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:

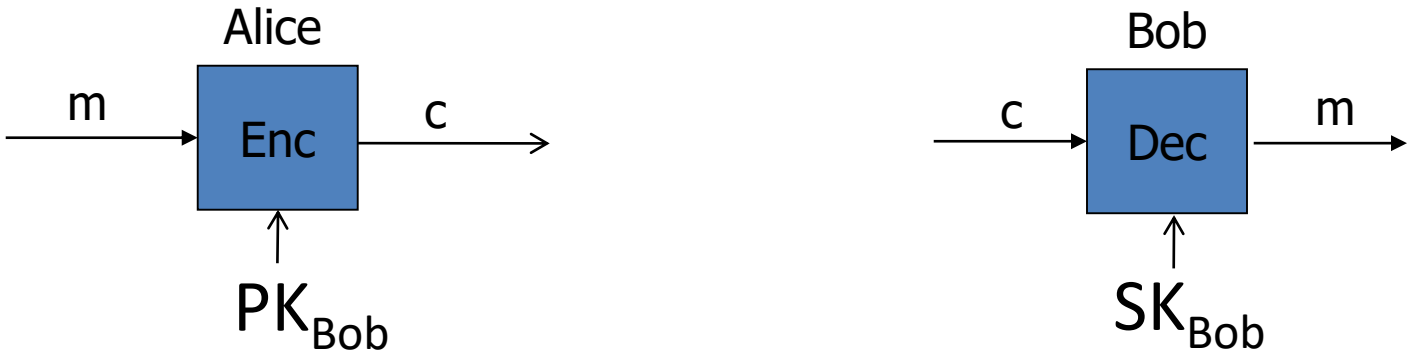
- Controls network infrastructure: Routers, DNS
- Eavesdrops, injects, blocks, and modifies packets

Examples:

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

SSL/TLS overview

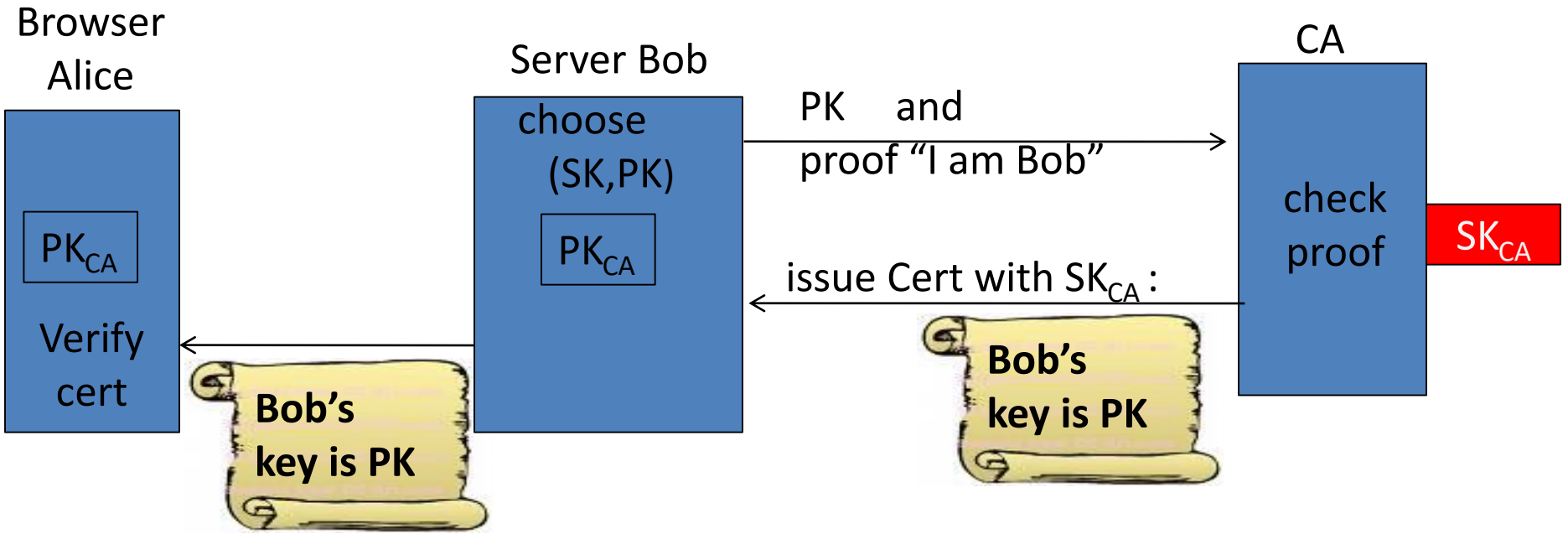
Public-key encryption:



