD and a Two-Way Transitive Trust to On-Premises** — This scenario includes the AWS Managed Microsoft AD Service (MAD) with a two-way transitive trust to the on-premises Microsoft AD Forest.
- **Scenario 5: AWS Microsoft AD using a Shared Services VPC** — This scenario uses AWS Managed Microsoft AD in a Shared Services VPC to be used as an Identity Domain for multiple AWS Services (Amazon EC2, Amazon WorkSpaces, and so on.) while using the AD Connector to proxy Lightweight Directory Access Protocol (LDAP) user authentication requests to the AD domain controllers.
- **Scenario 6: AWS Microsoft AD, Shared Services VPC, and a One-Way Trust to On-Premises AD** — This scenario is similar to Scenario 5, but it includes disparate identity and resource domains using a one-way trust to on-premises.

You need to make several considerations when selecting your deployment scenario for Active Directory Domain Services (ADDS). This section explains the role of the AD Connector with Amazon WorkSpaces, and covers some important considerations when selecting an ADDS deployment scenario. For further guidance on design and planning of ADDS on AWS, please consult the [Active Directory Domain Services on AWS Design and Planning Guide](#).

## The Role of the AWS AD Connector with Amazon WorkSpaces

The [AWS AD Connector](#) is an AWS Directory Service that acts as a proxy service for an Active Directory. It does not store or cache any user credentials, but forwards authentication or lookup requests to your Active Directory—on-premises or on AWS. Unless you are using AWS Managed Microsoft AD, it is also the only way to register your Active Directory (on-premises or extended to AWS) for use with Amazon WorkSpaces (WorkSpaces).

An AD Connector can point to your on-premises Active Directory, to an Active Directory extended to AWS (AD Domain Controllers on Amazon EC2), or to an AWS Managed Microsoft AD.

The AD Connector plays an important role with most of the deployment scenarios covered in the following sections. Using the AD Connector with WorkSpaces provides a number of benefits:

- When pointed to your corporate Active Directory, it allows your users to use their existing corporate credentials to log on to WorkSpaces and other services, such as [Amazon WorkDocs](#).
- You can consistently apply existing security policies (password expiration, account lockouts, etc.) whether your users are accessing resources in your on-premises infrastructure or in the AWS Cloud, such as WorkSpaces.
- The AD Connector enables a simple integration with your existing RADIUS-based MFA infrastructure to provide an additional layer of security.
- It enables segregation of your users. For example, it allows the configuration of a number of WorkSpaces options per business unit or persona, since multiple AD Connectors can be pointing to the same Domain Controllers (DNS servers) of Active Directory for user authentication:
  - Target Domain or Organizational Unit for targeted application of Active Directory Group Policy Objects (GPOs)
  - Different Security Groups to control traffic flow to/from WorkSpaces
  - Different Access Control Options (allowed client devices) and IP Access Control Groups (limit access to IP ranges)
  - Selective enabling of Local Administrator Permissions

- Different Self-Service Permissions
- Selective enforcement of Multi-Factor Authentication (MFA)
- Placement of your WorkSpaces Elastic Network Interfaces (ENI) into different VPCs or Subnets for isolation

Multiple AD Connectors also allow to support a larger number of users, if you are hitting the performance limit of a single small or large AD Connector. Please refer to the [Sizing of AWS Managed Microsoft AD](#) section for more detail.

The use of AD Connectors with WorkSpaces is free of charge, as long as you have at least one active WorkSpaces user in a small AD Connector and at least 100 active WorkSpaces users in a large AD Connector. For more information, see the [AWS Directory Services Pricing](#) page.

## The Importance of Your Network Link to AWS With an On-Premises Active Directory

WorkSpaces relies on connectivity to your Active Directory. Hence, the availability of the network link to your Active Directory is of utmost importance. For example, if your network link in [Scenario 1](#) is down, your users won't be able to authenticate, and as a result won't be able to use their WorkSpaces.

If an on-premises Active Directory is to be used as part of the scenario, you'll need to consider resiliency, latency, and traffic cost of your network link to AWS. In a multi-region WorkSpaces deployment, this may involve multiple network links in different AWS Regions, or multiple AWS Transit Gateways with peering established between them to route your AD traffic to the VPC with connectivity to your on-premises AD. These network link considerations apply to most of the scenarios outlined in the following sections, but are especially important for those scenarios where your AD traffic from AD Connectors and WorkSpaces needs to traverse the network link to reach your on-premise Active Directory. [Scenario 1](#) highlights some of the caveats.

## Using Multi-Factor Authentication with WorkSpaces

If you plan to use Multi-Factor Authentication (MFA) with WorkSpaces, you must use an AWS AD Connector or an AWS Managed Microsoft AD, since only these services allow registration of the directory for use with WorkSpaces and configuration of RADIUS. For the placement of your RADIUS servers, the network link considerations covered in the [The Importance of Your Network Link to AWS With an On-Premises Active Directory](#) section apply.

## Separating Account and Resource Domain

For security reasons or for better manageability, it might be desirable to separate the Account Domain from the Resource Domain. For example, place the WorkSpaces Computer Objects into a separate Resource Domain, while the Users are part of the Account Domain. An implementation like this can be used to allow a partner organization to manage the WorkSpaces using AD Group Policies in the Resource Domain, while not relinquishing control or granting access to the Account Domain. This can be accomplished by using two Active Directories with a configured Active Directory Trust. The following sections cover this in more detail:

- [Scenario 4: AWS Microsoft AD and a two-way transitive trust to on-premises](#)
- [Scenario 6: AWS Microsoft AD, shared services VPC, and a one-way trust to on-premises](#)

## Large Active Directory Deployments

You must ensure that Active Directory Sites & Services is configured accordingly. This is especially important if your Active Directory consists of a large number of domain controllers in different geographical locations. Your Windows WorkSpaces use the [standard Microsoft mechanism](#) to discover their domain controller for the Active Directory Site they're assigned to. This DC Locator process relies on DNS and may be significantly prolonged in case a lengthy list of domain controllers with unspecific priority and weight is returned at the early stage of the DC Locator process. More importantly, if your WorkSpaces get "pinned" to a sub-optimal domain controller, all subsequent communication with this domain controller may suffer from increased network latency and reduced bandwidth when traversing wide area network links. This will slow down any communication with the domain controller, including processing of a potentially large number of Group Policy Objects (GPOs), and file transfers from the domain controller. Depending on the network topology, it may also increase your networking cost, because the data exchanged between WorkSpaces and domain controllers might unnecessarily traverse a costlier network path. Refer to the [VPC design](#) and [Design considerations](#) sections for guidance on DHCP and DNS with your VPC design, and Active Directory Sites & Services.

## Using Microsoft Azure Active Directory or Active Directory Domain Services with WorkSpaces

If you intend to use Microsoft Azure Active Directory with WorkSpaces, you might use Azure AD Connect to synchronize your identity with your on-premises Active Directory or with your Active Directory on AWS (Domain Controller on Amazon EC2 or AWS Managed Microsoft AD). However,

this will not allow you to join WorkSpaces to your Azure Active Directory. For more information, see the [Microsoft Hybrid Identity Documentation](#) in the *Microsoft Azure Documentation*.

If you want to join your WorkSpaces to your Azure Active Directory, you will need to deploy Microsoft Azure Active Directory Domain Services (Azure AD DS), establish connectivity between AWS and Azure, and use an AWS AD Connector pointing to your Azure AD DS Domain Controllers. For more information about how to set this up, see the [Add your WorkSpaces to Azure AD using Azure Active Directory Domain Services](#) blog post.

When using AWS Directory Services with WorkSpaces, you'll have to consider the size of your WorkSpaces deployment and its expected growth in order to size the AWS Directory Service appropriately. This section provides guidance on sizing the AWS Directory Service for use with WorkSpaces. We also recommend you review the [Best practices for AD Connector](#) and the [Best practices for AWS Managed Microsoft AD](#) sections in the *AWS Directory Service Administration Guide*.

## Sizing of AD Connector with WorkSpaces

The Active Directory Connector (AD Connector) is available in two sizes, Small and Large. While there are no enforced user or connection limits, we recommend to use a small AD Connector for up to 500 WorkSpaces entitled users, and a large AD Connector for up to 5000 WorkSpaces entitled users. You can spread application loads across multiple AD Connector to scale to your performance needs. For example, if you need to support 1500 WorkSpaces users, you may spread your WorkSpaces equally across three small AD Connector, each supporting 500 users. If all of your users reside in the same Domain, the AD Connector can all point to the same set of DNS Servers resolving your Active Directory Domain.

Note, if you started with a small AD Connector, and your WorkSpaces deployment grows over time, you can raise a support ticket to have the size of your AD Connector changed from small to large in order to handle the larger number of WorkSpaces entitled users.

## Sizing of AWS Managed Microsoft AD

[AWS Managed Microsoft AD](#) lets you run Microsoft Active Directory as a managed service. You can choose between Standard Edition and Enterprise Edition when you launch the service. The Standard Edition is recommended for small and midsize business with up to 5,000 users, and supports up to roughly 30,000 directory objects, such as users, groups, and computers. The Enterprise Edition is designed to support up to 500,000 directory objects and also offers an additional feature, such as [multi-Region replication](#).

If you need to support more than 500,000 directory objects, consider deploying Microsoft Active Directory Domain Controllers on Amazon EC2. For the sizing of these Domain Controllers refer to Microsoft's [Capacity planning for Active Directory Domain Services](#) document.

## Scenario 1: Using AD connector to proxy authentication to on-premises Active Directory Service

This scenario is for customers who don't want to extend their on-premises AD service into AWS, or where a new deployment of AD DS is not an option. The following figure shows at a high level, each of the components, and the user authentication flow.

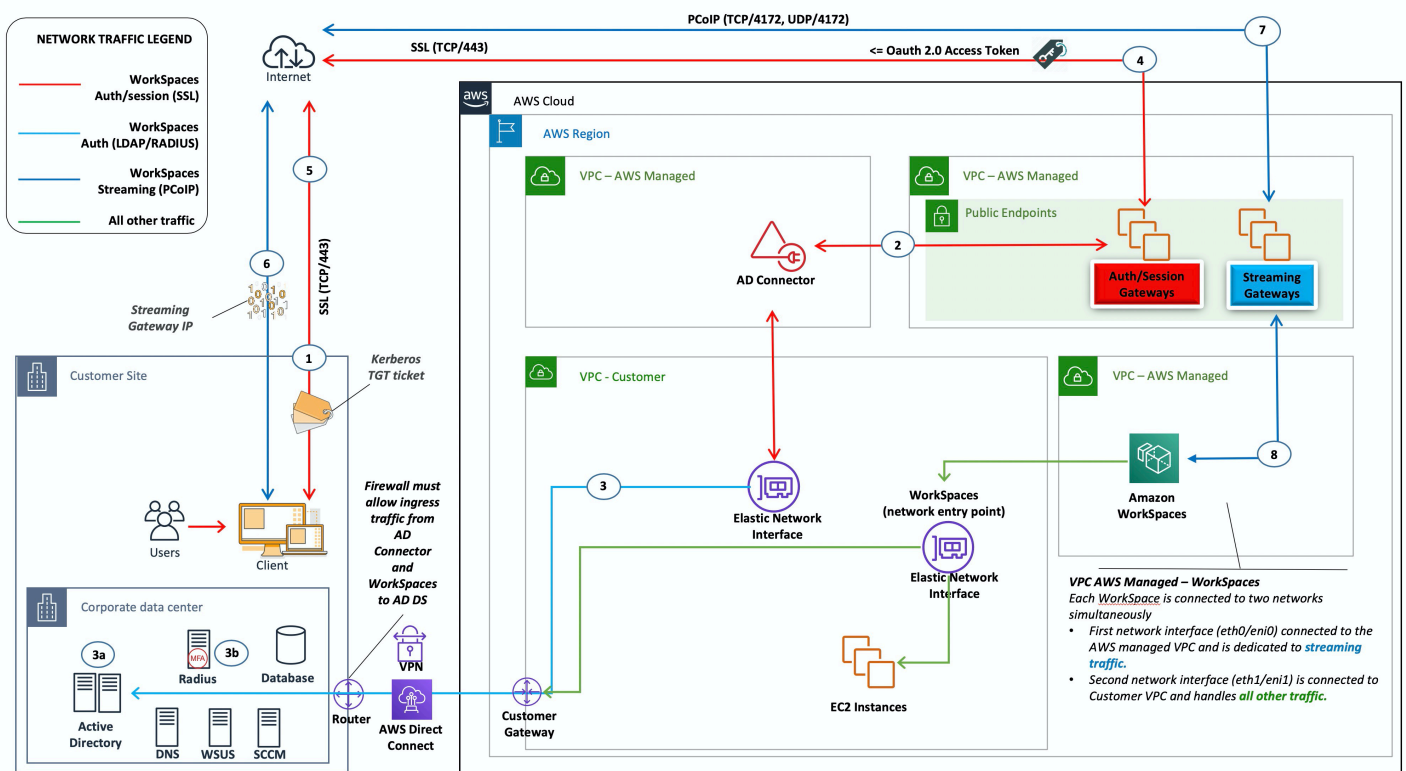


Figure 5: AD Connector to on-premises Active Directory

In this scenario, AWS Directory Service (AD Connector) is used for all user or MFA authentication that is proxied through the AD Connector to the customer on-premises AD DS (detailed in the following figure). For details on the protocols or encryption used for the authentication process, refer to the [Security](#) section of this document.

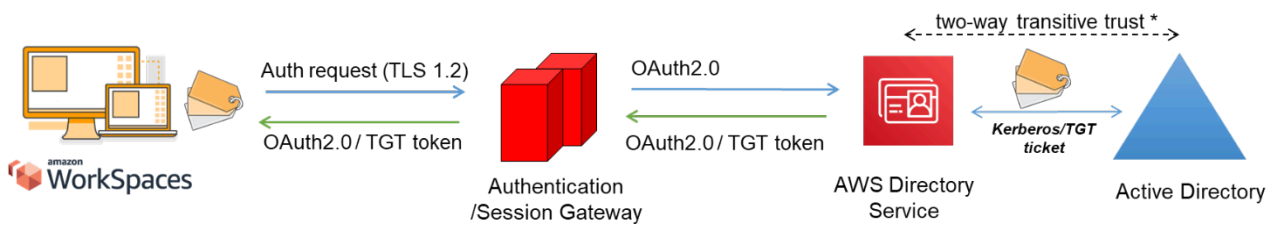


Figure 6: User authentication via the Authentication Gateway

Scenario 1 shows a hybrid architecture where the customer might already have resources in AWS, as well as resources in an on-premises data center that could be accessed via Amazon WorkSpaces. The customer can leverage their existing on-premises AD DS and RADIUS servers for user and MFA authentication.

This architecture uses the following components or constructs:

## AWS

- **Amazon VPC** — Creation of an Amazon VPC with at least two private subnets across two AZs.
- **DHCP Options Set** — Creation of an Amazon VPC DHCP Options Set. This allows customer-specified domain name and domain name servers (DNS) (on-premises services) to be defined. For more information, refer to [DHCP options sets](#).
- **Amazon Virtual Private Gateway** — Enable communication with your own network over an IPsec VPN tunnel or an AWS Direct Connect connection.
- **AWS Directory Service** — AD Connector is deployed into a pair of Amazon VPC private subnets.
- **Amazon WorkSpaces** — WorkSpaces are deployed in the same private subnets as the AD Connector. For more information, refer to the [Active Directory: Sites and Services](#) section of this document.

## Customer

- **Network connectivity** — Corporate VPN or Direct Connect endpoints.
- **AD DS** — Corporate AD DS.
- **MFA (optional)** — Corporate RADIUS server.
- **End user devices** — Corporate or bring your own license (BYOL) end user devices (such as Windows, Macs, iPads, Android tablets, zero clients, and Chromebooks) used to access the

Amazon WorkSpaces service. Refer to [this list of client applications for supported devices and web browsers](#).

Although this solution is great for customers who don't want to deploy AD DS into the cloud, it does come with some caveats:

- **Reliance on connectivity** — If connectivity to the data center is lost, users cannot log in to their respective WorkSpaces, and existing connections will remain active for the Kerberos/Ticket-Granting Ticket (TGT) lifetime.
- **Latency** — If latency exists via the connection (this is more the case with VPN than Direct Connect), then WorkSpaces authentication and any AD DS-related activity, such as Group Policy (GPO) enforcement, will take more time.
- **Traffic costs** — All authentication must traverse the VPN or Direct Connect link, and so it depends on the connection type. This is either Data Transfer Out from Amazon EC2 to internet or Data Transfer Out (Direct Connect).

#### Note

AD Connector is a proxy service. It doesn't store or cache user credentials. Instead, all authentication, lookup, and management requests are handled by your AD. An account with delegation privileges is required in your directory service with rights to read all user information and join a computer to the domain.

In general, the WorkSpaces experience is highly dependent on the Active Directory authentication process shown in the previous figure. For this scenario, the WorkSpaces authentication experience is highly dependent on the network link between the customer AD and the WorkSpaces VPC. The customer should ensure the link is highly available.

## Scenario 2: Extending on-premises AD DS into AWS (replica)

This scenario is similar to scenario 1. However, in this scenario, a replica of the customer AD DS is deployed on AWS in combination with AD Connector. This reduces latency of authentication or query requests to AD DS running on Amazon Elastic Compute Cloud (Amazon EC2). The following figure shows a high-level view of each of the components and the user authentication flow.

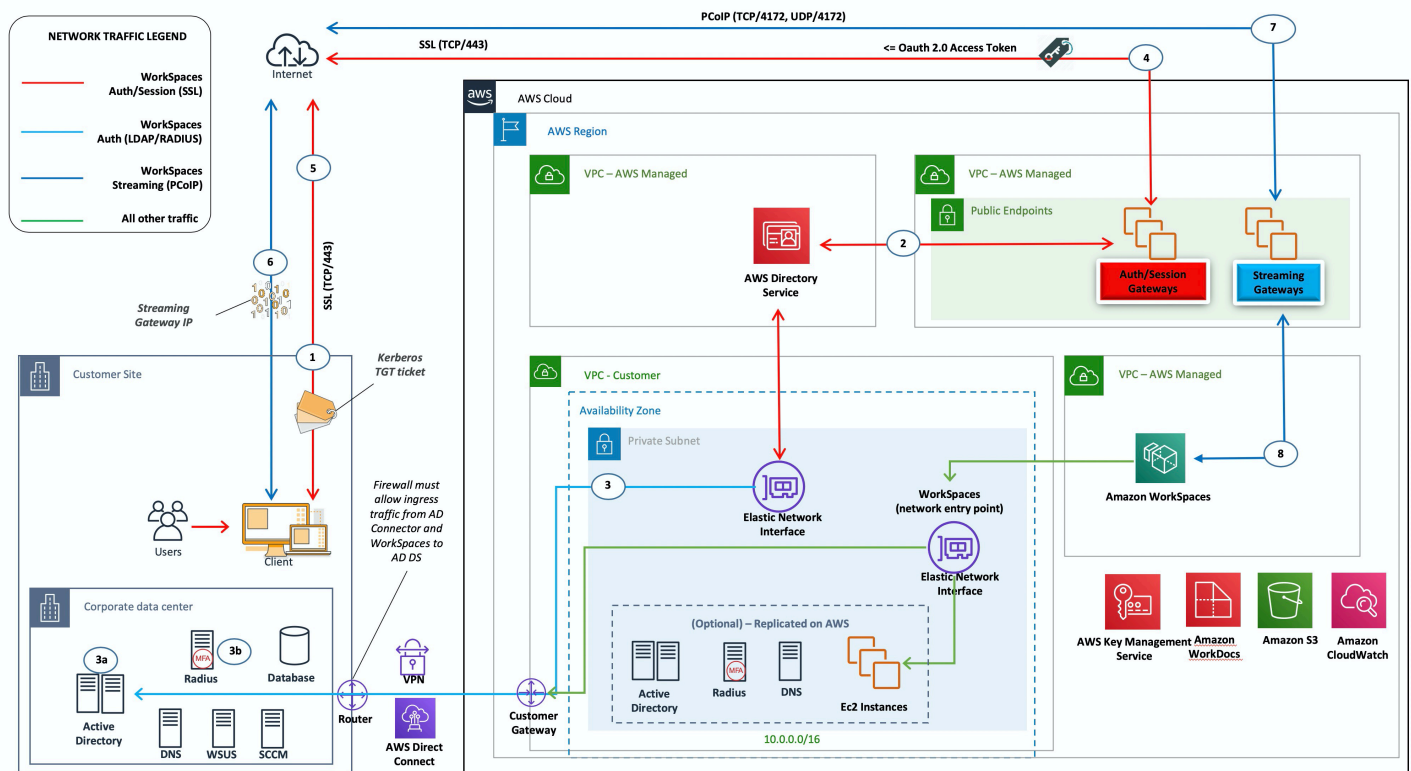


Figure 7: Extend customer Active Directory Domain to the cloud

As in scenario 1, AD Connector is used for all user or MFA authentication, which in turn is proxied to the customer AD DS (refer to [the previous figure](#)). In this scenario, the customer AD DS is deployed across AZs on Amazon EC2 instances that are promoted to be domain controllers in the customer's on-premises [AD forest](#), running in the AWS Cloud. Each domain controller is deployed into VPC private subnets to make AD DS highly available in the AWS Cloud. For best practices for deploying AD DS on AWS, refer to the [Design Considerations](#) section of this document.

After WorkSpaces instances are deployed, they have access to the cloud-based domain controllers for secure, low-latency directory services and DNS. All network traffic, including AD DS communication, authentication requests, and AD replication, is secured either within the private subnets or across the customer VPN tunnel or Direct Connect.

This architecture uses the following components or constructs:

## AWS

- **Amazon VPC** — Creation of an Amazon VPC with at least four private subnets across two AZs — two for the customer AD DS, two for AD Connector or Amazon WorkSpaces.

- **DHCP Options Set** — Creation of an Amazon VPC DHCP options set. This allows the customer to define a specified domain name and DNSs (AD DS local). For more information, refer to [DHCP Options Sets](#).
- **Amazon Virtual Private Gateway** — Enable communication with a customer-owned network over an IPsec VPN tunnel or AWS Direct Connect connection.
- **Amazon EC2**
  - Customer corporate AD DS domain controllers deployed on Amazon EC2 instances in dedicated private VPC subnets.
  - Customer (optional) RADIUS servers for MFA on Amazon EC2 instances in dedicated private VPC subnets.
- **AWS Directory Services** — AD Connector is deployed into a pair of Amazon VPC private subnets.
- **Amazon WorkSpaces** — WorkSpaces are deployed into the same private subnets as the AD Connector. For more information, refer to the [Active Directory: Sites and Services](#) section of this document.

