Autogenerating Content Security Policies to Prevent Code Injection in Mobile Web Applications

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28.01.20
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- **Disadvantage**: Susceptibility to code injection attacks
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6 Results
How does it work?

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3. Unsafe data is passed to DOM in an unsafe manner
4. Unsafe data is rendered, causing all present Javascript code to be executed
How does it work?

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- `<p><script>alert(’EVIL’) </script></p>`
What are the differences to traditional web apps?

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- Unconventional injection channels
  - Barcodes
  - WiFi SSIDs
  - File metadata
  - ...

More severe impacts

- More sensitive access via HTML5 (GPS, high-res cameras, always with its user)
- More extensive access via JS-interfaces (accelerometer, contacts, SMS, spreading of infection)
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- Directives: script-src, style-src, img-src, media-src, connect-src, plugin-types, ...
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Content Security Policy is a security mechanism that restricts what resources can be loaded by the browser and whether some types of JS/CSS code are blocked.

- **Directives**: `script-src`, `style-src`, `img-src`, `media-src`, `connect-src`, `plugin-types`, ...
- **Origins/Keywords**: `https://example.ch`, `data:`, `'self'`, `'unsafe-inline'`, `'unsafe-eval'`, `'sha-[hash]'`, `'strict-dynamic'`, ...
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- CSP rule: "img-src 'self' http://allowed.ch;"
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- **CSP rule**: "img-src 'self' http://allowed.ch;"
  - Allowed: `<img src="image.png">`
  - Allowed: `<img src="http://allowed.ch/image.png">`
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What can be restricted?

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  - `<embed src="https://example.ch"` >
  - `<link rel="stylesheet" href="https://example.ch"` >
  - `<script src="https://example.ch"` >
  - `new Worker('https://example.ch');`
  - `...`
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- URLs to connect to
  - `XMLHttpRequest.open('GET', 'https://example.ch');`
  - `new WebSocket('https://example.ch');`
  - `<form action="https://example.ch">`
  - ...

What can be restricted?

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  - `<script>alert('XSS')</script>`
  - `<div onclick="alert('XSS')">`
  - `<style>.content { width: 30px; } </style>`
  - `document.querySelector('div').setAttribute('style', 'width: 30px;');`
  - `...`
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  - ...

- **Evaluation of strings in scripts and styles**
  - `eval("alert('XSS')")`
  - `window.setTimeout("alert('XSS')", 1000);`
  - `CSSStyleSheet.insertRule(".content { width: 30px; }")`
  - ...

...
What can be restricted?

- Some other things
  - plugin-types
  - frame-ancestors
  - upgrade-insecure-requests
  - navigate-to
  - ...

How does CSP prevent/mitigate attacks?

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  - 87% of web apps analyzed by large-scale study
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- One reason for this is that frameworks like jQuery heavily rely on string evaluation
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Research questions

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3. Can we automatically generate sensible CSP definitions for real-world Cordova apps?

1. Can we rewrite real-world Cordova apps to allow more strict CSP definitions?
2. What patterns limit us in rewriting applications and generating CSP definitions?
3. How prevalent are the patterns we attempt to rewrite?
4. How prevalent are the patterns we can successfully rewrite?
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The problem

- The problem

Many applications don’t use any CSP at all. Of those that do, many apps use it in a way that doesn’t leverage its main advantages. Many applications make use of APIs that are incompatible with strict CSP rules.

A solution? Automatic generation of CSP rules would make it easy to deploy CSP for existing apps. Incompatible APIs should be rewritten in order to avoid losing strictness. Care must be taken to avoid breaking app functionalities.
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A solution?

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The pipeline
The pipeline

- Find all HTML files
- Iterate over HTML files
- Rewrite CSS and extract related sources
- Extract sources from HTML and JS
- Extract sources from HTML
- Set constant CSP directives
- Rewrite scripts and extract related sources
- Write changes to JS snippets
- Write changes to HTML files
- Write CSP definition to HTML file
The pipeline

1. Find all HTML files
2. Iterate over HTML files
3. Process related JS
4. Rewrite scripts and extract related sources
5. Extract sources from HTML and JS
6. Extract sources from HTML
7. Set constant CSP directives
8. Rewrite CSS and extract related sources
9. Write changes to JS snippets
10. Write changes to HTML files
11. Write CSP definition to HTML file
Setting constant CSP directives

- "default-src 'self'; upgrade-insecure-requests;"
The pipeline
Extracting sources from HTML

