Public Key Infrastructure (PKI)

Feature Overview and Configuration Guide

Introduction

The processes that provide data security on the Internet rely fundamentally on mathematical procedures known as Asymmetric Encryption Algorithms. The main distinguishing characteristic of Asymmetric Encryption Algorithms is that they have two encryption keys, public and private, which are used to encrypt and decrypt data.

The private key is known only to the owner of that key, and should never be revealed to anyone else. Each private key has a specific companion public key, that can be safely shared with anyone. Data encrypted by the private key can be decrypted by the public key. So, if an entity shares its public key, but not its private key, others can send encrypted messages to it. They use the public key to encrypt the data they send, which the recipient can decrypt using its private key.

In a way, a public key is an identifier for the person, organization or machine that is at one end of an exchange of encrypted data communication. When the public key is sent out, it effectively says "*this is me, and I am the valid owner of the corresponding private key*". But, how can you **trust** that entity sending you its public key REALLY is the valid owner of the corresponding private key, and really is who it says it is? You need to be very sure of who you are conversing with if you are going to send them sensitive information like credit card details, banking login credentials, or other private information.

Public Key Infrastructure (PKI) is a set of procedures, policies, servers, protocols, and special files that build up a system that enables Internet users to trust the identity of those from whom they receive public keys. The most popular PKI currently in use on the Internet is a system called **X.509**.

This guide:

- Introduces asymmetric encryption, and explains how it protects data communications
- Describes some of the core elements of the X.509 PKI
- Explains what aspects of the X.509 PKI are implemented in the AlliedWare Plus software
- Provides examples for configuring AlliedWare Plus to interact with an X.509 PKI, and to use this for setting up trusted, secure communication channels.

Contents

Products and software version that apply to this guide

This guide applies to AlliedWare Plus products that support PKI, running software version **5.4.7** or later.

However, support and implementation of PKI varies between products. To see whether a product supports a feature or command, see the following documents:

- The product's Datasheet
- The product's Command Reference

These documents are available from the above links on our website at alliedtelesis.com

Feature support may change in later software versions. For the latest information, see the above documents.

Securing Data Communications

In secure data transactions, there are three important requirements that must be satisfied:

1. **Encryption**—scrambling the contents of the packets with a sufficiently uncrackable algorithm, so that anyone eavesdropping on the conversation cannot work out the actual contents of the packets.
2. **Validation**—ensuring that the participants in the transaction are who they say they are.
3. **Tamper prevention**—ensuring that the packets that are transferred are not altered along the way.

The most popular method currently in use for achieving all three of these requirements in a reliable manner is the use of public/private key pairs, backed up with X.509 certificates.

Let us look at how this method works, and how it reliably achieves all the three requirements. This explanation will gradually introduce elements of the X.509 PKI - such as certificates, certificate authorities, certificate revocation - and describe where they fit into the process of enabling trusted secure data communication.

Encryption

Most encryption methods require an algorithm and a key (or multiple keys). The encrypting device feeds the data and key(s) into the encryption algorithm and scrambles the data. The decrypting device feeds the encrypted data and the same key(s) into the companion decryption algorithm, and recovers the original unscrambled data.

The important point is that both ends of the conversation need to have the same key(s). The distribution of the key(s) is a tricky problem to solve.

If the keys are shared at the start of the data transaction, they would have to be sent in an unencrypted form (as encrypted communication cannot begin until the keys are exchanged). But, then an eavesdropper would be able to see the keys, and steal them. Having stolen the keys, the eavesdropper could decrypt all the data transferred in the session, and the encryption was pointless.

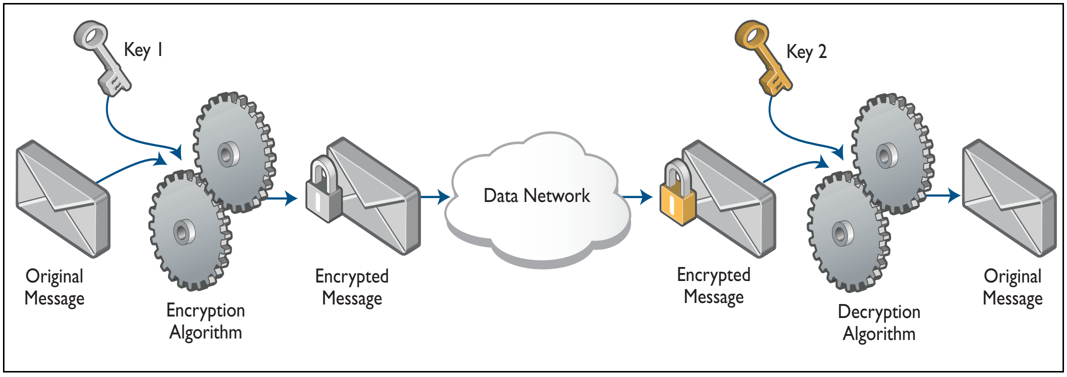
The keys could be shared by some other completely separate means—sent in an SMS message, written on paper and sent in the post, couriered on a Flash stick etc. But these methods are all rather slow and manual—and prone to human error. Moreover, they are still somewhat vulnerable to interception and key stealing.

It would be most desirable to have a completely secure way of exchanging keys at the start of the data session itself. Surprising as it may seem, there is actually a way to achieve this. The piece of magic that makes this possible is known as **asymmetric encryption**.

Asymmetric encryption

Asymmetric encryption algorithms are ones in which the key used to decrypt the data is different to that which is used to encrypt the data. These algorithms use key pairs. Data encrypted with one member of the pair can only be decrypted with the other member of the pair, and vice versa.

Figure 1: Asymmetric encryption



At first glance, this might not seem to be so powerful. In fact it might appear that we have simply introduced a new class of overly complicated encryption algorithms. But with the addition of one more simple idea, asymmetric encryption becomes very powerful.

Public/private pairs

The additional idea is to treat the key pair as a public/private pair. The public member of the pair is freely distributed, with no attempt to hide it from eavesdroppers, because its only job is to **encrypt**. The private member of the key pair is never divulged. The owner of the key never reveals it to anyone. The private key is required to **decrypt** anything that has been encrypted by the public key.

Let us examine why this concept of public/private key pairs is so powerful. The best way to examine it is to consider an example data transaction. In fact, let us consider a very familiar transaction that almost all of us have experienced, and which uses public/private keys (even if we had not realized it). The example transaction is that of using your credit card to buy goods from an e-commerce website.

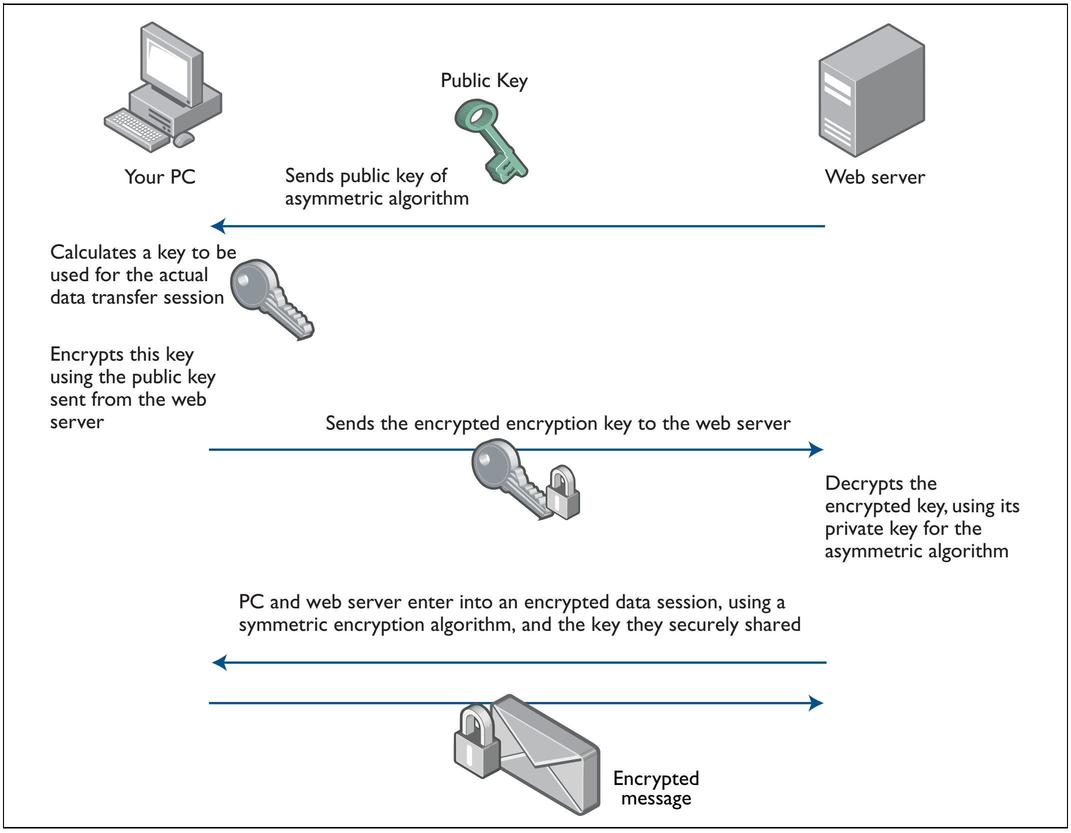
When your computer begins its session with a secure website:

1. The web server sends you its public encryption key.
2. Your computer then computes a key that will be used as the encryption key for the rest of the data session. Note that the encryption algorithm that will be used for the rest of the data session is a standard symmetric algorithm; it is only the key exchange that is secured by the asymmetric algorithm. Your computer computes a key that will be used for the subsequent encrypted data session.
3. Then, your computer encrypts this key using the public key that the web server sent to it.

4. This encrypted key is then transmitted to the web server. It does not matter who intercepts this message, and takes a copy of it; the **only** key that can decrypt the message is the web server's private key.

5. Then, the web server uses its private key to decrypt the message. Only the web server has a copy of the private key, so no eavesdropper will be able to decrypt the message and learn the key that you and the web server will be using for your data transfer.

Figure 2: Public/private key pairs


Your PC
Public Key
Web server
Sends public key of asymmetric algorithm
Calculates a key to be used for the actual data transfer session
Encrypts this key using the public key sent from the web server
Sends the encrypted encryption key to the web server
Decrypts the encrypted key, using its private key for the asymmetric algorithm
PC and web server enter into an encrypted data session, using a symmetric encryption algorithm, and the key they securely shared
Encrypted message

The asymmetric encryption algorithms, along with the idea of treating the keys as a public/private pair, securely transfer the key for a data session.

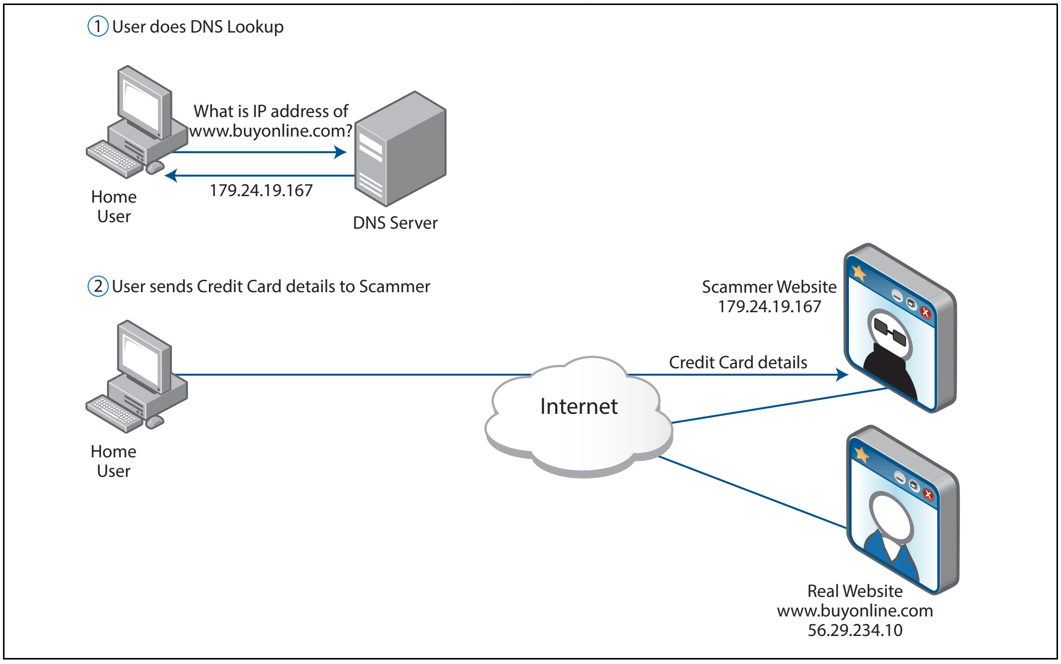
That is **encryption** dealt with. Now let us look at how adding X.509 certificates into the process satisfies the **validation** requirement.

