Implementing Secure Shell

Secure Shell (SSH) is an application and a protocol that provides a secure replacement to the Berkeley r-tools. The protocol secures sessions using standard cryptographic mechanisms, and the application can be used similarly to the Berkeley **rexec** and **rsh** tools.

Two versions of the SSH server are available: SSH Version 1 (SSHv1) and SSH Version 2 (SSHv2). SSHv1 uses Rivest, Shamir, and Adelman (RSA) keys and SSHv2 uses either Digital Signature Algorithm (DSA) keys or Rivest, Shamir, and Adelman (RSA) keys, or Ed25519 keys. Cisco software supports both SSHv1 and SSHv2.

This module describes how to implement Secure Shell.

Feature History for Implementing Secure Shell

Release	Modification
Release 6.0	This feature was introduced.
Release 7.0.1	Support was added for these features: • SSH Configuration Option to Restrict Cipher Public Key and HMAC Algorithm • Automatic Generation of SSH Host-Key Pairs • SSH and SFTP in Baseline Cisco IOS XR Software Image
Release 7.3.1	Support was added for these features: • Ed25519 Public-Key Algorithm Support for SSH • User Configurable Maximum Authentication Attempts for SSH • X.509v3 Certificate-based Authentication for SSH

Information About Implementing Secure Shell

To implement SSH, you should understand the following concepts:

SSH Server

The SSH server feature enables an SSH client to make a secure, encrypted connection to a Cisco router. This connection provides functionality that is similar to that of an inbound Telnet connection. Before SSH, security was limited to Telnet security. SSH allows a strong encryption to be used with the Cisco software authentication. The SSH server in Cisco software works with publicly and commercially available SSH clients.

SSH Client

The SSH client feature is an application running over the SSH protocol to provide device authentication and encryption. The SSH client enables a Cisco router to make a secure, encrypted connection to another Cisco router or to any other device running the SSH server. This connection provides functionality that is similar to that of an outbound Telnet connection except that the connection is encrypted. With authentication and encryption, the SSH client allows for a secure communication over an insecure network.

The SSH client works with publicly and commercially available SSH servers. The SSH client supports the ciphers of AES, 3DES, message digest algorithm 5 (MD5), SHA1, and password authentication. User authentication is performed in the Telnet session to the router. The user authentication mechanisms supported for SSH are RADIUS, TACACS+, and the use of locally stored usernames and passwords.

The SSH client supports setting DSCP value in the outgoing packets.

```
ssh client dscp <value from 0 - 63>
```

If not configured, the default DSCP value set in packets is 16 (for both client and server).

The SSH client supports the following options:

- DSCP—DSCP value for SSH client sessions.

```
RP/0/5/CPU0:router#configure
RP/0/5/CPU0:router(config)#ssh ?
  client   Provide SSH client service
  server   Provide SSH server service
  timeout  Set timeout value for SSH
RP/0/5/CPU0:router(config)#ssh client ?
```

- Knownhost—Enable the host pubkey check by local database.
- Source-interface—Source interface for SSH client sessions.

```
RP/0/5/CPU0:router(config)#ssh client source-interface ?
  ATM                 ATM Network Interface(s)
  BVI                 Bridge-Group Virtual Interface
  Bundle-Ether        Aggregated Ethernet interface(s)
  CEM                 Circuit Emulation interface(s)
  GigabitEthernet     GigabitEthernet/IEEE 802.3 interface(s)
  IMA                 ATM Network Interface(s)
  IMtestmain          IM Test Interface
  Loopback            Loopback interface(s)
  MgmtEth             Ethernet/IEEE 802.3 interface(s)
  Multilink           Multilink network interface(s)
  Null                Null interface
  PFItestmain         PFI Test Interface
  PFItestnothw        PFI Test Not-HW Interface
  PW-Ether            PWHE Ethernet Interface
  PW-IW               PWHE VC11 IP Interworking Interface
  Serial              Serial network interface(s)
  VASILeft            VASI Left interface(s)
  VASIRight           VASI Right interface(s)
  test-bundle-channel Aggregated Test Bundle interface(s)
  tunnel-ipsec        IPSec Tunnel interface(s)
  tunnel-mte          MPLS Traffic Engineering P2MP Tunnel interface(s)
  tunnel-te           MPLS Traffic Engineering Tunnel interface(s)
  tunnel-tp           MPLS Transport Protocol Tunnel interface
RP/0/5/CPU0:router(config)#ssh client source-interface
RP/0/5/CPU0:router(config)#
```

SSH also supports remote command execution as follows:

```
RP/0/5/CPU0:router#ssh ?
  A.B.C.D  IPv4 (A.B.C.D) address
  WORD     Hostname of the remote node
  X:X::X   IPv6 (A:B:C:D...:D) address
  vrf      vrf table for the route lookup
RP/0/5/CPU0:router#ssh 10.1.1.1 ?
  cipher            Accept cipher type
  command           Specify remote command (non-interactive)
  source-interface  Specify source interface
  username          Accept userid for authentication
  <cr>
RP/0/5/CPU0:router#ssh 192.68.46.6 username admin command "show redundancy sum"
Password:


Wed Jan  9 07:05:27.997 PST
    Active Node    Standby Node
    -----------    ------------
       0/4/CPU0        0/5/CPU0 (Node Ready, NSR: Not Configured)

RP/0/5/CPU0:router#
```

SFTP Feature Overview

SSH includes support for standard file transfer protocol (SFTP) , a new standard file transfer protocol introduced in SSHv2. This feature provides a secure and authenticated method for copying router configuration or router image files.

The SFTP client functionality is provided as part of the SSH component and is always enabled on the router. Therefore, a user with the appropriate level can copy files to and from the router. Like the **copy** command, the **sftp** command can be used only in XR EXEC mode.

The SFTP client is VRF-aware, and you may configure the secure FTP client to use the VRF associated with a particular source interface during connections attempts. The SFTP client also supports interactive mode, where the user can log on to the server to perform specific tasks via the Unix server.

The SFTP Server is a sub-system of the SSH server. In other words, when an SSH server receives an SFTP server request, the SFTP API creates the SFTP server as a child process to the SSH server. A new SFTP server instance is created with each new request.

The SFTP requests for a new SFTP server in the following steps:

- The user runs the **sftp** command with the required arguments
- The SFTP API internally creates a child session that interacts with the SSH server
- The SSH server creates the SFTP server child process
- The SFTP server and client interact with each other in an encrypted format
- The SFTP transfer is subject to LPTS policer "SSH-Known". Low policer values will affect SFTP transfer speeds

Note In IOS-XR SW release 4.3.1 onwards the default policer value for SSH-Known has been reset from 2500pps to 300pps. Slower transfers are expected due to this change. You can adjust the lpts policer value for this punt cause to higher values that will allow faster transfers

When the SSH server establishes a new connection with the SSH client, the server daemon creates a new SSH server child process. The child server process builds a secure communications channel between the SSH client and server via key exchange and user authentication processes. If the SSH server receives a request for the sub-system to be an SFTP server, the SSH server daemon creates the SFTP server child process. For each incoming SFTP server subsystem request, a new SSH server child and a SFTP server instance is created. The SFTP server authenticates the user session and initiates a connection. It sets the environment for the client and the default directory for the user.

Once the initialization occurs, the SFTP server waits for the SSH_FXP_INIT message from the client, which is essential to start the file communication session. This message may then be followed by any message based on the client request. Here, the protocol adopts a 'request-response' model, where the client sends a request to the server; the server processes this request and sends a response.

The SFTP server displays the following responses:

- Status Response
- Handle Response
- Data Response
- Name Response

Note The server must be running in order to accept incoming SFTP connections.

RSA Based Host Authentication

Verifying the authenticity of a server is the first step to a secure SSH connection. This process is called the host authentication, and is conducted to ensure that a client connects to a valid server.

The host authentication is performed using the public key of a server. The server, during the key-exchange phase, provides its public key to the client. The client checks its database for known hosts of this server and the corresponding public-key. If the client fails to find the server's IP address, it displays a warning message to the user, offering an option to either save the public key or discard it. If the server's IP address is found, but the public-key does not match, the client closes the connection. If the public key is valid, the server is verified and a secure SSH connection is established.

The IOS XR SSH server and client had support for DSA based host authentication. But for compatibility with other products, like IOS, RSA based host authentication support is also added.

RSA Based User Authentication

One of the method for authenticating the user in SSH protocol is RSA public-key based user authentication. The possession of a private key serves as the authentication of the user. This method works by sending a signature created with a private key of the user. Each user has a RSA keypair on the client machine. The private key of the RSA keypair remains on the client machine.

The user generates an RSA public-private key pair on a unix client using a standard key generation mechanism such as ssh-keygen. The max length of the keys supported is 4096 bits, and the minimum length is 512 bits. The following example displays a typical key generation activity:

```
bash-2.05b$ ssh-keygen -b 1024 -t rsa
Generating RSA private key, 1024 bit long modulus
```

The public key must be in base64 encoded (binary) formats for it to be imported correctly into the router.

Note You can use third party tools available on the Internet to convert the key to the binary format.

Once the public key is imported to the router, the SSH client can choose to use the public key authentication method by specifying the request using the "-o" option in the SSH client. For example:

```
client$ ssh -o PreferredAuthentications=publickey 1.2.3.4
```

If a public key is not imported to a router using the RSA method, the SSH server initiates the password based authentication. If a public key is imported, the server proposes the use of both the methods. The SSH client then chooses to use either method to establish the connection. The system allows only 10 outgoing SSH client connections.

Currently, only SSH version 2 and SFTP server support the RSA based authentication.

Note The preferred method of authentication would be as stated in the SSH RFC. The RSA based authentication support is only for local authentication, and not for TACACS/RADIUS servers.

Authentication, Authorization, and Accounting (AAA) is a suite of network security services that provide the primary framework through which access control can be set up on your Cisco router or access server.

SSHv2 Client Keyboard-Interactive Authentication

An authentication method in which the authentication information is entered using a keyboard is known as keyboard-interactive authentication. This method is an interactive authentication method in the SSH protocol. This type of authentication allows the SSH client to support different methods of authentication without having to be aware of their underlying mechanisms.

Currently, the SSHv2 client supports the keyboard-interactive authentication. This type of authentication works only for interactive applications.

Note The password authentication is the default authentication method. The keyboard-interactive authentication method is selected if the server is configured to support only the keyboard-interactive authentication.

Prerequisites for Implementing Secure Shell

The following prerequisites are required to implement Secure Shell:

- Download the required image on your router. The SSH server and SSH client require you to have a a crypto package (data encryption standard [DES], 3DES and AES) from Cisco downloaded on your router.

Note From Cisco IOS XR Software Release 7.0.1 and later, the SSH and SFTP components are available in the baseline Cisco IOS XR software image itself. For details, see, SSH and SFTP in Baseline Cisco IOS XR Software Image, on page 6.

- Configure user authentication for local or remote access. You can configure authentication with or without authentication, authorization, and accounting (AAA).
- AAA authentication and authorization must be configured correctly for Secure Shell File Transfer Protocol (SFTP) to work.

SSH and SFTP in Baseline Cisco IOS XR Software Image

From Cisco IOS XR Software Release 7.0.1 and later, the management plane and control plane components that were part of the Cisco IOS XR security package (k9sec package) are moved to the base Cisco IOS XR software image. These include SSH, SCP, SFTP and IPSec control plane. However, *802.1X protocol (Port-Based Network Access Control) and* data plane components like MACsec remain as a part of the security package as per the export compliance regulations. This segregation of package components makes the software more modular. It also gives you the flexibility of including or excluding the security package as per your requirements.

The base package and the security package allow FIPS, so that the control plane can negotiate FIPS-approved algorithms.

