# SSL/TLS Hands-on

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SecAppDev, 2014-02-12

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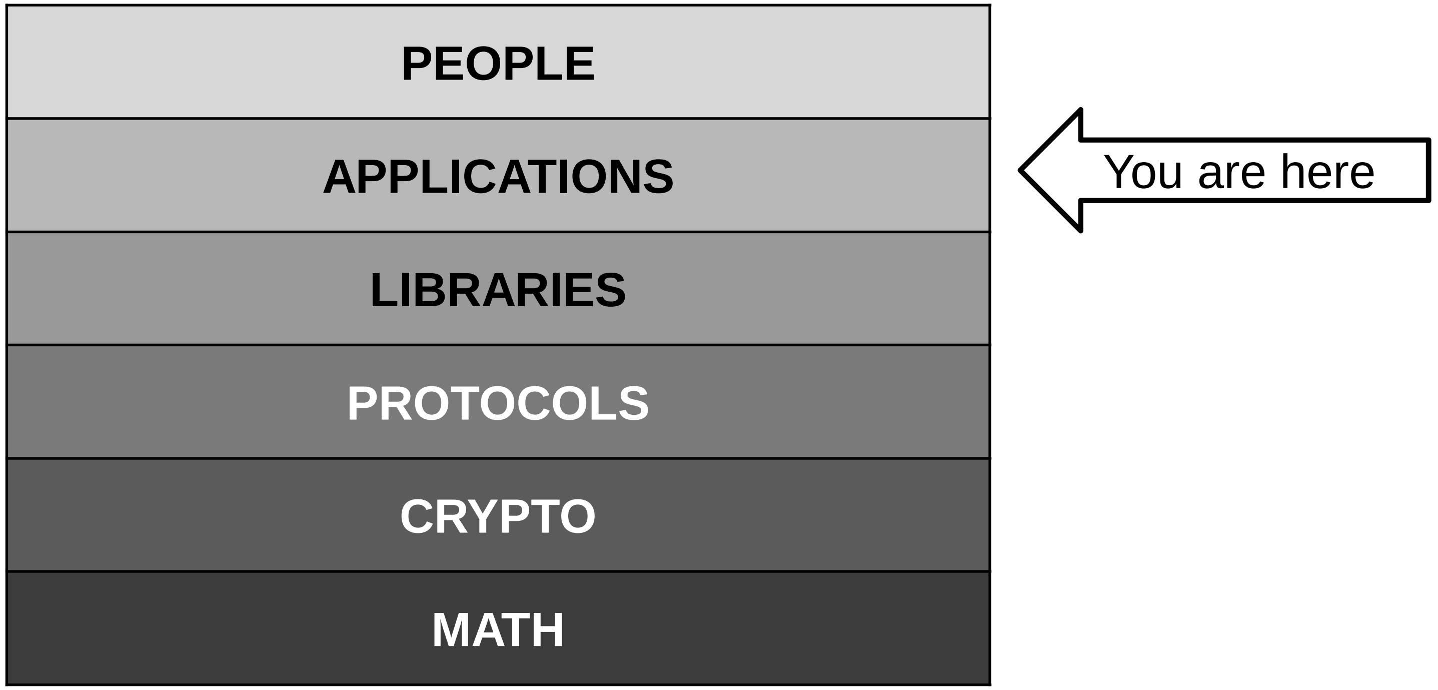
## A TLS Stack


PEOPLE
APPLICATIONS
LIBRARIES
PROTOCOLS
CRYPTO
MATH
You are here

## Disclaimer

- This hands-on session is focused on security aspects, not
  - Accessibility
  - Performance
  - Portability
  - Efficient maintenance

- Not even all known security aspects are covered

## Structure

- Today
  - Act I: “Let’s get a padlock on our web site!”
- In the future
  - Act II: “Configure TLS well on the server!”
  - Act III: “Make the web app play nice with TLS!”

