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: (1) DH key exchange

Anonymous key exchange secure against eavesdropping:

The Diffie-Hellman protocol in a group $G = \{1, g, g^2, g^3, \ldots, g^{q-1}\}$

Browser Alice

$a \longleftarrow \{1,\ldots,q\}$

$PMS = B^a$

$A = g^a \in G$

$B = g^b \in G$

Server Bob

$b \longleftarrow \{1,\ldots,q\}$

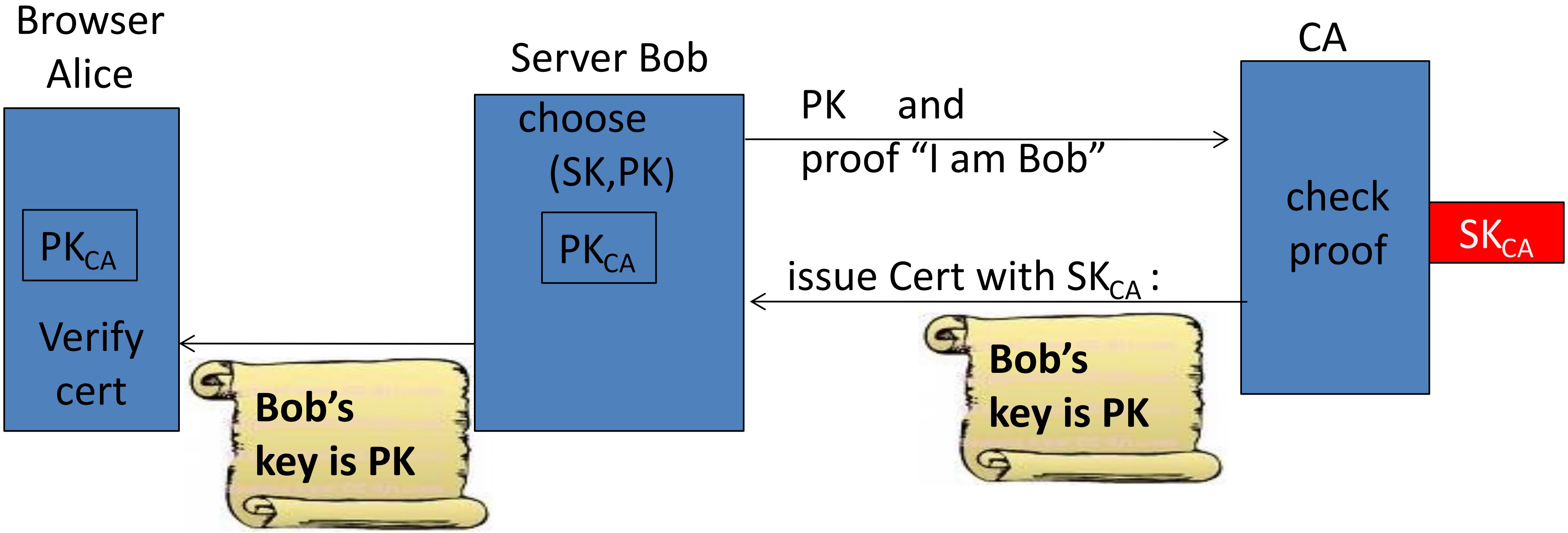
$PMS = A^b$

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

Dan Boneh

(2) Certificates

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



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

Sample certificate:

www.bankofamerica.com

Issued by: Entrust Certification Authority - L1M

Expires: Thursday, June 6, 2022 at 9:57:43 AM Pacific Daylight Time

This certificate is valid

Organization	Bank of America Corporation
Business Category	Private Organization
Organizational Unit	eComm Network Infrastructure
Serial Number	2927442
Common Name	www.bankofamerica.com

Public Key Info

Algorithm	RSA	(1.2.840.113549.1.1.1)
Parameters	None	
Public Key	256 bytes : BE E5 23 1D 17 9A 68 05 ...	
Exponent	65537	
Key Size	2,048 bits	
Key Usage	Encrypt, Verify, Wrap, Derive	

Signature (by CA) 256 bytes : 39 D0 09 7E 99 C6 B3 01 ...

