UserCSP:User Specified Content Security Policy

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Abstract. According to OWASP top vulnerability list, cross-site scripting (XSS) is among the top five web application vulnerabilities. It allows attackers to inject malicious code or resources from attacker domains into the DOM of a vulnerable web page. Browsers are not able to distinguish between legitimate and malicious content. Therefore, Content Security Policy (CSP) is a mechanism that enables the browser to identify potentially malicious injected content in web pages.
By-default CSP doesnt allow inline scripts and eval, which are used by almost all website. To use CSP, websites are required to change their code or allow these potential attack vectors, and hence mitigate the effectiveness of CSP. The code change requirement is hindering the adaptation of CSP by web applications (websites). However, there are savvy users who prefer security over usability. In addition, website developers need a tool to test different CSP rules for their website that secure their users and also achieve usability. To address these issues we propose UserCSP and prototype our approach in a Firefox extension using the JetPack framework. UserCSP allows savvy users to specify CSP rules to particular websites or to specify general CSP rules that are enforced on each and every website a user visits. Moreover, it allows website developers to try out different CSP rules and iterate to achieve the best suited CSP policy for their website.

Keywords: content security policy, web security, security policy, content restrictions

1 Introduction

The web browsers security model is rooted in the sameorigin policy (SOP) [6], which isolates resources of one origin from others. However, attackers can subvert the SOP by injecting malicious contents into a vulnerable website; this is known as Cross-site scripting (XSS) attacks [1]. Cross-site Scripting (XSS) attacks in web applications are considered a major threat. XSS allows an attacker to conduct a wide range of potential attacks, such as session hijacking, stealing sensitive data and passwords, creation of self-propagating JavaScript worms, etc. To mitigate XSS attacks, Content Security Policy (CSP) [8] provide website administrators with a way to enforce content restrictions at the client side.

Content Security Policy is a declarative policy that restricts what content can be loaded on a web page. Its primary purpose is to mitigate Cross-Site Scripting vulnerabilities. The core issue exploited by Cross-Site Scripting (XSS) attacks is that web browsers lack the knowledge to distinguish between content that's intended to be part of a web application, and content that's been maliciously injected into a web application. To address this problem, CSP defines the `Content-Security-Policy` HTTP header that allows web application developers to create a whitelist of trusted content sources, and instruct the client browsers to only execute or render resources from those sources. However, it is often difficult for developers to write a comprehensive Content Security Policy for their website. They may worry about their page breaking because unanticipated but necessary content is blocked. They may not be able to easily change the headers their site is sending when these situations occur, which makes it difficult for them to try different policies until they find one that is the most restrictive for their page without breaking site functionality.

UserCSP changes this! A developer or user can now view the current policy set by their site and add their own policy. They can choose to apply their custom policy on the site, or even combine their policy with the websites existing policy. When combining policies, they have an option to choose from the strictest subset of the two, or the most lax subset. They can locally test their site with the custom policy applied and tweak the policy until they have one that works.

UserCSP also allows automatic inference of a Content Security Policy for a website. Automatically inferred policies for a website help web developers figure out what CSP rules to set for their site by giving them the strictest possible policy they could apply without breaking the current page. To infer the CSP policy for a website, UserCSP analyzes the content on the current web page and recommends a CSP based on the content types and content sources. UserCSP

provides this inferred policy to developers in the proper syntax for the CSP header, so all a developer needs to do is start serving this policy for their site via the CSP header. Furthermore, UserCSP allows savvy users to voluntarily specify their own Content Security Policy for websites that may not have implemented CSP.

In summary, this paper makes the following contributions:

- We present an automated approach, UserCSP, for writing a Content Security Policy for a website.
- UserCSP allows savvy users to voluntarily specify their own Content Security Policy for websites that may not have implemented CSP.
- We implemented a prototype of our approach in a Firefox extension.

2 Background

Content Security Policy (CSP) helps to detect and mitigate attacks such as Cross-site scripting(XSS) and Clickjacking.

