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:

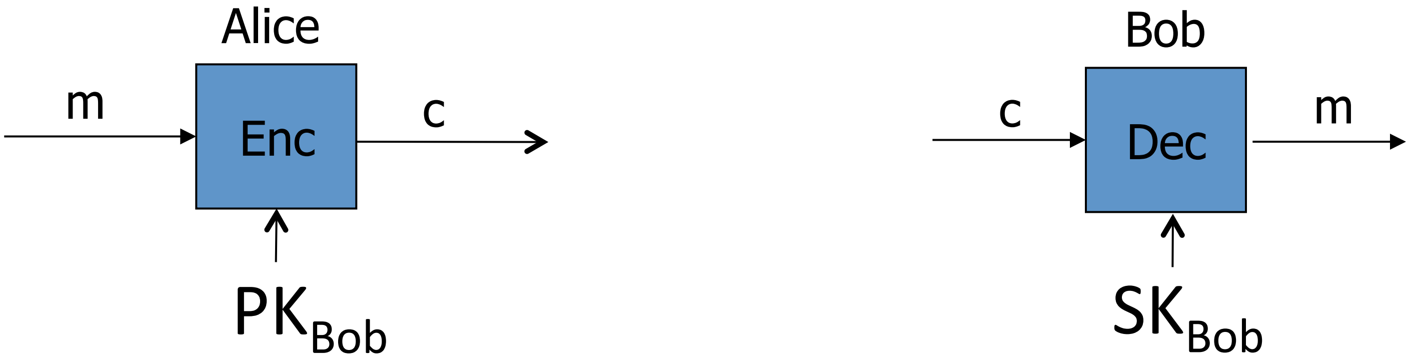
- Controls network infrastructure: Routers, DNS
- Eavesdrops, injects, blocks, and modifies packets

Examples:

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

SSL/TLS overview

Public-key encryption:

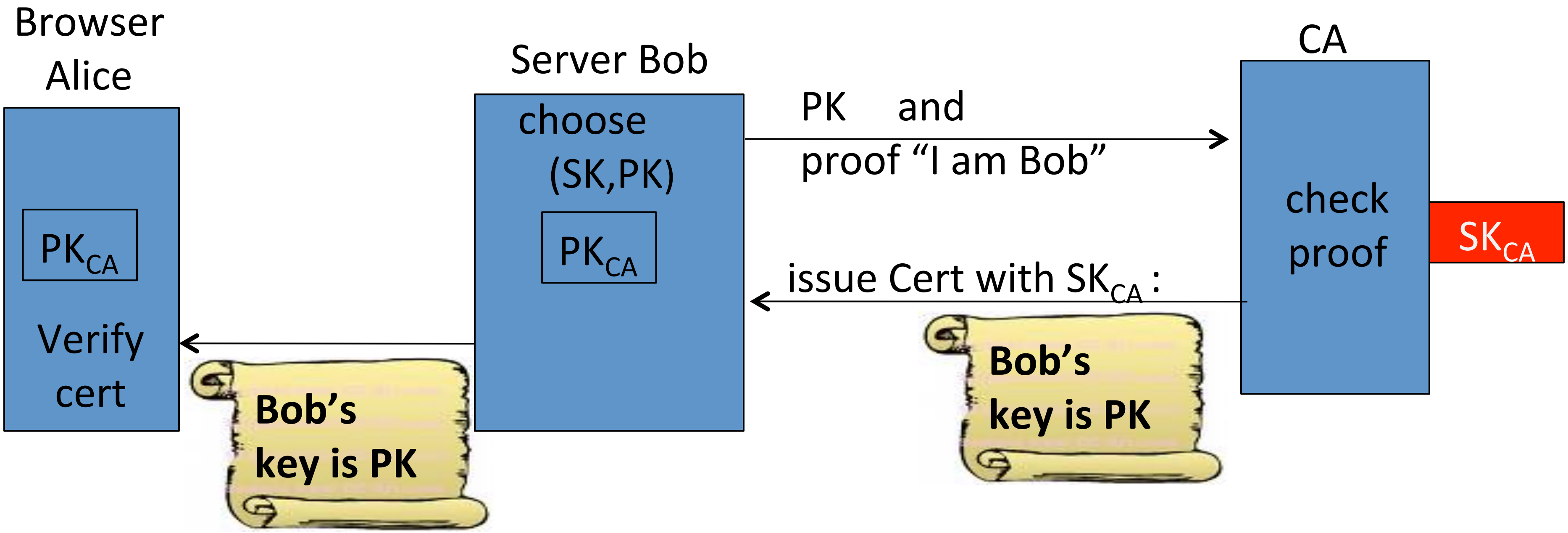


- Bob generates $(SK_{Bob}\ ,\ PK_{Bob})$

- Alice: using PK_{Bob} encrypts messages and only Bob can decrypt

Certificates

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



Browser Alice

PK_{CA}

Verify cert

Server Bob

choose (SK,PK)

PK_{CA}

PK and proof "I am Bob"

CA

check proof

SK_{CA}

issue Cert with SK_{CA} :