Validation

In the example above we see how your PC can exchange an encryption key with the web server in a way that keeps it safe from being stolen. But, how do you know that the web server to whom you sent your credit card details was actually the server it claimed to be?

A sophisticated scam might have installed false records into DNS servers, so that when you directed your browser to the URL of the trusted on-line store, your traffic was actually being sent to the scammer's fake look-alike site.

Figure 3: A scam to steal credit card details using a bogus server


1 User does DNS Lookup
What is IP address of www.buyonline.com?
179.24.19.167
Home User
DNS Server
2 User sends Credit Card details to Scammer
Scammer Website 179.24.19.167
Credit Card details
Internet
Home User
Real Website www.buyonline.com 56.29.234.10

This is where X.509 certificates and digital signatures come in.

Definition An X.509 certificate is an electronic file that verifies the identity of the owner of a public/private key pair.

The file contains information like the owner's domain name, some of their physical address, an email address, the public key, and the algorithm that the key pertains to. The certificate also contains fields stating the dates of the beginning and end of its period of validity. There are a large number of other fields that can be, but do not have to be, present in a certificate.

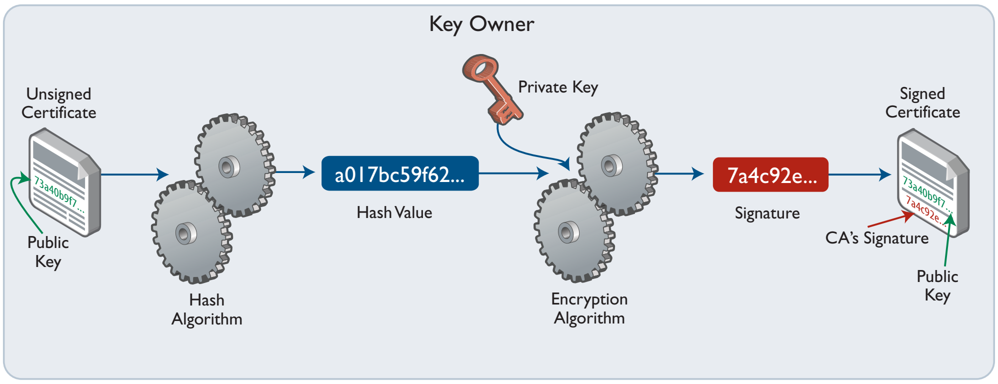
One field that every certificate **must** contain is the **digital signature**. The digital signature is a number that is computed as follows:

- All the rest of the contents of the certificate are fed into a hash algorithm, which generates a single number, which is the hash (rather like a checksum) of those contents.
- The resulting hash value is encrypted using the private key of a public/private key pair.

Most importantly, the private key used in the creation of the signature is typically **not** the certificate owner's private key. Instead it is the private key of a third party—a highly trusted entity known as a **Certification Authority (CA)**.

The fact that the certificate has been signed by this CA proves that this CA is satisfied that the certificate owner is who they claim to be. The CA has signed the certificate and given it to the owner.

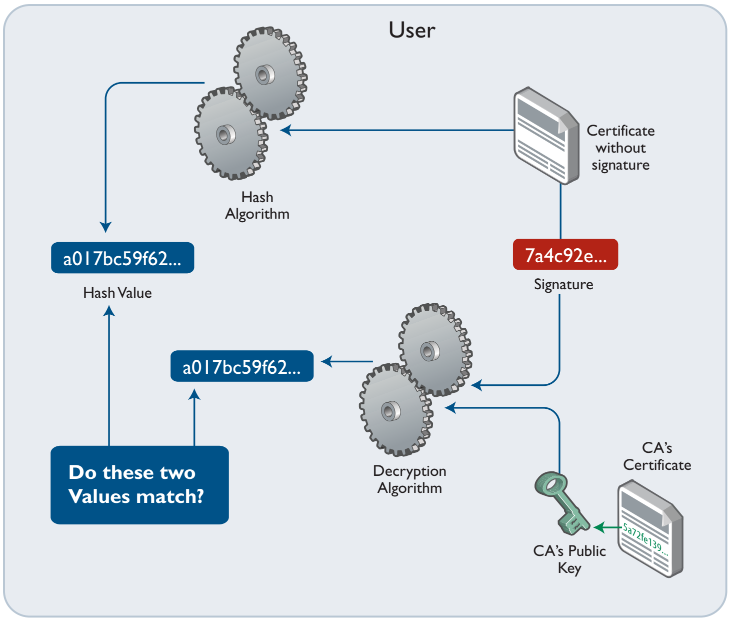
Figure 4: Digital signature



But, how does your PC know the signature is valid? It is just a number contained in a file, so how can your PC work out that this number was encrypted by the CA?

To do so, your PC needs to already have a copy of the CA's own certificate for the private key they used for signing the web server's certificate. In fact, most PC operating systems ship with a set of X.509 certificates from a number of highly trusted certification authorities. The CA's certificate will, of course, contain the CA's public key. Using this public key, your PC decrypts the signature. Then, the PC can calculate the hash on the rest of the contents of the certificate, and check that this matches the decrypted signature.

Figure 5: Verifying the CA certificate



If this all checks out, then your PC:

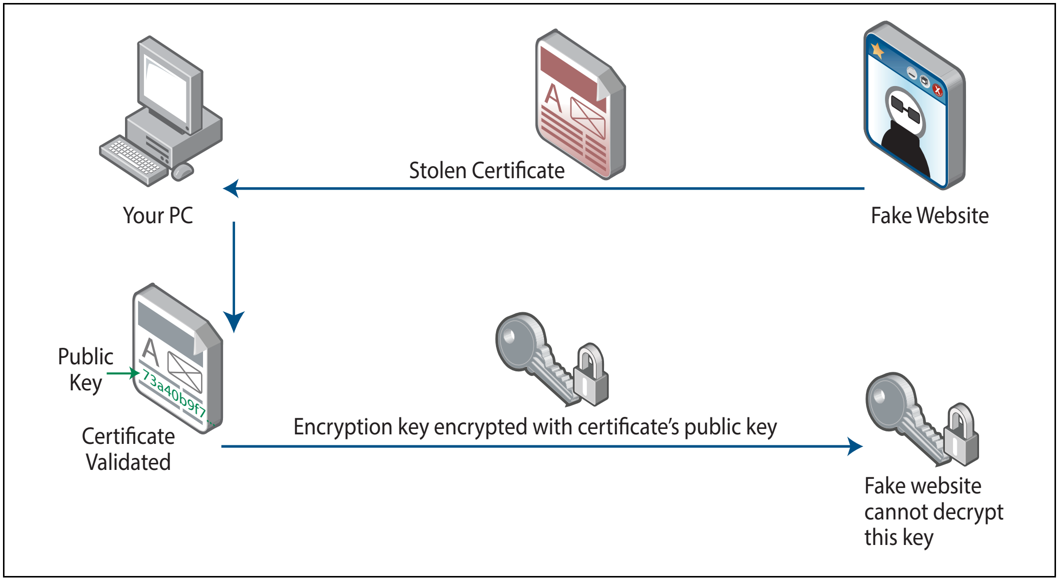
- knows that the web server's certificate was signed by the CA it claims to have been signed by.
- knows that the CA is satisfied that the website is who they claim to be.
- will follow suit, and trust that the website is who they claim to be.

Certificate signing

But, you might be thinking, once the website sends out a copy of its certificate, then anybody can get hold of it, including scammers. Couldn't the scammers just send out the stolen certificate of the website they are spoofing?

In fact, you would be correct. A certificate is fully available to the public domain. But, the really important point is that only the true owner of the certificate has a copy of the private key corresponding to the public key contained in the certificate. So if the scammer sent a stolen certificate to your PC, then certainly your PC would initially trust the scammer's site. But, when your PC sent the scammer an encryption key encrypted with the certificate's public key, the scammer would not possess the necessary private key to decrypt the key sent from your PC. So, the actual data transfer session would not be able to proceed.

Figure 6: Unsuccessful data transfer session


Stolen Certificate
Your PC
Fake Website
Public Key
73a40b9f7
Certificate Validated
Encryption key encrypted with certificate's public key
Fake website cannot decrypt this key

It is probably not entirely accurate to say that a certificate verifies the identity of the entity that sends the certificate to you.

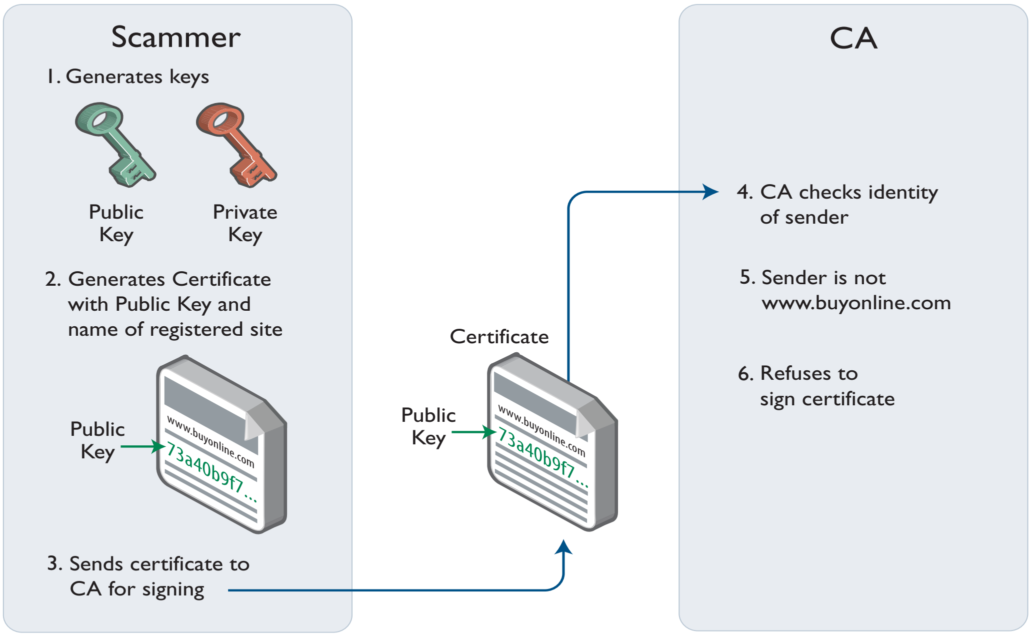
Definition A more accurate statement is that the certificate verifies the identity of the possessor of the private key corresponding to the certificate's public key.

The certificate prevents a scammer from creating their own public/private key pair, and then sending out a certificate containing the public member of that key pair, but showing the owner identity as being that of some valid on-line store. This is because the scammer would not be able to persuade a trusted CA to sign the certificate.

Certainly, we do need to trust in the competence and honesty of the Certification Authorities. If scammers could bribe or trick CAs into signing false certificates, then the whole web of trust falls apart. It is a simple fact of life that no electronic security system can entirely eliminate the human element.

However, the CAs' entire ability to stay in business is based on the integrity and trustworthiness of their systems, so they have very strong incentives to continue to deserve our trust.