2.1 Cross-site Scripting (XSS)

Cross-site Scripting (XSS) or script injection is well known vulnerability in web applications. According to Web Hacking Incident Database (WHID) 2010 semiannual report, XSS was in the top in the list of application security risks [9]. In XSS attack malicious script is injected into an otherwise trusted web page violating integrity of infected web application and causing an unexpected behavior such as stealing sensitive information or modifying server side state of a user. When a user visits a web page of trusted site that contains malicious injected script, the injected script is executed in user's browser with the principle of trusted site. Therefore, injected scripts have full control over the session and thus can send arbitrary requests with valid session and security tokens.

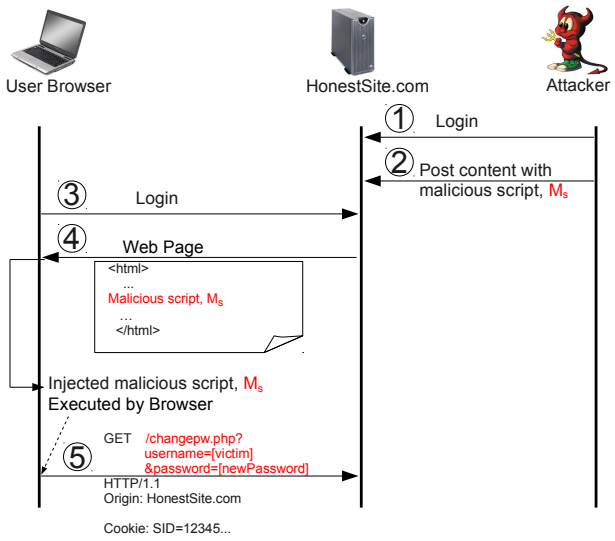

Fig. 1. Illustration of Cross-Site Scripting

An Example of XSS Attack. If user visits a web page of vulnerable trusted web site, say *HonestSite.com* in which attacker has injected inline malicious script, say M_s. Malicious script, M_s, is executed in the context of web site and can send state modifying request to *HonestSite.com*

As shown in Figure 1, attacker first login to a web site, *HonestSite.com* (Step 1). On the vulnerable web page of the web site, attacker submits malicious script, M_s (Step 2). When user login to the web site (Step 3), and visits the vulnerable web page (Step 4), injected malicious script, M_s is executed in the context of web site. When injected script

executed in the context of web site it will compromise the integrity of web site by sending malicious request to modify user state of the user on the web site (Step 5). Request is generated by injected script running with the principle of web site and carries valid authentication token, therefore web site processes the malicious request.

Mitigation of Cross-site Scripting(XSS). Content security policy allows website administrators to eliminate their XSS attack surface. To achieve this goal, CSP allows website administrators specify which domains the browser should treat as valid sources of script. Moreover, the web browser will only execute script in source files from the white-listed domains and will disregard everything else, including inline scripts.

2.2 Clickjacking

In Clickjacking attacks [2, 7], attackers exploit the layout feature introduced by iFrames. Specifically, they load a victim web page into an iFrame on the top and make it transparent. Then they load a deceptive page in another iFrame at the bottom layer to attract users to click.

```
<-- Page from www.Websitename.com -->
<html>
...
<iframe id="victim" src="http://example.com" scrolling="no"
     width="600px" height="600px" style="opacity:0;
     position:absolute; left:10px; top:10px;">
</iframe>
...
<div style = "position:absolute; top:Ypx;left:Xpx;">
     <a href= "http://example.com">Click Here</a>
</div>
...
</html>
```

Fig. 2. Clickjacking using transparent iFrame and overlay objects.