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

⋮

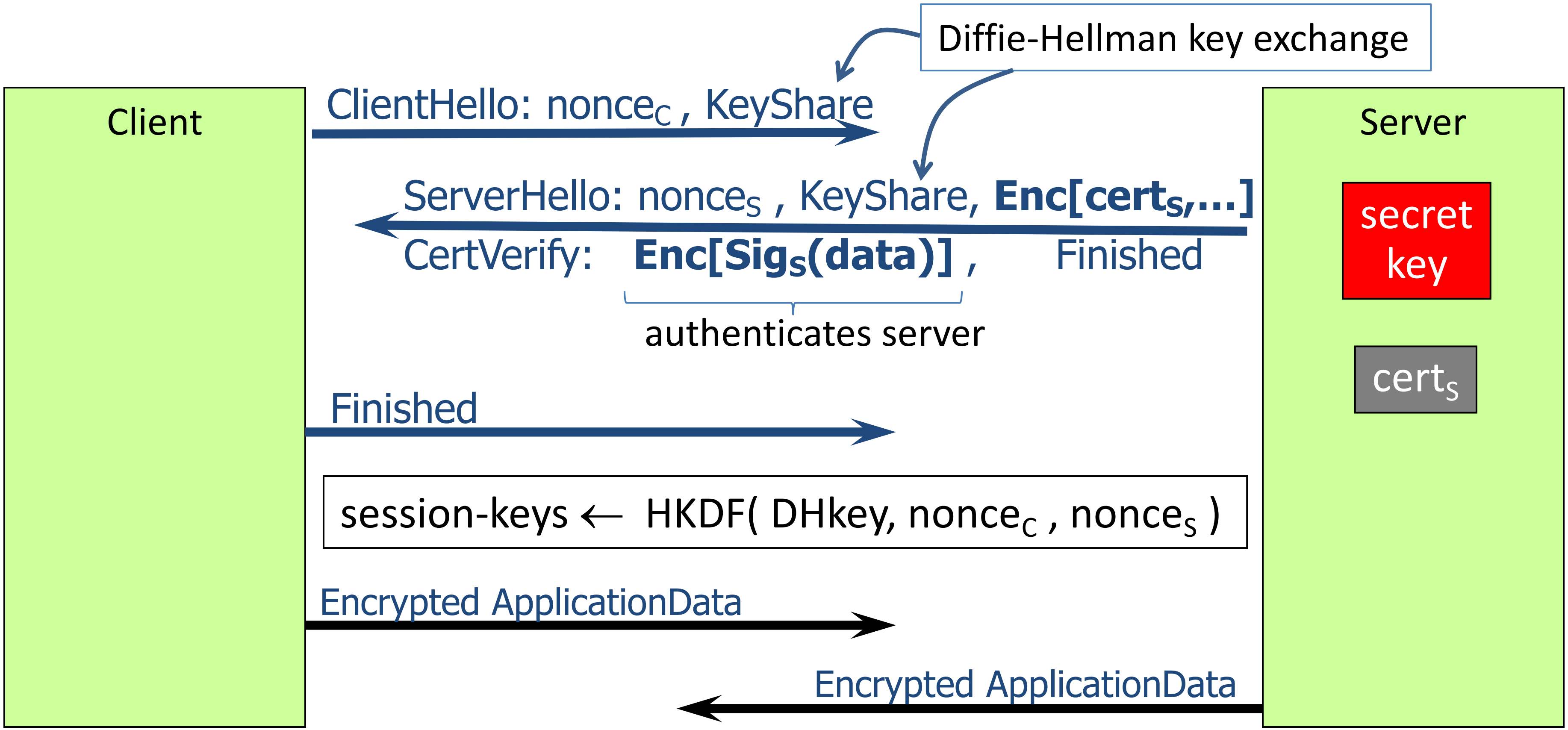
Entrust.net C…Authority (2048)	Jul 24, 2029 7:15:12 AM
Entrust.net S…ification Authority	May 25, 2019 9:39:40 AM
ePKI Root Certification Authority	Dec 19, 2034 6:31:27 PM
Equifax Secu…rtificate Authority	Aug 22, 2018 9:41:51 AM
Equifax Secure eBusiness CA-1	Jun 20, 2020 9:00:00 PM
Equifax Secure eBusiness 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

⋮

Top level CAs ≈ 60

Intermediate CAs ≈ 1200

(3) TLS 1.3 session setup (simplified)



Most common: server authentication only

(3) TLS 1.3 session setup: optimization (and caution)

