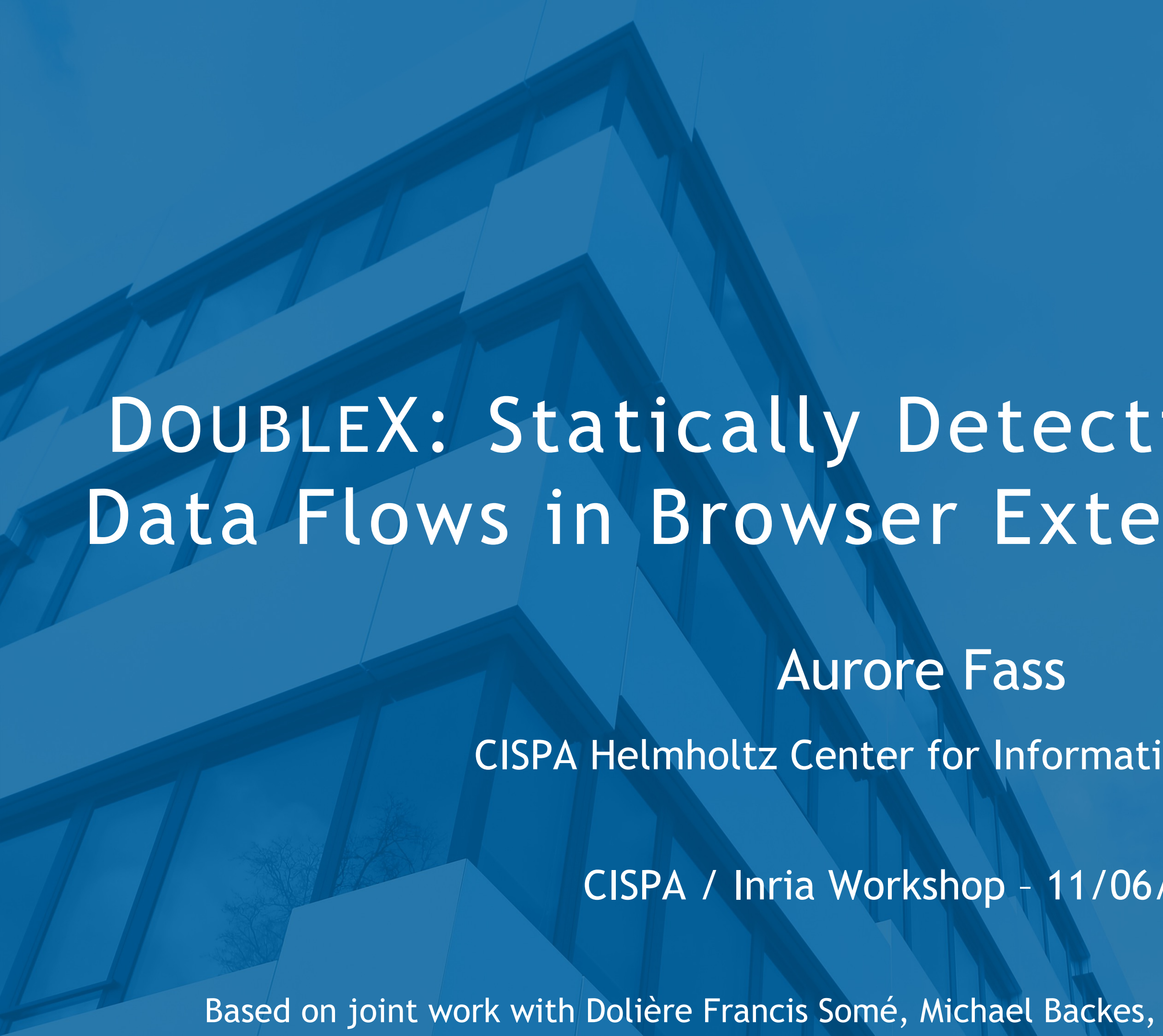


DoubleX: Statically Detecting Vulnerable Data Flows in Browser Extensions at Scale

Aurore Fass

CISPA Helmholtz Center for Information Security

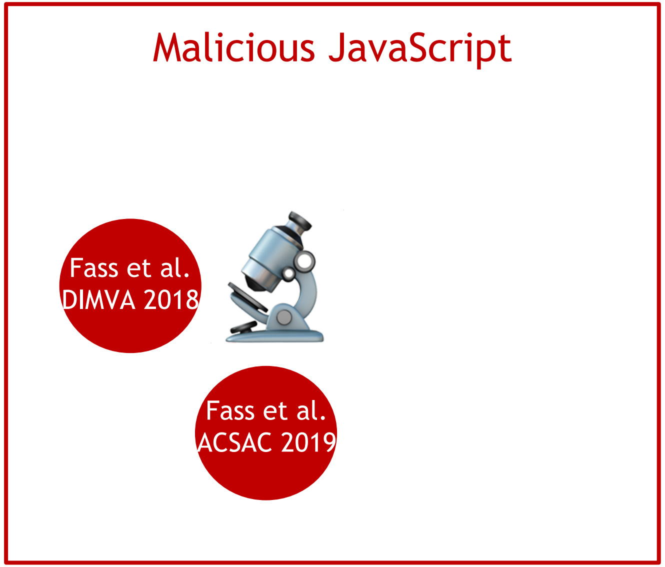
CISPA / Inria Workshop – 11/06/2023

Based on joint work with Dolière Francis Somé, Michael Backes, and Ben Stock at *ACM CCS 2021*

Aurore (/ɔʀɔʀ/)

- Graduated from TELECOM Nancy (2017)
- PhD Student + Postdoc at CISPA (2017—21)
- Visiting Assistant Professor at Stanford (2021—23)
- Tenure-Track Faculty at CISPA (2023—)

