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NEU SecLab

Cached and Confused: Web Cache Deception in the Wild

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Web Caches

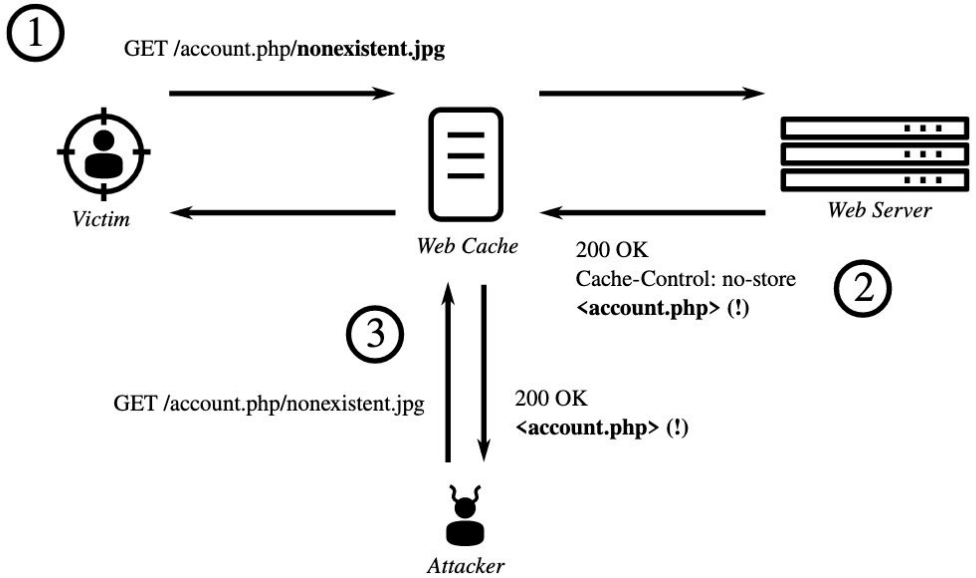
- ➔ Effective solution to decrease network latency and web application load
  - ◆ *Private* cache for single user (e.g., web browsers)
  - ◆ *Shared* cache for multiple users (e.g., web servers, MitM proxies)
  - ◆ Key component of *CDNs* to provide web availability (a.k.a. *Edge Servers*)
  - ◆ Study shows 74% of the *Alexa Top 1K* make use of CDNs
- ➔ Most common targets are static but frequently accessed resources
  - ◆ HTML pages, scripts, style sheets, images, ...
- ➔ Web servers use *Cache-Control* headers to communicate with web caches
  - ◆ *"Cache-Control: no-store"* indicates that the response should not be stored
  - ◆ Even though web caches **MUST** respect these headers, they offer configuration options for their users to ignore header instructions
    - Simple caching rules based on resource paths, file names and extensions (e.g., jpg, css, js)

Path Confusion

- Traditionally, URLs referenced web resources by directly mapping them to web server's file system structure:
  - example.com/**files/index.php**?p1=v1 correspond to the file **files/index.php** at the web server's document root directory
- Web servers introduced URL rewriting mechanisms to implement advanced application routing structures.
  - Clean URLs (a.k.a. RESTful URLs)
    - example.com/**index.php/v1** => example.com/**files/index.php?p1=v1**
- Browsers and proxies are not aware of this layer of abstraction between the resource file system path and its URL.
  - They process the URLs in an unexpected manner a.k.a ***Path Confusion***

Web Cache Deception (WCD)

- ➔ Introduced in 2017 by Omer Gil with PoC against PayPal
- ➔ WCD results different interpretations of a URL (*path confusion*) between a server and a web cache.