Figure 7: CA checks identity of sender


Scammer
1. Generates keys
Public Key
Private Key
2. Generates Certificate with Public Key and name of registered site
Public Key
www.buyonline.com
73a40b9f7...
3. Sends certificate to CA for signing
Certificate
Public Key
www.buyonline.com
73a40b9f7...
CA
4. CA checks identity of sender
5. Sender is not www.buyonline.com
6. Refuses to sign certificate

Tamper prevention

There are two aspects of tamper prevention we need to consider. The first is the prevention of tampering with X.509 certificates. The second is the prevention of tampering with the encrypted data session that occurs after the certificate exchange.

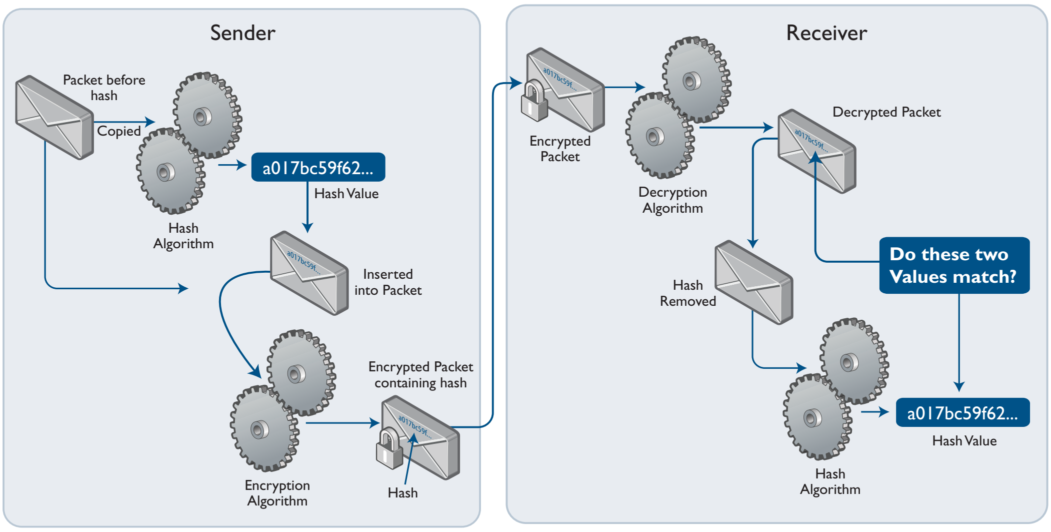
The key to tamper prevention is encrypted hashes.

As we have seen above, the signature in a certificate is an encrypted hash. A hash is calculated on the contents of the certificate, then the hash is encrypted using the CA's private key. If a man-in-the-middle intercepts the certificate and alters its contents, then they could recalculate the hash easily enough. But they do not possess the CA's private key, so they cannot correctly encrypt the new hash. So, when your PC receives the certificate, and validates the signature, the signature will not check out, and the certificate will be discarded.

In the subsequent encrypted data transaction, the web server and your PC can agree to use a hash algorithm like MD5 or SHA to calculate a hash on each packets' contents prior to encryption. The hash value can then be included in the packet, and encrypted along with the rest of the packet. Again, if the content of the packet is altered somewhere along its journey, the hash will not be able to be re-encrypted correctly (as only your PC and the web server know the encryption key).

When the packet arrives at its destination, the hash contained in the altered packet will no longer be correct, and the packet will be discarded.

Figure 8: Tamper prevention using encrypted hashes



Certificate chains

In the section "Certificate signing" above, there was an explanation that an end-user certificate will be signed by a CA, and that the PC receiving the certificate will also have a copy of the CA's certificate, which verifies the CA's private key. This explanation implies a two-step certificate chain:

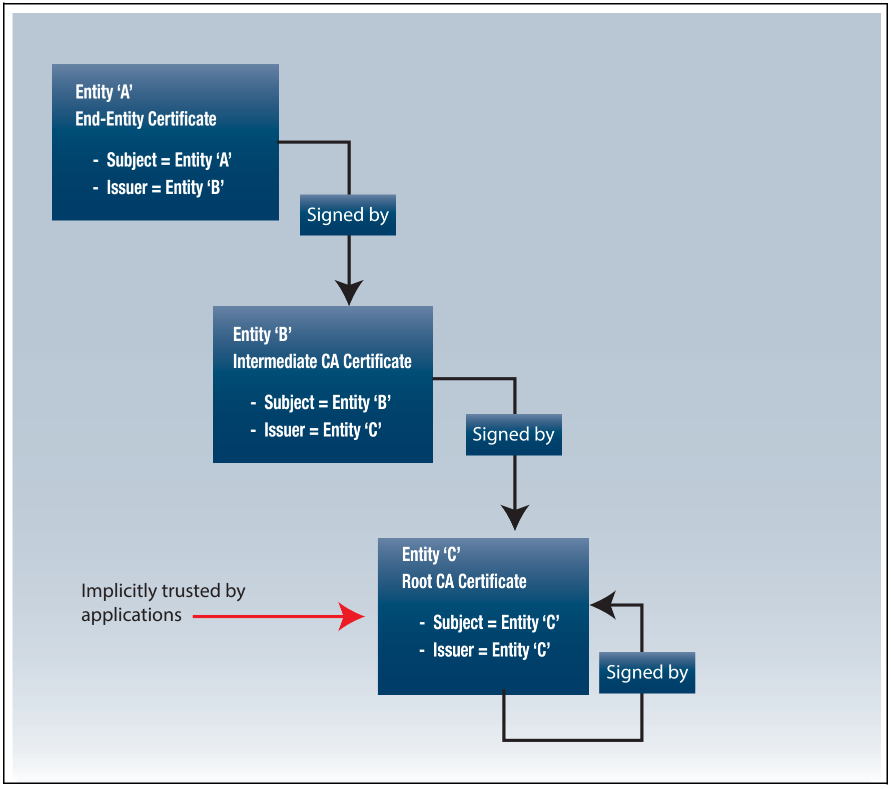
1. www.buyonline.com certificate is signed by CA
2. CA's certificate verifies the identity of the CA.

In fact, there is no requirement that a certificate chain have only two steps. It is quite possible that the CA certificate that verifies the private key used to sign the www.buyonline.com certificate is, itself, signed by a higher-level CA's private key.

That certificate must in turn be authenticated by checking its signature. If the CA certificate is signed by another entity, the CA is an **intermediate** CA, and its certificate must in turn be verified using the next higher level CA.

At some point, this chain of verification eventually must end at a trusted self-signed certificate, also known as a Root CA certificate. A root certificate is signed by itself (the signature is decrypted using the public key contained within the certificate). It may only be validated for consistency with itself. The application must implicitly trust that the certificate is valid. This is generally accomplished by having end users manually control the verification and installation of root certificates, or by the certificates being bundled with trusted operating system software.

Figure 9: Certificate chain



Commercial CAs will often use an intermediate CA in order to protect the root private key from exposure. When an intermediate CA is used to sign certificates, only the intermediate private key is needed; the root private key may remain locked away in off-line storage.

So, what happens is:

- The organisation that owns the CA will create their root public/private key, and a self-signed certificate for this key pair. This is the Root CA certificate and root key pair.
- Then, they create another public/private key pair. These are the intermediate CA key pair. A certificate is created for this key pair, and signed by the Root CA key.
- The Root CA private key is stored in a location that is not network accessible, and any copy of it is removed from any network accessible locations, so it is thoroughly secure.
- The intermediate CA private key is used for signing clients' certificates. The validity of the intermediate CA is backed up by the Root CA, but the Root CA private key does not need to be involved in the process of signing the clients' certificates.
- If an intermediate CA private key is ever stolen, it can be declared invalid (the term in X.509-speak is 'revoked') and a new intermediate CA key-pair created, along with a new certificate signed by the Root CA's private key.

Checking certificate validity

As mentioned above, it is possible for a private key corresponding to a trusted certificate to be stolen. If this happens, then the certificate effectively become worthless. The whole value of a certificate lies in the fact that you can trust the holder of the private key that corresponds to the certificate's public key. Once a private key has been stolen, then you have no idea whose hands that private key has fallen into, and therefore no reason to trust anyone who does hold that private key.

In that case, devices that use X.509 certificates to secure data communications need a way to know that a previously trusted certificate is now worthless, and should no longer be treated as implying any trust at all.

The X.509 PKI does provide a mechanism by which devices can learn of certificates that should no longer be trusted. The process is referred to as **revoking** the certificates.

There are two ways that a device can check if a certificate has been revoked:

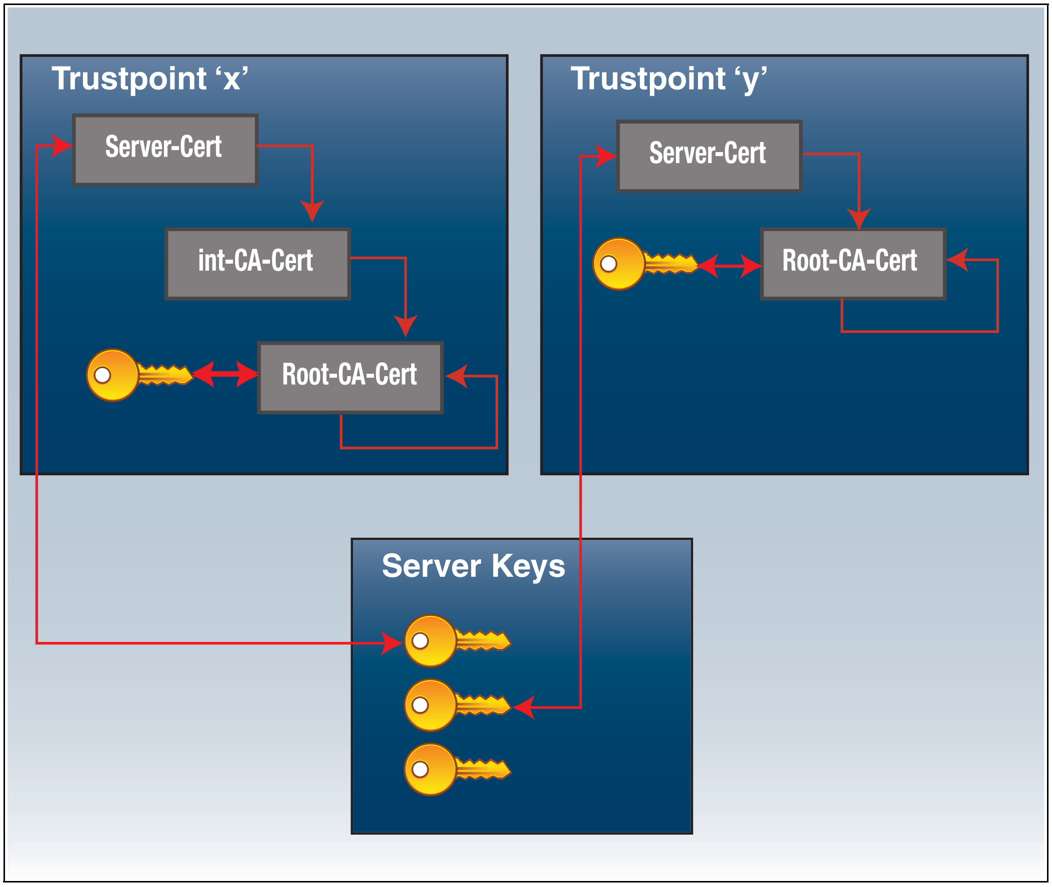
1. The original method is the use of Certificate Revocation Lists (CRLs). As a CA revokes certificates, it adds the revoked certificates to a CRL. When a device receives a certificate signed by a particular CA, it can request the CRL from that CA, and check whether or not the certificate it just received is in the CRL. If the certificate **is** in the CRL, then the device should not proceed to establish a communication session with the peer which sent it the certificate.
2. Because CRLs are potentially unwieldy (for some long-established CAs, the CRLs have grown to Megabytes in size), an alternative method has been developed, called Online Certificate Status Protocol (OCSP). With OCSP, the device sends to the CA some details of the certificate it has received, and the CA responds with a verdict on whether or not the certificate is still valid. This is a quicker, easier method than that of the CA sending out the full list of its revoked certificates.