## Customer

- **Network connectivity** — Corporate VPN or AWS Direct Connect endpoints.
- **AD DS** — Corporate AD DS (required for replication).
- **MFA (optional)** — Corporate RADIUS server.
- **End user devices** — Corporate or BYOL end user devices (such as Windows, Macs, iPads, Android tablets, zero clients, and Chromebooks) used to access the Amazon WorkSpaces service. Refer to the [list of client applications for supported devices and web browsers](#). This solution doesn't have the same caveats as scenario 1. Amazon WorkSpaces and AWS Directory Service have no reliance on the connectivity in place.
- **Reliance on connectivity** — If connectivity to the customer data center is lost, end users can continue to work because authentication and *optional* MFA are processed locally.
- **Latency** — With the exception of replication traffic, all authentication is local and low latency. Refer to the [Active Directory: Sites and Services](#) section of this document.
- **Traffic costs** — In this scenario, authentication is local, with only AD DS replication having to traverse the VPN or Direct Connect link, reducing data transfer.

In general, the WorkSpaces experience is enhanced and isn't highly dependent connectivity to the on-premises domain controllers, as shown in the previous figure. This is also the case when a customer wants to scale WorkSpaces to thousands of desktops, especially in relation to AD DS global catalog queries, as this traffic remains local to the WorkSpaces environment.

## Scenario 3: Standalone isolated deployment using AWS Directory Service in the AWS Cloud

This scenario, shown in the following figure, has AD DS deployed in the AWS Cloud in a standalone isolated environment. AWS Directory Service is used exclusively in this scenario. Instead of fully managing AD DS, customers can rely on AWS Directory Service for tasks such as building a highly available directory topology, monitoring domain controllers, and configuring backups and snapshots.

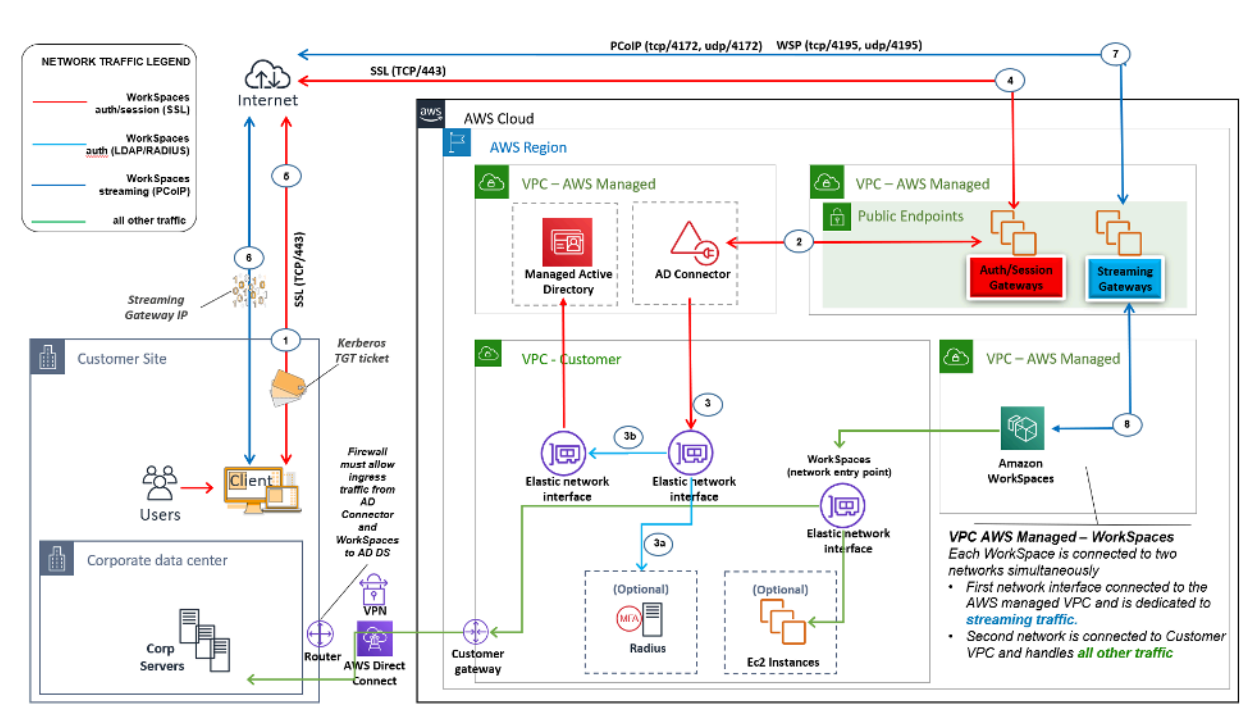


Figure 8: Cloud only: AWS Directory Services (Microsoft AD)

As in scenario 2, the AD DS (Microsoft AD) is deployed into dedicated subnets that span two AZs, making AD DS highly available in the AWS Cloud. In addition to Microsoft AD, AD Connector (in all three scenarios) is deployed for WorkSpaces authentication or MFA. This ensures separation of roles or functions within the Amazon VPC, which is a standard best practice. For more information, refer to the [Design Considerations](#) section of this document.

Scenario 3 is a standard, all-in configuration that works well for customers who want to have AWS manage the deployment, patching, high availability, and monitoring of the AWS Directory Service. The scenario also works well for proof of concepts, lab, and production environments because of its isolation mode.

In addition to the placement of AWS Directory Service, this figure shows the flow of traffic from a user to a workspace and how the workspace interacts with the AD server and MFA server.

This architecture uses the following components or constructs.

## AWS

- **Amazon VPC** — Creation of an Amazon VPC with at least four private subnets across two AZs — two for AD DS [Microsoft AD](#), two for AD Connector or WorkSpaces.
- **DHCP options set** — Creation of an Amazon VPC DHCP options set. This allows a customer to define a specified domain name and DNS (Microsoft AD). For more information, refer to [DHCP options sets](#).
- **Optional: Amazon virtual private gateway** — Enable communication with a customer-owned network over an IPsec VPN tunnel (VPN) or AWS Direct Connect connection. Use for accessing on-premises back-end systems.
- **AWS Directory Service** — Microsoft AD deployed into a dedicated pair of VPC subnets (AD DS Managed Service).
- **Amazon EC2** — Customer “Optional” RADIUS Servers for MFA.
- **AWS Directory Services** — AD Connector is deployed into a pair of Amazon VPC private subnets.
- **Amazon WorkSpaces** — WorkSpaces are deployed into the same private subnets as the AD Connector. For more information, refer to the [Active Directory: Sites and Services](#) section of this document.

## Customer

- **Optional: Network Connectivity** — Corporate VPN or AWS Direct Connect endpoints.
- **End user devices** — Corporate or BYOL end-user devices (such as Windows, Macs, iPads, Android tablets, zero clients, and Chromebooks) used to access the Amazon WorkSpaces service. Refer to [this list of client applications for supported devices and web browsers](#).



scenario requires a domain trust to be in place. Security groups and firewall rules need to allow communication between the two active directories.

In addition to the placement of AWS Directory Service, the previous figure outlines the flow of traffic from a user to a workspace, and how the workspace interacts with the AD server and MFA server.

This architecture uses the following components or construct.

## AWS

- **Amazon VPC** — Creation of an Amazon VPC with at least four private subnets across two AZs — two for AD DS [Microsoft AD](#), two for AD Connector or WorkSpaces.
- **DHCP options set** — Creation of an Amazon VPC DHCP options set. This enables a customer to define a specified domain name and DNS (Microsoft AD). For more information, refer to [DHCP options sets](#).
- **Optional: Amazon virtual private gateway** — Enable communication with a customer-owned network over an IPsec VPN tunnel (VPN) or AWS Direct Connect connection. Use for accessing on-premises back-end systems.
- **AWS Directory Service** — Microsoft AD deployed into a dedicated pair of VPC subnets (AD DS Managed Service).
- **Amazon EC2** — Customer *optional* RADIUS Servers for MFA.
- **Amazon WorkSpaces** — WorkSpaces are deployed into the same private subnets as the AD Connector. For more information, refer to the [Active Directory: Sites and Services](#) section of this document.

## Customer

- **Network Connectivity** — Corporate VPN or AWS Direct Connect endpoints.
- **End user devices** — Corporate or BYOL end-user devices (such as Windows, Macs, iPads, Android tablets, zero clients, and Chromebooks) used to access the Amazon WorkSpaces service. Refer to the [list of client applications for supported devices and web browsers](#).

This solution requires connectivity to the customer on-premises data center to allow the trust process to operate. If WorkSpaces users are using resources on the on-premises network, then latency and outbound data transfer costs need to be considered.

## Scenario 5: AWS Microsoft AD using a shared services Virtual Private Cloud (VPC)

This scenario, shown in the following figure, has an AWS Managed AD deployed in the AWS Cloud, providing authentication services for workloads that are either already hosted in AWS or are planned to be as part of a broader migration. The best practice recommendation is to have Amazon WorkSpaces in a dedicated VPC. Customers should also create a specific AD OU to organize the WorkSpaces computer objects.

To deploy WorkSpaces with a shared services VPC hosting Managed AD, deploy an AD Connector (ADC) with an ADC service account created in the Managed AD. The service account requires permissions to create computer objects in the WorkSpaces designated OU in the shared services Managed AD.

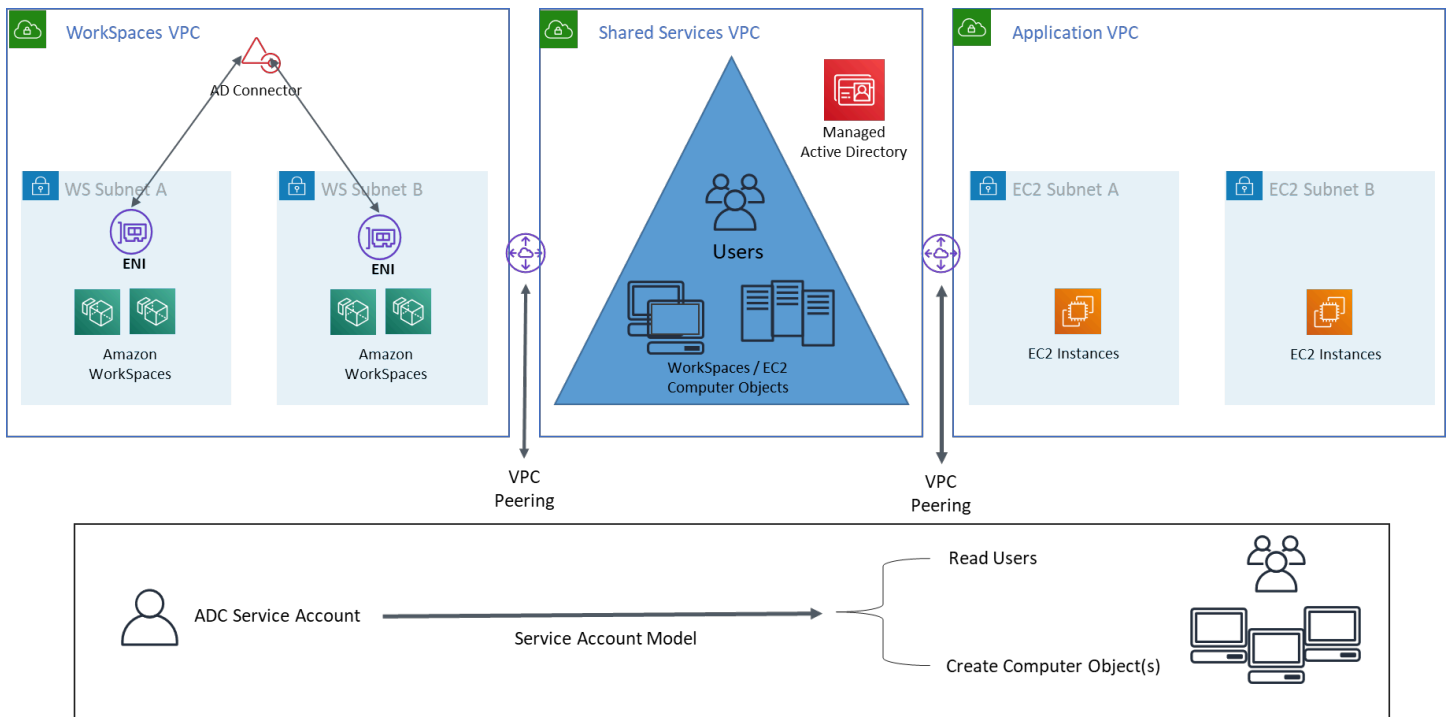


Figure 10: AWS Microsoft AD using a shared services VPC

This architecture uses the following components or constructs.

## AWS

- **Amazon VPC** — Creation of an Amazon VPC with at least two private subnets across two AZs (two for AD Connector and WorkSpaces).
- **DHCP options set** — Creation of an Amazon VPC DHCP options set. This allows a customer to define a specified domain name and DNS (Microsoft AD). For more information, refer to [DHCP options sets](#).
- **Optional: Amazon virtual private gateway** — Enable communication with a customer-owned network over an IPsec VPN tunnel (VPN) or AWS Direct Connect connection. Use for accessing on-premises back-end systems.
- **AWS Directory Service** — Microsoft AD deployed into a dedicated pair of VPC subnets (AD DS Managed Service), AD Connector
- **AWS Transit Gateway/VPC Peering** — Enable connectivity between Workspaces VPC and the Shared Services VPC
- **Amazon EC2** — Customer *optional* RADIUS Servers for MFA.
- **Amazon WorkSpaces** — WorkSpaces are deployed into the same private subnets as the AD Connector. For more information, refer to the [Active Directory: Sites and Services](#) section of this document.

## Customer

- **Network Connectivity** — Corporate VPN or AWS Direct Connect endpoints.
- **End user devices** — Corporate or BYOL end-user devices (such as Windows, Macs, iPads, Android tablets, zero clients, and Chromebooks) used to access the Amazon WorkSpaces service. Refer to the [list of client applications for supported devices and web browsers](#).

## Scenario 6: AWS Microsoft AD, shared services VPC, and a one-way trust to on-premises

This scenario, as shown in the following figure, uses an existing on-premises Active Directory for users, and introduces a separate Managed Active Directory in AWS Cloud to host the computer objects associated with the WorkSpaces. This scenario allows the computer objects and Active Directory group policies to be managed independently from the corporate Active Directory.

This scenario is useful when a third party wants to manage Windows WorkSpaces on a customer's behalf as it allows the third party to define and control the WorkSpaces and policies associated with them, without a need to grant the third-party access to the customer AD. In this scenario, a specific Active Directory organizational unit (OU) is created to organize the WorkSpaces computer objects in the Shared Services AD.

**Note**

Amazon Linux WorkSpaces require a two-way trust to be in place for them to be created.

To deploy Windows WorkSpaces with the computer objects created in the Shared Services VPC hosting Managed Active Directory using users from the customer identity domain, deploy an Active Directory Connector (ADC) referencing the corporate AD. Use an ADC service account created in the corporate AD (identity domain) that has delegated permissions to create computer objects in the Organizational Unit (OU) that was configured for the Windows WorkSpaces in the Shared Services Managed AD, and that has read permissions to the corporate Active Directory (identity domain).

To ensure the Domain Locator function is able to authenticate WorkSpaces users in the desired AD Site for the identity domain, name both domain's AD Sites for the Amazon WorkSpaces Subnets identically as per [Microsoft's documentation](#). It is a best practice to have both identity domain and Shared Services domain AD Domain Controllers in the same AWS Region as Amazon WorkSpaces.

For detailed instructions to configure this scenario, review the implementation guide to [set up a one-way trust for Amazon WorkSpaces with AWS Directory Services](#)

In this scenario we establish a one-way transitive trust between the AWS Managed Microsoft AD in the Shared Services VPC and the on-premises AD. Figure 11 shows the direction of trust and access, and how the AWS AD Connector uses the AD Connector service account to create computer objects in the resource domain.

A forest trust is used per Microsoft recommendation to ensure that Kerberos authentication is used whenever possible. Your WorkSpaces receive Group Policy Objects (GPOs) from your resource domain in the AWS Managed Microsoft AD. Furthermore, your WorkSpaces perform Kerberos authentication with your identity domain. For this to work reliably it is best practice to extend your identity domain to AWS as already explained above. We suggest to review the [Deploy Amazon WorkSpaces using a One-Way Trust Resource Domain with Directory Service](#) implementation guide for further detail.

Both, the AD Connector and your WorkSpaces, must be able to communicate with the Domain Controllers of your identity domain and your resource domain. For more information, see [IP address and port requirements for WorkSpaces](#) in the *Amazon WorkSpaces Administration Guide*.

If you use multiple AD Connectors, it is best practice for each of the AD Connectors to use its own AD Connector Service Account.

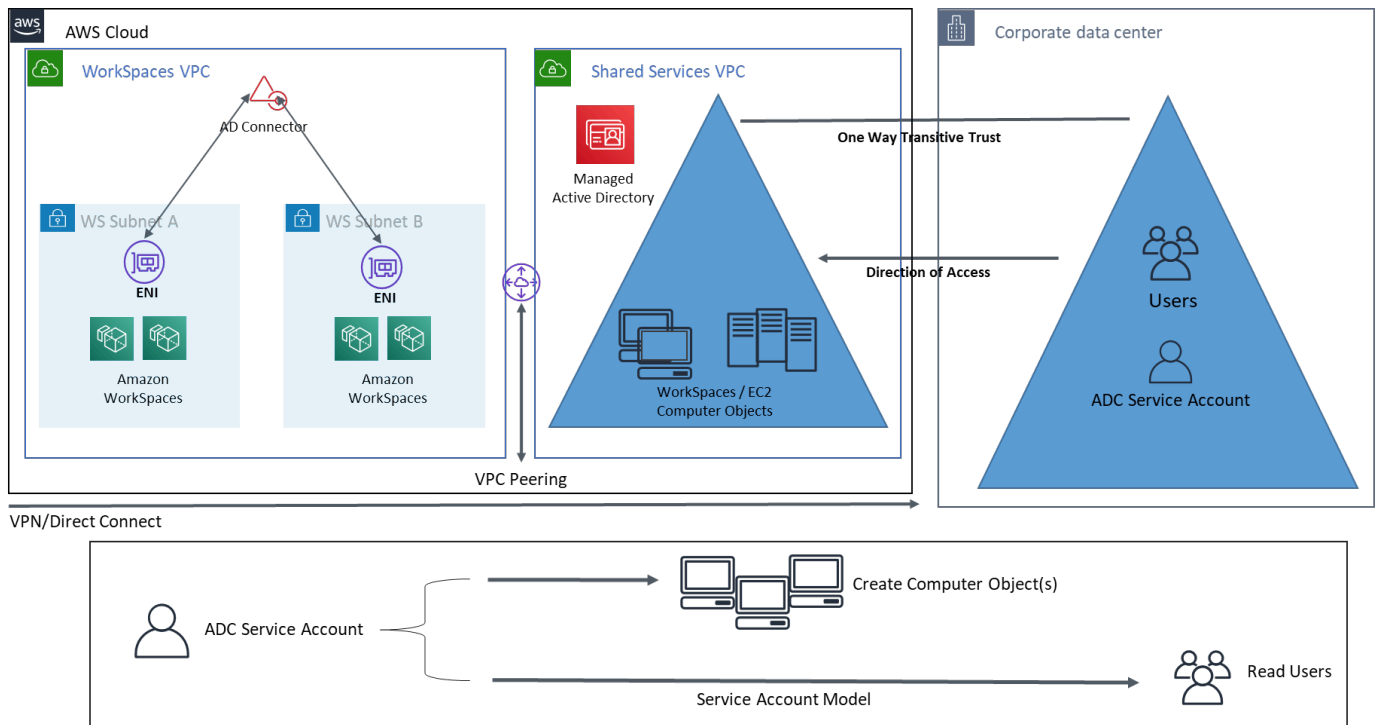


Figure 11: AWS Microsoft, shared services VPC, and a one-way trust to AD on-premises

This architecture uses the following components or constructs:

## AWS

- **Amazon VPC** — Creation of an Amazon VPC with at least two private subnets across two AZs — two for AD Connector and WorkSpaces.
- **DHCP options set** — Creation of an Amazon VPC DHCP options set. This allows a customer to define a specified domain name and DNS (Microsoft AD). For more information, refer to [DHCP options sets](#).
- **Optional: Amazon virtual private gateway** — Enable communication with a customer-owned network over an IPsec VPN tunnel (VPN) or AWS Direct Connect connection. Use for accessing on-premises back-end systems.

- **AWS Directory Service** — Microsoft AD deployed into a dedicated pair of VPC subnets (AD DS Managed Service), AD Connector.
- **Transit Gateway/VPC Peering** — Enable connectivity between Workspaces VPC and the Shared Services VPC.
- **Amazon EC2** — Customer “Optional” RADIUS Servers for MFA.
- **Amazon WorkSpaces** — WorkSpaces are deployed into the same private subnets as the AD Connector. For more information, refer to the [Active Directory: Sites and Services](#) section of this document.

## Customer

- **Network Connectivity** — Corporate VPN or AWS Direct Connect endpoints.
- **End user devices** — Corporate or BYOL end-user devices (such as Windows, Macs, iPads, Android tablets, zero clients, and Chromebooks) used to access the Amazon WorkSpaces service. Refer to [this list of client applications for supported devices and web browsers](#).

## Using multi-Region AWS Managed Active Directory with Amazon WorkSpaces

[AWS Directory Service for Microsoft Active Directory](#) (MAD) is a fully managed Microsoft Active Directory (AD) that can be paired with Amazon WorkSpaces. Customers choose AWS Managed Microsoft AD because it has built-in high availability, monitoring, and backups. AWS Managed Microsoft AD Enterprise edition adds the ability to configure [Multi-Region Replication](#). This feature automatically configures inter-region networking connectivity, deploys domain controllers, and replicates all the Active Directory data across multiple regions, ensuring that Windows and Linux workloads residing in those regions can connect to and use AWS MAD with low latency and high performance. Replicated MAD regions cannot be [directly registered with WorkSpaces](#), however a replicated MAD directory can be registered with WorkSpaces by configuring an AD Connector (ADC) to point to your replicated Domain Controllers.

The best practice when deploying AD Connectors with MAD is to create an AD Connector for each business unit within your WorkSpaces environment. This will allow you to align each business unit with a specific Organizational Unit within Active Directory. You can then assign AD Group Policy Objects at the Organization Unit level that directly align with the business unit in question.