- Bob generates (SK_{Bob}, PK_{Bob})
- Alice: using PK_{Bob} encrypts messages and only Bob can decrypt

Certificates

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



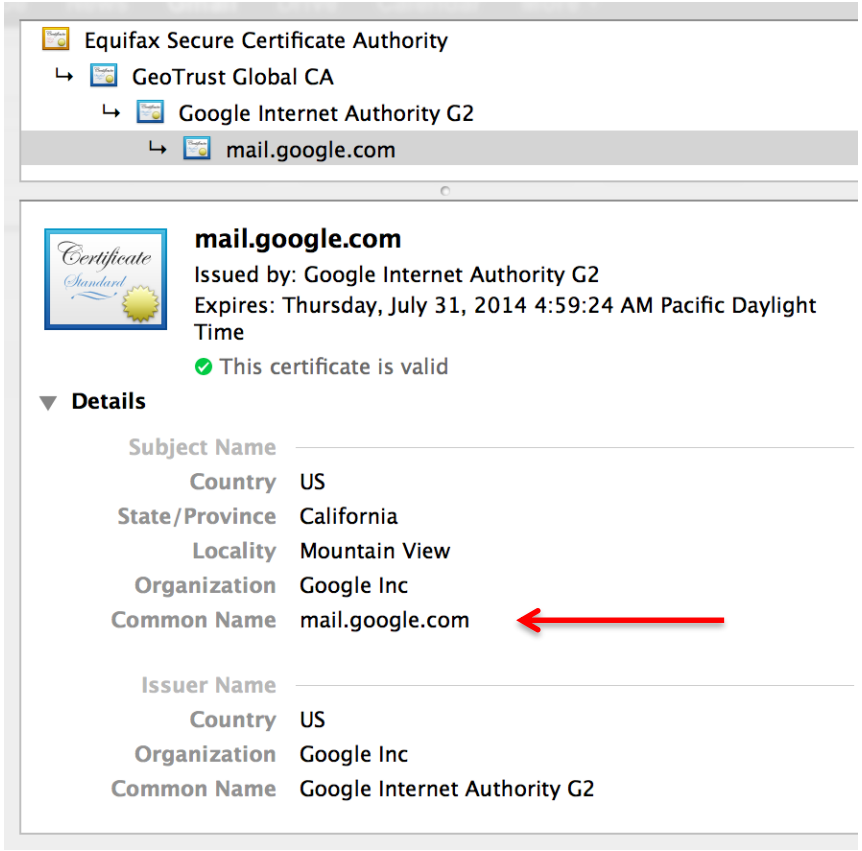
Bob uses Cert for an extended period (e.g. one year)

Dan Boneh

Certificates: example

Important fields:

Serial Number	5814744488373890497
Version	3
Signature Algorithm	SHA-1 with RSA Encryption (1.2.840.113549.1.1.5)
Parameters	none
Not Valid Before	Wednesday, July 31, 2013 4:59:24 AM Pacific Daylight Time
Not Valid After	Thursday, July 31, 2014 4:59:24 AM Pacific Daylight Time
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 71 6C DD E0 0A C9 76 …
Key Size	256 bits
Key Usage	Encrypt, Verify, Derive
Signature	256 bytes : 8A 38 FE D6 F5 E7 F6 59 …



