The Case for Prefetching and Prevalidating TLS Server Certificates

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Transport Layer Security

- Want to secure traffic between web browsers and servers
- One problem is latency from TLS handshake
The TLS handshake

Client

Server

Initialize handshake

https://encrypted.google.com
The TLS handshake

Client

Server

Initialize handshake

Certificate

https://encrypted.google.com
The TLS handshake

Certificate validation

Client

Initialize handshake

Certificate valid?

Response

Server
The TLS handshake

Certificate validation

Certificate valid?

Response

Initialize handshake

Certificate

Negotiate key

Client

Server

https://encrypted.google.com
The TLS handshake

Certificate validation

Certificate valid?

Response

Initialize handshake

Certificate

Negotiate key

HTTP request

HTTP response

Client

Server

https://encrypted.google.com
The TLS handshake

Certificate validation

Certificate valid?
  ←   Response

Client

Initialize handshake
  Certificaterequests

Server

Negotiate key
  ←

HTTP request
  HTTP response
Certificate validation: OCSP

- Online certificate status protocol
Certificate validation: OCSP

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- Server certificate specifies OCSP responder
Certificate validation: OCSP

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- Clients asks responder whether cert is valid
Certificate validation: OCSP

- Online certificate status protocol
- Server certificate specifies OCSP responder
- Clients asks responder whether cert is valid
- Responder specifies how long response is valid for
The TLS handshake

Certificate validation

Certificate valid?

Response

Initialize handshake

Certificate

Negotiate key

HTTP request

HTTP response

Client

Server
The TLS handshake

Certificate validation

Certificate valid?

Response

Client

Server

Initialize handshake

Certificate

Negotiate key

HTTP request

HTTP response
Removing round trips

Previous proposal, TLS Snap Start

- Zero round trip handshake
Removing round trips
Removing round trips

Client

Server

Initialize handshake
Snap Start extension
HTTP request
HTTP response
HTTP response
Snap Start challenges

- Client must know server certificate
- Cached from previous visit
Snap Start challenges

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Problem

- TLS imposes extra latency due to retrieving and validating server certificate
  - How to obtain certificate to do Snap Start handshake?
  - How to validate without extra latency?
Contribution

- Real world study of OCSP response times
- Certificate prefetching and prevalidation
  - Propose four prefetching strategies
  - Analysis of effectiveness
  - Prototype implementation
How long does OCSP take in the real world?

- Experimental setup
  - OCSP response times collected from users running Perspectives browser extensions
  - 242 clients, 4474 certificates, 24 responders
OCSP in the wild

CDF of OCSP response time:

Median: 291 ms, mean: 498 ms
OCSP in the wild

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Design

- Prefetch certificates
  - Enables Snap Start handshakes more frequently
- Prevalidate certificates
  - Removes OCSP lookup from critical path
Design questions

- When to prefetch? When to prevalidate?
- How to obtain certificate?
When to prefetch

Ideas borrowed from DNS prefetching:

• DNS prefetching triggers are effective for certs
When to prefetch

Ideas borrowed from DNS prefetching:

- DNS prefetching triggers are effective for certs
- Could be deployed with HTML hints for effective prefetching
How to prefetch

- Goal: Obtain server certificate
- Challenge: Full TLS handshake is expensive
- Four proposed methods that are more efficient
Prefetching methods

Option 1: Truncated handshake

Client → Server

Initialize handshake

Certificate

Negotiate key

HTTP request

HTTP response
Prefetching methods

Option 1: Truncated handshake
Prefetching methods

Option 1: Truncated handshake

- No public key crypto!
- Server admin does nothing
- But implementation requires new API in TLS layer
Prefetching methods

Option 2: HTTP GET request
e.g., to http://www.domain.com/cert

- Much less load than full TLS handshake, but still impacts the server
Prefetching methods

What if we want no additional load on server?
Prefetching methods

What if we want no additional load on server?

Option 3: Retrieve from CDN

- HTTP GET request, avoid hitting web server
Prefetching methods

What if we want no additional load on server?
Option 4: Retrieve from DNS

- DNS TXT record can store certificate
- No impact on web server
Prevalidation

- After prefetching cert, prevalidate it
- Normal OCSP lookup
Prototype

- Prefetching and prevalidating in Chromium
- Piggyback on DNS prefetching architecture
- DNS and HTTP GET prefetching
Analysis

- How much does prefetching and prevalidating affect handshake latency?
Handshake latency

- Normal TLS handshake: **122 ms**
  - Remove round trips by prefetching cert and using Snap Start
- Snap Start, unvalidated cert: **83 ms**
  - Remove OCSP validation by prevalidating cert
- Snap Start, prevalidated cert: **30 ms**

Server: Ubuntu 10.04, 256MB, Apache 2.2.17, Client: Ubuntu 10.04, 1GB RAM

HTTP GET request: 16 ms
Conclusions

- OCSP latency matters, especially when handshakes have fewer RTTs
- Need prefetched certificate to enable Snap Start and for OCSP prevalidation
- 4 proposed strategies for prefetching certs
- Reduce TLS handshake by two RTTs and OCSP response time (factor of 4 in our experiments)