## Architecture

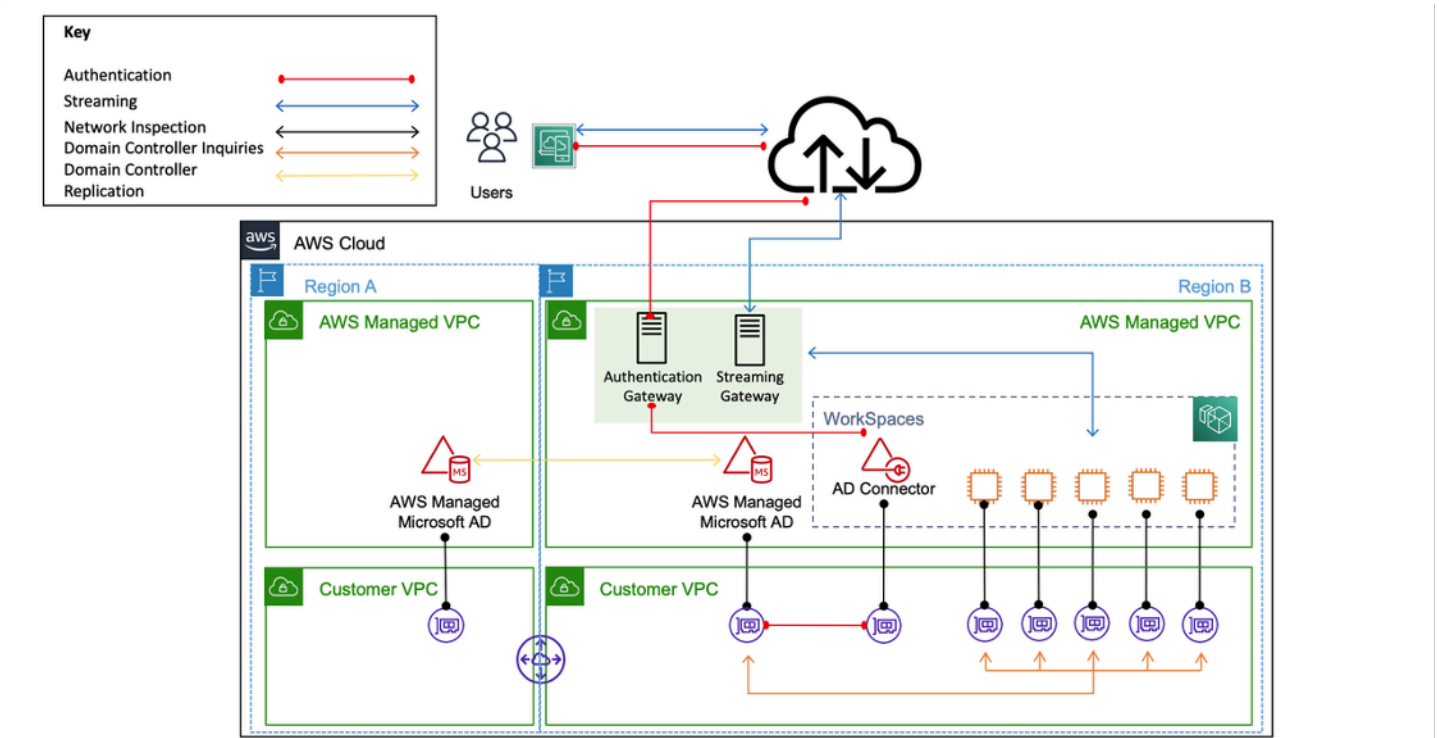


Figure 12: Sample architecture for registering a replicated MAD region to a WorkSpace

## Implementation

To register your replicated MAD region to WorkSpaces, you will need to create an AD Connector pointed to your MAD Domain Controller IPs. You can find your MAD Domain Controller IP addresses by going to the [AWS Directory Service console](#) navigation pane, selecting Directories and then choosing the correct directory ID. To create these AD Connectors, follow this [guide](#). Once they are created, you can [register them for WorkSpaces](#). Before you deploy WorkSpaces in your new region, ensure you have updated your VPCs [DHCP options set](#).

## Design considerations

A functional AD DS deployment in the AWS Cloud requires a good understanding of both Active Directory concepts and specific AWS services. This section discusses key design considerations when deploying AD DS for Amazon WorkSpaces, VPC best practices for AWS Directory Service, DHCP and DNS requirements, AD Connector specifics, and AD sites and services.

### VPC design

As previously discussed in the [Network Considerations](#) section of this document and documented earlier for scenarios 2 and 3, customers should deploy AD DS in the AWS Cloud into a dedicated pair of private subnets, across two AZs, and separated from AD Connector or WorkSpaces subnets. This construct provides highly available, low latency access to AD DS services for WorkSpaces, while maintaining standard best practices of separation of roles or functions within the Amazon VPC.

The following figure shows the separation of AD DS and AD Connector into dedicated private subnets (scenario 3). In this example all services reside in the same Amazon VPC.

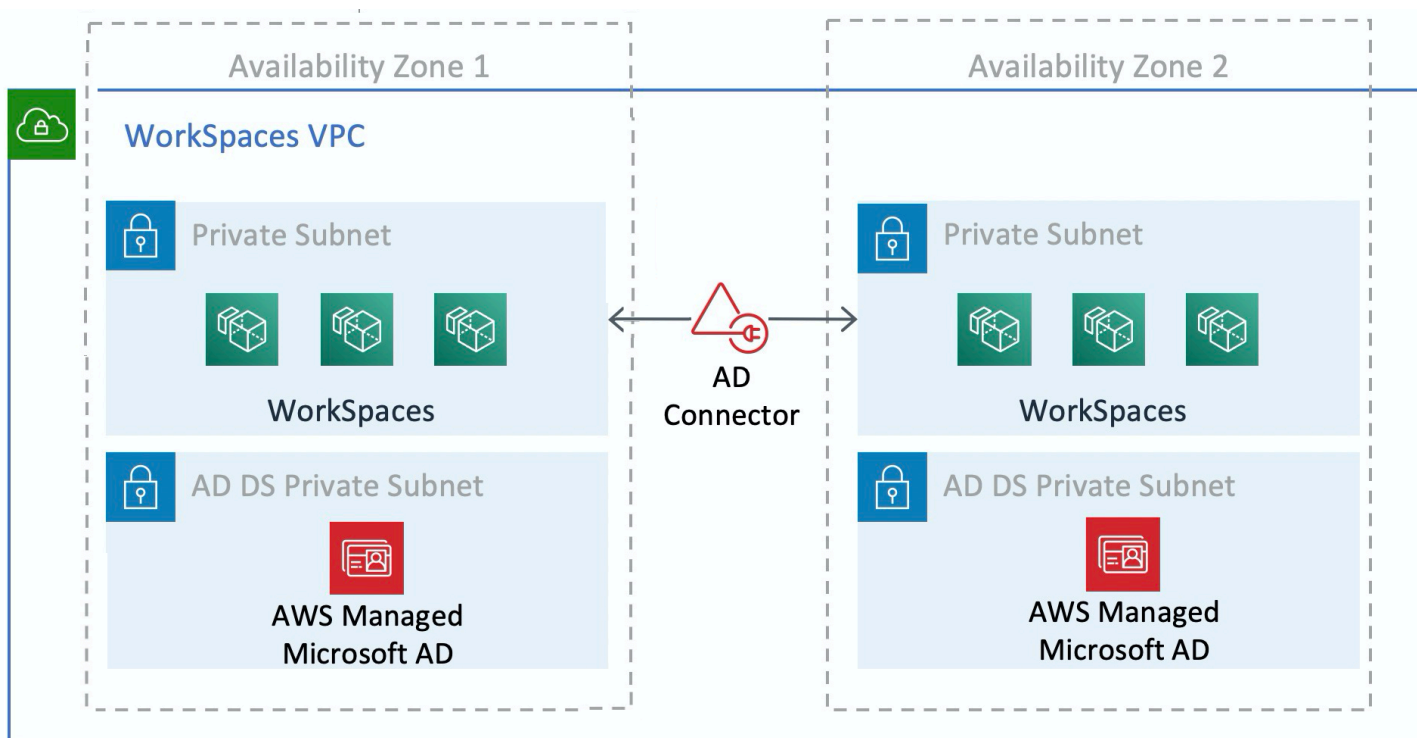


Figure 13: AD DS network separation

The following figure shows a design similar to scenario 1; however, in this scenario the on-premises portion resides in a dedicated Amazon VPC.

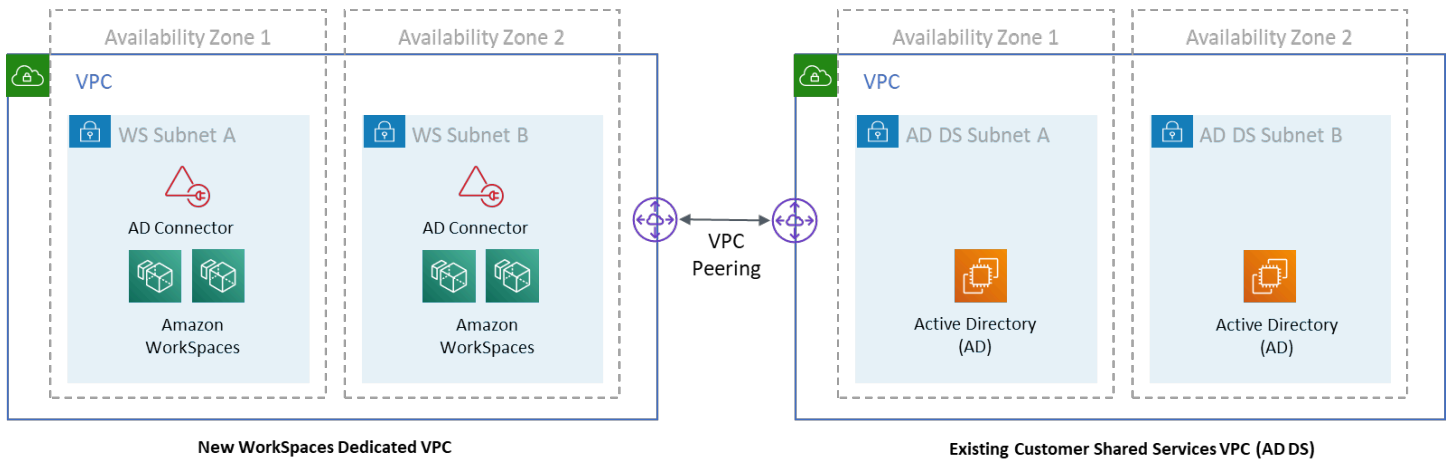


Figure 14: Dedicated WorkSpaces VPC

**Note**

For customers who have an existing AWS deployment where AD DS is being used, it’s recommended that they locate their WorkSpaces in a dedicated VPC, and use VPC peering for AD DS communications.

In addition to the creation of dedicated private subnets for AD DS, domain controllers and member servers require several Security Group rules to allow traffic for services, such as AD DS replication, user authentication, Windows Time services, and distributed file system (DFS).

**Note**

Best practice is to restrict the required security group rules to the WorkSpaces private subnets and, in the case of scenario 2, allow for bidirectional AD DS communications on-premises to and from the AWS Cloud, as shown in the following table.

Table 1 — Bidirectional AD DS communications to and from the AWS Cloud

| Protocol | Port                                    | Use  | Destination   |
|----------|---|--|---|
| TCP      | 53, 88, 135, 139, 389,<br>445, 464, 636 | Auth (primary)                                       | Active Directory<br>(private data center<br>or Amazon EC2) *  |
| TCP      | 49152 – 65535                           | RPC High Ports                                       | Active Directory<br>(private data center<br>or Amazon EC2) ** |
| TCP      | 3268-3269                               | Trusts   | Active Directory<br>(private data center<br>or Amazon EC2) *  |
| TCP      | 9389                                    | Remote Microsoft<br>Windows PowerShell<br>(optional) | Active Directory<br>(private data center<br>or Amazon EC2) *  |
| UDP      | 53, 88, 123, 137, 138,<br>389, 445, 464 | Auth (primary)                                       | Active Directory<br>(private data center<br>or Amazon EC2) *  |
| UDP      | 1812                                    | Auth (MFA) (optional)                                | RADIUS (private data<br>center or Amazon<br>EC2) *            |

For more information, refer to [Active Directory and Active Directory Domain Services Port Requirements](#) and [Service overview and network port requirements for Windows](#)

For step-by-step guidance for implementing rules, refer to [Adding Rules to a Security Group](#) in the *Amazon Elastic Compute Cloud User Guide*.

## VPC design: DHCP and DNS

With an Amazon VPC, Dynamic Host Configuration Protocol (DHCP) services are provided by default for your instances. By default, every VPC provides an internal Domain Name System (DNS) server that is accessible via the Classless Inter-Domain Routing (CIDR) +2 address space, and is assigned to all instances via a default DHCP options set.

DHCP options sets are used within an Amazon VPC to define scope options, such as the domain name or the name servers that should be handed to customer instances via DHCP. Correct functionality of Windows services within a customer VPC depends on this DHCP scope option. In each of the scenarios defined earlier, customers create and assign their own scope that defines the domain name and name servers. This ensures that domain-joined Windows instances or WorkSpaces are configured to use the AD DNS.

The following table is an example of a custom set of DHCP scope options that must be created for Amazon WorkSpaces and AWS Directory Services to function correctly.

Table 2 — Custom set of DHCP scope options

| Parameter            | Value  |
|----------------------|--|
| Name tag             | Creates a tag with key = name and value set to a specific string<br><br>Example: example.com         |
| Domain name          | example.com  |
| Domain name servers  | DNS server address, separated by commas<br><br>Example: 192.0.2.10, 192.0.2.21                       |
| NTP servers          | Leave this field blank   |
| NetBIOS name servers | Enter the same comma separated IPs as per domain name servers<br><br>Example: 192.0.2.10, 192.0.2.21 |
| NetBIOS node type    | 2  |

For details on creating a custom DHCP option set and associating it with an Amazon VPC, refer to [Working with DHCP options sets](#) in the *Amazon Virtual Private Cloud User Guide*.

In scenario 1, the DHCP scope would be the on-premises DNS or AD DS. However, in scenarios 2 or 3, this would be the locally deployed directory service (AD DS on Amazon EC2 or AWS Directory

Services: Microsoft AD). It's recommended that each domain controller that resides in the AWS Cloud be a global catalog and Directory-Integrated DNS server.

## Active Directory: sites and services

For [Scenario 2](#), sites and services are critical components for the correct function of AD DS. Site topology controls AD replication between domain controllers within the same site and across site boundaries. In scenario 2, at least two sites are present: on-premises, and the Amazon WorkSpaces in the cloud.

Defining the correct site topology ensures client affinity, meaning that clients (in this case, WorkSpaces) use their preferred local domain controller.

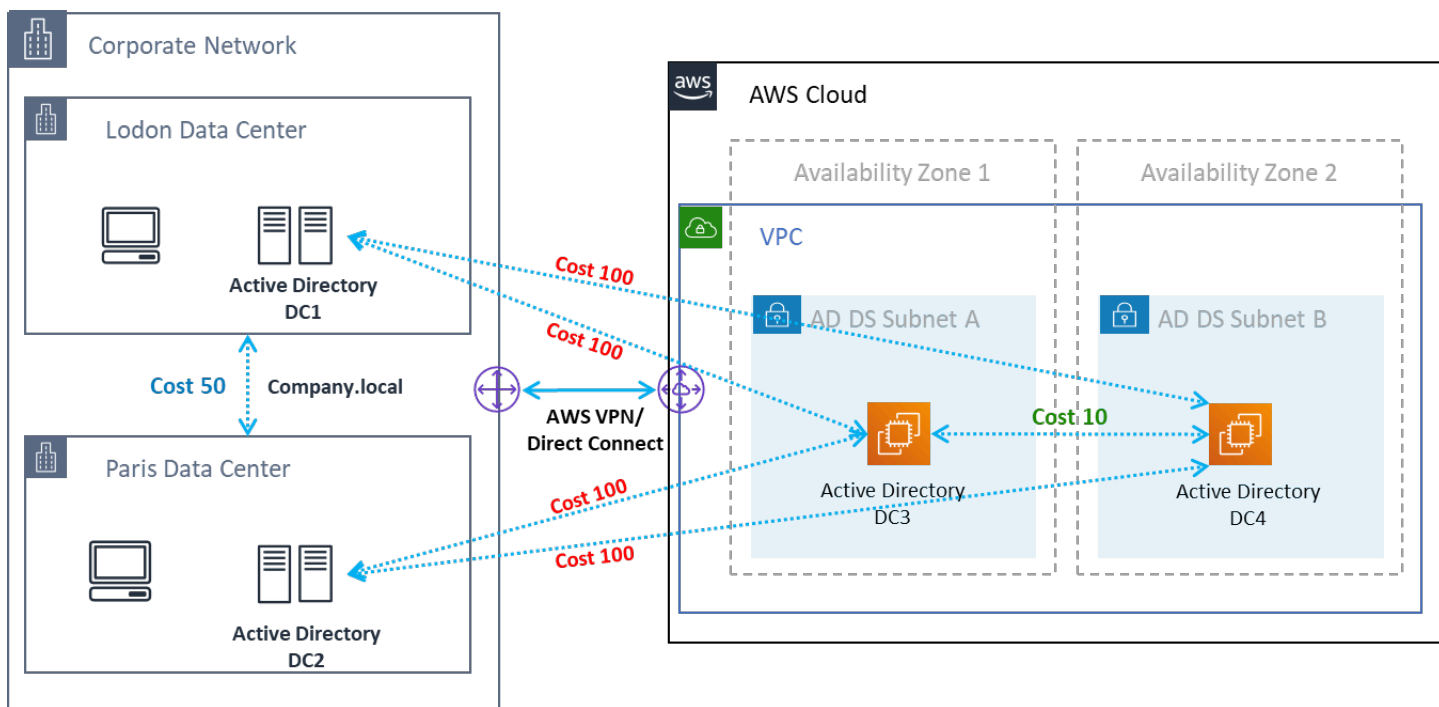


Figure 15: Active Directory sites and services: client affinity

**Best practice:** Define high cost for site links between on-premises AD DS and the AWS Cloud. The following figure is an example of what costs to assign to the site links (cost 100) to ensure site-independent client affinity.

These associations help ensure that traffic — such as AD DS replication, and client authentication — uses the most efficient path to a domain controller. In the case of scenarios 2 and 3, this helps ensure lower latency and cross-link traffic.

## Protocol

Amazon WorkSpaces Streaming Protocol (WSP) is a cloud-native streaming protocol that enables a consistent user experience across global distances and unreliable networks. WSP decouples the protocol from the WorkSpaces by offloading metric analysis, encoding, codec usage and selection. WSP uses port TCP/UDP 4195. When deciding whether or not use the WSP protocol, there are several key questions that should be answered prior to deployment. Please refer to the decision matrix below:

| Question  | WSP | PCoIP |
|---|-----|-------|
| Will the identified WorkSpaces users need bi-directional audio / video? | •   |       |
| Will zero clients be used as the remote endpoint (local device)?        |     | •     |
| Will Windows or macOS be used for remote endpoint?                      | •   | •     |
| Will Ubuntu 18.04 be used for remote endpoint?                          |     | •     |
| Will the users access Amazon WorkSpaces via web access?                 |     | •     |
| Is pre-session or in-session smartcard support (PIC/CAC) needed?        | •   |       |
| Will WorkSpaces be used in China (Ningxia) Region?                      |     | •     |
| Will smart card pre-authentication or in-session support be required?   | •   |       |

| Question  | WSP   | PCoIP |
|---|---|-------|
| Are the end-users using unreliable, high-latency, or low-bandwidth connections? | <ul style="list-style-type: none"> <li>•</li> </ul> |       |

The previous questions are critical to determine the protocol that should be used. Additional information on the recommended protocol use cases can be reviewed [here](#). The protocol used can also be changed at a later time using the Amazon WorkSpaces Migrate feature. More information on the use of this feature can be reviewed [here](#).

When deploying WorkSpaces using WSP, the [WSP Gateways](#) should be added to an allow list to ensure connectivity to the service. Additionally, users connecting to a WorkSpaces using WSP, the round-trip time (RTT) should be under 250ms for best performance. Connections with an RTT between 250ms and 400ms will be degraded. If the user's connection is consistently degraded, it's recommended to deploy an Amazon WorkSpaces in a [service-supported region](#) closest to the end-user, if possible.

## Multi-Factor Authentication (MFA)

Implementing MFA requires Amazon WorkSpaces to be configured with either an Active Directory Connector (AD Connector) or AWS Managed Microsoft AD (MAD) as its Directory Service, and have a RADIUS server that is network accessible by the Directory Service. Simple Active Directory does not support MFA.

Refer to the previous section, covering Active Directory and Directory Services Deployment considerations for AD, and RADIUS Design Options within each scenario.

### MFA – Two-Factor Authentication

After MFA is enabled, users are required to provide their Username, Password, and MFA Code to the WorkSpaces client for authentication to their respective WorkSpaces desktops.

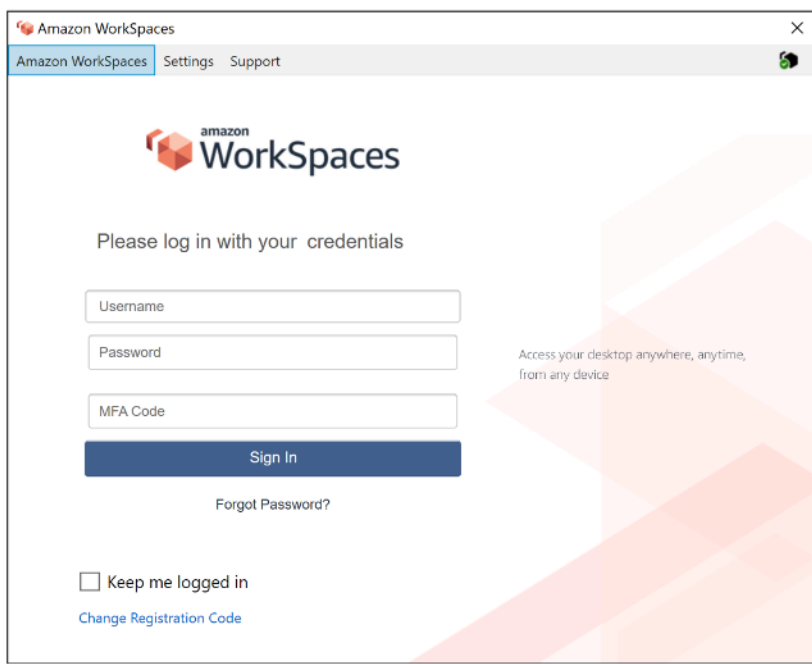


Figure 16: WorkSpaces client with MFA enabled

#### **Note**

The AWS Directory Service does not support selective *per user* or contextual MFA: this is a global setting per Directory. If selective “per user” MFA is required, users must be separated by an AD Connector, which can point back to the same source Active Directory.

