

Cisco Virtual Office—Public Key Infrastructure Integration

Scope of Document

This document describes the integration of Public Key Infrastructure (PKI) within the Cisco® Virtual Office deployment from a functional perspective. It explains some of the PKI enhancements available in recent Cisco IOS® Software releases that strengthen the Cisco Virtual Office infrastructure. This document does not explain the details of PKI, IPsec, or any VPN concepts. You should be familiar with these concepts; for more information, you can refer to the links provided in the “References” section.

Please refer to the Cisco Virtual Office overview at <http://www.cisco.com/go/cvo> for further information about the solution, its architecture, and its components.

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Introduction

Cisco IOS® Software PKI provides certificate management to support security protocols such as IP Security (IPsec), Secure Shell (SSH) Protocol, and Secure Sockets Layer (SSL). As defined in the IPsec protocol, peers must be authenticated during Internet Key Exchange (IKE) phase 1 before secure communication is established. When pairs of Cisco IOS Software routers are configured as IPsec peers, the routers can use preshared keys (PSKs) to authenticate each other as part of security establishment. Using PSKs may be a better choice for customers deploying a small to midsize network containing few routers.

As networks become larger in size and scale, PSK configuration becomes very complex, and managing multiple keys is difficult. PKI offers a much more secure and scalable method for midsize to large enterprise deployments—whether a full mesh of security connections for Dynamic Multipoint VPN (DMVPN) or any of the newly supported VPN technologies, or spoke-to-spoke communications, or enterprises deploying site-to-site VPN for hundreds of remote branch offices needing to communicate with each other. PKI reduces management overhead and simplifies the deployment of the network infrastructure by using digital certificate exchange instead of PSKs for device authentication.

PKI Overview

To help you understand the use of PKI within Cisco Virtual Office, this section provides a brief introduction to PKI.

A PKI is composed of the following entities:

- Peers communicating on a secure network
- At least one certification authority (CA) that grants and maintains certificates
- Digital certificates, which contain information such as the certificate validity period, peer identity information, encryption keys that are used for secure communication, and the signature of the issuing CA
- An optional registration authority (RA) to offload the CA by processing enrollment requests
- A distribution mechanism (such as Lightweight Directory Access Protocol [LDAP] or HTTP) for certificate revocation lists (CRLs)

PKI provides customers with a scalable, secure mechanism for distributing, managing, and revoking encryption and identity information in a secured data network. Each entity (router or PC) participating in the secure communication is enrolled, a process by which the entity generates a Rivest, Shamir, and Adelman (RSA) key pair (one private key and one public key) and has its identity validated by a trusted entity (also known as a CA).

After each entity enrolls in a PKI, every peer (also known as an end host) in a PKI is granted a digital certificate that has been issued by a CA. When peers must negotiate a secured communication session, they exchange their digital certificates. Using the information in the certificate, a peer can validate the identity of another peer and establish an encrypted session with the public keys contained in the certificate.

RSA Key Overview

An RSA key pair consists of a public key and a private key. When setting up a PKI, the router (also called the certificate client) must include the public key in the certificate enrollment request. After the certificate request has been granted, the public key is included in the certificate so that peers can use it to encrypt data that is sent to the router. The private key is kept on the router and used both to decrypt the data sent by peers and to digitally sign transactions when negotiating with peers.

RSA key pairs contain a key modulus value. The modulus determines the size of the RSA key. The larger the modulus, the more secure the RSA key. However, keys with large modulus values take longer to generate, and encryption and decryption operations take longer with larger keys.

Certificate Authority

A Certificate Authority (CA) manages certificate requests and issues certificates to participating network devices. These services provide centralized key management for the participating devices and are explicitly trusted by the receiver to validate identities and to create digital certificates. Before any PKI operations can begin, the CA generates its own public key pair and creates a self-signed CA certificate; thereafter, the CA can sign certificate requests and begin peer enrollment for the PKI.

The CA can be a third-party vendor such as Microsoft or VeriSign or a Cisco IOS Certificate Server performing the role of a CA. The deployment described in this guide uses the Cisco IOS Certificate Server.

Platforms and Cisco IOS Software Images

Images based on Cisco IOS Software Release 15.0.1M2 or later are recommended for the Cisco IOS Certificate Server and Subordinate Certificate Server. If you are using a third-party CA, then images based on Cisco IOS Software Release 15.1.3T or later are recommended. The following platforms are suggested for the CA role: Cisco 1900, 2900, or 3900 Series Integrated Services Router running the Cisco IOS Certificate Server or a Microsoft Certificate Authority.

For a list of supported and recommended Cisco Virtual Office hub-and-spoke platforms and images, please refer to the Cisco Virtual Office Supported Hardware and Software guide at <http://www.cisco.com/go/cvo>.

Deployment

Digital certificates are issued to each router, including the hub and spokes. Digital certificates are very difficult to spoof, so the use of the certificates for PKI authentication helps ensure that no unauthorized spokes are connected to the VPN. Unless marked as exportable, the RSA keys cannot be exported, so RSA keys cannot be transferred to another router.

Now we will look at how to configure the CA and the routers as PKI clients. As mentioned earlier, we can use a CA provided by a third-party vendor such as Microsoft or VeriSign, or a Cisco IOS Certificate Server. The following Cisco Virtual Office deployment uses the Cisco IOS Certificate Server. Please refer to Appendix A for details on using a third-party CA along with Cisco IOS Certificate Server in RA mode.