Client

ClientHello: $nonce_C$, KeyShare , **Enc[0-RTT data]**

ServerHello: $nonce_S$, KeyShare, **$cert_S$,…]**

CertVerify: **Enc[Sig_S(data)** ished

Server

secret key

$cert_S$

Data encrypted using a pre-shared key

Caution: 0-RTT data is vulnerable to replay

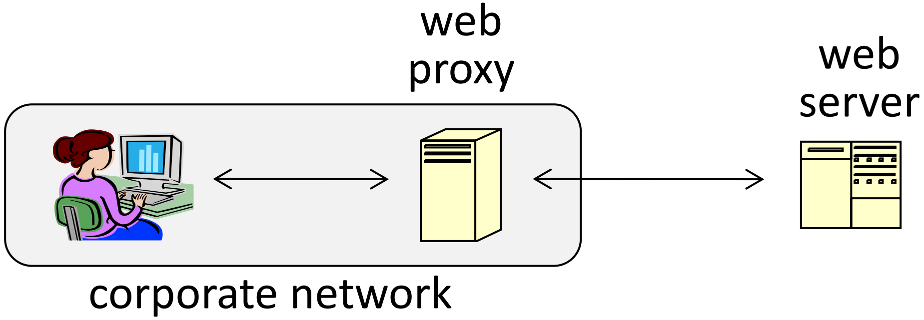
⇒ data should have no side effects

(i.e. GET but not POST)

Most common: server authentication only

Integrating TLS with HTTP: HTTPS

Two complications



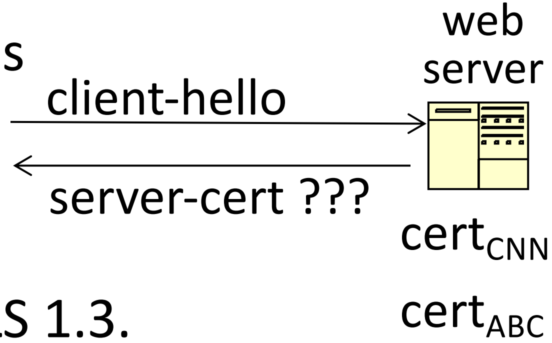
<u>Web proxies</u>

solution: browser sends

CONNECT domain-name

before client-hello

<u>Virtual hosting:</u> many sites hosted at same IP address



solution in TLS 1.1: SNI (June 2003)

client_hello_extension: **server_name=cnn.com**

SNI defeats privacy benefit of encrypted cert in TLS 1.3.

Solution: **enc. client hello (ECH)** [encrypted with pk in server DNS]

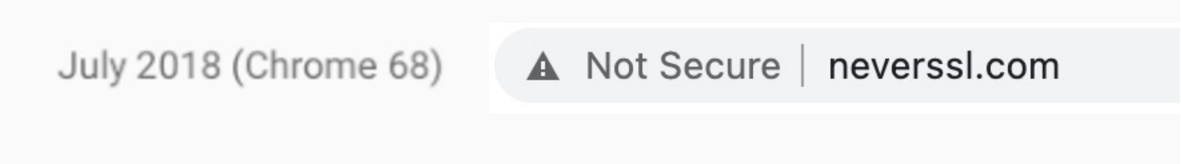
HTTPS for all web traffic?

<u>Old excuses</u>:

- Crypto slows down web servers
- Some ad-networks still do not support HTTPS

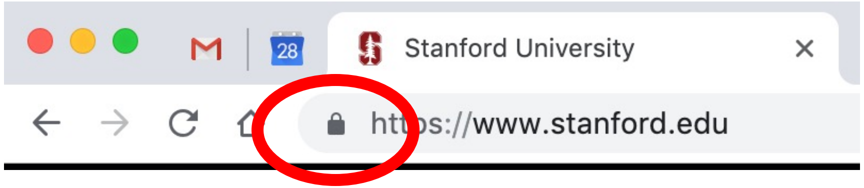
$\Longrightarrow$ both are no longer true (thanks to AES-NI)