WorkSpaces MFA requires one or more RADIUS servers. Typically, these are existing solutions you may already have deployed, for example RSA or Gemalto. Alternatively, RADIUS servers can be deployed within your VPC on EC2 Instances (refer to the AD DS Deployment Scenarios section of this document for architectural options). If you are deploying a new RADIUS solution, several implementations exist, such as [FreeRADIUS](#), along with SaaS offerings such as [Duo Security](#) or [Okta MFA](#).

It is best practice to leverage multiple RADIUS servers to ensure that your solution is resilient to failures. When configuring your Directory Service for MFA you are able to enter multiple IP addresses by separating them with a comma (e.g., 192.0.0.0,192.0.0.12). The Directory Services MFA feature will try the first IP address specified and will move to the second IP address in the event network connectivity cannot be established with the first. The configuration of RADIUS for a Highly Available architecture is unique to each solution set, however the over-arching recommendation is to place the underlying instances for your RADIUS capability in different

Availability Zones. One configuration example is [Duo Security](#) and for Okta MFA you are able to deploy multiple Okta RADIUS server agents in the same manner.

For detailed steps to enable your AWS Directory Service for MFA, refer to [AD Connector](#) and [AWS Managed Microsoft AD](#).

## Disaster Recovery / Business Continuity

### WorkSpaces Cross-Region Redirection

Amazon WorkSpaces is a regional service that provides remote desktop access to customers. Depending on business continuity and disaster recovery requirements (BC/DR), some customers require seamless failover to another region where the WorkSpaces service is available. This BC/DR requirement can be accomplished using the WorkSpaces cross-region redirection option. It allows customers to use a fully qualified domain name (FQDN) as their WorkSpaces registration code.

An important consideration is to determine at what point a redirection to a failover region should occur. The criteria for this decision should be based on your company policy, but should include the Recovery Time Objective (RTO) and the Recovery Point Objective (RPO). A Well-Architected WorkSpaces architecture design should include the potential for service failure. The time tolerance for normal business operation recovery will also factor into the decision.

When your end users log in to WorkSpaces with a FQDN as their WorkSpaces registration code, a DNS TXT record is resolved containing a connection identifier determining the registered directory the user will be directed to. The logon landing page of the WorkSpaces client will then be presented based on the registered directory associated with the connection identifier returned. This allows administrators to direct their end users to different WorkSpaces directories based on your DNS policies for the FQDN. This option can be used with public or private DNS zones, assuming the private zones can be resolved from the client machine. Cross-region redirection can be manual or automated. Both of these failovers can be achieved by changing the TXT record containing the connection identifier to be pointed at the desired directory.

While you develop your BC/DR strategy, it is important to consider the user data, since the WorkSpaces cross-region redirection option does not synchronize any user data, nor does it synchronize your WorkSpaces images. Your WorkSpaces deployments in different AWS Regions are independent entities. You will, therefore, have to take additional measures to ensure that your WorkSpaces users can access their data when a redirection to a secondary region occurs. There are many options available for user data replication such as WorkSpaces, Windows FSx (DFS

Share), or third party utilities to synchronize data volumes between regions. Likewise, you'll have to ensure that your secondary region has access to the required WorkSpaces images, for example, by copying the images across regions. For more information, see [Cross-Region Redirection for Amazon WorkSpaces](#) in the *Amazon WorkSpaces Administration Guide*, and the example in the diagram.

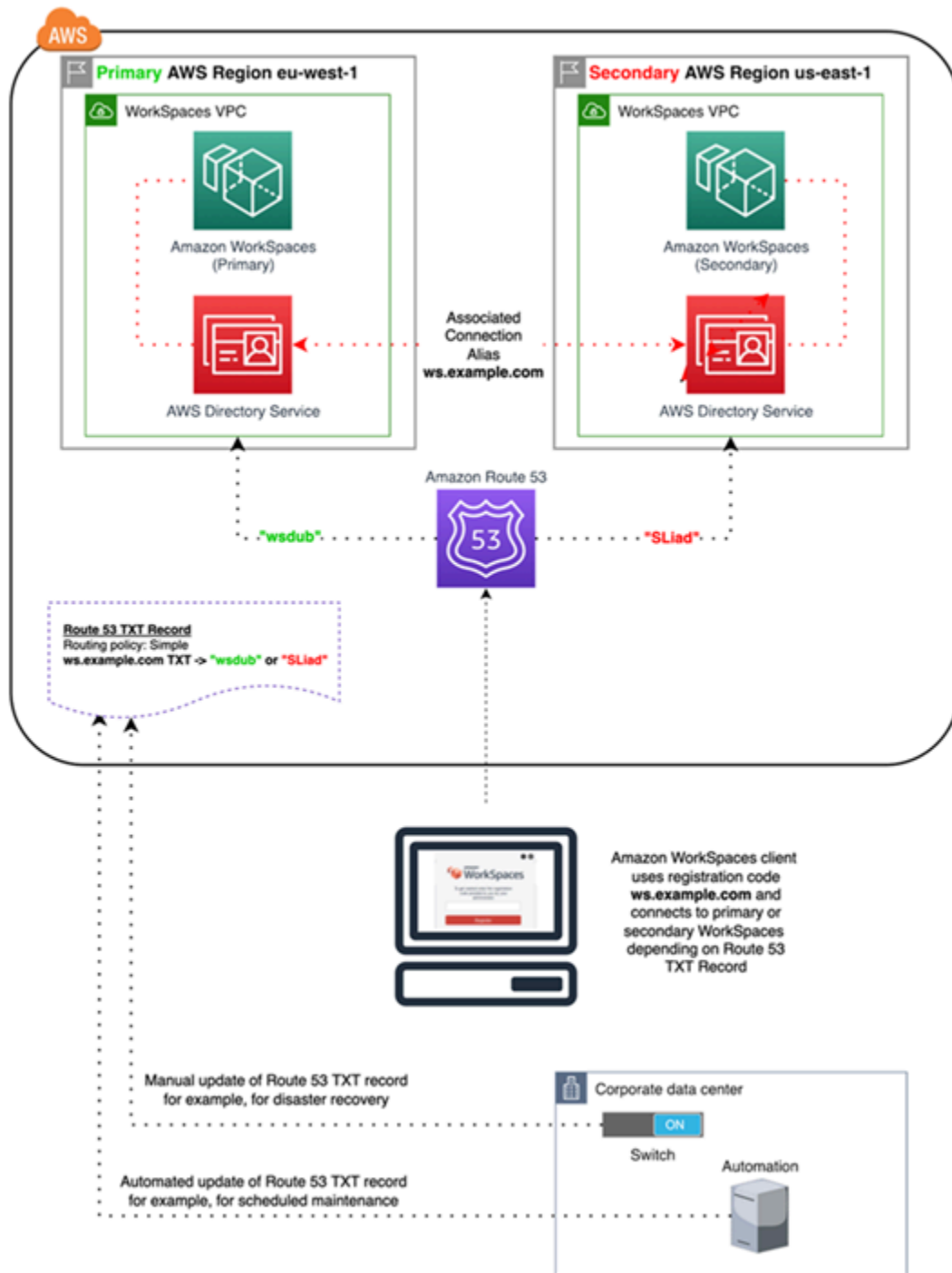


Figure 17: WorkSpaces cross-Region redirection example with Amazon Route 53

# WorkSpaces Interface VPC Endpoint (AWS PrivateLink) – API Calls

[Amazon WorkSpaces public APIs](#) are supported on [AWS PrivateLink](#). AWS PrivateLink increases the security of data shared with cloud-based applications by reducing the exposure of data to the public internet. WorkSpaces API traffic can be secured inside a VPC by using an [interface endpoint](#), which is an elastic network interface with a private IP address from the IP address range of your subnet that serves as an entry point for traffic destined to a supported service. This enables you to privately access WorkSpaces API services by using private IP addresses.

Using PrivateLink with WorkSpaces Public APIs also enables you to securely expose REST APIs to resources only within your VPC or to those connected to your data centers via AWS Direct Connect.

You can restrict access to selected Amazon VPCs and VPC Endpoints, and enable cross account access using resource-specific policies.

Ensure that the security group that is associated with the endpoint network interface allows communication between the endpoint network interface and the resources in your VPC that communicate with the service. If the security group restricts inbound HTTPS traffic (port 443) from resources in the VPC, you might not be able to send traffic through the endpoint network interface. An interface endpoint supports TCP traffic only.

- Endpoints support IPv4 traffic only.
- When you create an endpoint, you can attach an endpoint policy to it that controls access to the service to which you are connecting.
- You have a quota on the number of endpoints you can create per VPC.
- Endpoints are supported within the same region only. You cannot create an endpoint between a VPC and a service in a different region.

**Create Notification to receive alerts on interface endpoint events** — You can create a notification to receive alerts for specific events that occur on your interface endpoint. To create a notification, you must associate an [Amazon SNS topic](#) with the notification. You can subscribe to the SNS topic to receive an email notification when an endpoint event occurs.

**Create a VPC Endpoint Policy for Amazon WorkSpaces** — You can create a policy for Amazon VPC endpoints for Amazon WorkSpaces to specify the following:

- The principal that can perform actions.

- The actions that can be performed.
- The resources on which actions can be performed.

**Connect Your Private Network to Your VPC** — To call the Amazon WorkSpaces API through your VPC, you have to connect from an instance that is inside the VPC, or connect your private network to your VPC by using an Amazon Virtual Private Network (VPN) or AWS Direct Connect. For information about Amazon VPN, refer to [VPN connections](#) in the *Amazon Virtual Private Cloud User Guide*. For information about AWS Direct Connect, refer to [Creating a connection](#) in the *AWS Direct Connect User Guide*.

For more information about using Amazon WorkSpaces API through a VPC interface endpoint, refer to [Infrastructure Security in Amazon WorkSpaces](#).

## Smart card support

Smart card support is available for both Microsoft Windows and Amazon Linux WorkSpaces. Smart card support through Common Access Card (CAC) and Personal Identity Verification (PIV) are exclusively available through Amazon WorkSpaces using WorkSpaces Streaming Protocol (WSP). Smart card support on WSP WorkSpaces offers an increased security posture for authenticating users on organizationally approved connecting endpoints with specific hardware in the form of smart card readers. It is important to first become familiar with the [scope of support available for smart cards](#), and determining how smart cards would function in existing and future WorkSpaces deployments.

It is a best practice to determine which type of smart card support is required, pre-session authentication or in-session authentication. Pre-session authentication is only available at the time of this writing in [AWS GovCloud \(US-West\), US East \(Northern Virginia\), US West \(Oregon\), Europe \(Ireland\), Asia Pacific \(Tokyo\), and Asia Pacific \(Sydney\)](#). In-session smart card authentication is generally available with some considerations, such as:

- Does your organization possess smart card infrastructure integrated with your Windows Active Directory?
- Is your Online Certificate Status Protocol (OCSP) Responder public Internet accessible?
- Are user certificates issued with User Principal Name (UPN) in the Subject Alternative Name (SAN) field?
- More considerations are detailed for In-session and Pre-session sections.

Smart card support is enabled through Group Policy. It is a best practice to add the [Amazon WorkSpaces Group Policy administrative template for WSP to the Central Store](#) of your Active Directory Domain used by Amazon WorkSpaces Directory(ies). When applying this policy to an existing Amazon WorkSpaces deployment, all WorkSpaces will require the group policy update and a reboot for the change to take effect for all users as it is a computer-based policy.

## Root CA

The nature of the portability of Amazon WorkSpaces client and user necessitates the requirement to remotely deliver third-party root CA certificate to the trusted root certificate store of each device users use to connect to their Amazon WorkSpaces. AD Domain Controllers and user devices with smart cards must trust the root CAs. Review the [guidelines provided by Microsoft](#) for enabling third-party CAs for more information on the exact requirements.

In AD domain-joined environments, these devices meet this requirement through Group Policy distributing root CA certificates. In scenarios where Amazon WorkSpaces Client is used from non-domain-joined devices, an alternate delivery method for the third-party root CAs must be determined, such as [Intune](#).

## In-session

In-session authentication simplifies and secures application authentication after Amazon WorkSpaces user sessions have already started. As mentioned previously, the default behavior for Amazon WorkSpaces disables smart cards and must be enabled through Group Policy. From an Amazon WorkSpaces administration perspective, configuration is specifically required for applications that pass-through authentication (such as web browsers). No changes are required for AD Connectors and Directory(ies).

Most common applications requiring in-session authentication support are through web browsers such as Mozilla Firefox and Google Chrome. Mozilla Firefox requires [limited configuration for in-session smart card support](#). [Amazon Linux WSP WorkSpaces requires additional configuration](#) for in-session smart card support for both Mozilla Firefox and Google Chrome.

It is a best practice to ensure the root CAs are loaded in the user's Personal certificate store before troubleshooting, as the Amazon WorkSpaces Client may not have permissions to the local computer. Additionally, use [OpenSC](#) to identify smart card devices when troubleshooting any suspected in-session authentication issues with smart cards. Lastly, an Online Certificate

Status Protocol (OCSP) Responder is recommended to improve security posture of application authentication through a certificate revocation check.

## Pre-session

Support for pre-session authentication requires Windows WorkSpaces Client version 3.1.1 and later, or macOS WorkSpaces client version 3.1.5 and later. Pre-session authentication with smart cards is fundamentally different than standard authentication, requiring the user to authenticate through a combination of both inserting the smart card and entering a PIN code. With this authentication type, the duration of user's sessions is bounded by the lifetime of the Kerberos ticket. A full installation guide can be found [here](#).

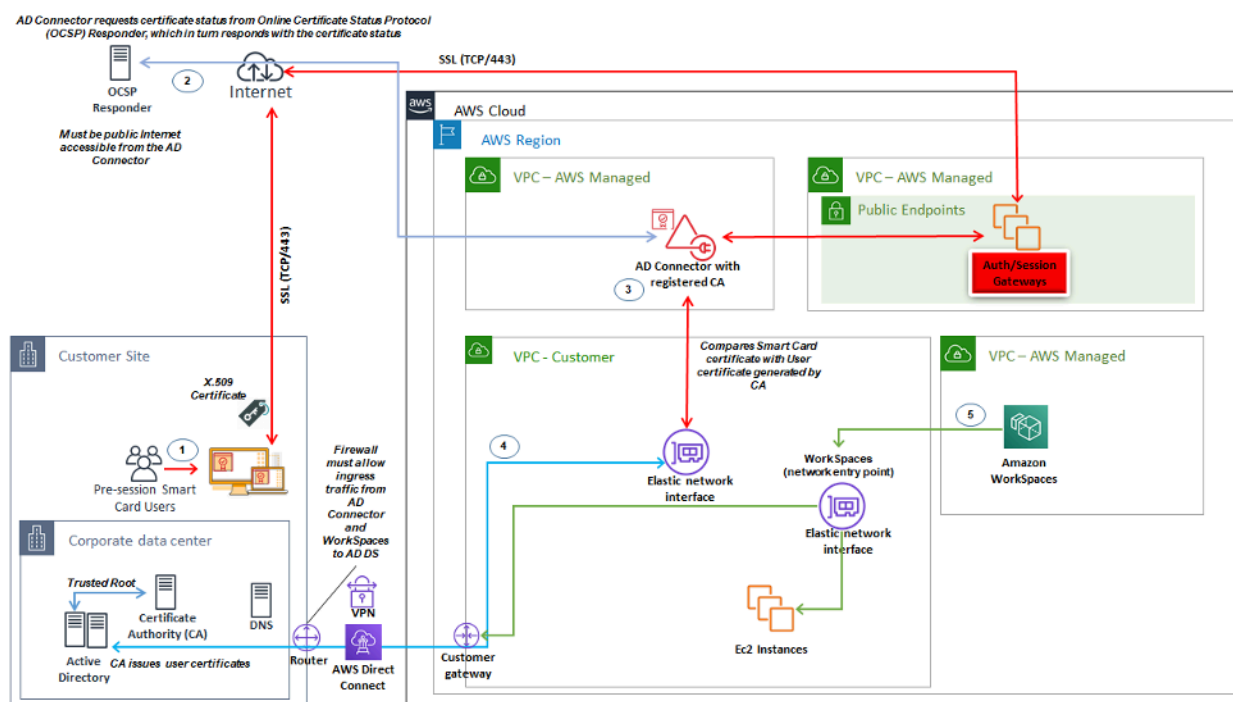


Figure 18: Overview of pre-session authentication

1. User opens Amazon WorkSpaces Client, inserts Smart Card, and enters their PIN. The PIN is used by Amazon WorkSpaces Client to decrypt the X.509 Certificate, which is the proxied to the AD Connector through the Authentication Gateway.
2. AD Connector validates the X.509 Certificate against the publicly accessible OCSP Responder URL specified in the Directory Settings to ensure the certificate has not been revoked.
3. If the certificate is valid, the Amazon WorkSpaces Client continues the authentication process by prompting the user to enter their PIN a second time to decrypt the X.509 Certificate and proxy

- to the AD Connector, where it is then matched with the AD Connector's root and intermediary certificates for validation.
4. Once the validation of the certificate is successfully matched, Active Directory is used by the AD Connector to authenticate the user and a Kerberos ticket is created.
  5. Kerberos ticket is passed to the user's Amazon WorkSpace to authenticate and begin the WSP session.

OCSP Responder must be publicly accessible as connection is performed through the AWS Managed network and not the Customer Managed network, therefore there is no routing to private networks in this step.

Entering the users name is not required as the user certificates presented to AD Connector includes the userPrincipalName (UPN) of the user in the subjectAltName (SAN) field of the certificate. It is a best practice to automate all users that require pre-session authentication with Smartcards have their AD user objects updated to authenticate with anticipated UPN in the certificate using PowerShell, rather than perform this individually in Microsoft Management Consoles.

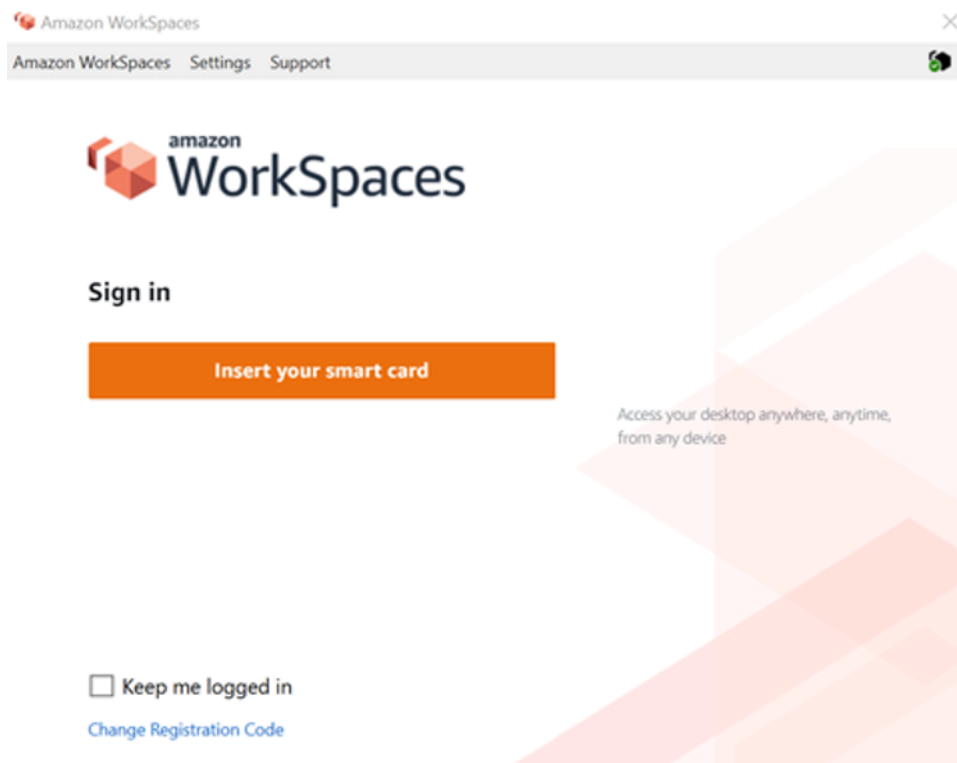


Figure 19: WorkSpaces sign in console

## Client deployment

The Amazon WorkSpaces Client (version 3.X+) uses standardized configuration files which can be leveraged by administrators to preconfigure their user's WorkSpaces Client. The path for the two main configuration files can be found at:

| OS                   | Configuration File Path   |
|----------------------|---|
| Windows              | C:\Users\USERNAME\AppData\Local\Amazon Web Services\Amazon WorkSpaces             |
| macOS                | /Users/USERNAME/Library/Application Support/Amazon Web Services/Amazon WorkSpaces |
| Linux (Ubuntu 18.04) | /home/ubuntu/.local/share/Amazon Web Services/Amazon WorkSpaces/                  |

Within these paths, you will find the two configuration files. The first configuration file is `UserSettings.json`, which will set things like current registration, proxy configuration, logging level, and the ability to save the registration list. The second configuration file is `RegistrationList.json`. This file will contain all of the WorkSpaces directory information for the client to use to map to the correct WorkSpaces directory. Preconfiguring the `RegistrationList.json` will populate all of the registration codes within the client for the user.

### Note

If your users are running WorkSpaces Client version 2.5.11, `proxy.cfg` will be used for Client proxy settings and `client_settings.ini` will set log level as well as the ability to save the registration list. The default proxy setting will use what is set within the OS.

Since these files are standardized, Administrators can download the [WorkSpaces Client](#), set all of the applicable settings, and then push out the same configuration files to all of the end users. For the settings to take effect, the client must be started after the new configurations are set. If you change the configuration while the client is running, none of the changes will be set within the client.