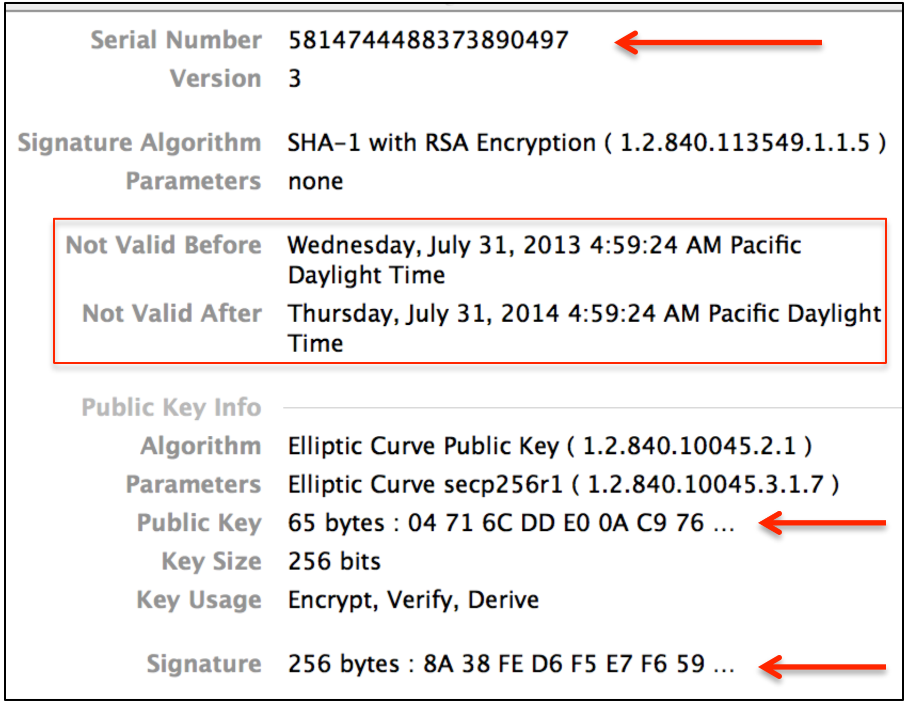
Bob's key is PK

Bob's key is PK

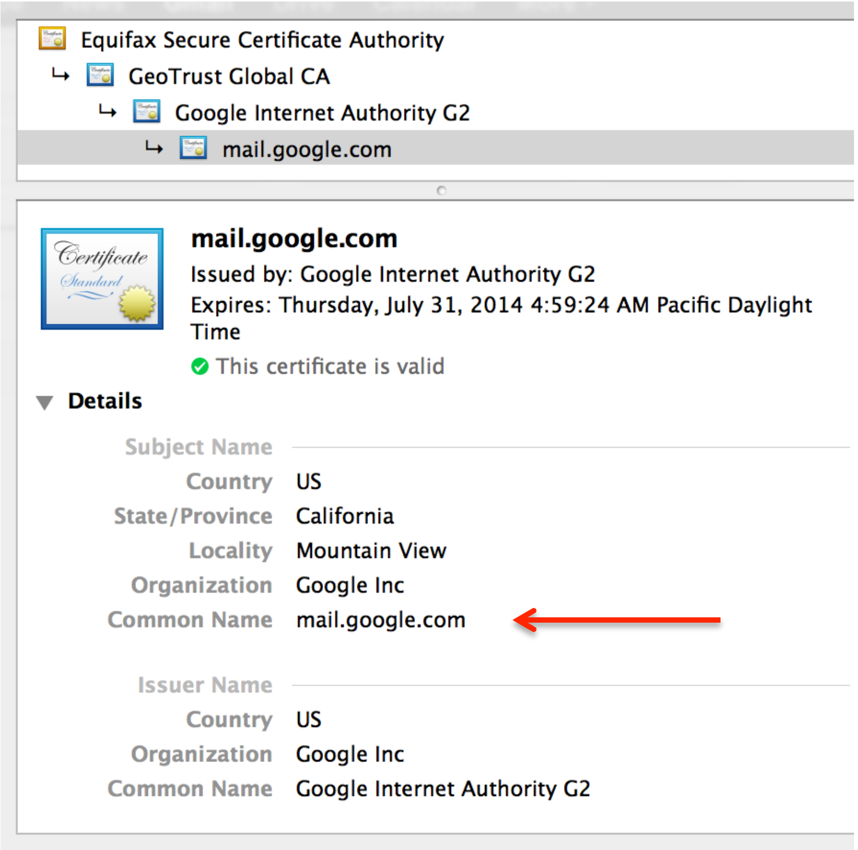
Bob uses Cert for an extended period (e.g. one year)

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 …



Equafax Secure Certificate Authority
↳ GeoTrust Global CA
↳ Google Internet Authority G2
↳ mail.google.com

mail.google.com
Issued by: Google Internet Authority G2
Expires: Thursday, July 31, 2014 4:59:24 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 Inc
Common Name	Google Internet Authority G2

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 "."

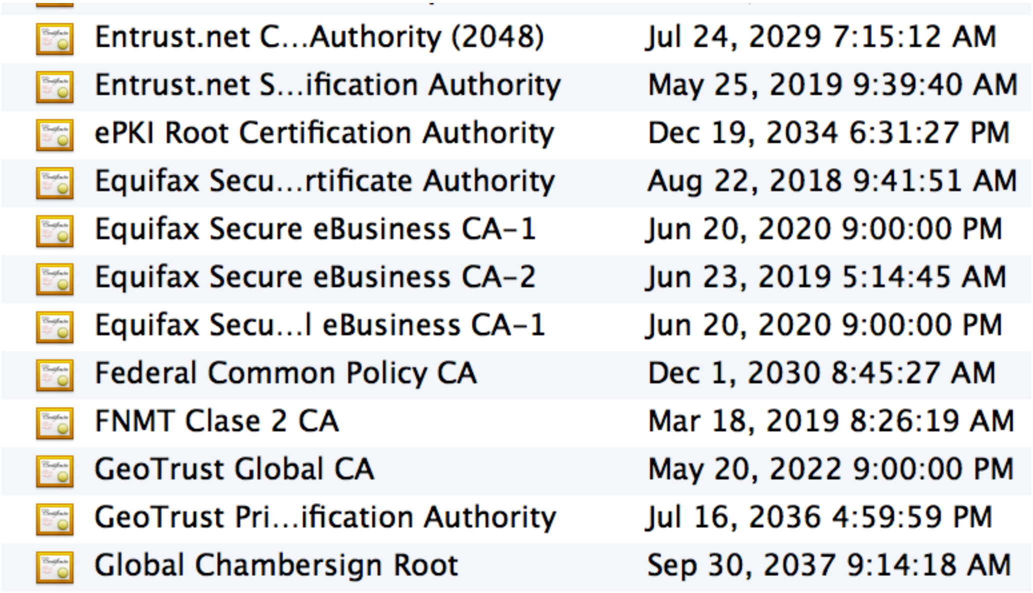
example: *.a.com matches x.a.com but not y.x.a.com

