Web security

HTTPS and the Lock Icon

Acknowledgments: Lecture slides are from the Computer Security course taught by Dan Boneh and John Mitchell at Stanford University. When slides are obtained from other sources, a a reference will be noted on the bottom of that slide. A full list of references is provided on the last slide.

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:

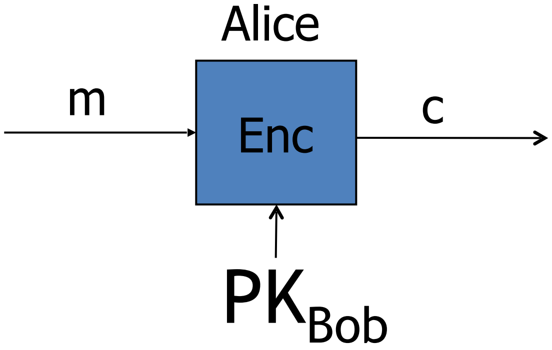
- Controls network infrastructure: Routers, DNS
- Eavesdrops, injects, blocks, and modifies packets

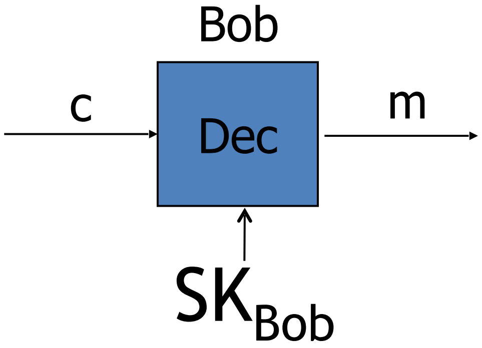
Examples:

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

SSL/TLS overview

Public-key encryption:

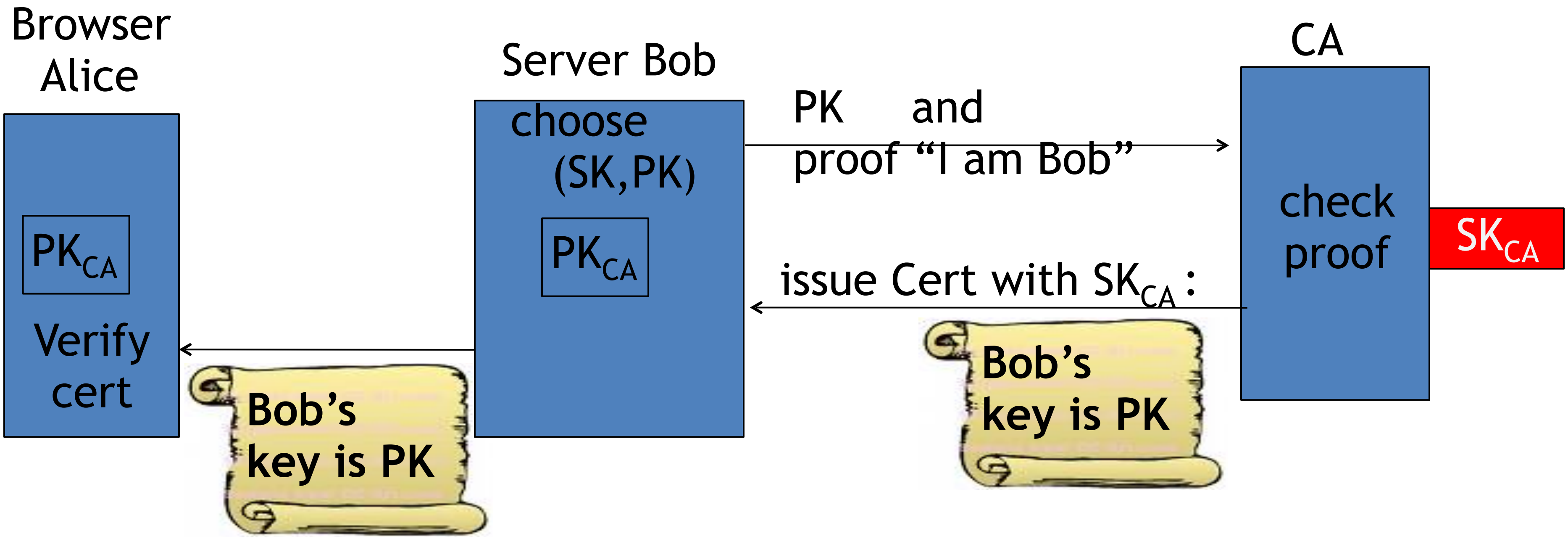




- Bob generates $(SK_{Bob}\ ,\ PK_{Bob})$
- Alice: using PK_{Bob} encrypts messages and only Bob can decrypt