The AlliedWare Plus implementation of X.509 uses OCSP. For more information on OCSP see "Configuring the OCSP Responder" on page 45.

AlliedWare Plus PKI Implementation

In AlliedWare Plus, certificates and keys are stored in containers called **trustpoints**. Within a trustpoint, the certificates form a chain that ends in a single Root CA certificate. The Root CA certificate's private key is also stored in the trustpoint, if the certificate is locally self-signed (i.e. if the certificate was generated and signed on the local device). Server keys are stored outside of trustpoints since they may be shared by multiple entities.

Figure 10: Trustpoints and keys



AlliedWare Plus allows you to create multiple trustpoints, and to use local (self-signed) certificates or external certificates signed by other CAs.

The work flow for using PKI on AlliedWare Plus

The standard work flow for the user is to:

1. **create** a trustpoint
2. **authenticate** it (create or import the Root CA certificate)
3. **enroll** the local server (create the server certificate)
4. then **configure** applications to use the trustpoint

The use cases below describe several common scenarios, including the creation and use of certificates from a local self-signed certificate authority, and the use of certificates from an external certificate authority.

Creating a trustpoint based on a local self-signed certificate

Use the following commands to create a trustpoint based on a local self-signed certificate:

Step 1.

```
enable
config terminal
```

Use these commands to enter configuration mode after logging in. PKI commands require maximum user privileges to execute.

Step 2.

```
crypto pki trustpoint raleigh
```

This command declares a trustpoint named “raleigh” and enters trustpoint configuration mode. You can use any name (so long as the first character is alphanumeric, and all characters are alphanumeric, underscores, dashes, or periods). The name “local” is special; if it is used, the trustpoint is assumed to use a local self-signed certificate authority, and the CA is automatically authenticated when the trustpoint is created. This is to retain consistency with legacy behavior. For all other trustpoint names, this command just instantiates the trustpoint by initializing its storage container.

Step 3.

```
enrollment selfsigned
```

This command declares that trustpoint will use a local self-signed certificate authority. It affects the authentication process (the creation of the trusted root certificate) and the server enrollment process (the creation of the server certificate), but doesn’t immediately cause any action to be taken. In other words, this command does not result in certificate generation; it only affects how certificate generation will be done later. The keyword ‘self-signed’ is a bit of a misnomer since all root certificates are self-signed, however, this is the industry standard term for locally generated CAs.

Step 4.

```
rsakeypair raleigh-server-key
```

This command declares that the trustpoint will use the keypair **raleigh-server-key** when enrolling the server (creating the server certificate). This command doesn’t result in the creation of the keypair. If the keypair does not exist, it will be created when you enter the **crypto pki enroll** command in a later step. You can specify the bit length of the key in this command, but the **length** parameter will be ignored if the key already exists and has a different length.

Step 5.

```
exit
```

This command exits trustpoint configuration mode.

Step 6. `crypto pki authenticate raleigh`

This command initiates creation of the local self-signed root certificate. This involves generating a 2048-bit public/private keypair for the CA. This keypair is distinct from the keypair used for the server certificate. You cannot use existing keypairs generated by the **crypto key generate rsa** command as the CA key, since CA keys should always be unique. The key is then used in the creation of the self-signed root certificate.

The subject name of the root certificate incorporates the serial number of the device, to help ensure uniqueness.

Step 7. `crypto pki enroll raleigh`

This command initiates creation of the server certificate. For a trustpoint with a local self-signed certificate authority, this is a single-step process. It creates a server certificate for the local device using the RSA keypair specified in the trustpoint parameters. If the keypair specified in the **rsakeypair** command does not exist, it will be created at this point. If the **rsakeypair** command has not been executed for this trustpoint, then a keypair will be created at this point, and given the name of the trustpoint.

By default, the subject name of the server certificate has the CN (common name) field set to the fully qualified domain name of the system, since that is commonly required when other systems validate the subject name. However, you can substitute a subject name of your choice by using the **subject** command in trustpoint-configuration mode. This command is described later in this guide.

At this point, the Trustpoint is set up. It contains the:

- trustpoint's self-signed root certificate
- root RSA public/private keys.
- trustpoint's own server certificate, signed by the root private key.

The following figure shows the commands entered in the above example, and the responses returned by the CLI.

```
awplus>enable
awplus#config terminal
Enter configuration commands, one per line.  End with CNTL/Z.
awplus(config)#crypto pki trustpoint raleigh
% Created trustpoint "raleigh".
awplus(ca-trustpoint)#enrollment selfsigned
awplus(ca-trustpoint)#rsakeypair raleigh-server-key
awplus(ca-trustpoint)#exit
awplus(config)#crypto pki authenticate raleigh
% Successfully authenticated trustpoint "raleigh".
awplus(config)#crypto pki enroll raleigh
% Using private key "raleigh-server-key"...
% Successfully enrolled the local server.
```

Creating a trustpoint based on an external Certificate Authority

This scenario assumes that the external certificate authority has a Root CA certificate and an intermediate (subordinate) CA certificate.

The steps in this process are described in detail below.

Step 1.

```
enable
configure terminal
```

These are the commands to enter configuration mode after logging in. PKI commands require maximum user privileges to execute.

Step 2.

```
crypto pki trustpoint christchurch
```

This command declares a trustpoint named “christchurch” and enters trustpoint configuration mode. You can use any name (so long as the first character is alphanumeric, and all characters are alphanumeric, underscores, dashes, or periods). The name “local” is special; if it is used, the trustpoint is assumed to use a local self-signed certificate authority, and the CA is automatically authenticated when the trustpoint is created. This is to retain consistency with legacy behavior. For all other trustpoint names, this command just instantiates the trustpoint by initializing its storage container.

Step 3.

```
enrollment terminal
```

This command declares that the trustpoint will use certificates that are cut-and-pasted into the system at the terminal. It affects the authentication process (the importing of the trusted root certificate) and the server enrollment process (the importing of the server certificate), but doesn’t immediately cause any action to be taken. In other words, this command does not result in certificate generation; it only affects how certificate generation will be done later.

Step 4.

```
exit
exit
```

These commands exit trustpoint configuration mode and return you to privileged exec mode.

Step 5.

```
crypto pki authenticate christchurch
```

This command causes the system to prompt for the external certificate authority’s root certificate to be pasted to the terminal, in Privacy Enhanced Mail (PEM) format. The file begins with a the flag “------BEGIN CERTIFICATE------” and ends with the flag “------ END CERTIFICATE------”. In between is a base-64 encoded representation of the certificate. The system detects the start and end flags as they are entered. When you have pasted the complete file, the system ensures that the certificate is valid.

So, you will need to have a copy of the external CA's root certificate at hand, in PEM format.

The command displays the certificate subject and issuer. It also displays the certificate fingerprint (a cryptographic hash of the certificate contents) so that you may manually verify the authenticity of the certificate (presuming that the fingerprint is available from the CA on an out-of-band channel). Alternatively, you could pre-enter the fingerprint (using the **fingerprint** command in trustpoint configuration mode; this is described later in this guide), in which case the certificate is accepted without prompting.

Step 6.

```
crypto pki enroll christchurch
```

This command initiates creation of the server certificate for this trustpoint. Because this trustpoint uses an external certificate authority, this is a two-step process. The **enroll** command results in the creation of a Certificate Signing Request (CSR), which is displayed at the terminal in PEM format. You should cut-and-paste this file, and transmit it to the external CA.

Step 7.

```
crypto pki import christchurch pem
```

In this example, the external certificate authority uses two levels of CA certificates: a root certificate and an intermediate certificate. On the local system, you need to import both the intermediate certificate and the server certificate from the external CA. Both import operations are accomplished with the same command syntax. The intermediate certificate must be imported first, since the system cannot validate the server certificate without it.

Similar to the **authenticate** operation for the root certificate, you must cut-and-paste the certificate PEM file at the terminal, and the system prompts you to verify the certificate fields and its fingerprint. (In fact, **import** may be used in place of **authenticate** to import the root certificate for external CAs; the commands behave in largely the same manner. **authenticate** has the advantage of being similar to the local self-signed trustpoint, from a command flow perspective, **import** has the advantage of being able to import PEM files directly from an external URL.)

Step 8.

```
crypto pki import christchurch pem
```

Enter the same **import** command a second time to import the server certificate that has been received back from the CA after having been signed. Again, you cut-and-paste a certificate file at the terminal, then verify the certificate’s fields and fingerprint.

At this point, the Trustpoint is set up. It contains the:

- external CA's root certificate
- external CA's intermediate certificate
- trustpoint's own server certificate, signed by the CA's intermediate key.
- trustpoint's own public/private keys.

The following figure shows the commands entered in the above example, and the responses returned by the CLI.

Figure 11: Configuring a trustpoint based on an external Certificate Authority

```
awplus> enable
awplus#configure terminal

Enter configuration commands, one per line. End with CNTL/Z.
awplus(config)#crypto pki trustpoint christchurch

Created trustpoint "christchurch".
awplus(ca-trustpoint)##enrollment terminal
awplus(ca-trustpoint)#exit
awplus(config)#exit
awplus#crypto pki authenticate christchurch

Paste the certificate PEM file into the terminal.
Type "abort" to cancel.
-----BEGIN CERTIFICATE-----
MIIE3DCCA8SgAwIBAgIJAOq+rPVNHe6PMA0GCSqGSIb3DQEBBQUAMIGkMQswCQYD
...
GX8wazKXK40bwtKBj2HaoBVlKy/Eie6Vikf6ToQrvdHeuOrnxjEMuUbrNA0KbWEw
-----END CERTIFICATE-----

Complete ("END CERTIFICATE" detected).
Subject     : /C=NZ/CN=Christchurch_Root_CA
Issuer      : /C=NZ/CN=Christchurch_Root_CA
Valid From  : Jul 23 18:12:10 2015 GMT
Valid To    : May 12 18:12:10 2025 GMT
Fingerprint : 594EDEF9 C7C4308C 36D408E0 77E784F0 A59E8792
This is a self-signed CA certificate.
The certificate has been validated successfully.
Accept this certificate? (y/n): y
Successfully authenticated trustpoint "christchurch".
awplus#crypto pki enroll christchurch

Using private key "server-default"...
Cut and paste this request to the certificate authority:
-----------------------------------------------------------------
-----BEGIN CERTIFICATE REQUEST-----
MIICwjCCAaoCAQAwMjEYMBYGA1UECgwPQWxsaWVkV2FyZSBQbHVzMRYwFAYDVQQD
...
N6asaQcD9s0mjNvVv6zobqrZdroSI2MOvHpkqSo8ybihO1HoZEo=
-----END CERTIFICATE REQUEST-----
-----------------------------------------------------------------
awplus#crypto pki import christchurch pem

Paste the certificate PEM file into the terminal.
Type "abort" to cancel.
-----BEGIN CERTIFICATE-----
MIIE5jCCA86gAwIBAgIJAK+WULQbjwzPMA0GCSqGSIb3DQEBBQUAMIGkMQswCQYD
...
tp1g9AKjg1Vb2jf837JDpQXADsRMlBY01iRhS3+gsDTTE2mA84H0SF+S2EuCRhmt
LpA+GhuhzNx8Gw==
-----END CERTIFICATE-----

#[continued on next page]
```

```
Complete ("END CERTIFICATE" detected).
Subject     : /C=NZ/CN=Christchurch_Signing_CA
Issuer      : /C=NZ/CN=Christchurch_Root_CA
Fingerprint : AE2D5850 9867D258 ABBEE95E 2E0E3D81 60714920
This is an intermediate CA certificate.
The certificate has been validated successfully.
Accept this certificate? (y/n): y
The certificate was successfully imported.
awplus#crypto pki import christchurch pem

Paste the certificate PEM file into the terminal.
Type "abort" to cancel.
-----BEGIN CERTIFICATE-----
MIIDXTCCAkUCCQCGKcNPqv+aTzANBgkqhkiG9w0BAQUFADCBrjELMAkGA1UEBhMC
...
UTNvtYju2SYDnBizxJWg6uF2vrPClNfQh4TXBNhul64Dg+mQ5UUwsQ31V3focd46
pQ==
-----END CERTIFICATE-----

Complete ("END CERTIFICATE" detected).
Subject     : /O=AlliedWare Plus/CN=awplus.atg.lc
Issuer      : /C=NZ/CN=Christchurch_Signing_CA
Valid From  : Sep 3 18:45:01 2015 GMT
Valid To    : Oct 10 18:45:01 2020 GMT
Fingerprint : 5A81D34C 759CC4DA CFCA9F65 0303AD83 410B03AF
This is a server certificate.
The certificate has been validated successfully.
Accept this certificate? (y/n): y
The certificate was successfully imported.
```

Setting the Organization and Common Name

You can set the distinguished **name** string used for the subject field in the server certificate. The **name** is used when enrolling the server (generating the server certificate or server certificate signing request).