Note: The Cisco IOS Certificate Server will be used to represent the CA in the remainder of this document.

Configuring the Cisco IOS Certificate Server

The first step in PKI deployment is to bring up the Cisco IOS Certificate Server, which is a router running Cisco IOS Software with IP connectivity enabled to reach resources such as Network Time Protocol (NTP), Trivial File Transfer Protocol (TFTP), and Domain Name System (DNS) servers necessary for proper functioning. Cisco IOS Certificate Server must be configured with **ip http server** to support enrollments done using Simple Certificate Enrollment Protocol (SCEP). This section describes only configurations relevant to Cisco IOS Certificate Server.

This configuration example uses a Cisco 2911 Integrated Services Router running Cisco IOS Software Release 15.0.1M4.

```

! !!! hostname and domain name form a fully qualified domain name in certificates
!!!
hostname cvo-pki-cs
ip domain name cisco.com

! !!! clock must be in sync between Cisco IOS Certificate Server and the
clients, including timezone !!!
clock timezone PST -8
clock summer-time PDT recurring
ntp server 10.1.1.101

! !!! FTP access configuration for storing .crt, .cnm, and .crl files in
external FTP server !!!
ip ftp username ftpusr
ip ftp password cisco
ip host ftpserver 10.1.1.100

! !!! To process enrollment requests and issue certificates !!!
ip http server
!

!!! RSA key pair is generated automatically when enabling Cisco IOS Certificate
Server using 1024 bits. Optionally, RSA keys with the rsakeypair name matching
the certificate server can be generated manually with different options such as
higher modulus, exportable, etc. Keys must be generated with the exportable
option to export them for later restoration in case of certificate server
failure. However, the user needs to take the utmost care to store keys securely
as it would be easy for someone to get access with the keys. !!!

cvo-pki-cs(config)#crypto key generate rsa general-keys label cvo-pki-cs modulus
1024 exportable

!!! The following Cisco IOS Certificate Server configuration uses a complete
database that stores separate .crt and .cnm files for each certificate it issues.
In general, router flash memory has less capacity to store all these files;
hence, only essential files should be stored in router flash memory, and all
other files can be stored on an external FTP server. The lifetime values shown
here are for illustration purposes only. !!!
!
crypto pki server cvo-pki-cs      !!! PKI server name must match rsakeypair name
!!!
    database level complete
    database archive pkcs12 password cisco123 !!! Keys can be auto archived !!!
    issuer-name cn=cvo-pki-cs,ou=cvo !!! Identification of the PKI server within
Cisco Virtual Office !!!
    grant auto !!! Certificate server automatically grants enrollment requests from
routers !!!
    lifetime crl 24              !!! Every 24 hours the CRL database is renewed and
published !!!
    lifetime certificate 60      !!! Issued router (client) certificates are valid
for 60 days !!!
    lifetime ca-certificate 75   !!! Root (certificate server) certificate is valid
for 75 days !!!
    cdp-url http://10.1.1.100/cvo-pki-cs.crl !!! PKI clients get CRL from this
location !!!
    database url ftp://10.1.1.100/pki !!! All files are stored on this external
FTP server !!!

```

```
!
!!! The following trustpoint configuration is autogenerated when Cisco IOS
Certificate Server is enabled. Optionally, this trustpoint configuration can be
created manually before enabling Cisco IOS Certificate Server. !!!
!
crypto pki trustpoint cvo-pki-cs
  enrollment url http://cvo-pki-cs:80      !!! Optional !!!
  serial-number
  revocation-check crl
  rsakeypair cvo-pki-cs      !!! rsakeypair name must match PKI server name !!!
!
!!! To enable the Cisco IOS Certificate Server, enter a "no shut" command in
server config mode. !!!
!
cvo-pki-cs(cs-server)#no shutdown
!
```

Note: It is recommended to use the database archive command with strong password to archive RSA keys in a pkcs12 file instead of generating RSA keys with an exportable option as mentioned earlier.

When Cisco IOS Certificate Server is enabled, this is how the root CA certificate appears:

```
cvo-pki-cs#show crypto pki certificates
CA Certificate                                     !!! Root CA certificate !!!
  Status: Available
  Certificate Serial Number: 0x1
  Certificate Usage: Signature
  Issuer:
    cn=cvo-pki-cs
    ou=cvo
    o=Cisco Systems
    c=US
    ea=admin@cisco.com
  Subject:
    cn=cvo-pki-cs
    ou=cvo
    o=Cisco Systems
    c=US
    ea=admin@cisco.com
  Validity Date:
    start date: 11:38:04 PDT May 01 2010
    end   date: 11:38:04 PDT Jul 15 2010
  Associated Trustpoints: cvo-pki-cs
  Storage: nvram:cvo-pki-cs#1CA.cert
```

Now, save the configuration.

Configuring Cisco Virtual Office Routers for PKI

After the Cisco IOS Certificate Server is set up, the PKI client can enroll with the certificate server and download client certificates. For Cisco Virtual Office, both the hub and spoke are PKI clients, and they must enroll with the certificate server before using PKI authentication.

This configuration example uses a Cisco 881 Integrated Services Router running Cisco IOS Software Release 15.0.1M4.

