Securing Communications with your Apache HTTP Server

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About Me

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Securing Communications with your Apache HTTP Server

Agenda

● Overview
● X.509, Keys and Certificates
● SSL/TLS protocol
● Apache HTTP Server configuration
  • Basic configuration details
  • Virtual Hosting and ACME Protocol Module
  • Cipher and Protocol configuration
  • Session Caching and TLS Session Tickets
  • Advanced Features
Why HTTPS and TLS?

• **Confidentiality and Data Privacy**
  • protects data from eavesdropping
  • only the intended recipient can read the data

• **Authentication**
  • allows for identification of server and optionally, the client

• **Data Integrity**
  • ensures that nobody can tamper with the data that is being transmitted
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**Keys and Certificates**

- X.509: ITU-T standard (1988) for PKIs
- PKI: Public-Key Infrastructure
- CA: Certification Authority
- CSR: Certificate Signing Request
- CRL: Certificate Revocation List
Common X.509 File Types and Extensions

- **PEM**: base64-encoded DER certificate(s) or private key(s)
- **DER**: binary format based on Distinguished Encoding Rules (encoded ASN.1 values)
- **p12**: PKCS#12 format, certificate(s) and/or private key(s)
- **key**: commonly used for a PEM-encoded private key
- **crt/cer**: commonly used for a PEM-encoded certificate
- **csr**: commonly used for a PEM-encoded certificate signing request
PEM-encoded Certificate Example

-----BEGIN CERTIFICATE-----
MIIC2zCCAkSgAwIBAgIJAJANWZuQf40KViMA0GCSqGSIb3DQEBBQUAMFMxCzAjBqNV
BAYTAlhYMQwwCgYDVQQIEwNYWFgxDDAKBgNVBAcTA1hYWDEMMMAoGA1UEChMDWFhY
MQwwCgYDVQQLEwM2NjYxDDAKBgNVBAoTVWFYMQwwCgYDVQQLEwM2NjYxDDAKBgNV
BAMTAzY2NjAeFw0wODEwMDEyMzU1MDlaFw0wODYwMDEyMzU1MDlaFw0w

BgNVHRMEBTADAQH/MA0GCSqGSIb3DQEBBQUAA4GBAF1aHQEXQdMVfvTay5x6fECa
QiefllN/69931EFmNX0mlpV8pFZ448PtoGlXiNd+rnfe2ttjPfmh4CXDN9q7NPUO
qntygrcWsGJxmVlu5s2q6KumrySEdqr+Da70zyed3Tfj/QYJfG1HAzfLCVZRKFQ
EuxxMbZd6XBXcXenuZzn

-----END CERTIFICATE-----
Certificate Structure

- Certificate
  - Version
  - Serial Number
  - Signature Algorithm
  - Issuer
  - Validity Period
  - Subject
  - Subject Public Key Info
  - Issuer Unique Identifier (*optional*)
  - Subject Unique Identifier (*optional*)
  - Extensions (*optional*)
- Certificate Signature Algorithm
- Certificate Signature
Certificate Subject DN

- **DN**: Distinguished Name
  - a sequence of identifiers in X.500 notation
- Common DN Keys:
  - **CN**: Common Name (e.g., first/last name or hostname)
  - **C**: Country (2-letter code)
  - **S**: State or province
  - **L**: Locality (e.g., City)
  - **O**: Organization
  - **OU**: Organizational Unit
- Example DN:  
  
  C=DE, L=Berlin, O=Example Inc., CN=www.example.com
Common Name for Server Certificates

• Fully-qualified domain name (FQDN)
  • e.g., www.example.com
  • does not match example.com

• Wildcard domain
  • e.g., *.example.com
  • matches example.com and hosts such as foo.example.com
  • does not match www.foo.example.com or example.com.foo
Certificate Types

- Single-domain certificates
- Wildcard certificates
- Multi-domain (SAN) certificates
  - uses `SubjectAlternativeName` X.509 extension
- Extended validation (EV) certificates
  - available since 2007 and supported by Firefox 3+, IE 7+, Edge 12+, Opera 9.5+, Safari 3.2+ and Chrome 1+
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Extended Validation Certificates

Internet Explorer

Chrome

Firefox

Safari

Opera
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Obtaining a Certificate

• create your own
  • self-signed certificate
  • signed by your own CA

• get a free certificate
  • free certificates from “Let's Encrypt” CA
  • trial or free certificates from commercial CAs

• buy a certificate from a CA
  • domain-only, organization or extended validation
    (6€ up to 1000€ per year)
Let's Encrypt CA

- https://letsencrypt.org
- Certificates are free of charge
- Fully automated validation
- Standard domain-validation certificates
- Multi-domain/SAN certificates
- Certificates are valid for 90 days
- Not valid as client certificate
- Supported by all modern Web clients
- Service provided by Internet Security Research Group (ISRG) since April 2016 (non-profit organisation)
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Browser SSL Warnings

If the browser doesn't know the issuing CA or if the server hostname does not match the certificate it displays a warning to the user.
Certificate Chain