To do so, use the following command in **trustpoint configuration mode**:

```
awplus(ca-trustpoint)#subject-name <name>
```

The **name** is specified as a variable number of fields, where each field begins with a forward-slash character ("/"). Each field is of the form "XX=value" where "XX" is the abbreviation of the node type in the tree. Supported values are "O" (organization) and "CN" (common name). For a server certificate, many applications require that the network name of the server matches the common name in the server's certificate.

If no **subject-name** is specified for the trustpoint, then the system automatically builds a name of the form “/O=AlliedWare Plus/CN=xxxx.yyyy.zzz”, where “xxxx” is the hostname of the system and “yyyy.zzz” is the default search domain for the system.

Example:

```
awplus> enable
awplus#configure terminal

Enter configuration commands, one per line. End with CNTL/Z.
awplus(config)#crypto pki trustpoint christchurch

Created trustpoint "christchurch".
awplus(ca-trustpoint)#subject-name "/O=My Company/CN=192.168.1.1"
```

Migrating and Destroying Trustpoints

Migrate a trustpoint to another system

When replacing an existing device in a network, it may be convenient to migrate the certificates and keys from a trustpoint from the device to its replacement. If the original device had signed any root or entity certificates, this saves you from having to re-issue them to all the other device in the network.

Consider the case where the device, a RADIUS server, has issued client certificates to a large number of network supplicant devices. The loss of the device’s root certificate would invalidate all the client certificates. The effort required to regenerate and redistribute all new client certificates could be extensive.

Thus, to avoid having to reconfigure an entire network, the PKI implementation provides a method of exporting the root certificate and key for a locally self-signed trustpoint to a new device. (Technically, the new device would only need to have the certificate to continue operating; however, it would be unable to issue new client certificates without the key.)

The implementation also supports export of the server certificate and key; however, this is less important as these items can be regenerated on a new device. In fact, regenerating the server certificate may be preferable to migrating it, for a couple of reasons: it avoids security issues from having the server key present on the old device; and the new certificate may require different elements in its “subject” field.

The steps to transfer a trustpoint called "Raleigh" from one device to another, via a TFTP server are as below:

Step 1. **Export the root certificate and keys from the original device:**

```
crypto pki export raleigh pkcs12 ca tftp://backup/raleigh.pk12
```

This command packages the root certificate and its associated private key into a PKCS#12-formatted file for export. The system will prompt you to enter a passphrase, which will be used to encrypt the private key. This command may only be used for locally self-signed CAs.

To export the certificate for an external CA, use the following command instead:

```
crypto pki export <trustpoint> pem
```

Step 2. **Create a new trustpoint on the new device:**

```
crypto pki trustpoint newraleigh
```

This command declares a trustpoint named “newraleigh” on the destination system.

Step 3. **Import the root certificate:**

```
crypto pki import newraleigh pkcs12 ca tftp://backup/raleigh.pk12
```

This command imports the root certificate and its associated private key from the specified PKCS#12 file to a trustpoint. The system will prompt you to enter the same passphrase that was used to encrypt the private key during the “export” operation.

Output 1: Source system commands and output

```
awplus>enable
awplus#crypto pki export raleigh pkcs12 ca tftp://backup/raleigh.pk12
% Enter an export passphrase, or "abort" to cancel.
*****
% Enter the export passphrase again.
*****
% Exporting...
% Successfully exported the trustpoint key and certificate.
```

Output 2: Destination system commands and output

```
awplus>enable
awplus#config terminal
Enter configuration commands, one per line.  End with CNTL/Z.
awplus(config)#crypto pki trustpoint newraleigh
% Created trustpoint "newraleigh".
awplus(ca-trustpoint)#exit
awplus(config)#crypto pki import newraleigh pkcs12 ca
               tftp://backup/raleigh.pk12
% Importing...
% Enter the import passphrase.
*****
% The certificate has been validated successfully.
% Successfully imported the trustpoint.
```

Step 4. **If you wish, you can also transfer the trustpoint's server certificate and private key, using the following command on the original device**

```
crypto pki export raleigh pkcs12 server tftp://backup/
raleigh_server.pk12
```

And, the corresponding command on the destination device:

```
crypto pki import newraleigh pkcs12 server tftp://backup/
raleigh_server.pk12
```

Destroy a trustpoint

Destroying a trustpoint involves removing all the certificates associated with the trustpoint from Flash memory storage. If the trustpoint is a local self-signed CA, then the private key associated with the root certificate is also removed. The consequence of this is that all certificates signed by the Root CA become invalid, including RADIUS user certificates that may have been issued and exported to client devices. Therefore, this is not an action to take lightly.

For trustpoints with imported root certificates, the consequences are not as severe. The root certificate may be re-imported from its original source, and the local server may be re-enrolled. The server private key is not destroyed along with the trustpoint (since the same key may be used for server enrollments across multiple trustpoints), so the previous key may be re-used if desired.

```
awplus>enable
awplus#config terminal
Enter configuration commands, one per line.  End with CNTL/Z.
awplus(config)#no crypto pki trustpoint raleigh
% Destroyed trustpoint "raleigh".
```

The Legacy Trustpoint "local"

Migrating the legacy “local” trustpoint

Prior to v5.4.6-1.1, AlliedWare Plus supported only one trustpoint. This was an automatically created trustpoint with the name **local**. The file system structure used in the legacy trustpoint is different to that used in the user-created trustpoints.

If your system already contains a trustpoint named “local” from a legacy configuration, and you want to use that trustpoint in a new configuration, you do not have to re-create it. Instead, you can just enter the command **crypto pki trustpoint local**, and the system will copy the previous certificates and keys into the new file locations.

This will make the trustpoint named “local” usable just as though it were a user-created trustpoint. The migration will occur on the first invocation of the command **crypto pki trustpoint local**.

Automatic creation of the “local” trustpoint by RADIUS

In the legacy implementation, the trustpoint named “local” was automatically created, authenticated, and enrolled by the local server when the local RADIUS server was instantiated (with the command **radius-server local**). From v5.4.6-1.1 onwards, this no longer occurs. If a configuration file contains the command **radius-server local** command, but the system does not already have a trustpoint named “local” with an enrolled server on the Flash memory, then EAP-TLS and PEAP will not function. This should not be an issue when upgrading an existing device, but, for a new device, PKI must be configured before RADIUS EAP-TLS and PEAP can be used.

Commands for Monitoring the State of PKI on the Device

There are a number of **show** commands, listed below. For more details of these commands, and their output, please see the Command Reference for your product.

- `show crypto key hostkey [dsa|rsa|rsa1]`
- `show crypto key mypubkey rsa [<`*`keylabel`*`>]`
- `show crypto key pubkey-chain knownhosts [<`*`1-65535`*`>]`
- `show crypto key pubkey-chain knownhosts [vrf <`*`vrf-name`*`>| global] [<`*`1-65535`*`>]`
- `show crypto key pubkey-chain userkey <`*`username`*`> [<`*`1-65535`*`>]`
- `show crypto key userkey <`*`username`*`> [dsa|rsa|rsa1]`
- `show crypto pki certificates [<`*`trustpoint`*`>]`
- `crypto pki enrollment user <`*`username`*`>`
- `show crypto pki trustpoint [<`*`trustpoint`*`>]`
- `show crypto pki trustpoints`

Using PKI for Secure Communications

The previous sections have described how to set up trustpoints.

Having set up a trustpoint, how do you make use of the certificates and keys that have been created? The following sections illustrate some examples of how to make use of a trustpoint once it has been created.

RADIUS over TLS (RadSec)

RadSec is an extension to the RADIUS authentication protocol that uses TLS as the transport protocol. It provides improved security over the standard RADIUS protocol by:

- ensuring that protocol messages are encrypted, preventing external entities from snooping usernames and passwords
- using X.509 certificate chains for identity validation and encrypted key exchange

AlliedWare Plus uses a **RadSecProxy** to act as an intermediary between local applications that use standard RADIUS UDP datagrams and external entities that use RadSec. RadSecProxy converts UDP datagrams into messages carried over TLS, and vice versa.

The TLS connection supports secure renegotiation, and if the connection is broken unintentionally then it recovers automatically after restoration of the connection.

RadSecProxy works for both the client and server sides of the RADIUS exchange.

Secure User Authentication with Remote RADIUS Server

On the client side, the switch should be configured to communicate by using a client proxy instance. The client RadSecProxy application is called the **RadSecProxy AAA** application, because it enables the use of RadSec for local authentication, authorization, and accounting operations using a remote RadSec server.

The steps for creating a client-side RadSecProxy (AAA) instance within the AlliedWare Plus device are given below. The device will use RadSec to authenticate local login sessions with remote RADIUS.

Prerequisites:

- A trustpoint (named “christchurch” in this example), authenticated to an external self-signed CA, is present on the system
- The device has been enrolled to the trustpoint
- An IPv4 interface or an IPv4 interface with DNS has been configured on the system
- The user names and passwords for remote users exist on the remote RADIUS Server
- The RadSec Server running on the remote machine is using version 1.6.7 or higher
- The configuration file for the RadSec Server running on the remote machine has been changed to ensure that it acts as a:
    - Client for receiving TLS connection/data on Port 2083
    - Client to receive replies from FreeRADIUS on Port 11812
    - Server to pass on RADIUS requests to FreeRADIUS Server on Port 1812

Result:
A RadSecProxy process that communicates to a remote RadSec Server called **radsecserver.local**. The steps in this process are described below.

Step 1.

```
enable
configure terminal
```

These are the commands to enter configuration mode after logging in. PKI commands require maximum user privileges to execute.

Step 2.

```
radius-secure-proxy aaa
```

This command enters the configuration mode for the RadSecProxy AAA application.

Step 3.

```
server radsecserver.local (or IP Address of Remote RADIUS Server)
```

This command adds a RadSec server with the domain name “radsecserver.local” to the RadSecProxy AAA application. Note that this name must be resolvable to an IPv4 address by DNS, or connection attempts to the server will fail. (The system will repeatedly attempt to reconnect to the server, so configuring an unresolvable address will result in unnecessary CPU usage.) The domain name must match the name provided in the server’s X.509 certificate, or the connection will fail. You can configure this server to bypass this check by adding the parameters **name-check off** to this command.

Step 4.

```
server trustpoint christchurch
```

This command specifies that the trustpoint “christchurch” should be used for the RadSecProxy AAA application. To use multiple trustpoints, you can specify more than one trustpoint in the command, or execute the command multiple times.

Step 5.

```
exit
```

This command exits RadSecProxy AAA configuration mode.

Step 6. `aaa authentication login default group radius local`

This command configures user login authentication to use the predefined group "radius" (representing all configured RADIUS servers, including RadSec servers), falling back to the local user database if no servers could be contacted. Once this command is executed, subsequent login sessions will be authenticated using RadSec.

Step 7. `exit`

This command exits configuration mode.

Step 8. `show radius-secure-proxy aaa`

This command displays information about the configuration and run-time status of the RadSecProxy AAA application. This information is also included in the **show radius** command (which also displays information about non-TLS RADIUS servers).

