Computer Security

13. Web Security

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Original Browser

- Static content on clients
- Servers were responsible for dynamic parts
- Security attacks were focused on servers
  - Malformed URLs, buffer overflows, root paths, unicode attacks

Today's Browsers

Complex!

- JavaScript – allows code execution
  - NaCl – run native code inside a browser (sandboxed)
  - WebAssembly – virtual machine (like JVM) code
- Document Object Model (DOM) – change appearance of page
- XMLHttpRequest (AJAX) – asynchronously fetch content
- WebSockets – open interactive communication session between JavaScript on a browser and a server
- Multimedia support - <audio>, <video>, <track>
  - MediaStream recording (audio and video), speech recognition & synthesis
- Geolocation

WebAssembly (Wasm)

- WebAssembly allows for execution of compiled code
- Simple, stack-based virtual machine
  - Sandboxed & designed with security in mind … but so was Java
  - Control flow hijacks and heap buffer overflows have been demonstrated
- Harder to detect malware & more opportunities to disguise malware
- Has been great for cryptominers
  - Malicious web pages can run cryptomining software far more efficiently than with JavaScript
- No mechanism for a browser to check the integrity of the downloaded code

Complexity creates a huge threat surface

- More features → more bugs
- Browsers experienced a rapid introduction of features
- Browser vendors don’t necessarily conform to all specs
- Check out

  quirksmode.org

Multiple sources

- Most desktop & mobile apps come from one place
  - They may use external libraries, but those are linked in and tested
- Web apps usually have components from different places
- E.g., www.cnn.com has
  - **Fonts** from cdn.cnn.com
  - **Images** from turner.com, outbrain.com, bleacherreport.net, chartbeat.net
  - **Scripts** from amazon-adsystem.com, rubiconproject.com, bing.com, krxd.net, gigya.com, krxd.net, livefyre.com, fyre.co, optimizely.com, facebook.net, cnn.com, criteo.com, outbrain.com, sharethrough.com, doubleclick.net, googletagservices.com, ugdturner.com
  - **XMLHttpRequests** from zone-manager.izi, optimizely.com, chartbeat.com, cnn.io, rubiconproject.com
  - **Other content** from scorecardresearch.com, imnworldwide.com, facebook.com

What should code on a page have access to?

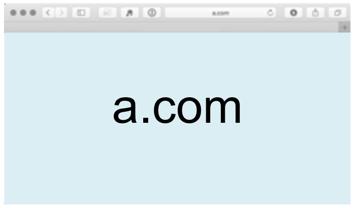
- Can analytics code access JavaScript variables from a script loaded from jQuery.com on the same page?
  - Scripts are from different places
    … ***but the page author selected them so shouldn't that be OK?***
- Can analytics scripts interact with event handlers?
- How about embedded frames?

Background: Frames and iFrames

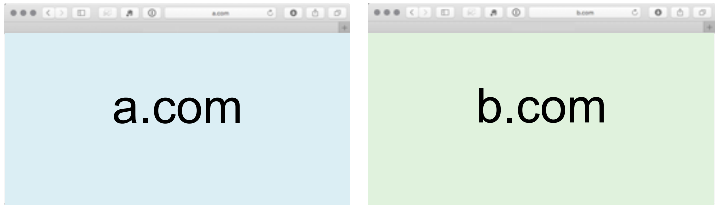
- Browser window may contain frames from different sources
  - Frame = rigid division as part of frameset
  - iFrame = floating inline frame
- Why use them?
  - Delegate screen area to content from another source
  - Browser provides isolation based on frames
  - Parent can continue to function even if frame is broken

Web security policy goals

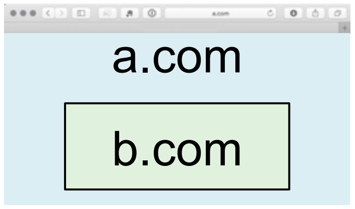
- Safe to visit an evil web site



- Safe to visit two pages at one time
  - Address bar distinguishes them



- Allow safe delegation
  - Frame inside a frame
  - Each frame = **origin** of the content within it
    - Enforce **same-origin policy**: a.com cannot access b.com's content
      b.com cannot access a.com's content



Same-origin Policy

Web application security model: **same-origin policy**

A browser permits scripts in one page to access data
in a second page ***only if*** both pages have the same origin