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

Certificate Authorities

Browsers accept certificates from a large number of CAs

⋮



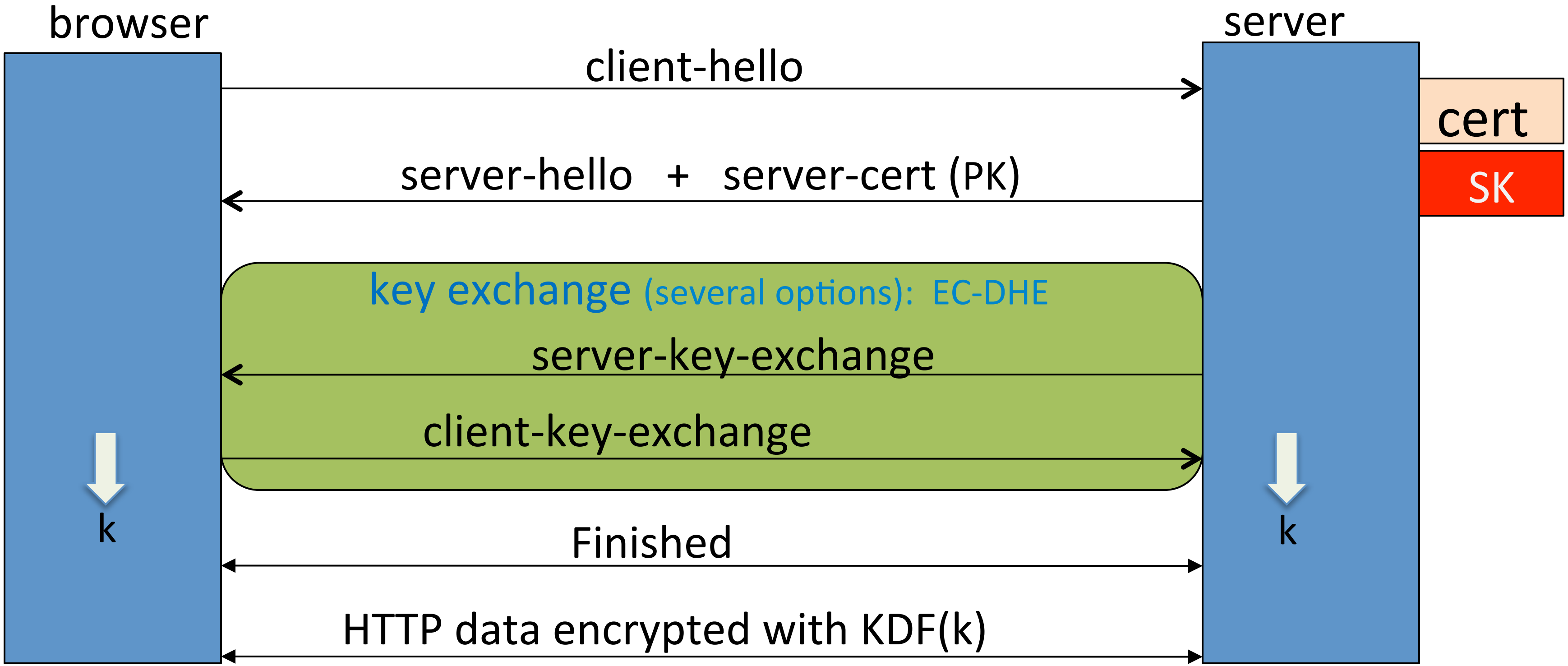
Entrust.net C...Authority (2048)	Jul 24, 2029 7:15:12 AM
Entrust.net S...ification Authority	May 25, 2019 9:39:40 AM
ePKI Root Certification Authority	Dec 19, 2034 6:31:27 PM
Equifax Secu...rtificate Authority	Aug 22, 2018 9:41:51 AM
Equifax Secure eBusiness CA-1	Jun 20, 2020 9:00:00 PM
Equifax Secure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

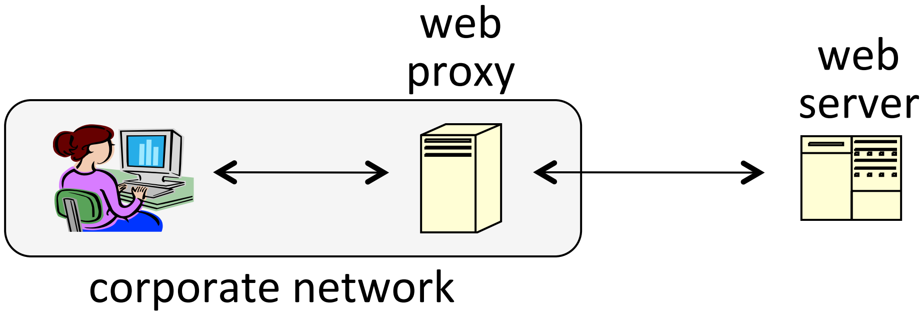
Brief overview of SSL/TLS


browser
server
cert
SK
client-hello
server-hello + server-cert (PK)
key exchange (several options): EC-DHE
server-key-exchange
client-key-exchange
k
k
Finished
HTTP data encrypted with KDF(k)

