

Pivotal

A NEW PLATFORM FOR A NEW ERA

Apache Tomcat and SSL

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Agenda

- Introductions
- Cryptography Basics
- SSL
- Configuring Tomcat for SSL
 - Java connectors (BIO, NIO)
 - APR/native connector
 - Reverse proxy
- Questions

Introductions

Introductions

- markt@apache.org
 - Apache Tomcat committer since December 2003
 - Apache Tomcat PMC member from the beginning
- Tomcat 8 release manager
- Member of the Apache Tomcat security team
- Apache Commons PMC member
- Member of the Apache Infrastructure team

Introductions

- Staff Engineer at Pivotal
- Primary role is to work on Apache Tomcat
- Pivotal tc Server
 - Based on Tomcat
 - Keep tc Server updated as new Tomcat versions are released
- 3rd line support for Tomcat and tc Server
 - tomcat@gopivotal.com
- Lead the Pivotal security team

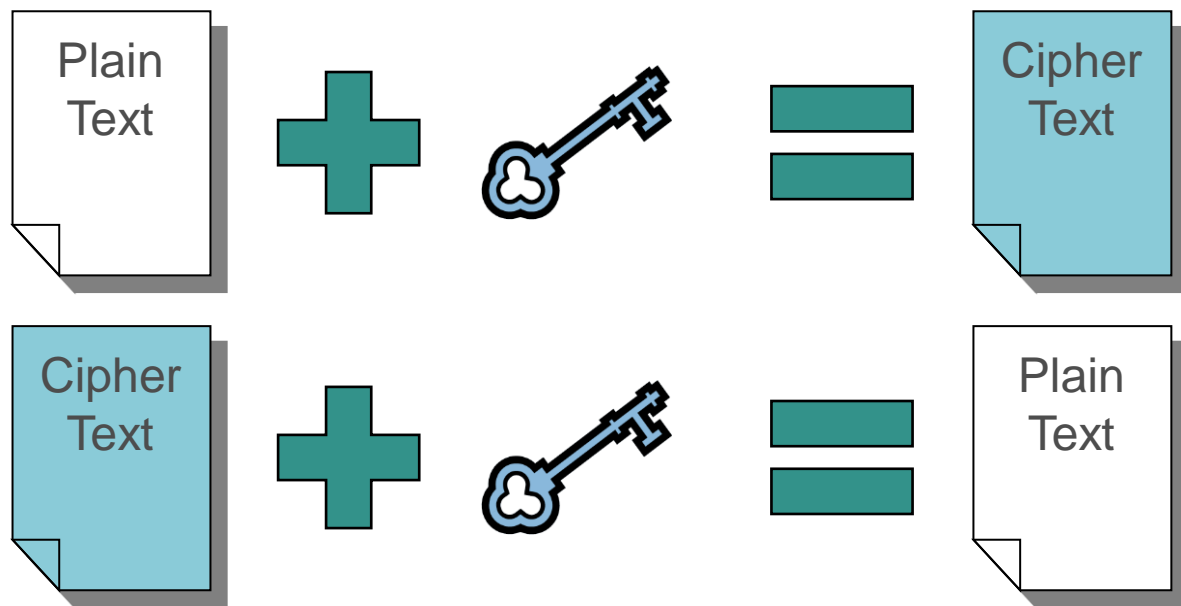
Why This Presentation?

- Lots of questions about SSL on the Tomcat mailing lists
- It is clear from the questions many folks don't understand how SSL works
- Debugging something you don't understand is much harder than debugging something you do understand

Cryptography Basics

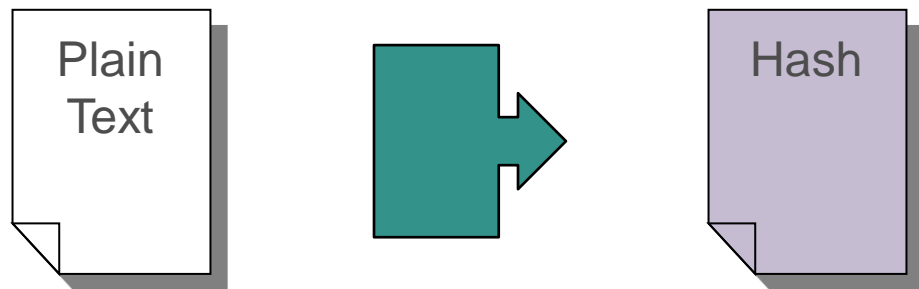
Cryptography Basics: Symmetric Encryption

- Use the same key to encrypt and decrypt



Cryptography Basics: Hash Functions

- Generate a fingerprint (hash) for the given input
- A small change in the input results in a large change in the hash
- Very difficult to generate an input for a given hash