Certificates

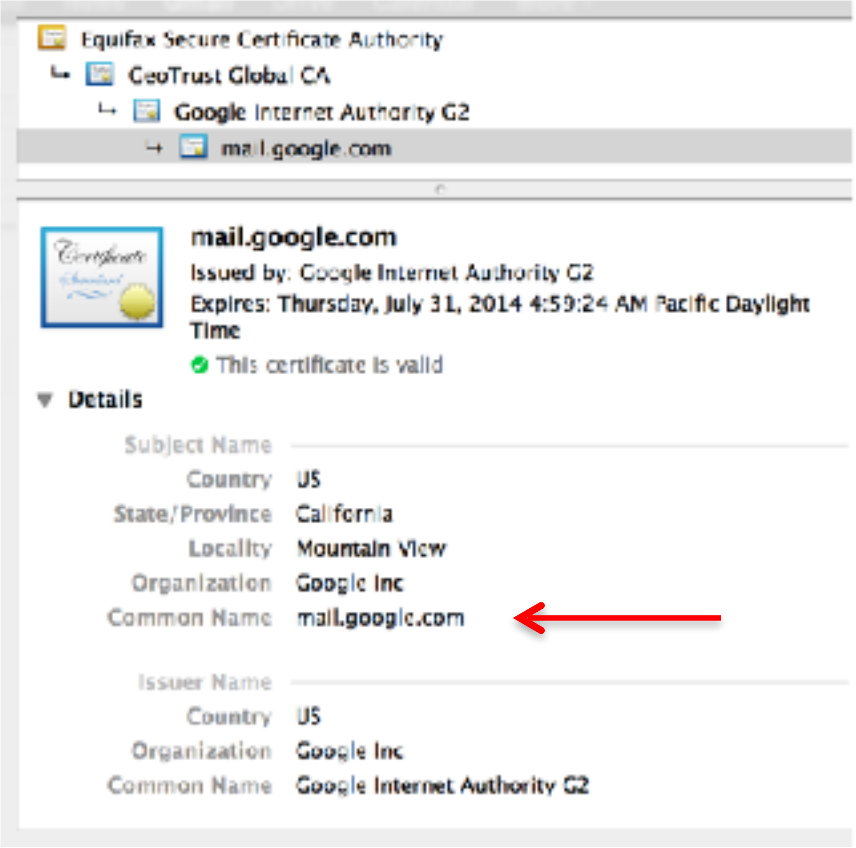
How does Alice (browser) obtain PK_{Bob} ?



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

Certificates: example

Important fields:



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

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Browsers accept certificates from a large number of CAs