- manifest-src:
  `<link rel=”manifest” href=”https://example.ch”>

- base-uri:
  `<base href=”https://example.ch/”>

- plugin-types:
  `<object data=”https://example.ch/flash”
type=”application/x-shockwave-flash”>

- form-action:
  `<form action=”javascript:alert(’FORM’)” method=”post”>
The pipeline
Processing related Javascript

- Gather all related Javascript
Processing related Javascript

- Gather all related Javascript
  - Extract code from inline Javascript tags
    `<script>alert('INLINE')</script>`
  - Load code from external Javascript tags
    `<script src="app.js"></script>`
  - Extract code from inline event handlers
    `<div onclick="alert('EVENT HANDLER')"></div>`
Processing related Javascript

- Extract all URLs
Processing related Javascript

- Extract all URLs
- Extract sources for connect-src
Processing related Javascript

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- Extract sources for connect-src
  - XMLHttpRequest.open("GET", "https://example.ch");
  - new WebSocket("https://example.ch");
  - ...

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- Extract sources for connect-src
  - XMLHttpRequest.open("GET", "https://example.ch");
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- Extract sources for worker-src
Processing related Javascript

- Extract all URLs
- Extract sources for connect-src
  - XMLHttpRequest.open("GET", "https://example.ch");
  - new WebSocket("https://example.ch");
  - ...
- Extract sources for worker-src
  - new Worker("https://example.ch/w.js");
  - navigator.serviceWorker.register("https://example.ch/w.js");
  - ...
Processing related Javascript

Rewriting APIs impacted by style-src

```javascript
// Original
a.setAttribute("style", "display:none");

// Rewritten
a.style.display = "none";
```
Rewriting APIs impacted by style-src

cssText

// Original
a.style.cssText = "background-color:none";

// Rewritten
a.style.backgroundColor = "none";
Processing related Javascript

Rewriting APIs impacted by style-src

`insertRule`

```javascript
// Original
stylesheet.insertRule("#someId { color: white }", 0);

// Rewritten
var newStyleTag = document.createElement("style");
newStyleTag.innerText = "#someId { color: white }";
document.head.appendChild(newStyleTag);
```
Rewriting APIs impacted by script-src

```javascript
// Original
eval('alert("Example")');
eval('{"key1": "value1", "key2": "value2"}');

// Rewritten
alert("Example");
JSON.parse('{"key1": "value1", "key2": "value2"}');
```
Processing related Javascript

Rewriting APIs impacted by script-src

```javascript
// Original
setTimeout('alert("Example")', 1000);
setInterval('alert("Example")', 1000);

// Rewritten
setTimeout(function() {alert("Example")}, 1000);
setInterval(function() {alert("Example")}, 1000);
```
Processing related Javascript

Rewriting APIs impacted by script-src

```
// Original
new Function("a", "b", "return a*b");

// Rewritten
function(a, b) {return a*b};
```
Rewriting APIs impacted by script-src

setAttribute for event handlers

// Original
a.setAttribute("onclick", 'alert("XSS")');

// Rewritten
a.onclick = function() {alert("XSS")};
The pipeline
Extracting sources from HTML and Javascript

- connect-src:
  `<a ping="https://example.ch"/>

- frame-src:
  `<iframe src="https://example.ch"/>

- img-src:
  `<img src="https://example.ch/image.jpg"/>

- media-src:
  `<audio src="https://example.ch"/>

- object-src:
  `<object data="https://example.ch"/>
Extracting sources from HTML and Javascript

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- Combine with data from JS
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- Write changes to JS snippets
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Rewriting styles and extracting related sources

Rewriting inline style attributes

// Original
<div style="height: 100px;">

// Rewritten
<div id="tmYuSGfL">
<style>#tmYuSGfL { height: 100px; }
</style>
Rewriting styles and extracting related sources

- Iterate over all CSS rules
Rewriting styles and extracting related sources

- Iterate over all CSS rules
  - style-src:
    @import url("https://example.ch/styles.css")
  - font-src:
    @font-face { src: url("https://not-example.com/font"); }
  - img-src:
    background-image: url("image.gif");
Rewriting styles and extracting related sources

- Iterate over all CSS rules
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    - @import url("https://example.ch/styles.css")
  - font-src:
    - @font-face { src: url("https://not-example.com/font"); }
  - img-src:
    - background-image: url("image.gif");
- Generate all hashes
Rewriting styles and extracting related sources

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  - style-src:
    - @import url("https://example.ch/styles.css")
  - font-src:
    - @font-face { src: url("https://not-example.com/font"); }
  - img-src:
    - background-image: url("image.gif");
- Generate all hashes
- Combine with data from JS
The pipeline
Rewriting inline event handlers