Restrictions for Implementing Secure Shell

The following are some basic SSH restrictions and limitations of the SFTP feature:

- In order for an outside client to connect to the router, the router needs to have an RSA (for SSHv1 or SSHv2) or DSA (for SSHv2) key pair configured. DSA and RSA keys are not required if you are initiating an SSH client connection from the router to an outside routing device. The same is true for SFTP: DSA and RSA keys are not required because SFTP operates only in client mode.
- In order for SFTP to work properly, the remote SSH server must enable the SFTP server functionality. For example, the SSHv2 server is configured to handle the SFTP subsystem with a line such as **/etc/ssh2/sshd2_config**:
- **subsystem-sftp /usr/local/sbin/sftp-server**
- The SFTP server is usually included as part of SSH packages from public domain and is turned on by default configuration.
- SFTP is compatible with sftp server version OpenSSH_2.9.9p2 or higher.
- RSA-based user authentication is supported in the SSH and SFTP servers. The support however, is not extended to the SSH client.
- Execution shell and SFTP are the only applications supported.
- The SFTP client does not support remote filenames containing wildcards (* ?, []). The user must issue the **sftp** command multiple times or list all of the source files from the remote host to download them on to the router. For uploading, the router SFTP client can support multiple files specified using a wildcard provided that the issues mentioned in the first through third bullets in this section are resolved.
- The cipher preference for the SSH server follows the order AES128, AES192, AES256, and, finally, 3DES. The server rejects any requests by the client for an unsupported cipher, and the SSH session does not proceed.
- Use of a terminal type other than vt100 is not supported, and the software generates a warning message in this case.
- Password messages of “none” are unsupported on the SSH client.
- Files created on the local device lose the original permission information because the router infrastructure does not provide support for UNIX-like file permissions. For files created on the remote file system, the file permission adheres to the umask on the destination host and the modification and last access times are the time of the copy.

Configure SSH

Perform this task to configure SSH.

Note For SSHv1 configuration, Step 1 to Step 4 are required. For SSHv2 configuration, Step to Step 4 are optional.

Note From Cisco IOS XR Software Release 7.0.1 and later, the SSH host-key pairs are auto-generated at the time of router boot up. Hence you need not perform steps 5 to 7 to generate the host keys explicilty. See, Automatic Generation of SSH Host-Key Pairs, on page 10 for details.

SUMMARY STEPS

1. **configure**
2. **hostname** *hostname*
3. **domain name** *domain-name*
4. Use the **commit** or **end** command.
5. **crypto key generate rsa** [**usage keys** | **general-keys**] [*keypair-label*]
6. crypto key generate dsa
7. configure
8. **ssh timeout** *seconds*
9. Do one of the following:
   - **ssh server** [**vrf** *vrf-name*]
   - ssh server v2
10. Use the **commit** or **end** command.
11. show ssh
12. show ssh session details

DETAILED STEPS

Step 1 **configure**

Example:

```
RP/0/RP0/CPU0:router# configure
```

Enters global configuration mode.

Step 2 **hostname** *hostname*

Example:

```
RP/0/RP0/CPU0:router(config)# hostname router1
```

Configures a hostname for your router.

Step 3 **domain name** *domain-name*

Example:

```
RP/0/RP0/CPU0:router(config)# domain name cisco.com
```

Defines a default domain name that the software uses to complete unqualified host names.

Step 4 Use the **commit** or **end** command.

commit —Saves the configuration changes and remains within the configuration session.

end —Prompts user to take one of these actions:

- **Yes** — Saves configuration changes and exits the configuration session.
- **No** —Exits the configuration session without committing the configuration changes.
- **Cancel** —Remains in the configuration session, without committing the configuration changes.

Step 5 **crypto key generate rsa** [**usage keys** | **general-keys**] [*keypair-label*]

Example:

```
RP/0/RP0/CPU0:router# crypto key generate rsa general-keys
```

Generates an RSA key pair. The RSA key modulus can be in the range of 512 to 4096 bits.

- To delete the RSA key pair, use the **crypto key zeroize rsa** command.
- This command is used for SSHv1 only.

Step 6 crypto key generate dsa

Example:

```
RP/0/RP0/CPU0:router# crypto key generate dsa
```

Enables the SSH server for local and remote authentication on the router. The supported key sizes are: 512, 768 and 1024 bits.

- The recommended minimum modulus size is 1024 bits.
- Generates a DSA key pair.

  To delete the DSA key pair, use the **crypto key zeroize dsa** command.
- This command is used only for SSHv2.

Step 7 configure

Example:

```
RP/0/RP0/CPU0:router# configure
```

Enters mode.

Step 8 **ssh timeout** *seconds*

Example:

```
RP/0/RP0/CPU0:router(config)# ssh timeout 60
```

(Optional) Configures the timeout value for user authentication to AAA.

- If the user fails to authenticate itself to AAA within the configured time, the connection is terminated.
- If no value is configured, the default value of 30 seconds is used. The range is from 5 to 120.

Step 9 Do one of the following:

- **ssh server** [**vrf** *vrf-name*]
- ssh server v2

Example:

```
RP/0/RP0/CPU0:router(config)# ssh server v2
```

- (Optional) Brings up an SSH server using a specified VRF of up to 32 characters. If no VRF is specified, the default VRF is used.

  To stop the SSH server from receiving any further connections for the specified VRF, use the **no** form of this command. If no VRF is specified, the default is assumed.

Note The SSH server can be configured for multiple VRF usage.

- (Optional) Forces the SSH server to accept only SSHv2 clients if you configure the SSHv2 option by using the **ssh server v2** command. If you choose the **ssh server v2** command, only the SSH v2 client connections are accepted.

Step 10 Use the **commit** or **end** command.

commit —Saves the configuration changes and remains within the configuration session.

end —Prompts user to take one of these actions:

- **Yes** — Saves configuration changes and exits the configuration session.
- **No** —Exits the configuration session without committing the configuration changes.
- **Cancel** —Remains in the configuration session, without committing the configuration changes.

Step 11 show ssh

Example:

```
RP/0/RP0/CPU0:router# show ssh
```

(Optional) Displays all of the incoming and outgoing SSHv1 and SSHv2 connections to the router.

Step 12 show ssh session details

Example:

```
RP/0/RP0/CPU0:router# show ssh session details
```

(Optional) Displays a detailed report of the SSHv2 connections to and from the router.

Automatic Generation of SSH Host-Key Pairs

This feature brings in the functionality of automatically generating the SSH host-key pairs for the DSA, ECDSA (such as **ecdsa-nistp256**, **ecdsa-nistp384**, and **ecdsa-nistp521**) and RSA algorithms. This in turn eliminates the need for explicitly generating each SSH host-key pair after the router boots up. Because the keys are already present in the system, the SSH client can establish connection with the SSH server soon after

the router boots up with the basic SSH configuration. This is useful especially during zero touch provisioning (ZTP) and Golden ISO boot up scenarios.

Before this automation, you had to execute the **crypto key generate** command to generate the required host-key pairs.

Although the host-key pairs are auto-generated with the introduction of this feature, you still have the flexibility to select only the required algorithms on the SSH server. You can use the **ssh server algorithms host-key** command in XR Config mode to achieve the same. Alternatively, you can also use the existing **crypto key zeroize** command in XR EXEC mode to remove the algorithms that are not required.

Prior to the introduction of this feature, you had to execute the **crypto key generate** command in XR EXEC mode to generate the required host-key pairs.

Note In a system upgrade scenario from version 1 to version 2, the system does not generate the SSH host-key pairs automatically if they were already generated in version 1. The host-key pairs are generated automatically only if they were not generated in version 1.

Configure the Allowed SSH Host-Key Pair Algorithms

When the SSH client attempts a connection with the SSH server, it sends a list of SSH host-key pair algorithms (in the order of preference) internally in the connection request. The SSH server, in turn, picks the first matching algorithm from this request list. The server establishes a connection only if that host-key pair is already generated in the system, and if it is configured (using the **ssh server algorithms host-key** command) as the allowed algorithm.

Note If this configuration of allowed host-key pairs is not present in the SSH server, then you can consider that the SSH server allows all host-key pairs. In that case, the SSH client can connect with any one of the host-key pairs. Not having this configuration also ensures backward compatibility in system upgrade scenarios.

Configuration Example

You may perform this (optional) task to specify the allowed SSH host-key pair algorithm (in this example, **ecdsa**) from the list of auto-generated host-key pairs on the SSH server:

```
/* Example to select the ecdsa algorithm */
Router(config)#ssh server algorithms host-key ecdsa-nistp521
```

Similarly, you may configure other algorithms.

Running Configuration

```
ssh server algorithms host-key ecdsa-nistp521
!
```

Verify the SSH Host-Key Pair Algorithms

Note With the introduction of the automatic generation of SSH host-key pairs, the output of the **show crypto key mypubkey** command displays key information of all the keys that are auto-generated. Before its introduction, the output of this show command displayed key information of only those keys that you explicitly generated using the **crypto key generate** command.

```
Router#show crypto key mypubkey ecdsa
Mon Nov 19 12:22:51.762 UTC
Key label: the_default
Type     : ECDSA General Curve Nistp256
Degree   : 256
Created  : 10:59:08 UTC Mon Nov 19 2018
Data     :
04AC7533 3ABE7874 43F024C1 9C24CC66 490E83BE 76CEF4E2 51BBEF11 170CDB26
14289D03 6625FC4F 3E7F8F45 0DA730C3 31E960FE CF511A05 2B0AA63E 9C022482
6E

Key label: the_default
Type     : ECDSA General Curve Nistp384
Degree   : 384
Created  : 10:59:08 UTC Mon Nov 19 2018
Data     :
04B70BAF C096E2CA D848EE72 6562F3CC 9F12FA40 BE09BFE6 AF0CA179 F29F6407
FEE24A43 84C5A5DE D7912208 CB67EE41 58CB9640 05E9421F 2DCDC41C EED31288
6CACC8DD 861DC887 98E535C4 893CB19F 5ED3F6BC 2C90C39B 10EAED57 87E96F78
B6

Key label: the_default
Type     : ECDSA General Curve Nistp521
Degree   : 521
Created  : 10:59:09 UTC Mon Nov 19 2018
Data     :
0400BA39 E3B35E13 810D8AE5 260B8047 84E8087B 5137319A C2865629 8455928F
D3D9CE39 00E097FF 6CA369C3 EE63BA57 A4C49C02 B408F682 C2153B7F AAE53EF8
A2926001 EF113896 5F1DA056 2D62F292 B860FDFB 0314CE72 F87AA2C9 D5DD29F4
DA85AE4D 1CA453AC 412E911A 419E9B43 0A13DAD3 7B7E88E4 7D96794B 369D6247
E3DA7B8A 5E
```

The following example shows the output for **ed25519**:

```
Router#show crypto key mypubkey ed25519
Wed Dec 16 16:12:21.464 IST
Key label: the_default
Type     : ED25519
Size     : 256
Created  : 15:08:28 IST Tue Oct 13 2020
Data     :
 649CC355 40F85479 AE9BE26F B5B59153 78D171B6 F40AA53D B2E48382 BA30E5A9

Router#
```

Related Topics

Automatic Generation of SSH Host-Key Pairs, on page 10

Associated Commands

- **ssh server algorithms host-key**
- **show crypto key mypubkey**

Ed25519 Public-Key Signature Algorithm Support for SSH

Table 1: Feature History Table

Feature Name	Release Information	Feature Description
Ed25519 Public-Key Signature Algorithm Support for SSH	Release 7.3.1	This algorithm is now supported on Cisco IOS XR 64-bit platforms when establishing SSH sessions. It is a modern and secure public-key signature algorithm that provides several benefits, particularly resistance against several side-channel attacks. Prior to this release, DSA, ECDSA, and RSA public-key algorithms were supported. This command is modified for this feature: ssh server algorithms host-key

This feature introduces the support for Ed25519 public-key algorithm, when establishing SSH sessions, on Cisco IOS XR 64-bit platforms. This algorithm offers better security with faster performance when compared to DSA or ECDSA signature algorithms.

The order of priority of public-key algorithms during SSH negotiation between the client and the server is:

- ecdsa-sha2-nistp256
- ecdsa-sha2-nistp384
- ecdsa-sha2-nistp521
- ssh-ed25519
- ssh-rsa
- ssh-dsa

Restrictions for ED25519 Public Key for SSH

The Ed25519 public key algorithm is not FIPS-certified. That is, if FIPS mode is enabled on the router, the list of public-key algorithms sent during the SSH key negotiation phase does not contain the Ed25519 key. This behavior is applicable only for new SSH connections. Any existing SSH session that has already negotiated Ed25519 public-key algorithm remains intact and continues to execute until the session is disconnected.