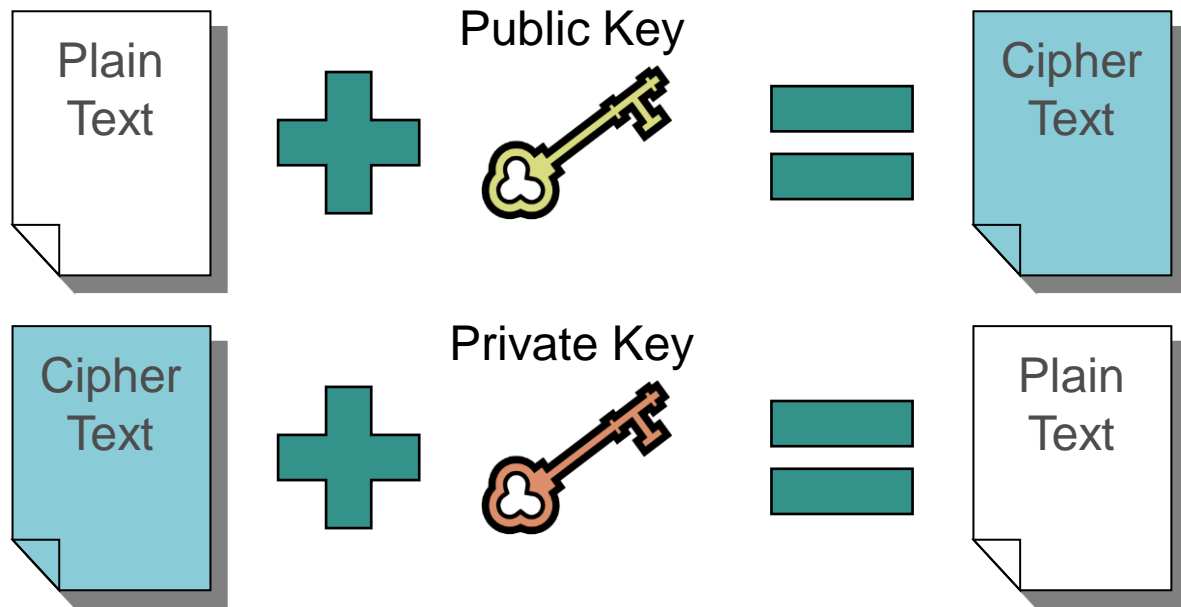


Cryptography Basics: Asymmetric Encryption

- Pair of keys, A and B
 - If key A is used to encrypt, key B must be used to decrypt
 - If key B is used to encrypt, key A must be used to decrypt
- Very difficult to determine one key from the other
- One key is used as the “Public Key”
 - This key is made widely available to the general public
- One key is used as the “Private Key”
 - This key must be protected

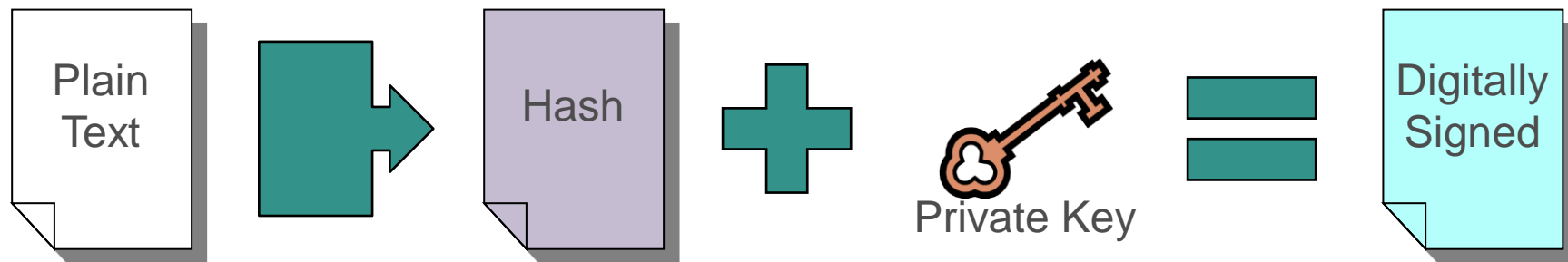
Cryptography Basics: Asymmetric Encryption