Most common: server authentication only

Integrating SSL/TLS with HTTP: HTTPS

Two complications



Web proxies

solution: browser sends

CONNECT domain-name

before client-hello

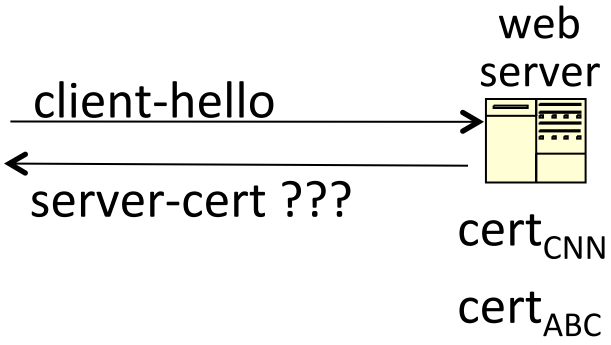
Virtual hosting:

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

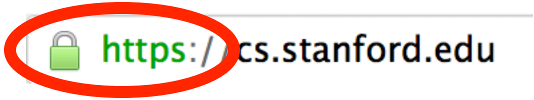
- Incompatible with virtual hosting (older browsers)

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

Aug 2014: Google boosts ranking of sites supporting HTTPS

HTTPS in the Browser

The lock icon: SSL indicator



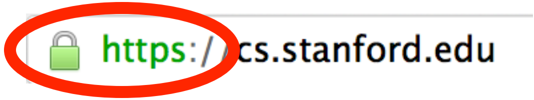
https://cs.stanford.edu

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



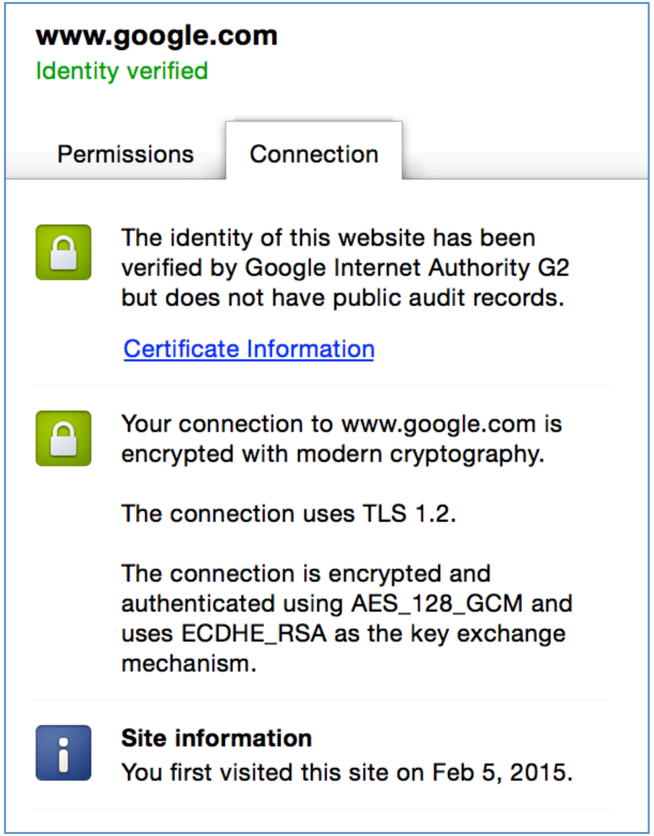
https://cs.stanford.edu

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)
- CommonName in cert matches domain in URL

The lock UI: help users authenticate site



www.google.com

Identity verified

Permissions | Connection

The identity of this website has been verified by Google Internet Authority G2 but does not have public audit records.

Certificate Information

Your connection to www.google.com is encrypted with modern cryptography.

The connection uses TLS 1.2.

The connection is encrypted and authenticated using AES_128_GCM and uses ECDHE_RSA as the key exchange mechanism.

Site information

You first visited this site on Feb 5, 2015.

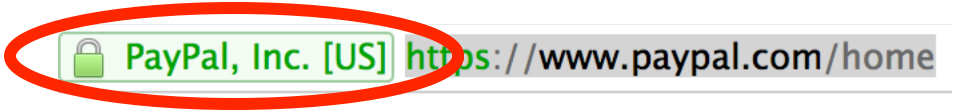
uninformative

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)