Origin = { URI scheme, hostname, port number }

- Same origin
  - http://www.poopybrain.com/419/test.html
  - http://www.poopybrain.com/index.html
- Different origin
  - https://www.poopybrain.com/index.html – different URI scheme (https)
  - http://www.poopybrain.com:8080/index.html – different port
  - http://poopybrain.com/index.html – different host

Goals of the same-origin policy

- Each frame is assigned the origin of its URL
- Each origin access to its own client-side resources
  - **Cookies**: simple way to implement state (*name, value* sets of data)
    - Browser sends cookies associated with the origin
  - **DOM storage**: key-value storage per origin
  - **JavaScript namespace**: functions & variables
  - **DOM tree**: JavaScript version of the HTML structure
- JavaScript code executes with the authority of its frame's origin
  - If cnn.com loads JavaScript from jQuery.com, the script runs with the authority of cnn.com
- Passive content (CSS files, images) has *no* authority
  - It doesn't (and shouldn't) contain executable code

Can two different frames communicate?

- Generally, no – they're isolated if they're not the same origin
- But postMessage() allows two independent frames to communicate
- Both sides have to opt in

Mixed content: http & https

- HTTPS page may contain HTTP content:

  `<script src="http://www.mysite.com/script.js"> </script>`

  – Active network attacker may now hijack the session

  – Content over the network is plain text

- Safer approach: don't specify the scheme (http or https)

  `<script src="//www.mysite.com/script.js"> </script>`

  – Served over the <u>same</u> protocol as the embedding page (frame)

- Some browsers warn you of mixed content

  – Some warning may be unclear to the user

Passive content has no authority

Makes sense … but why does it matter?

Usually no … but …

MIME sniffing attack

- Chance of security problems if browser parses object incorrectly
- Old versions of IE would examine leading bytes of object to fix wrong file types provided by the user
- Suppose a page contained passive content from an untrusted site
- Attacker could add HTML & JavaScript to the content
  - IE would reclassify the content

Cross-origin weirdness

- **Images**
  - A frame can load images from anywhere
  - But … same-origin policy does not allow it to inspect the image
  - However, it can infer the size of the rendered image
- **CSS**
  - A frame can embed CSS from any origin but cannot inspect the text in the file
  - **But**:
    It can discover what the CSS does by creating DOM nodes and seeing how styling changes
- **JavaScript**
  - A frame can fetch JavaScript and execute it … but not inspect it
  - But … you can call myfunction.toString() to get the source
  - Or … just download the source via a *curl* command and look at it

Cross-Origin Resource Sharing (CORS)

- Browsers enforce the same-origin policy
  - JavaScript can only access content from the same origin
    - Images, CSS, iframes within the page, embedded videos, other scripts, …
    - It cannot make asynchronous requests to other origins (e.g.,via XMLHttpRequest)
- But a page will often contain content from multiple origins
  - Images, CSS, scripts, iframes, videos
- **CORS** allows a server to define other origins (e.g., another domain name) as being equivalent
  - Example, a server at `service.example.com` may respond with

    ```
    Access-Control-Allow-Origin: http://www.example.com
    ```

  - Stating that it will treat `www.example.com` as the same origin

Cookies

- Mechanism created to allow websites to manage browser state
  - Cookies: <name, value> data stored in the browser
- Cookies are identified with a domain & a path

  `pk.org/419`

  All paths in the domain have access to the cookie
- Set at the client or server
  - JavaScript can set a cookie on the browser:

    document.cookie = “username=paul”;
  - Server can tell the browser to set a cookie by sending them in the HTTP header

    Set-Cookie: username=paul

When a browser generates an HTTP request it sends all matching cookies

Common uses for cookies

- **Authentication cookies**
  - Track whether a user is logged into a site
  - Upon successful login, the server sends a **session ID** cookie
  - This is sent with every future request to the site so it knows you’re logged in
  - Allows sites like Amazon, eBay, Instagram, Facebook to not prompt you for repeated logins
- **Tracking cookies**
  - Websites don’t need cookies to track you – they can look at logs
  - Cookies make it easier
    - Server creates a cookie containing a random ID when someone visits a page
    - The cookie is sent to every page you visit on the site
    - Server can build up a list of pages you visit correlated with your ID
      - It will be random if you’re not logged in – but can be correlated when you do log in

Third-party cookies: tracking

Third-party cookies: cookie that belongs to a domain other than the one on your URL bar

Common with pages containing content from other sides, such as banner ads

Because it belongs to the tracker’s domain

- … the cookie will be sent whenever you visit any other website that uses the same tracking server
- The website will see the same ID in the cookie so it can correlate what sites you visited