The last setting that can be set for WorkSpaces users is Windows Client auto update. This is not controlled via configuration files but the Windows Registry instead. When a new version of the client comes out, you can create a registry key to skip that version. This can be set by creating a string registry entry named `SkipThisVersion` with a value of the full version number in the path below: `Computer\HKEY_CURRENT_USER\Software\Amazon Web Services, LLC\Amazon WorkSpaces\WinSparkle`. This option is also available for macOS; however, the configuration is within a plist file which requires special software to edit. If you would still like to perform this action, it can be done by adding a `SUSkippedVersion` entry within the `com.amazon.workspaces` domain located at: `/Users/USERNAME/Library/Preferences`

## Amazon WorkSpaces endpoint selection

### Choosing an Endpoint for your WorkSpaces

Amazon WorkSpaces provides support for multiple endpoint devices, from Windows desktops, to iPads, and Chromebooks. You can download the available Amazon WorkSpaces clients from the [Amazon Workspaces website](#). Choosing the right endpoint for your users is an important decision. If your users require the use of bi-directional Audio/Video and will be utilizing the WorkSpaces Streaming Protocol, they must use the Windows or macOS client. For all clients ensure that the IP addresses and ports listed in [IP Address and Port Requirements for Amazon WorkSpaces](#) have been explicitly configured to ensure the client can connect to the service. Here are some additional considerations to assist you in choosing an endpoint device:

- **Windows** — To utilize the Windows Amazon WorkSpaces client, the 4.x client must run the requires 64-bit Microsoft Windows 8.1, Windows 10 desktop. Users can install the client for just their user profile without administrative privileges on the local machine. System administrators can deploy the client to managed endpoints with Group Policy, Microsoft Endpoint Manager Configuration Manager (MEMCM), or other application deployment tools used in an environment. The Windows client support a maximum of four displays and a maximum resolution of 3840x2160.
- **macOS** — To deploy the latest macOS Amazon WorkSpaces client, macOS devices must run macOS 10.12 (Sierra) or later. You can deploy an older version of the WorkSpaces client to connect to PCoIP WorkSpaces if the endpoint is running OSX 10.8.1 or later. The macOS client supports up to two 4K resolution monitors or four WUXGA (1920 x 1200) resolution monitors.
- **Linux** — The Amazon WorkSpaces Linux client requires 64-bit Ubuntu 18.04 (AMD64) to run. If your Linux endpoints do not run this OS version, the Linux client is not supported. Before you deploy Linux clients or provide users with their registration code, ensure that you [enable Linux](#)

[client access](#) at the WorkSpaces directory level, as this is disabled by default and users will not be able to connect from Linux clients until it is enabled. The Linux client supports up to two 4K resolution monitors or four WUXGA (1920 x 1200) resolution monitors.

- **iPad** — The Amazon WorkSpaces iPad client application supports PCoIP WorkSpaces. The iPads that are supported are the iPad2 or later with iOS 8.0 or later, iPad Retina with iOS 8.0 and later, iPad Mini with iOS 8.0 and later, and the iPad Pro with iOS 9.0 and later. Ensure the device the users will connect from meets those criteria. The iPad client application supports many different gestures. (Refer to [a full list of the supported gestures](#).) The Amazon WorkSpaces iPad client application also supports the Swiftpoint GT, ProPoint, and PadPoint mice. The Swiftpoint TRACPOINT, PenPoint and GoPoint mice are not supported.
- **Android / Chromebook** — When looking to deploy an Android device or Chromebook as the endpoint for your end users, there are a few considerations that must be taken into account. Ensure the WorkSpaces the users will be connecting to are PCoIP WorkSpaces, as this client only supports PCoIP WorkSpaces. This client only supports a single display. If users require multi-monitor support, utilize a different endpoint. If you want to deploy a Chromebook, ensure that the model you deploy supports installing Android applications. Full feature support is supported only on the Android client, and not the legacy Chromebook client. This typically is only a consideration for Chromebooks made prior to 2019. Android support is provided for both tablets and phones as long as the Android is running OS 4.4 and later. However, it is recommended that the Android device runs OS 9 or above to utilize the latest WorkSpace Android client. If your Chromebooks are running WorkSpaces client version 3.0.1 or above, your users can now take advantage of the self-service WorkSpaces features. Additionally, as an administrator, you can utilize trusted-device certificates to restrict WorkSpaces access to trusted devices with valid certificates.
- **Web Access** — Users can access their Windows WorkSpaces from any location using a web browser. This is ideal for users who must use a locked-down device or restrictive network. Instead of using a traditional remote access solution and installing the appropriate client application, users can visit the website to access their work resources. Users can utilize the WorkSpaces Web Access to connect to non-graphics-based Windows PCoIP WorkSpaces running Windows 10 or Windows Server 2016 with Desktop Experience. Users must connect using Chrome 53 or later, or Firefox 49 or later. For WSP based WorkSpaces, users can utilize the WorkSpaces Web Access to connect to non-graphics Windows based WorkSpaces. These users must connect using Microsoft Edge 91 or later or Google Chrome 91 or later. The minimum supported screen resolution is 960 x 720 with a maximum supported resolution of 2560 x 1600. Multiple monitors are not supported. For the best user experience, when possible, it's recommended that users use an OS version of the client.

- **PCoIP Zero Client** — You can deploy PCoIP zero clients to end users that have or will have PCoIP WorkSpaces assigned to them. The Tera2 zero client must have a firmware version of 6.0.0 or later to connect directly to the WorkSpace. To use multi-factor authentication with Amazon WorkSpaces, the Tera2 zero client device must run firmware version 6.0.0 or later. Support and troubleshooting of the zero-client hardware should be done with the manufacturer.
- **IGEL OS** — You can utilize IGEL OS on endpoint devices to connect to PCoIP based WorkSpaces as long as the firmware version is 11.04.280 or above. The supported features match that of the existing Linux client today. Before you deploy IGEL OS clients or provide users with their registration code, ensure you [enable](#) Linux client access at the WorkSpaces directory level as this is disabled by default and users will not be able to connect from IGEL OS clients until it is enabled. The IGEL OS client supports up to two 4K resolution monitors or four WUXGA (1920x1200) resolution monitors.

## Web access client

Designed for locked-down devices, the [Web Access client](#) delivers access to Amazon WorkSpaces without the need for deploying client software. The Web Access client is recommended only in settings where the Amazon WorkSpaces are Windows Operating System (OS) and are used for limited user workflows, such as a kiosk environment. Most use cases benefit from the feature set available from the Amazon WorkSpaces client. The Web Access client is only recommended in specific use cases where devices and network restrictions require an alternative connection method.

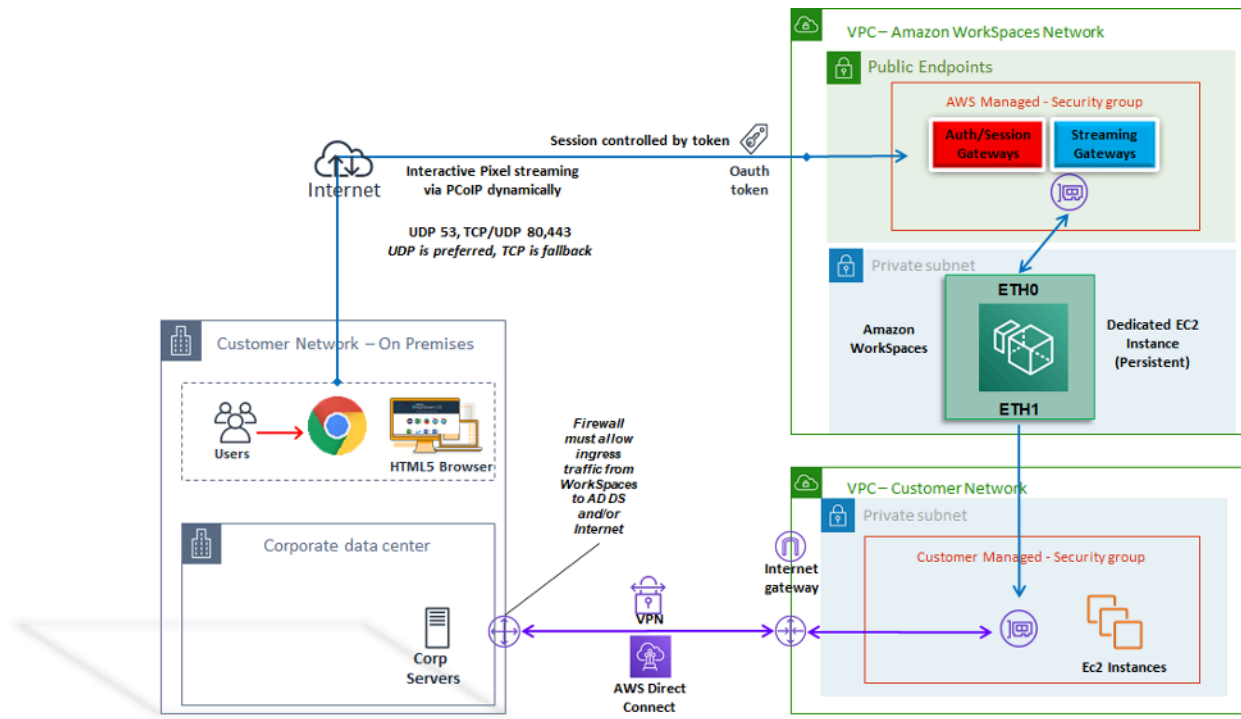


Figure 20: Web access client architecture

As shown in the diagram, The Web Access client has different [network requirements](#) to stream the session to users. Web Access is available for Windows WorkSpaces using either the PCoIP or WSP protocol. DNS and HTTP/HTTPS are required for authentication and registration with the WorkSpaces gateways. For WorkSpaces using the WSP protocol, direct connection of UDP/TCP 4195 is required to be opened to the WSP Gateway IP address ranges. Streaming traffic is not allocated to a fixed port as it is with the full Amazon WorkSpaces client; instead, it is dynamic allocated. UDP is preferable for streaming traffic; however, the web browser will fall back to TCP when UDP is restricted. In environments where TCP/UDP port 4172 is blocked and cannot be unblocked due to organizational restrictions, the Web Access client provides an alternative connection method for users.

By default, the Web Access client is disabled at the Directory level. To enable users to access their Amazon WorkSpaces through a web browser, either use the AWS Management Console to update the [Directory settings](#) or programmatically use the [WorkspaceAccessProperties API](#) to modify DeviceTypeWeb to Allow. Additionally, the administrator must ensure [Group Policy settings](#) do not conflict with login requirements.

# Amazon WorkSpaces tags

Tags enable you to associate metadata with AWS resources. Tags can be used with Amazon WorkSpaces to registered directories, bundles, IP Access Control Groups, or images. Tags assist with cost allocation to internal cost centers. Before using tags with Amazon WorkSpaces, refer to the [Tagging Best Practices](#) whitepaper.

## Tag restrictions

- Maximum number of tags per resource—50
- Maximum key length—127 Unicode characters
- Maximum value length—255 Unicode characters
- Tag keys and values are case-sensitive. Allowed characters are letters, spaces, and numbers representable in UTF-8, plus the following special characters: + - = . \_ : / @. Do not use leading or trailing spaces.
- Do not use the aws: or aws:workspaces: prefixes in your tag names or values because they are reserved for AWS use. You can't edit or delete tag names or values with these prefixes.

## Resources that you can tag

- You can add tags to the following resources when you create them: WorkSpaces, imported images, and IP access control groups.
- You can add tags to existing resources of the following types: WorkSpaces, registered directories, custom bundles, images, and IP access control groups.

## Using the cost allocation tag

To view your WorkSpaces resource tags in the Cost Explorer, activate the tags that you have applied to your WorkSpaces resources by following the instructions in [Activating User-Defined Cost Allocation Tags](#) in the AWS Billing and Cost Management and Cost Management User Guide.

Although tags appear 24 hours after activation, it can take four to five days for values associated with those tags to appear in the Cost Explorer, to appear and provide cost data in Cost Explorer, WorkSpaces resources that have been tagged must incur charges during that time. Cost Explorer shows only cost data from the time when the tags were activated forward. No historical data is available at this time.

## Managing tags

To update the tags for an existing resource using the AWS CLI, use the [create-tags](#) and [delete-tags](#) commands. For bulk updates and to automate the task on a large number of WorkSpaces resource, [Amazon WorkSpaces](#) adds support for AWS Resource Groups Tag Editor. AWS Resource Groups Tag Editor enables you to add, edit, or delete AWS tags from your WorkSpaces along with your other AWS resources.

## Amazon WorkSpaces service quotas

Service Quotas make it easy to look up the value of a particular *quota*, also referred to as a *limit*. You can also look up all quotas for a particular service.

### To view your quotas for WorkSpaces

1. Navigate to the [Service Quotas console](#).
2. In the left-hand navigation pane, choose **AWS services**.
3. Select **Amazon WorkSpaces** from the list, or enter **Amazon WorkSpaces** in the type-ahead search field.
4. To view additional information about a quota, such as its description and Amazon Resource Name (ARN), choose the quota name.

Amazon WorkSpaces provides different resources that you can use in your account in a given region, including WorkSpaces, images, bundles, directories, connection aliases, and IP control groups. When you create your Amazon Web Services account, default quotas are set (also referred to as limits) on the number of resources that you can create.

You can use the [Service Quotas console](#) to view the default Service Quotas or to [request quota increases](#) for adjustable quotas.

For more information, refer to [Viewing service quotas](#) and [Requesting a quota increase](#) in the *Service Quotas User Guide*.

## Automating Amazon WorkSpaces deployment

With Amazon WorkSpaces, you can launch a Microsoft Windows or Amazon Linux desktop within minutes, and connect to and access your desktop software from on-premises or an external

network securely, reliably, and quickly. You can automate the provisioning of Amazon WorkSpaces to enable you to integrate Amazon WorkSpaces into your existing provisioning workflows.

## Common WorkSpaces automation methods

Customers can use a number of tools to allow for rapid Amazon WorkSpaces deployment. The tools can be used to allow simplify management of WorkSpaces, reduce costs and enable an agile environment that can scale and move fast.

### AWS CLI and API

There are [Amazon WorkSpaces API operations](#) you can use to interact with the service securely, and at scale. All public APIs are available with the AWS CLI SDK and Tools for PowerShell, while private APIs such as image creation are available only through the AWS Management Console. When considering operational management and business self-service for Amazon WorkSpaces, consider that WorkSpaces APIs *do* require technical expertise and security permissions to use.

API calls can be made using the [AWS SDK](#). [AWS Tools for Windows PowerShell](#) and AWS Tools for PowerShell Core are PowerShell modules built on functionality exposed by the AWS SDK for .NET. These modules enable you to script operations on AWS resources from the PowerShell command line, and integrate with existing tools and services. For example, API calls can enable you to automatically manage the WorkSpaces lifecycle by integrating with AD to provision and decommission WorkSpaces based on a user's AD group membership.

### AWS CloudFormation

AWS CloudFormation enables you to model your entire infrastructure in a text file. This template becomes the single source of truth for your infrastructure. This helps you to standardize infrastructure components used across your organization, enabling configuration compliance and faster troubleshooting.

AWS CloudFormation provisions your resources in a safe, repeatable manner, enabling you to build and rebuild your infrastructure and applications. You can use CloudFormation to commission and decommission environments, which is useful when you have a number of accounts that you want to build and decommission in a repeatable fashion. When considering operational management and business self-service for Amazon WorkSpaces, consider that [AWS CloudFormation](#) *does* require technical expertise and security permissions to use.

## Self-Service WorkSpaces portal

Customers can use build on WorkSpaces API commands and other AWS Services to create a WorkSpaces self-service portal. This helps customers streamline the process to deploy and reclaim WorkSpaces at scale. Using a WorkSpaces portal, you can enable your workforce to provision their own WorkSpaces with an integrated approval workflow that does not require IT intervention for each request. This reduces IT operational costs, while helping end-users get started with WorkSpaces faster. The additional built-in approval workflow simplifies the desktop approval process for businesses. A dedicated portal can offer an automated tool for provisioning Windows or Linux cloud desktops, and enable users to rebuild, restart, or migrate their WorkSpace, as well as provide a facility for password resets.

There are guided examples of creating Self Service WorkSpaces Portals referenced in the [Further Reading](#) section of this document. AWS Partners provide preconfigured WorkSpaces management portals via the [AWS Marketplace](#).

## Integration with Enterprise IT Service Management

As enterprises adopt Amazon WorkSpaces as their virtual desktop solution at scale, there is a need to implement, or integrate with, IT Service Management (ITSM) systems. ITSM integration allows for self-service offerings for provisioning and operations. The [Service Catalog](#) enables you to manage commonly deployed AWS services and provisioned software products centrally. This service helps your organization achieve consistent governance and compliance requirements, while enabling users to deploy only the approved AWS services they need. The Service Catalog can be used to enable a self-service lifecycle-management offering for Amazon WorkSpaces from within IT Service Management tools such as [ServiceNow](#).

## WorkSpaces Deployment Automation best practices

You should consider Well Architected principles of selecting and designing WorkSpaces deployment automation.

- **Design for Automation** — Design to deliver the least possible manual intervention in the process to enable repeatability and scale.
- **Design for Cost Optimization** — By automatically creating and reclaiming WorkSpaces, you can reduce the administration effort needed to provide resources and remove idle or unused resources from generating unnecessary cost.

- **Design for Efficiency** — Minimize the resources needed to create and terminate WorkSpaces. Where possible, provide Tier 0 self-service capabilities for the business to improve efficiency.
- **Design for Flexibility** — Create a consistent deployment mechanism that can handle multiple scenarios, and can scale with the same mechanism (customized using tagged use case and profile identifiers).
- **Design for Productivity** — Design your WorkSpaces operations to allow for the correct authorization and validation to add or remove resources.
- **Design for Scalability** — The pay-as-you go model that Amazon WorkSpaces uses can drive cost savings by creating resources as needed, and removing them when they are no longer necessary.
- **Design for Security** — Design your WorkSpaces operations to allow for the correct authorization and validation to add or remove resources.
- **Design for Supportability** — Design your WorkSpaces operations to allow for non-invasive support and recovery mechanisms and processes.

## Amazon WorkSpaces patching and in-place upgrades

With Amazon WorkSpaces, you can manage patching and updates using existing third-party tools, such as Microsoft System Center Configuration Manager (SCCM), Puppet Enterprise, or Ansible. In-place deployment of security patches typically maintains a monthly patch cycle, with additional processes for escalation or rapid deployment. However, in the case of in-place operating system upgrades or feature updates, special considerations are often necessary.

### Workspace maintenance

Amazon WorkSpaces have a [default maintenance window](#) during which the Workspace installs Amazon WorkSpaces agent updates and any available operating system updates. WorkSpaces will be unavailable to user connections during the scheduled maintenance window.

- **AlwaysOn** WorkSpaces default maintenance window is 00h00 to 04h00, in the time zone of the Workspace, each Sunday morning.
- Time zone redirection is enabled by default and can override the default window to match the user's local time zone.
- You can [disable time zone redirection for Windows WorkSpaces](#) using Group Policy. You can [disable time zone redirection for Linux WorkSpaces](#) by using the PCoIP Agent conf.

- **AutoStop** WorkSpaces are started automatically once a month to install important updates. Beginning on the third Monday of the month, and for up to two weeks, the maintenance window is open each day from about 00h00 to 05h00, in the time zone of the AWS Region for the WorkSpace. The WorkSpace can be maintained on any one day in the maintenance window.
- Although you cannot modify the time zone that is used for maintaining AutoStop WorkSpaces, you can [disable the maintenance window for your AutoStop WorkSpaces](#).
- [Manual maintenance windows](#) can be set based on your preferred schedule by setting the state of the WorkSpace to ADMIN\_MAINTENANCE.
- The AWS CLI command [modify-workspace-state](#) can be used to modify the WorkSpace state to ADMIN\_MAINTENANCE.

## Amazon Linux WorkSpaces

For considerations, prerequisites, and suggested patterns for managing updates and patches on Amazon Linux WorkSpaces custom images, refer to the whitepaper [Best Practices to Prepare your Amazon WorkSpaces for Linux Images](#).

### Linux patching prerequisites and considerations

- Amazon Linux repositories are hosted in Amazon Simple Storage Service (Amazon S3) buckets which can be accessed via public Internet-accessible endpoints or private endpoints. If your Amazon Linux WorkSpaces do not have Internet access, please refer to this process for making updates accessible: [How can I update yum or install packages without internet access on my EC2 instances running Amazon Linux 1 or Amazon Linux 2?](#)
- You cannot configure the default maintenance window for Linux WorkSpaces. If customization of this window is required the [manual maintenance](#) process can be utilized.

## Amazon Windows patching

By default, your Windows WorkSpaces are configured to receive updates from Windows Update which require Internet access from your WorkSpaces VPC. To configure your own automatic update

mechanisms for Windows, refer to the documentation for [Windows Server Update Services \(WSUS\)](#) and [Configuration Manager](#).

## Amazon Windows in-place upgrade

- If you plan to create an image from a Windows 10 WorkSpace, note that image creation is not supported on Windows 10 systems that have been upgraded from a previous version (a Windows feature/version upgrade). However, Windows cumulative or security updates are supported by the WorkSpaces image creation and capture process.
- Custom Windows 10 Bring Your Own License (BYOL) images should start with the most current supported version of Windows on a VM as the source for the BYOL import process: refer to the [BYOL import documentation](#) for further detail.

## Windows In-place Upgrade Prerequisites

- If you have deferred or paused Windows 10 upgrades using Active Directory Group Policy or SCCM, enable operating system upgrades for your Windows 10 WorkSpaces.
- If the WorkSpace is an AutoStop WorkSpace, change the AutoStop time to at least three hours to accommodate the upgrade window.
- The in-place upgrade process recreates the user profile by making a copy of Default User (C:\Users\Default). **Do not use the default user profile to make customizations.** It's recommended to make any customizations to the user profile through Group Policy Objects (GPOs) instead. Customizations made through GPOs can be easily modified or rolled back, and are less prone to error.
- The in-place upgrade process can back up and recreate only one user profile. If you have multiple user profiles on drive D, delete all the profiles except for the one that you need.

## Windows In-place Upgrade Considerations

- The in-place upgrade process uses two registry scripts (enable-inplace-upgrade.ps1 and update-pvdrivers.ps1) to make the necessary changes to your WorkSpaces and enable the Windows Update process to run. These changes involve creating a temporary user profile on drive C instead of drive D. If a user profile already exists on drive D, the data in that original user profile remains on drive D.

- Once the in-place upgrade is deployed, you must restore the user profiles to the D drive to ensure that you can rebuild or migrate your WorkSpaces, and to avoid any potential problems with user shell folder redirection. You can do so by using the **PostUpgradeRestoreProfileOnD** registry key, as explained on the [BYOL upgrade reference page](#).

## Amazon WorkSpaces language packs

Amazon WorkSpaces bundles that provide the Windows 10 desktop experience supports English (US), French (Canadian), Korean, and Japanese. However, you can include additional language packs for Spanish, Italian, Portuguese, and many more language options. For more information, refer to [How do I create a new Windows WorkSpace image with a client language other than English?](#)

## Amazon WorkSpaces profile management

Amazon WorkSpaces separates the user profile from the base Operating System (OS) by redirecting all profile writes to a separate [Amazon Elastic Block Store](#) (Amazon EBS) volume. In Microsoft Windows, the user profile is stored in D:\Users\username. In Amazon Linux, the user profile is stored in /home. The EBS volume is snapshotted automatically every 12 hours. The snapshot is automatically stored in an AWS Managed S3 bucket, to be used in the event that an Amazon WorkSpace is rebuilt or restored.