The following output shows the commands entered in the above example, and the responses returned by the CLI.

Output 3: The **radius-secure-proxy aaa** command and output summary

```
awplus> enable
awplus#configure terminal

Enter configuration commands, one per line. End with CNTL/Z.
awplus(config)##radius-secure-proxy aaa
awplus(config-radsecproxy-aaa)#server radsecserver.local
awplus(config-radsecproxy-aaa)#server trustpoint christchurch

PKI trustpoints for the RADIUS AAA secure proxy changed to:
   christchurch
awplus(config-radsecproxy-aaa)#exit
awplus(config)#aaa authentication login default group radius
awplus(config)#exit
awplus#show radius-secure-proxy aaa

Secure (TLS) Proxy via : 127.0.0.1
   Proxy Port        : 1645
   Trustpoints       : christchurch
   Cert Name Check   : global default on
   Computed Timeout : 7 sec
   Proxy Status      : running
Secure (TLS) Server Host : radsecserver.local
   Timeout          : default (5 sec)
   Cert Name Check : default (on)

                          Auth   Acct    Auth      Acct
Server Host/IP Address    Port   Port    Status    Status
-----------------------------------------------------------------
radsecserver.local        (TLS Proxy)    Alive     Alive
```

Validating the RadSec Proxy

Use the following command to verify the configuration and status of the RadSecProxy:

```
show radius-secure-proxy aaa
```

```
awplus#show radius-secure-proxy aaa

Secure (TLS) Proxy via : 127.0.0.1
  Proxy Port           : 1645
  Trustpoints          : christchurch
  Cert Name Check      : global default on
  Computed Timeout     : 7 sec
  Proxy Status         : running
Secure (TLS) Server Host : 192.168.1.2
  Timeout              : default (5 sec)
  Cert Name Check      : off

                                          Auth           Acct
Server Host/IP Address        Server Type Status         Status
---------------------------------------------------------------------
192.168.1.2                    (TLS Proxy) Alive           Alive
```

Enrol local RADIUS users against a local self-signed CA

When using a local self-signed CA, certificate-based RADIUS clients (supplicants) require certificates that have been signed by the local CA. The process of generating a private key for the client and creating a certificate associated with it can all be done on the AlliedWare Plus device, on behalf of the client. This process is called “enrolling” the RADIUS user.

The local system does not enroll RADIUS users for external CAs, because the CA itself must perform that task. It is technically feasible to generate private keys and certificate signing requests on behalf of a RADIUS user, to be transmitted to the external CA, but the local system would really only be operating as a middleman. It is a more direct procedure if the supplicant devices generate keys and CSRs on their own and communicate directly with the external CA.

- **Prerequisites**: A local self-signed trustpoint (named **raleigh** in this example).

Output: PKCS#12 files containing private keys and public certificates for all RADIUS users defined on the system.

The steps and commands used in this process are described below.

Step 1.

```
enable
config terminal
```

These are the standard commands to enter configuration mode after logging in. PKI commands require maximum user privileges to execute.

Step 2.

```
radius-server local
server enable
```

These are the commands to enter RADIUS server configuration mode and enable the RADIUS server daemon.

Step 3.

```
no server trustpoint local
```

By default, the RADIUS server is associated with trustpoint named "local", meaning that it will use the CA and server certificates from "local" for TLS authentication. Using the **no server trustpoint** command removes the association from "local".

Step 4.

```
server trustpoint raleigh
```

This command declares that the local RADIUS server should use the trustpoint "raleigh" for CA and server certificates. It is possible to specify multiple trustpoints for use with the RADIUS server. RADIUS will use the first trustpoint's CA and server certificates when asserting its identity to the peer device in a TLS connection, but will use certificates from all specified trustpoints to verify connections received from peers.

In typical usage, both the local RADIUS server and the peer devices use the same root certificate, so only one trustpoint is needed. However, it is possible for the local server's certificate to be signed by one CA and the peer device's certificate to be signed by a different CA. If that is the case, you should configure the server to use two trustpoints. Configure the one containing the local server's certificate first.

Step 5.

```
user raduser1 password mypassword1
user raduser2 password mypassword2
exit
```

These are the commands to declare RADIUS users and specify their passwords, and to exit RADIUS server configuration mode.

Step 6.

```
crypto pki enroll raleigh local-radius-all-users
```

This command creates private keys and certificates for RADIUS clients. These certificates are not used directly on the local system; rather, they are intended to be exported to client devices (e.g. port authentication supplicants or wireless clients). Such devices will send the certificates as part of TLS connection establishment, where the local system can validate them by checking if they were signed by the local trustpoint's CA.

This command packages the keys and certificates into PKCS#12 files for export. Within the files, the private keys are encrypted, with a passphrase that the system prompts you to enter at the command-line. This passphrase is intended to be used when unpacking the files on the client device. The passphrase is not stored anywhere; if it is lost, you need to re-enroll the user.

Individual users may be specified instead of "local-radius-all-users", for example: **crypto pki enroll raleigh user raduser1**

Step 7.

```
crypto pki export raleigh pkcs12 raduser1 tftp://wd1/r1.pk12
crypto pki export raleigh pkcs12 raduser2 tftp://wd2/r2.pk12
```

This command exports PKCS#12 file that were generated from the RADIUS user enrollment in the previous step. It copies the file corresponding to the given user to the specified URL. (Note that if the user happens to be named “ca” or “server”, you must enter the user name as “user:ca” or “user:server”, respectively.)

The following figure shows the commands entered in the above example, and the responses returned by the CLI.

Figure 12: Enrolling local RADUIS users against a local self-signed CA

```
awplus>enable
awplus#config terminal
Enter configuration commands, one per line.  End with CNTL/Z.
awplus(config)#radius-server local
awplus(config-radsrv)#server enable
awplus(config-radsrv)#no server trustpoint local
% Current trustpoints for the local RADIUS server:
%    (None)
awplus(config-radsrv)#server trustpoint raleigh
% Current trustpoints for the local RADIUS server:
%    raleigh
awplus(config-radsrv)#user raduser1 password mypassword1
awplus(config-radsrv)#user raduser2 password mypassword2
awplus(config-radsrv)#exit
awplus(config)#crypto pki enroll raleigh local-radius-all-users
% Enter an export passphrase, or "abort" to cancel.
*****
% Enter the export passphrase again.
*****
% Generating a user private key for "raduser1"...
% Successfully enrolled user "raduser1".
% Generating a user private key for "raduser2"...
% Successfully enrolled user "raduser2".
% The PKCS#12 files are ready to export.
awplus(config)#
awplus(config)#crypto pki export raleigh raduser1 tftp://wd1/r1.pk12
% Exporting...
% Successfully exported the file.
awplus(config)#crypto pki export raleigh raduser2 tftp://wd2/r2.pk12
% Exporting...
% Successfully exported the file.
```

Syslog over TLS

Syslog over TLS uses certificates for establishing connections. Both the AlliedWare Plus device (the syslog client) and the Syslog server need certificates that are signed by the same CA.

The steps that need to be performed on the AlliedWare Plus device are:

Step 1. Create a trustpoint.

Step 2. Authenticate it to the external CA

Step 3. Create the Certificate Signing Request (CSR).

Step 4. Export the CSR to the CA

Step 5. Import the signed certificate back from the CA

Step 6. Configure the Syslog process on the device to make a secure connection, using this trustpoint.

Steps 1 - 5 are described above, in the section "Creating a trustpoint based on an external Certificate Authority" on page 17.

The commands to perform step 6 are as follows:

- Tell the syslog process to use the trustpoint you have created:

```
awplus(config)#log trustpoint myLoggingTrustpoint
```

- Configure the device to send encrypted log messages to a remote Syslog Server using TLS

```
awplus(config)#log host <syslog-server-IP-address> secure
```

- Set the logging severity level (for example, critical, debugging, etc.) for the log messages. This determines the type of messages that will be sent to the remote Syslog Server

```
awplus(config)#log host <syslog-server-IP-address> level
debugging
awplus(config)#exit
```

Securing a Web-authentication Connection

Web-authentication, also known as Captive Portal, is a simple way to provide secure guest-user access to a network. It is used in a wide range of environments including Wi Fi hot spots, hotels, universities, and business centers.

In basic terms, if the web-authenticating switch detects unauthorized users web browsing, then it re-directs them to a web-authentication login page. At this point, they are required to enter a username and password before they can begin to web browse. The web-authenticating switch then interacts with a RADIUS server.

The web-authentication service can be configured to use a non-secure HTTP or secure HTTPS connection. Secure HTTPS connections can either use locally created self-signed certificates or externally created certificates.

Previously, when using external certificates, users were required to prepare a file (consisting of a server certificate and a private key) and import it to their AlliedWare Plus switch. However, the new PKI infrastructure allows seamless use of server certificates (signed by the external CA certificate) without preparing and importing files consisting of a server certificate and private key.

Main components of a secure web-authentication connection

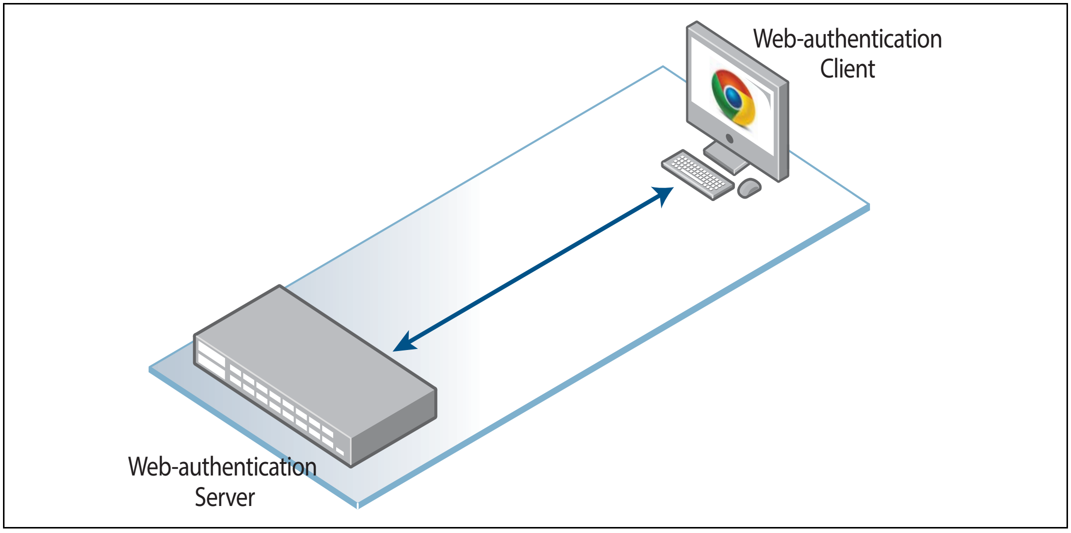
The following components are required for setting up a secure HTTPS connection between a web-authentication server (AlliedWare Plus switch) and a web-authentication client:

1. Web-authentication server: an AlliedWare Plus switch with software version 5.4.7 or later.
2. Web-authentication client: a remote device with a web browser installed, e.g. Google Chrome or Firefox.
3. To use an **external** CA: An external CA certificate and a web-authentication server certificate created on an AlliedWare Plus switch and signed by an external CA for installation on the AlliedWare Plus switch and remote Linux box.
4. To use a **local** self-signed CA: A local self-signed CA certificate and web-authentication server certificate, created on an AlliedWare Plus switch for installation on the web-authentication client.

Setup

An AlliedWare Plus switch (web-authentication server) connected to a web-authentication client.