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

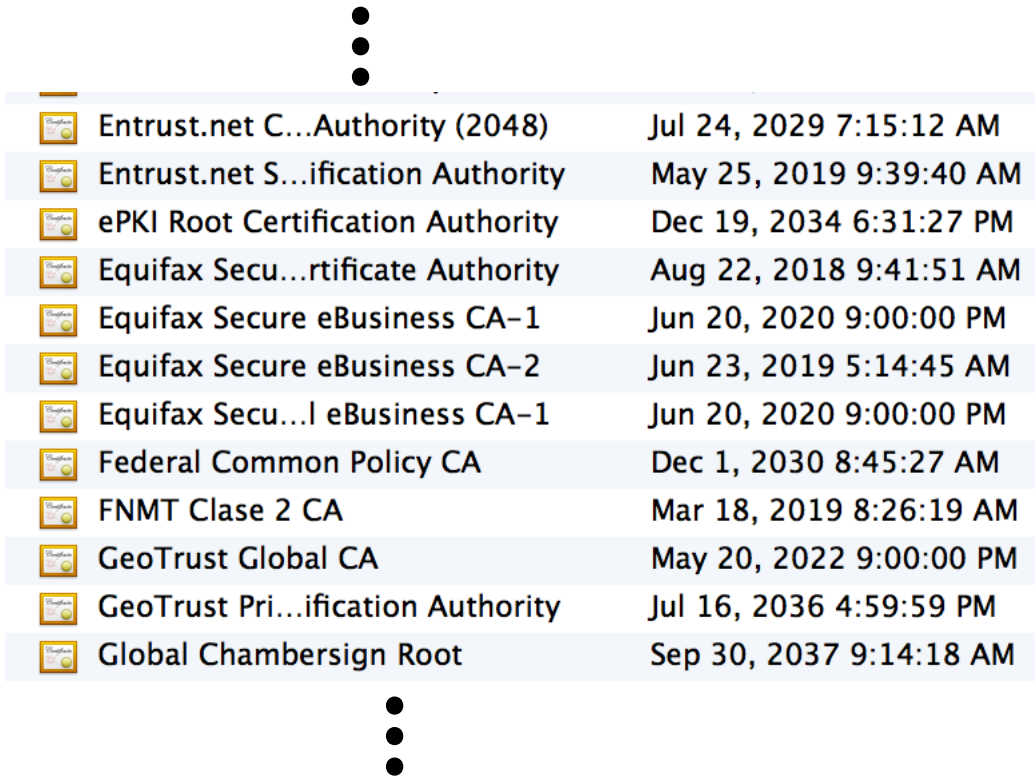
(as in RFC 2818: "HTTPS over TLS")

Certificate Authorities

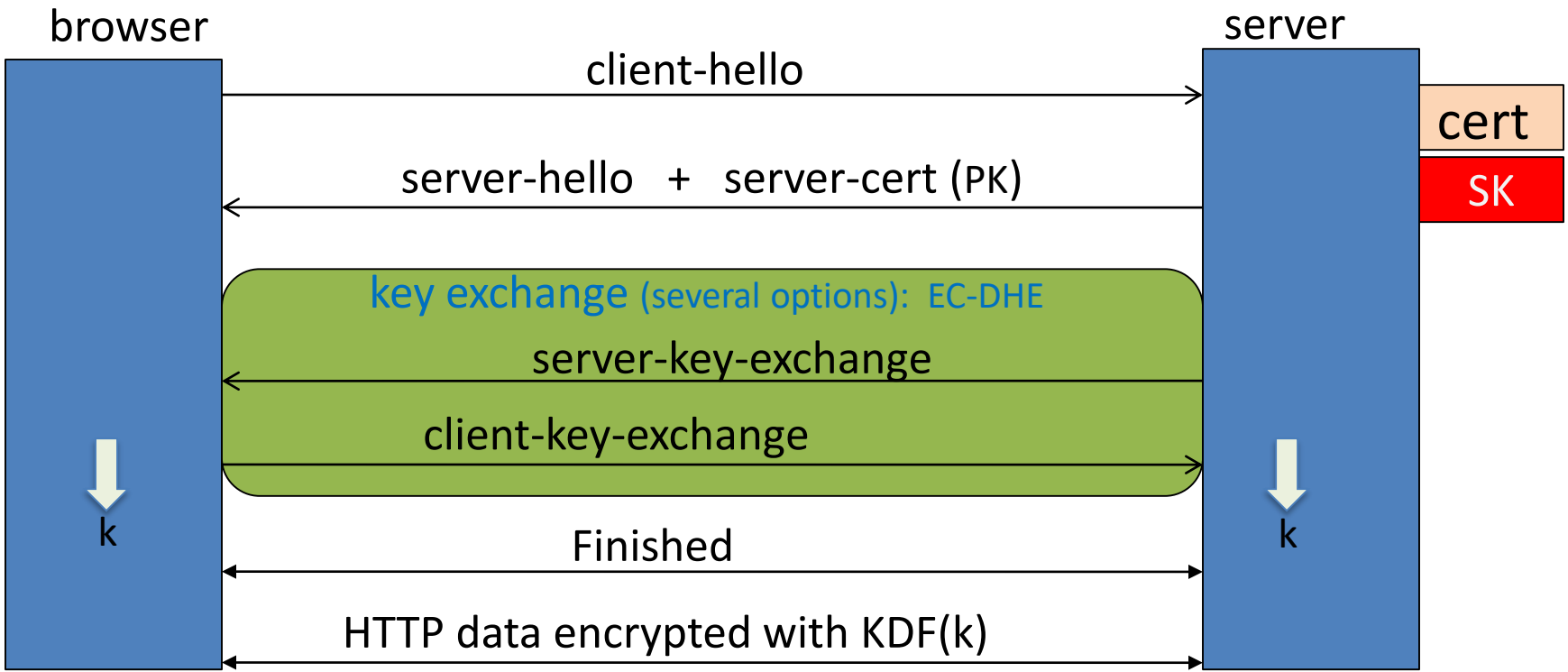
Browsers accept certificates from a large number of CAs