Further, if you have configured the router to negotiate only the Ed25519 public-key algorithm (using the **ssh server algorithms host-key** command), and if FIPS mode is also enabled, then the SSH connection to the router fails.

How to Generate Ed25519 Public Key for SSH

To generate Ed25519 public key for SSH, see .

You must also specify Ed25519 as the permitted SSH host-key pair algorithm from the list of auto-generated host-key pairs on the SSH server. For details, see .

To remove the Ed25519 key from the router, use the **crypto key zeroize ed25519** command in XR EXEC mode.

Configure SSH Client

Perform this task to configure an SSH client.

SUMMARY STEPS

1. **configure**
2. **ssh client knownhost** *device* **:** /*filename*
3. Use the **commit** or **end** command.
4. **ssh** {*ipv4-address* | *ipv6-address* | *hostname*} [**username** *user-* **cipher** | **source-interface** *type instance*]

DETAILED STEPS

Step 1 **configure**

Example:

```
RP/0/RP0/CPU0:router# configure
```

Enters global configuration mode.

Step 2 **ssh client knownhost** *device* **:** /*filename*

Example:

```
RP/0/RP0/CPU0:router(config)# ssh client knownhost slot1:/server_pubkey
```

(Optional) Enables the feature to authenticate and check the server public key (pubkey) at the client end.

Note The complete path of the filename is required. The colon (:) and slash mark (/) are also required.

Step 3 Use the **commit** or **end** command.

commit —Saves the configuration changes and remains within the configuration session.

end —Prompts user to take one of these actions:

- **Yes** — Saves configuration changes and exits the configuration session.

- **No** —Exits the configuration session without committing the configuration changes.
- **Cancel** —Remains in the configuration session, without committing the configuration changes.

Step 4 **ssh** {*ipv4-address* | *ipv6-address* | *hostname*} [**username** *user-* **cipher** | **source-interface** *type instance*]

Enables an outbound SSH connection.

- To run an SSHv2 server, you must have a VRF. This may be the default or a specific VRF. VRF changes are applicable only to the SSH v2 server.
- The SSH client tries to make an SSHv2 connection to the remote peer. If the remote peer supports only the SSHv1 server, the peer internally spawns an SSHv1 connection to the remote server.
- The **cipher des** option can be used only with an SSHv1 client.
- The SSHv1 client supports only the 3DES encryption algorithm option, which is still available by default for those SSH clients only.
- If the *hostname* argument is used and the host has both IPv4 and IPv6 addresses, the IPv6 address is used.

- If you are using SSHv1 and your SSH connection is being rejected, the reason could be that the RSA key pair might have been zeroed out. Another reason could be that the SSH server to which the user is connecting to using SSHv1 client does not accept SSHv1 connections. Make sure that you have specified a hostname and domain. Then use the **crypto key generate rsa** command to generate an RSA host-key pair, and then enable the SSH server.
- If you are using SSHv2 and your SSH connection is being rejected, the reason could be that the DSA, RSA host-key pair might have been zeroed out. Make sure you follow similar steps as mentioned above to generate the required host-key pairs, and then enable the SSH server.
- When configuring the RSA or DSA key pair, you might encounter the following error messages:
  - No hostname specified

  You must configure a hostname for the router using the **hostname** command.

  - No domain specified

  You must configure a host domain for the router using the **domain-name** command.
- The number of allowable SSH connections is limited to the maximum number of virtual terminal lines configured for the router. Each SSH connection uses a vty resource.
- SSH uses either local security or the security protocol that is configured through AAA on your router for user authentication. When configuring AAA, you must ensure that the console is not running under AAA by applying a keyword in the global configuration mode to disable AAA on the console.

Note If you are using Putty version 0.63 or higher to connect to the SSH client, set the 'Chokes on PuTTYs SSH2 winadj request' option under SSH > Bugs in your Putty configuration to 'On.' This helps avoid a possible breakdown of the session whenever some long output is sent from IOS XR to the Putty client.

Configuring Secure Shell

The following example shows how to configure SSHv2 by creating a hostname, defining a domain name, enabling the SSH server for local and remote authentication on the router by generating a DSA key pair, bringing up the SSH server, and saving the configuration commands to the running configuration file.

After SSH has been configured, the SFTP feature is available on the router.

From Cisco IOS XR Software Release 7.0.1 and later, the crypto keys are auto-generated at the time of router boot up. Hence, you need to explicitly generate the host-key pair only if it is not present in the router under some scenarios.

```
configure
hostname router1
domain name cisco.com
exit
crypto key generate rsa/dsa
configure
ssh server
end
```

Configuring CBC Mode Ciphers

In Cisco IOS XR Release 7.0.1, you can enable CBC mode ciphers 3DES-CBC and AES-CBC for SSHv2 server and client connections. The ciphers are disabled by default.

Step 1 **configure**

Example:

```
RP/0/RP0/CPU0:router# configure
```

Enters global configuration mode.

Step 2 **ssh server enable cipher aes-cbc 3des-cbc**

Example:

```
Router(config)# ssh server enable cipher aes-cbc 3des-cbc
```

Step 3 **ssh client enable cipher aes-cbc 3des-cbc**

Example:

```
Router(config)# ssh client enable cipher aes-cbc 3des-cbc
```

Step 4 Use the **commit** or **end** command.

commit —Saves the configuration changes and remains within the configuration session.

end —Prompts user to take one of these actions:

- **Yes** — Saves configuration changes and exits the configuration session.
- **No** —Exits the configuration session without committing the configuration changes.

- **Cancel** —Remains in the configuration session, without committing the configuration changes.

Step 5 **show ssh session details**

Example:

```
Router# show ssh session details
```

Configuring CBC Mode Ciphers

```
/*Enable CBC mode ciphers 3DES-CBC and AES-CBC */
Router# configure
Router(config)# ssh server enable cipher aes-cbc 3des-cbc
Router(config)# ssh client enable cipher aes-cbc 3des-cbc
Router(config)# commit
```

Verify CBC Mode Cipher Configuration.

```
Router# show ssh session details

Thu Sep  6 10:16:26.346 UTC
SSH version : Cisco-2.0

id  key-exchange        pubkey    incipher    outcipher   inmac         outmac
------------------------------------------------------------------------------
Incoming Session
2   ecdh-sha2-nistp256  ssh-rsa   aes128-cbc  aes128-cbc  hmac-sha2-256 hmac-sha2-256
```

Multi-channeling in SSH

The multi-channeling (also called multiplexing) feature on the Cisco IOS XR software server allows you to establish multiple channels over the same TCP connection. Thus, rather than opening a new TCP socket for each SSH connection, all the SSH connections are multiplexed into one TCP connection. For example, with multiplexing support on your XR software server, on a single SSH connection you can simultaneously open a pseudo terminal, remotely execute a command and transfer a file using any file transfer protocol. Multiplexing offers the following benefits:

- You are required to authenticate only once at the time of creating the session. After that, all the SSH clients associated with a particular session use the same TCP socket to communicate to the server.
- Saves time consumed otherwise wasted in creating a new connection each time.

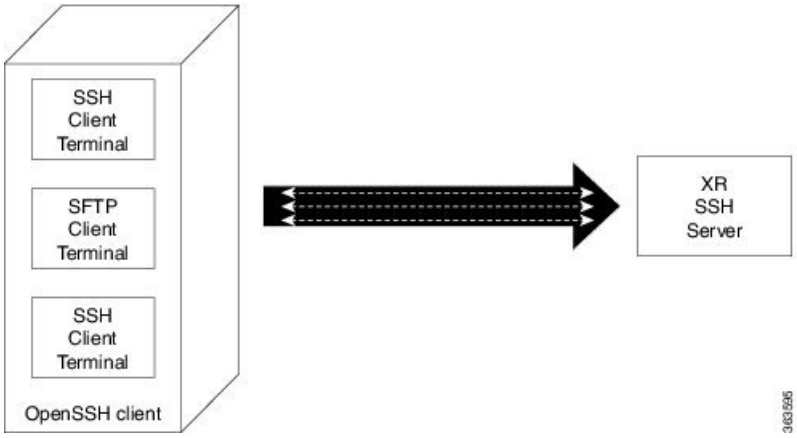
Multiplexing is enabled by default in the Cisco IOS XR software server. If your client supports multiplexing, you must explicitly set up multiplexing on the client for it to be able to send multi-channel requests to the server. You can use OpenSSH, Putty, Perl, WinSCP, Putty, FileZilla, TTSSH, Cygwin or any other SSH-based tool to set up multiplexing on the client. Configure Client for Multiplexing, on page 18 provides an example of how you can configure the client for multiplexing using OpenSSH.

Restrictions for Multi-channeling Over SSH

- Do not use client multiplexing for heavy transfer of data as the data transfer speed is limited by the TCP speed limit. Hence, for a heavy data transfer it is advised that you run multiple SSH sessions, as the TCP speed limit is per connection.
- Client multiplexing must not be used for more than 15 concurrent channels per session simultaneously.
- You must ensure that the first channel created at the time of establishing the session is always kept alive in order for other channels to remain open.
- The **line template default session-limit** command is not supported for SSH.

Client and Server Interaction Over Multichannel Connection

The following figure provides an illustration of a client-server interaction over a SSH multichannel connection.



As depicted in the illustration,

- The client multiplexes the collection of channels into a single connection. This allows different operations to be performed on different channels simultaneously. The dotted lines indicate the different channels that are open for a single session.
- After receiving a request from the client to open up a channel, the server processes the request. Each request to open up a channel represents the processing of a single service.

Note The Cisco IOS XR software supports server-side multiplexing only.

Configure Client for Multiplexing

The SSH client opens up one TCP socket for all the connections. In order to do so, the client multiplexes all the connections into one TCP connection. Authentication happens only once at the time of creating the session. After that, all the SSH clients associated with the particular session uses the same TCP socket to communicate to the server. Use the following steps to configure client multiplexing using OpenSSH:

1. Edit the ssh_config file.

Open the ssh_config file with your favorite text editor to configure values for session multiplexing. The system-wide SSH configuration file is located under /etc/ssh/ssh_config. The user configuration file is located under ~/.ssh/config or $HOME/.ssh/config.

2. Add entries **ControlMaster auto** and **ControlPath**

   Add the entry ControlMaster auto and ControlPath to the ssh_config file, save it and exit.

   - ControlMaster determines whether SSH will listen for control connections and what to do about them. Setting the ControlMaster to 'auto' creates a primary session automatically but if there is a primary session already available, subsequent sessions are automatically multiplexed.
   - ControlPath is the location for the control socket used by the multiplexed sessions. Specifying the ControlPath ensures that any time a connection to a particular server uses the same specified primary connection.

     Example:

     ```
     Host *
     ControlMaster auto
     ControlPath ~/.ssh/tmp/%r@%h:%p
     ```

3. Create a temporary folder.

   Create a temporary directory inside the /.ssh folder for storing the control sockets.

User Configurable Maximum Authentication Attempts for SSH

Table 2: Feature History Table

Feature Name	Release Information	Feature Description
User Configurable Maximum Authentication Attempts for SSH	Release 7.3.1	This feature allows you to set a limit on the number of user authentication attempts allowed for SSH connection, using the three authentication methods that are supported by Cisco IOS XR. The limit that you set is an overall limit that covers all the authentication methods together. If the user fails to enter the correct login credentials within the configured number of attempts, the connection is denied and the session is terminated. This command is introduced for this feature: ssh server max-auth-limit

The three SSH authentication methods that are supported by Cisco IOS XR are public-key (which includes certificate-based authentication), keyboard-interactive, and password authentication. The limit count that you set as part of this feature comes into effect whichever combination of authentication methods you use. The

limit ranges from 3 to 20; default being 20 (prior to Cisco IOS XR Software Release 7.3.2, the limit range was from 4 to 20).

Restrictions for Configuring Maximum Authentication Attempts for SSH

These restrictions apply to configuring maximum authentication attempts for SSH:

- This feature is available only for Cisco IOS XR routers functioning as SSH server; not for the ones functioning as SSH clients.
- This configuration is not user-specific; the limit remains same for all the users.
- Due to security reasons, the SSH server limits the number of authentication attempts that explicitly uses the password authentication method to a maximum of 3. You cannot change this particular limit of 3 by configuring the maximum authentication attempts limit for SSH.