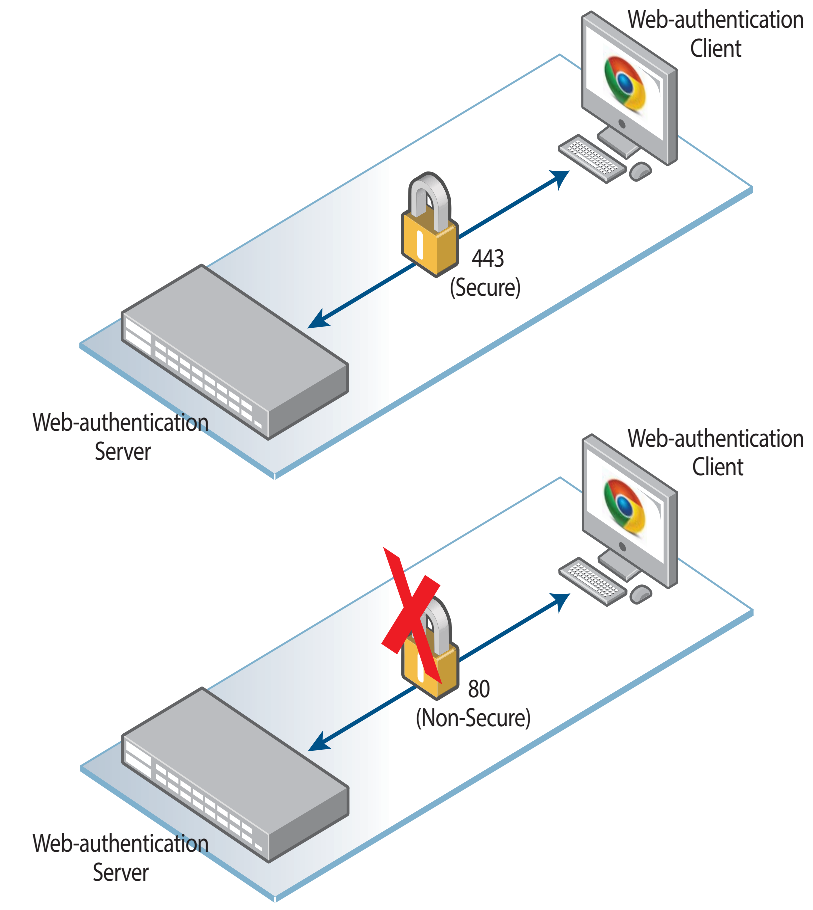
Figure 13: Simple web-authentication setup



Port numbers used for secure and non-secure connections

The AlliedWare Plus switch is connected to the web-authentication client via port 443 (secure) and port 80 (non-secure).

Figure 14: Port numbers used for secure and non-secure connections



Certificates

Secure HTTPS uses certificates to establish a connection between the web-authentication server (AlliedWare Plus switch) and the web-authentication client (device with the web browser on).

The AlliedWare Plus switch needs the CA certificate and web-authentication server certificate signed by the CA. The web-authentication client needs a CA certificate for validating the web-authentication server certificate.

You can use an external CA or you can generate the certificates locally on the switch.

- To use an **external** CA, purchase a CA certificate and web-authentication server certificate from a commercial CA, e.g. Comodo, Symantec, GoDaddy etc. or create an external self-signed CA on the Linux box using OpenSSL.
- To use a **local** self-signed CA, create the CA certificate and web-authentication server certificate on the AlliedWare Plus switch.

Using an external self-signed CA

Generating an external CA certificate using OpenSSL

You can create certificates on any Linux box. The steps and Linux commands to create a self-signed CA certificate using OpenSSL are:

Step 1.

```
$ openssl genrsa -out cakey.pem 2048
```

Create a Private key for the ROOT CA.

Step 2.

```
$ openssl req -x509 -days 1024 -new -nodes -key cakey.pem -out
cacert.pem
```

Create a self-signed certificate for the Root CA.

Step 3.

```
$ openssl x509 -noout -hash -in cacert.pem $ ln -s cacert.pem <hash
value calculated in above step>
```

Create a hash for the Root CA certificate file and a symbolic link to it. OpenSSL uses the hash for locating the certificate file.

Generating and installing the external web-authentication server certificate

Perform the following steps on the AlliedWare Plus switch:

1. Create a trustpoint e.g. externalauthweb
2. Authenticate it to the external CA.
3. Create the Certificate Signing Request (CSR).
4. Create the web-authentication server certificate (signed by the CA) on the client using CSR.
5. Import the web-authentication server certificate on the AlliedWare Plus switch.

The steps and commands used in this process are described below.

Step 1.

```
awplus(config)#crypto pki trustpoint externalauthweb
awplus(ca-trustpoint)#enrollment terminal
awplus(ca-trustpoint)#end
```

Create a Trustpoint for use with the external CA and name it **externalauthweb**

Step 2.

```
awplus#crypto pki authenticate externalauthweb
```

Paste the contents of **cacert.pem** into the command line when prompted to do so. This is the PEM file that you generated earlier on the Linux box.

Step 3.

```
awplus#crypto pki enroll  externalauthweb
```

Create a Certificate Signing Request (CSR) for the web-authentication server on the AlliedWare Plus switch. It will be displayed in the terminal in PEM format.

Step 4. On the Linux box, save/copy the CSR in a file, i.e. x930.csr. Create a client certificate for the AlliedWare Plus switch by executing the following command on the Linux box:

```
$ openssl x509 -req -days 1024 -in x930.csr -CA cacert.pem -CAkey
cakey.pem -CAcreateserial -out toe.pem
```

Print the contents of the web-authentication server certificate by executing the **cat toe.pem** command.

Step 5.

```
awplus#crypto pki import externalauthweb pem
```

Import the web-authentication server certificate onto the AlliedWare Plus switch, i.e. paste the contents of **toe.pem** into the command line when prompted to do so.

Installing the CA certificate on the client

To trigger the authentication attempt, clients use a web browser. Secure web browser connections require a signed CA certificate to validate the server certificate sent to them by the web-authentication server.

Obtain the CA certificate (cacert.pem) from the relevant systems administrator and copy it onto your client. Then import it into your web browser. The procedure below provides instructions for importing the signed CA certificate into Google Chrome or Firefox (please consult the official documentation for other web browsers).

For Google Chrome

1. Go to **Tools** > **Extensions**
2. Click **Settings** and then **Show Advanced Settings**
3. Click **Manage Certificates** under **HTTPS/SSL**
4. Click **Authorities** in the **Certificates Manager** window
5. Click **Import** and select the file containing the CA certificate

For Firefox

1. Go to **Edit** > **Preferences** > **Advanced** > **Certificates**
2. Click **View Certificates**
3. Click **Import** and select the file containing the CA certificate

Configuring the web-authentication server on the AlliedWare Plus switch to use the external CA

To configure the web-authentication server on the switch to use the external CA authority, use the following command:

```
awplus(config)#auth-web-server trustpoint externalauthweb
```

The following figure shows the output for the command **show running-config** using the external CA.

Figure 15: Output for the command **show running-config** using the external CA

```
awplus#show running-config
!
service password-encryption
!
hostname awplus
!
no banner motd
!
username manager privilege 15 password 8
$1$bJoVec4D$JwOJGPr7YqoExA0GVasdE0
!
no service ssh
!
platform hwfilter-size ipv4-limited-ipv6
!
service telnet
!
no service http
http trustpoint appweb externalauthweb
!
no clock timezone
!
snmp-server
!
crypto pki trustpoint externalauthweb
 enrollment terminal
 subject /CN=192.168.1.12
!
radius-server host 127.0.0.1 key test
!
aaa authentication enable default local
aaa authentication login default local
aaa authentication auth-web default group radius
!
radius-server local
 server enable
 nas 127.0.0.1 key test
 group admin
  attribute Service-Type Administrative-User
 user manager encrypted password
b4XLHHgxqoyrLchXkAs6+vna5HFN1ybm8eGSb1NKiYk=
 user pen encrypted password qMiD6Gy9u6WqRia6/nuMWfbCBRxPoui/z1/
Wuk6jqhE=
 user test encrypted password UukoSyvxY2v9iWXm8e/
JMDJd9iIc3RPyY09lGOb3pA4= group admin
!
stack virtual-chassis-id 3952
```

[continued on next page...]

```
stack virtual-chassis-id 3952
!
ip domain-lookup
!
!
!
no service dhcp-server
!
!
!
no ip multicast-routing
!
spanning-tree mode rstp
!
service power-inline
auth-web-server ipaddress 192.168.1.12
auth-web-server ssl hybrid
auth-web-server trustpoint externalauthweb
lacp global-passive-mode enable
no spanning-tree rstp enable
!
switch 1 provision x510-28
!
access-list hardware acl_webauth
 send-to-cpu ip any 192.168.1.12/24
!
interface port1.0.1-1.0.2
 switchport
 switchport mode access
!
interface port1.0.3
 switchport
 switchport mode access
 access-group acl_webauth
 auth-web enable
!
interface port1.0.4-1.0.26
 switchport
 switchport mode access
!
interface vlan1
 ip address 192.168.1.12/24
!
line con 0
 exec-timeout 0 0
line vty 0 4
 exec-timeout 0 0
!
end
```

Using a local self-signed CA

It is possible to create local self-signed CA and web-authentication server certificates on AlliedWare Plus products. The procedure and commands for creating a local self-signed CA certificate and a web-authentication server certificate is given below:

Step 1. **Create the RSA key pair for use with the web-authentication server certificate**

```
awplus> enable
awplus#crypto key generate rsa label local-authweb-server-key 2048
Generating 2048-bit key...
Created the key "local-authweb-server-key".
```

Step 2. **Create a trustpoint to use a local self-signed CA**

```
awplus#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
awplus(config)#crypto pki trustpoint localauthweb
Created trustpoint "localauthweb".
awplus(ca-trustpoint)#enrollment selfsigned
awplus(ca-trustpoint)#rsakeypair local-authweb-server-key
awplus(ca-trustpoint)#subject "/CN=192.168.1.12"
awplus(ca-trustpoint)#exit
awplus(config)#exit
```

Step 3. **Create a local self-signed Root CA certificate**

```
awplus#crypto pki authenticate localauthweb
Generating 2048-bit key for root certificate...
Successfully authenticated trustpoint "localauthweb".
```

Step 4. **Create a web-authentication server certificate using the RSA keypair specified in the trustpoint parameters**

```
awplus#crypto pki enroll localauthweb
Using private key "localauthweb"...
Successfully enrolled the local server.
```

Exporting a local self-signed CA certificate to the web-authentication client

The web-authentication client requires the CA certificate for validating the web-authentication server certificate. The contents of the local self-signed CA certificate can be printed by executing the following command:

```
awplus#crypto pki export localauthweb pem
```

These contents should be copied in a file e.g. **cacert.pem** and imported into the web-authentication client, i.e. Google Chrome, using the procedure detailed in "Installing the CA certificate on the client" on page 36.

Configuring the web-authentication server on an AlliedWare Plus switch to use the local self-signed CA

To commands to configure the AlliedWare Plus switch to use the local self-signed CA, i.e trustpoint **localauthweb** for the web-authentication server are:

```
awplus(config)#no auth-web-server trustpoint externalauthweb
awplus(config)#auth-web-server trustpoint localauthweb
```

Figure 16: The show output for using the local self-signed CA

```
awplus#show running-config
!
service password-encryption
!
hostname awplus
!
no banner motd
!
username manager privilege 15 password 8
$1$bJoVec4D$JwOJGPr7YqoExA0GVasdE0
!
no service ssh
!
platform hwfilter-size ipv4-limited-ipv6
!
service telnet
!
no service http
http trustpoint appweb localauthweb
!
no clock timezone
!
snmp-server
!
crypto pki trustpoint localauthweb
 enrollment terminal
 subject /CN=192.168.1.12
!
radius-server host 127.0.0.1 key test
!
!
aaa authentication enable default local
aaa authentication login default local
aaa authentication auth-web default group radius
!
radius-server local
 server enable
 nas 127.0.0.1 key test
 group admin
  attribute Service-Type Administrative-User
 user manager encrypted password
b4XLHHgxqoyrLchXkAs6+vna5HFN1ybm8eGSb1NKiYk=
 user pen encrypted password qMiD6Gy9u6WqRia6/nuMWfbCBRxPoui/z1/
Wuk6jqhE=
 user test encrypted password UukoSyvxY2v9iWXm8e/
JMDJd9iIc3RPyY09lGOb3pA4= group admin
```

![continued on next page...]

```
stack virtual-chassis-id 3952
!
ip domain-lookup
!
!
!
no service dhcp-server
!
!
!
no ip multicast-routing
!
spanning-tree mode rstp
!
service power-inline
auth-web-server ipaddress 192.168.1.12
auth-web-server ssl hybrid
auth-web-server trustpoint localauthweb
lacp global-passive-mode enable
no spanning-tree rstp enable
!
switch 1 provision x510-28
!
access-list hardware acl_webauth
 send-to-cpu ip any 192.168.1.12/24
!
interface port1.0.1-1.0.2
 switchport
 switchport mode access
!
interface port1.0.3
 switchport
 switchport mode access
 access-group acl_webauth
 auth-web enable
!
interface port1.0.4-1.0.26
 switchport
 switchport mode access
!
interface vlan1
 ip address 192.168.1.12/24
!
line con 0
 exec-timeout 0 0
line vty 0 4
 exec-timeout 0 0
!
end
awplus#
```

Configuring the IP address for the web-authentication server

If a guest VLAN has been configured on the supplicant-connected ports then: Use the IP address on the guest VLAN as the IP address of the web-authentication server, otherwise use the IP address on the supplicant-connected ports’ native VLAN.