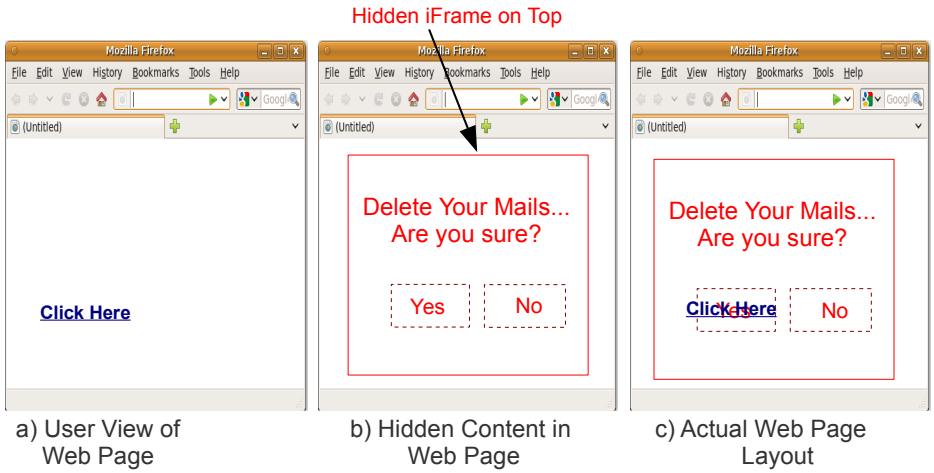

Fig. 3. Illustration of Clickjacking using transparent iFrame and overlay objects

An Example of Clickjacking. Figure 2 shows an example of a Clickjacking attack. The front page of `http://example.com` is loaded inside a transparent iFrame (zero opacity value to make it transparent). To lure users to click at a particular location of the page loaded inside the transparent iFrame, the attacker creates a link in the visible bottom layer, which

is located exactly at the same position where the attacker wants users to click in the top layer. As shown in Figure 2, the attacker specifies the location of a link by setting its X and Y coordinates. When users try to click on the link, they actually click on the transparent layer of the iFrame loaded with the page from `example.com`. An illustration of such a Clickjacking attack is presented in Figure 3.

Mitigation of Clickjacking. Content Security Policy enables a protected website `S` to specify which websites can embed `S`. That is, a protected website `S` can decide what other websites it trusts to embed it.

3 UserCSP Design

The goal of our approach, UserCSP, is to help web site administrators and website users to write comprehensive CSP rules for the website.

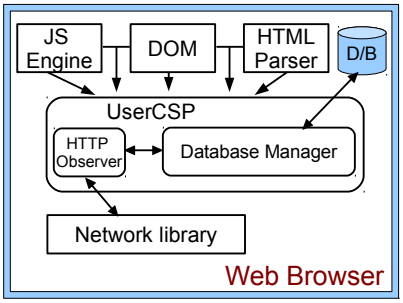

Fig. 4. UserCSP Architecture

Figure 4 illustrates the architecture of UserCSP. To enforce user specified Content Security Policy as well as to infer CSP policy for a website, UserCSP monitors web browsers internal events including HTML parsing, HTTP requests, XHR, etc., and analyzes the type of content loaded by a web page and source of that content. Database manager component of the UserCSP is responsible for storing user specified CSP rules for websites into local database and retrieves the corresponding CSP rules for the website when user loads the website.

When users visits a website, UserCSP performs one of the following actions:

- If website has defined CSP, but the user hasnt specified a CSP policy for that website, then UserCSP doesnt interfere with the website defined CSP rules. However, it allows the user the option to amend the website's CSP.
- If a user has specified CSP rules for a website, but the website administrators hasnt defined a CSP for their website, then the user specified CSP policy will be enforced by the UserCSP.
- If a user specified CSP exists as well as a website defined CSP, then users have a choice either to apply their own policy or adopt the website defined policy. Moreover, users can also select a strict or loose set of CSP rules by combining their own policy with the website defined policy. For example, if a website sets script-src www.example.com; and user specifies script-src www.example.com www.abc.com; then the strict policy would be script-src www.example.com; whereas the loose policy would be script-src www.example.com www.abc.com;.
- If neither user nor website administrators specifiy a CSP for a website then UserCSP doesnt interfere with the content loading on the website.
- To allow automatic inference of a CSP for websites, UserCSP monitors content loaded by web pages and recommends CSP rules based on the types of content and sources of that content. It also monitors the resources dynamically added to the web page by JavaScript.

4 Implementation of UserCSP

We implemented UserCSP [1] in Firefox extension using the Jetpack SDK v1.9 [5]. UserCSP intercepted various events, including the *READY*, *ACTIVATE*, and *CLOSE* events on tab. The READY event is used to retrieve a list of open

[1] UserCSP Source Code: https://github.com/patilkr/userCSP

websites in a user's Firefox web browser. The ACTIVATE event is used to select the currently active domain in the web browser. The CLOSE event is used to remove the domain name from the UI if a user closes the tab. UserCSP uses a sqlite database to store user specified CSP rules for websites.