Research: Web Security, Privacy, Measurements



Malicious JavaScript

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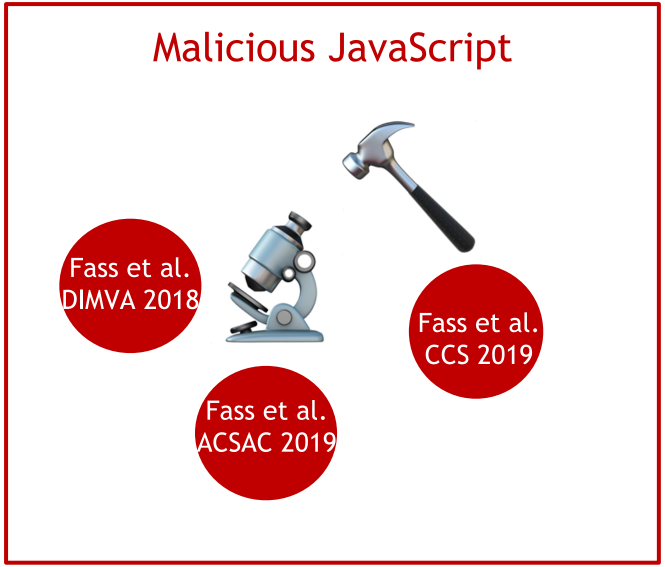

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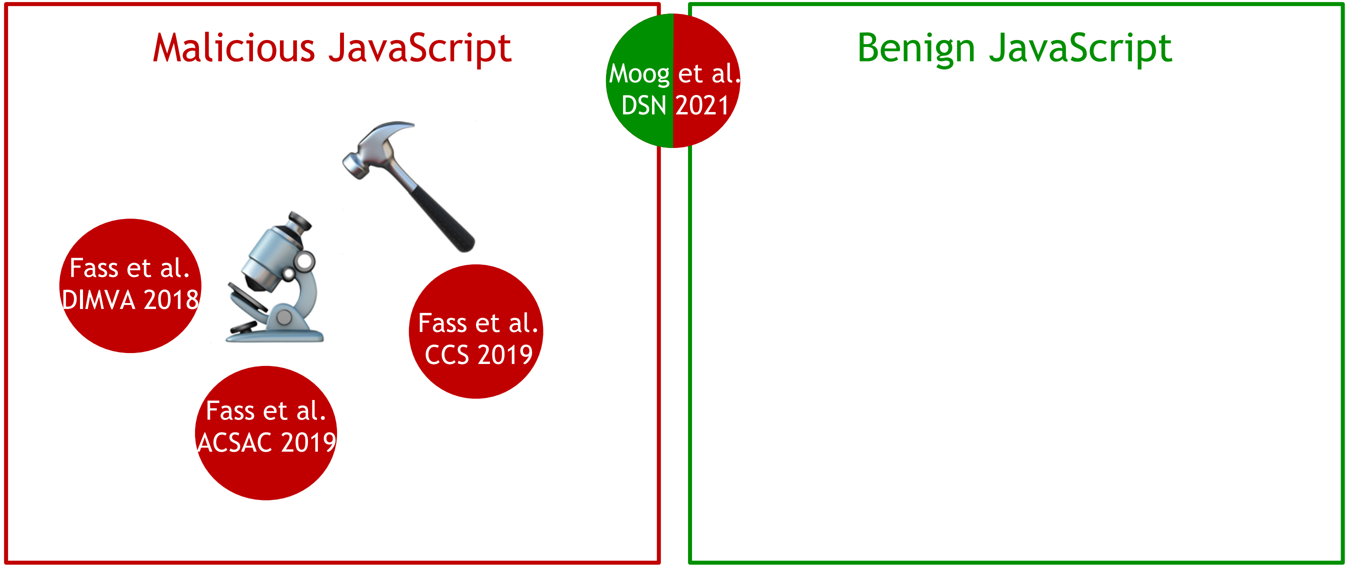

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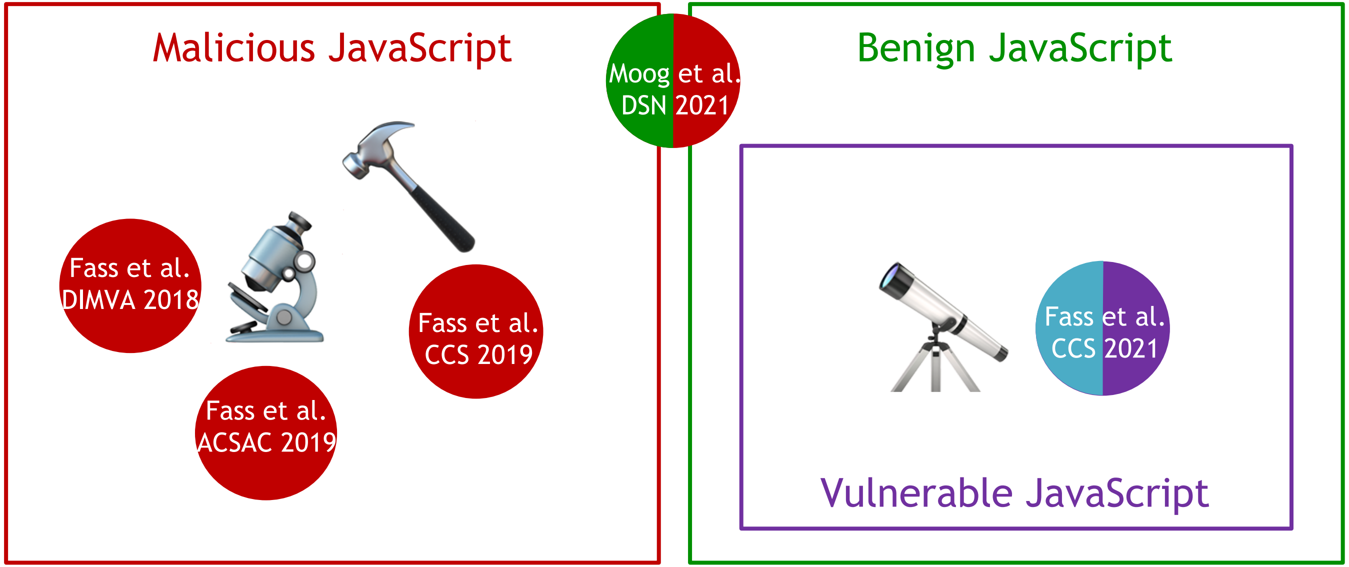