## Playground (1)

- Linux: Fedora 20 (http://fedoraproject.org/en/get-fedora)
  - Host name: learn.tls.now
  - User “secappdev”, password “secret”
  - We will use the command line:

```
$ user_command          <- type as 'user_command'
# root_command          <- same as 'sudo root_command'
```

  - We will edit configuration files

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## Playground (2)

- Already installed: Apache web server 2.4.6

```
# yum install httpd
# systemctl enable httpd.service
```

  - The document root is in **`/var/www/html/`**, linked from desktop
  - The configuration directory is **`/etc/httpd`**

- Already installed, but inactive: mod_ssl

```
# yum install mod_ssl
```

- Already installed: OpenSSL 1.0.1e

```
# yum install openssl
```

## ACT I

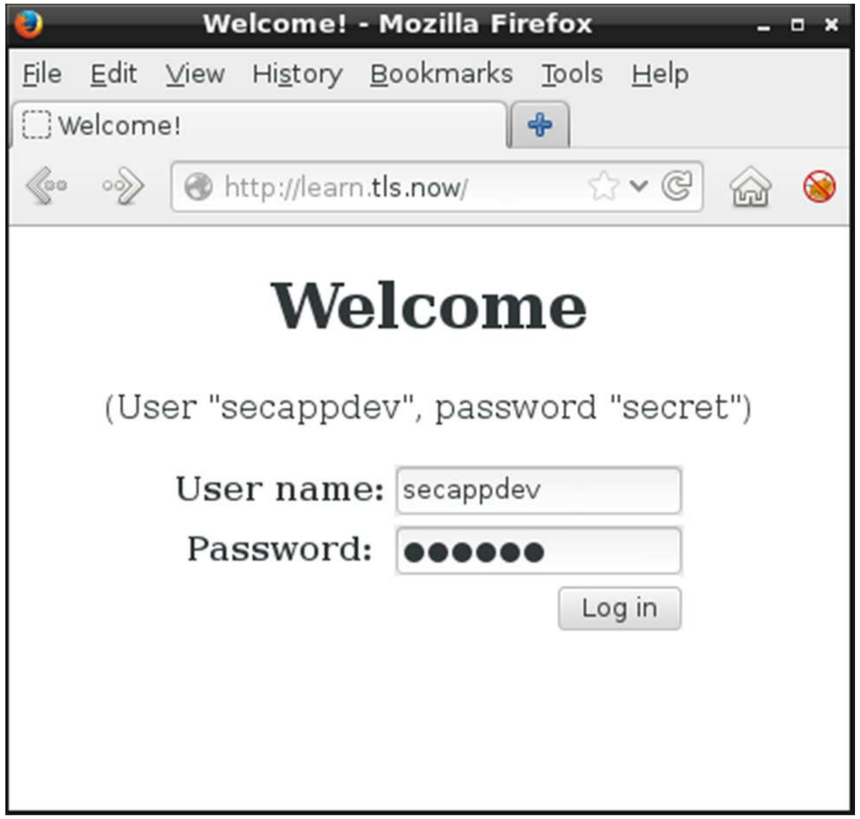
“Let’s get a padlock on our web site!”

## Act I Completion Criteria

- ☐ http://learn.tls.now loads without problems
- ☐ https://learn.tls.now loads without problems

## Try It!

**HTTP woks out of the box**


Welcome! - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Welcome!

http://learn.tls.now/

**Welcome**

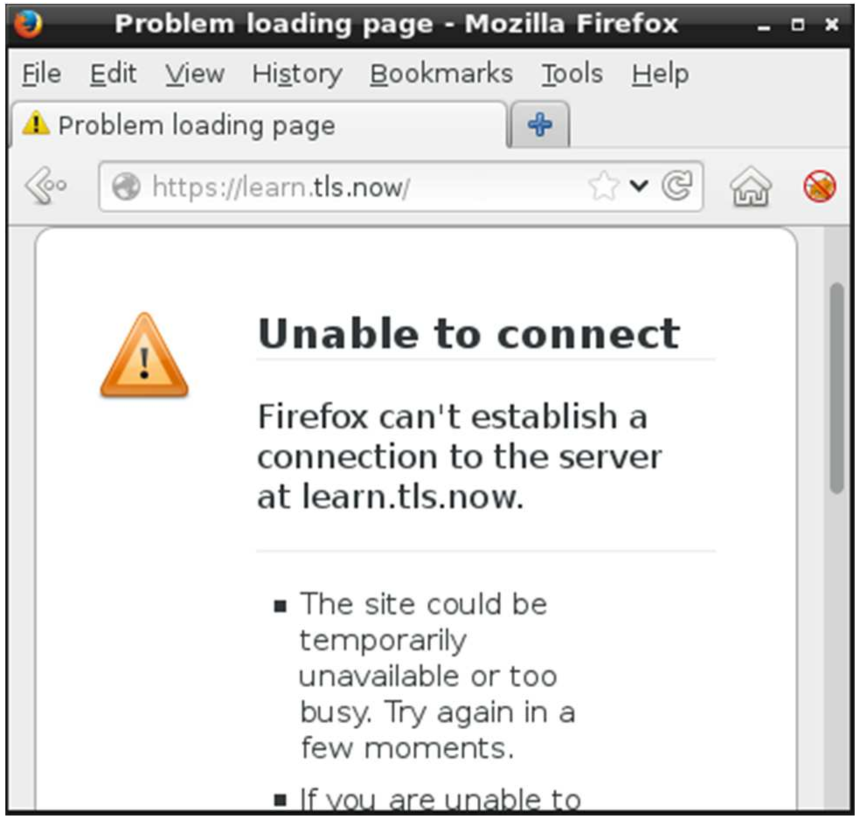
(User "secappdev", password "secret")