  For example, even if you configure the maximum authentication attempts limit as 5, the number of authentication attempts allowed using the password authentication method still remain as 3.

Configure Maximum Authentication Attempts for SSH

You can use the **ssh server max-auth-limit** command to specify the maximum number of authentication attempts allowed for SSH connection.

Configuration Example

```
Router#configure
Router(config)#ssh server max-auth-limit 5
Router(config)#commit
```

Running Configuration

```
Router#show running-configuration ssh
ssh server max-auth-limit 5
ssh server v2
!
```

Verification

The system displays the following SYSLOG on the router console when maximum authentication attempts is reached:

```
RP/0/RP0/CPU0:Oct 6 10:03:58.029 UTC: SSHD_[68125]: %SECURITY-SSHD-3-ERR_GENERAL : Max
authentication tries reached-exiting
```

Associated Commands

- **ssh server max-auth-limit**

X.509v3 Certificate-based Authentication for SSH

Table 3: Feature History Table

Feature Name	Release Information	Feature Description
X.509v3 Certificate-based Authentication for SSH	Release 7.3.1	This feature adds new public-key algorithms that use X.509v3 digital certificates for SSH authentication. These certificates use a chain of signatures by a trusted certification authority to bind a public key to the digital identity of the user who is authenticating with the SSH server. These certificates are difficult to falsify and therefore used for identity management and access control across many applications and networks. Commands introduced for this feature are: ssh server certificate ssh server trustpoint This command is modified for this feature: ssh server algorithms host-key

This feature adds new public-key algorithms that use X.509v3 digital certificates for SSH authentication. This feature support is available for the SSH server for server and user authentication.

The X.509v3 certificate-based authentication for SSH feature supports the following public-key algorithms:

- **x509v3-ssh-dss**
- **x509v3-ssh-rsa**
- **x509v3-ecdsa-sha2-nistp256**
- **x509v3-ecdsa-sha2-nistp384**
- **x509v3-ecdsa-sha2-nistp521**

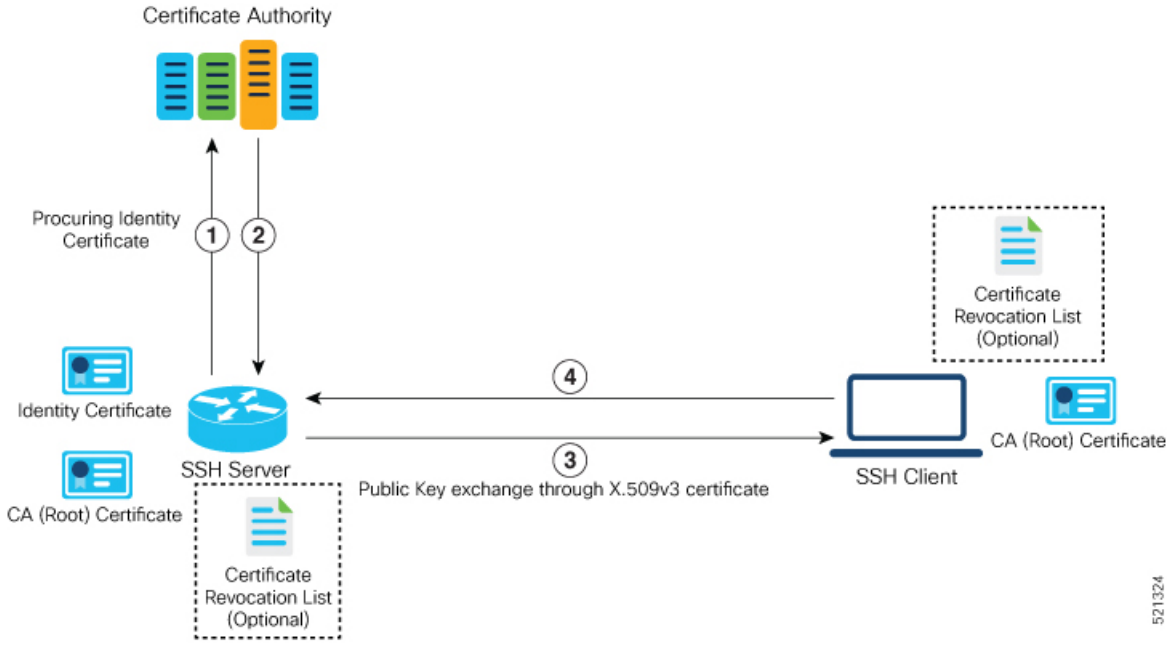
Note While user authentication by using X.509v3 certificate-based authentication for the SSH server is supported using all algorithms listed above, server authentication is supported only with the **x509v3-ssh-rsa** algorithm.

There are two SSH protocols that use public-key cryptography for authentication:

- Transport Layer Protocol (TLP) described in RFC4253—this protocol mandates that you use a digital signature algorithm (called the public-key algorithm) to authenticate the server to the client.
- User Authentication Protocol (UAP) described in RFC4252—this protocol allows the use of a digital signature to authenticate the client to the server (public-key authentication).

For TLP, the Cisco IOS XR SSH server provides its server certificate to the client, and the client verifies the certificate. Similarly, for UAP, the client provides an X.509 certificate to the server. The peer checks the validity and revocation status of the certificate. Based on the result, access is allowed or denied.

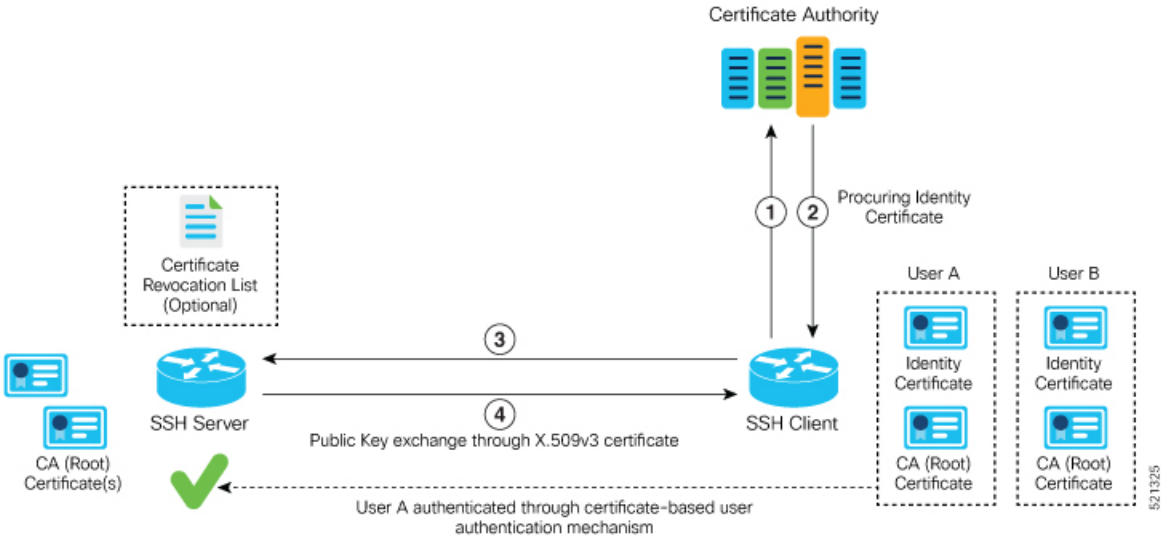
Server Authentication using X.509v3 Certificate



The server authentication process involves these steps:

1. The SSH server procures a valid identity certificate from a well-known certificate authority. This certificate can be obtained manually (through cut-and-paste mechanism) or through protocol implementations such as Simple Certificate Enrollment Protocol (SCEP).
2. The certificate authority provides valid identity certificates and associated root certificates. The requesting device stores these certificates locally.
3. The SSH server presents the certificate to the SSH client for verification.
4. The SSH client validates the certificate and starts the next phase of the SSH connection.

User Authentication using X.509v3 Certificate



The user authentication phase starts after the SSH transport layer is established. At the beginning of this phase, the client sends the user authentication request to the SSH server with required parameters. The user authentication process involves these steps:

1. The SSH client requests a valid identity certificate from a well-known certificate authority.
2. The certificate authority provides valid identity certificates and associated root certificates. The requesting device stores these certificates locally.
3. The SSH client presents the certificate to the SSH server for verification.
4. The SSH server validates the certificate and starts the next phase of the SSH connection.

The certificate-based authentication uses public key as the authentication method. The certificate validation process by the SSH server involves these steps:

- The SSH server retrieves the user authentication parameters, verifies the certificate, and also checks for the certificate revocation list (CRL).
- The SSH server extracts the *username* from the certificate attributes, such as *subject name* or *subject alternate name* (SAN) and presents them to the AAA server for authorization.
- The SSH server then takes the extracted *username* and validates it against the incoming *username* string present in the SSH connection parameter list.

Restrictions for X.509v3 Certificate-based Authentication for SSH

These restrictions apply to the X.509v3 certificate-based authentication feature for SSH:

- Supported only for Cisco IOS XR devices acting as the SSH server; not for the Cisco IOS XR devices acting as the SSH client.
- Supported only for local users because TACACS and RADIUS server do not support public-key authentication. As a result, you must include the **local** option for AAA authentication configuration.

Note Although this feature supports only local authentication, you can enforce remote authorization and accounting using the TACACS server.

- Certificate verification using the Online Certificate Status Protocol (OCSP) is currently not supported. The revocation status of certificates is checked using a certificate revocation list (CRL).
- To avoid user authentication failure, the chain length of the user certificate must not exceed the maximum limit of 9.

Configure X.509v3 Certificate-based Authentication for SSH

To enable X.509v3 certificate-based authentication for SSH, these tasks for server and user authentication:

Server Authentication:

- Configure the list of host key algorithms—With this configuration, the SSH server decides the list of host keys to be offered to the client. In the absence of this configuration, the SSH server sends all available algorithms to the user as host key algorithms. The SSH server sends these algorithms based on the availability of the key or the certificate.
- Configure the SSH trust point for server authentication—With this configuration, the SSH server uses the given trust point certificate for server authentication. In the absence of this configuration, the SSH server does not send **x509v3-ssh-rsa** as a method for server verification. This configuration is not VRF-specific; it is applicable to SSH running in all VRFs.

  The above two tasks are for server authentication and the following ones are for user authentication.

User Authentication:

- Configure the trust points for user authentication—With this configuration, the SSH server uses the given trust point for user authentication. This configuration is not user-specific; the configured trust points are used for all users. In the absence of this configuration, the SSH server does not authenticate using certificates. This configuration is not specific to a VRF; it is applicable to SSH running in all VRFs.

  You can configure up to ten user trust points.
- Specify the *username* to be picked up from the certificate—This configuration specifies which field in the certificate is to be considered as the *username*. The **common-name** from the **subject name** or the **user-principle-name(othername)** from the **subject alternate name**, or both can be configured.
- Specify the maximum number of authentication attempts allowed by the SSH server—The value ranges from 4 to 20. The default value is 20. The server closes the connection if the number of user attempts exceed the configured value.
- AAA authentication configuration—The AAA configuration for public key is the same as that for the regular or keyboard-interactive authentication, except that it mandates local method in the authentication method list.