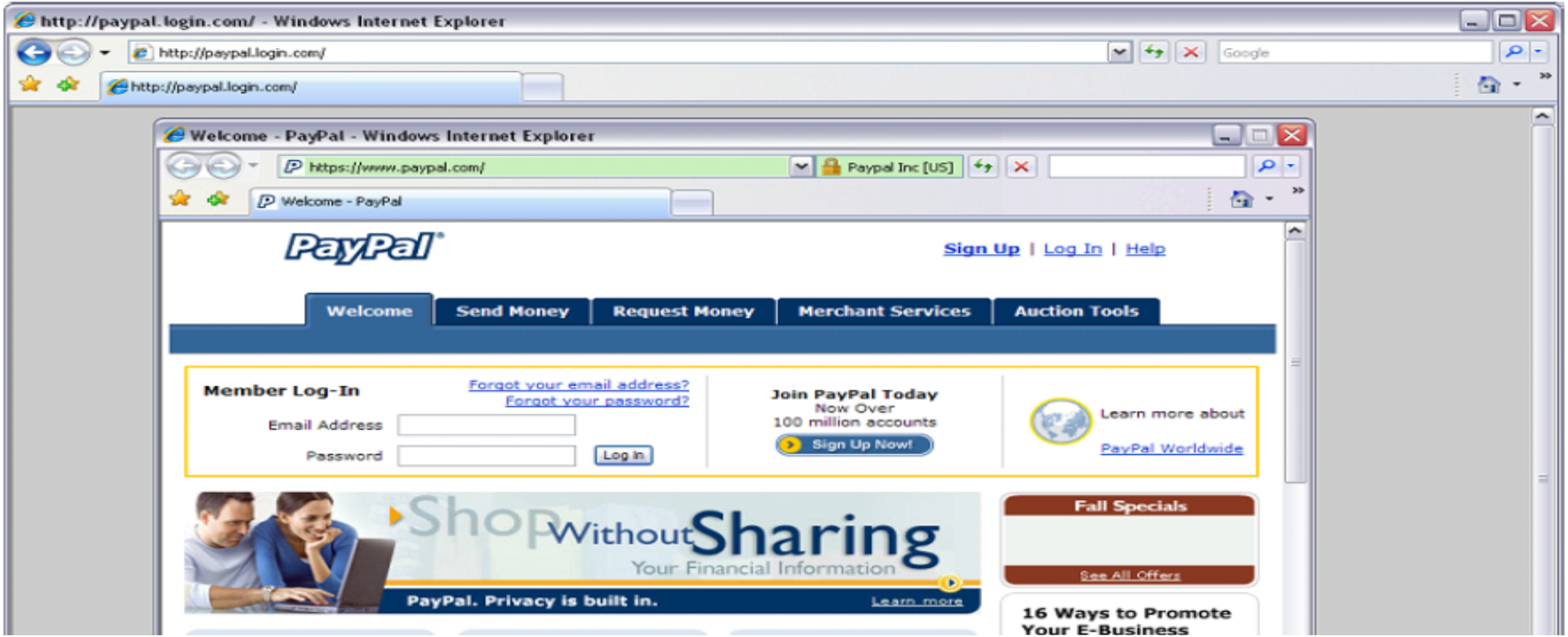
Helps block "semantic attacks": www.bankofthevvest.com



PayPal, Inc. [US] https://www.paypal.com/home

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

A general UI attack: picture-in-picture

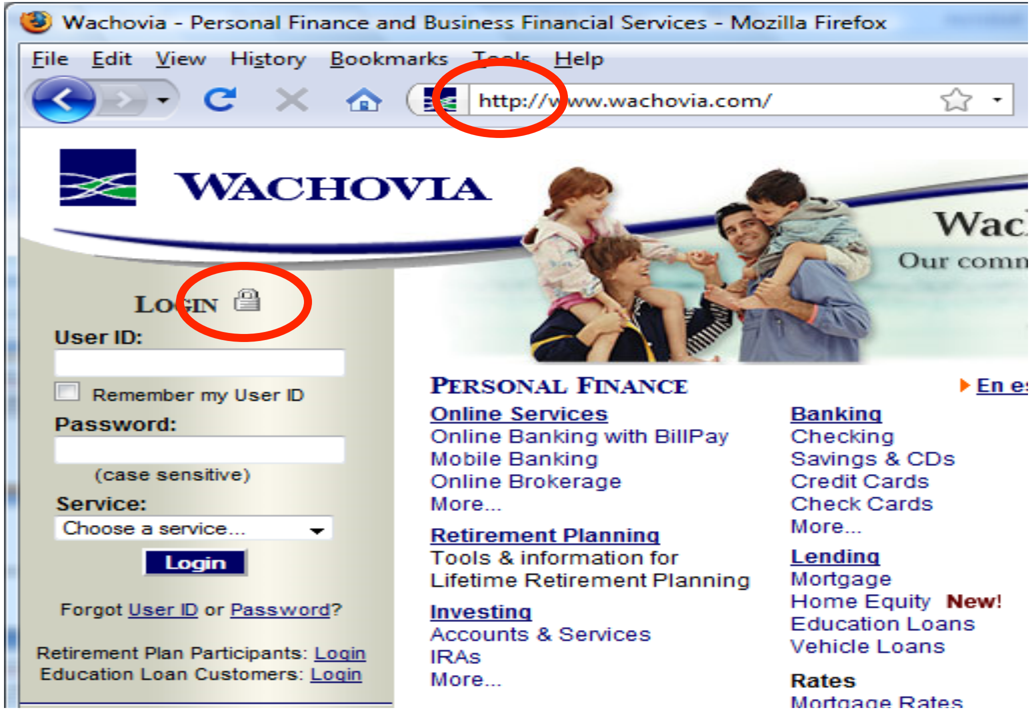


Trained users are more likely to fall victim to this [JSTB'07]

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

LOGIN

User ID:

□ Remember my User ID

Password:

(case sensitive)

Service:

Choose a service...

Forgot User ID or Password?

Retirement Plan Participants: Login
Education Loan Customers: Login

PERSONAL FINANCE

Online Services
Online Banking with BillPay
Mobile Banking
Online Brokerage
More...

Retirement Planning
Tools & information for Lifetime Retirement Planning

Investing
Accounts & Services
IRAs
More...