- Use different keys to encrypt and decrypt



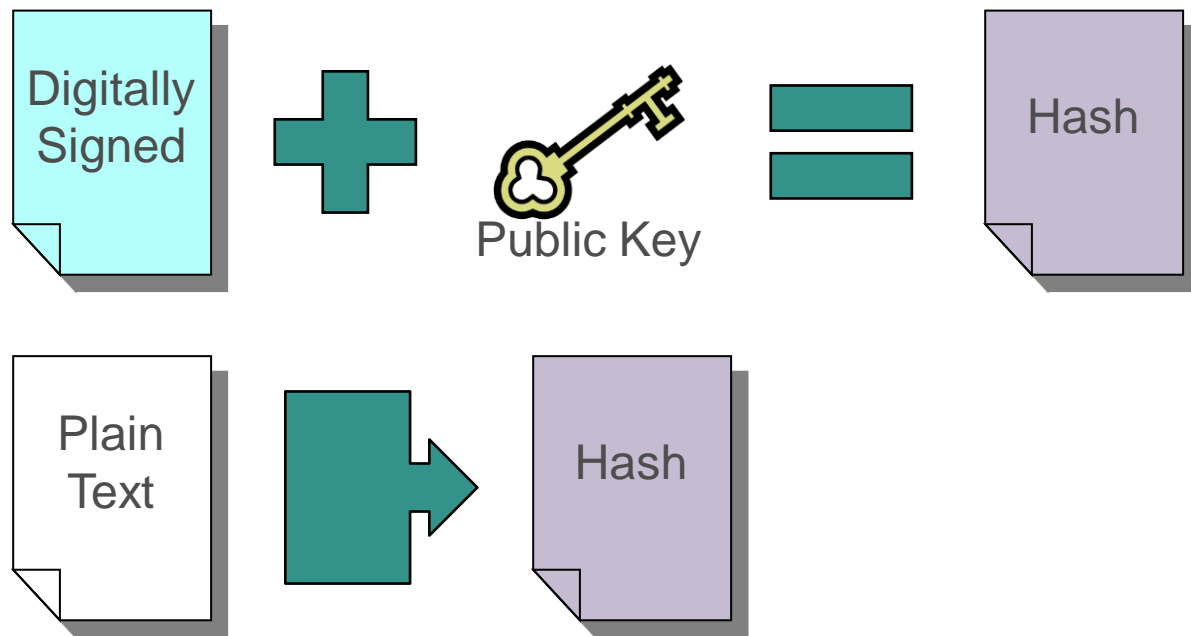
Cryptography Basics: Digital Signatures

- Proves that a document was sent by a particular entity



Cryptography Basics: Digital Signatures

- Validating a digital signature

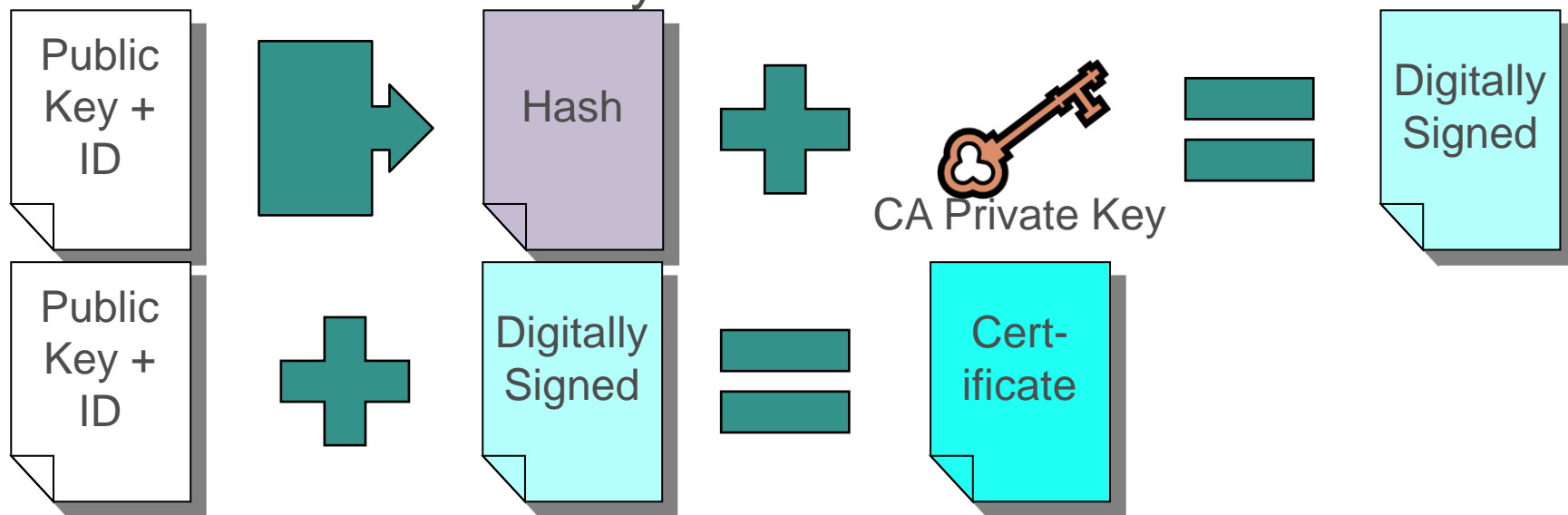


Cryptography Basics: Digital Signatures

- If the hashes match then:
 - The public key decrypted the digital signature
 - Therefore, the associated private key must have created the digital signature
 - Therefore, the recipient can be certain that the owner of the public/private key pair sent the document
- Determining who is the owner of the public/private key pair is the next problem

Cryptography Basics: Certificates

- Certificates link a public key with an identity
- Certificates are issued by certificate authorities

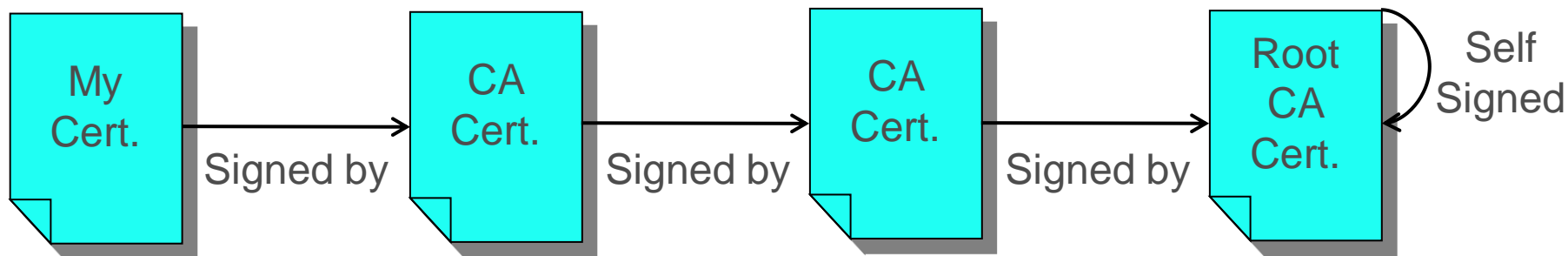


Cryptography Basics: Certificates

- To validate the certificate authority's signature, you need to be able to link their public key to their identity
- You do this with a certificate
- This builds a trust chain
- At the top of the chain is the root certificate from the root certificate authority
- There are multiple root certificate authorities

Cryptography Basics: Root Certificates

- Root certificates are self-signed
- Some other mechanism is required to trust root certificates
 - Usually installed by the operating system
 - You can manually validate them by checking them against the published versions on the CA's web site



SSL

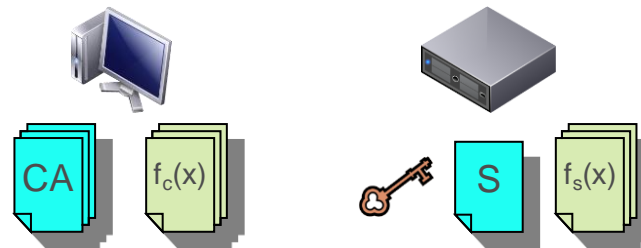
SSL

- SSL connections are initiated by a handshake
- Handshake
 - Mandatory steps
 - Optional steps
- This presentation considers the common case

SSL: Handshake Starting Point

- Server

- Private key
- Certificate
 - Public key
 - Identity (domain name)
- List of supported algorithms