Most browsers allow you to block third-party cookes

- But trackers find ways to track you without using cookies

Cookies

- Cookies are often used to track server sessions
  - If malicious code can modify the cookie or give it to someone else, an attacker may be able to
    - View your shopping cart
    - Get or use your login credentials
    - Have your web documents or email get stored into a different account

- HttpOnly flag: disallows scripts from accessing the cookie
  - Sent in a `Set-Cookie` HTTP response header

- Secure flag: send the cookie only if there is an https session

```
Set-Cookie: username=paul; path=/; HttpOnly; Secure
```

Cross-Site Request Forgery (XSRF)

- A browser sends cookies for a site along with a request
- If an attacker gets a user to access a site
  … the user's cookies will be sent with that request
- If the cookies contain the user's identity or session state
  - The attacker can create actions on behalf of the user
- Planting the link
  - Forums or spam
    http://mybank.com/?action=transfer&amount=100000&to=attacker_account

Cross-Site Request Forgery (XSRF)

Defenses

- Validate the *referrer header* at the server
- Require unique tokens per request
  - Add randomness to the URL that attackers will not be able to guess
  - E.g., legitimate server can set tokens via hidden fields instead of cookies

- Default-deny browser policy for cross-site requests
  (but may interfere with legitimate uses)

Screen sharing attack

- HTML5 added a screen sharing API
- Normally: no cross-origin communication from client to server
- This is violated with the screen sharing API
  - If a frame is granted permission to take a screenshot, it can get a screenshot of the entire display (monitor, windows, browser)
  - Can also get screenshots within the user's browser without consent
- User might not be aware of the scope of screen sharing

http://dl.acm.org/citation.cfm?id=2650789

http://mews.sv.cmu.edu/papers/oakland-14.pdf

Input sanitization

Remember SQL injection attacks?

- Any user input must be parsed carefully

```
<script> var name = “untrusted_data”; </script>
```

- Attacker can set `untrusted_data` to something like:

```
hi”; </script> <h1>Hey, some text!</h1> <script> malicious code …
```

- **Sanitization** should be used with any user input that may be part of
  – HTML
  – URL
  – JavaScript
  – CSS

Shellshock attack

Privilege escalation vulnerability in bash

- Function export feature is buggy, allowing functions defined in one instance of bash to be available to other instances via environment variable lists

- Discovered in 2014 … but existed since 1989!

- Web servers using CGI scripts (Common Gateway Interface)
  - HTTP headers get converted to environment variables
  - Command gets executed by the shell via *system()*

```
env x='() { :;}; echo vulnerable' bash -c "echo this is a test"
```

- Bogus function definition in bash
  - Bash gets confused while parsing function definitions and executes the second part ("echo vulnerable"), which could invoke any operation

Cross-Site Scripting (XSS)

Code injection attack

- Allows attacker to execute JavaScript in a user's browser
- Exploit vulnerability in a website the victim visits
  - Possible if the website **includes user input** in its pages
  - Example: user content in forums (feedback, postings)
- What's the harm?
  - Access cookies related to that website
  - Hijack a session
  - Create arbitrary HTTP requests with arbitrary content via XMLHtttpRequest
  - Make arbitrary modifications to the HTML document by modifying the DOM
  - Install keyloggers
  - Download malware – or run JavaScript ransomware
  - Try phishing by manipulating the DOM and adding a fake login page

Types of XSS attacks

- **Reflected XSS**
  - Malicious code is not stored anywhere
    - It is returned as part of the HTTP response
    - **Only impacts users who open a malicious link or third-party web page**
    - **Attack string is part of the link**
  - Web application passes unvalidated input back to the client

    The script is in the link and is returned in its original form & executed

```
www.mysite.com/login.asp?user=<script> malicious_code(…) </script>
```

- **Persistent XSS**
  - Website stores user input and serves it back to other users at a later stage
  - Victims do not have to click on a malicious link to run the payload
  - Example: forum comments

XSS Defenses

- One of the problems in preventing XSS is character encoding
  - Filters might check for "`<script>`" but not "`%3cscript%3e`"
- Key defense is **sanitizing ALL user input**
  - E.g., Django templates: `<b> hello, {{name}} </b>`
- Use a less-expressive markup language for user input
  - E.g., markdown
- Privilege separation
  - Use a different domain for untrusted content
    - E.g., googleusercontent.com for static and semi-static content
    - Limits damage to main domain
- **Content Security Policy** (CSP)
  - Designed to prevent XSS & clickjacking
  - Allows website owners to identify approved origins of content & types of content