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

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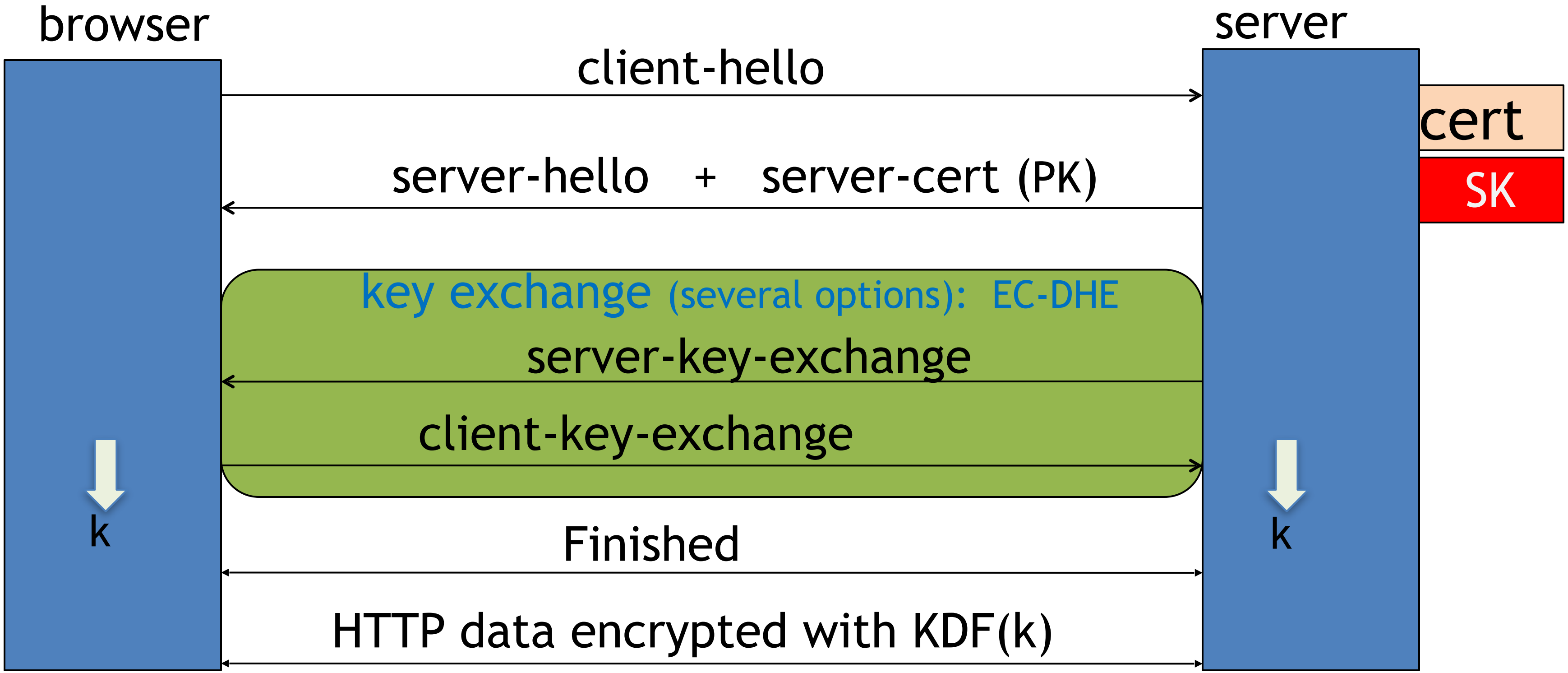
Top level CAs ≈ 60

Intermediate CAs ≈ 1200

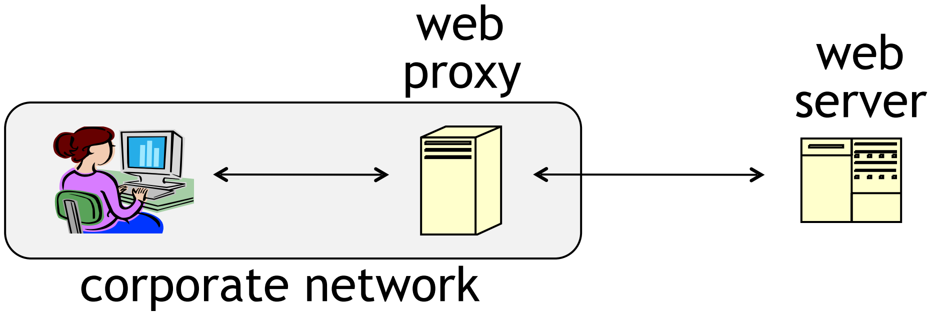
Brief overview of SSL/TLS



Most common: server authentication only

Integrating SSL/TLS with HTTP: HTTPS

Two complications



Web proxies

solution: browser sends

CONNECT domain-name

before client-hello

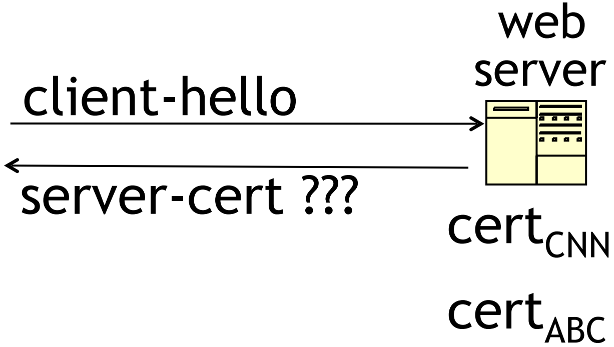
Virtual hosting:

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 do not support HTTPS (2015 stats: 20%)
  - Reduced revenue for publishers

- Incompatible with virtual hosting (older browsers)

  March 2015: IE6 ≈ 1% (ie6countdown.com)