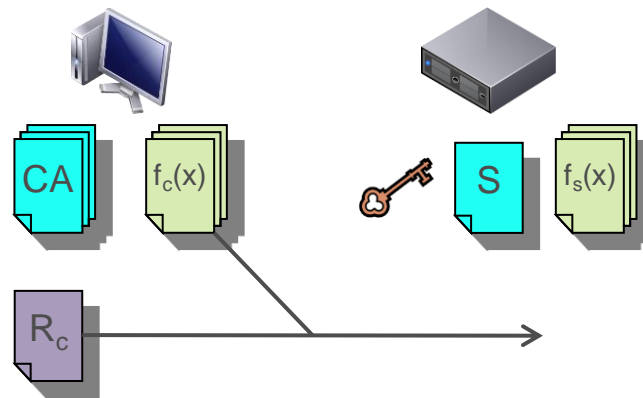


- Client

- List of trusted (Root) Certificate Authorities
- List of supported algorithms

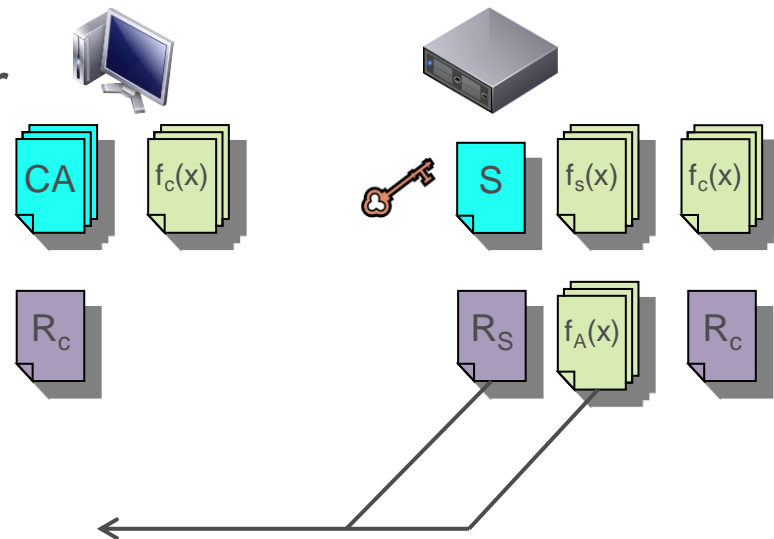
SSL: Handshake Step 1: ClientHello

- Client generates a random number
- Client sends message to server
 - Client's random number
 - List of supported algorithms



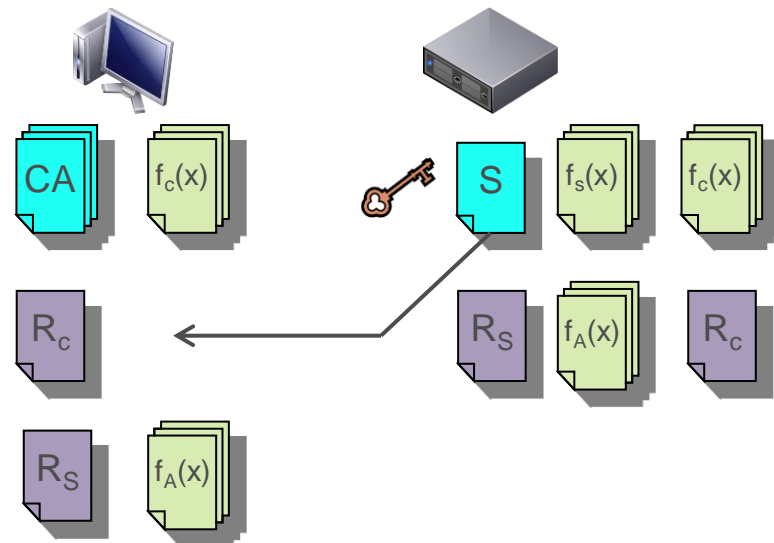
SSL: Handshake Step 2: ServerHello

- Server generates a random number
- Server compares algorithms
 - Selects appropriate algorithms
- Server sends message to client
 - Server's random number
 - Selected algorithms



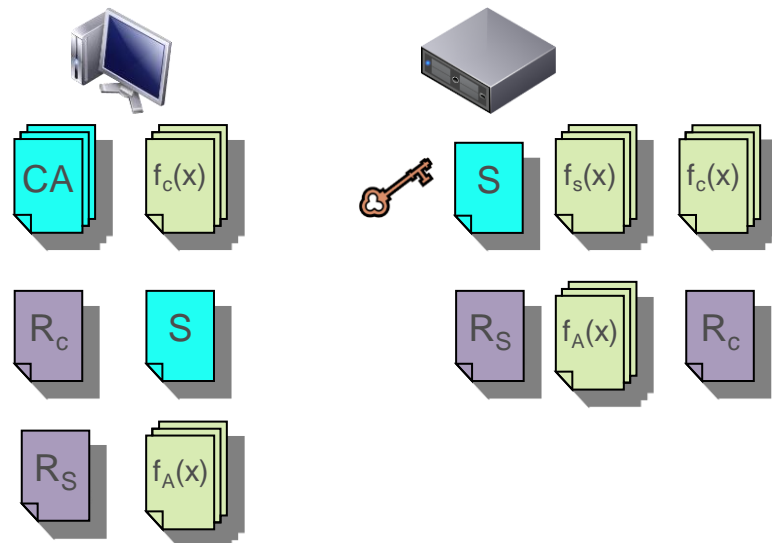
SSL: Handshake Step 3: Certificate

- Server sends message to client
 - Server's certificate
- Client validates server certificate



