MTAT.07.017
Applied Cryptography

Certificate Revocation List (CRL)
Online Certificate Status Protocol (OCSP)

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Certificate validity

It may be required to invalidate (revoke) a certificate before its expiration.

Examples:

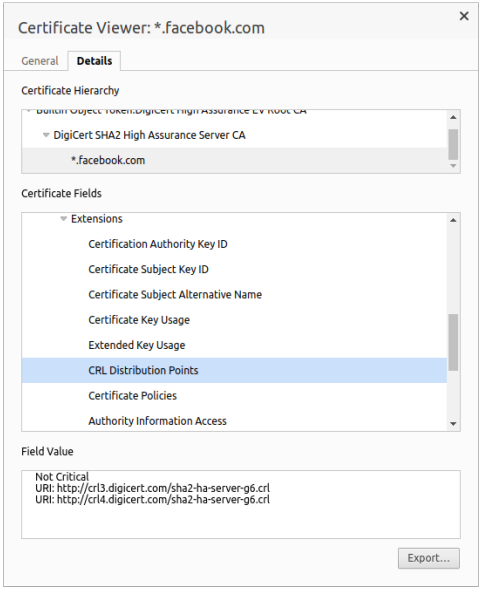
- Private key compromised
- Misissued certificate
- Data has changed

Solution – Certificate Revocation List (CRL):

List of unexpired certificates that have been revoked by CA

- Where can a relying party find the CRL?
- How can we assure the integrity of the CRL?
- How frequently should the CA issue the CRL?
- How frequently should the relying parties refresh the CRL?
- How can the relying party know that the CRL is fresh?

CRL Distribution Points



Certificate Revocation List (CRL)

```
CertificateList  ::=  SEQUENCE  {
    tbsCertList          TBSCertList,
    signatureAlgorithm   AlgorithmIdentifier,
    signatureValue       BIT STRING  }

TBSCertList  ::=  SEQUENCE  {
    version             Version OPTIONAL, -- if present, MUST be v2(1)
    signature           AlgorithmIdentifier,
    issuer              Name,
    thisUpdate          UTCTime,
    nextUpdate          UTCTime OPTIONAL,
    revokedCertificates SEQUENCE OF SEQUENCE  {
         userCertificate     CertificateSerialNumber,
         revocationDate      UTCTime,
         crlEntryExtensions  Extensions OPTIONAL -- in v2 }  OPTIONAL,
    crlExtensions       [0] EXPLICIT Extensions OPTIONAL  -- in v2 }
```

http://tools.ietf.org/html/rfc5280

Certificate Revocation List (CRL)

- `tbsCertList` – DER structure to be signed by CRL issuer
- `version` – for v1 absent, for v2 contains 1
  - v2 introduces CRL and CRL entry extensions
- `signature` – `AlgorithmIdentifier` from `tbsCertList` sequence
- `issuer` – identity of issuer who issued (signed) the CRL
- `thisUpdate` – date when this CRL was issued
- `nextUpdate` – date when next CRL will be issued
- `revokedCertificates` – list of revoked certificates
  - `userCertificate` – serial number of revoked certificate
  - `revocationDate` – time when CA processed revocation request
  - `crlEntryExtensions` – provides additional revocation information
- `crlExtensions` – provides more information about the CRL

Certificate chain

- How to validate a certificate chain?
- Where to check whether the subject's certificate is not revoked?
  - In the CRL issued by the intermediate CA (usually every 12h)
  - Grace period
- Where to check whether the intermediate CA is not revoked?
  - In the CRL issued by the root CA (usually every 3 months)
  - Grace period?!
- Where to check whether the root CA is not revoked?
  - In the CRL issued by the root CA itself (flawed)
  - Must be revoked by out-of-band means

Who should be liable for the actions made after the root CA private key has been compromised?

Liability analysis

Let's assume that a subject's private key has been compromised.

Who (subject, CA or relying party) is liable for actions made with the key:

- in the time period after revocation information has appeared in the CRL?
- in the time period after the CRL has been issued but not available to relying parties (e.g., CA server downtime)?
- in the time period before the next CRL has been issued?
- in the time period before the CA has marked the certificate revoked in their internal database?
- in the time period before the CA has been informed about the key compromise?

Questions

- How can a relying party find the CRL?
- How is the integrity of CRL data assured?
- How frequently should the CA issue a CRL?
- How frequently should the relying parties refresh the CRL?
- How can the relying party know that the CRL is fresh?
- How can it be verified that the root CA certificate has not been revoked?
- Is the subject liable for the transactions made after the certificate is revoked?
- Is the subject liable for the transactions made in the certificate validity period?