Note: For certificates to be valid, the clock on the certificate server and clients must be in sync. All clients must have IP reachability to the certificate server and use the same clock source as the certificate server.

```
!  
hostname cvo-spoke  
ip domain name cisco.com  
clock timezone PST -8  
clock summer-time PDT recurring  
ntp server 10.1.1.101  
!  
!!! Generate RSA keys in the client router. If not generated now, keys will be  
autogenerated during trustpoint authentication. !!!  
  
cvo-spoke(config)#crypto key generate rsa general-keys modulus 1024  
  
!!! Create the following trustpoint configuration in config mode in the router  
!!!  
!  
ip host cvo-pki-cs 10.1.1.105  
!  
crypto pki trustpoint cvo-pki-cs  
enrollment url http://cvo-pki-cs:80  
serial-number  
  
!!! Using CRL check is desirable for Cisco Virtual Office hubs because it  
prevents any unauthorized router from setting up a secure session with Cisco  
Virtual Office hubs. The advantage of using CRL check improves the security of  
Cisco Virtual Office spokes when spoke-to-spoke communication is permitted.  
However, it can be disabled for Cisco Virtual Office spokes if they connect to  
the hub only by issuing a revocation-check none command. !!!  
  
revocation-check crl
```

!!! To send enrollment requests securely, the router should use the internal address as the source when communicating with the certificate server. As defined in the Cisco Virtual Office spoke configuration, only the internal addresses are secured. !!!

source-interface Vlan10

!!! The router will attempt reenrollment after 60 percent of lifetime expires. If shorter lifetimes, such as 60 days, are used for router certificates, the auto-enroll period can be extended to 80 or 90 percent to avoid frequent reenrollment. !!!

auto-enroll 60

!!! Authenticate the client router with the certificate server, to download the root CA certificate so that the router will encrypt the enrollment request with the certificate server's public key. !!!

cvo-spoke(config)#crypto pki authenticate cvo-pki-cs

!!! Now enroll with the certificate server in config mode. Including the serial number and IP address in the subject name and password fields is optional. !!!

cvo-spoke(config)#crypto pki enroll cvo-pki-cs

!!! After the certificate is received, this message will pop up in the console !!!

"%PKI-6-CERTRET: Certificate received from Certificate Authority"

!!! Now save the configuration to make sure the certificate is stored !!!

When enrolled, the router should have two certificates. One is its own certificate signed by the Cisco IOS Certificate Server, and the other is the root CA certificate. An example of output follows:

cvo-spoke#show crypto pki certificates

Certificate !!! Router certificate !!!

Status: Available

Certificate Serial Number (hex): 04

Certificate Usage: General Purpose

Issuer:

cn=cvo-pki-cs

ou=cvo

o=Cisco Systems

c=US

ea=admin@cisco.com

Subject:

Name: cvo-spoke.cisco.com

Serial Number: FHK09312145

```
serialNumber=FHK09312145+hostname=cvo-spoke.cisco.com
CRL Distribution Points:
  http://10.1.1.100/cvo-pki-cs.crl
Validity Date:
  start date: 11:36:17 PDT May 01 2010
  end   date: 11:38:04 PDT Jun 30 2010
  renew date: 11:38:04 PST Jun 15 2010
Associated Trustpoints: cvo-pki-cs
```

```
CA Certificate                               !!! Root CA certificate !!!
Status: Available
Certificate Serial Number (hex): 01
Certificate Usage: Signature
Issuer:
  cn=cvo-pki-cs
  ou=cvo
  o=Cisco Systems
  c=US
  ea=admin@cisco.com
Subject:
  cn=cvo-pki-cs
  ou=cvo
  o=Cisco Systems
  c=US
  ea=admin@cisco.com
Validity Date:
  start date: 11:38:04 PDT May 01 2010
  end   date: 11:38:04 PDT Jul 15 2010
Associated Trustpoints: cvo-pki-cs
```

```
cvo-spoke#
A similar trustpoint configuration is required in the hub router for enrolling
with the CS, and is shown as follows. When the certificate is received, both hub
and spoke can use this certificate for PKI authentication.
crypto pki trustpoint cvo-pki-cs
  enrollment url http://cvo-pki-cs:80
  serial-number
  ip-address none
  revocation-check crl    !!! CRL checking enabled in DMVPN hub !!!
  auto-enroll 60
```


Configuring Certificate Rollover

Cisco Virtual Office routers (clients) can renew their router certificates by reenrolling with the Cisco IOS Certificate Server before the existing router certificates expire. The timing of reenrollment is based on the auto-enroll configuration as discussed earlier. The validity of a router certificate is always bound by the lifetime of the root CA certificate. During any enrollment, the validity of the router certificate cannot be extended beyond the lifetime of the root CA certificate. However, a router can reenroll itself until the validity of the router certificate expires along with the root CA certificate. After the root CA certificate expires, the router cannot successfully reenroll further. Either configure the certificate server certificate with a larger lifetime initially to allow longer validity or obtain a new certificate by reconfiguring both the certificate server and all routers as discussed earlier.

With Cisco IOS Software Release 12.4(4)T and later, the root CA certificate can be rolled over by the certificate server, a process by which the certificate server generates a shadow (or rollover) root CA certificate before the existing root CA certificate expires. Though the validity of the shadow root CA certificate starts at the expiration of the existing root CA certificate, the certificate server keeps both the root certificates for an overlapping period (or rollover period). During this overlapping period, all routers will reenroll with the certificate server and download the shadow root CA certificate along with shadow router certificates for further use. After the existing certificate expires, both the certificate server and the routers will delete the expired certificate and start using the shadow (or rolled over) certificate. In this way, root CA certificate rollover helps Cisco Virtual Office routers keep their certificates valid without incurring additional overhead for administrators to reconfigure.