Top level CAs ≈ 60

Intermediate CAs ≈ 1200



Brief overview of SSL/TLS



Most common: server authentication only

Integrating SSL/TLS with HTTP: HTTPS

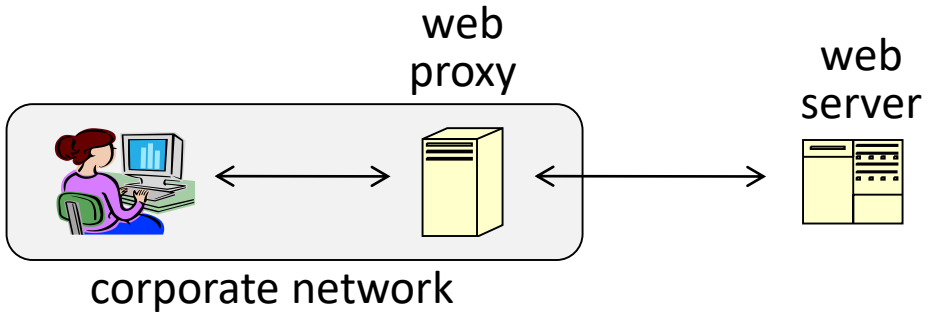
Two complications

Web proxies

solution: browser sends

CONNECT domain-name

before client-hello



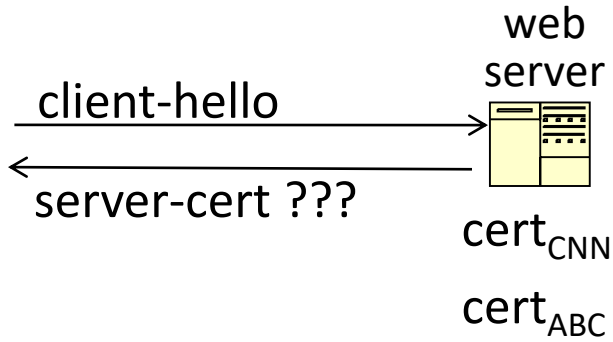
Virtual hosting:

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)



Why is HTTPS not used for all web traffic?

- Crypto slows down web servers (but not by much if done right)

- Some ad-networks still do not support HTTPS
  - Reduced revenue for publishers

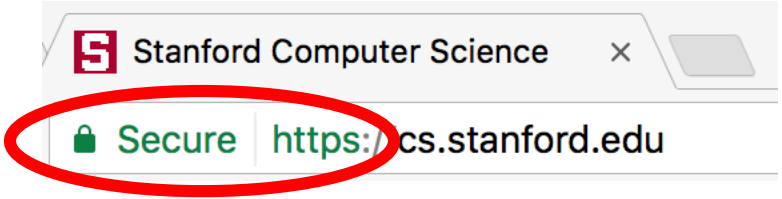
- Incompatible with virtual hosting (older browsers)

  March 2017: IE6 ≈ 1-5% in china (ie6countdown.com)