Online Certificate Status Protocol

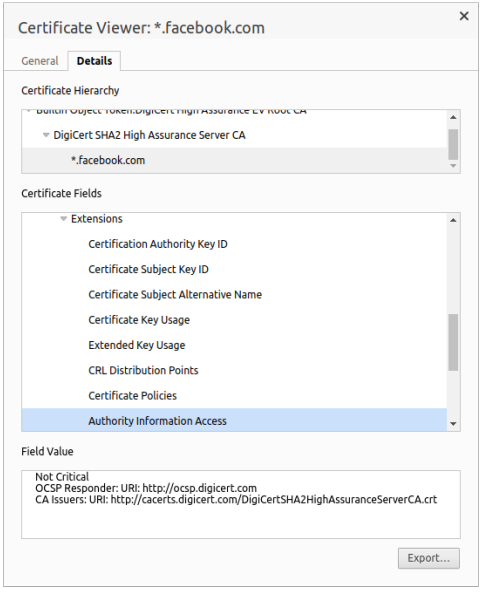
CRL shortcomings:

- Size of CRLs
- Client-side complexity
- Outdated status information

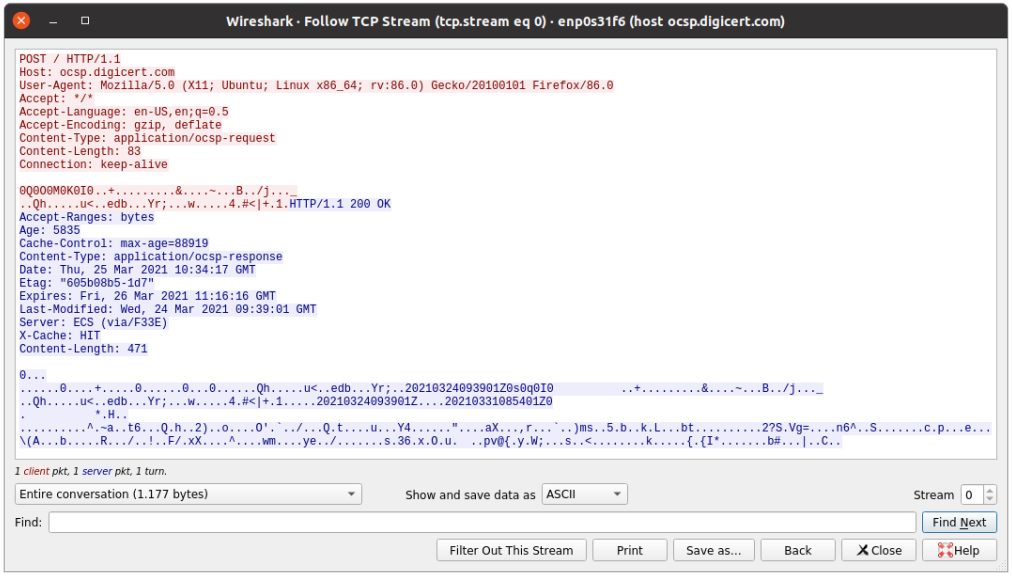
"The Online Certificate Status Protocol (OCSP)
enables applications to determine the (revocation) state of an identified certificate."

- Where can the relying parties find the OCSP responder?
- How is a certificate identified in the OCSP request?
- How is the integrity of an OCSP response assured?
- How can the freshness of an OCSP response be ensured?

Authority Information Access



OCSP over HTTP



Request syntax

```
OCSPRequest ::= SEQUENCE {
  tbsRequest TBSRequest,
  optionalSignature [0] Signature OPTIONAL }

Signature ::= SEQUENCE {
  signatureAlgorithm AlgorithmIdentifier,
  signature          BIT STRING,
  certs              [0] SEQUENCE OF Certificate OPTIONAL }

TBSRequest ::= SEQUENCE {
  version            [0] Version DEFAULT v1(0),
  requestorName      [1] GeneralName OPTIONAL,
  requestList        SEQUENCE OF SEQUENCE {
     reqCert                 CertID,
     singleRequestExtensions  [0] Extensions OPTIONAL }
  requestExtensions  [2] Extensions OPTIONAL }

CertID ::= SEQUENCE {
  hashAlgorithm       AlgorithmIdentifier,
  issuerNameHash      OCTET STRING, -- Hash of Issuer's DN
  issuerKeyHash       OCTET STRING, -- Hash of Issuer's public key
                (i.e., hash of subjectPublicKey BIT STRING content)
  serialNumber        CertificateSerialNumber }
```

http://tools.ietf.org/html/rfc6960

Response syntax

```
OCSPResponse ::= SEQUENCE {
      responseStatus         OCSPResponseStatus,
      responseBytes          [0] EXPLICIT ResponseBytes OPTIONAL }

   OCSPResponseStatus ::= ENUMERATED {
       successful             (0),  --Response has valid confirmations
       malformedRequest       (1),  --Illegal confirmation request
       internalError          (2),  --Internal error in issuer
       tryLater               (3),  --Try again later
                                    --(4) is not used
       sigRequired            (5),  --Must sign the request
       unauthorized           (6)   --Request unauthorized
   }

ResponseBytes ::=       SEQUENCE {
       responseType   OBJECT IDENTIFIER, --id-pkix-ocsp-basic
       response       OCTET STRING }
```