To use certificate rollover, configure the certificate server as follows:

```
crypto pki server cvo-pki-cs
auto-rollover 5          !!! Five-day overlapping period for keeping shadow
certificate !!!
```

No specific configuration is required in client routers; they will use the same process for reenrolling their router certificates. The routers will then determine whether the validity period of their certificates ends at the same time as the validity period of the root CA certificate. If so, they will download the shadow root CA certificate along with shadow router certificates. Shadow certificates are identified by the word rollover next to the certificate title.

Rollover can be performed manually by reenrolling during the rollover period.

```
cvo-spoke(config)#crypto pki enroll cvo-pki-cs
Trustpoint cvo-pki-cs is in rollover mode.
If you successfully re-enroll this trustpoint,
a shadow certificate will be obtained.
This will not affect the router certificate.

Do you want to continue with re-enrollment? [yes/no]: yes
Shadow enrollment will begin in 30 seconds and will
proceed in the background. You will be prompted to save
the configuration when the shadow enrollment completes
```

```

cvo-spoke#show crypto pki certificates cvo-pki-cs
Router Certificate (Rollover)                !!! Shadow router certificate !!!
Status: Available
Certificate Serial Number: 2F
...
Validity Date:
    start date: 11:38:04 PDT Jul 15 2010      !!! Validity period starts later !!!
    end   date: 11:38:04 PDT Sep 13 2010
Associated Trustpoints: cvo-pki-cs

CA Certificate (Rollover)                    !!! Shadow root CA certificate !!!
Status: Available
Certificate Serial Number: 23
...
Validity Date:
    start date: 11:38:04 PDT Jul 15 2010
    end   date: 11:38:04 PDT Sep 28 2010
Associated Trustpoints: cvo-pki-cs

cvo-spoke(config)#

```

Note: If the **database archive** command is configured in the certificate server, remember to store the pkcs12 file in a secure location after the certificate server generates rollover keys and certificates.

Managing the Certificate Database

As shown in the certificate server configuration earlier, the **database level complete** command creates .crt and .cnm files for each certificate issued, requiring a very large storage capacity when hundreds of routers are enrolling with the certificate server. With Cisco IOS Software Release 12.4(2)T and later, this database can be split and stored in different locations for different types of files. For example, .crl and .ser files are essential for running the certificate server, so they can be stored within the certificate server router flash memory. The certificate files .crt and .cnm are large files, so they can be stored on an external FTP server. CRLs can also be stored on an external HTTP server from which routers can download them.

Note: This configuration is optional, depending on user requirements for the database level and the size of the network.

```

!!! The following configuration shows the .crt and .cnm file types stored on an
FTP server and all other file types-.ser, .crl, and .pl2-stored by default in
flash memory. !!!

crypto pki server cvo-pki-cs
    database level complete
    database url flash:
    database url cnm ftp://10.1.1.100/pkifiles
    database url crl publish ftp://10.1.1.100/pkifiles  !!! CRL is published on the
FTP server !!!
    database url crt ftp://10.1.1.100/pkifiles

```

At this point, integration of PKI with Cisco Virtual Office is complete. This configuration may be good enough for a smaller Cisco Virtual Office network running with a single PKI server. For larger networks distributed across multiple locations, PKI servers can also be configured to form a hierarchy using subordinate certificate servers or RA mode certificate servers. Please refer to http://www.cisco.com/en/US/products/ps6664/products_ios_protocol_option_home.html for information about the various roles of PKI servers.

Following is just a portion of the configuration for a subordinate certificate server deployed with a root certificate server for Cisco Virtual Office. It follows the same configuration procedures as the root certificate server except the routers use trustpoint configuration for the subordinate certificate server.

Setting Up Cisco IOS RA Using a Third-Party CA

The Cisco IOS Certificate Server is capable of acting as a Registration Authority (RA) for a Cisco IOS CA or even another third-party CA.

For the purpose of this document, we will use the Microsoft CA as an example. The network administrator needs to ensure that the Microsoft CA has SCEP enabled and is capable of issuing certificates to Cisco routers over SCEP.

A basic configuration for this type of deployment follows:

```
crypto pki trustpoint name
enrollment url <Microsoft CA SCEP Enrollment URL>
subject-name x.500-name

crypto pki server cs-label
mode ra transparent !!! Required for Microsoft CA !!!
auto-rollover [time-period]
```

The transparent keyword is used to allow the CA server in RA mode to interoperate with more than one type of CA server. When the transparent keyword is used, the original PKCS#10 enrollment message is not resigned and is forwarded unchanged. This enrollment message makes the Cisco IOS RA Certificate Server work with CA servers like the Microsoft CA server.

Example Configuration

```
crypto pki server ca-ra
mode ra transparent
auto-rollover 30
crypto pki trustpoint ca-ra
enrollment mode ra
enrollment url http://msca.cisco.com:80/certsrv/mscep/mscep.dll
serial-number
ip-address 10.1.1.100
revocation-check crl
rsakeypair ca-ra
```

Configuring a Subordinate Certificate Server

Because the root RSA key pairs are extremely important in a PKI hierarchy, it is often advantageous to keep them offline or archived. To support this requirement, PKI hierarchies allow for subordinate CAs that have been signed by the root authority. In this way, the root authority can be kept offline (except to issue occasional CRL updates), and the subordinate CA can be used during normal operation.