Aug 2014: Google boosts ranking of sites supporting HTTPS

HTTPS in the Browser

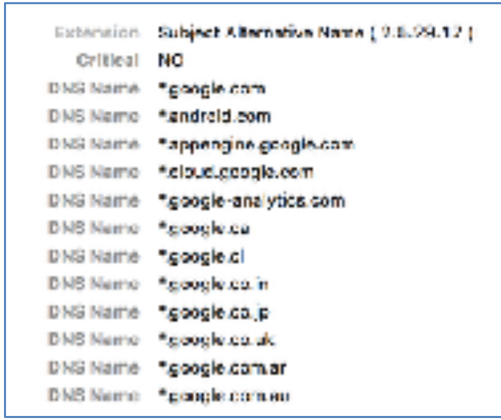
The lock icon: SSL indicator

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)

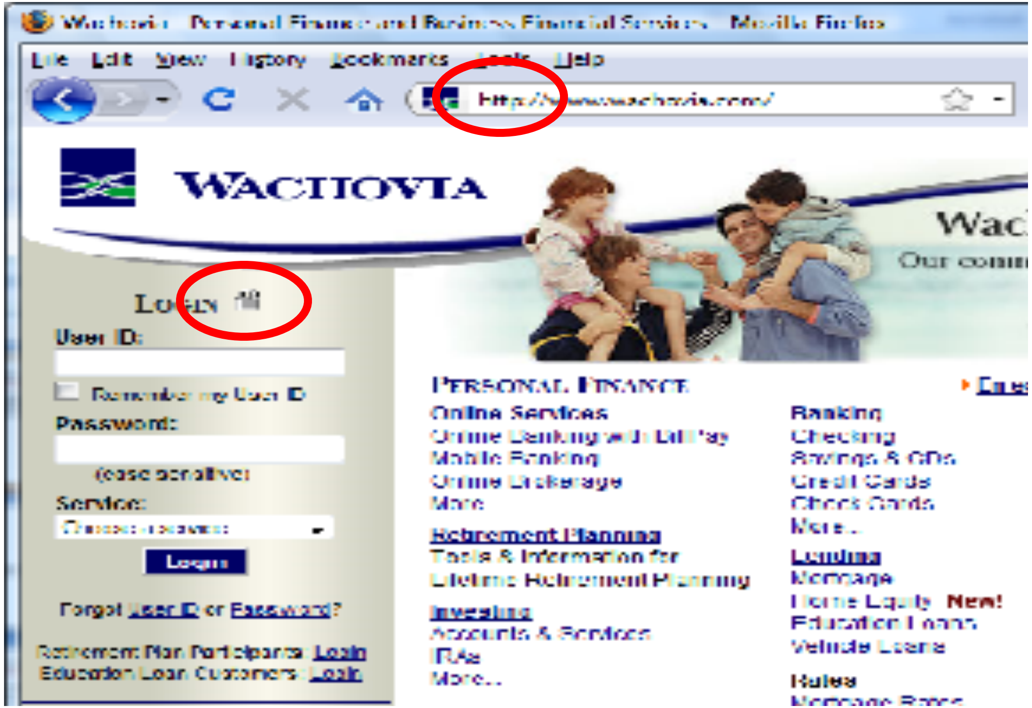
Helps block "semantic attacks": www.bankofthevvest.com

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

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/..."

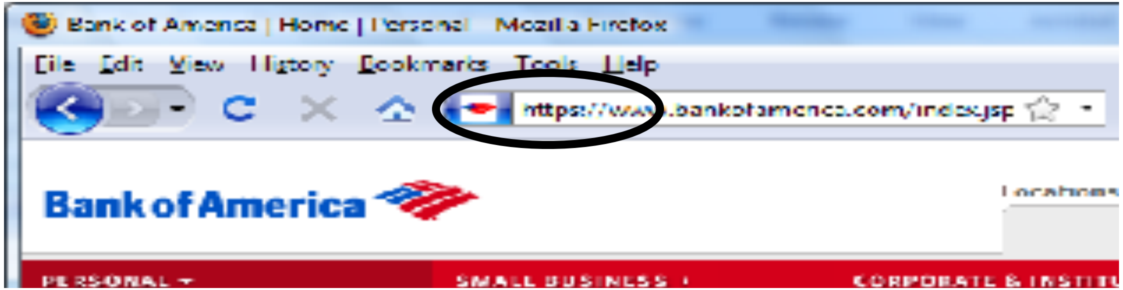
HTTPS and login pages: guidelines

General guideline:

Response to http://login.site.com

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

(redirect)