En es

Banking
Checking
Savings & CDs
Credit Cards
Check Cards
More...

Lending
Mortgage
Home Equity New!
Education Loans
Vehicle Loans

Rates
Mortgage Rates

View source:

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

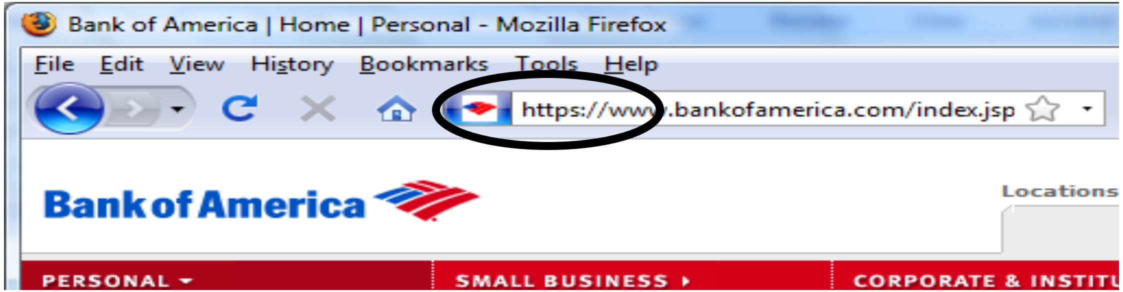
(old site)

HTTPS and login pages: guidelines

General guideline:

Response to http://login.site.com

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



Bank of America | Home | Personal - Mozilla Firefox

File Edit View History Bookmarks Tools Help
https://www.bankofamerica.com/index.jsp
Bank of America
Locations
PERSONAL
SMALL BUSINESS
CORPORATE & INSTITU

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

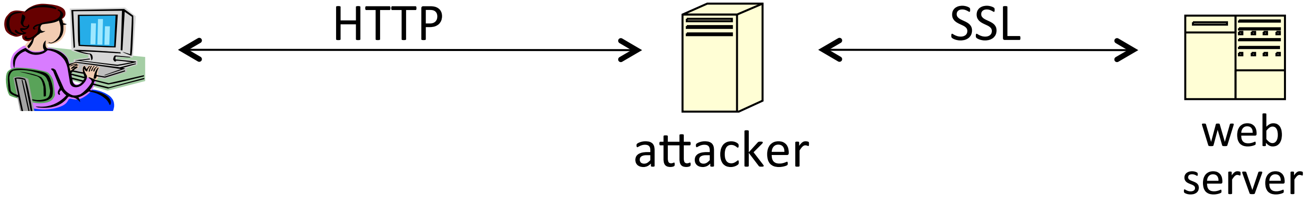
4. Does HTTPS hide web traffic?
   - Problems: traffic analysis, compression attacks

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]



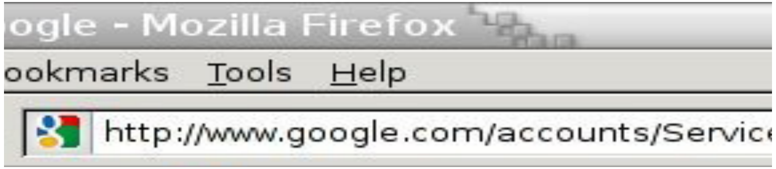
<a href=https://…> ⇒ <a href=http://…>

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

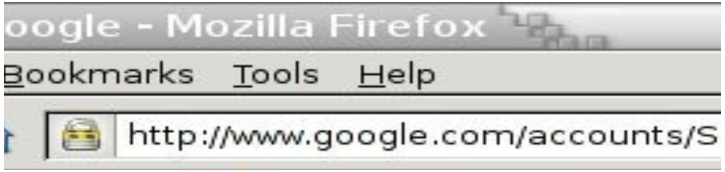
<form action=https://… > ⇒ <form action=http://…>

Tricks and Details

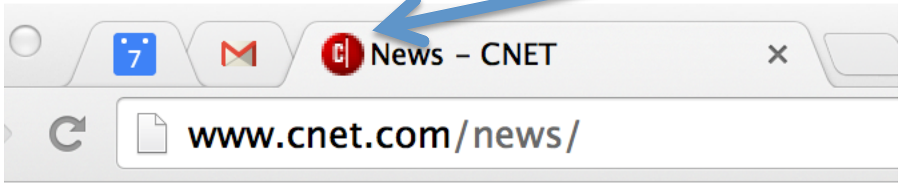
Tricks: drop-in a clever fav icon (older browsers)



⇒



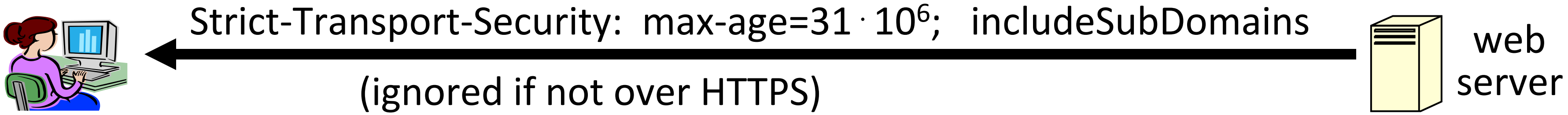
⇒ fav icon no longer presented in address bar



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)



Strict-Transport-Security: max-age=$31 \cdot 10^6$; includeSubDomains

(ignored if not over HTTPS)

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 entire site be served over HTTPS