For most organizations, having automatic snapshots every 12 hours is superior to the existing desktop deployment of no backups for user profiles. However, customers can require more granular control over user profiles; for example, migration from desktop to WorkSpaces, to a new OS/AWS Region, support for DR, and so on. There are alternative methods for profile management available for Amazon WorkSpaces.

## Folder redirection

While folder redirection is a common design consideration in Virtual Desktop Infrastructure (VDI) architectures, it is not a best practice, or even a common requirement in Amazon WorkSpaces designs. The reason for this is Amazon WorkSpaces is a persistent Desktop as a Service (DaaS) solution, with application and user data persisting out of the box.

There are specific scenarios where Folder Redirection for User Shell Folders (for example, D:\Users\username\Desktop redirected to \\Server\RedirectionShare\$\username\Desktop) are required,

such as immediate recovery point objective (RPO) for user profile data in disaster recovery (DR) environments.

## Best practices

The following best practices are listed for a robust folder redirection:

- Host the Windows File Servers in the same AWS Region and AZ that the Amazon WorkSpaces are launched in.
- Ensure AD Security Group Inbound Rules include the Windows File Server Security Group or private IP addresses; otherwise ensure that the on-premises firewall allows those same TCP and UDP port-based traffic.
- Ensure Windows File Server Security Group Inbound Rules include TCP 445 (SMB) for all Amazon WorkSpaces Security Groups.
- Create an AD Security Group for Amazon WorkSpaces users to authorize users' access to the Windows File Share.
- Use DFS Namespace (DFS-N) and DFS Replication (DFS-R) to ensure your Windows File Share is agile, not tied to anyone one specific Windows File Server, and all user data is automatically replicated between Windows File Servers.
- Append '\$' to the end of the share name to hide the share hosting user data from view when browsing the network shares in Windows Explorer.
- Create the file share following Microsoft's guidance for redirected folders: [Deploy Folder Redirection with Offline Files](#). Follow the guidance for Security Permissions and GPO configuration closely.
- If your Amazon WorkSpaces deployment is Bring Your Own License (BYOL), you must also specify disabling Offline Files following Microsoft's guidance: [Disable Offline Files on Individual Redirected Folders](#).
- Install and run Data Deduplication (commonly referred to as 'dedupe') if your Windows File Server is Windows Server 2016 or newer to reduce storage consumption and optimize cost. Refer to [Install and enable Data Deduplication](#) and [Running Data Deduplication](#).
- Back up your Windows File Server file shares using existing organizational backup solutions.

## Thing to avoid

- Do not use Windows File Servers that are accessible only across a wide area network (WAN) connection, as the SMB protocol is not designed for that use.
- Do not use the same Windows File Share that is used for Home Directories to mitigate the chances of users accidentally deleting their User Shell folders.
- While enabling [Volume Shadow Copy Service](#) (VSS) is recommended for ease of file restores, this alone does not remove the requirement to back up the Windows File Server file shares.

## Other considerations

- Amazon FSx for Windows File Server offers a managed service for Windows file shares, and simplify the operational overhead of folder redirection, including automatic backups.
- Utilize [AWS Storage Gateway for SMB File Share](#) to back up your file shares if there is no existing organizational backup solution.

## Profile settings

### Group policies

A common best practice in enterprise Microsoft Windows deployments is to define user environment settings through Group Policy Object (GPO) and Group Policy Preferences (GPP) settings. Settings such as shortcuts, drive mappings, registry keys, and printers are defined through the Group Policy Management Console. The benefits to defining the user environment through GPOs include, but are not limited to:

- Centralized configuration management
- User profile defined by AD Security Group Membership or OU placement
- Protection against deletion of settings
- Automate profile creation and personalization at first logon
- Ease of future updating

**Note**

Follow Microsoft's [Best Practices for optimizing Group Policy performance](#).

Interactive Logon Banners Group Policies must not be used as they are not supported on Amazon WorkSpaces. Banners are presented on the Amazon WorkSpaces Client through AWS support requests. Additionally, removable devices must not be blocked through group policy, as they are required for Amazon WorkSpaces.

GPOs can be used to manage Windows WorkSpaces. For more information, refer to [Manage Your Windows WorkSpaces](#).

## Amazon WorkSpaces volumes

Each Amazon WorkSpaces instance contains two volumes: an *operating system* volume and a *user* volume.

- **Amazon Windows WorkSpaces** — The C:\ drive is used for the Operating System (OS) and the D:\ drive is user volume. The user profile is located on the user volume (AppData, Documents, Pictures, Downloads, and so on).
- **Amazon Linux WorkSpaces** — With an Amazon Linux Workspace, the system volume (/dev/xvda1) mounts as the root folder. The user volume is for user data and applications; /dev/xvdf1 mounts as /home.

For operating system volumes, you can select a starting size for this drive of 80 GB or 175 GB. For user volumes, you can select a starting size of 10 GB, 50 GB, or 100 GB. Both volumes can be increased up to 2TB in size as needed; however, to increase the user volume beyond 100 GB, the OS volume must be 175 GB. Volume changes can be performed only once every six hours per volume. For additional information on modifying the WorkSpaces volume size, refer to the [Modify a Workspace](#) section of the Administration Guide.

### WorkSpaces volumes best practices

When planning an Amazon WorkSpaces deployment, it's recommended to factor the minimum requirements for OS installation, in-place upgrades, and additional core applications that will be added to the image on the OS volume. For the user volume, it's recommended to start with a

smaller disk allocation, and incrementally increasing the user volume size as needed. Minimizing the size of the disk volumes reduces the cost of running the WorkSpace.

### Note

While a volume size can be increased, it cannot be decreased.

## Amazon WorkSpaces logging

In an Amazon WorkSpaces environment, there are many log sources that can be captured to troubleshoot issues and monitor the overall WorkSpaces performance.

**Amazon WorkSpaces Client 3.x** On each Amazon WorkSpaces client, the client logs are located in the following directories:

- Windows — %LOCALAPPDATA%\Amazon Web Services\Amazon WorkSpaces\logs
- macOS — ~/Library/"Application Support"/"Amazon Web Services"/"Amazon WorkSpaces"/logs
- Linux (Ubuntu 18.04 or later) — /opt/workspacesclient/workspacesclient

There are many instances where diagnostic or debugging details may be needed for a WorkSpaces session from the client side. Advanced client logs can be enabled as well by adding an “-l3” to the workspaces executable file. For example:

```
"C:\Program Files (x86)\Amazon Web Services, Inc\Amazon WorkSpaces"  
workspaces.exe -l3
```

### Amazon WorkSpaces service

Amazon WorkSpaces service is integrated with Amazon CloudWatch Metrics, CloudWatch Events, and CloudTrail. This integration allows of the performance data and API calls to be logged into central AWS service.

When managing an Amazon WorkSpaces environment, it is important to constantly monitor certain CloudWatch metrics to determine the overall environment health status. **Metrics**

While there are other CloudWatch metrics available for Amazon WorkSpaces (refer to [Monitor Your WorkSpaces Using CloudWatch Metrics](#)), the three following metrics will assist in maintaining the WorkSpace instance availability:

- **Unhealthy** — The number of WorkSpaces that returned an unhealthy status.
- **SessionLaunchTime** — The amount of time it takes to initiate a WorkSpaces session.
- **InSessionLatency** — The round-trip time between the WorkSpaces client and the WorkSpace.

For more information on WorkSpaces logging options, refer to [Logging Amazon WorkSpaces API Calls by Using CloudTrail](#). The additional CloudWatch Events will assist with capturing the client-side IP of the user session, when the user connected to the WorkSpaces session, and the what endpoint was used during the connection. All of these details assist with isolating or pinpointing user reported issues during troubleshooting sessions.

 **Note**

Some CloudWatch Metrics are available only with AWS Managed AD.

# Containers and Windows subsystem for Linux on Amazon WorkSpaces

## Containers and Amazon WorkSpaces

End user computing is often approached by customers who are looking to service container workloads with Amazon WorkSpaces. While possible, this is not the preferred or recommended solution. Customers looking to unlock the potential cost and operational savings of containers are strongly encouraged to evaluate [Amazon Elastic Container Service](#) (Amazon ECS) and/or [Amazon Elastic Kubernetes Service](#) (Amazon EKS).

In cases where customer requirements mandate enabling containers using Amazon WorkSpaces, a [technical how-to](#) has been published that enables the use of Docker. Customers should be informed that this requires other trailing services, and that there are increased costs and complexity when compared with decoupled, native container services.

## Windows subsystem for Linux

With the launch of Windows Server 2019 as the underlying operating system for Amazon WorkSpaces, customers have been eager to implement Windows Subsystem for Linux (WSL), specifically WSL2. Because WSL2 invokes a virtual machine (Hyper-V) in order to perform its functions, it cannot run on Amazon WorkSpaces, which are managed by AWS hypervisors. Customers should know that only WSL1 will be available for this reason, and understand [the differences between WSL1 and WSL2](#).

# Amazon WorkSpaces migrate

Amazon WorkSpaces migrate feature enables you to bring your user volume data to a new bundle. You can use this feature to:

- Migrate your WorkSpaces from the Windows 7 Experience to the Windows 10 Desktop Experience.
- Migrate from a PCoIP WorkSpace to a WorkSpaces Streaming Protocol (WSP) WorkSpace.
- Migrate WorkSpaces from one public, or custom, bundle to another. For example, you can migrate from GPU-enabled (Graphics and GraphicsPro) bundles to non-GPU-enabled bundles, and vice versa.

## Migration process

With WorkSpaces migrate, you can specify the target WorkSpaces bundle. The migration process recreates the WorkSpace using a new root volume from the target bundle image, and the user volume from the latest original user volume snapshot. A new user profile is generated during migrate for better compatibility. The data in your old user profile that cannot be moved to the new profile is stored in a `.notMigrated` folder.

During migration, the data on the user volume (drive D) is preserved, but all the data on the root volume ( C:\ drive) is lost. This means that none of the installed applications, settings, and changes to the registry are preserved. The old user profile folder is renamed with the `.NotMigrated` suffix, and a new user profile is created.

The migration process takes up to one hour per WorkSpace. In addition, if the migrate workflow fails to complete the process, the service will automatically roll back the WorkSpace to its original state before migration, minimizing any data loss risk.

Any tags assigned to the original WorkSpace are carried over during migration. The running mode of the WorkSpace is preserved. The migrated WorkSpace has a new WorkSpace ID, computer name, and IP address. **Migration procedure**

You can migrate WorkSpaces through the Amazon WorkSpaces console, the AWS CLI using the [migrate-workspace](#) command, or the Amazon WorkSpaces API. All migration requests get queued, and the service will automatically throttle the total number of migration requests if there are too many. **Migration limits**

- You cannot migrate to a public or custom Windows 7 desktop experience bundle.
- You cannot migrate to BYOL Windows 7 bundles.
- You can migrate BYOL WorkSpaces *only* to other BYOL bundles.
- You cannot migrate a WorkSpace created from public or custom bundles to a BYOL bundle.
- Migrating Linux WorkSpaces is not currently supported.
- In AWS Regions that support more than one language, you can migrate WorkSpaces between language bundles.
- The source and target bundles must be different. (However, in regions that support more than one language, you can migrate to the same Windows 10 bundle as long as the languages differ.) If you want to refresh your WorkSpace using the same bundle, [rebuild the WorkSpace](#) instead.
- You cannot migrate WorkSpaces across Regions.
- WorkSpaces cannot be migrated when they are in ADMIN\_MAINTENANCE mode.

## Cost

During the month in which migration occurs, you are charged prorated amounts for both the new and the original WorkSpaces. For example, if you migrate WorkSpace A to WorkSpace B on May 10, you will be charged for WorkSpace A from May 1 to May 10, and you will be charged for WorkSpace B from May 11 to May 30.

## WorkSpaces migration best practices

Before you migrate a WorkSpace, do the following:

- Back up any important data on drive C to another location. All data on drive C is erased during migration.
- Make sure that the WorkSpace being migrated is at least 12 hours old, to ensure that a snapshot of the user volume has been created. On the **Migrate WorkSpaces** page in the Amazon WorkSpaces console, you can refer to the time of the last snapshot. Any data created after the last snapshot is lost during migration.
- To avoid potential data loss, make sure that your users log out of their WorkSpaces, and don't log back in until after the migration process is finished.
- Make sure that the WorkSpaces you want to migrate have a status of AVAILABLE, STOPPED, or ERROR.

- Make sure that you have enough IP addresses for the WorkSpaces you are migrating. During migration, new IP addresses will be allocated for the WorkSpaces.
- If you are using scripts to migrate WorkSpaces, migrate them in batches of no more than 25 WorkSpaces at a time.

# Well-Architected Framework

[AWS Well-Architected](#) helps cloud architects build secure, high-performing, resilient, and efficient infrastructure for their applications and workloads. It describes the key concepts, design principles, and architectural best practices for designing and running workloads in the cloud. It is based on five key pillars:

- Operational excellence
- Security
- Reliability
- Performance efficiency
- Cost optimization

When architecting an Amazon WorkSpaces environment, it is important to evaluate these key pillars to determine the maturity deployment level, and discover additional features that can be used with the Amazon WorkSpaces. While there is overall guidance for the [AWS Well-Architect Framework](#), the following provides some key questions that can be included in the planning phase of your WorkSpaces deployment to ensure each of the five pillars are considered.

## General

- What is the business driver for this project?

## Operational excellence

- How do you segregate access control between users and different admin groups?

## Security

1. What are the security and compliance requirements to be considered for the WorkSpaces to operate in?
2. Are there any restrictions on routing to external IP addresses?
3. Are the required WorkSpaces ports allowed through the corporate firewall?
4. Is or will multi-factor authentication be used with this deployment?

5. How do you manage user identities and authorization requests today?

## Reliability

1. What is the data retention policy for desktops?
2. What is the Recovery Point Objective (RPO) for end-user data?
3. What is the Recovery Time Objective (RTO) for end-user data?

## Cost optimization

1. Have the WorkSpaces bundles been [right sized](#) for the user case and applications?
2. Will the users consume WorkSpaces more than 82 hours per month?

While the questions above do not constitute an exhaustive list of items that should be considered, they provide some overarching guidance to assist you with a Well-Architected Amazon WorkSpaces deployment.

# Security

This section explains how to secure data by using encryption when using Amazon WorkSpaces services. It describes encryption in transit and at rest, and the use of security groups to protect network access to the WorkSpaces. This section also provides information on how to control end device access to WorkSpaces by using Trusted Devices, and IP Access Control Groups.

Additional information on authentication (including MFA support) in the AWS Directory Service can be found in this section.

## Encryption in transit

Amazon WorkSpaces uses cryptography to protect confidentiality at different stages of communication (in transit) and also to protect data at rest (encrypted WorkSpaces). The processes in each stage of the encryption used by Amazon WorkSpaces in transit is described in the following sections.

For information about the encryption at rest, refer to the [Encrypted WorkSpaces](#) section of this document.

## Registration and updates

The desktop client application communicates with Amazon for updates and registration using HTTPS.

## Authentication stage

The desktop client initiates authentication by sending credentials to the authentication gateway. The communication between the desktop client and authentication gateway uses HTTPS. At the end of this stage, if the authentication succeeds, the authentication gateway returns an OAuth 2.0 token to the desktop client, through the same HTTPS connection.

### Note

The desktop client application supports the use of a proxy server for port 443 (HTTPS) traffic, for updates, registration, and authentication.

After receiving credentials from the client, the authentication gateway sends an authentication request to AWS Directory Service. The communication from the authentication gateway to AWS Directory Service takes place over HTTPS, so no user credentials are transmitted in plaintext.

## Authentication — Active Directory Connector (ADC)

AD Connector uses [Kerberos](#) to establish authenticated communication with on-premises AD, so it can bind to LDAP and execute subsequent LDAP queries. Client-side LDAPS support in ADC is also available to encrypt queries between Microsoft AD and AWS Applications. Before implementing client-side LDAPS functionality, review the [prerequisites for client-side LDAPS](#).

The AWS Directory Service also supports LDAP with TLS. No user credentials are transmitted in plaintext at any time. For increased security, it is possible to connect a WorkSpaces VPC with the on-premises network (where AD resides) using a VPN connection. When using an AWS hardware VPN connection, customers can set up encryption in transit by using standard IPSEC (Internet Key Exchange (IKE) and IPSEC SAs) with AES-128 or AES-256 symmetric encryption keys, SHA-1 or SHA-256 for integrity hash, and DH groups (2,14-18, 22, 23 and 24 for phase 1; 1,2,5, 14-18, 22, 23 and 24 for phase 2) using perfect forward secrecy (PFS).

## Broker stage

After receiving the OAuth 2.0 token (from the authentication gateway, if the authentication succeeded), the desktop client queries Amazon WorkSpaces services (Broker Connection Manager) using HTTPS. The desktop client authenticates itself by sending the OAuth 2.0 token and, as a result, the client receives the endpoint information of the WorkSpaces streaming gateway.

## Streaming stage

The desktop client requests to open a PCoIP session with the streaming gateway (using the OAuth 2.0 token). This session is AES-256 encrypted and uses the PCoIP port for communication control (4172/TCP).

Using the OAuth2.0 token, the streaming gateway requests the user-specific WorkSpaces information from the Amazon WorkSpaces service, over HTTPS.

The streaming gateway also receives the TGT from the client (which is encrypted using the client user's password) and, by using Kerberos TGT pass-through, the gateway initiates a Windows login on the WorkSpace, using the user's retrieved Kerberos TGT.

The WorkSpace then initiates an authentication request to the configured AWS Directory Service, using standard Kerberos authentication.

After the WorkSpace is successfully logged in, the PCoIP streaming starts. The connection is initiated by the client on port TCP 4172 with the return traffic on port UDP 4172. Additionally, the initial connection between the streaming gateway and a WorkSpaces desktop over the management interface is via UDP 55002. (Refer to documentation for [IP Address and Port Requirements for Amazon WorkSpaces](#). The initial outbound UDP port is 55002.) The streaming connection, using ports 4172 (TCP and UDP), is encrypted by using AES 128- and 256-bit ciphers, but default to 128-bit. Customers can actively change this to 256-bit, either using PCoIP-specific AD Group Policy settings for Windows WorkSpaces, or with the [pcoip-agent.conf](#) file for Amazon Linux WorkSpaces. For more information about Group Policy administration for Amazon WorkSpaces, refer to the [documentation](#).

## Network interfaces

Each Amazon WorkSpace has two network interfaces, called the [primary network interface and management network interface](#).

The primary network interface provides connectivity to resources inside the customer VPC, such as access to AWS Directory Service, the internet, and the customer corporate network. It is possible to attach security groups to this primary network interface. Conceptually, the security groups are differentiated attached to this ENI based on the scope of the deployment: WorkSpaces security group and ENI security groups.

### Management network interface

The management network interface cannot be controlled via security groups; however, customers can use a host-based firewall on WorkSpaces to block ports or control access. We don't recommend applying restrictions on the management network interface. If a customer decides to add host-based firewall rules to manage this interface, a few ports should be open so the Amazon WorkSpaces service can manage the health and accessibility to the WorkSpace. For more information, refer to [Network Interfaces](#) in the Amazon Workspaces Administration Guide.

## WorkSpaces security groups

A default security group is created per AWS Directory Service and is automatically attached to all WorkSpaces that belong to that specific directory.

Amazon WorkSpaces, like many other AWS services, makes use of security groups. Amazon WorkSpaces creates two AWS Security Groups when you register a directory with the WorkSpaces service. One for directory controllers `directoryId_controllers` and one for WorkSpaces in the directory `directoryId_workspacesMembers`. Do not delete either of these security groups, or your WorkSpaces will become impaired. By default, the WorkSpaces Members security group has egress open to 0.0.0.0/0. You can add a default WorkSpaces security group to a directory. After you associate a new security group with a WorkSpaces directory, new WorkSpaces that you launch or existing WorkSpaces that you rebuild will have the new security group. You can also add this new default security group to existing WorkSpaces without rebuilding them. When you associate multiple security groups with a WorkSpaces directory, WorkSpaces aggregate the rules from each security group into a single set of rules. We recommend condensing your security group rules as much as possible. For more information about security groups, refer to [Security Groups for Your VPC](#) in the *Amazon VPC User Guide*.


For more information about adding a security group to a WorkSpaces directory or existing WorkSpace, refer to the [WorkSpaces Admin guide](#).

Some customers want to restrict ports and destinations the WorkSpaces traffic can egress. To restrict egress traffic from the WorkSpaces, you must ensure you leave specific ports required for service communication; otherwise, your users will not be able to log in to their WorkSpaces.

WorkSpaces utilize the Elastic Network Interface (ENI) in the customer VPC for communication to the domain controllers during WorkSpace log in. To allow your users to log in to their WorkSpaces successfully, you must allow the following ports to access your domain controllers or the CIDR ranges that include your domain controllers in the `_workspacesMembers` security group.

- TCP/UDP 53 - DNS
- TCP/UDP 88 - Kerberos authentication
- TCP/UDP 389 - LDAP
- TCP/UDP 445 - SMB
- TCP 3268-3269 - Global Catalog
- TCP/UDP 464 - Kerberos password change
- TCP 139 - Netlogon
- UDP 137-138 - Netlogon
- UDP 123 - NTP
- TCP/UDP 49152-65535 Ephemeral ports for RPC

If your WorkSpaces need to access other applications, the Internet, or other locations, you will need to allow those ports and destinations in CIDR notation within the `_workspacesMembers` security group. If you do not add those ports and destinations, the WorkSpaces will not reach anything other than the ports listed above. One final consideration, by default, a new security group has no inbound rules. Therefore, no inbound traffic originating from another host to your instance is allowed until you add inbound rules to the security group. The above steps are only required if you want to either restrict egress from the WorkSpaces or have ingress rules locked down to only the resources or CIDR ranges that should have access to them.

 **Note**

A newly associated security group will be attached only to WorkSpaces created or rebuilt after the modification.

## ENI security groups

Because the primary network interface is a regular ENI, it can be managed by using the different AWS management tools. For more information, refer to [Elastic Network Interfaces](#). Navigate to the Workspace IP address (in the WorkSpaces page in the Amazon WorkSpaces console), and then use that IP address as a filter to find the corresponding ENI (in the Network Interfaces section of the Amazon EC2 console).

