Web security

HTTPS and the Lock Icon

Goals for this lecture

Brief overview of HTTPS:

- How the SSL/TLS protocol works (very briefly)
- How to use HTTPS

Integrating HTTPS into the browser

- Lots of user interface problems to watch for

Threat Model: Network Attacker

Network Attacker:

- Controls network infrastructure: Routers, DNS
- Eavesdrops, injects, blocks, and modifies packets

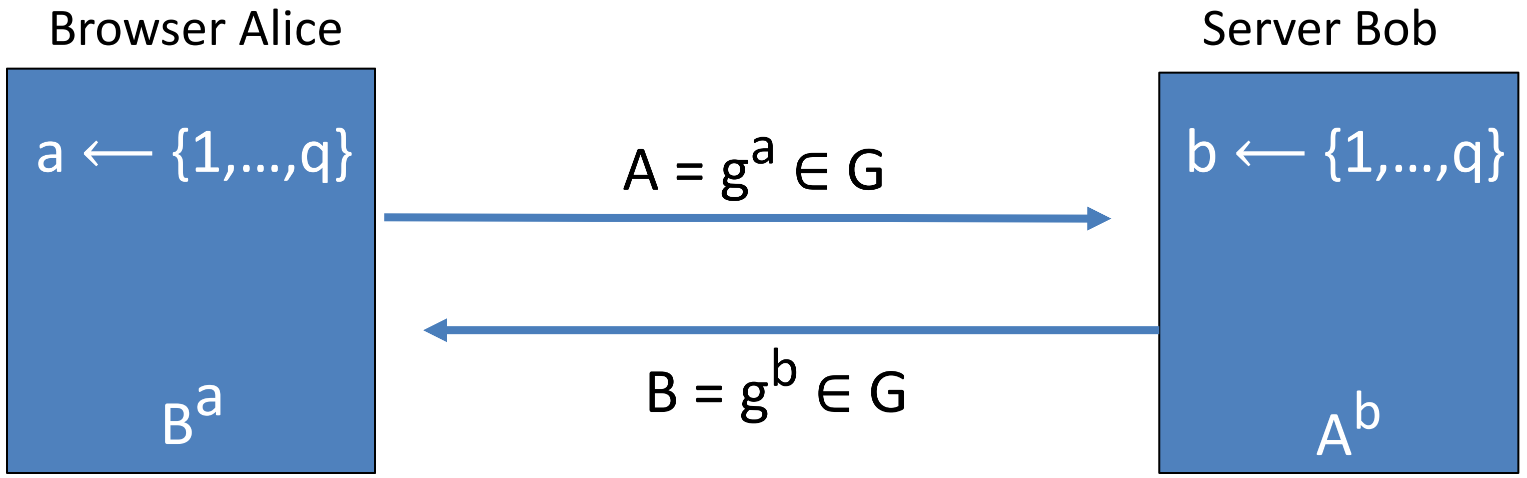
Examples:

- Wireless network at Internet Café
- Internet access at hotels (untrusted ISP)

TLS overview: DH key exchange

(1) Anonymous key exchange secure against eavesdropping:

The Diffie-Hellman protocol in a group G with generator $g \in G$

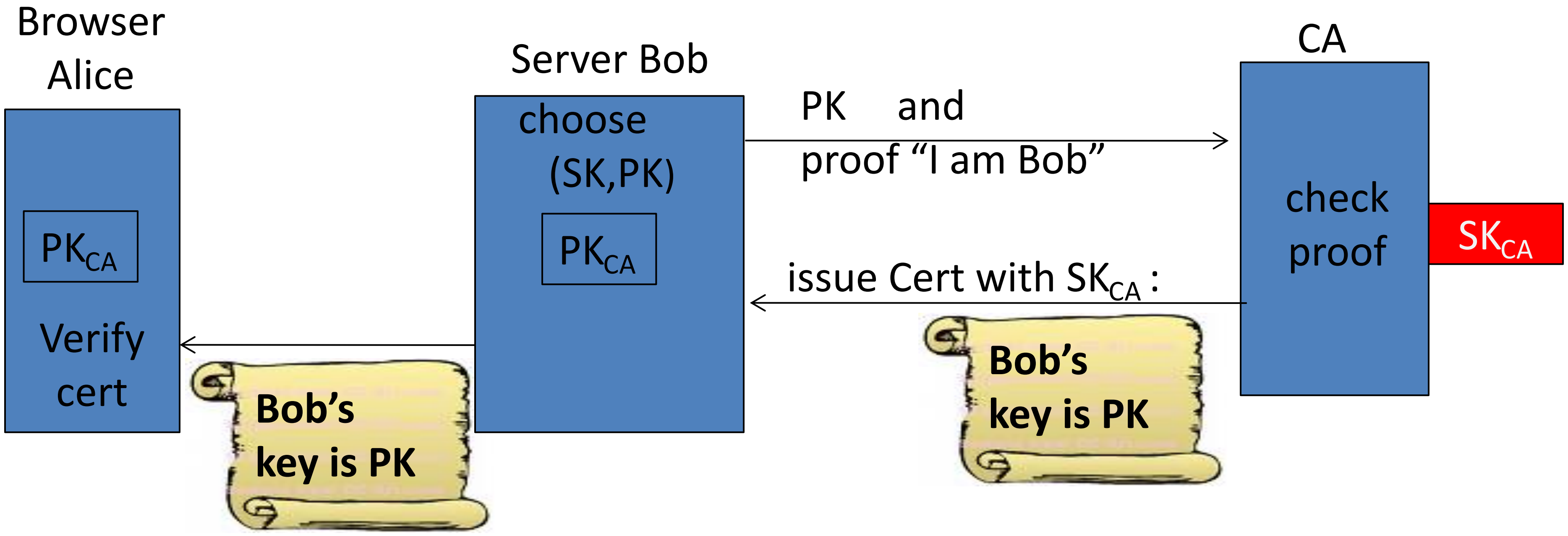


$$\text{DHkey} = g^{ab} \quad = \quad (g^a)^b = A^b \quad = \quad (g^b)^a = B^a$$