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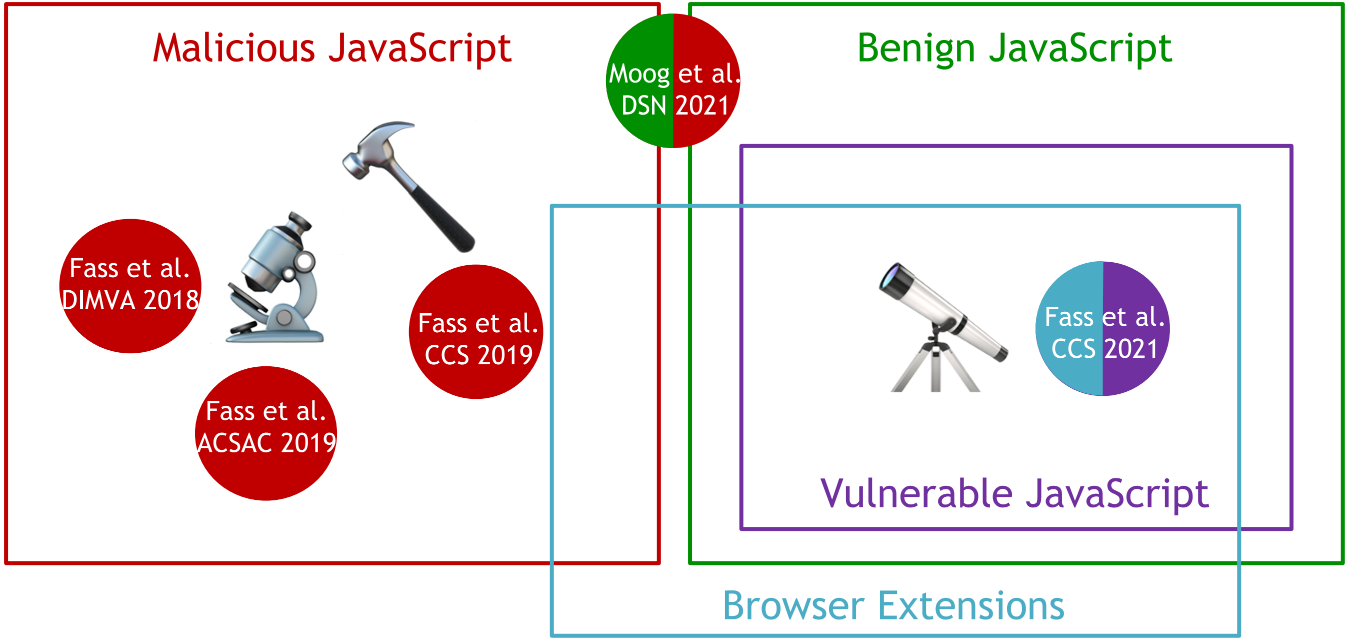

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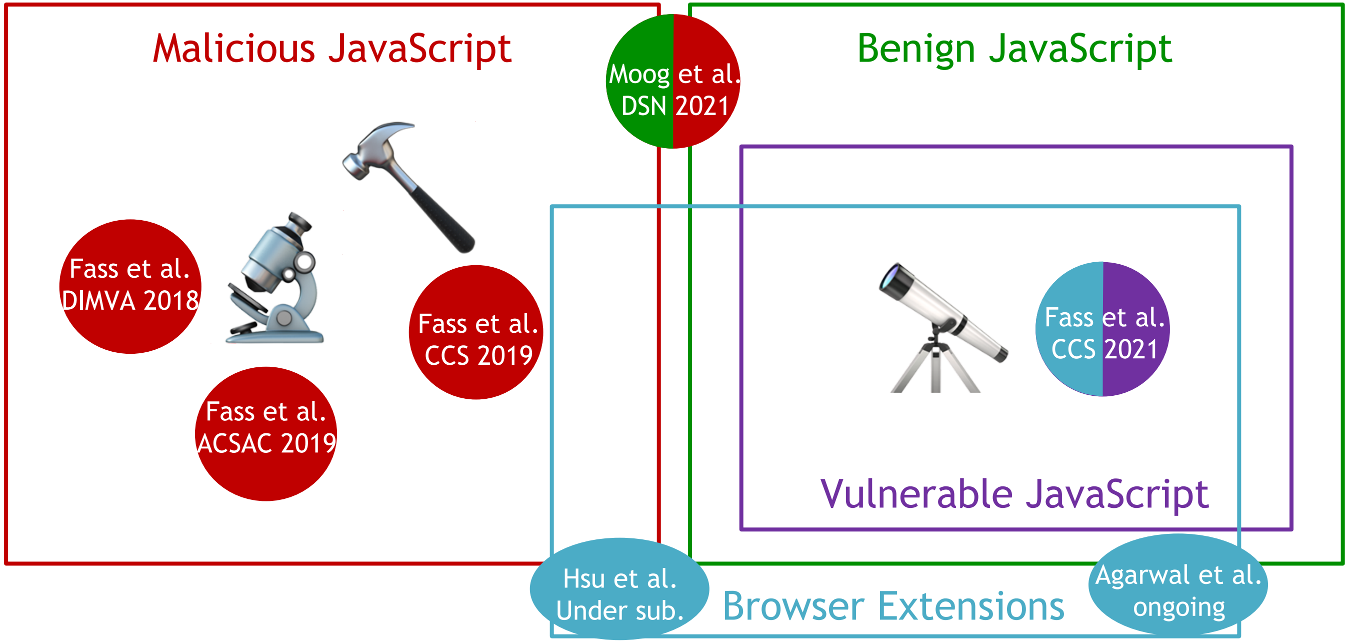