User name: secappdev

Password: ●●●●●●

Log in

**HTTPS doesn’t work yet**


Problem loading page - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Problem loading page

https://learn.tls.now/

**Unable to connect**

Firefox can't establish a connection to the server at learn.tls.now.

- The site could be temporarily unavailable or too busy. Try again in a few moments.
- If you are unable to

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## Wireshark

- Launch Wireshark
- Browse the site through http
- Find the password in the traffic

## Act I Completion Criteria (2)

- ☑ http://learn.tls.now loads without problems
- ☒ https://learn.tls.now loads without problems
  - ☐ No connection error

## Enable “https”

- "Activate" mod_ssl:

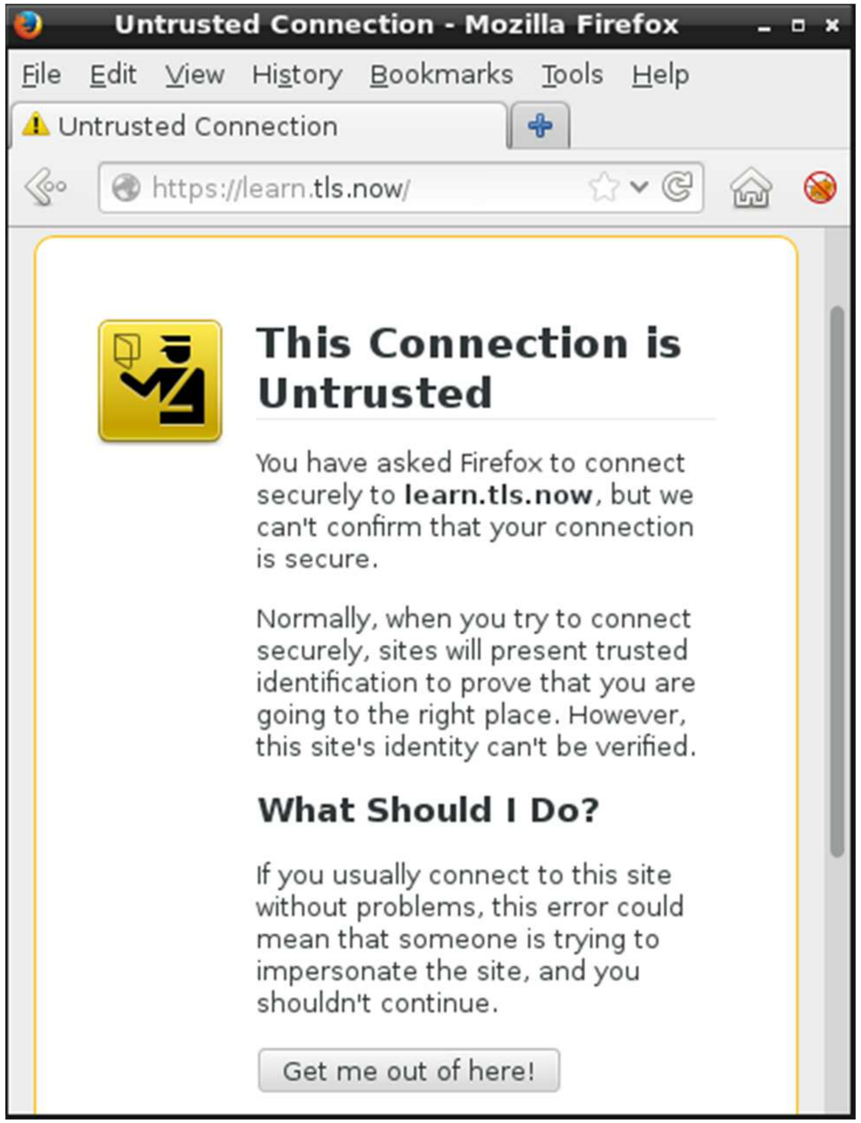
```
# mv /etc/httpd/conf.d/ssl.conf.dead
     /etc/httpd/conf.d/ssl.conf
```