Dan Boneh

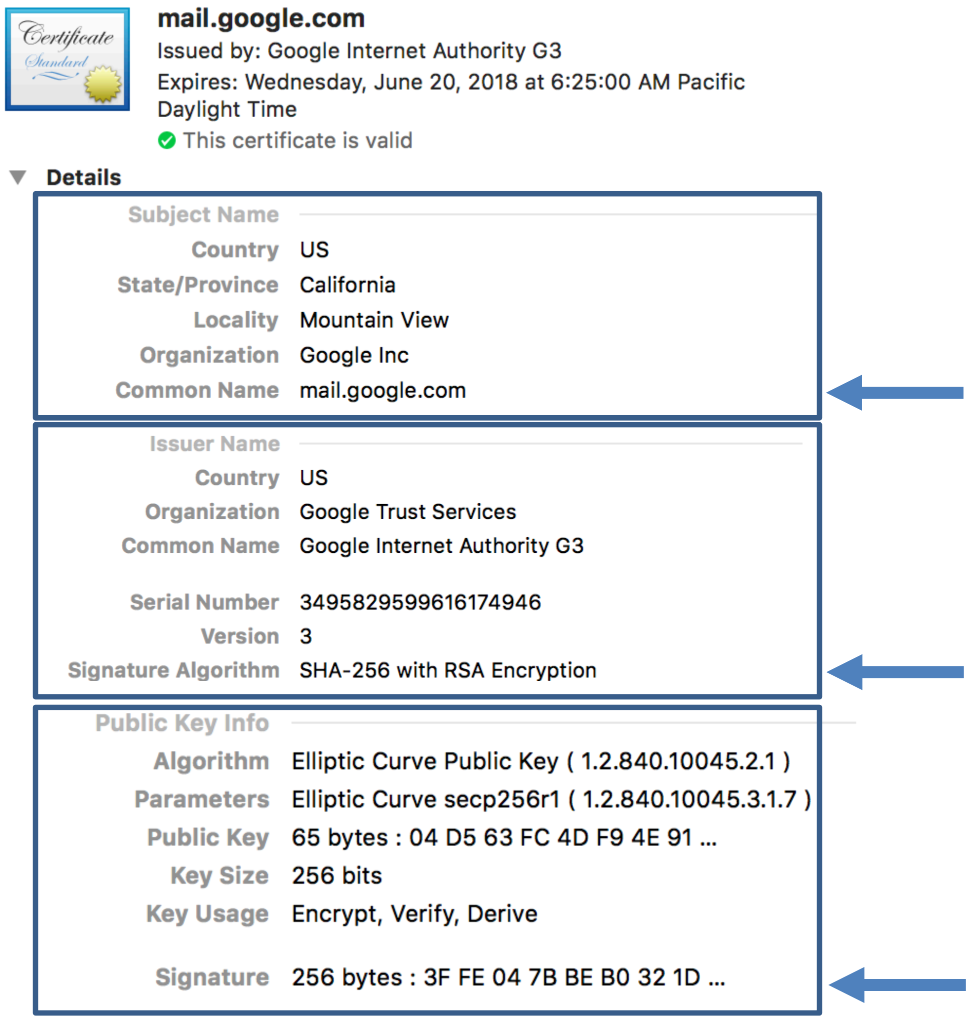
(2) Certificates

How does Alice (browser) obtain PK_{Bob} ?



Bob uses Cert for an extended period (e.g. one year)

Sample certificate:



mail.google.com
Issued by: Google Internet Authority G3
Expires: Wednesday, June 20, 2018 at 6:25:00 AM Pacific Daylight Time
✓ This certificate is valid

▼ **Details**

Subject Name	
Country	US
State/Province	California
Locality	Mountain View
Organization	Google Inc
Common Name	mail.google.com
Issuer Name	
Country	US
Organization	Google Trust Services
Common Name	Google Internet Authority G3
Serial Number	3495829599616174946
Version	3
Signature Algorithm	SHA-256 with RSA Encryption
Public Key Info	
Algorithm	Elliptic Curve Public Key (1.2.840.10045.2.1)
Parameters	Elliptic Curve secp256r1 (1.2.840.10045.3.1.7)
Public Key	65 bytes : 04 D5 63 FC 4D F9 4E 91 ...
Key Size	256 bits
Key Usage	Encrypt, Verify, Derive
Signature	256 bytes : 3F FE 04 7B BE B0 32 1D ...

Certificates on the web

Subject's CommonName can be:

- An explicit name, e.g. cs.stanford.edu , or
- A wildcard cert, e.g. *.stanford.edu or cs*.stanford.edu

matching rules:

"*" must occur in leftmost component, does not match "."

example: *.a.com matches x.a.com but not y.x.a.com

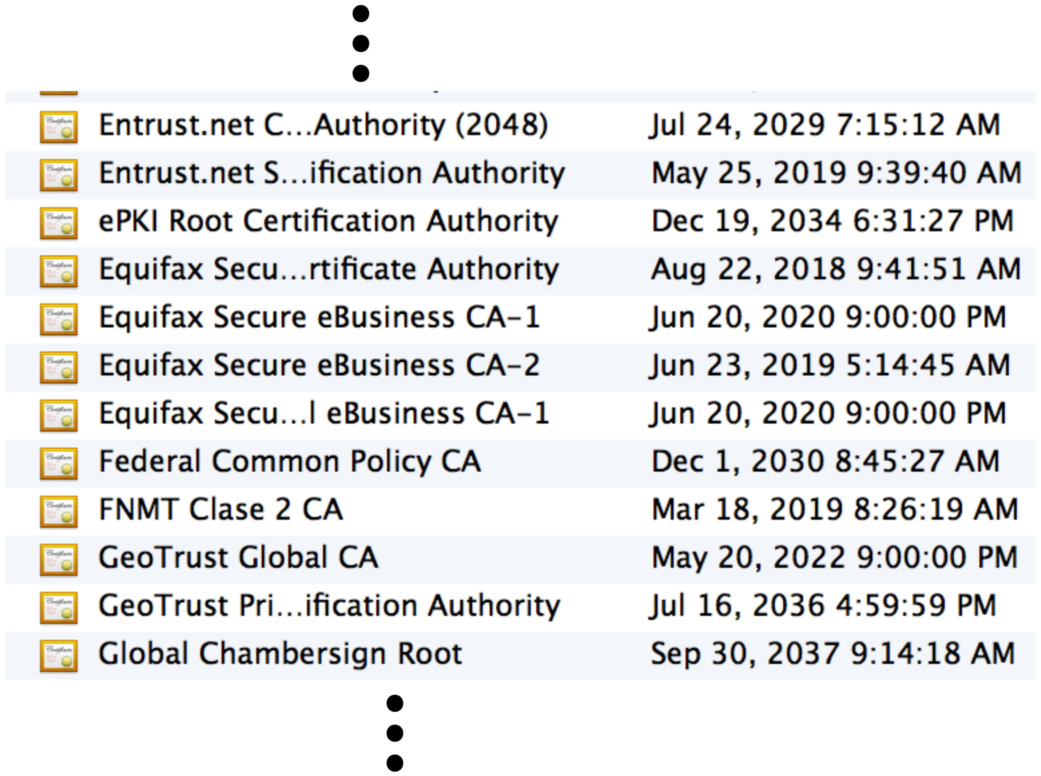
(as in RFC 2818: "HTTPS over TLS")