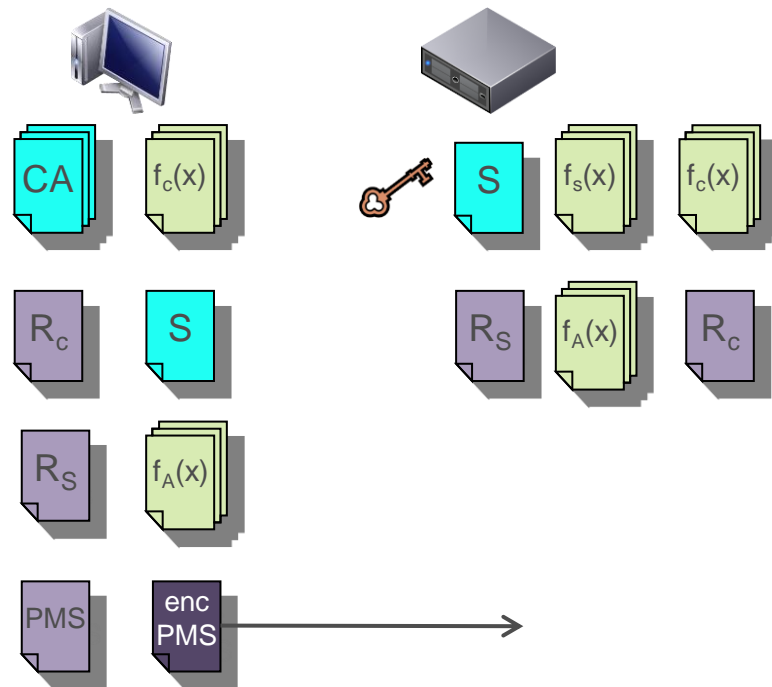
SSL: Handshake Step 6: ServerHelloDone

- Server sends message to client
 - No content



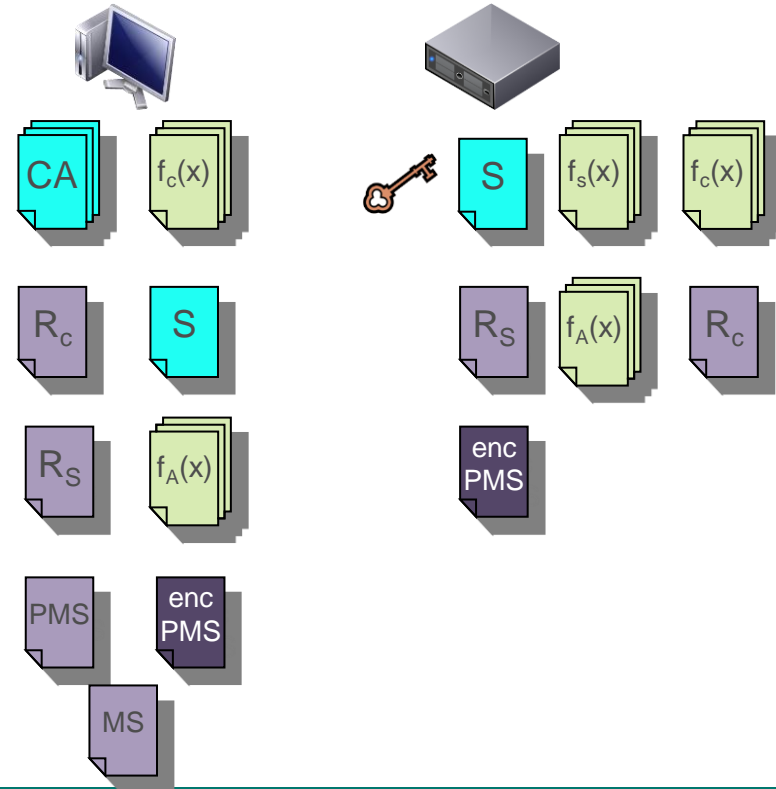
SSL: Handshake Step 8: Client Key Exchange

- Client generates pre-master secret
- Client encrypts PMS with server's public key
- Client sends message to server
 - Encrypted PMS



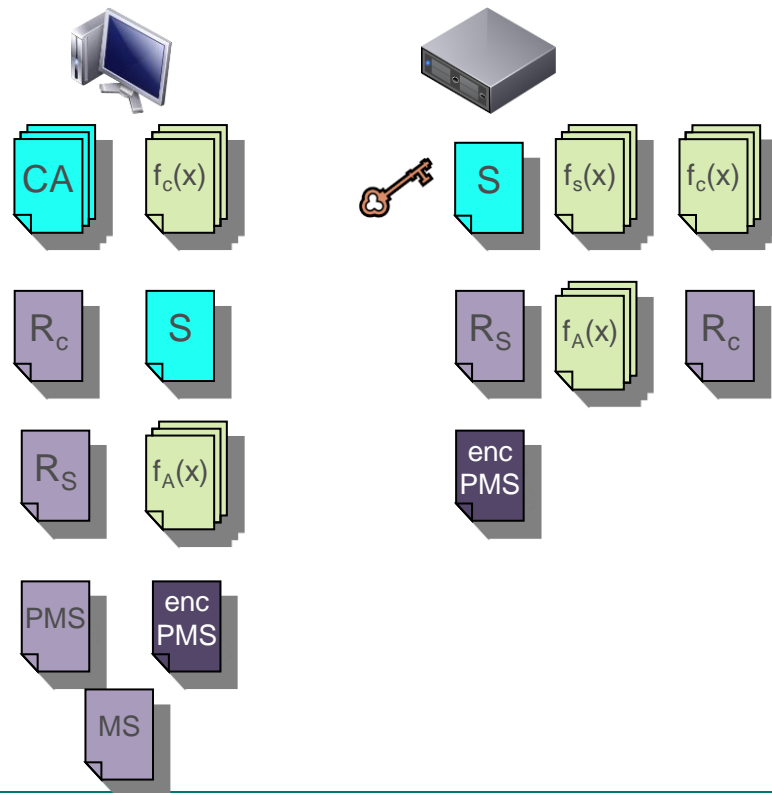
SSL: Handshake Step 10: ChangeCipherSpec

- Client creates master secret
 - $R_C + R_S + PMS$
- Client switches to encrypted mode
 - Algorithm agreed in step 2
 - Symmetric encryption with MS
- Client sends message to server
 - No content