- Root Certificate
  - Intermediate Certificate 1
    - Intermediate Certificate $n$
    - End-Entity (Leaf) Certificate
      (Server/Client Certificate)
SSL vs. TLS

- SSL: Secure Sockets Layer
  - originally developed by Netscape (1994)
  - SSL 2.0 and 3.0 deprecated and insecure

- TLS: Transport Layer Security
  - IETF standard (1999)
  - TLS 1.0, 1.1, 1.2, and 1.3
  - TLS 1.0, 1.1 should no longer be used

- When people talk about SSL these days they actually mean TLS.
- An “SSL certificate” is an X.509 certificate for use with TLS.
Apache SSL/TLS Module - mod_ssl

- Included as default module since Apache HTTP Server version 2.0
- Uses OpenSSL library
- Supports TLS 1.0, 1.1, 1.2 protocols
  - TLS 1.3 supported in Apache 2.5-dev (with OpenSSL 1.1+)
- SSL 3.0 is still supported, but SSL 2.0 support was removed in Apache HTTP Server version 2.4
- (Apache HTTP Server 2.0 and 2.2 are end of life!)
Module Configuration

• Required modules:
  • LoadModule ssl_module modules/mod_ssl.so
  • LoadModule socache_shmcb_module \modules/mod_socache_shmcb.so

• SSL configuration file:
  • Include conf/extra/httpd-ssl.conf
Basic Configuration

• Certificate and private key (PEM format):
  • SSLCertificateFile \ /usr/local/apache2/conf/ssl/server.crt
  • SSLCertificateKeyFile \ /usr/local/apache2/conf/ssl/server.key
    • Ensure the key file is only readable by root

• Enable SSL (per virtual host):
  • SSLEngine On
  • Listen 443
Intermediate CA Certificates

• Add server and all intermediate certificates to a single file and use SSLCertificateFile
  • Sort multiple certificates from leaf to root certificate!
• Multiple server certificates can be added to support (different authentication algorithms (ECC, RSA, DSA, etc.)
• SSLCertificateChainFile became obsolete with version 2.4.8
TLS Virtual Hosting

- TLS can be enabled for any virtual host
- Name-based virtual hosts with SSL/TLS only possible with SNI support available in Apache 2.4
- SNI: TLS Server Name Indication
- Clients must support SNI as well
- Clients without SNI support get either the first virtual host or a "403 Forbidden" response if SSLStrictSNIVHostCheck is enabled
ACME Protocol (Let's Encrypt) Module

• mod_md (Managing Domains)
• Available since 2.4.30, but still experimental!
• Enable certificate management for a virtual host:
  • MDomain example.com www.example.com
  • MDCertificateAgreement
  • ServerAdmin webmaster@example.com
Ciphers and Protocols (default)

• Define ciphers and protocol:
  • `SSLCipherSuite HIGH:MEDIUM:!MD5:!RC4:!3DES`
  • `SSLHonorCipherOrder On`
  • `SSLProtocol All -SSLv3`

• Cipher string format (`SSLCipherSuite`):
  • prefix with “!” to permanently remove ciphers
  • prefix with “-” to remove ciphers
  • prefix with “+” to add ciphers (unless they have been removed with “!”)
Ciphers and Protocols (recommendation)

• Only use TLS 1.2 (or higher) with strong ciphers supporting forward secrecy:
  • SSLCipherSuite HIGH:!MD5:!RC4:!3DES:!CAMELLIA:!kRSA
  • SSLProtocol All -SSLv3 -TLSv1 -TLSv1.1

• Check which ciphers are enabled:
  • openssl ciphers -v 'HIGH:MEDIUM:!MD5:!RC4:!3DES'

• Apache and OpenSSL force-disable certain ciphers

• Check “ciphers” man page for meanings of the various cipher strings such as “HIGH”, “MEDIUM”, “ECDH”, etc.
Random Seeds

- Define random seeds:
  - `SSLRandomSeed startup file:/dev/urandom 2048`
  - `SSLRandomSeed connect file:/dev/urandom 2048`

- multiple sources can be defined

- Apache's built-in default is not very secure (provides very little entropy)
**TLS Session Cache**

- Using SHM session cache is recommended
  - `SSLSessionCache shmcb:/var/run/ssl_cache(1024000)`
  - `SSLSessionCacheTimeout 600`

- avoid DBM session cache, it's slow and unstable under load
- each TLS session is about 150 bytes
- Using a very large session cache and/or long timeout compromises forward secrecy!
TLS Session Tickets

• Session tickets are enabled by default:
  • SSLSessionTickets On

• Disabling session tickets decreases performance!

• Recommendation when using TLS 1.2:
  • Disable session tickets if forward secrecy is a required.
  • If enabled, restart Apache at least once a day to reduce the impact on forward secrecy (this rotates the encryption key).