Problems with HTTPS and the Lock Icon

Problems with HTTPS and the Lock Icon

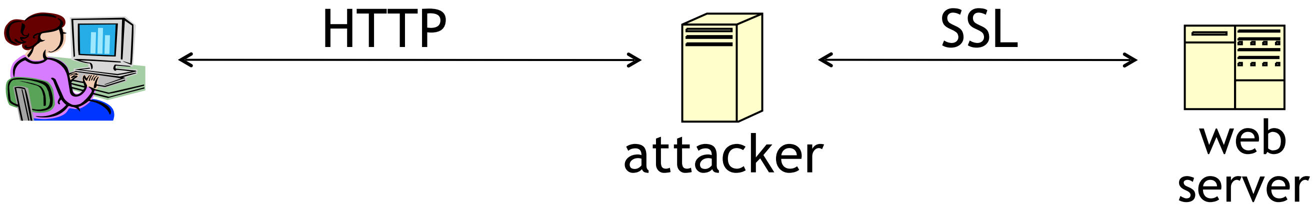
1. Upgrade from HTTP to HTTPS
2. Forged certs
3. Mixed content: HTTP and HTTPS on the same page
4. Does HTTPS hide web traffic?
   - Problems: traffic analysis, compression attacks

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

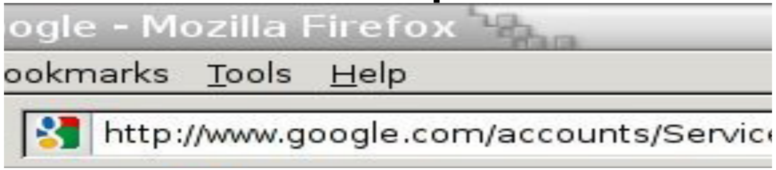
SSL_strip attack: prevent the upgrade [Moxie'08]



- a href=http://…> <—— <a href=https://…>
- Location: http://… <—— Location: https://… (redirect)
- <form action=http://… > <—— <form action=https://…>

Tricks and Details

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



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⇒ fav icon no longer presented in address bar

More tricks: inject “Set-cookie” headers to delete existing session cookies in browser. Force login.

Number of users who detected HTTP downgrade: 0

Defense: Strict Transport Security (HSTS)

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 self-signed cert
- Requires that <u>entire</u> site be served over HTTPS

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

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">

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

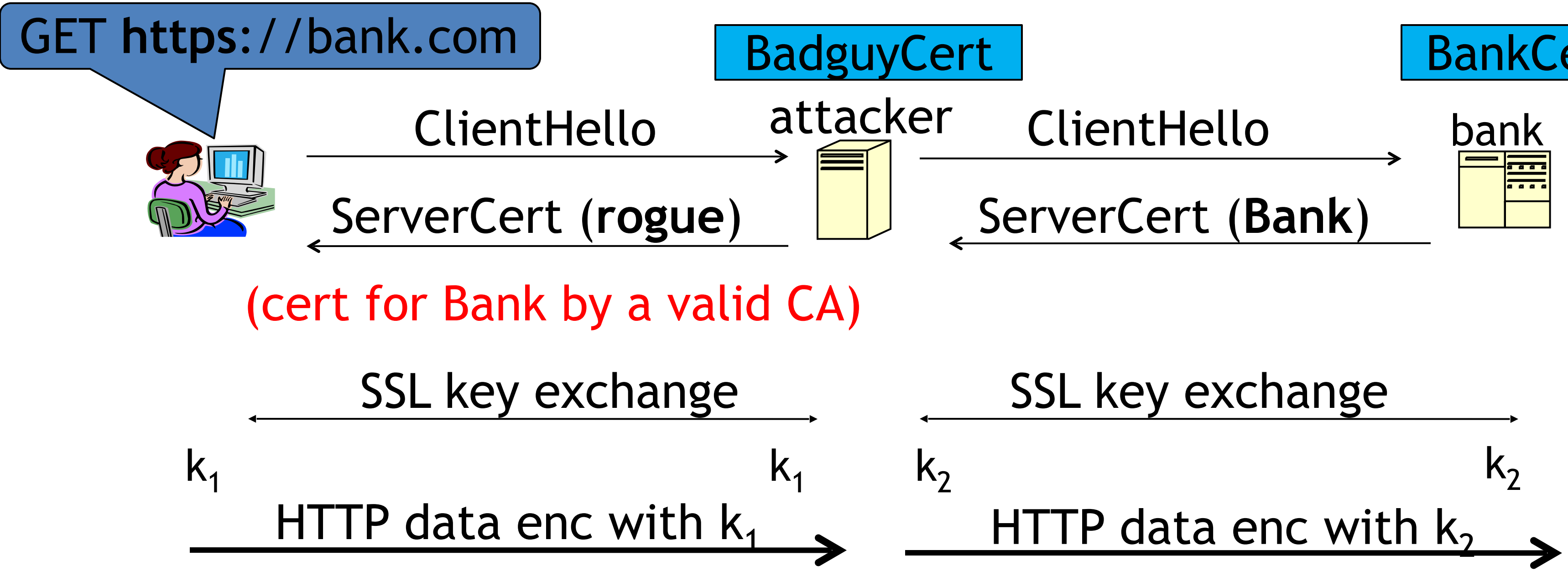
(2) Chrome restricts India CCA root to only seven Indian domains