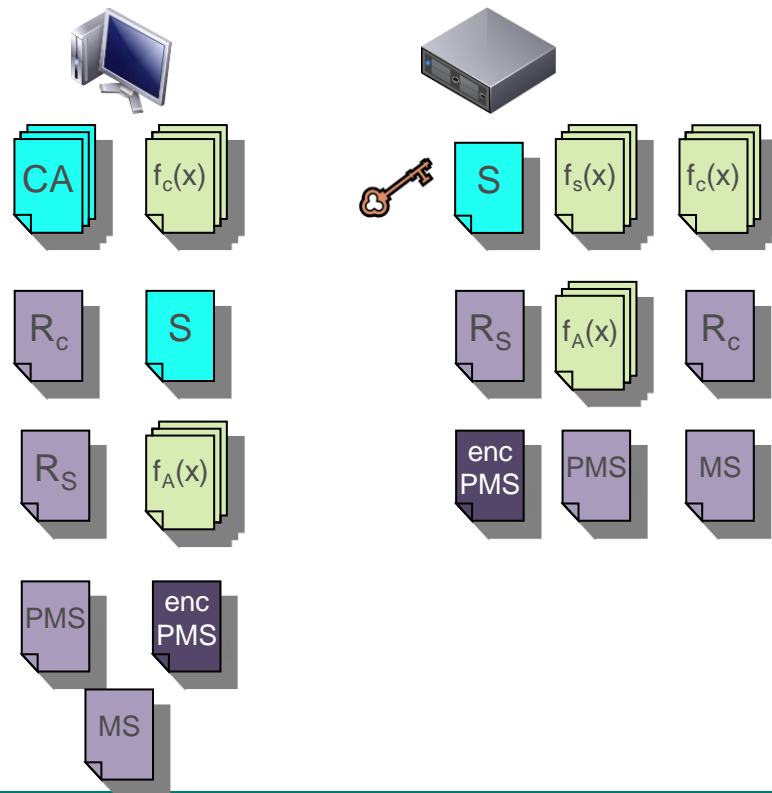
SSL: Handshake Step 11: Finished

- Client has completed SSL handshake
- Client sends message to server
 - No content



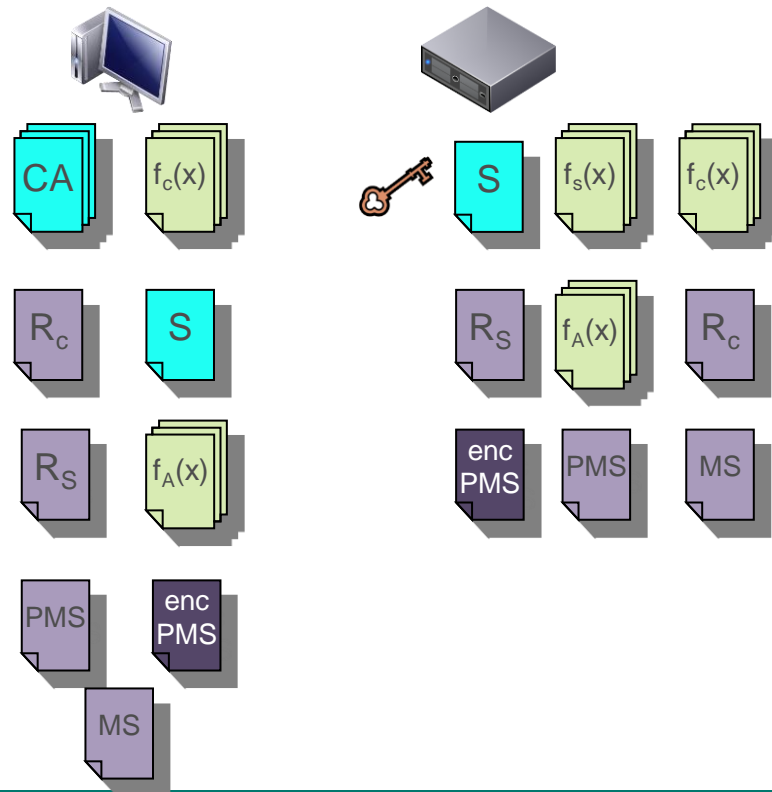
SSL: Handshake Step 12: ChangeCipherSpec

- Server decrypts PMS
- Server creates master secret
 - $R_c + R_s + PMS$
 - Server switches to encrypted mode
 - Algorithm agreed in step 2
 - Symmetric encryption with MS
- Server sends message to client
 - No content



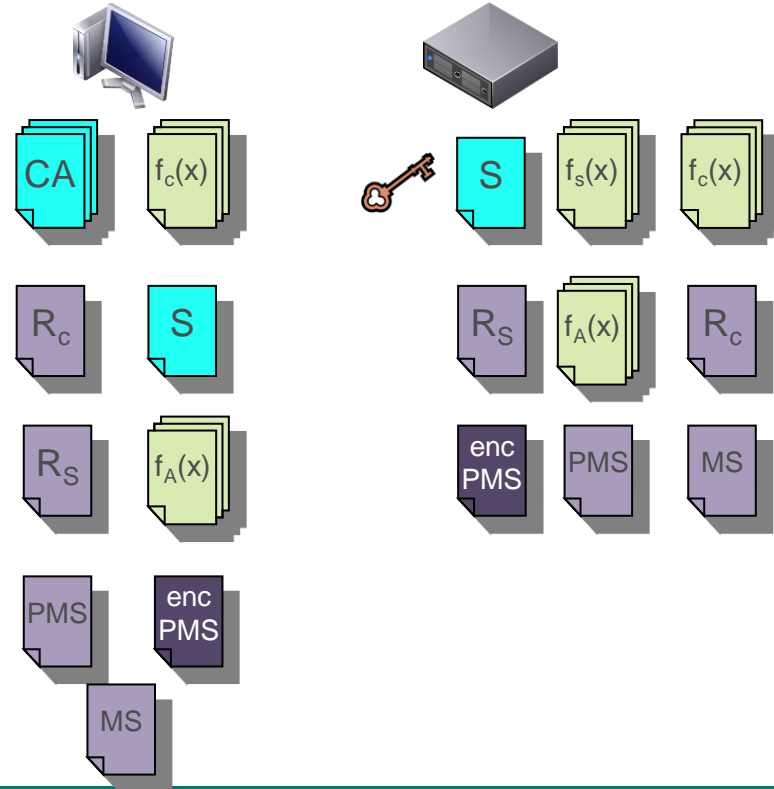
SSL: Handshake Step 13: Finished

- Server has completed SSL handshake
- Server sends message to client
 - No content



