CSE 361: Web Security
Cross-domain Communication

Nick Nikiforakis
A World Without Separation between Sites

http://kittenpics.org

https://gmail.com
The Same-Origin Policy for JavaScript

• Most basic access control policy
  • controls how active content can access resources

• Same-Origin Policy for JavaScript for three actions
  • Script access to other document in same browser
    • frames/iframes
    • (popup) windows
  • Script access to application-specific local state
    • cookies, Web Storage, or IndexedDB
  • Explicit HTTP requests to other hosts
    • XMLHttpRequest
The Same-Origin Policy for JavaScript

- Only allows access if origins match
  - Origin defined by protocol, hostname, and port

<table>
<thead>
<tr>
<th>Originating document</th>
<th>Accessed document</th>
<th>Non-IE Browser</th>
<th>Internet Explorer</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://example.org/a">http://example.org/a</a></td>
<td><a href="http://example.org/b">http://example.org/b</a></td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td><a href="http://example.org">http://example.org</a></td>
<td><a href="http://www.example.org">http://www.example.org</a></td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td><a href="http://example.org">http://example.org</a></td>
<td><a href="https://example.org">https://example.org</a></td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td><a href="http://example.org">http://example.org</a></td>
<td><a href="http://example.org:81">http://example.org:81</a></td>
<td>✗</td>
<td>✔️</td>
</tr>
</tbody>
</table>
Domain Relaxation

- Two sub-domains of a common parent domain want to communicate
  - Notably: can overwrite different port!

- Browsers allow setting `document.domain` property
  - Can only be set to valid suffix including parent domain
    - `test.example.org` -> `example.org` ok
    - `example.org` -> `org` forbidden

- When first introduced, relaxation of single sub-domain was sufficient
- Nowadays: both (sub-)domains must explicitly set `document.domain`
Domain Relaxation

http://sub.kittenpics.org

```
document.domain = "kittenpics.org"
```

http://kittenpics.org

```
document.domain = "kittenpics.org"
```
Domain Relaxation

document.domain = "kittenpics.org"
Cross-Origin Communication
Cross-origin communication

• Subdomains of the same domain can use domain relaxation when they want to talk to one another.

• What happens when two different domains want to be able to communicate?
  • E.g. Access your Dropbox files via your Gmail account?

• No way to “relax” to a different domain
• Same Origin Policy will block the access
  • JavaScript can be used to automatically submit an HTML form but cannot read the response
Cross-Domain Communication: window.name

• SOP prohibits access to other document's window object
  • unless origins match/are relaxed

• On the Web, there is always an exception to the rule
  • in this case, the name of a window

• Dirty Hack
  • load "communication partner" in frame
  • have other site set window.name
  • access frame.name

• Should not really be used for anything new
Cross-Domain Communication: JSONP

• Recall Web model: may include resources from remote origins
  • access from JavaScript to cross-domain resources is restricted though

• Weird case: scripts
  • can be included from remote origin
  • execute in **including** origin (side effects observable on global scope)
  • source code not accessible from including page

• JSONP ("JSON with Padding") (ab)uses this
  • callback function as parameter
  • creates script code dynamically
$.getJSON("https://mail.google.com/userdata.json", function (userdata) {
  // handle userdata here
})

<script>
  function read(userdata) {
    // handle userdata here
  }
</script>
<script src="https://mail.google.com/user.js?cb=read"></script>
The Rosetta Flash Attack

- Discovered in 2014 by Michele Spagnuolo of Google
- **Flash does not inherit origin when included**
  - Flash on a.com can conduct GET and POST requests (with cookies) to a.com
  - even if it is included in b.com
- JSONP allows attacker to control first bytes of a file (callback function)
  - albeit most likely only ASCII characters
- Flash will execute any file as SWF if
  - object tag with correct Content-Type is used
  - file appears to be valid flash
The Rosetta Flash Attack

• Requirement for big trouble: find ASCII-only Flash file
  • possible by utilizing zlib and Huffman encoding in just the right way
  • See https://miki.it/blog/2014/7/8/abusing-jjsonp-with-rosetta-flash/ for technical details

• Exploit by setting callback parameter accordingly
  • `<object type="application/x-shockwave-flash" data="https://vulnerable.com/endpoint?callback=CWSMIKI0hCD0Up0IZUnnnnnnnnn..">` <object>

• Affected Google, Twitter, LinkedIn, ...
JSONP Drawbacks

• Dirty hack around the Same-Origin Policy
• Full trust on remote website
  • Website providing a JSONP response can instead provide malicious code
• No error management
  • What happens when the cross-origin JSONP request fails (e.g. 404 response)?
• Only "security" measure: Referer checking
  • Referer can be stripped
    • on purpose by attacker
    • for privacy reasons by proxies
• Callback controllable by attacker
  • partially controllable resource on JSONP-hosting server
Cross-Domain Communication: CORS