Configuration Example

In this example, the **x509v3-ssh-rsa** is specified as the allowed host key algorithm to be sent to the client. Similarly, you can configure other algorithms, such as **ecdsa-sha2-nistp521, ecdsa-sha2-nistp384, ecdsa-sha2-nistp256, ssh-rsa**, and **ssh-dsa**.

```
/* Configure the lits of host key algorithms */
Router#configure
Router(config)#ssh server algorithms host-key x509v3-ssh-rsa
Router(config)#commit


/* Configure the SSH trustpoint for server authentication */
Router#configure
Router(config)#ssh server certificate trustpoint host tp1
Router(config)#commit


/* Configure the trustpoints to be used for user authentication */
Router#configure
Router(config)#ssh server trustpoint user tp1
Router(config)#ssh server trustpoint user tp2
Router(config)#commit


/* Specifies the username to be picked up from the certificate.
In this example, it specifies the user common name to be picked up from the subject name
field */
Router#configure
Router(config)#ssh server certificate username common-name
Router(config)#commit


/* Specifies the maximum authentication limit for the SSH server */
Router#configure
Router(config)#ssh server max-auth-limit 5
Router(config)#commit


/* AAA configuration for local authentication with certificate and
remote authorization with TACACS+ or RADIUS */
Router#configure
Router(config)#aaa authentication login default group tacacs+ local
Router(config)#aaa authorization exec default group radius group tacacs+
Router(config)#commit
```

Running Configuration

```
ssh server algorithms host-key x509v3-ssh-rsa
!
ssh server certificate trustpoint host tp1
!
ssh server trustpoint user tp1
ssh server trustpoint user tp2
!
ssh server certificate username common-name
!
ssh server max-auth-limit 5
!
```

Verification of Certificate-based Authentication for SSH

You can use the **show ssh server** command to see various parameters of the SSH server. For certificate-based authentication for SSH, the **Certificate Based** field displays *Yes*. Also, the two new fields, **Host Trustpoint** and **User Trustpoints**, display the respective trust point names.

```
Router#show ssh server
Wed Feb 19 15:23:38.752 IST
---------------------
SSH Server Parameters
---------------------

Current supported versions := v2
                  SSH port := 22
                  SSH vrfs := vrfname:=default(v4-acl:=, v6-acl:=)
              Netconf Port := 830
              Netconf Vrfs := vrfname:=default(v4-acl:=, v6-acl:=)

 Algorithms
---------------
        Hostkey Algorithms := x509v3-ssh-rsa,
ecdsa-sha2-nistp521,ecdsa-sha2-nistp384,ecdsa-sha2-nistp256,ssh-rsa,ssh-dsa
   Key-Exchange Algorithms :=
ecdh-sha2-nistp521,ecdh-sha2-nistp384,ecdh-sha2-nistp256,diffie-hellman-group14-sha1
     Encryption Algorithms :=
aes128-ctr,aes192-ctr,aes256-ctr,aes128-gcm@openssh.com,aes256-gcm@openssh.com
            Mac Algorithms := hmac-sha2-512,hmac-sha2-256,hmac-sha1

 Authetication Method Supported
------------------------------------
                 PublicKey := Yes
                  Password := Yes
      Keyboard-Interactive := Yes
         Certificate Based := Yes

 Others
------------
                     DSCP  := 16
                Ratelimit  := 60
             Sessionlimit  := 100
                Rekeytime  := 60
       Server rekeyvolume  := 1024
  TCP window scale factor  := 1
            Backup Server  := Enabled, vrf:=default, port:=11000
Host Trustpoint            := tp1
User Trustpoints           := tp1 tp2
```

You can use the **show ssh session details** command to see the chosen algorithm for an SSH session:

```
Router#show ssh session details
Wed Feb 19 15:33:00.405 IST
SSH version : Cisco-2.0

id      key-exchange           pubkey               incipher    outcipher   inmac
outmac
-----------------------------------------------------------------------------------------------

Incoming Sessions
1       ecdh-sha2-nistp256     x509v3-ssh-rsa       aes128-ctr  aes128-ctr  hmac-sha2-256
hmac-sha2-256
```

Similarly, you can use the **show ssh** command to verify the authentication method used. In this example, it shows as *x509-rsa-pubkey*:

```
Router#show ssh
Sun Sep 20 18:14:04.122 UTC
SSH version : Cisco-2.0

id  chan pty  location   state        userid    host          ver authentication connection
 type
-----------------------------------------------------------------------------------------------
Incoming sessions
4   1    vty0 0/RP0/CPU0 SESSION_OPEN  9chainuser 10.105.230.198 v2  x509-rsa-pubkey
Command-Line-Interface

Outgoing sessions
```

SYSLOGS

You can observe relevant SYSLOGS on the router console in various scenarios listed here:

- On successful verification of peer certificate:

```
RP/0/RP0/CPU0:Aug 10 15:01:34.793 UTC: locald_DLRSC[133]: %SECURITY-PKI-6-LOG_INFO :
Peer certificate verified successfully
```

- When user certificate CA is not found in the trust point:

```
RP/0/RP0/CPU0:Aug  9 22:06:43.714 UTC: locald_DLRSC[260]: %SECURITY-PKI-3-ERR_GENERAL
: issuer not found in trustpoints configured
RP/0/RP0/CPU0:Aug  9 22:06:43.714 UTC: locald_DLRSC[260]: %SECURITY-PKI-3-ERR_ERRNO :
Error:='Crypto Engine' detected the 'warning' condition 'Invalid trustpoint or trustpoint
 not exist'(0x4214c000), cert verificationn failed
```

- When there is no CA certificate or host certificate in the trust point:

```
RP/0/RP1/CPU0:Aug 10 00:23:28.053 IST: SSHD_[69552]: %SECURITY-SSHD-4-WARNING_X509 :
could not get the host cert chain, 'sysdb' detected the 'warning' condition 'A SysDB
client tried to access a nonexistent item or list an empty directory', x509 host auth
will not be used
RP/0/RP1/CPU0:Aug 10 00:23:30.442 IST: locald_DLRSC[326]: %SECURITY-PKI-3-ERR_ERRNO :
Error:='Crypto Engine' detected the 'warning' condition 'Invalid trustpoint or trustpoint
 not exist'(0x4214c000), Failed to get trustpoint name from
```

How to Disable X.509v3 Certificate-based Authentication for SSH

- Server Authentication — You can disable X.509v3 certificate-based server authentication for SSH by using the **ssh server algorithms host-key** command. From the list of auto-generated host-key pairs algorithms on the SSH server, this command configures allowed SSH host-key pair algorithms. Hence, if you have this configuration without specifying the **x509-ssh-rsa** option in the preceding command, it is equivalent to disabling the X.509v3 certificate-based server authentication for the SSH server.
- User Authentication — You can remove the user trust point configuration (**ssh server trustpoint user**) so that the SSH server does not allow the X.509v3 certificate-based authentication.

Failure Modes for X.509v3 Certificate-based Authentication for SSH

If the **ssh server certificate trustpoint host** configuration is missing, or if the configuration is present, but the router certificate is not present under the trust point, then the SSH server does not add **x509-ssh-rsa** to the list of supported host key methods during key exchange.

Also, the user authentication fails with an error message if:

- User certificate is in an incorrect format.
- The chain length of the user certificate is more than the maximum limit of 9.
- Certificate verification fails due to any reason.

Related Topics

- X.509v3 Certificate-based Authentication for SSH, on page 21

Associated Commands

- **ssh server algorithms hostkey**
- **ssh server certificate username**
- **ssh server max-auth-limit**
- **ssh server trustpoint host**
- **ssh server trustpoint user**
- **show ssh server**
- **show ssh session details**

OpenSSH Certificate based Authentication for Router

Table 4: Feature History Table

Feature Name	Release Information	Feature Description
OpenSSH Certificate based Authentication for Router	Release 7.5.3	You can now use OpenSSH certificates to authenticate to the remote routers from a client machine. This feature uses the ssh-keygen utility, a standard SSH component to generate and manage authentication keys, available in OpenSSH to create a CA (Certificate Authority) like infrastructure for logging into the router. In this feature, the certificates that are used to authenticate router and client are both signed by the same CA. This automatically establishes trust between router and client, and eliminates the need to establish trust, while using the client for remote logging to router for the first time.

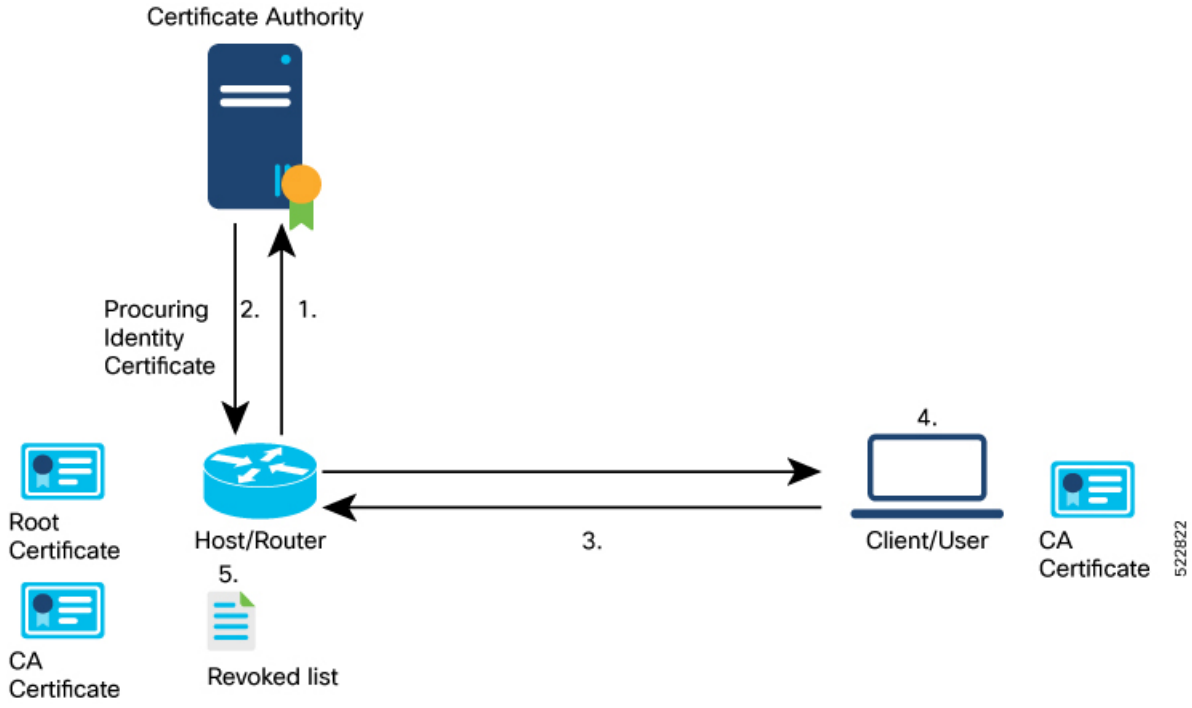
OpenSSH is the open-source implementation of the SSH Protocol. In OpenSSH certificate-based authentication, you can use the ssh-keygen utility to create a certificate signing infrastructure. A digital certificate with public and private key pair, created using the ssh-keygen utility, authenticates the host and the user certificates. The user certificate authenticates the client machine to the router. The client machine is a system that the user utilizes to establish remote access to the router. When a user attempts to log in to the router using the client machine, the client machine presents its certificate to the router. The router checks for the identity and validity of the certificate to decide whether to allow or deny the connection request. The host certificate in the router authenticates the router to the client. Overall, the host and user certificates together establish a two-way secure communication channel.