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



HTTPS in the Browser

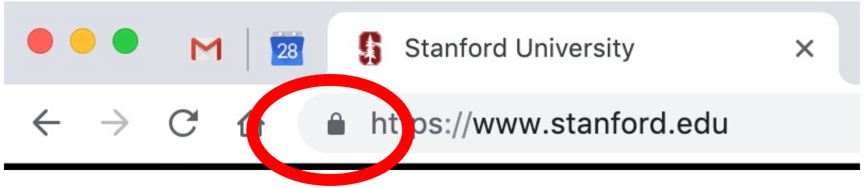
The lock icon: TLS indicator

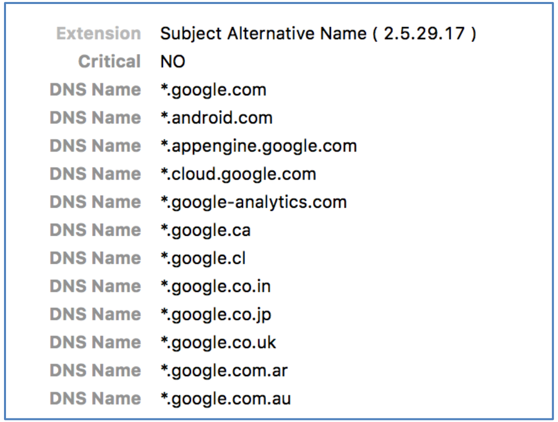


Intended goal:

- 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





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 new chromium lock icon

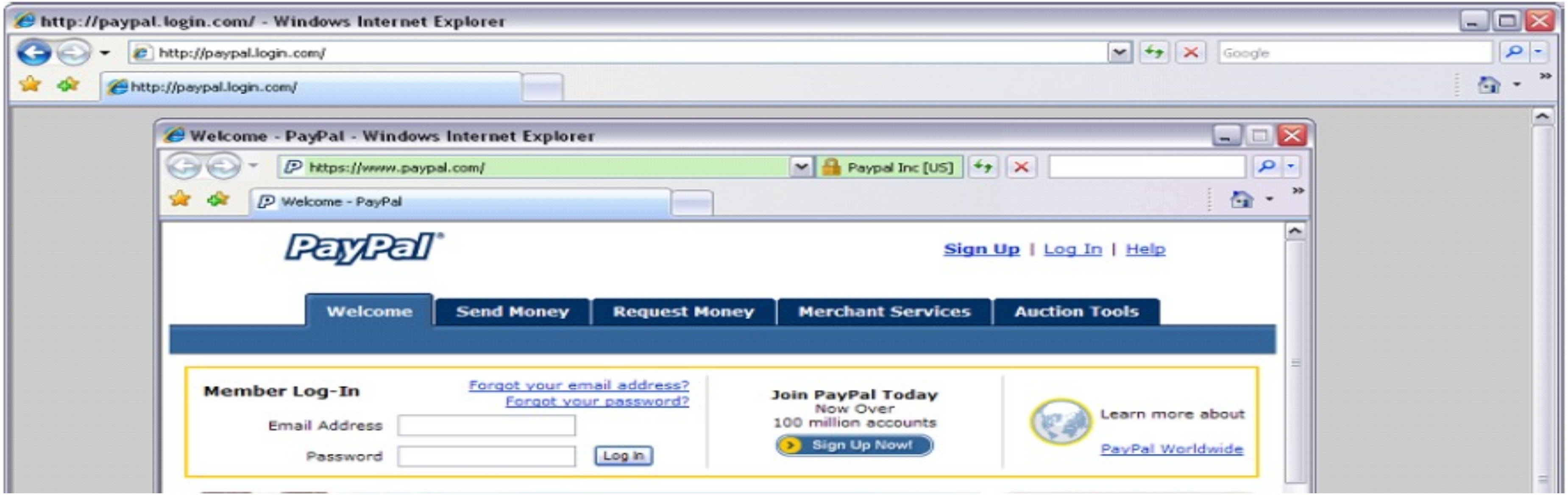
May’23:   95% of all pages loaded in Chrome use HTTPS

⇒   icon is (almost) always there

Purpose of new icon: a button providing security info about site

Positive security indicators are dangerous

The lock icon is a **positive security indicator**. Problem: picture-in-picture attacks.



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

HTTPS and login pages: incorrect usage

Suppose user lands on HTTP login page.