Once the ENI is located, it can be directly managed by security groups. When manually assigning security groups to the primary network interface, consider the port requirements of Amazon WorkSpaces. For more information, refer to [Network Interfaces](#) in the *Amazon Workspaces Administration Guide*.

Network Interface: eni-09ac2dbc00840eac

| Property                   | Value  |
|----------------------------|--|
| Network interface ID       | eni-09ac2dbc00840eac   |
| VPC ID                     | vpc-0da3fcbbc4a19855   |
| MAC address                | 0a:d4:c6:04:c2:02  |
| Security groups            | d-93672fbcce_workspacesMembers. <a href="#">view inbound rules</a> . <a href="#">view outbound rules</a> |
| Status                     | in-use   |
| Private DNS (IPv4)         | ip-192-168-30-113.eu-west-1.compute.internal   |
| Secondary private IPv4 IPs | -  |
| Elastic Fabric Adapter     | Disabled   |
| Attachment ID              | eni-attach-00e22b8db1897f1dd   |
| Attachment owner           | 368321020290   |
| Attachment status          | attached   |
| Elastic IP owner           | -  |
| Association ID             | -  |
| Subnet ID                  | subnet-0f0d2d4b9696bb8e2   |
| Availability Zone          | eu-west-1a   |
| Description                | Created By Amazon Workspaces for AWS Account ID [REDACTED]   |
| Network interface owner    | [REDACTED]   |
| Primary private IPv4 IP    | 192.168.30.113   |
| IPv4 Public IP             | -  |
| IPv6 IPs                   | -  |
| Source/dest. check         | true   |
| Instance ID                | -  |
| Device index               | 1  |
| Delete on termination      | false  |
| Allocation ID              | -  |
| Outpost ID                 | -  |

Figure 21: WorkSpaces client with MFA enabled

## Network Access Control Lists (ACLs)

Due to the added complexity in managing yet another firewall, Network ACLs are commonly used in very complex deployments and not generally used as a best practice. As Network ACLs are attached to the subnets in the VPC, that focuses their function at Layer 3 (Network) of the OSI model. Due to Amazon WorkSpaces being designed on Directory Services, two subnets must be defined. Network ACLs are managed separately from Directory Services, and it is entirely likely that a Network ACL may be assigned to only one of the WorkSpaces' assigned subnets.

When a stateless firewall is required, Network ACLs are a best practice for security. Ensure any changes made to Network ACLs beyond the default settings are validated on a per subnet basis as a best practice. If the Network ACLs are not performing as intended, consider using [VPC Flow Logs](#) to analyze the traffic.

## AWS Network Firewall

[AWS Network Firewall](#) offers functionality beyond what native Security Groups and Network ACLs offer, however at a cost. When customers have asked for the ability to increase security around network connections such as Server Name Inspection (SNI) for HTTPS-based websites, Intrusion Detection and Prevent, and an allow and deny list for domain names, they were left to

find alternative firewalls on the AWS Marketplace. The complexity in deploying these firewalls presented challenges beyond what standard EUC administrators are skilled at. AWS Network Firewall offers a native AWS experience while enabling Layers 3 through 7 protections. Using AWS Network Firewall in conjunction with NAT Gateway is a best practice when organizations do not possess any other means (existing on-premises licensing for third party firewalls that can be transferred to the cloud or separate teams that manage firewalls excluded) to cover all the EUC network protections. NAT Gateway is also free of charge with AWS Network Firewall.

Deployments of AWS Network Firewall are designed around the existing EUC design. Single VPC designs can achieve a simplified architecture with subnets for firewall endpoints and separate Internet egress routing considerations, whereas multi VPC designs benefit great from a consolidated inspection VPC with firewall and Transit Gateways endpoints.

## Design scenarios

### Scenario 1: Basic instance lockdown

The default WorkSpaces Security Group does not allow any traffic inbound, as Security Groups are denied by default, and stateful. This means that there are no additional configurations that need to be configured to further secure the WorkSpaces instances themselves. Consider the outbound rules which allow all traffic, and if that fits the use case. For instance, it may be best to deny all outbound traffic to port 443 to any address, and specific IP ranges that that fit port use cases such as 389 for LDAP, 636 for LDAPS, 445 for SMB, among others; although note the complexity of the environment may necessitate multiple rules and thus be better served through Network ACLs or a firewall appliance.

### Scenario 2: Inbound exceptions

While it is not a constant requirement, there may be times when network traffic is initiated inbound to WorkSpaces. For instance, triaging instances when the WorkSpaces Client cannot connect require alternative remote connectivity. In these instances, it is best to temporarily enable inbound TCP 3389 to the Security Group of the Workspace's customer ENI.

Another scenario are organizational scripts that perform commands for inventory or automation functions, initiated by a centralized instance. Securing the traffic on that port from those specific centralized instances on the Inbound can be permanently configured, however, it is a best practice to do this on the additional Security Group attached to the Directory configuration as it can be applied to multiple deployments in the AWS account.

Lastly, there is some network traffic that is not stateful-based and will require ephemeral ports to be specified in the inbound exceptions. If queries and scripts are failing, it is a best practice to allow ephemeral ports, at least temporarily, while determining the root cause of connectivity failure.

### Scenario 3: Single VPC inspection

Simplified deployments of WorkSpaces (such as a single VPC with no scaling plans) do not require a separate VPC for inspection, and thus connection to other VPCs can be simplified with VPC peering. Separate subnets, however, for firewall endpoints must be created with routing configured to those endpoints as well as Internet Gateway (IGW) egress routing, which otherwise would not need to be configured. Existing deployments may not have the available IP space if all subnets utilize the entire of the VPC CIDR block. In those instances, Scenario 4 may serve better as the deployment has already scaled beyond its initial design.

### Scenario 4: Centralized inspection

Often preferred in multiple EUC deployments in an AWS Region, simplifying the administration of the AWS Network Firewall's stateful and stateless rules. Existing VPC peers will be replaced with Transit Gateways, as this design necessitates the use of Transit Gateway attachments as well as the inspection routing that can only be configured through those attachments. Greater degree of control is exercised over this configuration as well, and enables security beyond the default WorkSpaces experience.

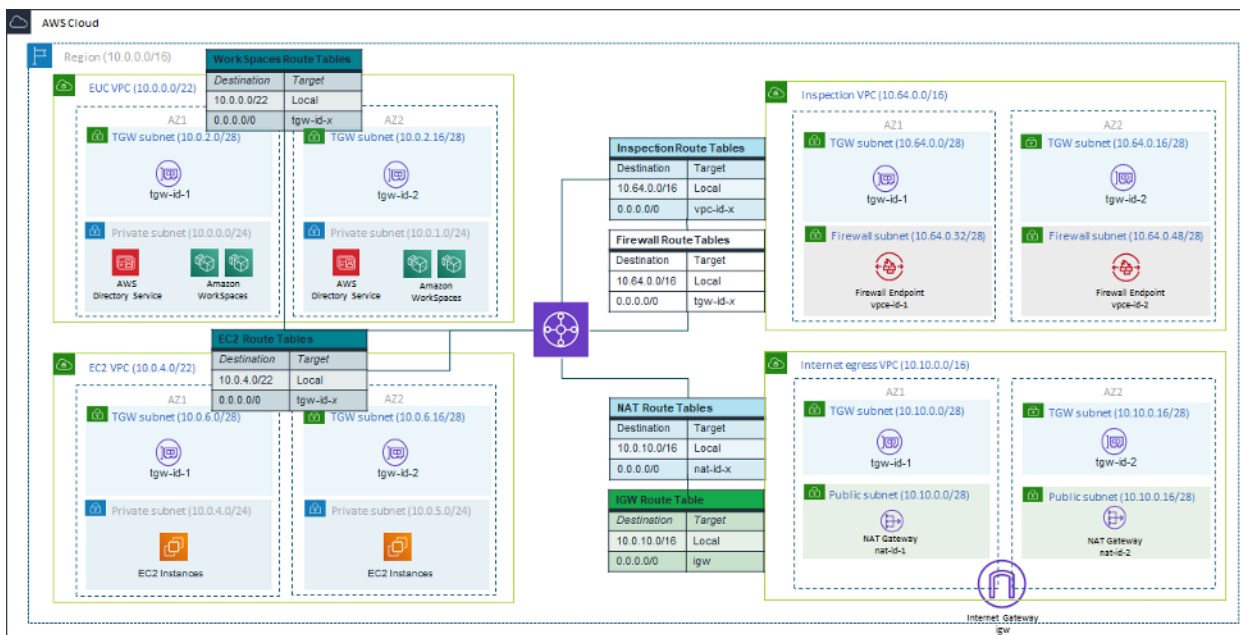


Figure 22: Sample architecture using Transit Gateway attachments

# Encrypted WorkSpaces

Each Amazon WorkSpace is provisioned with a root volume (C: drive for Windows WorkSpaces, root for Amazon Linux WorkSpaces) and a user volume (D: drive for Windows WorkSpaces, /home for Amazon Linux WorkSpaces). The encrypted WorkSpaces feature enables one or both volumes to be encrypted.

## What is encrypted?

The data stored at rest, disk input/output (I/O) to the volume, and snapshots created from encrypted volumes are all encrypted.

## When does encryption occur?

Encryption for a WorkSpace should be specified when launching (creating) the WorkSpace. WorkSpaces volumes can be encrypted only at launch time: after launch, the volume encryption status cannot be changed. The following figure shows the Amazon WorkSpaces console page for choosing encryption during the launch of a new WorkSpace.

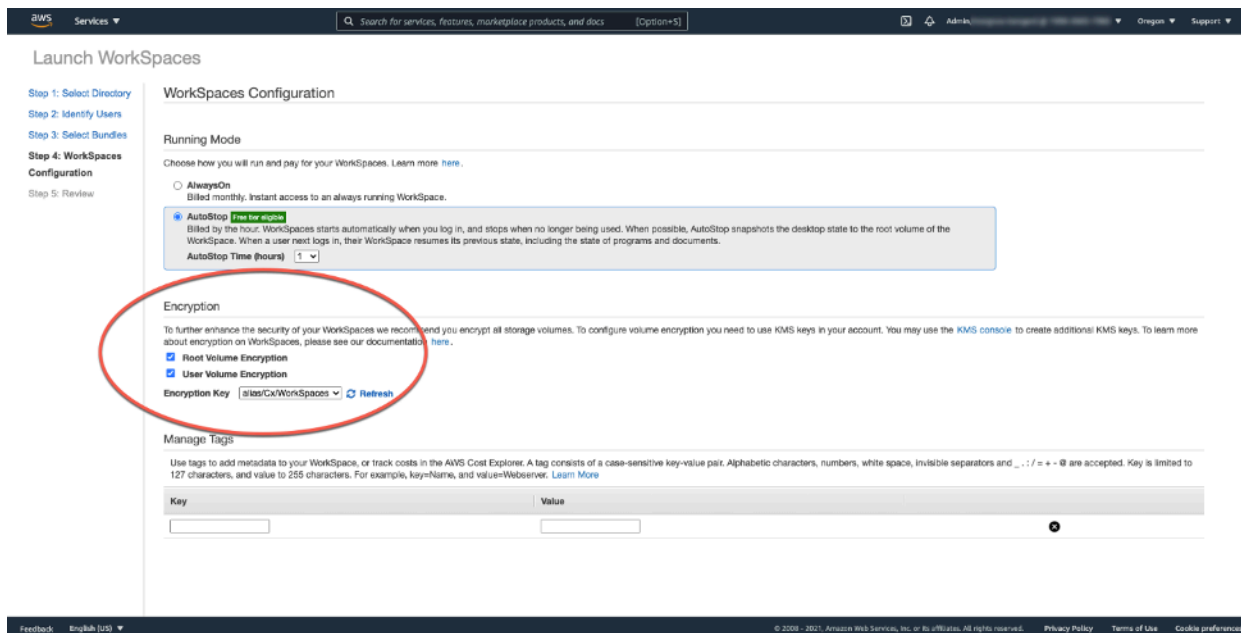


Figure 23: Encrypting WorkSpace root volumes

## How is a new WorkSpace encrypted?

A customer can choose the Encrypted WorkSpaces option from either the Amazon WorkSpaces console or AWS CLI, or by using the Amazon WorkSpaces API when a customer launches a new WorkSpace.

To encrypt the volumes, Amazon WorkSpaces uses a CMK from AWS Key Management Service (AWS KMS). A default AWS KMS CMK is created the first time a WorkSpace is launched in a Region. (CMKs have a Region scope.)

A customer can also create a customer-managed CMK to use with encrypted WorkSpaces. The CMK is used to encrypt the data keys that are used by Amazon WorkSpaces service to encrypt each of the WorkSpace volumes. (In a strict sense, it is [Amazon EBS](#) that will encrypt the volumes). For current CMK limits, refer to [AWS KMS Resource quotas](#).

### Note

Creating custom images from an encrypted WorkSpace is not supported. Also, WorkSpaces launched with root volume encryption enabled can take up to an hour to be provisioned.

For a detailed description of the WorkSpaces encryption process, refer to [How Amazon WorkSpaces uses AWS KMS](#). Consider how the use of CMK will be monitored to ensure that a request for an encrypted WorkSpace is serviced correctly. For additional information about AWS KMS keys and data keys, refer to the [AWS KMS page](#).

## Access control options and trusted devices

Amazon WorkSpaces provides customers options to manage which client devices can access WorkSpaces. Customers can limit WorkSpaces access to trusted devices only. Access to WorkSpaces can be allowed from macOS and Microsoft Windows PCs using digital certificates. It can also allow or block access for iOS, Android, Chrome OS, Linux, and zero clients, as well as the WorkSpaces Web Access client. With these capabilities, it can further improve the security posture.

Access control options are enabled for new deployments for users to access their WorkSpaces from clients on Windows, MacOS, iOS, Android, ChromeOS, and Zero Clients. Access using Web Access or a Linux WorkSpaces client is not enabled by default for a new WorkSpaces deployment and will need to be enabled.

If there are limits on corporate data access from trusted devices (also known as managed devices), WorkSpaces access can be restricted to trusted devices with valid certificates. When this feature is enabled, Amazon WorkSpaces uses certificate-based authentication to determine whether a device is trusted. If the WorkSpaces client application can't verify that a device is trusted, it blocks attempts to log in or reconnect from the device.

Trusted device support is available for the following clients:

- Amazon WorkSpaces Android Client app on [Google Play](#) that runs on Android and [Android-compatible Chrome OS devices](#)
- Amazon WorkSpaces macOS Client app running on macOS devices
- Amazon WorkSpaces Windows Client app running on Windows devices

For more information about controlling which devices can access WorkSpaces, refer to [Restrict WorkSpaces Access to Trusted Devices](#).

#### Note

Certificates for trusted devices apply only to Amazon WorkSpaces Windows, macOS, and Android clients. This feature does not apply to the Amazon WorkSpaces Web Access client, or any third-party clients, including but not limited to Teradici PCoIP software and mobile clients, Teradici PCoIP zero clients, RDP clients, and remote desktop applications.

## IP Access control groups

Using IP address-based control groups, customers can define and manage groups of trusted IP addresses, and allow users to access their WorkSpaces only when they're connected to a trusted network. This feature helps customers gain greater control over their security posture.

IP access control groups can be added at the WorkSpaces directory level. There are two ways to get started using IP access control groups.

- **IP Access Controls page** — From the WorkSpaces management console, IP access control groups can be created on the **IP Access Controls** page. Rules can be added to these groups by entering the IP addresses or IP ranges from which WorkSpaces can be accessed. These groups can then be added to directories on the **Update Details** page.

- **Workspace APIs** — WorkSpaces APIs can be used to create, delete, and view groups; create or delete access rules; or to add and remove groups from directories.

For a detailed description of the using IP access control groups with the Amazon WorkSpaces encryption process, refer to [IP Access Control Groups for Your WorkSpaces](#).

## Monitoring or logging using Amazon CloudWatch

Monitoring network, servers, and logs is an integral part of any infrastructure. Customers who deploy Amazon WorkSpaces need to monitor their deployments, specifically the overall health and connection status of individual WorkSpaces.

### Amazon CloudWatch metrics for WorkSpaces

CloudWatch metrics for WorkSpaces is designed to provide administrators with additional insight into the overall health and connection status of individual WorkSpaces. Metrics are available per Workspace, or aggregated for all WorkSpaces in an organization within a given directory.

These metrics, like all CloudWatch metrics, can be viewed in the AWS Management Console (shown in the following figure), accessed via the CloudWatch APIs, and monitored by CloudWatch alarms and third-party tools.

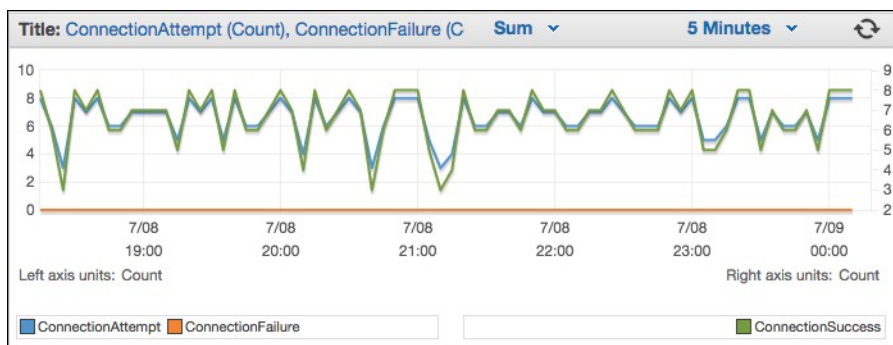


Figure 24: CloudWatch metrics: ConnectionAttempt / ConnectionFailure

By default, the following metrics are enabled and are available at no extra cost:

- **Available** — WorkSpaces that respond to a status check are counted in this metric.
- **Unhealthy** — WorkSpaces that don't respond to the same status check are counted in this metric.
- **ConnectionAttempt** — The number of connection attempts made to a Workspace.

- **ConnectionSuccess** — The number of successful connection attempts.
- **ConnectionFailure** — The number of unsuccessful connection attempts.
- **SessionLaunchTime** — The amount of time taken to initiate a session, as measured by the WorkSpaces client.
- **InSessionLatency** — The round-trip time between the WorkSpaces client and WorkSpaces, as measured and reported by the client.
- **SessionDisconnect** — The number of user-initiated and automatically closed sessions.

Additionally, alarms can be created, as shown in the following figure.

Figure 25: Create CloudWatch alarm for WorkSpaces connection errors

## Amazon CloudWatch Events for WorkSpaces

Events from Amazon CloudWatch Events can be used to view, search, download, archive, analyze, and respond to successful logins to WorkSpaces. The service can monitor client WAN IP addresses, Operating System, WorkSpaces ID, and Directory ID information for users' logins to WorkSpaces. For example, it can use events for the following purposes:

- Store or archive WorkSpaces login events as logs for future reference, analyze the logs to look for patterns, and take action based on those patterns.

- Use the WAN IP address to determine where users are logged in from, and then use policies to allow users access only to files or data from WorkSpaces that meet the access criteria found in the CloudWatch Event type of WorkSpaces Access.
- Use policy controls to block access to files and applications from unauthorized IP addresses.

For more information on how to use CloudWatch Events, refer to the [Amazon CloudWatch Events User Guide](#). To learn more about CloudWatch Events for WorkSpaces, refer to [Monitor your WorkSpaces using Cloudwatch Events](#).

## YubiKey support for Amazon WorkSpaces

In order to add an additional security layer, customers often choose to secure tools and sites with multifactor authentication. Some customers choose to do this with a Yubico YubiKey. Amazon WorkSpaces supports both one-time passcodes (OTP) and FIDO U2F authentication protocol with YubiKeys.


Amazon WorkSpaces currently supports OTP mode, and there are no additional steps required from an administrator or end user to utilize a YubiKey with OTP. The user can attach their YubiKey to their computer, ensure the keyboard is focused within the Workspace (specifically in the field where the OTP needs to be entered), and touch the gold contact on the YubiKey. The YubiKey will automatically enter the OTP into the selected field.

In order to utilize FIDO U2F mode with YubiKey and WorkSpaces, additional steps are required. Ensure your users are issued one of these supported YubiKey models in order to utilize U2F redirection with WorkSpaces:

- YubiKey 4
- YubiKey 5 NFC
- YubiKey 5 Nano
- YubiKey 5C
- YubiKey 5C Nano
- YubiKey 5 NFC

### To enable USB redirection for YubiKey U2F

By default, USB redirection is disabled for PCoIP WorkSpaces; to utilize U2F mode with YubiKeys, you must enable it.

1. Make sure that you've installed the most recent [WorkSpaces Group Policy administrative template for PCoIP \(32-Bit\)](#) or [WorkSpaces Group Policy administrative template for PCoIP \(64-Bit\)](#).
  2. On a directory administration WorkSpace or an Amazon EC2 instance that is joined to your WorkSpaces directory, open the Group Policy Management tool (**gpmc.msc**) and navigate to **PCoIP Session Variables**.
  3. To allow the user to override your setting, choose **Overridable Administrator Defaults**. Otherwise, choose **Not Overridable Administrator Defaults**.
  4. Open the Enable/disable USB in the PCoIP session setting.
  5. Choose **Enabled**, and then choose **OK**.
  6. Open the Configure PCoIP USB allowed and unallowed device rules setting.
  7. Choose **Enabled**, and under **Enter the USB authorization table (maximum ten rules)**, configure your USB device allow list rules.
    - a. Authorization rule - 110500407. This value is a combination of a Vendor ID (VID) and a Product ID (PID). The format for a VID/PID combination is 1xxxxyyyy, where xxxx is the VID in hexadecimal format and yyyy is the PID in hexadecimal format. For this example, 1050 is the VID, and 0407 is the PID. For more YubiKey USB values, refer to [YubiKey USB ID Values](#).
  8. Under Enter the USB authorization table (maximum ten rules), configure your USB device blocklist rules.
    - a. For **Unauthorization Rule**, set an empty string. This means that only USB devices in the authorization list are allowed.
-  **Note**

You can define a maximum of 10 USB authorization rules and a maximum of 10 USB unauthorization rules. Use the vertical bar (|) character to separate multiple rules. For detailed information about the authorization/unauthorization rules, refer to [Teradici PCoIP Standard Agent for Windows](#)
9. Choose **OK**.
  10. The Group Policy setting change takes effect after the next Group Policy update for the WorkSpace and after the WorkSpace session is restarted. To apply the Group Policy changes, do one of the following:
    - a. Reboot the WorkSpace (in the Amazon WorkSpaces console, select the WorkSpace, then choose **Actions, Reboot WorkSpaces**).

b. In an administrative command prompt, enter `gpupdate /force`.