- Goal: enable fine-grained cross-domain access
- Result: Cross-Origin Resource Sharing
  - Policy sent by server, interpreted by browser accordingly
  - Uses Origin header (not complete URL)
- HTTP headers sent along with response
  - for simple requests, headers interpreted by browser afterwards
CORS Concept (simple request)

```javascript
var xhr = new XMLHttpRequest();
xhr.open('GET', 'https://mail.google.com/userdata.json');
xhr.withCredentials = true;
xhr.send(null);
```

HTTP/1.1 200 OK
Access-Control-Allow-Origin: https://google.com
Access-Control-Allow-Credentials: true

JSON

https://mail.google.com
CORS Response Headers (part 1)

- **Access-Control-Allow-Origin**: `<origin> | *`
  - Controls whether origin can access
  - * allows all, but cannot be used with credentialed requests
  - **Secure by default**

- **Access-Control-Allow-Credentials**
  - Controls whether response can also be read if credentials (mostly cookies) were requested

- **Access-Control-Expose-Headers**
  - Specifies which headers may be accessed by JavaScript
  - By default, 6 simple response headers are always allowed
    - Cache-Control, Content-Language, Content-Type
    - Expires, Last-Modified, Pragma
CORS Complex requests

- CORS serves both functionality and security goals
  - Allow cross-domain sharing of data
  - Must not make requests less secure
- Idea: simple requests can be executed via JavaScript in any case
  - POST/GET requests by automatically filling a form
  - Everything that goes beyond capability of JS + forms must be protected
- Complex requests require **preflight** request
  - e.g., PUT/DELETE/CONNECT, custom headers, …
  - preflight: OPTIONS request with requested parameters
CORS Preflight requests

```javascript
var xhr = new XMLHttpRequest();
xhr.open('GET', 'https://mail.google.com/userdata.json', true);
xhr.setRequestHeader('Custom', 'Header')
xhr.withCredentials = true;
xhr.send(null);
```

OPTIONS /userdata.json
Origin: https://google.com
Access-Control-Request-Headers: Custom
Access-Control-Request-Method: GET

HTTP/1.1 200 OK
Access-Control-Allow-Origin: https://google.com
Access-Control-Allow-Credentials: true
Access-Control-Allow-Headers: Custom
Access-Control-Allow-Methods: GET

GET /userdata.json
Custom: Header

JSON

https://mail.google.com
CORS Request Headers

• Access-Control-Request-Method
  • Specify which HTTP method is supposed to be used by following cross-origin request

• Access-Control-Request-Headers
  • List all headers that client wants to use for subsequent request

• Origin
  • Contains origin of the resource wanting to make a cross-origin request
  • (privacy-friendly: no full URL)
CORS Response Headers (part 2)

- **Access-Control-Max-Age**
  - Control cache lifetime of **preflight** request

- **Access-Control-Allow-Methods**
  - Determines which HTTP methods are allowed by preflighted request

- **Access-Control-Allow-Headers**
  - Determines which HTTP headers may be sent by client in preflighted request
CORS - How you can still mess up

```php
function cors() {
   // Allow from any origin
   if (isset($_SERVER['HTTP_ORIGIN'])) {
      // Decide if the origin in
      // $_SERVER['HTTP_ORIGIN'] is one
      // you want to allow, and if so:
      header("Access-Control-Allow-Origin: {$_SERVER['HTTP_ORIGIN']}";
      header("Access-Control-Allow-Credentials: true";
      header("Access-Control-Max-Age: 86400"; // cache for 1 day
   }
   // ....
}
```

https://stackoverflow.com/a/9866124/1613775

http://web-in-security.blogspot.de/2017/07/cors-misconfigurations-on-large-scale.html
CORS Misconfiguration - null Origin

```php
header("Access-Control-Allow-Credentials: true");

if (is_allowed($_SERVER['HTTP_ORIGIN'])) {
    header("Access-Control-Allow-Origin: {$_SERVER['HTTP_ORIGIN']}");
} else {
    header("Access-Control-Allow-Origin: null");
}
```

- Attacker can force null origin to be sent
  - data URLs have their origin set to null

```html
<iframe src='data:text/html,
<html><body><script>
xhr = new XMLHttpRequest();
xhr.open("GET", "https://null-origin-cors.com/file", false);
xhr.send();
alert(xhr.responseText);
</script></body></html>'></iframe>
```
Domain Relaxation vs. CORS

• Domain relaxation affects two documents
  • JavaScript API
    • two HTML pages use document.domain to set a **common parent domain**
    • these documents can read any data and call any API in other document
• CORS allows fine-grained access control to any origin
  • HTTP header
    • no need to share parent domain
    • if domain a.com sets CORS to **Access-Control-Allow-Origin: b.com**, b.com can read the content from a.com
      • does not allow b.com to call any JavaScript in a.com
• Requesting page sends along its **origin** in HTTP header
PostMessages
Cross-Domain Communication: Web Messaging