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

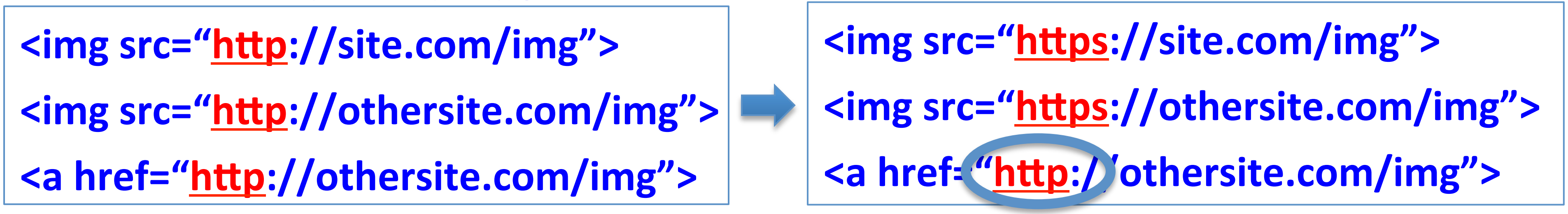
CSP: upgrade-insecure-requests

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

- Makes it difficult to migrate site to HTTPS

Solution:

Content-Security-Policy: upgrade-insecure-requests



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

```
<img src="https://site.com/img">
<img src="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

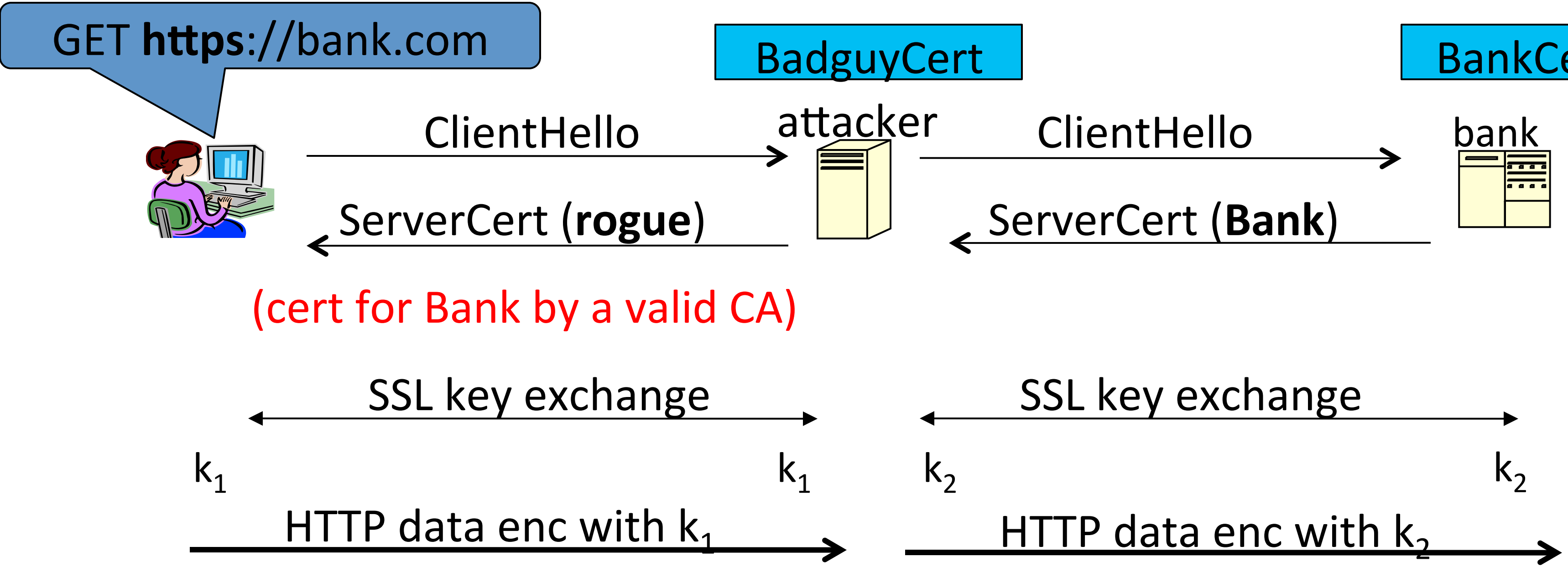
(2) Chrome restricts India CCA root to only seven Indian domains

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

Result: 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



GET **https**://bank.com

BadguyCert

BankCert

attacker

bank

ClientHello

ClientHello

ServerCert (**rogue**)

ServerCert (**Bank**)

(cert for Bank by a valid CA)

SSL key exchange

SSL key exchange

k_1 k_1

k_2 k_2

HTTP data enc with k_1

HTTP data enc with k_2

Attacker proxies data between user and bank.
Sees all traffic and can modify data at will.

What to do? (many good ideas)

1. HTTP public-key pinning, TACK
   - 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

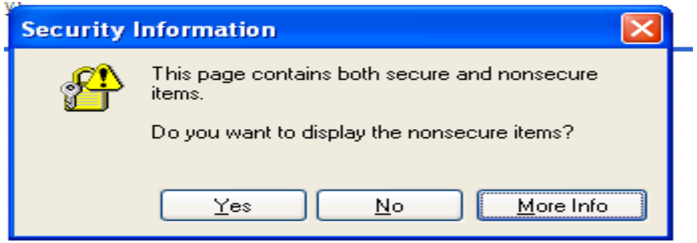
(e.g. <script src="http://.../script.js>)

never write this

⇒ Active network attacker can hijack session