The Subordinate Certificate Server feature allows you to configure a subordinate certificate server to grant all or certain SCEP enrollment or manual certificate requests.

The subordinate certificate server provides all the same features as a root certificate server. Following are some points to remember when adding a subordinate certificate server:

- Enrollment requests that come from a subordinate certificate server must always be **manually** granted in the root certificate server.
- The root certificate server should be a Cisco IOS Certificate Server.

The same steps as for configuring the Cisco IOS Certificate Server described earlier are required to set up a subordinate certificate server: IP reachability to the root certificate server; access to other resources such as NTP, FTP, and DNS servers; IP HTTP server configuration; RSA keys generated; etc.

Note: Only the relevant configuration information is shown here; all other configuration details are required as for the root certificate server.

```
!!! The following trustpoint configuration should be created manually before
enabling subordinate certificate server to provide a valid enrollment URL to the
root certificate server !!!
crypto pki trustpoint cvo-pki-subcs
  enrollment url http://cvo-pki-cs:80          !!! Enrolls with root certificate
server !!!
  serial-number
  revocation-check crl
  rsakeypair cvo-pki-subcs
!
crypto pki server cvo-pki-subcs
  database level complete
  database archive pkcs12 password cisco123
  grant auto          !!! Enrollment requests are automatically granted
!!!
  lifetime crl 24
  lifetime certificate 45      !!! Valid period for router certificates !!!
  lifetime ca-certificate 60 !!! Validity must match lifetime certificate defined
in root certificate server !!!
  cdp-url http://10.1.1.100/cvo-pki-subcs.crl
  mode sub-cs          !!! Certificate server runs in subordinate certificate
server mode!!!
  database url flash:
!
!!! The following configuration shows the client routers using a subordinate
certificate server trustpoint. The rest of the configuration is still needed !!!
```

```

!
ip host cvo-pki-subcs 10.1.1.102
!
crypto pki trustpoint cvo-pki-subcs
  enrollment url http://cvo-pki-subcs:80
  serial-number
  revocation-check crl
  source interface Vlan10
  auto-enroll 60
!
!!! The subordinate certificate server is enabled by entering the "no shut"
command in server config mode. !!!
!
cvo-pki-subcs(cs-server)#no shutdown
!

```

Configuring Certificate Rollover for the Subordinate Certificate Server

If certificate rollover is set up for the root certificate server, it should also be set up for the subordinate certificate server because all the routers will enroll with the subordinate certificate server. From the perspective of the root certificate server, the subordinate certificate server is also a client. Just as routers keep shadow certificates for their own certificates and also for the root CA certificate, the subordinate certificate server also downloads shadow certificates for itself and the root certificate server during rollover. Although enrollment requests that the root certificate server receives from the subordinate certificate server must be granted manually, the root certificate server can automatically grant rollover enrollment requests from the subordinate certificate server.

```

!!! The following configuration is needed in the root certificate server !!!
!
crypto pki server cvo-pki-cs
  grant auto rollover ca-cert  !!! Root certificate server automatically grant
rollover requests from subordinate certificate server !!!
  auto-rollover 5          !!! Overlapping period to keep shadow certificates !!!
!
!!! The following configuration is needed in subordinate certificate server !!!
!
crypto pki server cvo-pki-subcs
  auto-rollover 4          !!! Four-day overlapping period to keep shadow
certificates !!!

```

As earlier, no additional configuration is needed in Cisco Virtual Office routers for certificate rollover.

Note: The rollover period in the root certificate server should be longer than the rollover period in the subordinate certificate server. Because the subordinate certificate server itself is a client for the root certificate server, root certificate server rollover may occasionally occur at the same time as subordinate certificate server rollover. If the subordinate certificate server rollover period occurs before the root certificate server rollover period, the subordinate certificate server can have only a subordinate certificate server rollover certificate because the root certificate server rollover certificate is not generated at that time. This situation may cause the subordinate

certificate server to reenroll, and all the router clients as well. To avoid this situation, you should keep the rollover period longer in the root certificate server than in the subordinate certificate server. Then the subordinate certificate server will receive both the subordinate certificate server and root certificate server rollover certificates during the same enrollment. You should also use higher values for lifetime ca-certificate in the root certificate server to avoid frequent rollovers in the subordinate certificate server as a result of root certificate server rollover.

Note: Refer to Appendix B for detailed output.

```
cvo-pki-subcs#sh crypto pki certificates
Certificate (subordinate CA certificate)   !!! Existing subordinate CA certificate
!!!
    Status: Available
    Certificate Serial Number: 0C
    ...
Certificate (subordinate CA certificate, Rollover)   !!! Rollover certificate !!!
    Status: Available
    Certificate Serial Number: 11
    ...
cvo-pki-subcs#
```

PKI-AAA Authentication and Authorization

Security on the Cisco Virtual Office hub router can be strengthened by configuring PKI-AAA authorization in addition to CRL validation for each peer certificate. When a Cisco Virtual Office spoke negotiates an IPsec session with the hub, the hub router extracts a specified field from the peer certificate subject and sends it to a RADIUS server. This field is sent as the username, and the password is preconfigured. The field that is sent as the username is specified in the trustpoint configuration; by default, it is the subject name, which is a fully qualified domain name.