Aug 2014: Google boosts ranking of sites supporting HTTPS

HTTPS in the Browser

The lock icon: SSL indicator

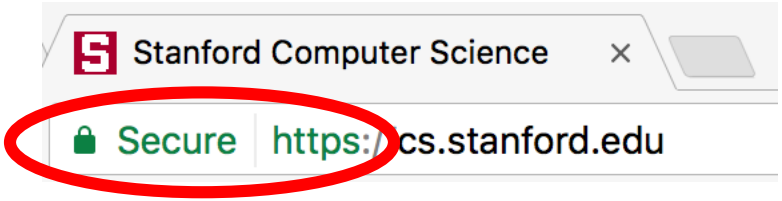


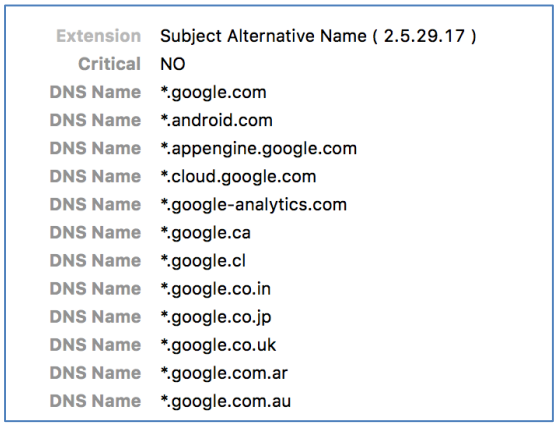
Intended goal:

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

In reality: many problems (next few slides)

When is the (basic) lock icon displayed





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

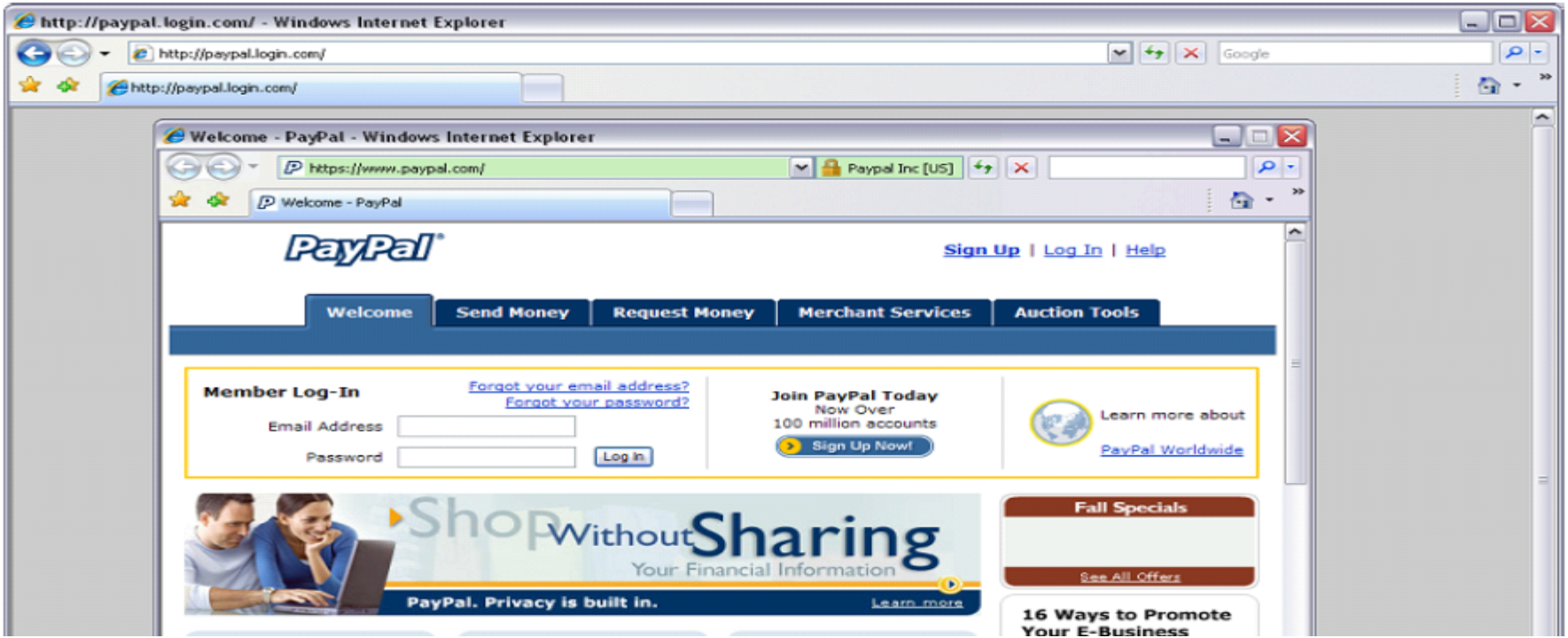
Harder to obtain than regular certs

- 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

(old site)

View source:

