Securing Webviews &
The Story Behind CVE-2021–21136

The techniques to secure Webviews and the journey on CVE-2021–21136

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Any opinions or personal views expressed belongs to us and not to our employer
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Introduction to CVE and Webview
Hello World!

Let's know what is a CVE and understand the high level details of CVE-2021-21136

Common Vulnerability Exposure

CVE, short for Common Vulnerabilities and Exposures, is a list of publicly disclosed computer security flaws. When someone refers to a CVE, they mean a security flaw that's been assigned a CVE ID number.

CVE-2021-21136

During security research we found that a mobile application is leaking sensitive data in headers to a third-party. This kickstarted the research behind identifying a security issue in Android Chromium webview leading to leakage of auth tokens to third-parties.
Introduction to Webview

Webview and its applications in modern mobile application development

- Dedicated web browser instance of an application allows to display web content directly in the application
- Webviews are used extensively currently in the polyglot architectures
Loading Web Content

Loading web content in webview(Normal Load)

We can load the web content using Webview#loadUrl method as shown below:

```java
Webview myWebView = (Webview) findViewById(R.id.webview);
myWebView.loadUrl("http://www.google.com");
```
Loading Web Content

Loading web content in WebView (Authenticated Load)

Android also provides an overloaded version of WebView#loadUrl method which lets us pass additional request headers such as auth headers to the request as shown below:

```java
Map<String, String> headers = new HashMap<>();
headers.put("Authorization", token);

WebView myWebView = (WebView) findViewById(R.id.webview);
myWebView.loadUrl("http://shivsahni.com", headers);
```
Deeplinks

An introduction to deeplinks and how an improved user experience through deeplinks could affect security if implemented insecurely

- Deep links are specific URIs (Uniform Resource Identifiers) that are handled by our application to improve the user experience.

For example, fb://profile/33138223345 is a deep link, the URI contains all the information needed to launch directly into a particular location within the Facebook mobile app, in this case, the profile with id ‘33138223345’
Journey on CVE-2021-201136
oAuth Use Case

Understanding oAuth flow in mobile applications

Mobile Application

GET
/oauth/config?client_id=<client_id>&redirect_url=<third-party_url>

Identity Service

Auth Token sent in header

Verify Auth token and generates id_token for the third-party

returns id_token

Third-Party Service

Redirect to <third-party_url> along with id_token
The Bug

Mobile Application

GET
/oauth2/config?client_id=<client_id>
&redirect_url=<third_party_url>

Identity Service

Auth Token sent in header

Verify Auth token and generate id_token for the third-party

returns id_token

Third Party Service

Redirect to <third_party_url> along with id_token

User’s Auth Token exposed to Third-party
Initial Observation

The story behind leakage of auth tokens to third-parties!

During our security research we observed that in Android webviews if a webpage is loaded with some additional headers using `loadUrl(String url, Map<String, String>additionalHttpHeaders)` then it sends the additional headers to any other requests triggered in the process of loading the URL such as redirects.
Timeline
The Journey on Chromium CVE 2021-21136

- **August, 2019**: Initial observation
  - Suspected issue in Chromium
- **December, 2019**: Deep Down Investigation
  - Initiated the analysis with suspected zero day in Android webviews & reported to Google
- **January, 2020**: Response from Google
  - It seems intended behavior and would need more time for thorough analysis
- **February, 2020**: Google Accepted
  - Need more time to fix. Compatibility issue
- **November, 2020**: Official Fix Released in Chromium 88
In-depth Analysis
An Android webview component. The component loads the webpage with additional header (Authorization)

```java
String URL = extras.getString("URL");
String auth= extras.getString("Authorization");
if (URL != null && auth!=null) {
    webView.loadUrl(URL);
    Map<String, String> headers = new HashMap<>();
    headers.put("Authorization", auth);
    WebViewClient wc= new myWebClient();
    webView.setWebViewClient(wc);
    webView.loadUrl(URL, headers);
}
```

Reference: https://github.com/shivsahni/OhMyInsecureWebview
Backend : Python Server

I want DEMO!