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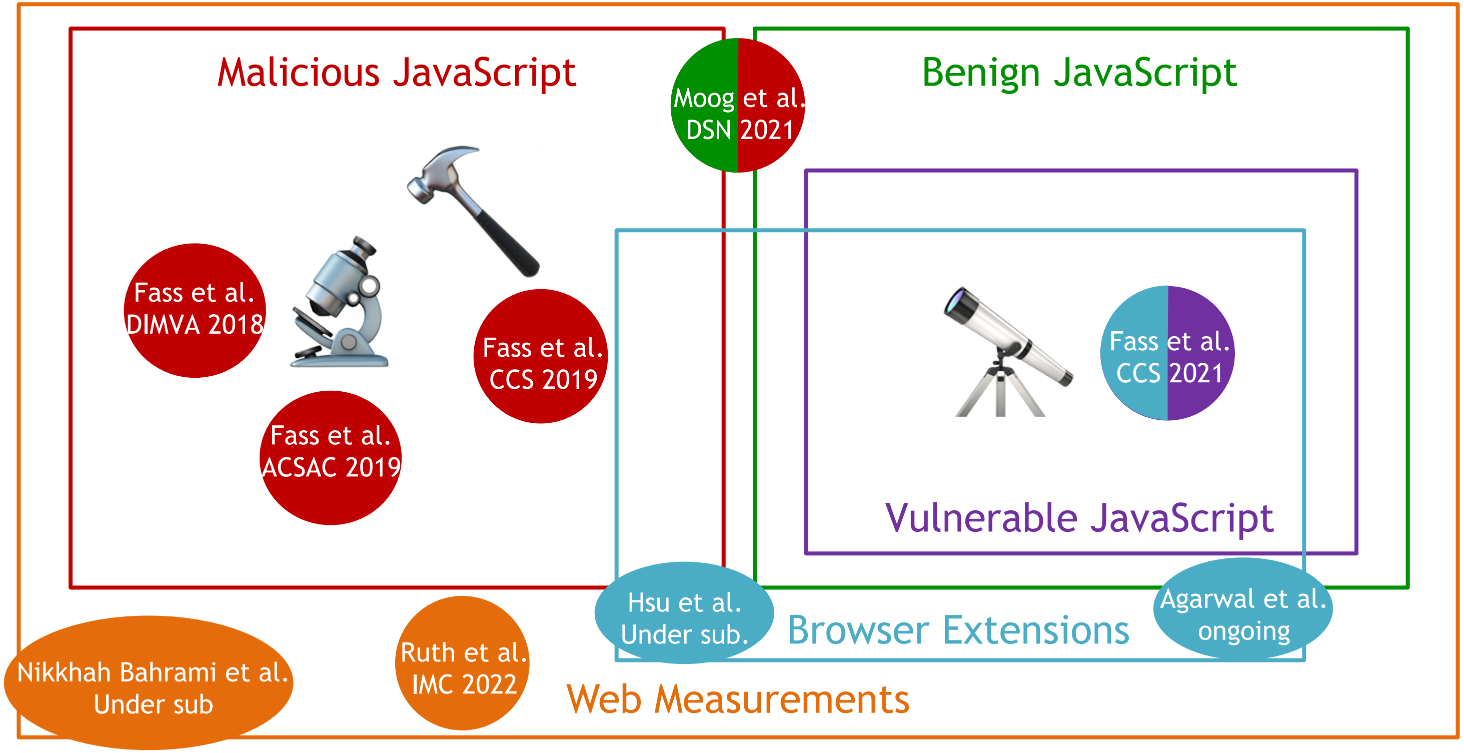