Certificate Authorities

Browsers accept certificates from a large number of CAs

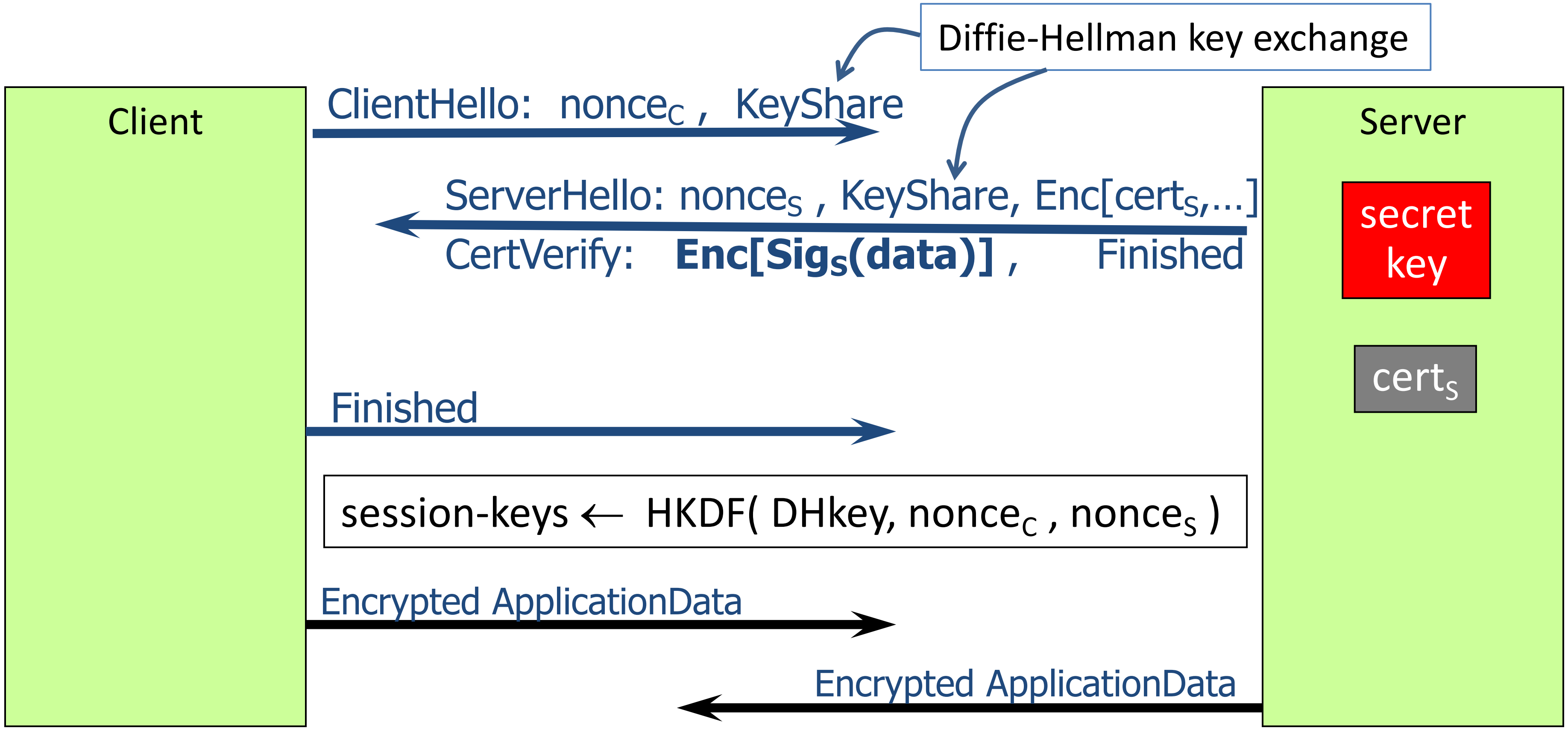
Top level CAs ≈ 60

Intermediate CAs ≈ 1200



Entrust.net C...Authority (2048)	Jul 24, 2029 7:15:12 AM
Entrust.net S...ification Authority	May 25, 2019 9:39:40 AM
ePKI Root Certification Authority	Dec 19, 2034 6:31:27 PM
Equifax Secu...rtificate Authority	Aug 22, 2018 9:41:51 AM
Equifax Secure eBusiness CA-1	Jun 20, 2020 9:00:00 PM
Equifax Secure eBusiness CA-2	Jun 23, 2019 5:14:45 AM
Equifax Secu...l eBusiness CA-1	Jun 20, 2020 9:00:00 PM
Federal Common Policy CA	Dec 1, 2030 8:45:27 AM
FNMT Clase 2 CA	Mar 18, 2019 8:26:19 AM
GeoTrust Global CA	May 20, 2022 9:00:00 PM
GeoTrust Pri...ification Authority	Jul 16, 2036 4:59:59 PM
Global Chambersign Root	Sep 30, 2037 9:14:18 AM

TLS 1.3 session setup (simplified)

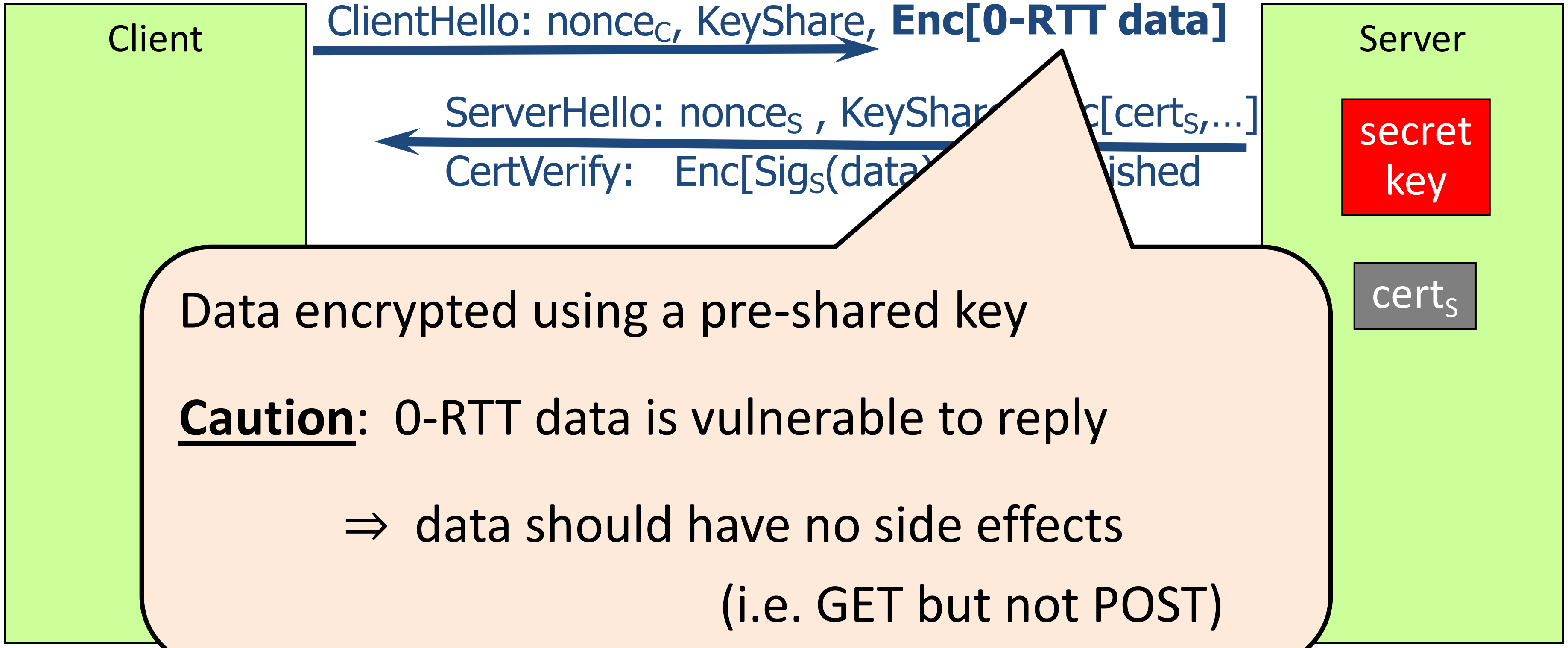


Diffie-Hellman key exchange
Client
Server
ClientHello: nonce$_C$, KeyShare
ServerHello: nonce$_S$, KeyShare, Enc[certs$_S$,…]
CertVerify: **Enc[Sig$_S$(data)]** , Finished
secret key
certs$_S$
Finished
session-keys ← HKDF(DHkey, nonce$_C$, nonce$_S$)
Encrypted ApplicationData
Encrypted ApplicationData