- Tell Apache to reload its configuration

```
# systemctl reload httpd.service
```

- Refresh the browser…

## Try it again!


Untrusted Connection - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Untrusted Connection
https://learn.tls.now/
Get me out of here!

**This Connection is Untrusted**

You have asked Firefox to connect securely to **learn.tls.now**, but we can't confirm that your connection is secure.

Normally, when you try to connect securely, sites will present trusted identification to prove that you are going to the right place. However, this site's identity can't be verified.

**What Should I Do?**

If you usually connect to this site without problems, this error could mean that someone is trying to impersonate the site, and you shouldn't continue.

- If the user continued:
  - Confidentiality OK
  - Integrity OK
  - Authenticity of the server UNKNOWN
- If your production site is like this you're teaching your users bad habits!
  - And you are hurting our collective security!

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## "Technical Details" of Firefox Warning

- “This Connection is Untrusted”
- …
- Technical Details
  - learn.tls.now uses an invalid security certificate.
  - The certificate is not trusted because it is self-signed.

## Security Certificate?

- I did not do anything about certificates!
- You did not do anything, either!
- But Fedora did:
  - The **`mod_ssl`** installation generated a dummy certificate
  - Why: it gets the server up and running without friction
    - Good for **novices**, they can learn later to do it properly
    - Neutral for **professionals**, they are supposed to have a secure procedure anyway
- Most Linux distros do it this way

## Not Trusted?

- “because it is self-signed”
  - Misnomer: the trusted Root CA certificates are self-signed, too
  - Should be: “… because certificate signer is not trusted.”

- For continuing the browser asks the user: “Do you trust the certificate signer?”
  - When continuing, the user answers “Yes”
  - Actually, most users just want to answer “Get out of my way!”
  - Risky - the certificate could belong to an attacker-in-the-middle!
  - The “Add exception… permanently” option makes the risk permanent

- Lesson: avoid exposing your users to this warning in the first place!

## Act I Completion Criteria (3)

- ☑ http://learn.tls.now loads without problems
- ☒ https://learn.tls.now loads without problems
  - ☑ No connection error
  - ☒ No trust warning

## Where is the Certificate?

- You have already met **`/etc/httpd/conf.d/ssl.conf`**
- In it you can find the directives:

```
# TLS Configuration per virtual host
<VirtualHost _default_:443>
    SSLEngine on
    SSLCertificateFile
        /etc/pki/tls/certs/localhost.crt
    SSLCertificateKeyFile
        /etc/pki/tls/private/localhost.key
    ...
</VirtualHost>
```

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## Crash Course OpenSSL CLI

- In Fedora 20 the version of OpenSSL is 1.0.1e
- OpenSSL has a command mode:

```
# openssl SUBCOMMAND OPTIONS
```

- Which subcommands?
  - Run **`man openssl`**, see the COMMAND SUMMARY section
  - Then run **`man SUBCOMMAND`**
- Options are in single dash format
  - E.g.: **`-noout`**, “do not re-display raw input”
- Some options can have parameters
  - E.g.: **`-in INPUTFILE`**, “read input from INPUTFILE, not stdin”

## Inspect Certificate with OpenSSL (1)

```
# cd /etc/pki/tls/
# openssl x509 -in certs/localhost.crt –text -noout
Certificate:
    Data:[…]
    Signature Algorithm: sha1WithRSAEncryption
        Issuer: C=--, ST=SomeState, […]
        Validity
            Not Before: Feb 11 09:35:21 2014 GMT
            Not After : Feb 11 09:35:21 2015 GMT
        Subject: C=--, ST=SomeState, […]
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (1024 bit)
                Modulus:[…]
                Exponent: 65537 (0x10001)
```