by modifying script en-route to browser

IE7:

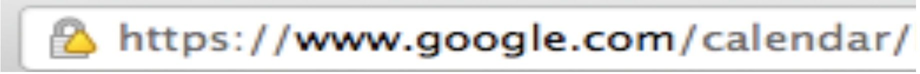


Security Information

This page contains both secure and nonsecure items.

Do you want to display the nonsecure items?

Chrome:



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

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

4. Peeking through SSL: traffic analysis

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

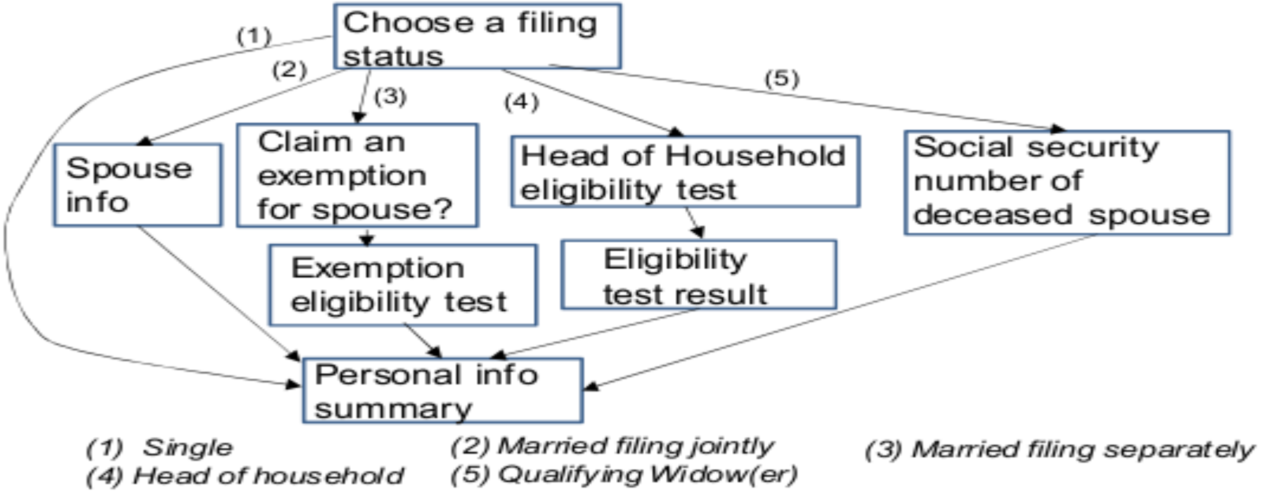
- AJAX-rich pages have lots and lots of interactions with the server

- 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

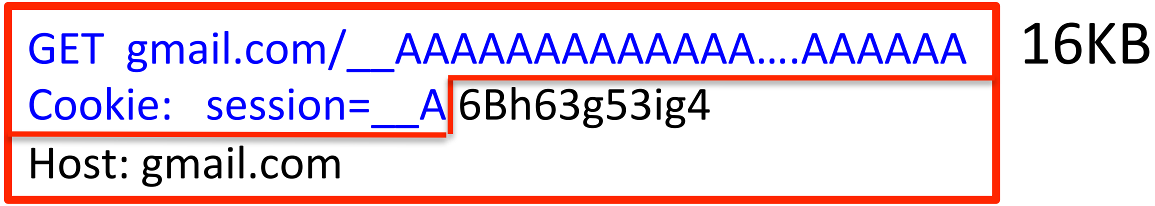
No easy fix. Can also be used to ID Tor traffic

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

1st byte of cookie is "A" ⇒ record will compress more than when not

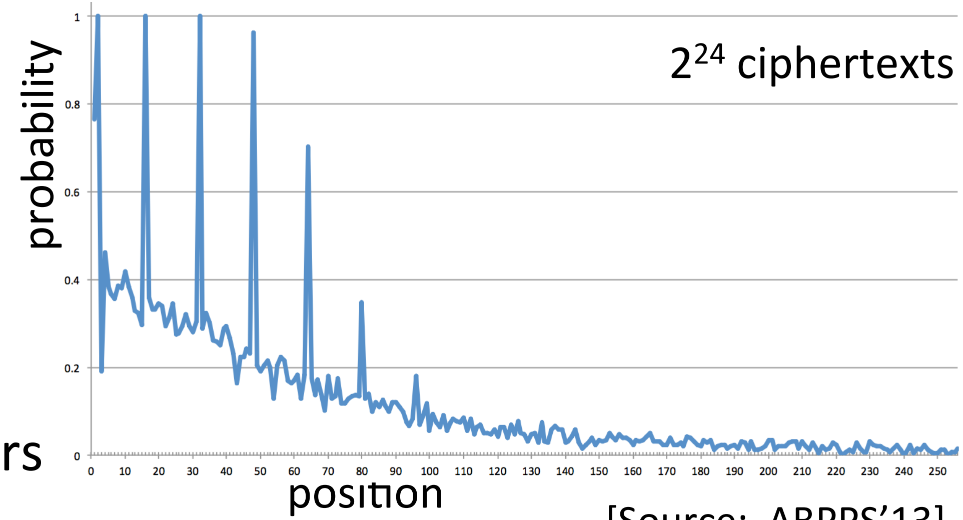
- Script tries all possibilities to expose 1st byte. Moves to 2nd bytes …

What to do: do not use compression with HTTPS

Peeking through SSL: weak algs. [ABPPS'13]

RC4: a stream cipher commonly used in HTTPS
(fast, other options in TLS 1.0 are problematic)

Bad news: [MS'01, M'02, ABPPS'13]
RC4 does not hide
plaintext well



[Source: ABPPS'13]

What to do:

- Push for TLS 1.2 support in browsers
- If must use RC4, pad HTTP headers so that nothing important in first 512 bytes

THE END