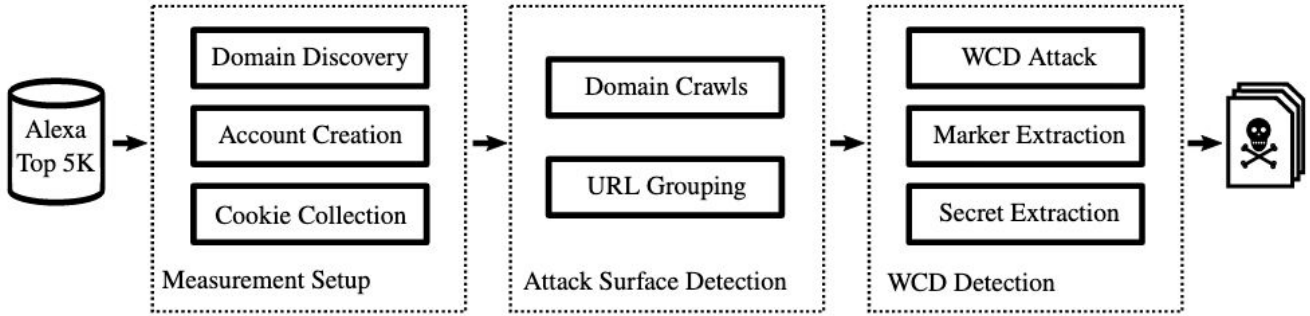


Research Questions

- ➔ What is the prevalence of WCD vulnerabilities on popular, highly-trafficked domains?
- ➔ Do WCD vulnerabilities expose PII and, if so, what kinds?
- ➔ Can WCD vulnerabilities be used to defeat defenses against web application attacks?
- ➔ Can WCD vulnerabilities be fully exploited by unauthenticated users?
- ➔ Can variation of Path Confusion techniques expand the number of vulnerable/exploitable sites?
- ➔ Is attacker geographical location important?
- ➔ Are default configurations of major CDN providers vulnerable?

Methodology

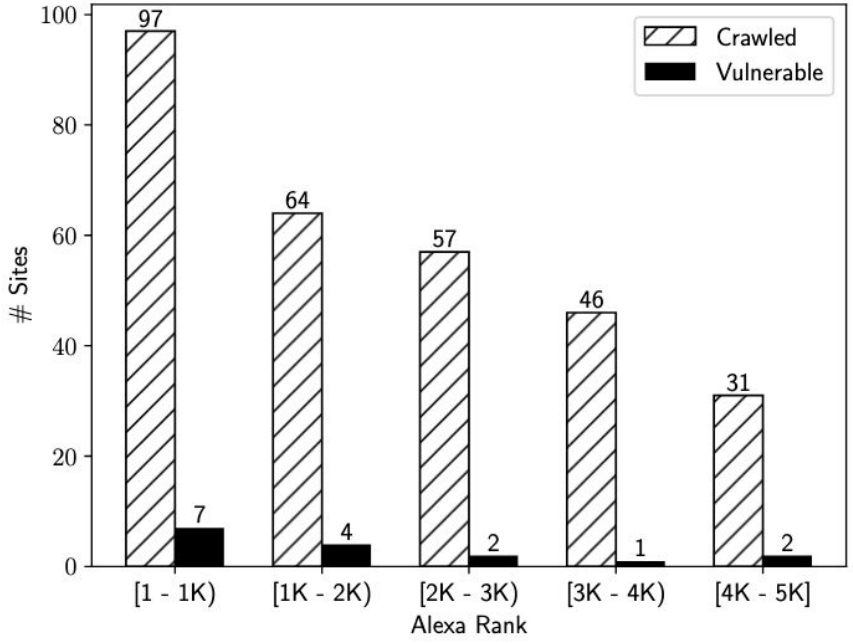
- ➔ Subdomain discovery to increase site coverage.
- ➔ Created account for **295 sites** from **Alexa Top 5K**



- ➔ Appended **"/<random>.css"** to each URL from the victim account..
- ➔ visited same page from the (un)authenticated attack crawler and compare responses.
- ➔ Responses analyzed for the disclosure of security tokens.

Crawling Stats & Alexa Ranking

	Crawled	Vulnerable
Pages	1,470,410	17,293 (1.2%)
Domains	124,596	93 (0.1%)
Sites	295	16 (5.4%)



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Vulnerabilities

- ➔ 14 vulnerable sites leaked PII including names, usernames, email addresses, and phone numbers.
- ➔ 6 vulnerable sites leaked CSRF tokens
- ➔ 6 vulnerable sites leaked session identifiers or user-specific API tokens
- ➔ Our results show that WCD can fully exploit with unauthenticated attackers.