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

HTTPS and login pages: guidelines

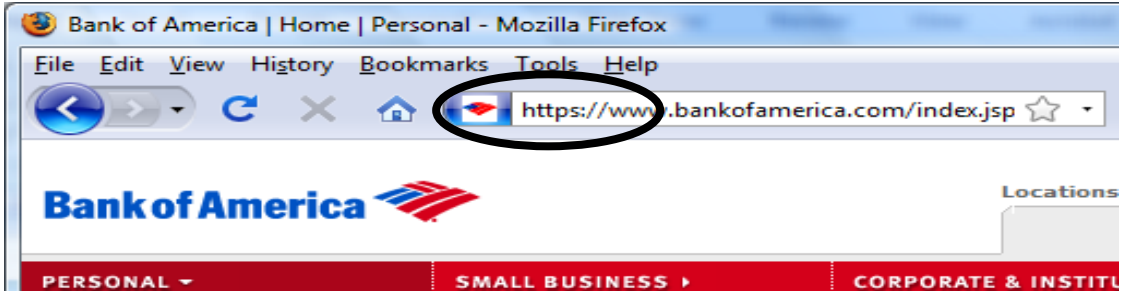
General guideline:

Response to http://login.site.com

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

(redirect)

Should be the response to every HTTP request …



Problems with HTTPS and the Lock Icon

Problems with HTTPS and the Lock Icon

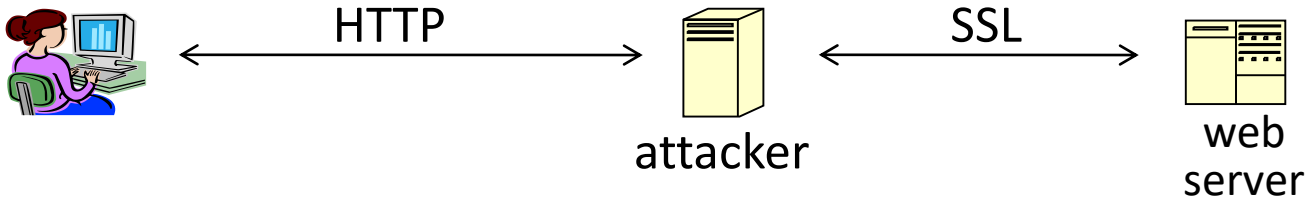
1. Upgrade from HTTP to HTTPS
2. Forged certs
3. Mixed content: HTTP and HTTPS on the same page
4. Does HTTPS hide web traffic?
   - Problems: traffic analysis, compression attacks

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]



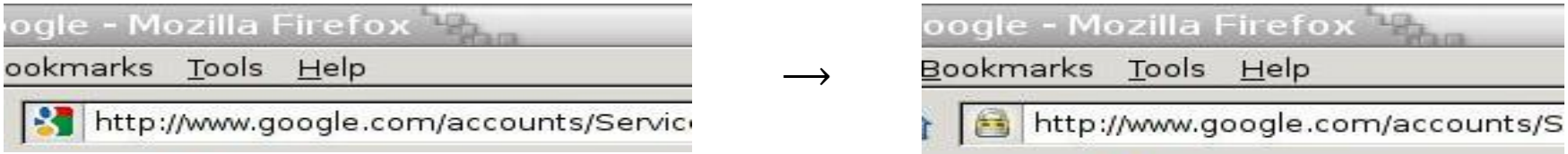
<a href=https://…> ⟶ <a href=http://…>

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

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

Tricks and Details

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



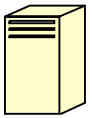
⇒ fav icon no longer presented in address bar

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

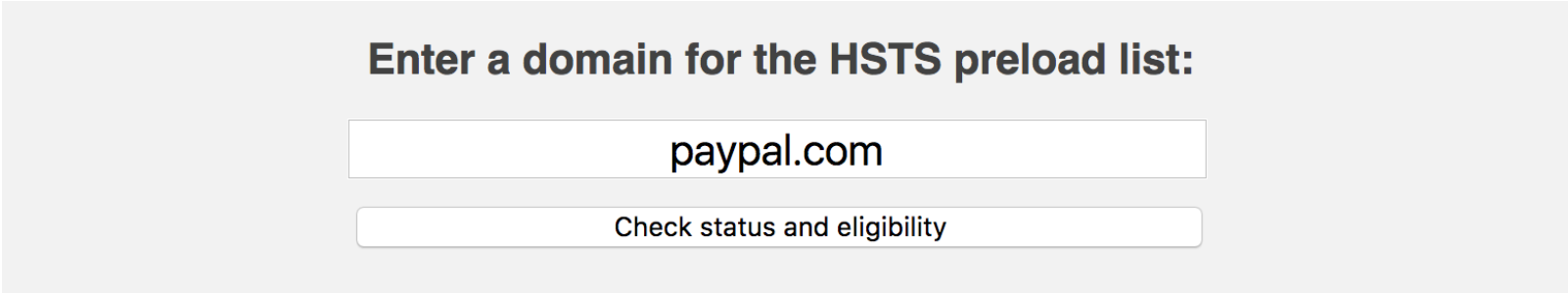
Subsequent visits must be over HTTPS (self signed certs result in an error)