- `responseBytes` provided only if `responseStatus` is “successful”

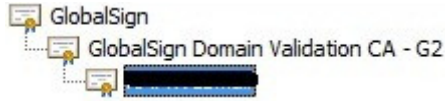
Response syntax

```
response ::= SEQUENCE {
    tbsResponseData      ResponseData,
    signatureAlgorithm   AlgorithmIdentifier,
    signature            BIT STRING,
    certs                [0] EXPLICIT SEQUENCE OF Certificate OPTIONAL }

ResponseData ::= SEQUENCE {
    version             [0] EXPLICIT Version DEFAULT v1,
    responderID         [1] Name,
    producedAt          GeneralizedTime,
    responses           SEQUENCE OF SEQUENCE {
          certID           CertID,
          certStatus       CertStatus,
          thisUpdate       GeneralizedTime,
          nextUpdate       [0] EXPLICIT GeneralizedTime OPTIONAL,
          singleExtensions [1] EXPLICIT Extensions OPTIONAL }
    responseExtensions  [1] EXPLICIT Extensions OPTIONAL }

CertStatus ::= CHOICE {
    good        [0]     IMPLICIT NULL,
    revoked     [1]     IMPLICIT SEQUENCE {
          revocationTime   GeneralizedTime,
          revocationReason [0] EXPLICIT CRLReason OPTIONAL }
    unknown     [2]     IMPLICIT NULL }
```

Who signs OCSP responses?



The key used to sign the response MUST belong to one of the following:

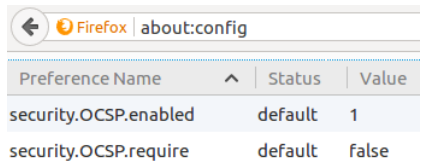
- CA who issued the certificate in question
- CA Authorized Responder who holds a specially marked certificate issued directly by the CA, indicating that the responder may issue OCSP responses for that CA
  - OCSP signing delegation SHALL be designated by the inclusion of `id-kp-OCSPSigning` flag in an `extendedKeyUsage` extension of the responder's certificate
  - How can the revocation status of this certificate be checked?
- Trusted Responder whose public key is trusted by the requester
  - Trust must be established by some out-of-band means

How can the freshness of a response be checked?

- Replay attack
- Check the signed `producedAt` field
  - What should be the allowed time difference?
  - Reliance on the correctness of system clock
- Include a random nonce in the OCSP request and check it in the response
  - OCSP nonce extension (optional)
  - Prevents replay attacks
  - Vulnerable to downgrade attacks
- OCSP response caching
  - The current time between `thisUpdate` and `nextUpdate`

Revocation checking by browsers

- CRLs are not supported
- Problems with OCSP:
  - Privacy leakage
  - Initial page loading slower
  - Online checks are not, generally, performed by Chrome (uses CRLSets)
  - Firefox is not brave enough to fail-safe:



- Solution is OCSP stapling (web server provides OCSP response to the browser)
  - OCSP must-staple x509v3 extension to prevent downgrade attacks
- How fresh should the OCSP response be?
- Shorter certificate validity period may help

Questions

- Where can a relying party find the OCSP responder?
- How is a certificate identified in the OCSP request?
- How is the integrity of the OCSP response assured?
- How can the freshness of the OCSP response be ensured?
- How frequently should the validity status be checked?
- What problem does the OCSP nonce extension solve?
- What is a replay attack?
- What is a downgrade attack?

Hypertext Transfer Protocol (HTTP)

- Application layer client-server, request-response protocol
- Runs over TCP (Transmission Control Protocol) port 80

Client request (`http://example.com/hello`):

```
GET /hello HTTP/1.1
Host: example.com
Connection: close
```

```
POST /hello HTTP/1.1
Host: example.com
Content-Length: 24
Connection: close

sending_this_binary_blob
```

Server response:

```
HTTP/1.1 200 OK
Date: Thu, 25 Mar 2021 11:39:23 GMT
Server: Apache
Content-Length: 7033
Content-Type: text/html

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Tran...
```

- Header lines must all end with <CR><LF> (`b"\r\n"`)
- Header lines are separated from the body by an empty line
- POST requests have a non-empty request body