11 After the setting takes effect, all supported USB devices will be able to be redirected to WorkSpaces unless restrictions are configured through the USB device rules setting.

Once you have enabled USB redirection for YubiKey U2F you can utilize your YubiKey with Fido U2F mode.

# Cost optimization

## Self-service WorkSpace management capabilities

In Amazon WorkSpaces, self-service WorkSpace management capabilities can be enabled for users to provide them with more control over their experience. Allowing users self-service capability can reduce your IT support staff workload for Amazon WorkSpaces. When self-service capabilities are enabled, it allows users to perform one or more of the following tasks directly from their Windows, macOS, or Linux client for Amazon WorkSpaces:

- Cache their credentials on their client. This lets users reconnect to their WorkSpace without re-entering their credentials.
- Restart their WorkSpace.
- Increase the size of the root and user volumes on their WorkSpace.
- Change the compute type (bundle) for their WorkSpace.
- Switch the running mode of their WorkSpace.
- Rebuild their WorkSpace.

There are no ongoing cost implications for allowing users the Restart and Rebuild options for their WorkSpaces. Users should be aware that a Rebuild of their WorkSpace will cause their WorkSpace to be unavailable for up to an hour, as the rebuild process takes place.

Options to increase the size of the volumes, change the compute type, and switch the running mode can incur additional costs for WorkSpaces. A best practice is to enable self-service to reduce the workload for the support team. Self-service for additional cost items should be allowed within a workflow process that ensures that authorization for additional charges has been obtained. This can be through a dedicated self-service portal for WorkSpaces, or by integration with existing Information Technology Service Manage (ITSM) services, such as [ServiceNow](#).

For more detailed information, refer to [Enabling Self-Service WorkSpace Management Capabilities for Your Users](#). For an example describing enabling a structured portal for user self-service, refer to [Automate Amazon WorkSpaces with a Self-Service Portal](#).

# Amazon WorkSpaces Cost Optimizer

The Amazon WorkSpaces Cost Optimizer solution analyzes all of your Amazon WorkSpaces usage data. Depending on your usage, it automatically converts the WorkSpace to the most cost-effective billing option (hourly or monthly). This solution helps you monitor your WorkSpace usage and optimize costs, and uses AWS CloudFormation to automatically provision and configure the necessary AWS services to analyze usage every 24 hours and convert individual WorkSpaces. The latest version, 2.4 gives customers the flexibility to deploy the solution in an existing VPC, configure optional for region and termination. It also improved the accuracy of billing hour calculations for WorkSpaces and enhanced reporting metadata. If you have previously deployed an earlier version (v2.2.1 or lower) of this solution, follow the [update stack documentation](#) to update the Amazon WorkSpaces Cost Optimizer CloudFormation stack to get the latest version of the solution's framework.

The *running mode* of a WorkSpace determines its immediate availability and billing. Here are the current running WorkSpaces running mode:

**AlwaysOn** — Use when paying a fixed monthly fee for unlimited usage of WorkSpaces. This mode is best for users who use their WorkSpace as their primary desktop and needs instant access to a running WorkSpace at all times.

**AutoStop** — Use when paying for WorkSpaces by the hour. With this mode, WorkSpaces stop after a specified period of inactivity and the state of apps and data is saved. To set the automatic stop time, use AutoStop Time (hours). This mode is best for users who only need part-time access to their WorkSpaces.

A best practice is to monitor usage and set the Amazon WorkSpaces' running mode to be the most cost effective using a solution such as the [Amazon WorkSpaces Cost Optimizer](#). This solution deploys an [Amazon CloudWatch](#) events rule that invokes an [AWS Lambda](#) function every 24 hours.

This solution can convert individual WorkSpaces from an hourly billing model to a monthly billing model on any day after it meets the threshold. If the solution converts a WorkSpace from hourly billing to monthly billing, the solution does not convert the WorkSpace back to hourly billing until the beginning of the next month, and only if usage was below the threshold. However, the billing model can be manually changed at any time using the AWS Management Console or Amazon WorkSpaces API. The solution's AWS CloudFormation template includes parameters that will run these conversions and allow for running the solution in dry run mode to provide reports of the recommendations.

## Opting out with tags

To prevent the solution from converting a WorkSpace between billing models, apply a resource tag to the WorkSpace using the tag key `Skip_Convert` and any tag value. This solution will log tagged WorkSpaces, but it will not convert the tagged WorkSpaces. Remove the tag at any time to resume automatic conversion for that WorkSpace. For more details, refer to [Amazon WorkSpaces Cost Optimizer](#).

## Opting in regions

By default, this solution will monitor WorkSpaces in all available AWS Region by scanning for directories registered with Amazon WorkSpaces in the same AWS account. You can provide a comma separated list of AWS Regions that you want to monitor in the **List of AWS Regions** input parameter to limit the regions to monitor.

## Deployment in an existing VPC

This solution requires a VPC to run the ECS task. By default, the solution will create a new VPC, but you can deploy in an existing VPC by providing the subnet IDs and security group ID as part of the input parameter. Your current subnet has a route to the Internet for the ECS task to pull the Docker image hosted in a public Amazon ECR repository.

## Termination of unused WorkSpaces

This solution allows you to terminate unused WorkSpaces on the last day of the month when all the criteria have been met. You can opt in to this feature by changing the **TerminateUnusedWorkSpaces** input parameter to the CloudFormation template. A best practice is to run this feature in Dry Run mode for a couple of months and check the monthly reports to review the WorkSpaces marked for termination.

# Amazon Connect Customer Optimization for Amazon WorkSpaces

The end user experience for contact center agents needs to be a top priority because if their audio is degraded, it creates a bad call experience for the customer they are serving. When running a contact center solution within a remote desktop, audio performance will always be impacted on some measurable scale when voice traffic is not prioritized over the network connection. This impact is due to the audio flowing from the audio endpoint to the virtual session and then being compressed over the streaming protocol to be delivered to the end user. This additional routing results in the audio to have degraded performance through network bottlenecks.

An approach to avoid this behavior is to split the audio out of session, meaning all of the contact center agent's resources remain in-session while the audio stream stays out of the session. This split allows the audio to stream from the audio endpoint directly to the end user while all other call resources, including the PII the agent is viewing, to remain in a secure session. This audio optimization is considered a best practice since it ensures the customer's call experience is as good as it can be.

[Amazon Connect Customer](#) offers a [Streams API](#) that allows administrators to customize their [Contact Control Panel](#) (CCP) to meet their business requirements. One of the options an administrator has is to control if the custom CCP can receive audio for the call. These settings allow us to configure a split CCP; an audio-only CCP for out of session and a media-less CCP for in-session. Once administrators have configured these custom CCPs, they are able to leverage [Amazon Connect audio optimization for WorkSpaces](#). Since CCPs are delivered within the browser, this setting allows administrators to provide their audio-only CCP URL to the WorkSpaces directory. Once configured, when WorkSpaces Connect contact center agents successfully authenticate to their WorkSpaces, the WorkSpaces client will automatically open the provided audio-only CCP URL in the agent's local default browser. This action allows the audio to flow directly to the agent's local machine while the media-less CCP handles everything else within the secure WorkSpaces session.

Architecture Diagram

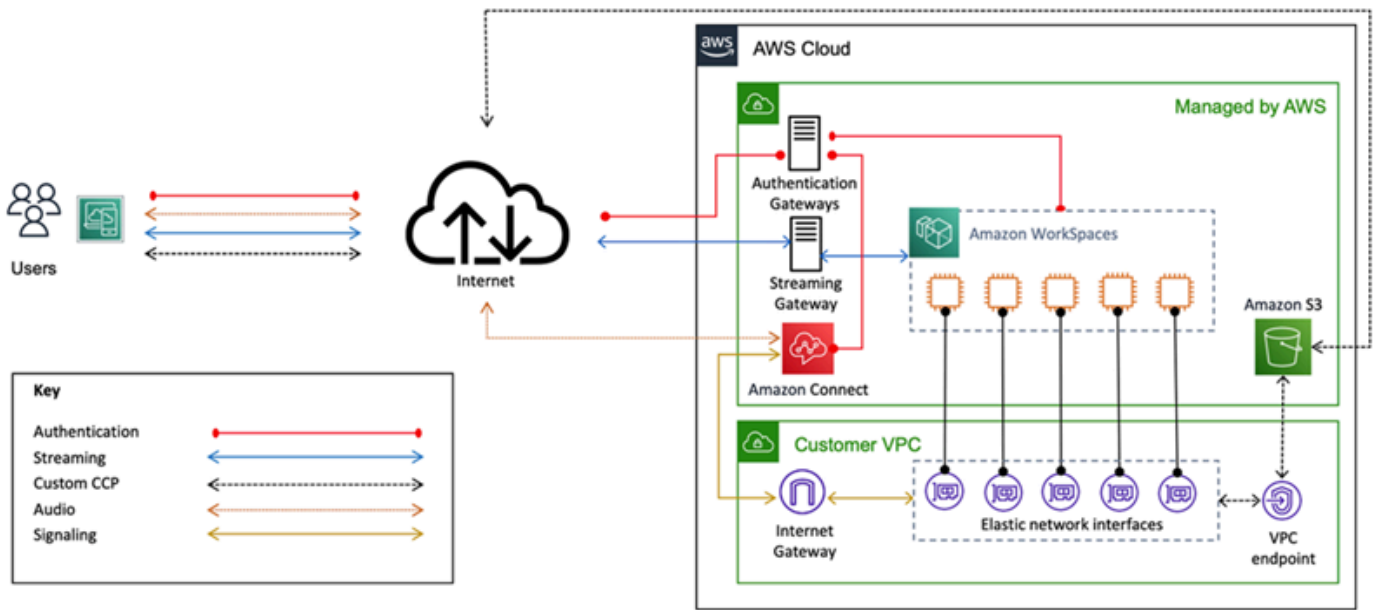


Figure 26 — Connect Customer and WorkSpaces Architecture Diagram

# Troubleshooting

Common administration and client issues, such as error messages such as **Your device is not able to connect to the WorkSpaces Registration service** or **Can't connect to a Workspace with an interactive logon banner**, can be found on the [Client](#) and [Admin Troubleshooting pages](#) in the Amazon WorkSpaces Administration Guide.

## Topics

- [AD Connector cannot connect to Active Directory](#)
- [Troubleshooting A Workspace custom image creation error](#)
- [Troubleshooting a Windows Workspace marked as unhealthy](#)
- [Collecting a WorkSpaces support log bundle for debugging](#)
- [How to check latency to the closest AWS Region](#)

## AD Connector cannot connect to Active Directory

For AD Connector to connect to the on-premises directory, the firewall for the on-premises network must have certain ports open to the CIDRs for both subnets in the VPC. Refer to [Scenario 1: Using AD Connector to Proxy Authentication to On-Premises Active Directory Service](#). To test if these conditions are met, perform the following steps.

### To test the connection:

1. Launch a Windows instance in the VPC and connect to it over RDP. The remaining steps are performed on the VPC instance.
2. Download and unzip the [DirectoryServicePortTest](#) test application. The source code and Microsoft Visual Studio project files are included to modify the test application, if desired.
3. From a Windows command prompt, run the DirectoryServicePortTest test application with the following options:

```
DirectoryServicePortTest.exe -d <domain_name>  
-ip <server_IP_address> -tcp "53,88,135,139,389,445,464,636,49152" -udp  
"53,88,123,137,138,389,445,464" <domain_name>
```

<*domain\_name*> — The fully qualified domain name, used to test the forest and domain functional levels. If the domain name is excluded, the functional levels won't be tested.

<*server\_IP\_address*> — The IP address of a domain controller in the on-premises domain. The ports are tested against this IP address. If the IP address is excluded, the ports won't be tested.

This test determines if the necessary ports are open from the VPC to the domain. The test app also verifies the minimum forest and domain functional levels.

## Troubleshooting A WorkSpace custom image creation error

If a Windows or Amazon Linux WorkSpace has been launched and customized, a custom image can be created from that WorkSpace. A custom image contains the operating system, application software, and settings for the WorkSpace.

Review the [requirements to create a Windows custom image](#) or the [requirements to create an Amazon Linux custom image](#). Image creation requires that all prerequisites are met before image creation can start.

To confirm that the Windows WorkSpace meets the requirements for image creation, we recommend running the Image Checker. The Image Checker performs a series of tests on the WorkSpace when an image is created, and provides guidance on how to resolve any issues it finds. For detailed information, refer to [installing and configuring the image checker](#).

After the WorkSpace passes all tests, a “Validation Successful” message appears. You can now create a custom bundle. Otherwise, resolve any issues that cause test failures and warnings, and repeat the process of running the Image Checker until the WorkSpace passes all tests. All failures and warnings must be resolved before an image can be created.

For more information, follow the [tips for resolving issues detected by the Image Checker](#).

## Troubleshooting a Windows WorkSpace marked as unhealthy

The Amazon WorkSpaces service periodically checks the health of a WorkSpace by sending it a status request. The WorkSpace is marked as Unhealthy if a response isn't received from the WorkSpace in a timely manner. Common causes for this problem are:

- An application on the WorkSpace is blocking network connection between the Amazon WorkSpaces service and the WorkSpace.

- High CPU utilization on the WorkSpace.
- The computer name of the WorkSpace is changed.
- The agent or service that responds to the Amazon WorkSpaces service isn't in running state.

The following troubleshooting steps can return the WorkSpace to a healthy state:

- First, [reboot the WorkSpace](#) from the [Amazon WorkSpaces console](#). If rebooting the WorkSpace doesn't resolve the issue, either use [RDP](#), or connect to an [Amazon Linux WorkSpace using SSH](#).
- If the WorkSpace is unreachable by a different protocol, [rebuild the WorkSpace](#) from the Amazon WorkSpaces console.
- If a WorkSpaces connection cannot be established, verify the following:

## Verify CPU utilization

Use Open Task Manager to determine if the WorkSpace is experiencing high CPU utilization. If it is, try any of the following troubleshooting steps to resolve the issue:

1. Stop any service that is consuming a high amount of CPU.
2. Resize the WorkSpace to a compute type greater than what is currently used.
3. Reboot the WorkSpace.

### Note

To diagnose high CPU utilization, and for guidance if the above steps don't resolve the high CPU utilization issue, refer to [How do I diagnose high CPU utilization on my EC2 Windows instance when my CPU is not throttled?](#)

## Verify the computer name of the WorkSpace

If the computer name of the Workspace was changed, change it back to the original name:

1. Open the Amazon WorkSpaces console, and then expand the Unhealthy WorkSpace to show details.
2. Copy the Computer Name.

3. Connect to the WorkSpace using RDP.
4. Open a command prompt, and then enter hostname to view the current computer name.
  - a. If the name matches the Computer Name from step 2, skip to the next troubleshooting section.
  - b. If the names don't match, enter sysdm.cpl to open system properties, and then follow the remaining steps in this section.
5. Choose **Change**, and then paste the Computer Name from step 2.
6. Enter the domain user credentials if prompted.
7. Confirm that **SkyLightWorkspaceConfigService** is in Running State
  - a. From **Services**, verify that the WorkSpace service SkyLightWorkspaceConfigService is in running state. If it's not, start the service.

## Verify Firewall rules

Confirm that the Windows Firewall and any third-party firewall that is running have rules to allow the following ports:

- Inbound TCP on port 4172: Establish the streaming connection.
- Inbound UDP on port 4172: Stream user input.
- Inbound TCP on port 8200: Manage and configure the WorkSpace.
- Outbound UDP on port 55002: PCoIP streaming.

If the firewall uses stateless filtering, then open ephemeral ports 49152-65535 to allow return communication.

If the firewall uses stateful filtering, then ephemeral port 55002 is already open.

## Collecting a WorkSpaces support log bundle for debugging

When troubleshooting WorkSpaces issues, it is necessary to gather the log bundle from the affected WorkSpace and the host where the WorkSpaces client is installed. There are two fundamental categories of logs:

- **Server-side logs:** The WorkSpace is the server in this scenario, so these are logs that live on the WorkSpace itself.



7. Choose **OK** and close the Windows Registry Editor.
8. Restart the WorkSpace.

## PCoIP server-side logs

All of the PCoIP components write their log files into one of two folders:

- **Primary location:** `C:\ProgramData\Teradici\PCoIPAgent\logs`
- **Archive location:** `C:\ProgramData\Teradici\logs`

Sometimes when working with AWS Support on a complex issue, it is necessary to put the PCoIP Server agent into verbose logging mode. To enable this:

1. Open the following registry key: `HKEY_LOCAL_MACHINE\SOFTWARE\Policies\Teradici\PCoIP\pcoip_admin_defaults`
2. In the `pcoip_admin_defaults` key, create the following 32-bit DWORD:  
`pcoip.event_filter_mode`
3. Set the value for `pcoip.event_filter_mode` to "3" (Dec or Hex).

For reference, these are the log thresholds which can be defined in this DWORD.

- 0 — (CRITICAL)
- 1 — (ERROR)
- 2 — (INFO)
- 3 — (Debug)

If the `pcoip_admin_default` DWORD doesn't exist, the log level is 2 by default. It is recommended to restore a value of 2 to the DWORD after it no longer need verbose logs, as they are much larger and will consume disk space unnecessarily.

## WebAccess server-side logs

For PCoIP and WSP (version 1.0+) WorkSpaces, the WorkSpaces Web Access client uses the STXHD service. The logs for WorkSpaces Web Access are stored at `C:\ProgramData\Amazon\Stxhd\Logs`.

For WSP (version 2.0+) WorkSpaces, the logs for WorkSpaces Web Access are stored at C : \ProgramData\Amazon\WSP\.

## Client-side logs

These logs come from the WorkSpaces client that the user connects with, so the logs are on the end user's computer. The log file locations for Windows and Mac are:

- **Windows:** "%LOCALAPPDATA%\Amazon Web Services\Amazon WorkSpaces\Logs"
- **macOS:** ~/Library/"Application Support"/"Amazon Web Services"/"Amazon WorkSpaces"/logs
- **Linux:** ~/.local/share/Amazon Web Services/Amazon WorkSpaces/logs

To help troubleshoot issues that users might experience, enable advanced logging that can be used on any Amazon WorkSpaces client. Advanced logging is enabled for every subsequent client session until it is disabled.

1. Before connecting to the WorkSpace, the end user should [enable advanced logging](#) for their WorkSpaces client.
2. The end user should then connect as usual, use their WorkSpace, and attempt to reproduce the issue.
3. Advanced logging generates log files that contain diagnostic information and debugging-level details, including verbose performance data.

This setting persists until explicitly turned off. After the user has successfully reproduced the issue with verbose logging on, this setting should be disabled, as it generates large log files.

## Automated server-side log bundle collection for Windows

The Get-WorkSpaceLogs.ps1 script is helpful for quickly gathering a server-side log bundle for AWS Support. The script can be requested from AWS Support by requesting it in a support case:

1. Connect to the WorkSpace using the client or using Remote Desktop Protocol (RDP).
2. Start an administrative Command Prompt (run as administrator). You must have permission to access the C : drive (WorkSpaces Root Volume).
3. Launch the script from the Command Prompt with the following command:

```
powershell.exe -NoLogo -ExecutionPolicy RemoteSigned -NoProfile -File "C:\Program Files\Amazon\WorkSpacesConfig\Scripts\Get-WorkSpaceLogs.ps1"
```

#### 4. The script creates a log bundle on the user's desktop.

The script creates a zip file with the following folders:

- **C** — Contains the files from Program Files, Program Files (x86), ProgramData, and Windows related to Skylight, EC2Config, Teradici, Event viewer, and Windows logs (Panther and others).
- **CliXML** — Contains XML files that can be imported in Powershell by using `Import-CliXML` for interactive filtering. Refer to [Import-Clixml](#).
- **Config** — Detailed logs for each check that is performed
- **ScriptLogs** — Logs about the script execution (not relevant to the investigation, but useful to debug what the script does).
- **tmp** — Temporary folder (it should be empty).
- **Traces** — Packet capture done during the log collection.

We try to ensure this script doesn't collect AWS-related credentials. However, it does collect environmental variables that help AWS with troubleshooting issues. Make sure you review the output before submitting the script to AWS to ensure you don't expose confidential credentials.

## How to check latency to the closest AWS Region

The [Connection Health Check website](#) quickly checks whether all the required services that use Amazon WorkSpaces can be reached. It also does a performance check to each AWS Region where Amazon WorkSpaces is available, and lets users know which one will be the fastest.

## Conclusion

There is a strategic shift in end-user computing, as organizations strive to be more agile, better protect their data, and help their workers be more productive. Many of the benefits already realized with cloud computing also apply to end user computing. By moving their Windows or Linux desktops to the AWS Cloud with Amazon WorkSpaces, organizations can quickly scale as they add workers, improve their security posture by keeping data off devices, and offer their workers a portable desktop, with access from anywhere, using the device of their choice.

Amazon WorkSpaces is designed to be integrated into existing IT systems and processes, and this whitepaper described the best practices for doing this. The result of following the guidelines in this whitepaper is a cost-effective cloud desktop deployment that can securely scale with your business on the AWS global infrastructure.

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## Further reading

For additional information, refer to:

- [Amazon WorkSpaces Administration Guide](#)
- [Amazon WorkSpaces Developer Guide](#)
- [Amazon WorkSpaces Clients](#)
- [Managing Amazon Linux 2 Amazon WorkSpaces with AWS OpsWorks for Puppet Enterprise](#)
- [Customizing the Amazon Linux WorkSpace](#)
- [How to improve LDAP security in AWS Directory Service with client-side LDAPS](#)
- [Use Amazon CloudWatch Events with Amazon WorkSpaces and AWS Lambda for greater fleet visibility](#)
- [How Amazon WorkSpaces uses AWS KMS](#)
- [AWS CLI Command Reference – WorkSpaces](#)
- [Monitoring Amazon WorkSpaces Metrics](#)
- [MATE Desktop Environment](#)
- [Troubleshooting AWS Directory Service Administration Issues](#)
- [Troubleshooting Amazon WorkSpaces Administration Issues](#)
- [Troubleshooting Amazon WorkSpaces Client Issues](#)
- [Automate Amazon WorkSpaces with a Self-Service Portal](#)

# Document revisions

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| Change                             | Description   | Date              |
|------------------------------------|---|-------------------|
| <a href="#">Minor update</a>       | Updated content for AD Directory Services, Disaster Recovery / Business Continuity & Cross Region Redirection. Added WorkSpaces & Connect Customer Audio Optimization. Minor updates to formatting. | May 26, 2022      |
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# AWS Glossary

For the latest AWS terminology, see the [AWS glossary](#) in the *AWS Glossary Reference*.