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 <u>all</u> 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

3. Mixed Content: HTTP and HTTPS

Page loads over HTTPS, but contains content over HTTP

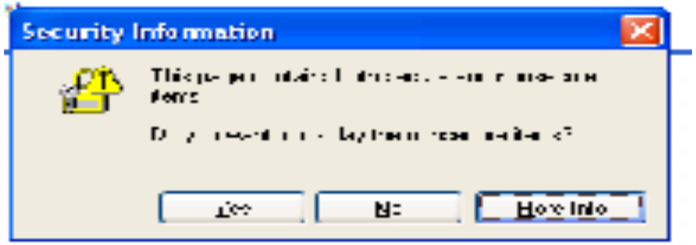
(e.g. <script src="http://.../script.js>)

never write this

⇒ Active network attacker can hijack session

by modifying script en-route to browser

IE7:



Old Chrome:

Chrome policy: blocked: CSS, script, frame; allowed: images, XHR

4. Peeking through SSL: traffic analysis

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

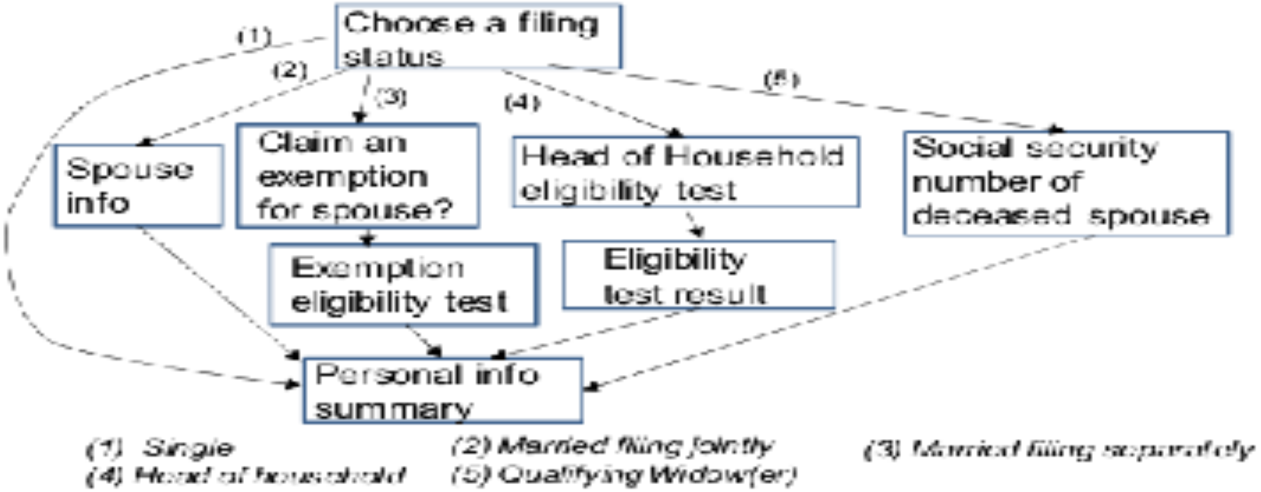
- AJAX-rich pages have lots and lots of interactions with the server

- These interactions expose specific internal state of the page

BAM!

Chen, Wang, Wang, Zhang, 2010

Peeking through SSL: an example [CWWZ'10]



Vulnerabilities in an online tax application

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

Peeking through SSL: compression [DR'12]

HTTPS: supports compressing data before encryption (16KB records)

Attacker: wants to recover Gmail session cookie (say)

- Places Javascript on some site that issues request:

```
GET gmail.com/__AAAAAAAAAAAA….AAAAAA
Cookie: session=__A 6Bh63g53ig4
Host: gmail.com
```

16KB

- 1st byte of cookie is "A" ⇒ record will compress more than when not
- Script tries all possibilities to expose 1st byte. Moves to 2nd bytes …

What to do: do not use compression with HTTPS

THE END