## Inspect Certificate with OpenSSL (2)

```
(continued)
    X509v3 extensions:
      X509v3 Basic Constraints:
                CA:FALSE
      X509v3 Key Usage:
        Digital Signature, Non Repudiation, Key Encipherment
  Signature Algorithm: sha1WithRSAEncryption
```

## Act I Completion Criteria (4)

- ☑ http://learn.tls.now loads without problems
- ☒ https://learn.tls.now loads without problems
  - ☑ No connection error
  - ☒ No trust warning
    - ☒ Private key of at least 2048 bits
    - ☒ Public exponent of at least 17 bits
    - ☒ Certificate corresponding to the domain
    - ☑ Certificate corresponding to private key
    - ☑ Signature on certificate valid
    - ☒ Certificate signing key is trusted (maybe through recursion)
    - ☑ Signature algorithm not using MD5
    - ☑ Validity period of 1 year
    - ☑ Usage compatible with being a web site certificate

    …

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## We Need to Generate a New Certificate

- Steps:
  1. You generate a key pair
  2. You generate a Certificate Signing Request (CSR)
  3. A Registration Authority verifies the CSR
  4. A Certificate Authority creates the certificate for you
- There are numerous helper tools and wizards
  – Fedora recommends **`genkey`** from package **`crypto-utils`**
  – Fedora provides OpenSSL GUI package **`xca`**
  – Fedora provides heavyweight set of packages **`pki-*`**
  – OpenSSL wrapper: **`/etc/pki/tls/misc/CA`**
  – OpenSSL subcommand: **`openssl ca`**
- We will take the route that shows a lot of detail

## Generate a Keypair

- Keys will be for RSA (a little simpler than for DSA)
- Default keyfile format is PEM, accepted by Apache
  - The conventional keypair file extension is **`.key`**
- Key length of at least 2048 bits is based on estimated strength
  - NIST Special Publication 800-57 (July 2012)
  - CA/Browser Forum Baseline Requirements (November 2011)
- Public exponent of at least 32 bits, because of:
  - 2006: Belichenbacher attack against exponent “3” PKCS #1 v1.5
  - SecAppDev 2012, Bart Preneel: “use >32 bits”
- So far, recommended key generation:

```
# openssl genpkey -algorithm rsa -out private/keys.key
  -pkeyopt rsa_keygen_bits:2048
  -pkeyopt rsa_keygen_pubexp:0x100000001
```

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## Keyfile Protection

- Option 1: password protect the keyfile
  - Add cipher option, e.g. **`-aes-128-cbc`**
  - By default, passphrase provided interactively at generation
    - See **`man openssl`**, section PASS PHRASE ARGUMENTS
  - But passphrase must be provided every time Apache starts up
    - See docs for SSLPassPhraseDialog
- Option 2: keyfile protected at filesystem and SELinux level

```
# chmod u=rw,go= private/keys.key
# selinux…
```

# Act I Completion Criteria (5)

- ☑ http://learn.tls.now loads without problems
- ☒ https://learn.tls.now loads without problems
  - ☑ No connection error
  - ☒ No trust warning
    - ☑ Private key of at least 2048 bits
    - ☑ Public exponent of at least 17 bits
    - ☐ Certificate corresponding to the domain
    - ☐ Certificate corresponding to private key
    - ☐ Signature on certificate valid
    - ☐ Certificate signing key is trusted (maybe through recursion)
    - ☐ Signature algorithm not using MD5
    - ☐ Validity period of 1 year
    - …

## The Certificate Signing Request

- Command:

```
# openssl req -new [OPTIONS]
  -key private/keys.key -out certreq.csr
```

- One-year validity period with **`-days 365`**
- Default hash algorithm is SHA1, not MD5
- Other constraints do not have command line options, but are indicated in a configuration file

## OpenSSL Configuration Files

- Config file can be default or specified with **`-config CONFIGFILE`**
  - On Fedora the default file is: **`/etc/pki/tls/openssl.cnf`**
- Sections are introduced by lines like **`[ section_name ]`**
- Section **`[ v3_req ]`** has some good values:
  - basicConstraints = CA:FALSE
    - If lost, the private key can not be used to sign other certificates
  - keyUsage = nonRepudiation, digitalSignature, keyEncipherment
    - Compatible with being a web site certificate
- Use that section with **`-extensions v3_req`**