Leakage	Pages	Domains	Sites
PII	17,215 (99.5%)	88 (94.6%)	14 (87.5%)
User	934 (5.4%)	17 (18.3%)	8 (50.0%)
Name	16,281 (94.1%)	71 (76.3%)	7 (43.8%)
Email	557 (3.2%)	10 (10.8%)	6 (37.5%)
Phone	102 (0.6%)	1 (1.1%)	1 (6.2%)
CSRF	130 (0.8%)	10 (10.8%)	6 (37.5%)
JS	59 (0.3%)	5 (5.4%)	4 (25.0%)
POST	72 (0.4%)	5 (5.4%)	3 (18.8%)
GET	8 (<0.1%)	4 (4.3%)	2 (12.5%)
Sess. ID / Auth. Code	1,461 (8.4%)	11 (11.8%)	6 (37.5%)
JS	1,461 (8.4%)	11 (11.8%)	6 (37.5%)
Total	17,293	93	16

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Variations on Path Confusion

```
example.com/account.php
example.com/account.php/nonexistent.css
```

(a) Path Parameter

```
example.com/account.php
example.com/account.php%0Anonexistent.css
```

(b) Encoded Newline (\n)

```
example.com/account.php;par1;par2
example.com/account.php%3Bnonexistent.css
```

(c) Encoded Semicolon (;)

```
example.com/account.php#summary
example.com/account.php%23nonexistent.css
```

(d) Encoded Pound (#)

```
example.com/account.php?name=val
example.com/account.php%3Fname=valnonexistent.css
```

(e) Encoded Question Mark (?)

Path Confusion Results

- ➔ Results confirm our hypothesis that launching WCD attacks with variations on path confusion increased possibility of successful exploitation significantly.
- ➔ Some variations elicit more *200 OK* server responses increasing the likelihood of the web server returning sensitive information.
- ➔ Each path confusion variation was able to attack a set of unique pages that were not vulnerable to other techniques.

Technique	Pages	Domains	Sites
Path Parameter	29,802 (68.9%)	103 (69.6%)	14 (56.0%)
Encoded \n	25,933 (59.9%)	86 (58.1%)	11 (44.0%)
Encoded ;	29,488 (68.2%)	105 (70.9%)	14 (56.0%)
Encoded #	28,643 (66.2%)	109 (73.6%)	15 (60.0%)
Encoded ?	37,374 (86.4%)	130 (87.8%)	19 (76.0%)
All Encoded	42,405 (98.0%)	144 (97.3%)	23 (92.0%)
Total	43,258 (100.0%)	148 (100.0%)	25 (100.0%)

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Empirical Experiments

- ➔ Cache Location
  - ◆ Victim in *Boston, MA, USA* and Attacker in *Trento, Italy.*
  - ◆ Attack failed for **19** sites but **6** sites were still exploitable.
- ➔ Cache Expiration
  - ◆ Web caches typically store objects for a short amount of time.
  - ◆ Attackers have a limited window of opportunity to launch a successful WCD attack.
  - ◆ Repeated the attack with **1 hour**, **6 hour**, and **1 day** delays for 19 sites.
  - ◆ **16**, **10**, and **9** sites were exploitable in each case, respectively.
- ➔ Cache configuration
  - ◆ We tested the basic content delivery solutions offered by major vendor to extract the default configuration.
  - ◆ By default, many Major CDN vendors do not make RFC-compliant caching decision.

Lessons Learned & Conclusion

- ➔ Configuring web caches correctly is not a trivial task.
  - ◆ Caching rules based on file extensions are prone to security problem.
  - ◆ CDNs are not intended to be plug & play solutions.
- ➔ As WCD attacks impact all web cache technologies, there is a widespread lack of user awareness.
  - ◆ There exists no technology to reliably determine if any part of system is vulnerable
- ➔ WCD is generally a "*system safety*" problem
  - ◆ There are no isolated faulty components.
  - ◆ Complex interactions among different technologies must take into consideration.
- ➔ Variations of path confusion techniques make it possible to exploit sites that are otherwise not impacted by the original attacks.

Thanks! Questions?

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