Most common: server authentication only

Dan Boneh

TLS 1.3 session setup: optimization (and caution)



Client
ClientHello: nonce$_C$, KeyShare, **Enc[0-RTT data]**
ServerHello: nonce$_S$, KeyShar c[certs$_S$,…]
CertVerify: Enc[Sig$_S$(data) ished
Server
secret key
certs$_S$

Data encrypted using a pre-shared key

Caution: 0-RTT data is vulnerable to reply

$\Rightarrow$ data should have no side effects

(i.e. GET but not POST)

Most common: server authentication only

Integrating TLS with HTTP: HTTPS

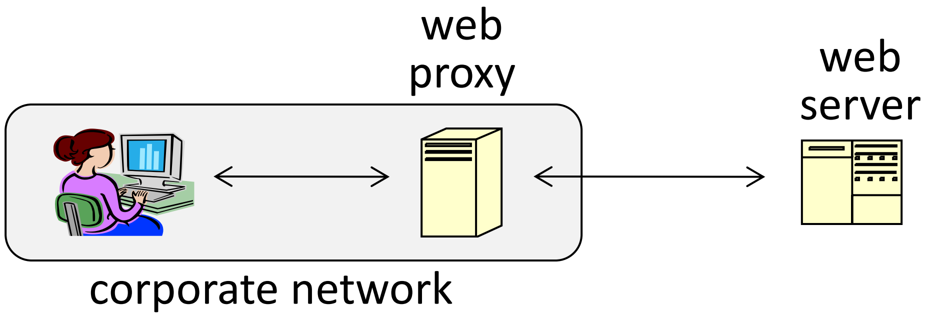
Two complications

<u>Web proxies</u>

solution: browser sends

CONNECT domain-name

before client-hello



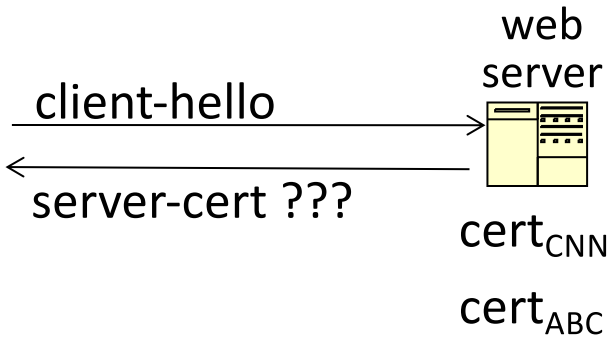
<u>Virtual hosting:</u>

two sites hosted at same IP address.

solution in TLS 1.1: SNI (June 2003)

client_hello_extension: server_name=cnn.com

implemented since FF2 and IE7 (vista)

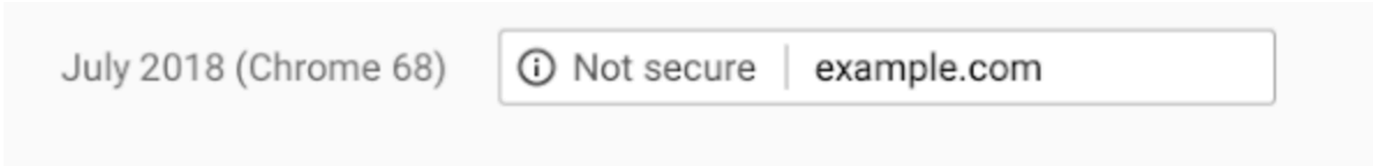


HTTPS for all web traffic?

<u>Old excuses</u>:

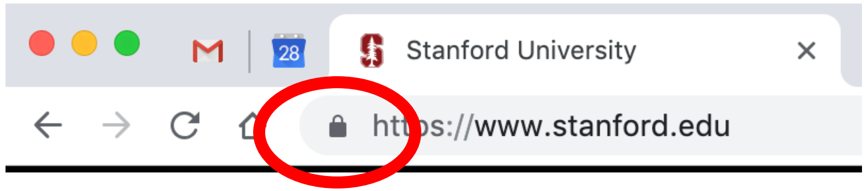
- Crypto slows down web servers (not true anymore)
- Some ad-networks still do not support HTTPS
  - reduced revenue for publishers
- Incompatible with virtual hosting (older browsers)

<u>Since July 2018</u>: Chrome marks HTTP sites as insecure



HTTPS in the Browser

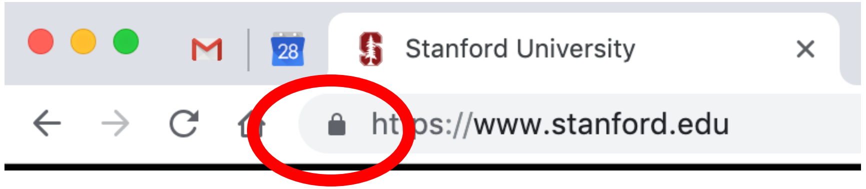
The lock icon: TLS indicator

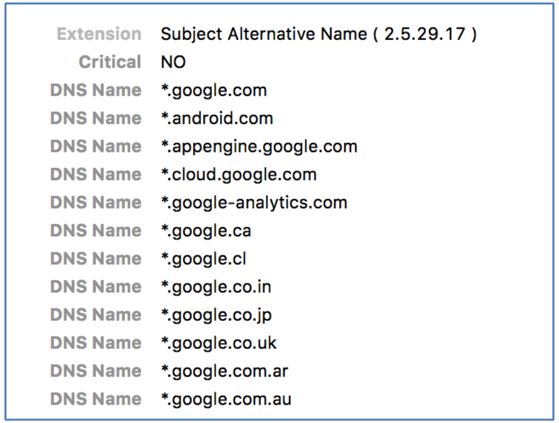


Intended goal:

- Provide user with identity of page origin
- Indicate to user that page contents were not viewed or modified by a **network attacker**