The OpenSSH based authentication for the router has the following major phases:

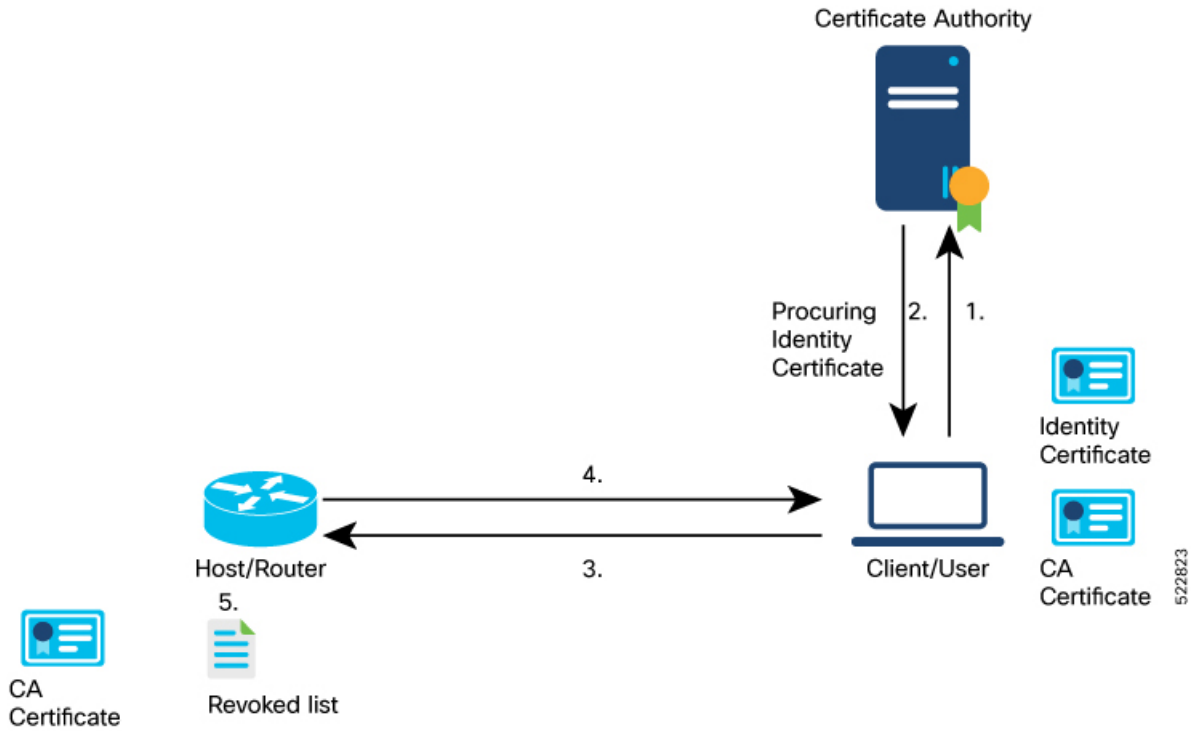
Establishing the trustpoints: In the router, you must create a trustpoint and configure the router to use this trustpoint for the host and user authentication. You can have a same or different trustpoints for these entities. While the router can have only one trustpoint, the user can have up to ten trustpoints.

Creating the CA: Any system with the OpenSSH feature acts like the CA. The ssh-keygen creates the CA certificate and utilizes it to sign the router and user certificate.

Router authentication: You must copy the CA public key in the CA server to the router and ensure to create a CSR (Certificate Signing Request) in the router. The CSR file is further copied to the CA server and signed using the CA certificate. The CA signed certificate is copied back to the router to complete its authentication with CA.



User authentication: You must create a digital certificate for the user using the ssh-keygen utility and sign the public key using the CA certificate. The CA signed user certificate must be copied to the client system using which you would log into the router using the specified user.



Remote access to the router: After the host and user authentication, you can access the router using SSH in the client system that is used to authenticate the user.

Feature Highlights

- OpenSSH certificates use the Certificate Authority (CA) infrastructure to act as a trusted entity while signing the host or user certificates.
- OpenSSH certificates contain a public and private key pair, including identity and validity information. These are signed using a standard SSH public key using the ssh-keygen utility.
- The router certificate includes information such as the host public key, public key of the signing CA, type (host), certificate validity, Key ID, serial number of the certificate, and so on.
- The user certificate contains the user's public key, the public key of the signing CA, Key ID, type (user), serial number, certificate validity, principals matched against the login username, and so forth.
- The CA is just another SSH key created using the ssh-keygen utility. However, rather than utilizing it for authenticating the router or user directly, it's used to sign and validate the other keys that are used for authenticating the router and the user.
- You can view the router and user certificate properties using the ssh-keygen.
- The OpenSSH certificates support the following encryptions:
  - RSA
  - DSA
  - ECDSA
  - ED25519

Prerequisites

- You must have a client machine which has OpenSSH feature with the **ssh-keygen** utility to act as CA.

Configuration Example

The following high-level steps help you set up OpenSSH based Authentication:

1. Create a trustpoint in the router and configure the router to use this trustpoint for the host and user authentication.
2. Creating CA, the CA here is a dedicated system with OpenSSH feature that provides a certificate signing infrastructure using the ssh-keygen utility.
3. Host authentication, the host here is the Cisco IOS XR router.
4. User authentication, a user is any entity attempting to access the router. Generally refers to system to access the router CLI remotely. User is also referred to as client.
5. Access the router in the client using the OpenSSH authentication

This section contains the detailed procedure to enable this feature in your router.

1. Create a trustpoint in the router and configure the router to use this trustpoint for the host and user authentication.

   a. [Router Config mode] Create a trustpoint in the router.

   ```
   Router# config
   Router(config)# crypto ca openssh trustpoint test
   Router(config)# commit
   ```

   b. [Router Config mode] Configure the trustpoint for host authentication.

   ```
   Router# config
   Router(config)# ssh server openssh trustpoint host test
   Router(config)# commit
   ```

   c. [Router Config mode] Configure the trustpoint for user authentication

   ```
   Router# config
   Router(config)# ssh server openssh trustpoint user test
   Router(config)# commit
   ```

2. Creating CA

   a. [CA Server] In the dedicated machine with OpenSSH feature to act as CA, generate a certificate using the **ssh-keygen** utility:

   ```
   [root@CAServer test]# ssh-keygen -t rsa -f cacert
   Generating public/private rsa key pair.
   Enter passphrase (empty for no passphrase):
   Enter same passphrase again:
   Your identification has been saved in cacert.
   Your public key has been saved in cacert.pub.
   The key fingerprint is:
   SHA256:/B2b8V7jKXwGphf75fkO74U/mpuHgDHmvF4okexdKhY root@CAServer
   The key's randomart image is:
   +---[RSA 2048]----+
   |                 |
   |                 |
   |                 |
   |      ...+       |
   |       ES +.o    |
   |      . +=+o X . |
   |       = +o.O O.+|
   |      . o... B+@*|
   |        ..  .=XBX|
   +----[SHA256]-----+

   [root@CAServer test]# ls
   cacert  cacert.pub
   ```

Note Leave the passphrase empty.

3. Host (Router) authentication

   a. [CA Server] Open the CA public key from CA server and copy it contents.

   ```
   [root@CAServer test]# cat cacert.pub
   ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCigl/zhyjuGOBYz5bu+GL76
   HBaROV0pVS4Lx3pf1jcjrFkVibPKKkVeX/lE7sZIJ0anU9vYSJZW8zrl8z06G
   ```

```
qzmnJqRRaXa9vfwNmjvNdRwxuBA3Uk/G1sbmcusMXBXoY6z0IEMhlVN0hCqE4
cIFgLxgHpYAaqyl2hISaomTCNhkbD770Ot8zbyRjl6G0Ps0ggYHWmfLZf/tbF
IBPWpuuuA3LvpZIiTaztevQaWYSyK22h3tp3K62IOBX3gUd4Yr+Gvo4PNA26e
21cUE2aVJsl6J9MeFITR2NzY1cmZ44KWi6bglkPlE4KBiRsbHCvs4wlaUaO5q
hNj1BdH3/Hha4x root@CAServer
```

b. [Router EXEC mode] Add the contents of the CA public key to router trustpoint.

```
Router#crypto ca openssh authenticate test
Enter the CA pubkey.
End with a blank line or the word "quit" on a line by itself
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCigl/zhyjuGOBYz5bu+GL7
6HBaROV0pVS4Lx3pf1jcjrFkVibPKKkVeX/lE7sZIJ0anU9vYSJZW8zrl8z0
6GqzmnJqRRaXa9vfwNmjvNdRwxuBA3Uk/G1sbmcusMXBXoY6z0IEMhlVN0hC
qE4cIFgLxgHpYAaqyl2hISaomTCNhkbD770Ot8zbyRjl6G0Ps0ggYHWmfLZf
/tbFIBPWpuuuA3LvpZIiTaztevQaWYSyK22h3tp3K62IOBX3gUd4Yr+Gvo4P
NA26e21cUE2aVJsl6J9MeFITR2NzY1cmZ44KWi6bglkPlE4KBiRsbHCvs4wl
aUaO5qhNj1BdH3/Hha4x root@CAServer
Do you accept this certificate? [yes/no]: yes
```

c. [Router EXEC mode] Validate the copied CA public key by viewing the OpenSSH certificates in the CA trustpoint configured in the router.

```
Router#show crypto ca openssh certificates
Fri Sep 16 06:59:38.347 UTC

Trustpoint       : test
================================================================
CA certificate
================================================================

ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCigl/zhyjuGOBYz5bu+GL76HBa
ROV0pVS4Lx3pf1jcjrFkVibPKKkVeX/lE7sZIJ0anU9vYSJZW8zrl8z06GqzmnJq
RRaXa9vfwNmjvNdRwxuBA3Uk/G1sbmcusMXBXoY6z0IEMhlVN0hCqE4cIFgLxgHp
YAaqyl2hISaomTCNhkbD770Ot8zbyRjl6G0Ps0ggYHWmfLZf/tbFIBPWpuuuA3Lv
pZIiTaztevQaWYSyK22h3tp3K62IOBX3gUd4Yr+Gvvcjdvjwevfo4PNA26e21cUE
2aVJsl6J9eFITR2NzY1cmZ44KWi6bglkPlE4KBiRsbHCvs4wlaUaO5qhNj1BdH3/
Hha4x root@CAServer
```

d. [Router EXEC mode] Generate a CSR for the CA public key in the router.

```
Router#crypto ca openssh enroll test
Fri Sep 16 06:34:41.230 UTC
Display Certificate Request to terminal? [yes/no]: yes
---Hostkey follows---

ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCaXqjc45LohfiHJ1iq8sSpaJmdR
QQJo6bRMhkdxY1pbjEYrwjPTn5SnC1NZYwsTPSHlbYBxQRLBHLv80Gbb0v+uJ1T0T
4tAmLgSYPXaHqYIyepCeMKSkSKLgZ0Pf+oGBMtf3uUuLqCgnFAwjrzDBXJYfF+bd/
ieXMwKKNH3YiceLOqe4BAYRU6m+wiuZ8is+bIfy32Eq7gWuPUz8XpxaCt3icpqfrj
7/vm7amKf1GpiheaRJH0Cg4JAmJpAQkuPjx+Y9SZw2yTJP+IKr9tSoSWyiHo2B/Yg
3yERd7M8dQEsvrGy5KIf92x+eLPlGl5gB9ykEPDUpXeaYTu5wtDR/Jd

---End - This line not part of hostkey---
Redisplay enrollment request? [yes/no]: n
```

e. [Router EXEC mode] Select the hostkey contents of the CSR file and copy the hostkey of the CSR.

f. [CA server] Create a .pub file in the CA server for the CSR hostkey and paste the copied hostkey contents in this file.

```
[root@CAServer test]# vim host.pub
/* Here we are using the vim text editor to create the host.pub file */
/* You can use any text editor of your choice  */
```

g. [CA server] Execute the following block to sign the CSR file using the CA certificate

```
[root@CAServer test]# ssh-keygen -h -s cacert -I "server" -V +10w -z 10 host.pub
Signed host key host-cert.pub: id "server" serial 10 valid from 2022-09-16T12:26:00
 to 2022-11-25T12:27:17
```

Note Use the following command to sign the CSR file using the CA certificate:

ssh-keygen -h -s <CACert> -I <IdentityOfCSRSys> -V <CertValidity> -z <CertSerialNo> <CopiedCSRFile>

Parameter	Description
CACert	Specify the filename of the CA Server private key
CertValidity	Specify the validity period for the certificate.
CertSerialNo	Specify a serial number for the certificate.
CopiedCSRFile	Specify the name of the file created to copy the contents of CSR in the router.

