CSE 361: Web Security

CSRF, XSSI, SRI, and Sandboxing

Nick Nikiforakis
CSRF (Sea Surf)
Regular Web site usage

https://acmebank.com

Destination account: 123-456-789
Amount: $50
Submit

Behind the scenes

<form method="POST"
target=https://acmebank.com/transfer>
  <input type="text" name="acct-to">
  <input type="text" name="amount">
  <input type="submit">
</form>
Forcing browser to perform an action for the attacker
Cross-Site Request Forgery (CSRF / "Sea Surf")

- Web application does not ensure that state-changing request came from "within" the application itself

- Attack works for GET ...
  - Image tag with src attribute:
    ```html
    <img src="https://acmebank.com/transfer?to=attacker&amount=10000">
    ```
  - Hidden iframes, css files, scripts, ...

- and POST
  - create iframe (or pop-up window)
  - fill created viewport with prefilled form
  - submit form

• digg.com determines frontpage based on how many "diggs" a story gets
• vulnerable against CSRF, could be used to digg an URL of the attacker's choosing
• Guess which article made it to the front page...
CSRF Example: WordPress < 2.06 (2007)

- WordPress theme editor was susceptible
- WordPress themes are PHP files
- Attacker could modify files when logged-in admin visited his page
  - arbitrary code execution on targeted page
CSRF Example: Gmail filters (2007)

• Google Mail insufficiently protected against CSRF
• Attacker could add mail filters
  • e.g., forward all emails to a certain address
• According to a victim, this led to a domain takeover
  • Attacker adds redirect filter
  • Attacker request AUTH code for domain transfer
  • Voila
  • Actually, this incident occurred after the bug was fixed...
CSRF Example: TP-Link routers (CVE-2013-2645)

- TP-Link Web interface was vulnerable to configuration changes via CSRF
  - set root of built-in FTP server, enable FTP via WAN, ...
  - modify DNS server
- Exploited in the wild to change DNS server
  - redirects all DNS traffic to attacker's server
    - leaking all visited domains
    - allowing for trivial MitM attacks
- Only worked when user was logged in
CSRF in 2017 to 2019

- CVE-2017-7404 D-Link router, firmware upload possible
- CVE-2017-9934 Joomla! CSRF to XSS
- CVE-2018-100053 LimeSurvey Delete Themes
- CVE-2018-6288 Kaspersky Secure Mail Gateway Admin Account Takeover
- CVE-2019-10673 WordPress CSRF to change admin email, password recovery for full compromise
(Not really) Preventing CSRF: Refer(r)er Checking

• CSRF entails cross-domain requests
  • in theory, these should carry a referrer
  • server could decide based on header

• In practice, there are several problems
  • Middleboxes/proxies might strip (complete URL is sent, privacy concerns)
  • Attacker may strip Referer header by
    • using a data: URL
    • Referrer-Policy header

• Utility vs. Security trade-off
  • what do we do when the header is not present?
Preventing CSRF: Origin Header Checking

• Privacy-friendly version of Referer
  • Contains only the origin, not the complete URL
• Always sent along XMLHttpRequests and WebSockets
  • requires changing program logic to use these requests for state-changing operations
• In modern browsers, also sent along with any cross-origin POST requests
  • server should not necessarily rely on only having modern clients, though

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Sent URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Referer</td>
<td><a href="https://www.news.com/blahblah?foo=bar">https://www.news.com/blahblah?foo=bar</a></td>
</tr>
<tr>
<td>Origin</td>
<td><a href="https://www.news.com">https://www.news.com</a></td>
</tr>
</tbody>
</table>
Regular Web site usage

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Behind the scenes

<form method="POST"
target=https://acmebank.com/transfer">
  <input type="text" name="acct-to">
  <input type="text" name="amount">
  <input type="hidden" name="tk" value="n73gn9ia345ntu">
  <input type="submit">
</form>

Transfer OK
Preventing CSRF: Using CSRF tokens/nonces

```
<form method="POST" action="https://acmebank.com/transfer"
id="transfer">
  <input type="hidden" name="act-to" value="987-654-3210">
  <input type="hidden" name="amount" value="100000">
  <input type="hidden" name="tk" value="noclue">
</form>
<script>
  transfer.submit()
</script>
```
Preventing CSRF: Using CSRF tokens/nonces

- Server generates token randomly for user
  - stores currently valid token in session for user
- Tokens are placed in all forms
  - inaccessible to the attacker without an XSS due to the SOP
- On submission, checks server-side token against submitted token
  - only allows action if tokens match
- Assures that a request's origin must be in the same origin
Preventing CSRF: Double Submit Cookie

https://acmebank.com

Destination account: 123-456-789
Amount: $50

Transfer OK
Preventing CSRF: Double Submit Cookie

• Require value in posted content to match value of certain cookie
  • generate token randomly on server, store in cookie
  • insert cookie's value into each form
    • server-side addition for protected forms or
    • via JavaScript after form was loaded

• Advantage: no server-side state required
  • just compare submitted form value against cookie