Troubleshooting

Here are some common issues - and suggested solutions:

- The CA certificate has not been imported into the web browser for validation of the web-authentication server certificate.
  - The Common Name in the certificate has not been configured correctly.
- The Fire Fox web browser sends multiple “Close Notify” alerts to the web-authentication server before the end of a normal TLS session. Use Google Chrome to avoid multiple “Close Notify” alerts.

Using the AR-Series Firewall GUI to securely manage the firewall

The Firewall GUI allows you to configure entities (zones, networks and hosts) and then create firewall, NAT, and traffic-control rules for managing traffic between these entities.

You can also configure and customize advanced firewall features like Application control and web control, as well as threat management features such as Intrusion Prevention, Malware protection, and Antivirus, for a comprehensive security solution.

Accessing and installing the latest GUI file

This section describes how to access the firewall GUI, to manage and monitor your AR-Series firewall.

The GUI provides setup of the firewall, enabling the configuration of entities (Zones, Networks and Hosts) and then creating firewall and NAT rules for traffic between these entities. Advanced firewall features can be enabled, configured and customized for a comprehensive security solution, such as Application control and Web control, as well as threat management features such as Intrusion Prevention, Malware protection, and Antivirus. Various other features can be managed through the GUI, and the dashboard provides at-a-glance monitoring of traffic, application use, and threat protection statistics.

If your AR-Series firewall came with the GUI pre-installed, perform the following steps to browse to the GUI:

Step 1. **Connect to any of the LAN switch ports**

Step 2. **Open a web browser and browse to https://192.168.1.1.**

This is the pre-configured IP address of VLAN1. The default username is *manager* and the default password is *friend*.

If your AR-Series firewall did not come with the GUI pre-installed, perform the following steps through the command-line interface:

Step 1. **Create one or more IP interfaces and assign them IP addresses, including configuring WAN connectivity.**

For information about configuring PPP, see the **PPP Feature Overview and Configuration Guide**. For information about configuring IP, see the **IP Feature Overview and Configuration Guide**.

Step 2. **If you plan to enable the firewall functionality, first create a firewall rule to allow traffic from the Update Manager to pass through the firewall.**

This is needed because AR-Series firewalls block all traffic by default. The following figure shows a recommended example configuration, when WAN connectivity is through ppp0:

```
zone public
 network wan
  ip subnet 0.0.0.0/0 interface ppp0
  host ppp0
   ip address dynamic interface ppp0

firewall
 rule 10 permit dns from public.wan.ppp0 to public.wan
 rule 20 permit https from public.wan.ppp0 to public.wan
 protect
```

Step 3. **Use the following command to download and install the GUI:**

```
awplus#update webgui now
```

Step 4. **Enable the HTTP service:**

```
awplus#configure terminal
awplus(config)#service http
```

Step 5. **Log into the GUI.**

Start a browser and browse to the firewall IP address, using HTTPS. You can access the GUI via any reachable IP address on any interface.

The GUI starts up and displays a login screen. Log in with your username and password.

For more information about using the GUI, see Getting Started with the UTM Firewall GUI.

Setting the Firewall GUI to use a local or external CA

Step 1. **Create the CA and Firewall certificates as described in:**

- "Generating and installing the external web-authentication server certificate" on page 35
- "Creating a trustpoint based on a local self-signed certificate" on page 15

Step 2. **Enable the web GUI on the Firewall using the following commands:**

```
awplus#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
awplus(config)#service http
```

Setting the Firewall GUI to use **local** self-signed CAs

Step 1. **Configure the Firewall GUI to use local self-signed CA using the following commands:**

```
awplus#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
awplus(config)#http trustpoint localappweb
```

Step 2. **Confirm that the Firewall GUI works with the local self-signed CA.**

Check for errors by typing the IP address of the Firewall in the web browser and then by configuring the Firewall security features e.g. IPS, Web Control etc. from the GUI.

Setting the Firewall GUI to use **external** self-signed CAs

Step 1. **Configure the Firewall GUI to use external self-signed CAs using the following commands:**

```
awplus#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
awplus(config)#http trustpoint externalappweb
```

Step 2. **Confirm that the Firewall GUI works with the external self-signed CA.**

Check for errors by typing the IP address of Firewall in the web browser and then by configuring the UTM Firewall Security Features e.g. IPS, Web Control etc. from the GUI.

Configuring the OCSP Responder

This section describes how to configure the OCSP Responder for verification of the CA, client, and Server certificates.

Introduction

An OCSP Responder is used for real-time verification of certificates. The OCSP client (AlliedWare Plus switch) sends a request to the OCSP Responder (a server typically run by the certificate issuer) for verification of a certificate's status. The OCSP Responder checks the request to ensure that it contains all the information required for the processing of the request. If the request meets all the criteria then the Responder checks its list of revoked certificates and sends back a reply to the client.

The OpenSSL OCSP tool can be used for setting up the OCSP Responder.

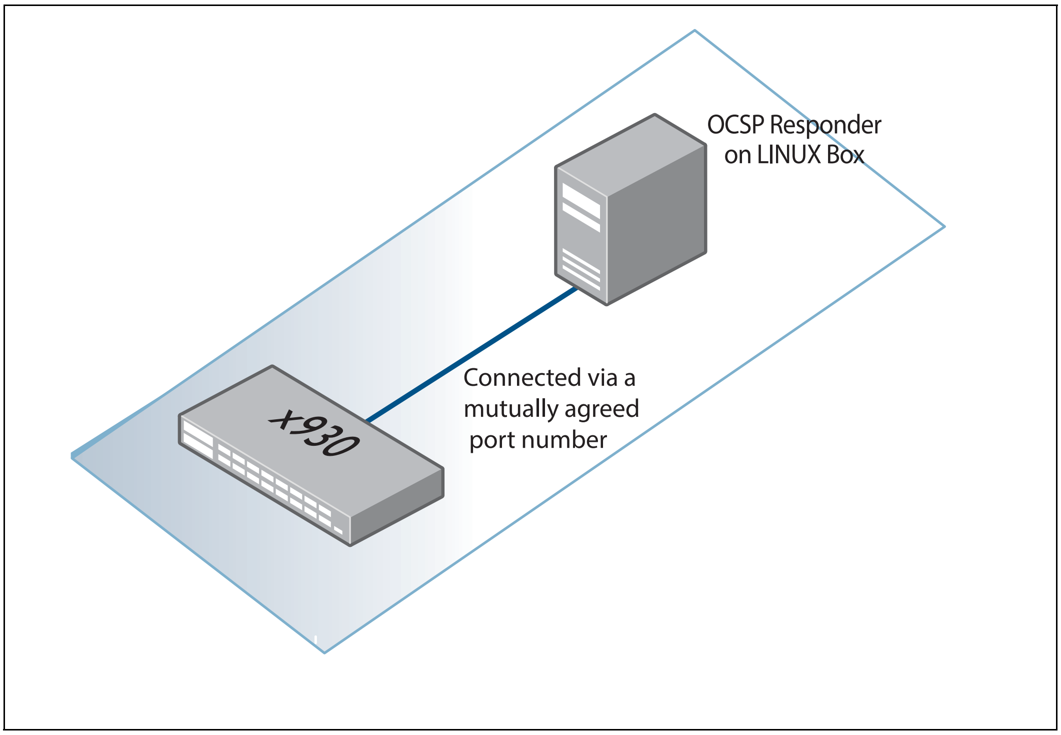
Building blocks

The following components are required to set up an OCSP Responder:

- CA, Responder, and client certificates for installation on the AlliedWare Plus switch
- A remote Linux box with OpenSSL installed on it
- An AlliedWare Plus switch running software release 5.4.6-1 or above

Setup

The setup consists of an AlliedWare Plus switch (for example an x930 switch) connected to an OCSP Responder running on a Linux Box.



Creating the CA, Server, and client certificates

- **First, make changes to the OpenSSL configuration file:**
  In the openssl.cnf file, add a new line to the `[ usr_cert ]` stanza and also create a new stanza `[ v3_OCSP ]`as shown below:

```
[ usr_cert ]
authorityInfoAccess = OCSP;URI:http://<IP Address of OCSP Responder>:Port Number

[ v3_OCSP ]
basicConstraints = CA:FALSE
keyUsage = nonRepudiation, digitalSignature, keyEncipherment
extendedKeyUsage = OCSPSigning
```

- **Create the CA, Server, and client certificates** - as described in "Using an external self-signed CA" on page 34.

Generating the OCSP certificate

On the Linux box, generate a private key and OCSP signing certificate for the OCSP Responder with the OSCP signing attributes:

Step 1. **Create a root private key**

```
$ openssl genrsa -out oc.key 2048
```

Step 2. **Create a CSR**

```
$ openssl req -new -nodes -key oc.key -out oc.csr
```

Step 3. **Create a configuration file, i.e ‘oc.cnf’ with the following elements:**

```
authorityInfoAccess = OCSP;URI:http://192.168.1.2:8888
basicConstraints = CA:FALSE
extendedKeyUsage = OCSPSigning
```

Step 4. **Create a certificate for the OCSP Responder which is signed by the CA**

```
$ openssl x509 -req -days 1024 -in oc.csr -CA cacert.pem -CAkey
cakey.pem -CAcreateserial -extfile oc.cnf -out oc.pem
```

Create a text file containing the certificates status information

On the Linux box, create a text file e.g. “index.txt” which will be used by the OCSP Responder for checking the status of the certificate i.e. is it valid, revoked, etc.

A sample “index.txt” file with valid and revoked entries for certificates is given below:

```
V   1905150213Z     946A3EA18038C966   unknown ATL-NZ
R   191214042327Z   160224025251Z   C97DAD2133A4D266   unknown 192.168.2.2
```

An explanation of the different columns in the sample file is given below:

```
*  Certificate status flag (V=valid, R=revoked, E=expired).
*  Certificate expiration date in YYMMDDHHMMSSZ format.
*  Certificate revocation date in YYMMDDHHMMSSZ[,reason] format. Empty if
not revoked.
*  Certificate serial number in hex.
*  Certificate filename or literal string ‘unknown’.
*  Certificate distinguished name
```

Starting the OCSP Responder

Execute the following command to start the OCSP Responder on the Linux box which is listening for the OCSP client requests on port # 8888.

```
openssl ocsp -index index.txt -port 8888 -rsigner oc.pem -rkey
oc.key -CA cacert.pem -text -out log.txt
```

```
Waiting for OCSP client connections...
```

Testing the OCSP Responder

We can use an OpenSSL command to manually send an OCSP request to the OCSP Responder.

Execute the following command to send a request to the OCSP Responder running on IP address 192.168.2.2 and listening on port number 8888.

```
openssl ocsp -issuer cacert.pem -cert servercert.pem -text -url
http://192.168.2.2:8888
```

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