- Python Webserver: The loaded webpage is expected to return a HTTP-302 redirect response.

```python
from flask import Flask, redirect
import os
app = Flask(__name__)

@app.route('/redirect')
def hello_world():
    return redirect("http://scratchpads.org/", code=302)

if __name__ == '__main__':
    print ("Hello World!")
    port = int(os.environ.get('PORT', 5000))
    app.run(debug=True, host='0.0.0.0')
```
Token leakage in header

Authorization header is sent to the redirected request as shown in Burpsuite (HTTPS Proxy)
Demo! Demo! Demo!
Response from http://192.168.1.86:5000/redirect

HTTP/1.0 302 FOUND
Content-Type: text/html; charset=utf-8
Content-Length: 193
Location: http://scratchpad.org/
Server: Werkzeug/0.16.0 Python/3.8.2
Date: Mon, 31 May 2021 08:04:21 GMT

<title>Redirecting...</title>
&lt;h1&gt;Redirecting...&lt;/h1&gt;
&lt;p&gt;You should be redirected automatically to target URL: &lt;a href="http://scratchpad.org/">http://scratchpad.org/</a&gt;, If not click the link.
Rollout Plan & Official Fix!

https://chromium.googlesource.com/chromium/src.git/+/6e46cca3ee484bac0cdb5d4bdae69a18857f8efd

- Remove any extra headers from the request if the request is redirected to a different origin, since they might be sensitive.

- Record metrics on when we add headers and what was done with them on redirect.

- Add an additional test verifying that the extra headers are cleared if the app loads the same URL again via loadUrl(url).
Common Webview Security Issues
Common Webview Related Security Issues

Let’s understand some common webview related security issues

- Lack of URL Validation
- Insufficient URL Validation
- Unintended Leakage of Sensitive Data to Third-parties
- Insufficient Webview Isolation>Loading Untrusted Content
Triggering URL Load in Webviews

User Experience and Security Tradeoff

- Improved User Experience
- Code Reuse
- Security

* Deeplink:
  `sampleapp://open?screenType=WEBVIEW&webviewUrl=<urlToOpen>`

* Vanilla Intents:
  `am start -n <packageName>/.<componentName> --es urlParam <urlToOpen>`

* Once Deeplink/Intent is triggered, it opens URL in the webview component

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Load of Arbitrary Web Content Due to Misconfigured Webviews

AKA Insecure Deeplink Implementation-No URL Validation

For example if an application acknowledges the following deep link:

```javascript
//parse URL from deeplink
--
/*deeplinkURL=https://scripts.shivsahni.com/testsample.html*/
--
webView.loadUrl(deeplinkURL);
--
```
Demo-No URL Validation

Loading the URL directly into the webview component?

Demo URL Link: https://drive.google.com/u/0/uc?id=1Rbfu-spHxY1Dws8XzmW4Y_TPWBDU83QT

Reference: https://github.com/t4kemyh4nd/vulnwebview
Insufficient URL Validation

Insecure Deeplink Implementation-Insufficient URL Validation

For example if an application acknowledges the following deep link
webviewdemoapp://issue=1$url=https://scripts.shivsahni.com/testsample.html

```java
Uri uri =
    Uri.parse(deeplinkURL); /*https://scripts.shivsahni.com/testsample.html*/
if("shivsahni.com".equals(uri.getHost()) ||
    uri.getHost().endsWith(".shivsahni.com"))
{
    webView.loadUrl(deeplinkURL);
}
```
Insufficient URL Validation-Example

Through the crafted URL in the Deeplink the validation could be bypassed resulting in arbitrary load of malicious scripts

In the scenario wherein the webview is privileged (JS Bridges), it could even lead to exfiltration of auth tokens

The issue was fixed in API level 28. However, API 27 and below are still vulnerable to such attacks

Read more here: Golden techniques to bypass host validations in Android apps by Bagipro
Escalating The Impact

From Insecure URL Validation to Exfiltration of User’s Auth Tokens

The Impact majorly depends on the privileges of the webview component under attack. The webview could be having the following privileges:

- Executing JavaScript
- Access JavaScript Interfaces/Bridges (Allowing JavaScript to execute Native Code)
- Access to other application components such as Content Providers, Local Storage, etc.
- `setAllowUniversalAccessFromFileURLs`: Sets whether cross-origin requests in the context of a file scheme URL should be allowed to access content from any origin

Read more here: [Golden techniques to bypass host validations in Android apps](https://example.com) by Bagipro
Unintended Data Leakage

How we could be sharing user’s PII/sensitive information to third-parties unintentionally

- Authenticated load to third-party domains
- Authenticated load with JWT in query string
- Leakage of JWT in Referer header
Leaking Token in Referer Header

Unintended Data Leakage

GET /gtm.js?id=GTM-TSGF649 HTTP/1.1
Host: www.googletagmanager.com
Referrer: https://myapp.com/?id_token={id_token}
Accept-Language: en-us
Accept-Encoding: gzip, deflate
Connection: Keep-Alive
Authenticated Loads to Third-Party Domains