The *http-on-examine-response* observer notification is used to intercept the HTTP response. In the intercepted response, the domain that initiated the request is checked against the sqlite local database to determine whether user defined rules were set. If there are no rules associated with the website, the response is processed without any change. However, if user defined CSP rules exist, the `Content- Security-Policy` header is added to the response with the rules specified by the user. If user has opted to enforce their own rules then UserCSP replaces the existing `Content- Security-Policy` header if it is already set by the website.

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5 Evaluation

We implemented our approach in Firefox v14.0 using JetPack SDK v1.9. We used Alexa Top 10 Sites [2] to test our approach against user defined CSP policies as well as automatically inferred CSP policies. Automatically inferred CSP policies dont break websites whereas manually defined CSP policies required several rounds of refinement and web page source code inspection to record content sources. The reason for that is initially we set CSP rules for a website to load resources from its own domain only, but websites were loading content from CDNs or sub-domains. Appendix 8 shows examples of inferred CSP policies.

6 Related Work

Content Security Policy(CSP) [8] provides content restriction enforcement that allows web sites to specify which sites are trusted and then rely on the users browser to forbid loading resources from untrusted sites or from the sites not in the list specified by the web application. We extended CSP mechanism to allow users to specify CSP policy for a web site, and then enforce it.

BEAP [4] mitigates the CSRF attack at client side. It infers whether a request reflects user's intention using the heuristics derived from analyzing real-world web applications. If a sensitive request does not reflects users' intention, BEAP strips authentication token from it. Whereas CSP blocks all requests except for those that the web site has explicitly granted.

Browser-enforce Embedded Policies (BEEP) [3] aims to allow web applications to specify which scripts can run on its web site. As compared to our approach, BEEP is limited to restricting scripts that can run on a web site, whereas other contents such as images, frames, style sheets, etc are not restricted.

7 Conclusion

In complex web application attackers find various ways to inject malicious content in a website. Content Security Policy (CSP) provides a content restriction mechanism to allow website administrators to client side control of the types of content that can be loaded and the sources they can be loaded from. It also provides the ability for web browsers to distinguish web site intended contents and injected content. In this work, we present an approach, UserCSP, that helps web administrators and users write compressive CSP rules for websites. It also automatically infers CSP rules for websites. Our prototype was implemented in the Firefox extension using the JetPack SDK.

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8 Appendix: Examples of inferred CSP policy by UserCSP

CSP policies that were automatically inferred by UserCSP for `www.facebook.com` and `in.yahoo.com` are given below:

Inferred CSP policy for www.facebook.com Figure 5 shows an inferred CSP policy by UserCSP for `www.facebook.com`.

```
default-src 'self';
script-src http://static.ak.fbcdn.net;
img-src http://photos-g.ak.fbcdn.net
        http://photos-c.ak.fbcdn.net
        http://photos-a.ak.fbcdn.net
        http://photos-b.ak.fbcdn.net
        http://secure-us.imrworldwide.com
        http://static.ak.fbcdn.net
        http://profile.ak.fbcdn.net;
style-src  http://static.ak.fbcdn.net;
```

Fig. 5. Inferred CSP for www.facebook.com

Inferred CSP for in.yahoo.com/?p=us Figure 6 shows an inferred CSP policy by UserCSP for `in.yahoo.com`.

```
default-src 'self';
script-src http://bs.serving-sys.com
           http://l.yimg.com
           http://mi.adinterax.com;
object-src http://mi.adinterax.com ;
img-src http://l.yimg.com
        http://l1.yimg.com
        http://d.yimg.com
        http://ads.yimg.com
        http://ad.yieldmanager.com
        http://ds.serving-sys.com
        http://b.scorecardresearch.com
        http://row.bc.yahoo.com;
style-src http://l.yimg.com;
frame-src http://ads.yimg.com
          http://ad.yieldmanager.com;
```

Fig. 6. Inferred CSP for in.yahoo.com