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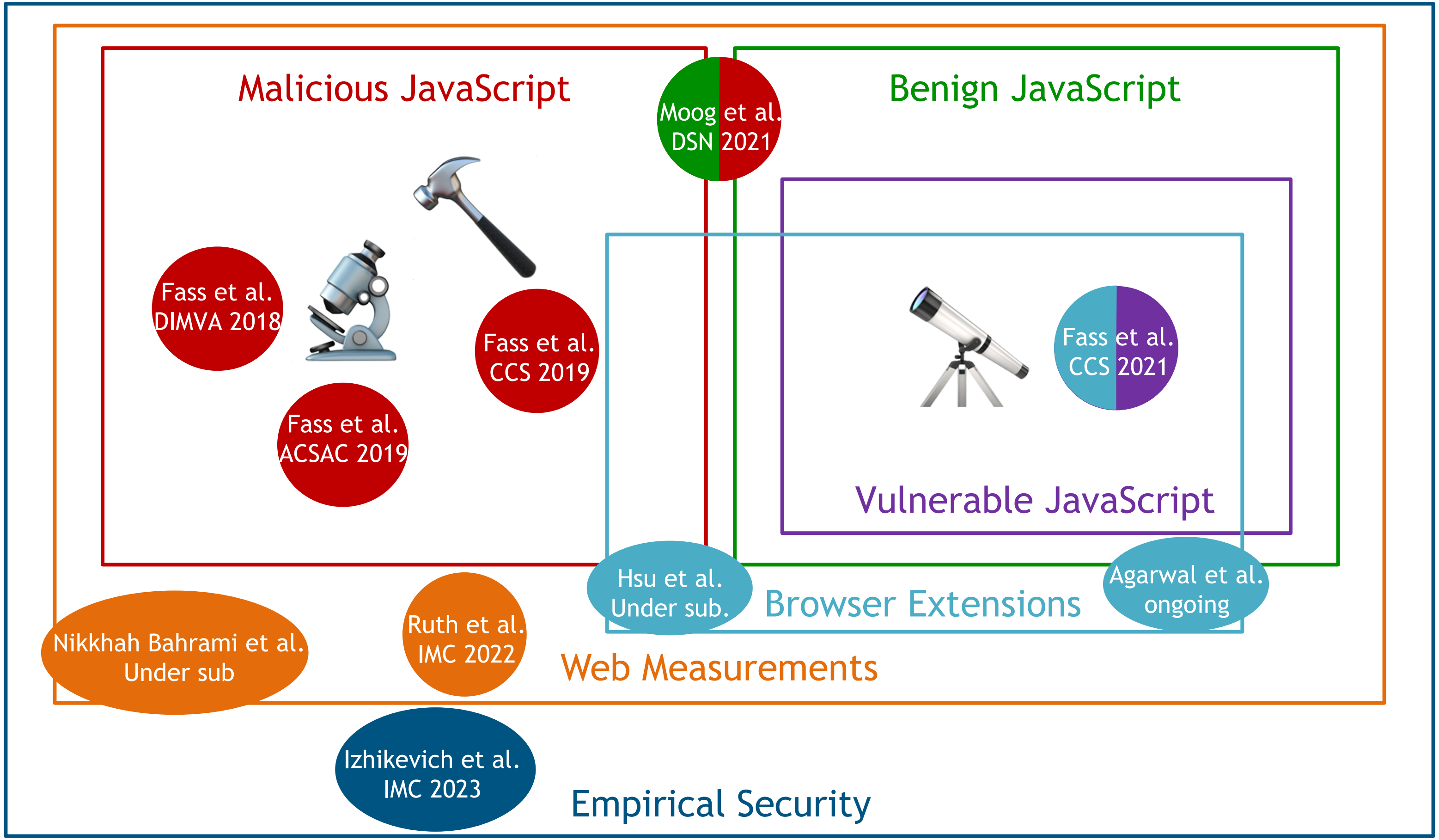