## The Domain Name for the Certificate

- Express the domain name as a Distinguished Name: **`-subj "/C=BE/ST=Vlaams Brabant/L=Leuven/O=SecAppDev/CN=learn.tls.now/"`**
- What about co-hosting related web sites on the same IP address?
  - https://learn.tls.now:443, but also
  - https://www.tls.now:443 and
  - https://tls.now:443
- Same web server, same configuration, cannot serve more than one certificate…
- Specify all names in the **`[v3_req]`** section of the configuration file, which the simulated CA will later use:

```
subjectAltName=DNS:learn.tls.now,DNS:www.tls.now,DNS:tls.now
```

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## CSR Generation Summary

- Generate a CSR (Certificate Signing Request)

```
# openssl req -new -subj "/C=BE/ST=Vlaams
Brabant/L=Leuven/O=SecAppDev/CN=learn.tls.now/"
  -days 365 -extensions v3_req
  -key /etc/pki/tls/private/keys.key
  -out /etc/pki/tls/certreq.csr
```

## Trust in the Certificate – Between Strangers

- Anyone can generate a CSR for your web site…
- You need to be able to prove to strangers it’s your web site
- Employ Trusted Third Parties
  - professional Registration Authorities
  - professional Certification Authorities
- Luckily, browsers come preloaded with trusting a bunch of them
  - Or “Unfortunately,…” (in case one of them is corrupted)
- Certifying your public key usually has a price tag
- We will simulate the CA’s procedure

## Extended Validation Certificates

- What exactly is certified?
- It should be: “requester’s ownership of the FQDN”
- How stringent checks?
  - Verify photo ID of the requester?
  - Verify business ownership of the FQDN?
  - Verify control of the indicated e-mail address?
  - Verify possession of the private key?
  - Don’t verify, just issue a limited-time “testing” cert?
- “Extended Validation” certificates
  - a.k.a. “the way it should have been done in the first place”
  - Validation requirements are no less than a known threshold
  - Certificates contain a reference to the CA’s verification policy
- Current browsers display additional positive assurance for EV certs

## Simulated CA Step

- Sign the Certificate Signing Request
  - Prepare a file to keep track of the serial numbers
  - Prepare a file to keep track of the issued certificates
  - Configure various other values in **`openssl.conf`**

```
$ ~/ca/casign /etc/pki/tls/certreq.csr
```

- The passphrase for the CA’s private key is “trustedca”
- The signed certificate will be saved to **`/etc/pki/tls/certs/casigned.crt`**

## Deploy Certificates to Apache

- The files are already in the folders expected by Apache on Fedora
  - Therefore they have inherited the correct SELinux context
- Let **`mod_ssl`** know about them
  - Replace old values in **`/etc/httpd/conf.d/ssl.conf:`**

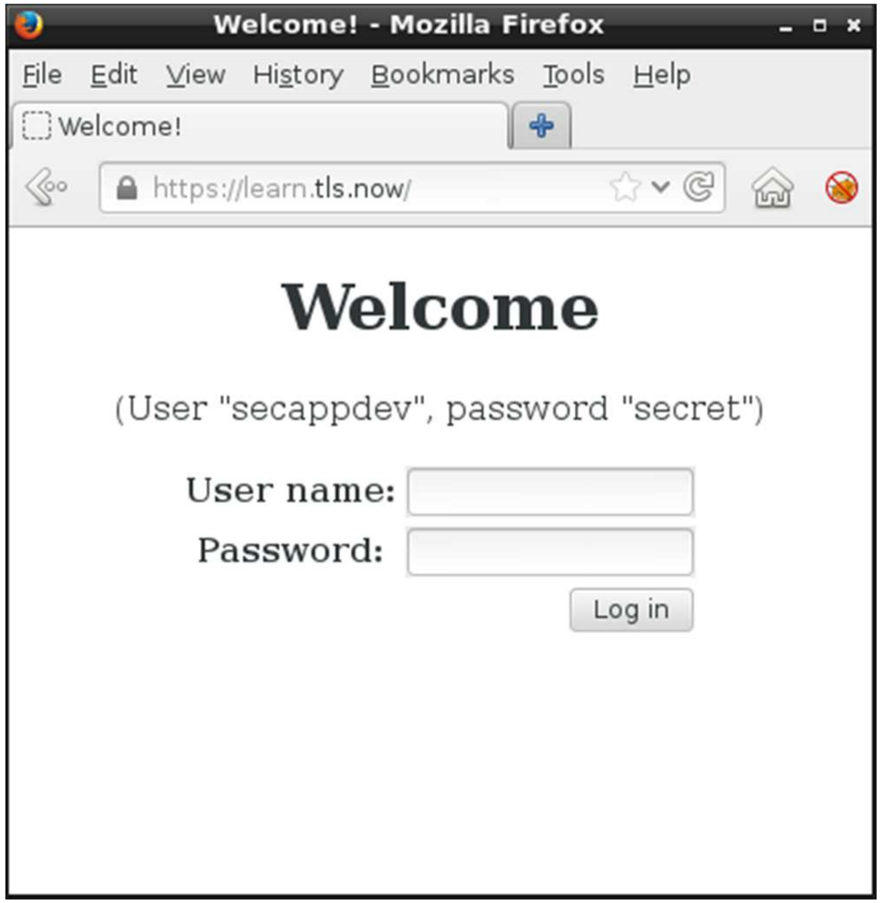
```
SSLCertificateFile /etc/pki/tls/certs/casigned.crt
SSLCertificateKeyFile /etc/pki/tls/private/keys.key
```