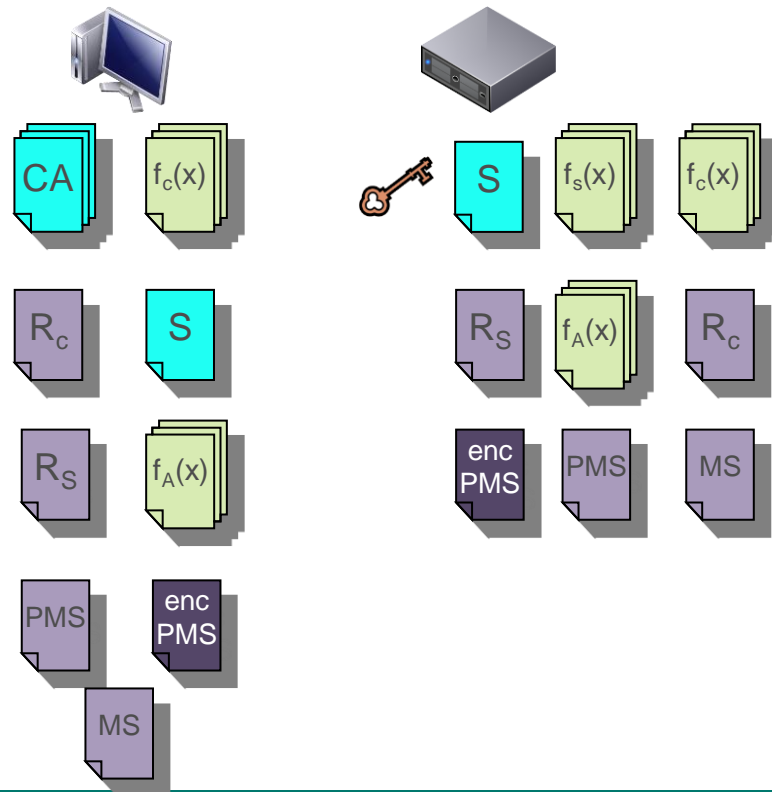
SSL: Encrypted communication

- Algorithm agreed in step 2
- Symmetric
- Use Master Secret as key



SSL: Extensions

- Client certificate authentication
 - Client authenticates to server with certificate
- Server Name Indication
 - Client tells server which host it wants to connect to and server sends appropriate certificate (virtual hosting)
- Renegotiation



SSL Config for Tomcat

Requirements

- A public/private key-pair
- A certificate
 - Public key
 - Identity (domain name e.g. `www.apache.org`)
- A Certificate Authority (CA) to generate the certificate
- The certificates for each CA in the trust chain
 - Root CA plus any intermediate CAs

Formats

- Java keystore
 - Keys and certificates
 - Only used by Java
 - Generally easier insert than extract information
 - OpenSSL does not understand this format
- PKCS #12
 - Keys and certificates
 - OpenSSL does understand this format

Formats

- DER
 - Certificates
 - Binary encoding
 - OpenSSL does understand this format
- PEM
 - Certificates
 - ASCII encoding
 - OpenSSL does understand this format

Tools

- Apache Tomcat 8.0.x
 - Latest source as at time of presentation
 - Works equally well with any 6.0.x, 7.0.x or 8.0.x release
- OpenSSL 1.0.1f
 - OSX
 - Works on other platforms – adjust paths as necessary

Configuration

- Initial set up

```
$ cd
$ mkdir demo
$ cd demo
$ mkdir certs newcerts private requests
$ echo 1000 > serial
$ touch index.txt
$ cp /opt/local/etc/openssl/openssl.cnf .
```

Configuration

- Modify copy of openssl.cnf

```
$ vi openssl.cnf
```

```
dir = .
```

```
default_bits = 2048
```

```
countryName_default = US
```

Configuration

- Create your own root certificate authority

```
$ openssl req -new -x509 -days 3650 -extensions v3_ca \  
    -keyout private/cakey.pem -out cacert.pem \  
    -config ./openssl.cnf
```


Configuration

- Create and sign host certificate request

```
$ openssl req -new -nodes \  
    -out requests/localhost-req.pem \  
    -keyout private/localhost-key.pem \  
    -config ./openssl.cnf
```

```
$ openssl ca -days 730 -config ./openssl.cnf \  
    -out certs/localhost-cert.pem \  
    -infiles requests/localhost-req.pem
```

Configuration

- Convert the host key and certificate to PKCS #12

```
$ openssl pkcs12 -export -out private/localhost.p12 \  
-inkey private/localhost-key.pem \  
-in certs/localhost-cert.pem \  
-certfile cacert.pem
```

Configuration

- Configure Tomcat for SSL using the PKCS #12 file

```
<Connector port="8443"  
    protocol="org.apache.coyote.http11.Http11NioProtocol"  
    SSLEnabled="true" scheme="https" secure="true"  
    clientAuth="false" sslProtocol="TLS"  
    keystoreType="pkcs12"  
    keystoreFile="{catalina.base}/conf/localhost.p12"  
    keyPass="changeit"  
/>
```

Configuration

- Similarly using BIO

```
<Connector port="8443"  
  protocol="org.apache.coyote.http11.Http11Protocol"  
  maxThreads="150"  
  SSLEnabled="true" scheme="https" secure="true"  
  clientAuth="false" sslProtocol="TLS"  
  keystoreType="pkcs12"  
  keystoreFile="${catalina.base}/conf/localhost.p12"  
  keyPass="changeit"  
>
```