SQL Injection & pathnames

We examined these earlier

SQL Injection

- Many web sites use a back-end database
- Links contain queries mixed with user input

```
query = “select * from table where user=” + username
```

Pathnames

- Escape the HTML directory

```
//mysite/images/../../../etc/shadow
```

Homograph attacks

Unicode confusion

Unicode represents virtually all the worlds glyphs

Some symbols look the same (or similar) but have different values

Potential for deception

They're totally different to software but look the same to humans

/ = solidus (slash) = U+002F

⁄ = fraction slash = U+2044

∕ = division slash = U+2215

̷ = combining short solidus overlay = U+0337

̸ = combining long solidus overlay = U+0338

／ = fullwidth solidus = U+FF0F

Yuck!

Paul ≠ Paul

Paul ≠ ΡаυI

This is an uppercase i

This is a Greek υ (upsilon)

This is a Cyrillic a

This is a Greek P

Homograph (Homoglyph) Attacks

- Some characters may look alike:
  - 1 (one), l (L), I (i)
  - 0 (zero), O
- Homograph attack = deception
  - paypal.com vs. paypaI.com (I instead of L)
- It got worse with internationalized domain names (IDN)
  - wikipedia.org
    - Cyrillic a (U+0430), e (U+435), p (U+0440)
    - Belarusian-Ukrainian i (U+0456)
  - Paypal
    - Cyrillic P, a, y, p, a; ASCII l

Check out the Homoglyph Attack Generator at
https://www.irongeek.com/homoglyph-attack-generator.php

https://en.wikipedia.org/wiki/IDN_homograph_attack

Network addresses

- A frame can send http & https requests to hosts that match the origin
- **The security of *same origin* is tied to the security of DNS**
  - Recall the DNS rebinding attack
    - Register attacker.com; get user to visit attacker.com
    - Browser generates request for attacker.com
    - DNS response contains a really short TTL
    - After the first access, attacker reconfigures the DNS server
      - Binds attacker.com to the victim's IP address
  - JavaScript on a site can fetch a new object from a different address
    - Web browser only sees the domain name and thinks request goes to an external site
    - Really, it goes to a server in the victim's network
  - The attacker can access data within the victim's servers and send data back to an attacker's site … all by dynamically changing the name-address mapping

Network addresses

- Solution – no foolproof solutions
  - Don’t allow DNS resolutions to return internal addresses
  - Force longer TTL even if the DNS response has a short value

Images

Clickjacking

- Attacker overlays an image to trick a user to clicking a button or link
- User sees this

FREEiPad
Click Here

- Not realizing there's an ***invisible frame*** over the image
- Clicking there could generate a Facebook *like*
  … or download malware
  … or change security settings for the Flash plugin
- Defense
  – JavaScript in the legitimate code to check that it's the top layer
    `window.self == window.top`
  – Set `X-Frame-Options` to not allow frames from other domains

GIFAR attack

- Java applets are sent as JAR files
  - This is just a zip format
  - Header is stored at the *end* of the file
- GIF files are images
  - Header is stored at the *beginning* of the file
- We can combine the two files: gif + jar
- GIFAR attack
  - Submit a GIFAR file (myimage.gif) to a site that only allows image uploads
  - Use XSS to inject `<applet archive:”myimage.gif”>`
  - Code will run in the context of the server
    - Attacker gets to run with the authority of the origin (server)

HTML image tags

```
<img src="http://pk.org/images/balloons.jpg" height="300" width="400"/>
```

- Images are static content with no authority
- Any problems with images?

HTML image tags

```
<img src="http://evil.com/images/balloons.jpg?extra_information"
height="300" width="400"/>
```

- URL may pass arguments
  - Communicate with other sites
- Hide resulting image

  `<img src="…" height="1" width="1"/>`

Common way for a sender to force HTML-formatted email to provide read notifications

Almost 25% of mail messages contain a tracking link. Of popular sending domains, about 50% perform tracking

Example tracking pixel

```
<img height="1" width="1" style="display:none”
src="https://www.facebook.com/tr?id=156391275199118&amp;ev=PageView&amp;noscript=1"/>
s
```

- Origin = www.facebook.com
- Accessing the web page with this pixel will
  - Contact Facebook to get the “value”
  - Send Facebook cookies from your browser to Facebook
  - Enable Facebook to record the fact that you visited this page