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Izhikevich et al. IMC 2023

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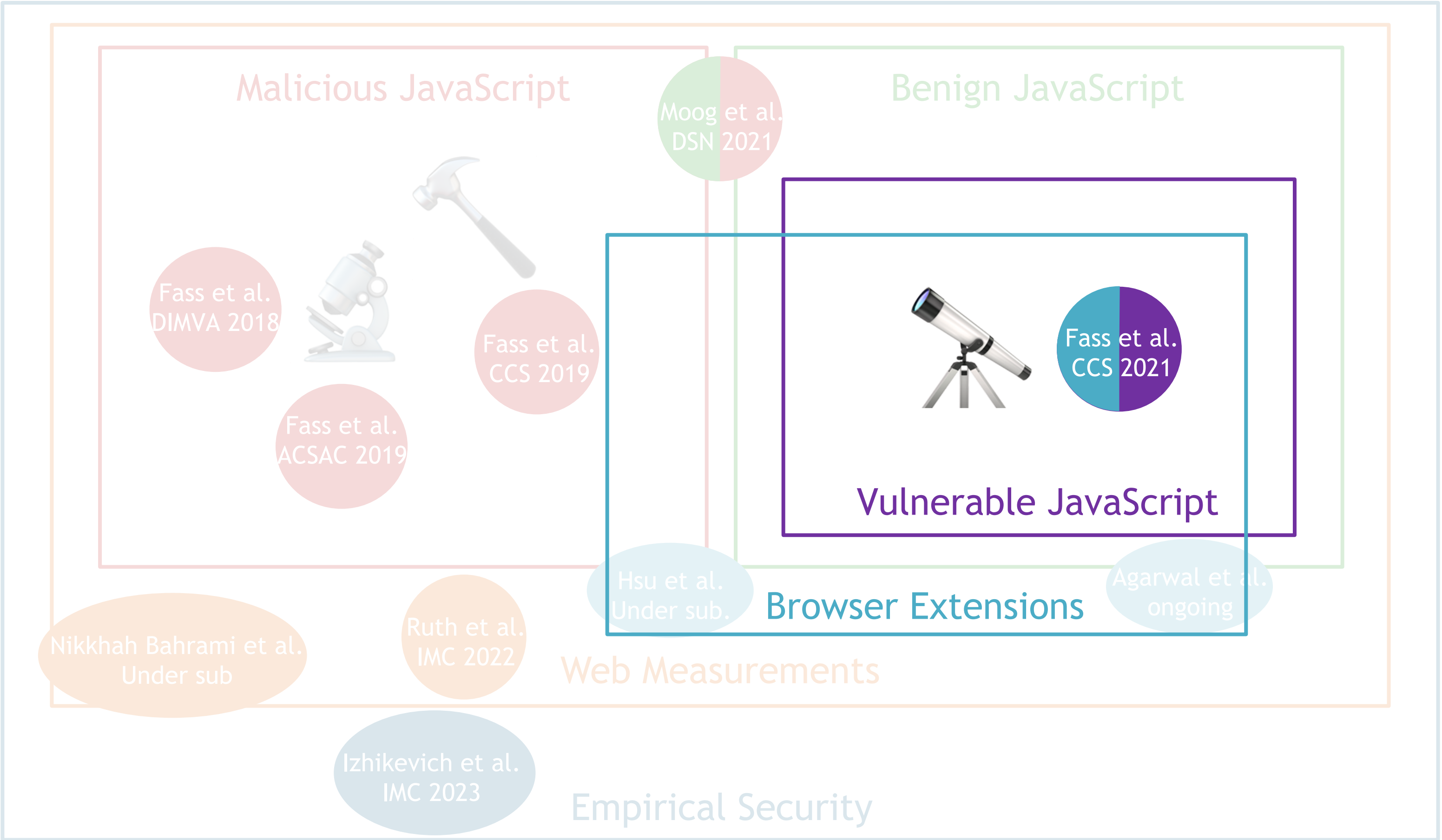
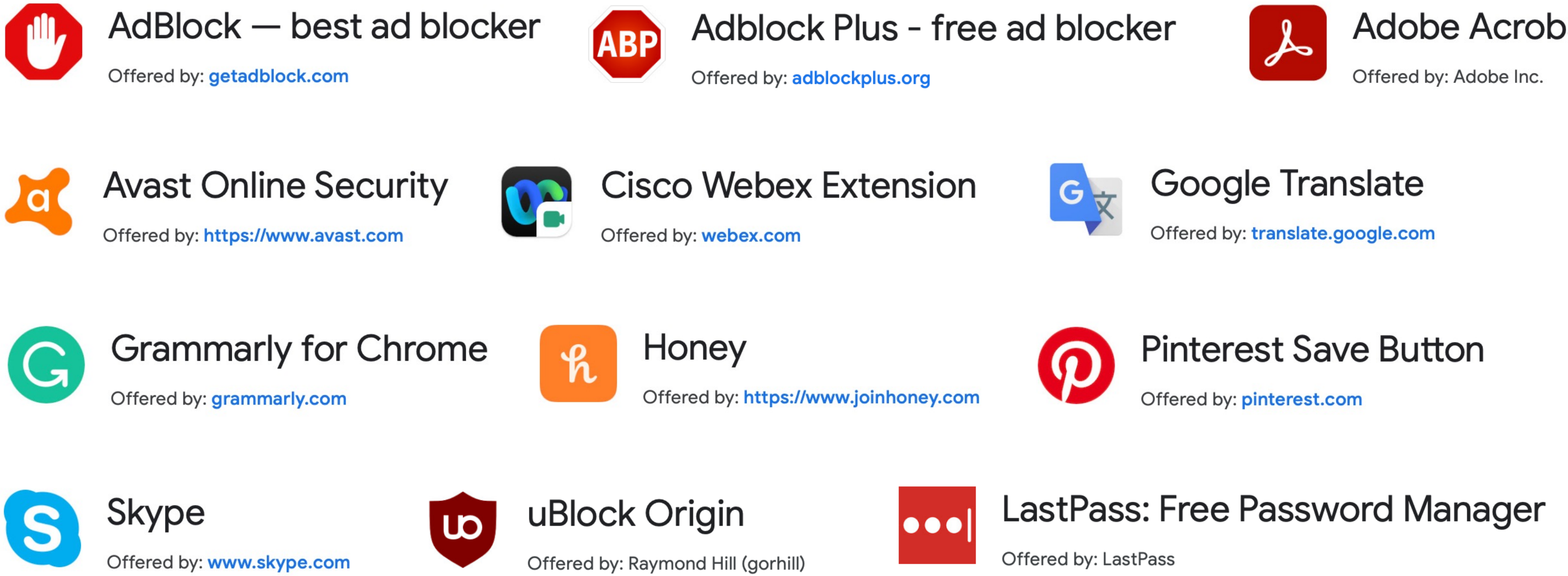


Browser Extensions…

are popular to improve user browsing experience



AdBlock — best ad blocker
Offered by: getadblock.com

Adblock Plus - free ad blocker
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Adobe Acrobat
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Avast Online Security
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Cisco Webex Extension
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Browser Extensions…

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BUT

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Browser Extensions…

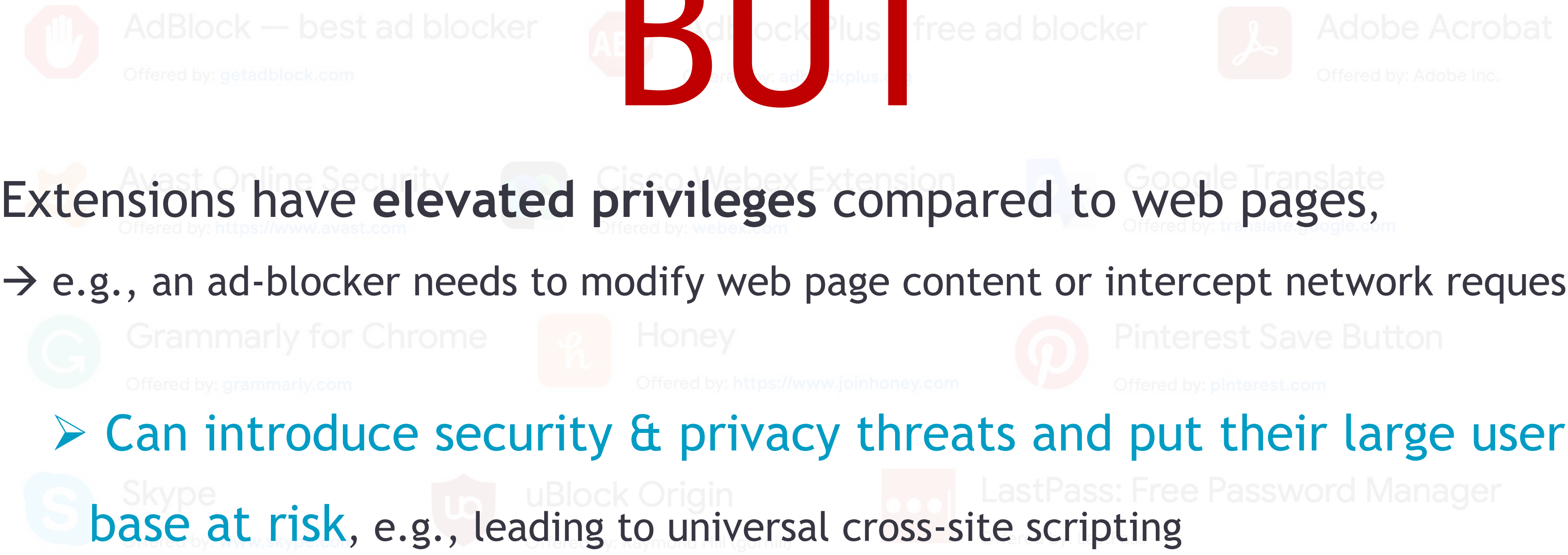
are popular to improve user browsing experience