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

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

Preloaded HSTS list

https://hstspreload.org/



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

Always use protocol relative URLs **<img src="//site.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

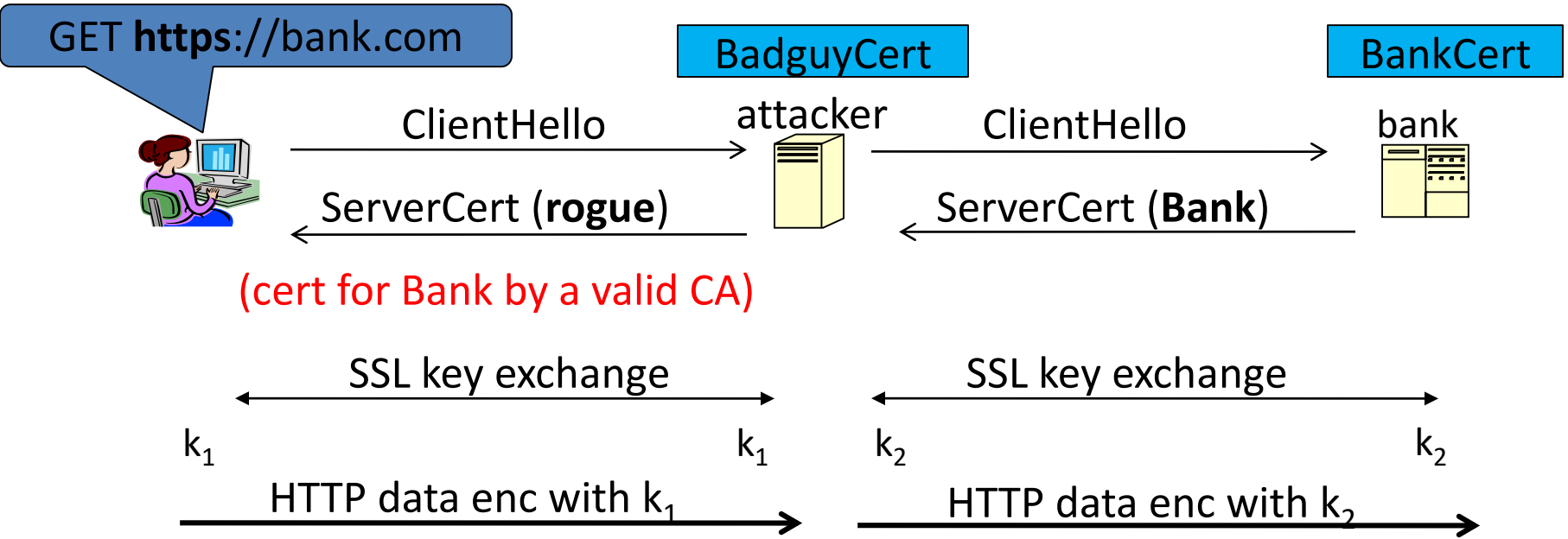
(2) Chrome restricts India CCA root to only seven Indian domains

2015: **MCS** (intermediate CA cert issued by **CNNIC**) issues certs for Google domains

Result: current CNNIC root no longer recognized by Chrome

⇒ 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. Dynamic HTTP public-key pinning (RFC 7469)
   - Let a site declare CAs that can sign its cert (similar to HSTS)
   - on subsequent HTTPS, browser rejects certs issued by other CAs
   - TOFU: Trust on First Use

2. Certificate Transparency: [LL'12]
   - idea: CA's must advertise a log of all certs. they issued
   - Browser will only use a cert if it is published on log server
     - Efficient implementation using Merkle hash trees
   - Companies can scan logs to look for invalid issuance

HPKP example (HTTP header from server)

Public-Key-Pins[-Report-only]: **max-age**=2592000;
pin-sha256="E9CZ9INDbd+2eRQozYqqbQ2yXLVKB9+xcprMF+44U1g=";
pin-sha256="LPJNul+wow4m6DsqxbninhsWHlwfp0JecwQzYpOLmCQ=";
report-uri="https://example.net/pkp-report"

Note: not currently supported by IE, Edge, and Safari

Max-age: 2,592,000 seconds is the most common max-age value used (30 days)

Examine browser's pinning DB: chrome://net-internals/#hsts

Max-age statistics provided by Andrei Sabelfeld and Steven Van Acker in Apr. 2017.