Deception via image tags

Social engineering: add logos to fool a user

- Impersonate site
- Impersonate credentials

Bank of America

Merrill Lynch
Bank of America Corporation

charles SCHWAB

ebay

IRS
Department of the Treasury
Internal Revenue Service

Citi Private Bank
citi

PayPal

COMODO SECURE

Certification Authorities
WebTrust

100% SECURE 100% SECURE

SAFE & SECURE

Norton SECURED
powered by digicert

Encrypted sessions & Authenticating the server

HTTP communication

- The web uses HTTP: Hypertext Transfer Protocol
- Like many IP-based protocols, HTTP sends contents as plain text
  - No validation that you are talking to the legitimate server
  - No encryption of content
  - No assurance that content is not modified
- DNS or DHCP attacks
  - Can get you to connect to the wrong server
- An eavesdropper can
  - See all requests & responses
  - Including cookies (which may contain login session IDs)

HTTP vs. HTTPS

- SSL/TLS provide a way to add authenticated, encrypted communications with integrity assurance over any TCP service
- This enables the creation of “secure” versions of protocols

– ftp → sftp	file transfer protocol
– rcp → scp	remote copy
– http → https	hypertext transfer protocol

- HTTPS is just HTTP over an TLS session
  - Optional server authentication (server provides certificate)
  - Symmetric data encryption with forward secrecy
  - MAC for message integrity

Secure ≠ trustworthy

- HTTPS is a good thing!
- Browsers would display a padlock icon to tell a users that their session is over a secure link (TLS)
- This gave users a false sense of security
  - It does not mean that you are not talking to a phishing site
  - Anyone can get a certificate and create a website
    - E.g., gooogle.com, g00gle.com
  - A large % of phishing sites will present the TLS padlock icon

Extended Validation Certificates

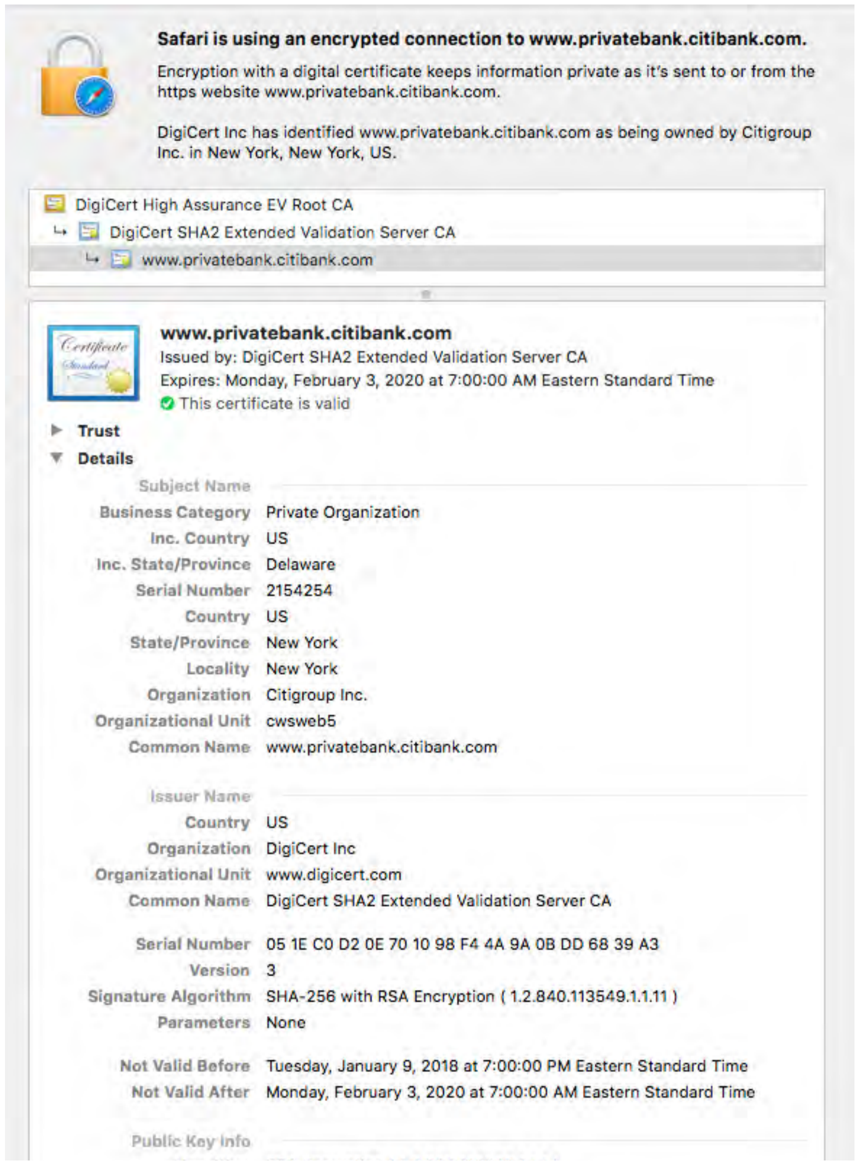
For SSL/TLS authentication to be meaningful, the server's X.509 certificate must belong to the party the user believes it belongs to