BUT

Extensions have **elevated privileges** compared to web pages,

→ e.g., an ad-blocker needs to modify web page content or intercept network requests

➢ Can introduce security & privacy threats and put their large user base at risk, e.g., leading to universal cross-site scripting



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Motivation — Detecting *Vulnerable* Extensions

- Prior work: focus on *malicious* extensions [1—4]

[1] Chen et al., ACM CCS 2018
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→ Vetting process before an extension is published on the Chrome Web Store

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  → Vetting process before an extension is published on the Chrome Web Store

- Our focus: **vulnerable extensions** (= benign but buggy)
  - Designed by **well-intentioned developers** but contain vulnerabilities that an attacker could exploit
  - **Challenging to detect**, due to their inherently benign intent
  - Prior work mostly manual + 95% false positives [5]

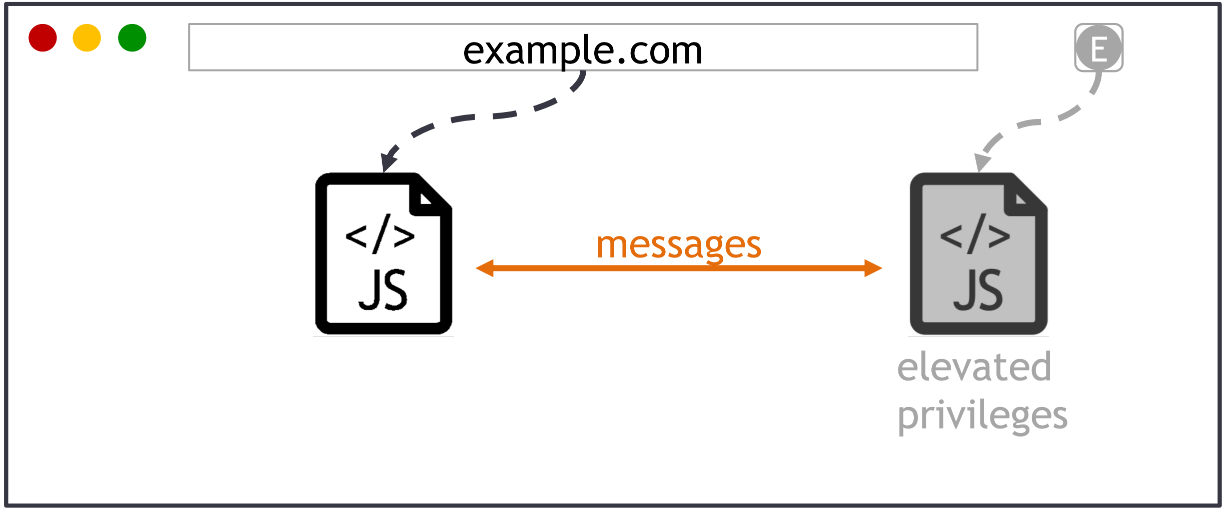
[5] Somé, IEEE S&P 2019

DOUBLEX: Statically Detecting Vulnerable Data Flows in Browser Extensions at Scale

Aurore Fass, Dolière Francis Somé, Michael Backes, and Ben Stock

ACM CCS 2021

Exploiting Vulnerable Extensions



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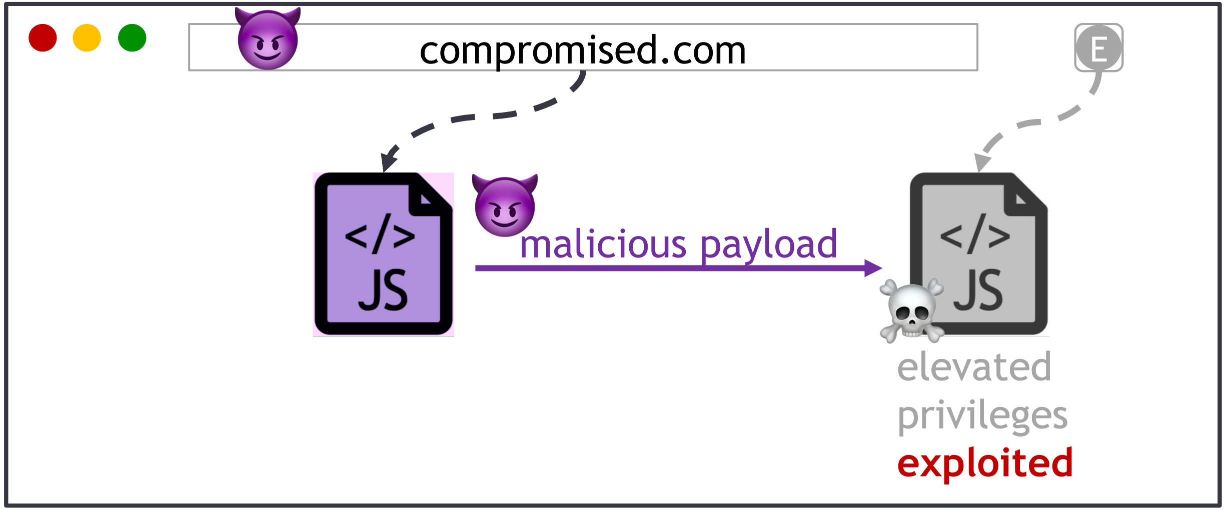