3. Mixed Content: HTTP and HTTPS

Page loads over HTTPS, but contains content over HTTP

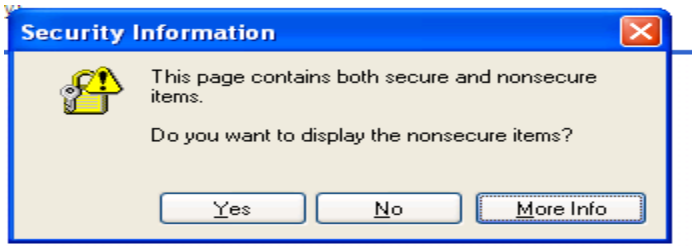
(e.g. <script src="http://.../script.js>)

never write this

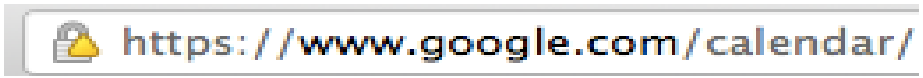
⇒ Active network attacker can hijack session

by modifying script en-route to browser

IE7:



Old Chrome:



Mostly ignored by users …

https://badssl.com (Chrome 58, 2017)

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

(script is blocked, click to load)

Mixed image: <img class="mixed" src=http://mixed.badssl.com/image.jpg”>

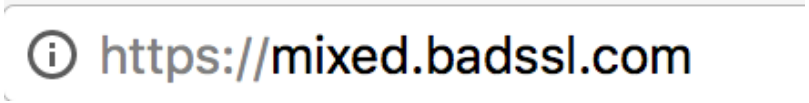


Image loaded, but no HTTPS indicator

4. Peeking through SSL: traffic analysis

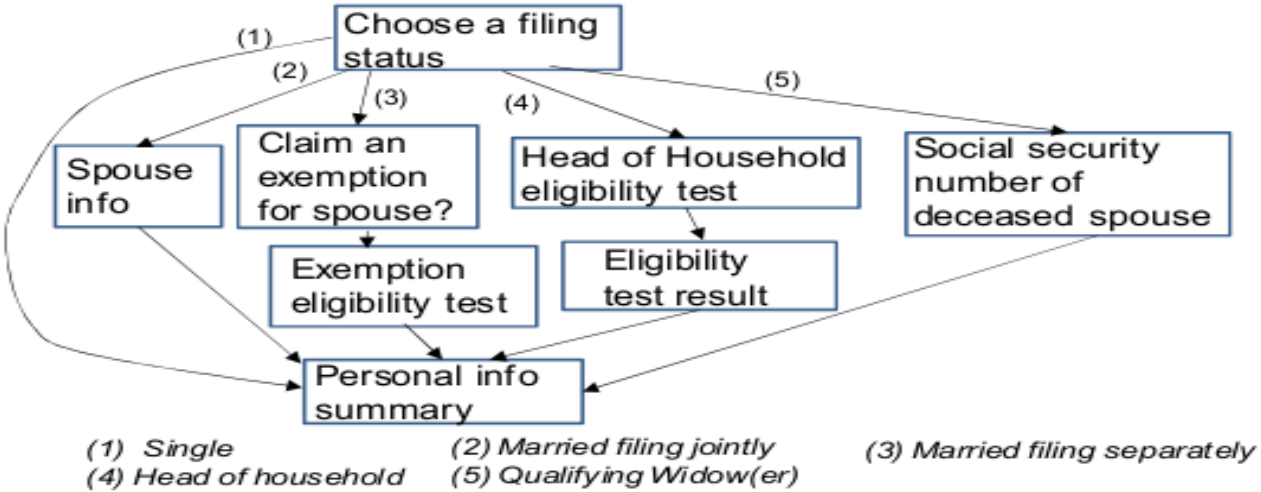
- Network traffic reveals length of HTTPS packets
  - TLS supports up to 256 bytes of padding

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

- These interactions expose specific internal state of the page

Chen, Wang, Wang, Zhang, 2010

Peeking through SSL: an example [CWWZ'10]



Vulnerabilities in an online tax application

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

THE END