- **Domain validated** certificates
  - Only require proof of domain control – prove the site has the private key
  - Do not prove that a legal entity has a relationship with the domain
- **Extended validation** (**EV**) certificates
  - Belong to the legal entity controlling the domain (or software)
  - Certificate Authority must validate the entity's identity
    - More stringent validation: check company incorporation, domain registration, position of applicant, etc.

Extended Validation Certificates

EV certificate will contain

- Government-registered serial number
- Physical address
- + the usual stuff: name, location, issuer, …



Safari is using an encrypted connection to www.privatebank.citibank.com.

Encryption with a digital certificate keeps information private as it's sent to or from the https website www.privatebank.citibank.com.

DigiCert Inc has identified www.privatebank.citibank.com as being owned by Citigroup Inc. in New York, New York, US.

DigiCert High Assurance EV Root CA
↳ DigiCert SHA2 Extended Validation Server CA
↳ www.privatebank.citibank.com

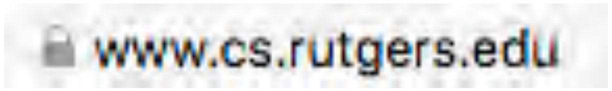
www.privatebank.citibank.com
Issued by: DigiCert SHA2 Extended Validation Server CA
Expires: Monday, February 3, 2020 at 7:00:00 AM Eastern Standard Time
✓ This certificate is valid

▶ **Trust**
▼ **Details**

Subject Name	
Business Category	Private Organization
Inc. Country	US
Inc. State/Province	Delaware
Serial Number	2154254
Country	US
State/Province	New York
Locality	New York
Organization	Citigroup Inc.
Organizational Unit	cwsweb5
Common Name	www.privatebank.citibank.com
Issuer Name	
Country	US
Organization	DigiCert Inc
Organizational Unit	www.digicert.com
Common Name	DigiCert SHA2 Extended Validation Server CA
Serial Number	05 1E C0 D2 0E 70 10 98 F4 4A 9A 0B DD 68 39 A3
Version	3
Signature Algorithm	SHA-256 with RSA Encryption (1.2.840.113549.1.1.11)
Parameters	None
Not Valid Before	Tuesday, January 9, 2018 at 7:00:00 PM Eastern Standard Time
Not Valid After	Monday, February 3, 2020 at 7:00:00 AM Eastern Standard Time
Public Key Info	

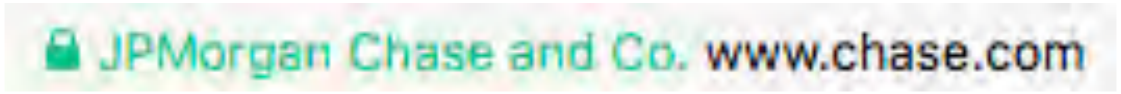
Extended Validation Certificates

- Browsers would show a lock icon for *any* SSL/TLS connection



www.cs.rutgers.edu

- Modern browsers
  - Identify & validate EV certificates
  - Present a security indicator that identifies the certificate owner



JPMorgan Chase and Co. www.chase.com

Can You Trust the Browser Status Bar?

Mouseover on a link shows link target

https://www.paypal.com/signin/

Trivial to spoof with JavaScript

```
<a href="http://www.paypal.com/signin"
        onclick="this.href = 'http://www.evil.com/';">
        PayPal</a>
```

The situation is not good

- HTML, JavaScript, and CSS continue to evolve
- All have become incredibly complex
- Web apps themselves can be incredibly complex, hence buggy
- Web browsers are forgiving
  - You don’t see errors
  - They try to correct syntax problems and guess what the author meant
  - Usually, *something* gets rendered

The end