Unintended Data Leakage

GET /oauth2/authorize HTTP/1.1
Host: www.third-party.com
Authorization: {JWT}
Accept-Language: en-us
Accept-Encoding: gzip, deflate
Connection: close

HTTP/1.1 302 Found
Date: Fri, 27 Aug 2021 09:44:33 GMT
Content-Type: text/html; charset=utf-8
Content-Length: 50
Connection: close
Location: https://third-party.com/init/start

Auth Token exposed to third-party
Authenticated Loads with JWT in Query String

Unintended Data Leakage

GET /?authToken={token} HTTP/1.1
Host: myapp.com
Accept-Language: en-us
Accept-Encoding: gzip, deflate
Connection: close
Lack of Webview Isolation

An introduction to Custom Chrome Tabs and Safari View Controller

- Are you loading third-party websites in the webview instance of your application?
- Is that webview instance privileged? JavaScript Enabled/JS Bridges?
- What happens if there is breach of trust or the third-party is compromised?
Secure URL Validation

Let’s Secure Android Webviews!

For example if an application acknowledges the following deep link

```kotlin
private fun validateURL(urlString: String): Boolean {
    try {
        URL urlObject = new URL(urlString);
        if ((urlObject.getAuthority() == "shivsahni.com") && (urlObject.getScheme() == "https")) {
            return true;
        }
    } catch (MalformedURLException e) {
        e.printStackTrace();
        return false;
    }
}
```
Secure URL Validation

Let's Secure iOS Webviews!

It is highly recommended to check a URL against a whitelisted domain and explicitly match with urlComponents.scheme, urlComponents.host

```swift
//Swift code
func validateURL(url: URL) -> Bool {
    guard let urlComponents = URLComponents(url: self,
                                            resolvingAgainstBaseURL: false),
         urlComponents.scheme == "https:" &&
         urlComponents.host == "myapp.com" else {
        return false
    }
    return true
}
```
Webview Isolation

An introduction to Custom Chrome Tabs and Safari View Controller

※ Chrome Custom Tabs and Safari View Controllers are what we recommend when browsing 3rd party sites, as the loaded web content is being executed under the chrome process, it minimizes the risk of malicious javascript accessing application’s non-exported services.

※ Chrome Custom Tabs and Safari View Controller will embed the browser into the native app, to make transitions between native and web content more seamless without having to resort to a WebView.
Defence in Depth

Let's harden Android webviews!

- Disable implicit access to Content Providers: `setAllowContentAccess()`
- Disable implicit access to Local Storage: `setAllowFileAccess()`
- Reduce sensitive data exposure by flushing webview cache whenever webview component is no longer required: `clearCache()`
- Ensure that the JS is not unnecessarily enabled, in case the JS execution is required make sure that it is coming from trusted source over a secure channel: `setJavaScriptEnabled()`
Defence in Depth: Risk of using UIWebView?

Let's harden iOS webviews!

- **UIWebView** is deprecated on iOS 12. The App Store does not accept new apps or updated to existing apps that use UIWebView. [https://developer.apple.com/news/?id=edwud51q](https://developer.apple.com/news/?id=edwud51q)

- Javascript cannot be disabled.

- Security-sensitive settings are enabled by default
Defence in Depth: Why use WKWebview?

* Let’s harden iOS webviews!

- Although JavaScript is enabled by default, it can be disabled using `javaScriptEnabled` property.

- The `hashOnlySecureContent` property can be used to verify resources loaded by the WebView are retrieved through encrypted connections.

- While using `allowingReadAccessToURL` do not give access to local storage directory rather specify the file to be accessed by webview.

- Security-sensitive settings such as `allowFileAccessFromFileURLs` & `allowUniversalAccessFromFileURLs` are disabled by default
Follow the principle of least privileges while configuring webviews. For example, only enable JS if explicitly required.

Use Chrome Custom Tabs/Safari View Controllers wherever possible to load untrusted content (third-party web content, etc.)

If your webview is programmed to load the URL in deeplink ensure the URL is validated before the load

While validating the URL before loading in the webview, explicitly match against URL authority and protocol

While doing a third-party integration make sure no sensitive user information is shared unintentionally.
Honorable Contributors

Movnavinothan V and Changmook Lim for helping us during the analysis to come up
References

- [Carnegie Mellon University-Webview Secure Coding Practices](#)
- [Leakage of Sensitive Data Through Android Webviews](#)
- [OWASP Mobile Security Testing Guide](#)
- [Bypassing Webview Host Validation-Bagipro](#)
- [Unintended Data Leakage Through HTTP Request Headers](#)
- [Building Safe URL in Swift](#)
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