• Disadvantage: cookie tossing
  • If an attacker controls a subdomain, he might set token value
  • if the server only compares cookie and form token, CSRF protection is bypassed
Preventing CSRF: Custom Headers

- Idea: use XMLHttpRequests for all state-changing requests
  - and attach a custom header (e.g., "X-CSRF-Free")
  - only handle requests with that header on the server

- Protection by existing technologies
  - Same-domain requests are always allowed
  - Cross-domain requests with custom headers requires pre-flight CORS request

- Advantage: no server-side state or randomness required

- Disadvantage: applications must be changed
Preventing CSRF: Same-Site Cookies

• Two modes
  • Strict: even in top-level navigation, never send cookies with cross-origin request
    • if facebook.com set that, every user following a link there would not be logged in
  • Lax: non top-level navigation will not send cookies
    • cookies only send along with safe requests (GET, HEAD, OPTIONS, TRACE)
    • protects against POST-based CSRF, not against GET-based though

• Until May 2018 only supported by Chrome and Opera
• Since Chrome 80, defaults to SameSite=lax
  • SameSite=none only works with Secure flag
CSRF Conclusion

• CSRF caused by servers accepting requests from outside their origin
  • hard to determine based on Referer header though
• CSRF can have severe effects
  • compromised firmware, hijacked Web sites, ...
• Several options for fixing exist
  • CSRF tokens nowadays implemented in any (good) framework
  • protection can be achieved using well-established principles (SOP, CORS)
  • SameSite cookies also address the issue, already default in Chrome

• Support still varies (https://caniuse.com/?search=samesite)
  • Use defense in depth
Cross-Origin Data Leakage
JSON/JavaScript Hijacking (2006)

• Recall from previous lectures
  • script inclusion is exempt from SOP
  • all requests are made with cookies attached

```html
<script src="/gmail.com/contacts.json"></script>
```
JSON/JavaScript Hijacking (2006)

• Recall from previous lectures
  • script inclusion is exempt from SOP
  • all requests are made with cookies attached

Based on browser quirks, fixed nowadays

```html
<script>
// Override array constructor
function Array() {
  // Steal data here
}
</script>
<script src="//gmail.com/contacts.json">
</script>
```

```
[
  {"ct": "John Doe", "foo@gmail.com" },
  {"ct": "Jane Doe", "bar@gmail.com" }
]
```
Cross-Site Scripting Inclusion (XSSI)

- Regular scripts may also be dynamically generated
  - We cannot read the source code, but can observe side-effects
Exploiting XSSI

// Local variable at top level
var first_name = "John";

// Global variable due to missing var keyword
last_name = "Doe";

// Explicitly defined global variable
window.user_email = "john@doe.com";

function example() {
    var email = "john@doe.com";
    window.MyLibrary.doSomething(email);
}

example();

console.log(first_name);
console.log(last_name);
console.log(user_email);

window.MyLibrary = {};
window.MyLibrary.doSomething = function(email) {
    console.log(email);
}
Exploiting XSSI

```javascript
function example2() {
    var secret_values = ["secret", "more secret"];

    secret_values.forEach(function(secret) {
        // do something secret in here
    });
}
example2();
```

```javascript
(function() {
    function test(someInput) {
        var email = "john@doe.com";
        doNothingWithEmail(someInput);
    }

    test.call(someThing, "myInput");
})();
```

```javascript
Array.prototype.forEach = function(callback) {
    // "this" is bound secret_values
    console.log(this);
}
```

```javascript
Function.prototype.call = function() {
    // "this" is bound test
    console.log(this.toString());
};
```
Exploiting XSSI

• Trivial case: global variables registered
  • simply access the variable (registered in global scope of site)
• Little more involved: global function called
  • overwrite function (if necessary, create object before)
• Local variables accessible if functions are called on them
  • overwrite prototype
  • e.g., forEach or call
Identifying potential XSSI\textsuperscript{[USENIX15]}

- On each page visit, request included scripts twice
  - with and without cookies
- Diff the two results
XSSI in the Wild [USENIX15]

- Conducted a study of 150 highest-ranked sites with logins
  - sites for which we could create a login (not banks, for example)

<table>
<thead>
<tr>
<th></th>
<th>Domains</th>
<th>Exploitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic scripts</td>
<td>49</td>
<td>40</td>
</tr>
<tr>
<td>Unique identifier</td>
<td>34</td>
<td>28</td>
</tr>
<tr>
<td>Other personal data</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>CSRF / auth tokens</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

- Several high impact flaws
  - leaked credit card info on my own bank
  - reading senders and subjects of emails
  - account hijacking for file hosting service
Preventing XSSI