When is the (basic) lock icon displayed





Extension	Subject Alternative Name (2.5.29.17)
Critical	NO
DNS Name	*.google.com
DNS Name	*.android.com
DNS Name	*.appengine.google.com
DNS Name	*.cloud.google.com
DNS Name	*.google-analytics.com
DNS Name	*.google.ca
DNS Name	*.google.cl
DNS Name	*.google.co.in
DNS Name	*.google.co.jp
DNS Name	*.google.co.uk
DNS Name	*.google.com.ar
DNS Name	*.google.com.au

All elements on the page fetched using HTTPS

For all elements:

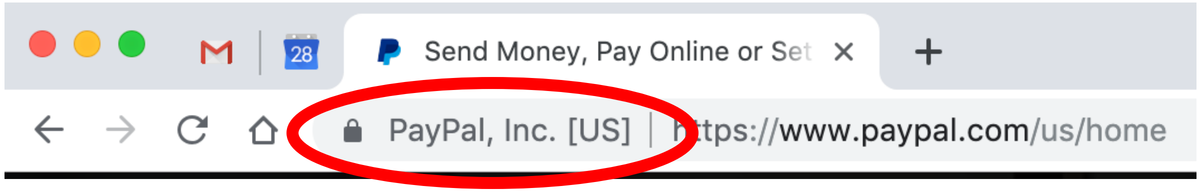
- HTTPS cert issued by a CA trusted by browser
- HTTPS cert is valid (e.g. not expired)
- Domain in URL matches:
  CommonName or **SubjectAlternativeName** in cert

The lock UI: Extended Validation Certs

Harder to obtain than regular certs

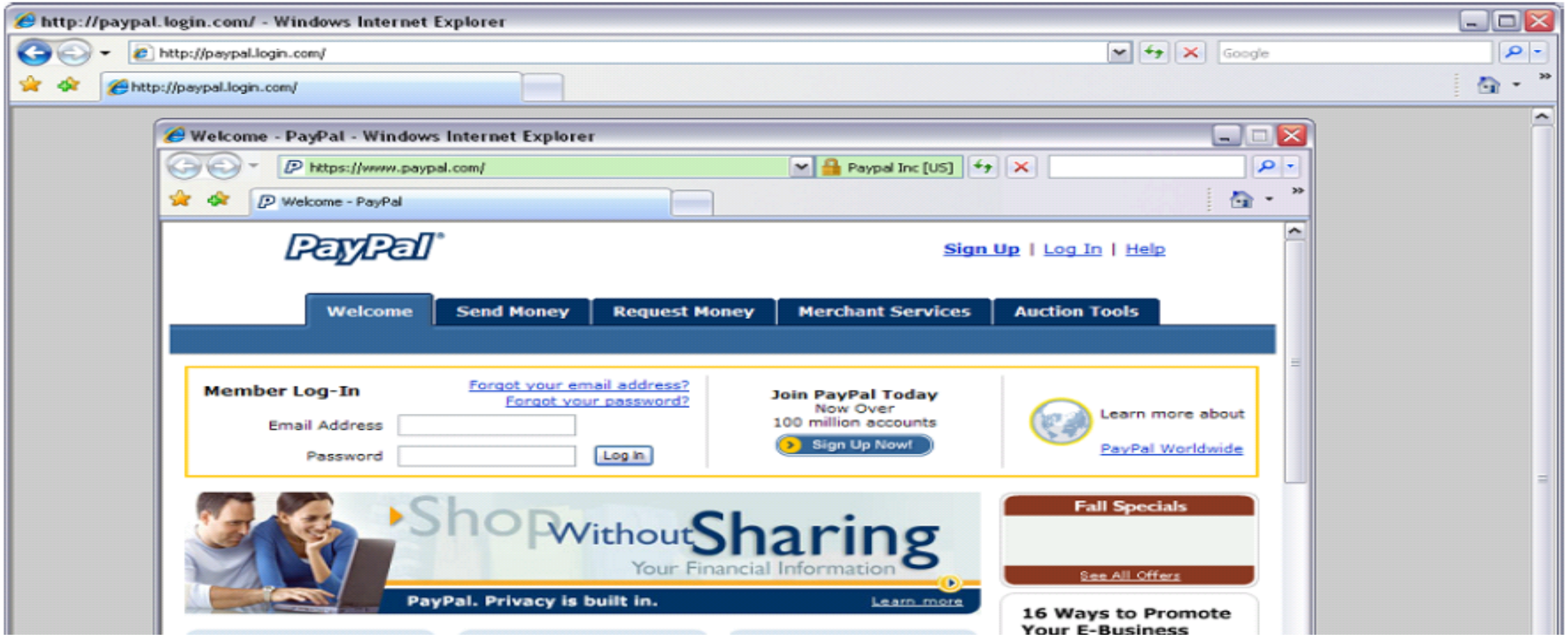
- requires human at CA to approve cert request
- no wildcard certs (e.g. *.stanford.edu)

Helps block "semantic attacks": www.bankofthevvest.com



note: HTTPS-EV and HTTPS are in the same origin

A general UI attack: picture-in-picture

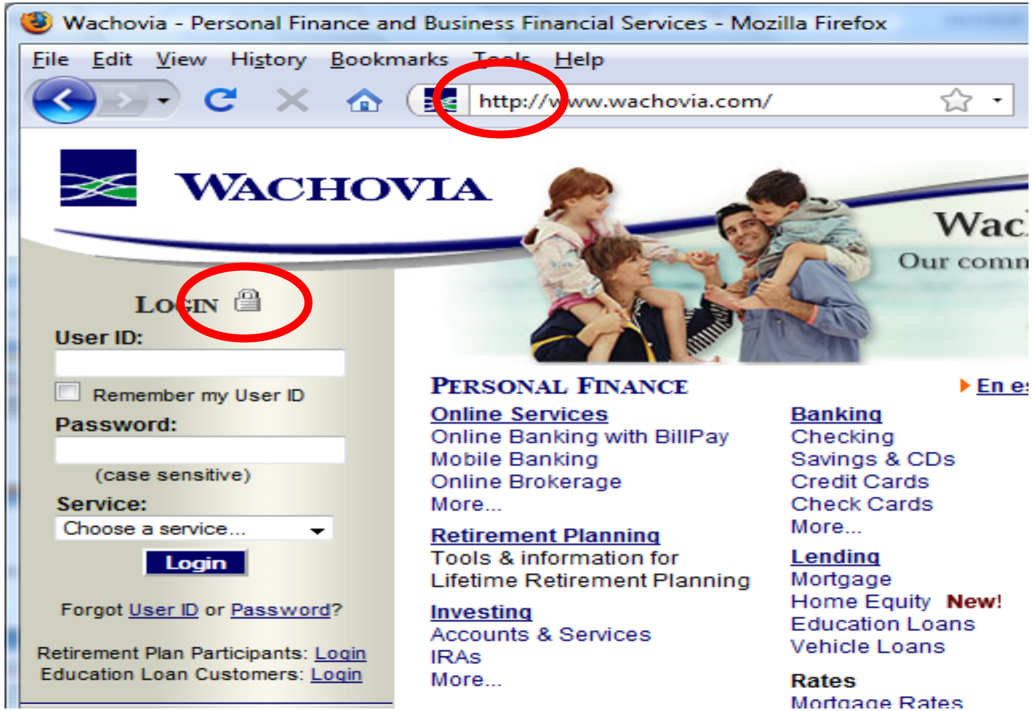


Trained users are more likely to fall victim to this [JSTB'07]

HTTPS and login pages: incorrect usage

Users often land on login page over HTTP:

- Type HTTP URL into address bar
- Google links to HTTP page



Wachovia - Personal Finance and Business Financial Services - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.wachovia.com/

WACHOVIA

Wac

Our comm

LOGIN

User ID:

Remember my User ID

Password:

(case sensitive)

Service:

Choose a service...