- say, by typing HTTP URL into address bar

View source:

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

(old site)

HTTPS and login pages: guidelines

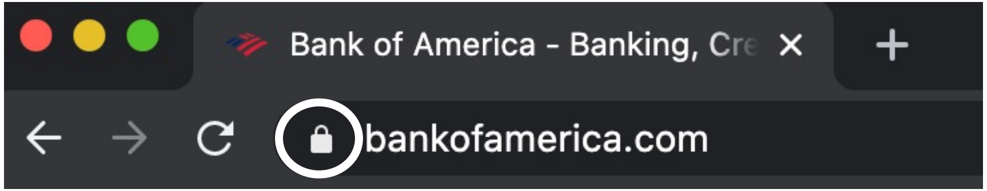
General guideline:

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

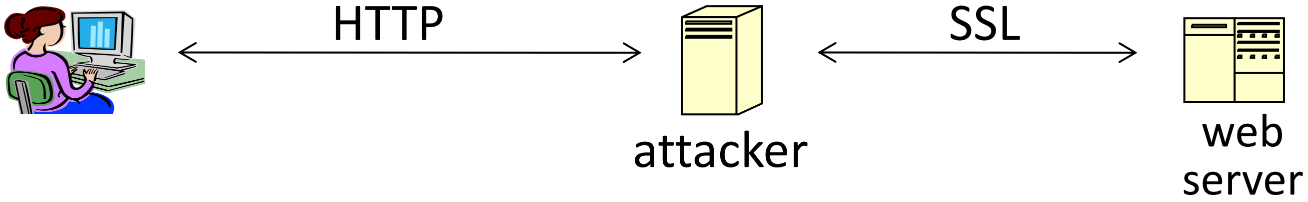
1. Upgrade from HTTP to HTTPS
2. Forged certs
3. Mixed content: HTTP and HTTPS on the same page
4. Does HTTPS hide web traffic?
   - Problems: traffic analysis, compression attacks

1. HTTP ⇒ HTTPS upgrade

Suppose user does:

- connect to bank site over HTTP;   bank redirects to HTTPS

SSL_strip attack: prevent the upgrade [Moxie'08]



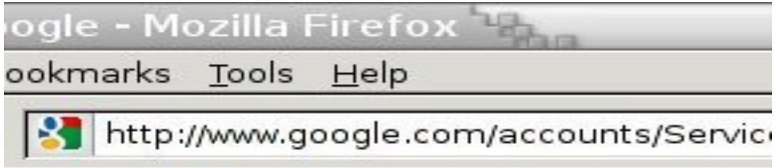
<a href=https://…>   ⟶   <a href=http://…>

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

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

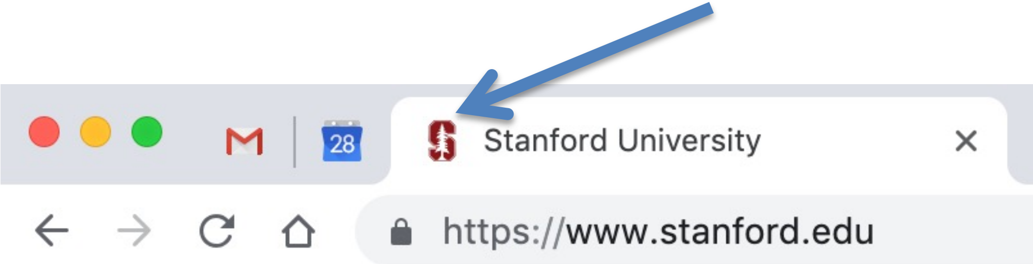
Tricks and Details

UI design flaw in old browsers: location of fav icon



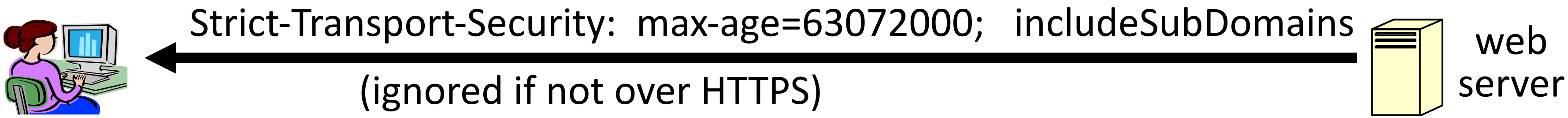
→

⇒ fav icon no longer presented in address bar



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 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/