h. [CA server] Open the signed host certificate and copy the contents.

```
[root@CAServer test]# cat host-cert.pub
ssh-rsa-cert-v01@openssh.com AAAAHHNzaC1yc2EtY2VydC12MDFAb3BlbnNza
C5jb20AAAAgzv0OXl42NNK9C4PtLZniRwBk5jbeS8quNhzVKsRpO7UAAAADAQABAAA
BAQCaXqjc45LohfiHJ1iq8sSpaJmdRQQJo6bRMhkdxY1pbjEYrwjPTn5SnC1NZYwsT
PSHlbYBxQRLBHLv80Gbb0v+uJ1T0T4tAmLgSYPXaHqYIyepCeMKSkSKLgZ0Pf+oGBM
tf3uUuLqCgnFAwjrzDBXJYfF+bd/ieXMwKKNH3YiceLOqe4BAYRU6m+wiuZ8is+bIf
y32Eq7gWuPUz8XpxaCt3icpqfrj7/vm7amKf1GpiheaRJH0Cg4JAmJpAQkuPjx+Y9S
Zw2yTJP+IKr9tSoSWyiHo2B/Yg3yERd7M8dQEsvrGy5KIf92x+eLPlGl5gB9ykEPDU
pXeaYTu5wtDR/JdAAAAAAAAAAoAAAACAAAABnNlcnZlcgAAAAAAAAAAYyQeAAAAAAB
jgGdNAAAAAAAAAAAAAAAAAAAABFwAAAAdzc2gtcnNhAAAAAwEAAQAAAQEAooJf84co7
hjgWM+W7vhi++hwWkTldKVUuC8d6X9Y3I6xZFYmzyipFXl/5RO7GSCdGp1Pb2EiWVv
M65fM9Ohqs5pyakUWl2vb38DZo7zXUcMbgQN1JPxtbG5nLrDFwV6GOs9CBDIZVTdIQ
qhOHCBYC8YB6WAGqspdoSEmqJkwjYZGw++9DrfM28kY5ehtD7NIIGB1pny2X/7WxSA
T1qbrrgNy76WSIk2s7Xr0GlmEsittod7adyutiDgV94FHeGK/hr6ODzQNunttXFBNm
lSbJeifTHhSE0djc2NXJmeOCloum4JZD5ROCgYkbGxwr7OMJWlGjuaoTY9QXR9/x4W
uMQAAAQ8AAAAHc3NoLXJzYQAAAQAIywc9o2OWzFq32MnE9IZVVRRiItdXaMVE1EvYu
G92JK7wnMJd50M6QDyfkNmGF4ramF90/bVQpl3UYJzVxCJSEodAq6OmlG3zx/MVayT
unMwV2Fq75PpaoZVpyEKx4kLKA6rNU5Tmbht2OfMQKFvIWyxTDmeLFMvnpt8R0Yrz4
sG5EP1+4E3WthfzZr42Mq2LQJt6aBeYHZDZSp++j7RpA7+T/6n1aGtAjtDIKprOQuE
1higCZmdI+kUZDOXjMJlPmJAnV8fdtnnEpYCyzYeD+rSSF7dlDVrTaiFdqrfCXh+uY
jR1E621sP7UEJOWeiBqSDTJxSRdRBNZq9TLmgJH host.pub
```

i. [Router EXEC mode] Import the signed host certificate to the router.

```
Router# crypto ca openssh import test certificate
/* This command opens the CA trustpoint and you must paste the contents of signed
certificate copied from the CA server */
Fri Sep 16 07:00:27.573 UTC


Enter the OpenSSH certificate.
End with a blank line

ssh-rsa-cert-v01@openssh.com AAAAHHNzaC1yc2EtY2VydC12MDFAb3BlbnNzaC
5jb20AAAAgzv0OXl42NNK9C4PtLZniRwBk5jbeS8quNhzVKsRpO7UAAAADAQABAAABA
```

```
QCaXqjc45LohfiHJ1iq8sSpaJmdRQQJo6bRMhkdxY1pbjEYrwjPTn5SnC1NZYwsTPSH
lbYBxQRLBHLv80Gbb0v+uJ1T0T4tAmLgSYPXaHqYIyepCeMKSkSKLgZ0Pf+oGBMtf3u
UuLqCgnFAwjrzDBXJYfF+bd/ieXMwKKNH3YiceLOqe4BAYRU6m+wiuZ8is+bIfy32Eq
7gWuPUz8XpxaCt3icpqfrj7/vm7amKf1GpiheaRJH0Cg4JAmJpAQkuPjx+Y9SZw2yTJ
P+IKr9tSoSWyiHo2B/Yg3yERd7M8dQEsvrGy5KIf92x+eLPlGl5gB9ykEPDUpXeaYTu
5wtDR/JdAAAAAAAAAAoAAAACAAAABnNlcnZlcgAAAAAAAAAAYyQeAAAAABjgGdNAAA
AAAAAAAAAAAAAAAABFwAAAAdzc2gtcnNhAAAAAwEAAQAAAQEAooJf84co7hjgWM+W7v
hi++hwWkTldKVUuC8d6X9Y3I6xZFYmzyipFXl/5RO7GSCdGp1Pb2EiWVvM65fM9Ohqs
5pyakUWl2vb38DZo7zXUcMbgQN1JPxtbG5nLrDFwV6GOs9CBDIZVTdIQqhOHCBYC8YB
6WAGqspdoSEmqJkwjYZGw++9DrfM28kY5ehtD7NIIGB1pny2X/7WxSAT1qbrrgNy76W
SIk2s7Xr0GlmEsittod7adyutiDgV94FHeGK/hr6ODzQNunttXFBNmlSbJeifTHhSE0
djc2NXJmeOCloum4JZD5ROCgYkbGxwr7OMJWlGjuaoTY9QXR9/x4WuMQAAAQ8AAAAHc
3NoLXJzYQAAAQAIywc9o2OWzFq32MnE9IZVVRRiItdXaMVE1EvYuG92JK7wnMJd50M6
QDyfkNmGF4ramF90/bVQpl3UYJzVxCJSEodAq6OmlG3zx/MVayTunMwV2Fq75PpaoZV
pyEKx4kLKA6rNU5Tmbht2OfMQKFvIWyxTDmeLFMvnpt8R0Yrz4sG5EP1+4E3WthfzZr
42Mq2LQJt6aBeYHZDZSp++j7RpA7+T/6n1aGtAjtDIKprOQuE1higCZmdI+kUZDOXjM
JlPmJAnV8fdtnnEpYCyzYeD+rSSF7dlDVrTaiFdqrfCXh+uYjR1E621sP7UEJOWeiBq
SDTJxSRdRBNZq9TLmgJH host.pub
```

j. [Router EXEC mode] Verify the host certificate import in the router.

```
Router#show crypto ca openssh certificates
Fri Sep 16 07:00:49.488 UTC

Trustpoint       : test
================================================================
CA certificate
================================================================
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCigl/zhyjuGOBYz5bu+GL76HBaROV
0pVS4Lx3pf1jcjrFkVibPKKkVeX/lE7sZIJ0anU9vYSJZW8zrl8z06GqzmnJqRRaXa9
vfwNmjvNdRwxuBA3Uk/G1sbmcusMXBXoY6z0IEMhlVN0hCqE4cIFgLxgHpYAaqyl2hI
SaomTCNhkbD770Ot8zbyRjl6G0Ps0ggYHWmfLZf/tbFIBPWpuuuA3LvpZIiTaztevQa
WYSyK22h3tp3K62IOBX3gUd4Yr+Gvo4PNA26e21cUE2aVJsl6J9MeFITR2NzY1cmZ44
KWi6bglkPlE4KBiRsbHCvs4wlaUaO5qhNj1BdH3/Hha4x root@CAServer

Router certificate
================================================================
Type         : Host Certificate
Key ID       : server
Serial       : 10
Valid        : from Fri Sep 16 06:56:00 2022 to Fri Nov 25 06:57:17 2022
```

4. User authentication

a. [Client machine] Generate an SSH key pair in the client system using the **ssh-keygen** utility for the user.

```
[root@userclient test]# ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/root/.ssh/id_rsa): /root/openssh_client/test/user
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /root/openssh_client/test/user.
Your public key has been saved in /root/openssh_client/test/user.pub.
The key fingerprint is:
SHA256:rNmS7P0u6l1pm75Kb4KhMxZThwaJ/AMnA9C//Z1GVEY root@userclient.cisco.com
The key's randomart image is:
+---[RSA 2048]----+
|++ . .     .E    |
|  B +       o    |
|   B . .   o     |
|    + +.. .      |
|     * .S.       |
|    +.o=  ..     |
```

```
|     +*+oo+.     |
|    =..=++=o     |
|   . ++.+XO.     |
+----[SHA256]-----+
[root@userclient test]# ls
user  user.pub
```

b. [Client machine] Open the SSH public key file.

Note Copy the public key content for the user certificate.

```
[root@userclient test]# cat user.pub
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCspUNwiwlEy0VXQ1Ruh2peRnAP12LSICNe9
H76xyBiCIXFLLXHTUZZM+W/Pa97pg3fObxaqyNYaeojfwmGeNyPLS9Ha0mqRuLmVCT/1got5I
Rn1AZhufZz7iz1AdW8DMC//KUnUS/T+cEwGrZ//sbIPTMsQZhhaQVk9xqFp9ghPMxwar3vaHa
t9NL6ThrR+viue9IOY5LKMeRnqrf2GFX3L6gHfcgYv9fQOKxI11WjTA645rQyB+NumVlrG6KI
as/xmBCEFHpChGZ1/GSB/atrKeVEWqzsJkpQHXEtE7hwK8gMrL+ad38mbV2Zz6Cc7KHJFEWaZ
sfjFscCP0kzU1gX root@userclient.cisco.com
```

c. [CA server] Create a .pub file in the CA server for the user certificate public key and paste the public key contents from the previous step in this file.

```
[root@CAServer test]# vim user.pub
/* Here we are using the vim text editor to create the user.pub file */
/* You can use any text editor of your choice  */
```

d. [CA server] Sign the user public key using the CA certificate private key.

```
[root@CAServer test]# ssh-keygen -s cacert -I "user" -V +10w -n testuser -z 20 user.pub

Signed user key user-cert.pub: id "user" serial 20 valid from 2022-09-16T12:42:00 to
 2022-11-25T12:43:24
```

Note The command to sign the CSR file using the CA certificate:

`ssh-keygen -s <CACert> -I <IdentityOfSysReqCert> -V <CertValidity> -n <Username> -z <CertSerialNo> <CopiedUserCertName>`

Note In addition to the mandatory fields specified for the user certificate, you can also configure critical options and extensions for the user certificate. For detailed information on the critical options and extensions, refer ssh-keygen.

Parameter	Description
`CACert`	Specify the filename of the CA Server private key/
`IdentityOfSysReqCert`	Specify the identity of the certificate as User
`CertValidity`	Specify the validity period for the certificate.

Parameter	Description
<Username>	Specify the principals that you want to add to the certificate. **Note** During authentication to the router, the principal in the user certificate is matched against the login username and requests with matching principal and username are permitted for further communication. **Note** You can have multiple principals that are associated with the same certificate. The principals must be separated by commas in the **IdentityOfSysReqCert** field in command to sign the user certificate file using CA certificate.
CertSerialNo	Specify a serial number for the certificate.
CopiedUserCertName	Specify the name of the file created to copy the contents of the user certificate file in the client machine.