Configuration

- Configuration for APR/native is significantly different

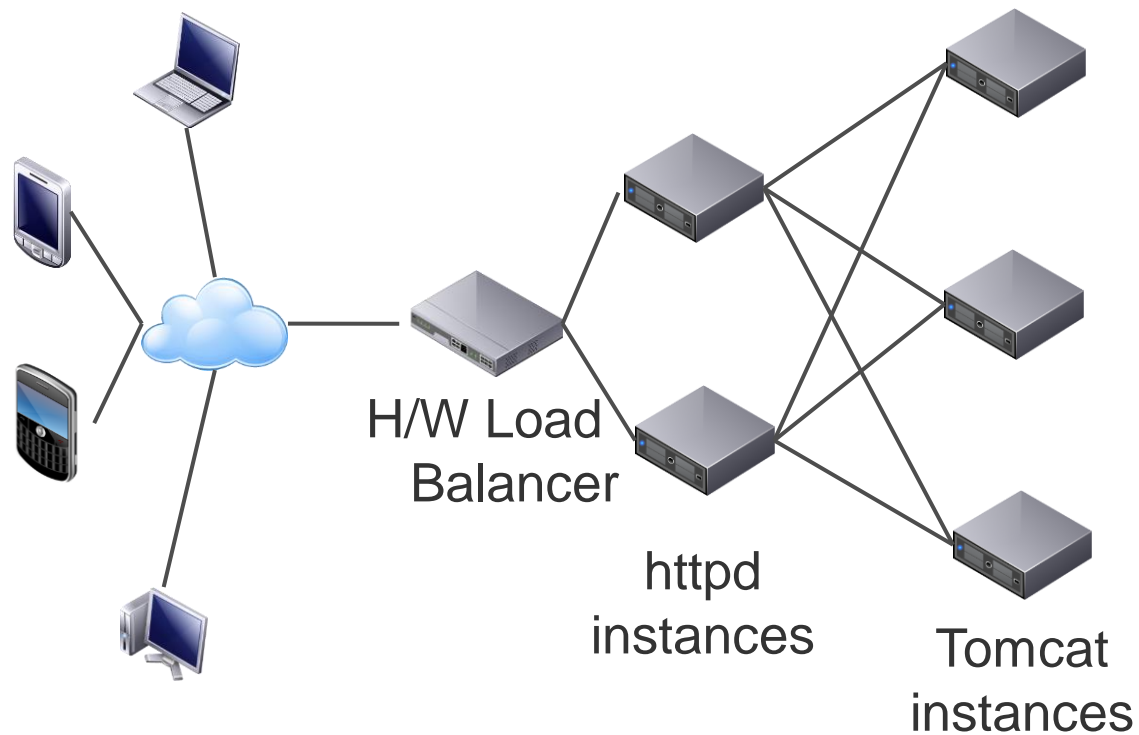
```
<Connector port="8443"  
  protocol="org.apache.coyote.http11.Http11AprProtocol"  
  maxThreads="150"  
  SSLEnabled="true"  scheme="https"  secure="true"  
  clientAuth="false" sslProtocol="TLS"  
  SSLCertificateFile="${catalina.base}/conf/localhost-cert.pem"  
  SSLCertificateKeyFile="${catalina.base}/conf/localhost-key.pem"  
  SSLCertificateChainFile="${catalina.base}/conf/cacert.pem"  
/>
```

Configuration

- There are other options
- Convert *.pem files to Java KeyStore
 - Historically painful
 - Better now but still requires you to create the *.p12 file
 - Since Tomcat can use the *.p12 file why bother with a keystore?
- Easy to move between separate *.pem files and a single .p12 file

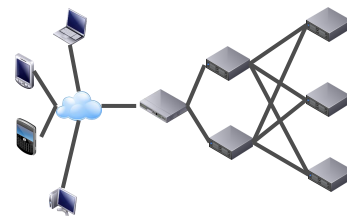
SSL & Reverse Proxies

What Is A Reverse Proxy?



Design Considerations

- How will Tomcat differentiate between clients using http and https?
- Does the proxy <-> Tomcat traffic need to be encrypted?



Why Does Tomcat Need SSL Information?

- To enforce transport guarantees specified in web.xml
- To determine if session was created over a secure connection
 - In which case session cookie needs to be marked as secure
- To correctly construct links, redirects etc. with http or https
- To obtain the identity of the authenticated user
 - When user client certificate authentication

Protocol Choices

- AJP
 - Proxy implementations includes client <-> proxy SSL information automatically
 - Does not support encryption
- HTTP
 - Proxy implementations do not include client <-> proxy SSL information automatically
 - Supports encryption (proxy using https)

Recommended Protocol

- If you do not need to encrypt proxy <-> Tomcat traffic
 - AJP
- If you do need to encrypt proxy <-> Tomcat traffic
 - HTTPS

- But if you use HTTPS, how do you get the SSL information?

SSLValve

- In httpd:

```
<IfModule ssl_module>  
  RequestHeader set SSL_CLIENT_CERT "%{SSL_CLIENT_CERT}s"  
  RequestHeader set SSL_CIPHER "%{SSL_CIPHER}s"  
  RequestHeader set SSL_SESSION_ID "%{SSL_SESSION_ID}s"  
  RequestHeader set SSL_CIPHER_USEKEYSIZE "%{SSL_CIPHER_USEKEYSIZE}s"  
</IfModule>
```

- In Tomcat:

```
<Host ... >  
  <Valve className="org.apache.catalina.valves.SSLValve"  
  ...  
</Host>
```

An Alternative Solution

- Create two HTTP connectors in Tomcat
- Configure the first with
 - `SSLEnabled="false" scheme="http" secure="false" proxyPort="80"`
- Configure the second with
 - `SSLEnabled="false" scheme="https" secure="true" proxyPort="443"`
- Proxy HTTP traffic to the first connector over HTTP
- Proxy HTTPS traffic to the second connector over HTTP

Questions

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