• Recommendation when using TLS 1.3:
  • Enable session tickets
OCSP Stapling

- OCSP: Online Certificate Status Protocol
- OCSP Stapling is known as the “TLS Certificate Status Request Extension”

- SSLUseStapling on
- SSLStaplingReturnResponderErrors off
- SSLStaplingCache shmcb:/var/run/ocsp(128000)
Client Certificate Authentication

- SSLVerifyClient require

- Using SSLVerifyClient in a per-directory context triggers renegotiation and should be avoided if possible.
Defining allowed Client Certificates

• Path to “bundle” file with one or more PEM-encoded CA certificates:
  • SSLCACertificateFile

• Path to CRL file:
  • SSLCARevocationFile

• Use CRL if possible, but OCSP can be used as an alternative:
  • SSLOCSPEnable On
Securing Communications with your Apache HTTP Server

Apache as an TLS Reverse Proxy

- SSLProxyEngine
- SSLProxyCipherSuite
- SSLProxyProtocol
- SSLProxyCACertificateFile
- SSLProxyCACertificatePath
- SSLProxyCARevocationFile
- SSLProxyCARevocationPath
- SSLProxyCheckPeerCN
- SSLProxyCheckPeerExpire
- SSLProxyCheckPeerName
- SSLProxyMachineCertificateFile
- SSLProxyMachineCertificatePath
HTTP Strict Transport Security

- Web security policy mechanism to protect against protocol downgrade. Enforce use of HTTPS.
  - Example header:
    - `Strict-Transport-Security: max-age=31536000`
  - Once the browser has cached the header, using plain HTTP or untrusted certificates is no longer possible.
  - Can be configured with `mod_md` (incl. redirect to HTTPS): `MDRequireHttps permanent`
Securing Communications with your Apache HTTP Server

Any Questions?
Useful OpenSSL Commands

• Create self-signed certificate
  ```bash
  openssl req -x509 -nodes -days 3650 -newkey rsa:2048 \ 
  -subj '/C=XX/L=Foo/CN=www.example.com' \ 
  -keyout server.key -out server.crt
  ```

• Remove passphrase from private key:
  ```bash
  openssl rsa -in server.key -out server-nopass.key
  ```

• List available ciphers
  ```bash
  openssl ciphers -v
  openssl ciphers -v 'HIGH:MEDIUM:!MD5:!RC4'
  ```
Useful OpenSSL Commands

- Display certificate contents
  ```
  openssl x509 -text -in server.crt
  ```

- Verify if a private key matches a certificate
  ```
  openssl x509 -noout -modulus -in server.crt | md5sum
  openssl rsa -noout -modulus -in server.key | md5sum
  ```

- Connect to a Web server using HTTPS
  ```
  openssl s_client -connect www.example.com:443
  ```
Useful OpenSSL Commands

• Check if OCSP response or client certificate authentication request is sent by server:
  * openssl s_client -connect www.example.com:443 -status

• Connect and define SNI server name:
  * openssl s_client -connect www.example.com:443 -servername www.example.com

• Show description of error code:
  * openssl errstr <ERROR-NUMBER>
Cryptography Essentials

- Public-Key (asymmetric) Cryptography (e.g., RSA, DSA, ECC)
  - Data encrypted with the public key can only be decrypted with the corresponding private key
  - Data signed with the private key can be verified by anyone using the public key
- Symmetric-Key Cryptography (e.g., AES, Twofish)
- Hash Function (e.g., SHA-2, SHA-3)
- Message Authentication Code (e.g., HMAC)
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TLS Protocol

Application Layer
- TLS Handshake Proto
- TLS CCS Proto
- TLS Alert Proto
- HTTP
- ...

TLS Record Layer

Transport Layer
- TCP

Internet Layer
- IP

Network Layer
- Network
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**TLS Handshake**

- Perform server and optionally client authentication
- Select cryptographic algorithms (ciphers) supported by client and server
- Generate and exchange session key
- Establish an encrypted connection
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TLS Handshake Protocol

- Client Hello
- Server Hello
- Server Hello Done
- Server Certificate
- Client Certificate
- Change Cipher Spec
- Finished
- Change Cipher Spec
- Finished
- Start Request

SSL Handshake
TLS and SSL Versions

- SSL 2.0: original Netscape standard (no longer secure)
- SSL 3.0: revised version to fix various security vulnerabilities (no longer secure)
- TLS 1.0: first IETF standard
- TLS 1.1: protection against CBC attacks
- TLS 1.2: SSL 2.0 and MD5 no longer supported
- TLS 1.3: draft (as of July 2016)
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**XCA Tool**

- Open Source
- Graphical user interface for OpenSSL

- [https://hohnstaedt.de/xca](https://hohnstaedt.de/xca)
Restricting Client Certificates

• Restrict access based on client certificate details or any other SSL environment variable
  • Require expr "<expression>"

• Example: accept only certificate with specific common name
  • Require expr "{SSL_CLIENT_S_DN_CN} \in {'client.example.com', 'other.example.org'}"
Online Certificate Status Protocol

- OCSP issues:
  - End-user privacy
  - Efficiency
  - Does not mitigate against MITM attacks after server key compromise
- “OCSP Stapling” exists as an alternative to OCSP and should be enabled