• Scripts must not be loadable from other origins
  • referrer checking (recall the problems associated with that)
  • use of secret tokens (similar to CSRF)
• Only provide code in scripts, use provisioning service for data
  • use XHR to retrieve data
  • easily protectable by SOP or CORS
• Use inline scripts only
  • with CSP nonces, even possible to use with CSP
  • can not be included remotely, hence data is secure there
The Great Cannon
Including third-party resources on the Web

```html
<html>
  ....
  <script src="/googletagmanager.com/tag.js">
  </script>
  ...
</html>

var tags = "cnn.com";
document.write("Doing tagging stuff here");
// ...
```
Including third-party resources on the Web (with MitM)

```html
<html>
  ....
  <script src="//googletagmanager.com/tag.js"
  </script>
  ...
</html>

var target = "http://github.com"
var x = new XMLHttpRequest();
x.open("GET", target);
// ...
```
The Great Cannon

• China already has a powerful firewall
  • "The Great Firewall"
  • drops unwanted connections (e.g. NY Times)

• Mirror sites exists for blocked sites
  • e.g., greatfire.org and several GitHub repos

• Great Cannon injected JavaScript into content from, e.g., baidu.com
  • millions of users opened connections to GitHub, New York Times, greatfire.org

• Massively Distributed Denial of Service

https://citizenlab.ca/2015/04/chinas-great-cannon/
Subresource Integrity (SRI)

• To thwart such injection attacks, SRI was proposed

• Use cryptographic hash of remote resource
  • for scripts and style sheets
  • if hash does not match, resource is ignored

```html
<script src="https://code.jquery.com/jquery-2.1.4.min.js"
integrity="sha384-R4/ztc4ZlRqWjqIuvf6RX5yb/v90qNGx6fS48N0tRxiGkqveZETq72KgDVJCp2TC"
crossorigin="anonymous"></script>

• Protects against malicious CDNs/MitM attackers
  • also allows to pin to a specific version of third-party libraries

```

```html
<script>window.jQuery || /* reload from own domain here */;</script>
```
Subresource Integrity (SRI)

• SRI resources must be CORS-enabled
  • otherwise, SRI could be used to test remote resource for certain content
• Integrity attribute can have multiple values
  • Only strongest hash is used

```
<script src="https://code.jquery.com/jquery-2.1.4.min.js"
integrity="sha384-R4/ztc4ZlRqWjv6f5y6fS480tRxiGkqveZETq72KgDVJcp2TC sha256-8WqyJLuWKBBVhxXIL1jBDD75DxU9360ZkCnxQbWwJVw="
crossorigin="anonymous"></script>
```

• Cannot be used to allow different versions of a script

```
<script src="https://code.jquery.com/jquery-2.1.4.min.js"
integrity="sha256-t1X5SBfMY4/0kYdt8H1CP/90Gg0i1G6U9UnjC6AVYHA= sha256-8WqyJLuWKBBVhxXIL1jBDD75DxU9360ZkCnxQbWwJVw="
crossorigin="anonymous"></script>
```
Sandboxing Content
Multi-origin Web applications

• Modern Web applications use code from multiple origins
  • Analytics
  • Advertisement
  • Maps
  • ....
• Even framed content may, e.g., open a popup
  • or redirect the parent frame
• Necessity for control privileges of included content arises
  • putting everybody in their own little sandbox
Sandboxing iframes

• Limits iframe's ability to conduct certain actions
  • e.g., disable JavaScript, putting them in an isolated origin
• Just adding sandbox to the iframe will restrict everything
  • rights have to be granted explicitly
    • allow-forms: allows for form submission in iframe
    • allow-popups: enables popups
    • allow-pointer-lock: enable PointerLock API to get raw mouse movements
    • allow-scripts: enable scripting
    • allow.same-origin: enable origin of included page, not isolated one
    • allow-top-navigation: enables navigating the top frame
Sandbox usage examples

Parent page

```html
<textarea id='code'></textarea>
<button id='safe'>eval() in a sandboxed frame.</button>
<iframe sandbox='allow-scripts' id='sbox' src='frame.html'></iframe>

<script>
    function evaluate() {
        sandboxed.contentWindow.postMessage(code.value, '*');
    }
    safe.addEventListener('click', evaluate);

    window.addEventListener('message', function (e) {
        if (e.origin === "null" && e.source === sbox.contentWindow) {
            alert('Result: ' + e.data);
        }
    });
</script>
```

frame.html

```html
<script>
    window.addEventListener('message', function (e) {
        if (e.origin !== "https://main.com") {
            return;
        }
        var mainWindow = e.source;
        var result = '';
        try {
            result = eval(e.data);  
        } catch (e) {
            result = 'eval() threw an exception.';
        }
        mainWindow.postMessage(result, e.origin);
    });
</script>
```

https://www.html5rocks.com/static/demos/evalbox/index.html
Determining least privilege

- Example: tweet button
  - opens popup window
  - submit a form
  - sends authenticated request to twitter.com (using and accesses document.cookie)

- Requires four permissions
  - allow-popups (well, it opens a popup..)
  - allow-forms (well, it is a form?)
  - allow-same-origin (JavaScript needs access to cookies)
  - allow-scripts (not too much of a surprise)
Determining least privilege

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Sandbox usage examples
Credits

- Original slide deck by Ben Stock
- Modified by Nick Nikiforakis