Enter a domain for the HSTS preload list:

paypal.com

Check status and eligibility

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

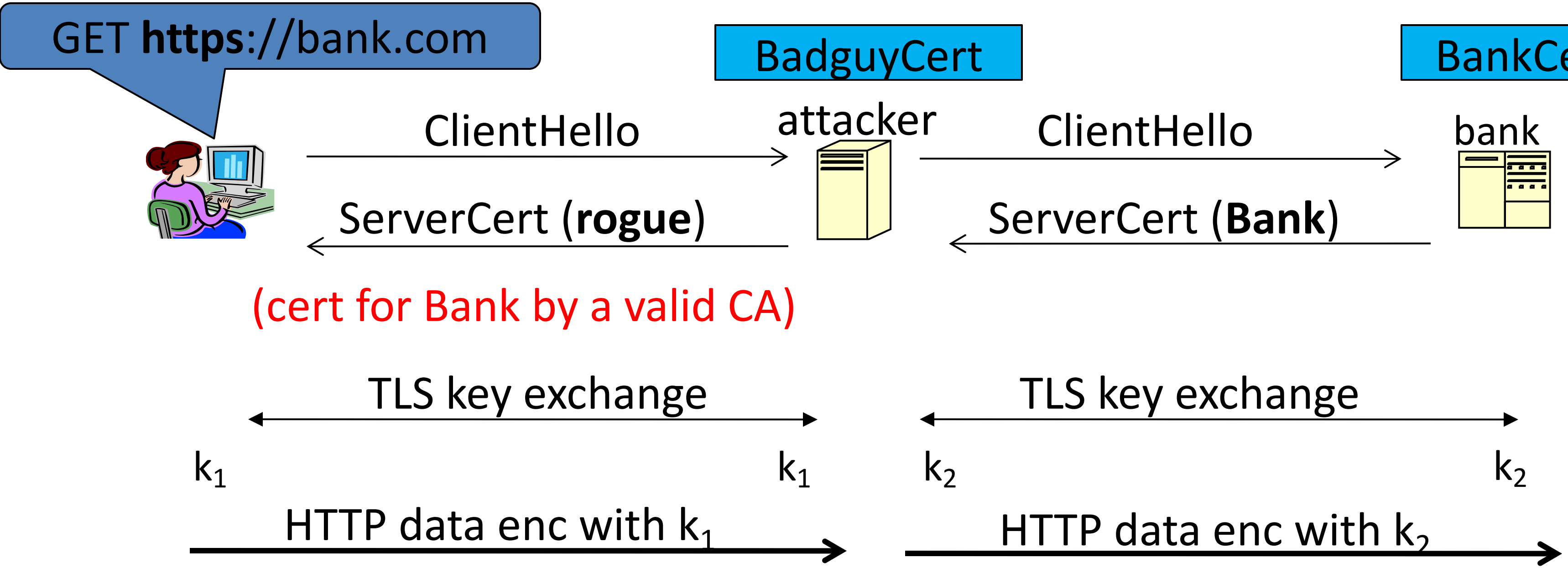
(2) Chrome restricts India CCA root to only seven Indian domains

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

2. **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 to certificate a signed statement from log (SCT)
   - Companies can scan logs to look for invalid issuance

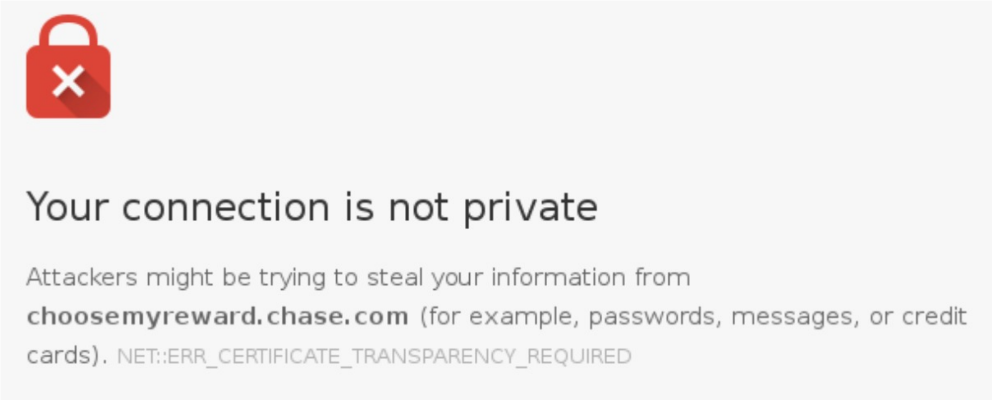
CT requirements

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



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

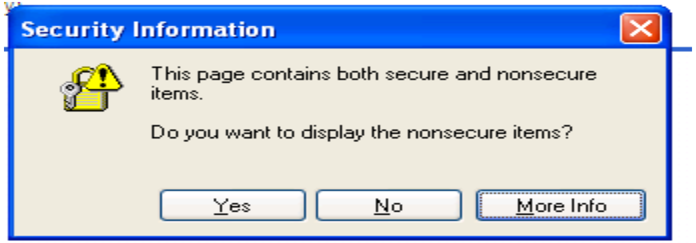
(e.g. <script src="http://.../script.js>)