If the RADIUS server has an entry for this username with the password set as "cisco", the query returns successfully along with the following Cisco attribute-value pairs configured for that username:

- Certificate use (cert-application)
- Certificate trustpoint (cert-trustpoint)
- Serial number (cert-serial)
- Certificate lifetime (cert-lifetime-end)

The RADIUS server returns a failure if the record is not found or the password is not "cisco". The peer certificate is not accepted if the RADIUS request fails.

If either or both cert-trustpoint and cert-serial are specified, the router compares these values with the trustpoint name and serial number extracted from the peer certificate. The certificate is accepted only if these fields match. The cert-lifetime-end value can be used to bypass the actual expiry date of the certificate—useful when an expired peer certificate needs to be accepted. A different date can be specified in the attribute-value pair, and the router uses this date for the expiry date calculation.

With the PKI-AAA feature, the hub accepts a certificate only if it has an entry on the RADIUS server. For more information about PKI-AAA, please refer to http://www.cisco.com/en/US/docs/ios/12_3/feature/guide/g_pkii.html.

Here is the PKI-AAA configuration:

```
aaa new-model
aaa group server radius pki-aaa-server
server <ip addr> auth-port 1645 acct-port 1646 key cisco123
!
aaa authorization network pkiaaa group pki-aaa-server
!
crypto pki trustpoint cvo-pki-subcs
enrollment url http://cvo-pki-subcs:80
authorization list pkiaaa
```

Benefits of PKI Integration

- PKI integration reduces the need for complex management of preshared keys for Cisco Virtual Office routers.
- Security of the Cisco Virtual Office router can be increased by the use of RSA keys that are nonexportable and CRL checking to prevent sessions from unauthorized devices.
- Root certificate rollover helps the Cisco Virtual Office router renew and keep valid certificates.
- The use of a subordinate certificate server with certificate rollover extends the benefit of prolonged validity of router certificates to the hierarchical design of certificate servers for widely distributed Cisco Virtual Office networks.
- PKI integration with AAA protects Cisco Virtual Office hubs with even more security.

Caveats and Final Notes

- A certificate server using RA mode cannot get rollover certificates automatically.
- To disconnect a user from Cisco Virtual Office, just revoking the router certificate in the certificate server is not sufficient because the hub or spokes may not get the latest CRL immediately. Hence, it is strongly recommended that the administrator manually remove the certificate from the router as well. Users can use shorter lifetimes for CRL publishing to get new CRLs published frequently. Integrating the PKI-AAA feature also helps reject session requests from disconnected spokes.
- When performing CRL checking, if the CRL is published to an internal FTP or HTTP server, IPsec sessions will fail between Cisco Virtual Office routers if the FTP or HTTP server is not accessible. Hence, place the CRL in an externally accessible HTTP server or use an LDAP server.
- If Cisco Virtual Office routers lose connection with the root certificate server or subordinate certificate server during a rollover period and shadow certificates are not installed, automatic recovery is not possible. The administrator can manually reenroll to obtain shadow certificates, but if the certificate server certificate has expired, trustpoint configuration in the Cisco Virtual Office routers should be removed and reinstalled for a fresh enrollment.
- The administrator should consider any performance concerns related to PKI before deploying this solution in a large-scale network.

References

- PKI deployment: http://www.cisco.com/en/US/products/ps6664/products_ios_protocol_option_home.html
- Implementing and managing PKI—Cisco documentation: http://www.cisco.com/univercd/cc/td/doc/product/software/ios124/124cg/hsec_c/part20/index.htm
- <file:///localhost/PKI-AAA/> http://www.cisco.com/en/US/docs/ios/12_3/feature/guide/g_pkii.html
- Cisco Virtual Office Deployment Guides: <http://www.cisco.com/go/cvo>