Login

Forgot User ID or Password?

Retirement Plan Participants: Login

Education Loan Customers: Login

PERSONAL FINANCE

En e

Online Services

Online Banking with BillPay

Mobile Banking

Online Brokerage

More...

Retirement Planning

Tools & information for Lifetime Retirement Planning

Investing

Accounts & Services

IRAs

More...

Banking

Checking

Savings & CDs

Credit Cards

Check Cards

More...

Lending

Mortgage

Home Equity New!

Education Loans

Vehicle Loans

Rates

Mortgage Rates

(old site)

View source:

```
<form method="post"
      action="https://onlineservices.wachovia.com/..."
```

HTTPS and login pages: guidelines

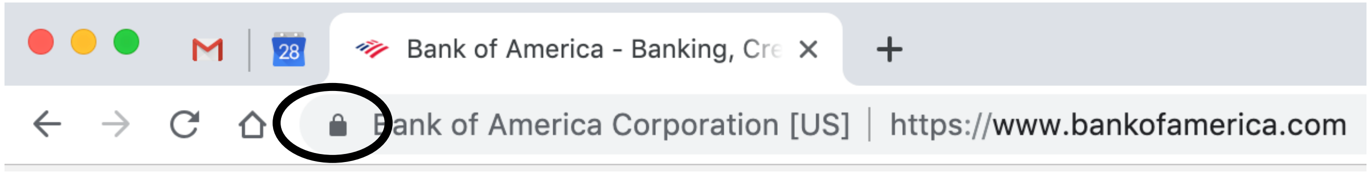
General guideline:

Response to http://login.site.com

should be Location: https://login.site.com

(redirect)

Should be the response to every HTTP request …


Bank of America - Banking, Cre
Bank of America Corporation [US]
https://www.bankofamerica.com

Problems with HTTPS and the Lock Icon

Problems with HTTPS and the Lock Icon

1. Upgrade from HTTP to HTTPS

2. Forged certs

3. Mixed content: HTTP and HTTPS on the same page

4. Does HTTPS hide web traffic?

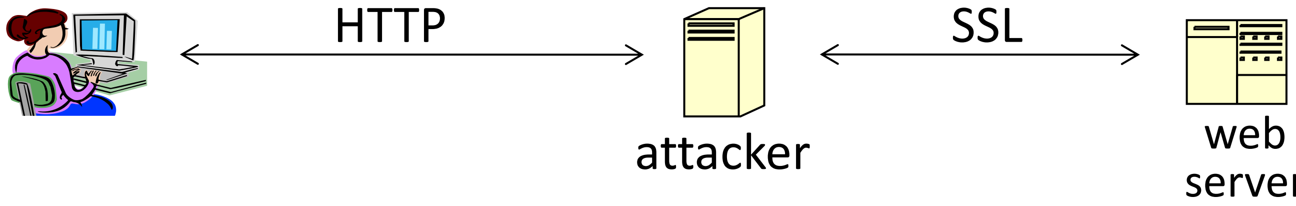
    – Problems: traffic analysis, compression attacks

1. HTTP ⇒ HTTPS upgrade

Common use pattern:

- browse site over HTTP; move to HTTPS for checkout
- connect to bank over HTTP; move to HTTPS for login

SSL_strip attack: prevent the upgrade [Moxie'08]



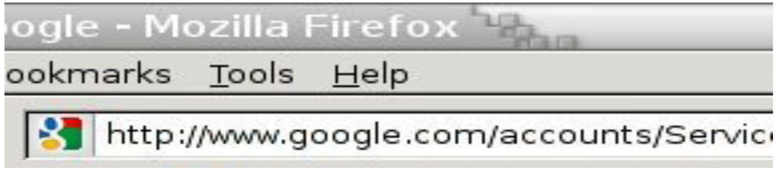
<a href=https://…> ⟶ <a href=http://…>

Location: https://… ⟶ Location: http://… (redirect)

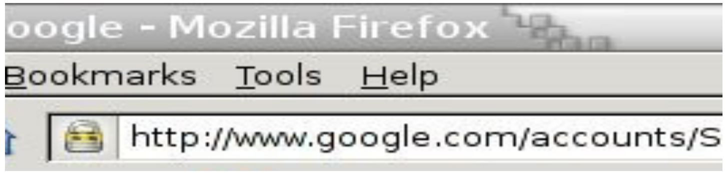
<form action=https://… > ⟶ <form action=http://…>

Tricks and Details

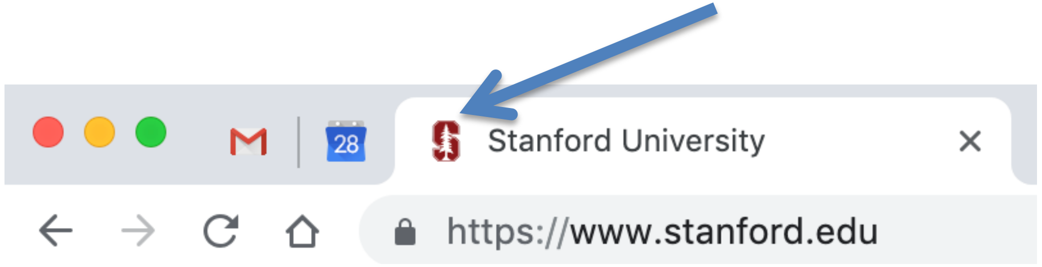
Tricks: drop-in a clever fav icon (older browsers)



→

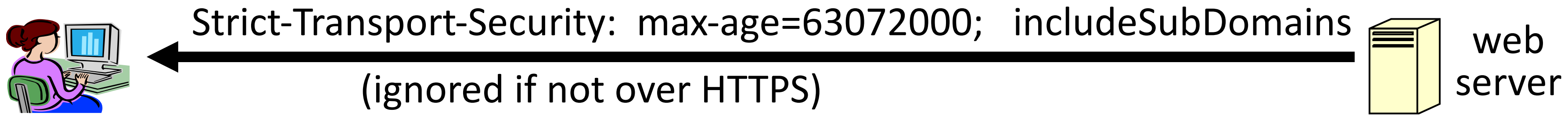


⇒ fav icon no longer presented in address bar



Number of users who detected HTTP downgrade: 0

Defense: Strict Transport Security (HSTS)


Strict-Transport-Security: max-age=63072000; includeSubDomains
(ignored if not over HTTPS)
web server