`http://en.wikipedia.org/wiki/Hypertext_Transfer_Protocol`

Sockets in Python

```
>>> import socket
>>> s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
>>> s.connect(("example.com", 80))
>>> s.send(b'GET / HTTP/1.1\r\nHost: example.com\r\n\r\n')
37
>>> s.recv(20)
b'HTTP/1.1 200 OK\r\nAge'
```

- `recv()` returns bytes that are available in the read buffer
- `recv()` will wait if the read buffer is empty (blocking by default)
- `recv()` will return 0 bytes if the connection is closed
- We must know how many bytes we must get
- Correct way to read HTTP response:
  - Read byte-by-byte until the full response header is received
  - Extract body size from `Content-Length` header
  - Read byte-by-byte until the full response body is received
  - Avoid endless loops by checking the return value of `recv()`

`http://docs.python.org/3/howto/sockets.html`

Task: OCSP checker

Implement a utility that queries an OCSP responder for a certificate's validity:

```
$ ./ocsp_check.py valid.pem
[+] URL of OCSP responder: http://ocsp.digicert.com
[+] Downloading issuer certificate from: http://cacerts.digicert.com/DigiCertSHA2HighAssuranceServerC
[+] OCSP request for serial: 46103917524641749714270592234963726O7
[+] Connecting to ocsp.digicert.com...
[+] OCSP producedAt: 2021-03-25 09:39:00
[+] OCSP thisUpdate: 2021-03-25 09:39:00
[+] OCSP nextUpdate: 2021-04-01 08:54:00
[+] OCSP status: good


$ ./ocsp_check.py revoked.pem
[+] URL of OCSP responder: http://evrootocsp.pkioverheid.nl
[+] Downloading issuer certificate from: http://cert.pkioverheid.nl/EVRootCA.cer
[+] OCSP request for serial: 10000616
[+] Connecting to evrootocsp.pkioverheid.nl...
[+] OCSP producedAt: 2021-03-25 12:00:56
[+] OCSP thisUpdate: 2021-03-25 12:00:56
[+] OCSP nextUpdate: 2021-03-27 12:00:56
[+] OCSP status: revoked
```

Task: OCSP checker

- Extract OCSP responder's URL and CA certificate's URL from certificate's Authority Information Access (AIA) extension
- Send HTTP requests using Python sockets (**the correct way!** – see slide 20)
- Use `urlparse` for easy URL parsing:

```
>>> from urllib.parse import urlparse
>>> urlparse("http://example.com/abc")
ParseResult(scheme='http', netloc='example.com', path='/abc', params='', query='', fragment='')
>>> urlparse("http://example.com/abc").netloc
'example.com'
```

- Use regular expression to extract the length of an HTTP response body:

```
>>> import re
>>> re.search('content-length:\s*(\d+)\s', header.decode(), re.S+re.I).group(1)
```

- Construct OCSP request using your ASN.1 DER encoder
- To construct `issuerKeyHash` (`CertID`) encode `subjectPublicKey` bits to bytes
- OCSP response parsing code is in the template
- Signature verification checks can be skipped

Task: OCSP checker

- OCSP requests must include "`Content-Type: application/ocsp-request`"
- To debug HTTP errors use Wireshark's "Follow → TCP Stream" feature
- `ocsp.digicert.com` returns "unauthorized" for unrecognized CertIDs
- OCSP request for `valid.pem`:

```
$ dumpasn1 valid.pem_ocsp_req
  0  81: SEQUENCE {
  2  79:   SEQUENCE {
  4  77:     SEQUENCE {
  6  75:       SEQUENCE {
  8  73:         SEQUENCE {
 10   9:           SEQUENCE {
 12   5:             OBJECT IDENTIFIER sha1 (1 3 14 3 2 26)
 19   0:             NULL
      :             }
 21  20:           OCTET STRING
      :             CF 26 F5 18 FA C9 7E 8F 8C B3 42 E0 1C 2F 6A 10
      :             9E 8E 5F 0A
 43  20:           OCTET STRING
      :             51 68 FF 90 AF 02 07 75 3C CC D9 65 64 62 A2 12
      :             B8 59 72 3B
 65  16:           INTEGER 03 77 ED DC FA F8 BE 34 BA 23 3C 7C 2B 9A 31 7F
      :           }
      :         }
      :       }
      :     }
      :   }
```

Comments

The **wrong** way of downloading HTTP response body:

- Reading the response in one go (**wrong!**):

```
body = s.recv(content_length)
```

"The receive calls normally return any data available, up to the requested amount, rather than waiting for receipt of the full amount requested."

- Reading until the socket is closed (**wrong!**):

```
body = b''
buf = s.recv(1024)
while len(buf):
      buf = s.recv(1024)
      body+= buf
```

After sending a response, an HTTP/1.1 server will wait for more request/response exchanges, unless the header "`Connection: close`" was specified by the client.

- `s.recv()` will hang until the timeout configured by the server is reached