Appendix A: Verification and Troubleshooting

Root Certificate Server

```
cvo-pki-cs#show crypto pki server    !!! Certificate server status and details !!!
Certificate Server cvo-pki-cs:
```

```
  Status: enabled
  State: enabled
  Server's configuration is locked (enter "shut" to unlock it)
  Issuer name: cn=cvo-pki-cs,ou=cvo,o=Cisco systems,c=US,ea=admin@cisco.com
  CA cert fingerprint: 933C312F 17290BA3 A7179EDE FE2C6E7E
  Granting mode is: auto
  Last certificate issued serial number: 0x2F
  CA certificate expiration timer: 11:38:04 PST Jul 15 2008
  CRL NextUpdate timer: 15:59:49 PDT Jun 28 2008
  Current primary storage dir: flash:
  Current storage dir for .cnm files: flash:
  Current storage dir for .crt files: ftp://10.1.1.100/pkifiles
  Database Level: Complete - all issued certs written as <serialnum>.cer
  Auto-Rollover configured, overlap period 5 days
  Autorollover timer: 11:38:04 PST Jul 10 2008
```

```
!!! Check root CA certificate details !!!
```

```
cvo-pki-cs#show crypto pki certificates
```

```
CA Certificate
```

```
  Status: Available
  Certificate Serial Number: 0x1
  Certificate Usage: Signature
  Issuer:
    cn=cvo-pki-cs
    ou=cvo
    o=Cisco Systems
    c=US
    ea=admin@cisco.com
  Subject:
    cn=cvo-pki-cs
    ou=CVO
    o=Cisco Systems
```

```
c=US
ea=admin@cisco.com
Validity Date:
  start date: 11:38:04 PDT May 01 2008
  end   date: 11:38:04 PDT Jul 15 2008
Associated Trustpoints: cvo-pki-cs
Storage: nvram:cvo-pki-cs#1CA.cer
```

```
!!! RSA keys generated in certificate server !!!
cvo-pki-cs#show crypto key mypubkey rsa
% Key pair was generated at: 11:38:42 PDT May 01 2008
Key name: cvo-pki-cs
Storage Device: not specified
Usage: General Purpose Key
Key is not exportable.
Key Data:
  30819F30 0D06092A 864886F7 0D010101 05000381 8D003081 89028181 00BC33EA
.....<key data removed>
% Key pair was generated at: 11:38:42 PDT May 01 2008
Key name: cvo-pki-cs.server
Temporary key
Usage: Encryption Key
Key is not exportable.
Key Data:
  307C300D 06092A86 4886F70D 01010105 00036B00 30680261 00B01B54 C037B330
.....<key data removed>
cvo-pki-cs#
```

```
!!! To perform any server activities, use this CLI command. There are some
differences between Cisco IOS Software Releases 12.4(15)T and 12.4(20)T. Examples
given below are for essential options only. !!!
```

```
!!! For Cisco IOS Software Release 12.4(15)T !!!
cvo-pki-cs#cry pki server cvo-pki-cs ?
  grant      Grant enrollment requests
  info       Display info
  password    One Time Password for SCEP enrollment
  reject      Reject enrollment requests
  remove      Remove enrollment requests from database
  request     Retrieve an enrollment request
  revoke      Revoke certificate
```

```
!!! To check any pending enrollment requests !!!
cvo-pki-cs#crypto pki server ect-pki-cs info request
```

```
!!! For Cisco IOS Software Release 12.4(20)T !!!
cvo-pki-cs#crypto pki server cvo-pki-cs ?
  grant      Grant enrollment requests
  password    One Time Password for SCEP enrollment
  reject      Reject enrollment requests
  remove      Remove enrollment requests from database
  request     Retrieve an enrollment request
  revoke      Revoke certificate
  trim        Trim the CRL based on the expired-certs file.
  unrevoke    Unrevoke certificate
```

```
!!! To check issued certificates, CRL and pending enrollment requests !!!
cvo-pki-cs#show cry pki server cvo-pki-cs ?
  certificates  Show certificates issued by this Certificate Server
  crl           Certificate Revocation List
  requests      Enrollment Requests
  |             Output modifiers
  <cr>
```

```
!!! The following commands are the same on both versions !!!
```

```
!!! To manually grant enrollment requests !!!
cvo-pki-cs#crypto pki server cvo-pki-cs grant ?
  <1-999>      Request ID
  all          all pending requests      !!! Grant all pending request !!!
cvo-pki-cs#
```

```
!!! To revoke router certificate with serial number 0xDD, use this CLI command.
This will publish a new CRL to the HTTP server, but the router can download this
new CRL only if a CRL is not already available in the router cache !!!
```

```
cvo-pki-cs#crypto pki server cvo-pki-cs revoke 0xDD
writing crl ...
```

```
!!! To reject any specific enrollment requests !!!
```

cvo-pki-cs#crypto pki server cvo-pki-cs reject ?

<1-999> Request ID
all all pending requests

!!! During rollover period, the certificate server installs shadow certificates
!!!

cvo-pki-cs#sh crypto pki certificates

CA Certificate

Status: Available
Certificate Serial Number: 0x1
Certificate Usage: Signature
Issuer:
cn=cvo-pki-cs
ou=cvo
o=Cisco Systems
c=US
ea=admin@cisco.com

Subject:
cn=cvo-pki-cs
ou=cvo
o=Cisco Systems
c=US
ea=admin@cisco.com

Validity Date:
start date: 11:38:04 PDT May 01 2008
end date: 11:38:04 PDT Jul 15 2008

Associated Trustpoints: cvo-pki-cs
Storage: nvram:cvo-pki-cs#1CA.cer

CA Certificate (Rollover)

!!! Shadow root CA certificate !!!

Status: Available
Certificate Serial Number: 0x13
Certificate Usage: Signature
Issuer:
cn=cvo-pki-cs
ou=cvo
o=Cisco Systems
c=US
ea= admin@cisco.com

Subject:
Name: cvo-pki-cs
cn=cvo-pki-cs
ou= cvo
o=Cisco Systems
c=US
ea= admin@cisco.com

CRL Distribution Points:

```
http://10.1.1.100/cvo-pki-cs.crl
Validity Date:
  start date: 11:38:04 PDT Jul 15 2008      !!! Note the validity !!!
  end   date: 11:38:04 PDT Sep 28 2008
Associated Trustpoints: cvo-pki-cs
Storage: nvram:cvo-pki-cs#10.cer
```