Header tells browser to always connect over HTTPS

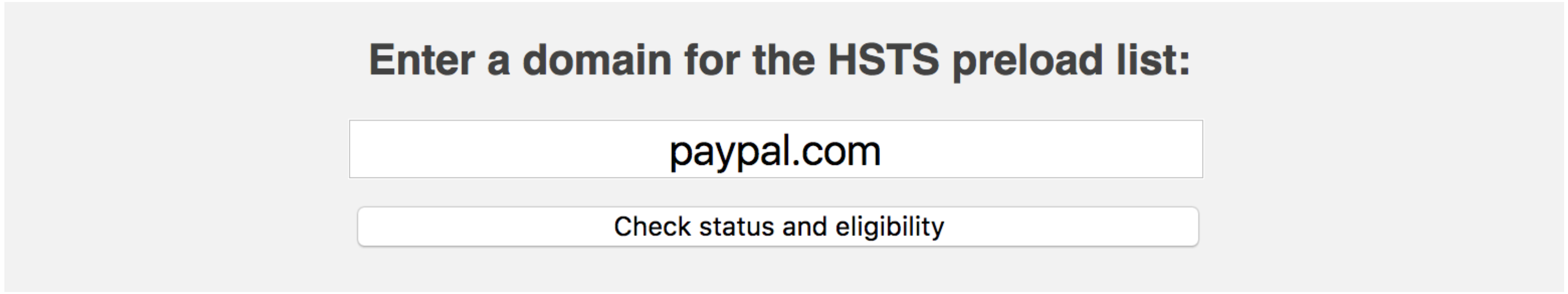
Subsequent visits must be over HTTPS (self signed certs result in an error)

- Browser refuses to connect over HTTP or if site presents an invalid cert
- Requires that <u>entire</u> site be served over <u>valid</u> HTTPS

HSTS flag deleted when user "clears private data" : security vs. privacy

Preloaded HSTS list

https://hstspreload.org/


Enter a domain for the HSTS preload list:

paypal.com

Strict-Transport-Security: max-age=63072000; includeSubDomains; **preload**

Preload list hard-coded in Chrome source code. Examples:

Google, Paypal, Twitter, Simple, Linode, Stripe, Lastpass, …

CSP: upgrade-insecure-requests

The problem: many pages use **<img src="http://site.com/img">**

- Makes it difficult to migrate a section of a site to HTTPS

Solution: gradual transition using CSP

Content-Security-Policy: upgrade-insecure-requests

```
<img src="http://site.com/img">
<img src="http://othersite.com/img">
<a href="http://site.com/img">
<a href="http://othersite.com/img">
```

```
<img src="https://site.com/img">
<img src="https://othersite.com/img">
<a href="https://site.com/img">
<a href="http://othersite.com/img">
```

2. Certificates: wrong issuance

2011: **Comodo** and **DigiNotar** CAs hacked, issue certs for Gmail, Yahoo! Mail, …

2013: **TurkTrust** issued cert. for gmail.com (discovered by pinning)

2014: **Indian NIC** (intermediate CA trusted by the root CA **IndiaCCA**) issue certs for Google and Yahoo! domains

Result: (1) India CCA revoked NIC's intermediate certificate

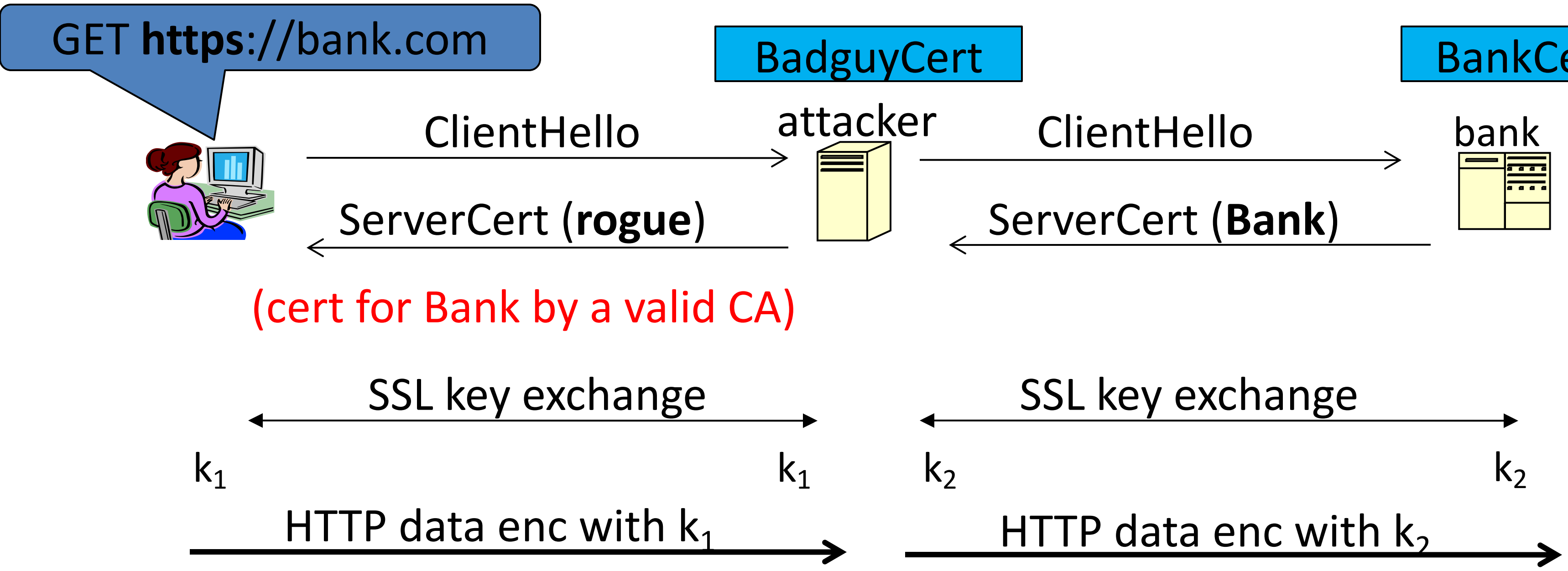
(2) Chrome restricts India CCA root to only seven Indian domains

2016: **WoSign** (Chinese CA) issues cert for GitHub domain (among other issues)

Result: WoSign certs no longer trusted by Chrome and Firefox

⇒ enables eavesdropping w/o a warning on user's session

Man in the middle attack using rogue cert



Attacker proxies data between user and bank.

Sees all traffic and can modify data at will.