- Let Apache know about the change

```
# systemctl reload httpd.service
```

  - Use **`systemctl reload`**, because we just changed configs

## It Worked!


Welcome! - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Welcome!
https://learn.tls.now/
Log in

Welcome

(User "secappdev", password "secret")

User name:

Password:

## Act I Completion Criteria (6)

- ☑ http://learn.tls.now loads without problems
- ☑ https://learn.tls.now loads without problems
  - ☑ No connection error
  - ☑ No trust warning
    - ☑ Private key of at least 2048 bits
    - ☑ Public exponent of at least 17 bits
    - ☑ Certificate corresponding to the domain
    - ☑ Certificate corresponding to private key
    - ☑ Signature on certificate valid
    - ☑ Certificate signing key is trusted (maybe through recursion)
    - ☑ Signature algorithm not using MD5
    - ☑ Validity period of 1 year

    …

## Discussion: Certificate Chains

- There are sub-CAs and sub-sub-CAs, …
- Browser only knows root CA certificate in the beginning
- Web site must provide the intermediate links in order:
  – TLS RFC says so: each certificate certifies the one before it

```
-----BEGIN CERTIFICATE-----
MIICzzCCAbegAwIBAgIJAIXRQJSXK2HAYD
Ap  Sub-sub-CA certificate  FLVQQD
U2olbGhvc3QubG9jYWxkb
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
MIIDCTCCAnKgAwIBAgICNtQwDQYJKoDBVs
MR    Sub-CA certificate    ETb2Nh
IGS25sSHgrz8OU28eA==
-----END CERTIFICATE-----
```

- The cert chain goes into the file specified in ssl.conf

```
SSLCertificateChainFile
      /etc/pki/tls/certs/server-chain.crt
```

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## Discussion: Certificate Expiration and Revocation

- At expiry, assume private key to be compromised
  - Cryptanalysis: deriving it from the public key
  - Breach: breaking into web server and copying the file
  - Brute force 1: trying enough candidates for a match
  - Brute force 2: “convince” a sysadmin to disclose it
- Generate a new keypair for every new certificate, it’s cheap
- Reasons for renewing the keypair even before expiration:
  - You have evidence of key compromise (see above)
  - You have lost control of the private key (no disaster recovery)
- Inform the CA, who updates a CRL or an OCSP server
- Browsers would ignore the old cert if they encountered it

## Bibliography

- Fedora 18 System Administrator’s Guide, Ch. 14, Web Servers: http://docs.fedoraproject.org/en-US/Fedora/18/html/System_Administrators_Guide/ch-Web_Servers.html#s2-apache-mod_ssl
- Apache 2.4 Module mod_ssl: http://httpd.apache.org/docs/2.4/mod/mod_ssl.htm
- OpenSSL man pages and HOWTOs: http://www.openssl.org/docs/
- OWASP Transport Layer Protection Cheat Sheet: https://www.owasp.org/index.php/Transport_Layer_Protection_Cheat_Sheet

QUESTIONS?

SEE YOU AGAIN AT SECAPPDEV 2014!

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