Subordinate Certificate Server

```
!!! Subordinate CA certificate with rollover !!!
cvo-pki-subcs#sh crypto pki certificates
Certificate (subordinate CA certificate)      !!! Existing subordinate server
certificate !!!
Status: Available
Certificate Serial Number: 0xC
Certificate Usage: Signature
Issuer:
  cn=cvo-pki-cs
  ou=cvo
  o=Cisco Systems
  c=US
  ea=admin@cisco.com
Subject:
  cn=cvo-pki-subcs
  ou=cvo
  o=Cisco Systems
  c=US
  ea=admin@cisco.com
CRL Distribution Points:
  http://10.1.1.100/cvo-pki-cs.crl
Validity Date:
  start date: 11:38:04 PDT May 01 2008
  end   date: 11:38:04 PDT Jun 30 2008
Associated Trustpoints: cvo-pki-subcs
Storage: nvram:cvo-pki-cs#C.cer
```

```
CA Certificate                                     !!! Existing root CA certificate !!!
Status: Available
Certificate Serial Number: 0xB
Certificate Usage: Signature
Issuer:
  cn=cvo-pki-cs
  ou=cvo
  o=Cisco Systems
  c=US
  ea=admin@cisco.com
Subject:
  cn=cvo-pki-cs
```

ou=cvo
o=Cisco Systems
c=US
ea=admin@cisco.com

Validity Date:

start date: 11:38:04 PDT May 01 2008

end date: 11:38:04 PDT Jul 15 2008

Associated Trustpoints: cvo-pki-subcs

Storage: nvram:cvo-pki-cs#BCA.cer

Certificate (subordinate CA certificate, Rollover) !!! Shadow subordinate
server certificate !!!

Status: Available

Certificate Serial Number: 0x11

Certificate Usage: Signature

Issuer:

cn=cvo-pki-cs

ou=cvo

o=Cisco Systems

c=US

ea=admin@cisco.com

Subject:

cn=cvo-pki-subcs

ou=cvo

o=Cisco Systems

c=US

ea=admin@cisco.com

CRL Distribution Points:

http://10.1.1.100/cvo-pki-cs.crl

Validity Date:

start date: 11:38:04 PDT Jun 30 2008

end date: 11:38:04 PDT Jul 15 2008 !!! Validity expires along with root CA
certificate !!!

Associated Trustpoints: cvo-pki-subcs

Storage: nvram:cvo-pki-cs#11.cer

Router Clients with Subordinate Certificate Server Trustpoint

```
cvo-spoke#sh crypto pki certificates cvo-pki-subcs
Certificate
  Status: Available
  Certificate Serial Number (hex): 10
  Certificate Usage: General Purpose
  Issuer:
    cn=cvo-pki-subcs
    ou=cvo
    o=Cisco Systems
    c=US
    ea=admin@cisco.com
  Subject:
    Name: cvo-spoke.cisco.com
    Serial Number: FHK09312145
    serialNumber=FHK09312145+hostname=cvo-spoke.cisco.com
  CRL Distribution Points:
    http://10.1.1.100/cvo-pki-subcs.crl
  Validity Date:
    start date: 11:38:04 PDT May 01 2008
    end   date: 11:38:04 PDT Jun 15 2008
    renew date: 11:38:04 PDT May 26 2008
  Associated Trustpoints: cvo-pki-subcs
```

```
CA Certificate                                     !!! Subordinate CA certificate !!!
  Status: Available
  Certificate Serial Number (hex): C
  Certificate Usage: Signature
  Issuer:
    cn=cvo-pki-cs
    ou=cvo
    o=Cisco Systems
    c=US
    ea=admin@cisco.com
  Subject:
    cn=cvo-pki-subcs
    ou=cvo
    o=Cisco Systems
    c=US
    ea=admin@cisco.com
  CRL Distribution Points:
    http://10.1.1.100/cvo-pki-cs.crl
  Validity Date:
    start date: 11:38:04 PDT May 01 2008
    end   date: 11:38:04 PDT Jun 30 2008
  Associated Trustpoints: cvo-pki-subcs
```

!!! During subordinate certificate server rollover period !!!

cvo-spoke#sh crypto pki certificates cvo-pki-subcs

Router Certificate (Rollover) !!! Shadow router certificate !!!

Status: Available

Certificate Serial Number (hex): 1B

Certificate Usage: General Purpose

Issuer:

cn=cvo-pki-cs

ou=cvo

o=Cisco Systems

c=US

ea= admin@cisco.com

Subject:

Name: cvo-spoke.cisco.com

Serial Number: FHK09312145

serialNumber=FHK09312145+hostname=cvo-spoke.cisco.com

CRL Distribution Points:

http://10.1.1.100/cvo-pki-subcs.crl

Validity Date:

start date: 11:38:04 PDT Jun 30 2008 !!! Validity starts at subordinate
CA certificate rollover !!!

end date: 11:38:04 PDT Jul 15 2008 !!! Valid until root CA certificate
expires !!!

Associated Trustpoints: cvo-pki-subcs

Certificate (subordinate CA certificate, Rollover) !!! Shadow subordinate CA
certificate !!!

Status: Available

Certificate Serial Number (hex): 11

Certificate Usage: Signature

Issuer:

cn=cvo-pki-cs

ou=cvo

o=Cisco Systems

c=US

ea=admin@cisco.com

Subject:

cn=cvo-pki-subcs

ou=cvo

o=Cisco Systems

c=US

ea=admin@cisco.com

CRL Distribution Points:

http://10.1.1.100/cvo-pki-cs.crl

Validity Date:

start date: 11:38:04 PDT Jun 30 2008

```
end    date: 11:38:04 PDT Jul 15 2008  !!! Validity expires along with root CA
certificate !!!
Associated Trustpoints: cvo-pki-subcs
Storage: nvram:cvo-pki-cs#11.cer
cvo-spoke#
```

Debug Commands

The following debug commands are useful for certificate server and router clients.

```
debug crypto pki server
debug crypto pki transactions
```



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Printed in USA

C11-684610-00 08/11