e. [CA server] Open the signed user certificate in the CA server and copy the contents.

```
[root@CAServer test]# cat user-cert.pub
ssh-rsa-cert-v01@openssh.com AAAAHHNzaC1yc2EtY2VydC12MDFAb3BlbnNzaC5jb20AA
AAg6xlcZNQTKmUO27dHFcUCk7UzVCPWFMCep7Ldb4lBF6MAAAADAQABAAABAQCspUNwiwlEy0V
XQ1Ruh2peRnAP12LSICNe9H76xyBiCIXFLLXHTUZZM+W/Pa97pg3fObxaqyNYaeojfwmGeNyPL
S9Ha0mqRuLmVCT/1got5IRn1AZhufZz7iz1AdW8DMC//KUnUS/T+cEwGrZ//sbIPTMsQZhhaQV
k9xqFp9ghPMxwar3vaHat9NL6ThrR+viue9IOY5LKMeRnqrf2GFX3L6gHfcgYv9fQOKxI11WjT
A645rQyB+NumVlrG6KIas/xmBCEFHpChGZ1/GSB/atrKeVEWqzsJkpQHXEtE7hwK8gMrL+ad38
mbV2Zz6Cc7KHJFEWaZsfjFscCP0kzU1gXAAAAAAAAABQAAAABAAAABHVzZXIAAAAAAAAAAGMkI
cAAAAAAY4BrFAAAAAAAAACCAAAAFXBlcm1pdC1YMTEtZm9yd2FyZGluZwAAAAAAAAAXcGVybWl
0LWFnZW50LWZvcndhcmRpbmcAAAAAAAAAFnBlcm1pdC1wb3J0LWZvcndhcmRpbmcAAAAAAAAAC
nBlcm1pdC1wdHkAAAAAAAAADnBlcm1pdC11c2VyLXJjAAAAAAAAAAAAAAAEXAAAAB3NzaC1yc2E
AAAADAQABAAABAQCigl/zhyjuGOBYz5bu+GL76HBaROV0pVS4Lx3pf1jcjrFkVibPKKkVeX/lE
7sZIJ0anU9vYSJZW8zrl8z06GqzmnJqRRaXa9vfwNmjvNdRwxuBA3Uk/G1sbmcusMXBXoY6z0I
EMhlVN0hCqE4cIFgLxgHpYAaqyl2hISaomTCNhkbD770Ot8zbyRjl6G0Ps0ggYHWmfLZf/tbFI
BPWpuuuA3LvpZIiTaztevQaWYSyK22h3tp3K62IOBX3gUd4Yr+Gvo4PNA26e21cUE2aVJsl6J9
MeFITR2NzY1cmZ44KWi6bglkPlE4KBiRsbHCvs4wlaUaO5qhNj1BdH3/Hha4xAAABDwAAAAdzc
2gtcnNhAAABABKOHeuTo9OMg6K+HjASpRXD7rQgiiOdljKdkpw4FZlwCOdBegQwPQkFYTNHmrH
frQYY72ZINCAjseq+ZSUCkCqJjyXbvY+ZdmRyy76pQvjitgolZjppJqX38nz3uqz/81A/ZuJiF
811sgJF0Loj7XDN9wjF/zBtsxsXPp7R5c775dmmFgZWQHbSWDlNmnPd9vLZMyBwId//+HV/bCF
LjbqI/nr/amLVjcI0liOZXzsH7bcLFBSDZ3Epd6IAqFEe+URqvscjaaghcvnshvcafdgfaruO0
wedsZX53/pEBKhlGacsachFa+S2QuYqTafqnEtkvJoNKVe7UDq/R4kEXM1s9CclIMOficYJm5L
as+ALR4= root@CAServer.cisco.com
```

f. [CA server] Create a .pub file in the client machine fo the CA signed user certificate and past the signed certificate contents in this file.

```
[root@CAServer test]# vim user-cert.pub
/* Here we are using the vim text editor to create the user-cert.pub file */
/* You can use any text editor of your choice  */
```

g. [Client machine] View the user certificate in the client machine.

```
[root@userclient test]# ssh-keygen -Lf user-cert.pub
user-cert.pub:
        Type: ssh-rsa-cert-v01@openssh.com user certificate
        Public key: RSA-CERT SHA256:rNmS7P0u6l1pm75Kb4KhMxZThwaJ/AMnA9C//Z1GVEY
        Signing CA: RSA SHA256:/B2b8V7jKXwGphf75fkO74U/mpuHgDHmvF4okexdKhY
        Key ID: "user"
        Serial: 20
        Valid: from 2022-09-16T12:44:00 to 2022-11-25T12:45:51
        Principals:
                testuser
        Critical Options: (none)
        Extensions:
                permit-X11-forwarding
                permit-agent-forwarding
                permit-port-forwarding
                permit-pty
                permit-user-rc
```

h. [Client machine] Open the known hosts file in the client system and add the public key of the CA to this file.

Note Add the CA public key to the known hosts file in the following format:

`@cert-authority <hostname> <CA Public Key>`

```
cat testuser@192.0.2.2 /root/.ssh/known_hosts
@cert-authority ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQCigl/zhyjuGOBYz5bu
+GL76HBaROV0pVS4Lx3pf1jcjrFkVibPKKkVeX/lE7sZIJ0anU9vYSJZW8zrl8z06GqzmnJq
RRaXa9vfwNmjvNdRwxuBA3Uk/G1sbmcusMXBXoY6z0IEMhlVN0hCqE4cIFgLxgHpYAaqyl2h
ISaomTCNhkbD770Ot8zbyRjl6G0Ps0ggYHWmfLZf/tbFIBPWpuuuA3LvpZIiTaztevQaWYSy
K22h3tp3K62IOBX3gUd4Yr+Gvo4PNA26e21cUE2aVJsl6J9MeFITR2NzY1cmZ44KWi6bglkP
lE4KBiRsbHCvs4wlaUaO5qhNj1BdH3/Hha4x root@CAServer.cisco.com
```

i. [Router Config mode] Configure the username in the router

```
Router# config
Router(config)# username testuser
Router(config-un)# group root-lr
Router(config-un)# commit
```

5. [Client machine] Access the router in the client using the OpenSSH certificate.

```
[root@userclient test]# ssh -o CertificateFile=user-cert.pub -i user testuser@192.0.2.2
 -o StrictHostKeyChecking=yes
Router#
```

Note The command to access the router in the client machine remotely:

`ssh -o CertificateFile=<CA_Signed_User_Certificate_Name> -i <User_Certificate_Private_Key> <Username >@<Router_IP> -o StrictHostKeyChecking=yes`

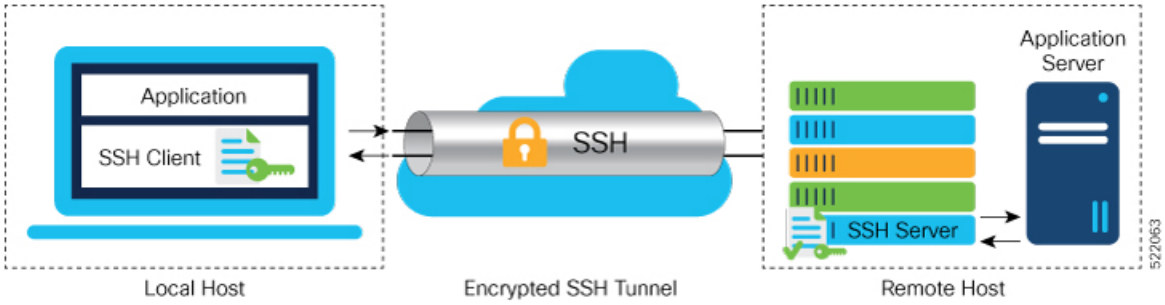
SSH Port Forwarding

Table 5: Feature History Table

Feature Name	Release Information	Feature Description
SSH Port Forwarding	Release 7.3.2	With this feature enabled, the SSH client on a local host forwards the traffic coming on a given port to the specified host and port on a remote server, through an encrypted SSH channel. Legacy applications that do not otherwise support data encryption can leverage this functionality to ensure network security and confidentiality to the traffic that is sent to remote application servers. This feature introduces the ssh server port-forwarding local command.

SSH port forwarding is a method of forwarding the otherwise insecure TCP/IP connections from the SSH client to server through a secure SSH channel. Since the traffic is directed to flow through an encrypted SSH connection, it is tough to snoop or intercept this traffic while in transit. This SSH tunneling provides network security and confidentiality to the data traffic, and hence legacy applications that do not otherwise support encryption can mainly benefit out of this feature. You can also use this feature to implement VPN and to access intranet services across firewalls.

Figure 1: SSH Port Forwarding

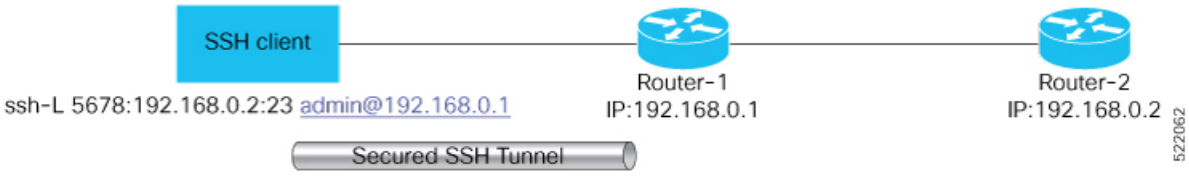


Consider an application on the SSH client residing on a local host, trying to connect to an application server residing on a remote host. With tunneling enabled, the application on the SSH client connects to a port on the local host that the SSH client listens to. The SSH client then forwards the data traffic of the application to the SSH server over an encrypted tunnel. The SSH server then connects to the actual application server that is either residing on the same router or on the same data center as the SSH server. The entire communication of the application is thus secured, without having to modify the application or the work flow of the end user.

The SSH port forwarding feature is disabled, by default. You can enable the feature by using the **ssh server port-forwarding local** command in the XR Config mode.

How Does SSH Port Forwarding Work?

Figure 2: Sample Topology for SSH Port Forwarding



Consider a scenario where port forwarding is enabled on the SSH server running on Router-1, in this topology. An SSH client running on a local host tries to create a secure tunnel to the SSH server, for a local application to eventually reach the remote application server running on Router-2.

The client tries to establish an SSH connection to Router-1 using the following command:

```
ssh -L local-port:remote-server-hostname:remote-port username@sshserver-hostname
```

where,

local-port is the local port number of the host where the SSH client and the application reside. Port 5678, in this example.

remote-server-hostname:remote-port is the TCP/IP host name and port number of the remote application server where the recipient (SSH server) must connect the channel from the SSH client to. 192.168.0.2 and 23, in this example.

sshserver-hostname is the domain name or IP address of the SSH server which is the recipient of the SSH client request. 192.168.0.1, in this example.

For example,

```
ssh -L 5678:192.168.0.2:23 admin@192.168.0.1
```

When the SSH server receives a TCP/IP packet from the SSH client, it accepts the packet and opens a socket to the remote server and port specified in that packet. Once the connection between SSH client and server is established, the SSH server connects that communication channel to the newly created socket. From then onwards, SSH server forwards all the incoming data from the client on that channel to that socket. This type of connection is known as port-forwarded local connection. When the client closes the connection, the SSH server closes the socket and the forwarded channel.

How to Enable SSH Port Forwarding

Guidelines for Enabling SSH Port Forwarding Feature

- The Cisco IOS XR software supports SSH port forwarding only on SSH server; not on SSH client. Hence, to utilize this feature, the SSH client running at the end host must already have the support for SSH port forwarding or tunneling.
- The remote host must be reachable on the same VRF where the current SSH connection between the server and the client is established.
- Port numbers need not need match for SSH port forwarding to work. You can map any port on the SSH server to any port on the client.

- If the SSH client tries to do port forwarding without the feature being enabled on the SSH server, the port forwarding fails, and displays an error message on the console. Similarly the port-forwarded channel closes in case there is any connectivity issue or if the server receives an SSH packet from the client in an improper format.

Configuration Example

```
Router#configure
Router(config)#ssh server port-forwarding local
Router(config)#commit
```

Running Configuration

```
Router#show running-configuration

ssh server port-forwarding local
!
```

Verification

Use the **show ssh** command to see the details of the SSH sessions. The **connection type** field shows as **tcp-forwarded-local** for the port-forwarded session.

```
Router#show ssh

Wed Oct 14 11:22:05.575 UTC
SSH version : Cisco-2.0

id chan pty  location   state        userid host          ver authentication connection
type
-----------------------------------------------------------------------------------------
Incoming sessions
15 1    XXX  0/RP0/CPU0 SESSION_OPEN  admin  192.168.122.1 v2  password
port-forwarded-local

Outgoing sessions

Router#
```

Use the **show ssh server** command to see the details of the SSH server. The **Port Forwarding** column shows as **local** for the port-forwarded session. Whereas, for a regular SSH session, the field displays as **disabled**.

```
Router#show ssh server
```

Syslogs for SSH Port Forwarding Feature

The router console displays the following syslogs at various SSH session establishment events.

- When SSH port forwarding session is successfully established:

```
RP/0/RP0/CPU0:Aug 24 13:10:15.933 IST: SSHD_[66632]:
%SECURITY-SSHD-6-PORT_FWD_INFO_GENERAL : Port Forwarding, Target:=10.105.236.155,
Port:=22, Originator:=127.0.0.1,Port:=41590, Vrf:=0x60000000, Connection forwarded
```

- If SSH client tries to establish a port forwarding session without SSH port forwarding feature being enabled on the SSH server:

```
RP/0/RP0/CPU0:Aug 24 13:20:31.572 IST: SSHD_[65883]: %SECURITY-SSHD-3-PORT_FWD_ERR_GENERAL
 : Port Forwarding, Port forwarding is not enabled
```

Associated Command

- **ssh server port-forwarding local**