What to do? (many good ideas)

1. **Public-key pinning (static pins)**
   - Hardcode list of allowed CAs for certain sites (Gmail, facebook, …)
   - Browser rejects certs issued by a CA not on list
   - Now deprecated (because often incorrectly used in practice)

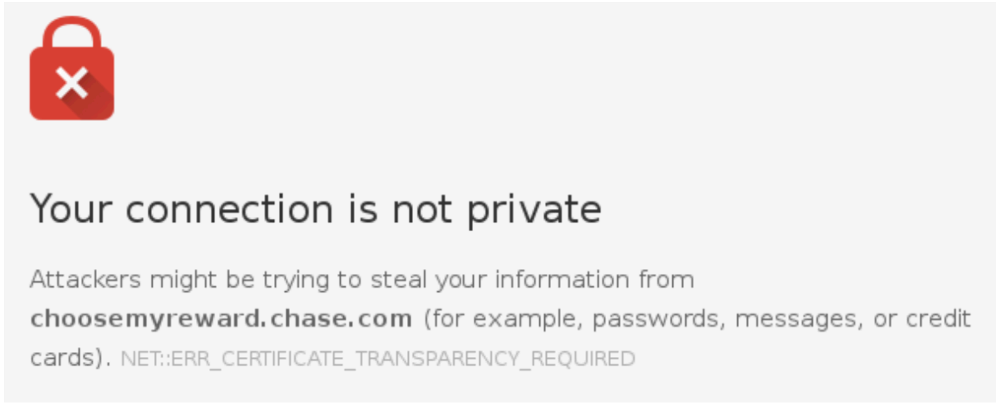
1. **Certificate Transparency (CT)**: [LL'12]
   - idea: CA's must advertise a log of <u>all</u> certs. they issued
   - Browser will only use a cert if it is published on (two) log servers
     - Server attaches a signed statement from log (SCT) to certificate
   - Companies can scan logs to look for invalid issuance

CT requirements

April 30, 2018: CT required by chrome

- Required for all certificates with a path to a trusted root CA

  (not required for an installed root CA)
- Otherwise: HTTPS errors



Your connection is not private

Attackers might be trying to steal your information from **choosemyreward.chase.com** (for example, passwords, messages, or credit cards). NET::ERR_CERTIFICATE_TRANSPARENCY_REQUIRED

Cert for crypto.stanford.edu published on five logs:

cloudflare_nimbus2018

google_argon2018, google_aviator

google_pilot, google_rocketeer

3. Mixed Content: HTTP and HTTPS

Page loads over HTTPS, but contains content over HTTP

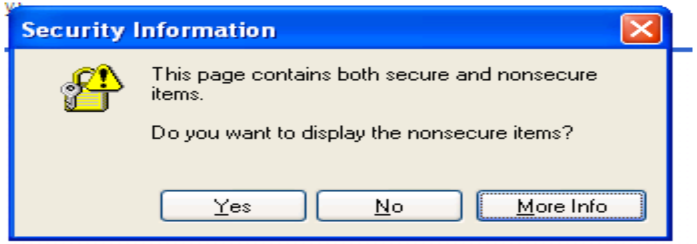
(e.g. <script src="$\underbrace{\text{http}}$://.../script.js>)

never write this

⇒ Active network attacker can hijack session

by modifying script en-route to browser

IE7:

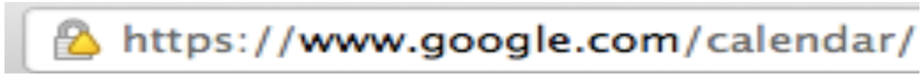


Security Information

This page contains both secure and nonsecure items.

Do you want to display the nonsecure items?

Old Chrome:

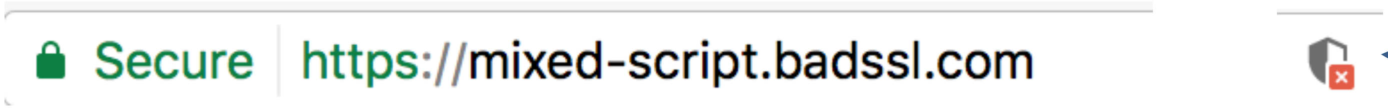


https://www.google.com/calendar/

Mostly ignored by users …

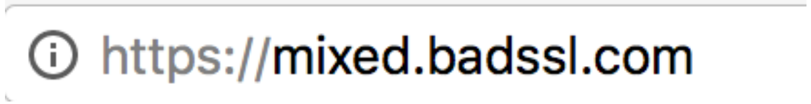
https://badssl.com (Chrome 73, 2019)

Mixed script: `<script src="http://mixed-script.badssl.com/nonsecure.js"></script>`


Secure https://mixed-script.badssl.com

(script is blocked, click to load)

Mixed form: `<form action="http://http.badssl.com/resources/submit.html">`


https://mixed.badssl.com

Form loaded, but no HTTPS indicator

4. Peeking through SSL: traffic analysis

- Network traffic reveals length of HTTPS packets
  - TLS supports up to 256 bytes of padding

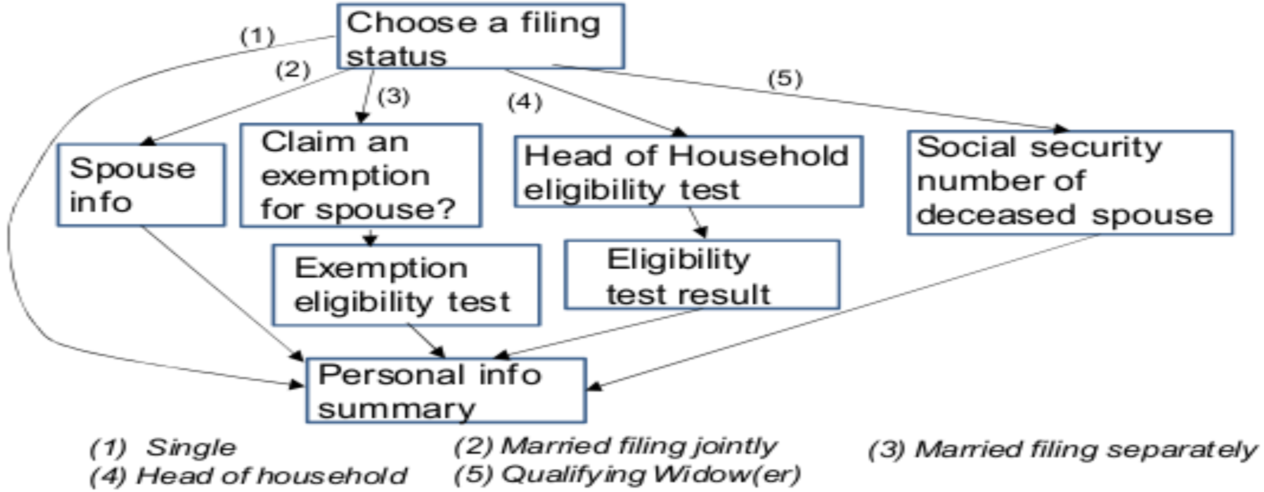
- AJAX-rich pages have lots and lots of interactions with the server

- These interactions expose specific internal state of the page

BAM!

Chen, Wang, Wang, Zhang, 2010

Peeking through SSL: an example [CWWZ'10]


Choose a filing status
(1)
(2)
(3)
(4)
(5)
Spouse info
Claim an exemption for spouse?
Head of Household eligibility test
Social security number of deceased spouse
Exemption eligibility test
Eligibility test result
Personal info summary
(1) Single
(2) Married filing jointly
(3) Married filing separately
(4) Head of household
(5) Qualifying Widow(er)

Vulnerabilities in an online tax application

No easy fix. Can also be used to ID Tor traffic

THE END