- Goal: enable safe message exchange between two sites
  - preserving authenticity and confidentiality of a message
- Result: HTML5 Web Messaging
  - initially only postMessage, now also supports message channels
- Messages can be sent via window.postMessage
- .. and received with an event handler
postMessage Concept

```javascript
// sender
var message = {/* would contain some data */}
var other_site = document.getElementById("other_site");
other_site.contentWindow.postMessage(message, 'http://other.site');

window.addEventListener("message", receiveMessage);

function receiveMessage(event) {
  if (event.origin !== "http://main.site")
    return;
  var message = event.data;
  process(message);
}
```
postMessage security

• Origin of message can be checked
  • can ensure authenticity of message
  • message.origin provides origin

• Target can be specifically set
  • if target is not matched, message is not delivered
  • allows for wildcards

```javascript
window.addEventListener("message", receiveMessage);

function receiveMessage(event) {
  var message_data = event.data;
  // we expect this to be JSON
  if (event.origin == 'http://expected.site') {
    var data = eval(message_data);
  }
}
```

```javascript
window.addEventListener("message", receiveMessage);

function receiveMessage(event) {
  var message_data = event.data;
  if (message_data == 'get_userdata') {
    event.source.postMessage('....', 'http://target.site');
  }
}
```
postMessage insecurity

• Origin of message can be checked
  • can ensure authenticity of message
  • message.origin provides origin

• Target can be specifically set
  • if target is not matched, message is not delivered
  • allows for wildcards

```javascript
window.addEventListener("message", receiveMessage);

function receiveMessage(event) {
  var message_data = event.data;
  // we expect this to be JSON
  var data = eval(message_data);
}
```

```javascript
window.addEventListener("message", receiveMessage);

function receiveMessage(event) {
  var message_data = event.data;
  if (message_data == 'get_userdata') {
    event.source.postMessage('....', '*');
  }
}
```
postMessage in the Wild [NDSS 2013]

• Son and Shmatikov investigated insecure use of postMessage
• Checked Alexa Top 10,000 domains for origin checks
  • missing completely
  • improper checks
    • if(a.origin && a.origin.match(//\.kissmetrics\.com/))
    • if(/id.rambler.ru$/i.test(a.origin))
    • a.origin.indexOf("widgets.ign.com") !== -1
• Found 84 popular sites to be vulnerable
  • Cross-Site Scripting
  • Persistent changes to Web Storage
postMessage in the Wild [USENIX 2017]

- Recent study from CISPA about how the Web evolved
- Analysis of the top 500 sites over 20 years

<table>
<thead>
<tr>
<th>Year</th>
<th>postMessage received</th>
<th>no origin check</th>
<th>postMessage sent</th>
<th>wildcard target</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>0.5%</td>
<td>0%</td>
<td>20.9%</td>
<td>2.2%</td>
</tr>
<tr>
<td>2010</td>
<td>10.8%</td>
<td>2.4%</td>
<td>5.9%</td>
<td>3.9%</td>
</tr>
<tr>
<td>2011</td>
<td>18.5%</td>
<td>8.4%</td>
<td>19.0%</td>
<td>14.8%</td>
</tr>
<tr>
<td>2012</td>
<td>32.7%</td>
<td>11.4%</td>
<td>32.7%</td>
<td>17.9%</td>
</tr>
<tr>
<td>2013</td>
<td>31.9%</td>
<td>21.8%</td>
<td>41.2%</td>
<td>22.8%</td>
</tr>
<tr>
<td>2014</td>
<td>40.0%</td>
<td>19.6%</td>
<td>52.2%</td>
<td>33.0%</td>
</tr>
<tr>
<td>2015</td>
<td>50.5%</td>
<td>18.1%</td>
<td>62.9%</td>
<td>45.8%</td>
</tr>
<tr>
<td>2016</td>
<td>48.0%</td>
<td>26.3%</td>
<td>64.1%</td>
<td>50.3%</td>
</tr>
</tbody>
</table>
Summary - Cross-Origin Communication

The Same-Origin Policy for JavaScript
- Only allows access if origins match
- Origin defined by protocol, hostname, and port

<table>
<thead>
<tr>
<th>Originating document</th>
<th>Accessed document</th>
<th>NonIE Browser</th>
<th>Internet Explorer</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://example.org/a">http://example.org/a</a></td>
<td><a href="http://example.org/b">http://example.org/b</a></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><a href="http://example.org">http://example.org</a></td>
<td><a href="http://www.example.org">http://www.example.org</a></td>
<td>❌</td>
<td>❌</td>
</tr>
<tr>
<td><a href="http://example.org">http://example.org</a></td>
<td><a href="http://example.org">http://example.org</a></td>
<td>❌</td>
<td>✓</td>
</tr>
<tr>
<td><a href="http://example.org">http://example.org</a></td>
<td><a href="http://example.org/a">http://example.org/a</a></td>
<td>❌</td>
<td>✓</td>
</tr>
</tbody>
</table>

CORS Concept (simple request)

PostMessage Concept
Credits

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