never write this

⇒ Active network attacker can hijack session

by modifying script en-route to browser

IE7:

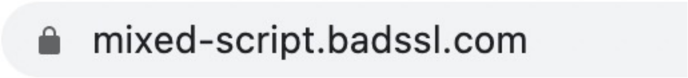


Old Chrome:

Mostly ignored by users …

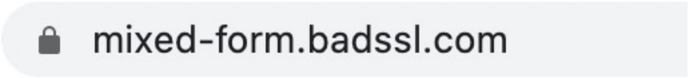
https://badssl.com (Chrome 90, 2021)

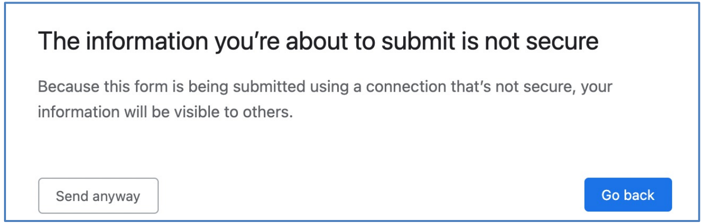
Mixed script: **<script src="http://mixed-script.badssl.com/nonsecure.js"></script>**



script is not loaded! developer tools show an error.

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





Warning if user tries to submit data

4. Peeking through TLS: traffic analysis

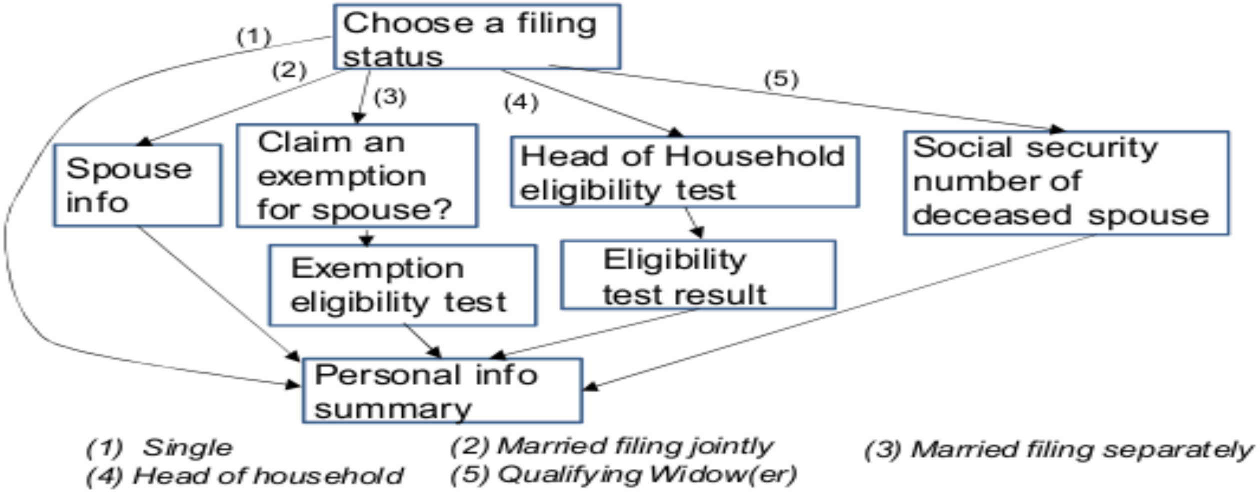
- Network traffic reveals length of HTTPS packets
  - TLS supports up to 256 bytes of padding

- Some sites interact frequently with the web server
  - These interactions expose specific internal state of the page

BAM!

Chen, Wang, Wang, Zhang, 2010

Peeking through TLS: an example [CWWZ'10]



Vulnerabilities in an online tax application

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

THE END