// Original
<div onclick='alert("Example")'></div>

// Rewritten
<div id="tmYuSGfL">
<script>
    document.getElementById("tmYuSGfL").
        addEventListener(
            "onclick",
            function() { alert("Example") }
        )
</script>
Rewriting scripts and extracting related sources

- Generate all hashes
Rewriting scripts and extracting related sources

- Generate all hashes
- Combine with data from JS
Rewriting scripts and extracting related sources

- Generate all hashes
- Combine with data from JS
- Add ‘strict-dynamic’
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    - setTimeout(someVariable, 1000)
    - ...
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  - Non-constant parameters in restricted APIs
    - `a.style.cssText = someVariable`
    - `setTimeout(someVariable, 1000)`
    - ... 
  - Adding styles/scripts implicitly from strings
    - `someElement.innerHTML = " <div onclick='...'> </div>";`
    - `someElement.innerHTML = " <div style='...'> </div>";`
    - `someElement.innerHTML = " <style>...</style>";`
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      </style>";
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# Empirical results

<table>
<thead>
<tr>
<th>API</th>
<th>% Apps</th>
<th>% Apps (w/o library files)</th>
</tr>
</thead>
<tbody>
<tr>
<td>setTimeout / setInterval</td>
<td>98.30</td>
<td>73.65</td>
</tr>
<tr>
<td>eval</td>
<td>89.45</td>
<td>36.89</td>
</tr>
<tr>
<td>cssText</td>
<td>83.27</td>
<td>28.68</td>
</tr>
<tr>
<td>Function</td>
<td>61.21</td>
<td>29.41</td>
</tr>
<tr>
<td>setAttribute (style)</td>
<td>30.91</td>
<td>21.45</td>
</tr>
<tr>
<td>insertRule</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>setAttribute (event handler)</td>
<td>3.88</td>
<td>3.31</td>
</tr>
</tbody>
</table>

**Table 1:** Apps containing CSP-relevant APIs
Empirical results

<table>
<thead>
<tr>
<th>Keyword</th>
<th>% Rewritten</th>
<th>% Not rewritten</th>
</tr>
</thead>
<tbody>
<tr>
<td>script-src: unsafe-inline</td>
<td>3.27</td>
<td>0.61</td>
</tr>
<tr>
<td>script-src: unsafe-eval</td>
<td>0</td>
<td>98.55</td>
</tr>
<tr>
<td>style-src: unsafe-inline</td>
<td>8</td>
<td>22.91</td>
</tr>
<tr>
<td>style-src: unsafe-eval</td>
<td>2.42</td>
<td>81.33</td>
</tr>
</tbody>
</table>

Table 2: Apps we could/couldn’t rewrite in relation to total number of apps
### Empirical results

<table>
<thead>
<tr>
<th>Keyword</th>
<th>% Rewritten</th>
<th>% Not rewritten</th>
</tr>
</thead>
<tbody>
<tr>
<td>script-src: unsafe-inline</td>
<td>84.28</td>
<td>15.72</td>
</tr>
<tr>
<td>script-src: unsafe-eval</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>style-src: unsafe-inline</td>
<td>25.88</td>
<td>74.12</td>
</tr>
<tr>
<td>style-src: unsafe-eval</td>
<td>2.89</td>
<td>97.11</td>
</tr>
</tbody>
</table>

**Table 3:** Apps we could/couldn’t rewrite in relation to number of apps that needed rewriting
Research questions revisited

1. What attack methods against mobile web applications exist?
Research questions revisited

1. What attack methods against mobile web applications exist?
2. How can CSP prevent or mitigate such attacks?
Research questions revisited

1. What attack methods against mobile web applications exist?
2. How can CSP prevent or mitigate such attacks?
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Research questions revisited

1. What attack methods against mobile web applications exist?
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3. Can we automatically generate sensible CSP definitions for real-world Cordova apps?
   1. Can we rewrite real-world Cordova apps to allow more strict CSP definitions?
Research questions revisited

1. What attack methods against mobile web applications exist?
2. How can CSP prevent or mitigate such attacks?
3. Can we automatically generate sensible CSP definitions for real-world Cordova apps?
   1. Can we rewrite real-world Cordova apps to allow more strict CSP definitions?
   2. What patterns limit us in rewriting applications and generating CSP definitions?

4. How prevalent are the patterns we attempt to rewrite?
5. How prevalent are the patterns we can successfully rewrite?
6. How prevalent are the patterns we cannot rewrite?
Research questions revisited

1. What attack methods against mobile web applications exist?
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Thank You for Your Attention.

Questions?