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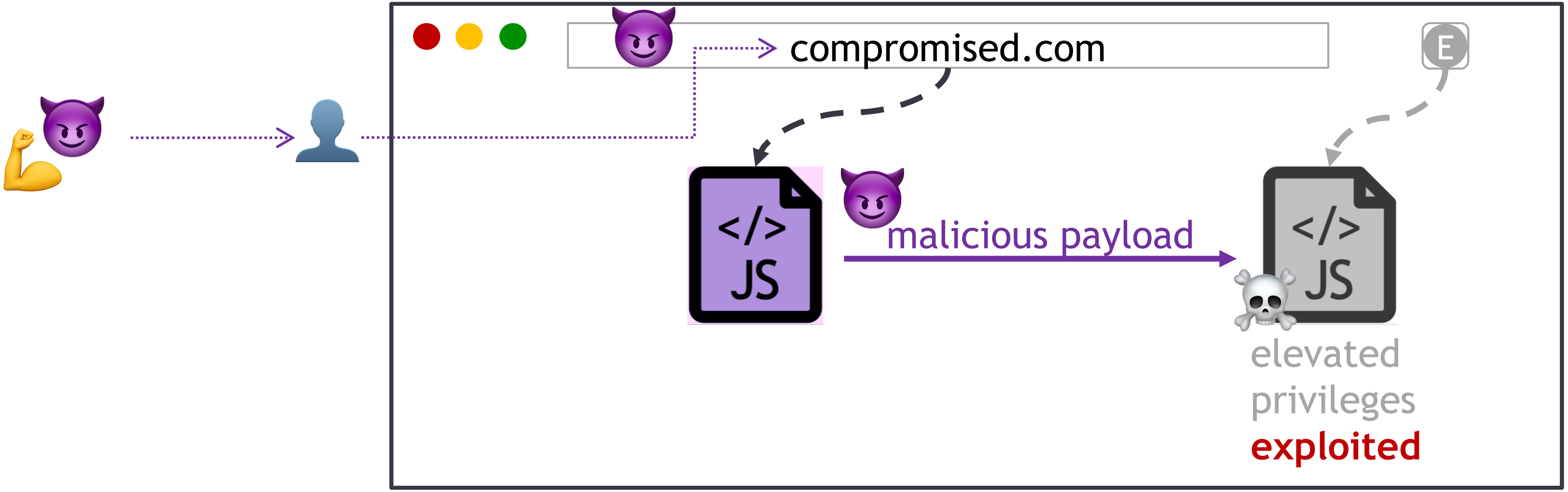

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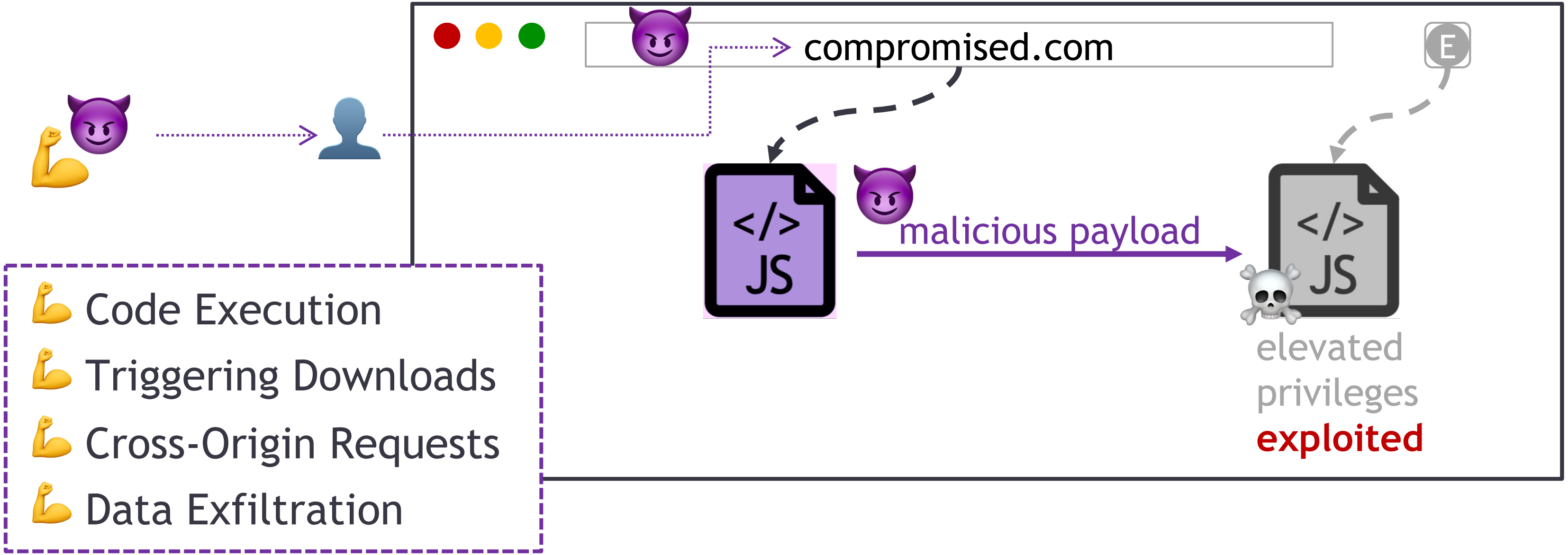

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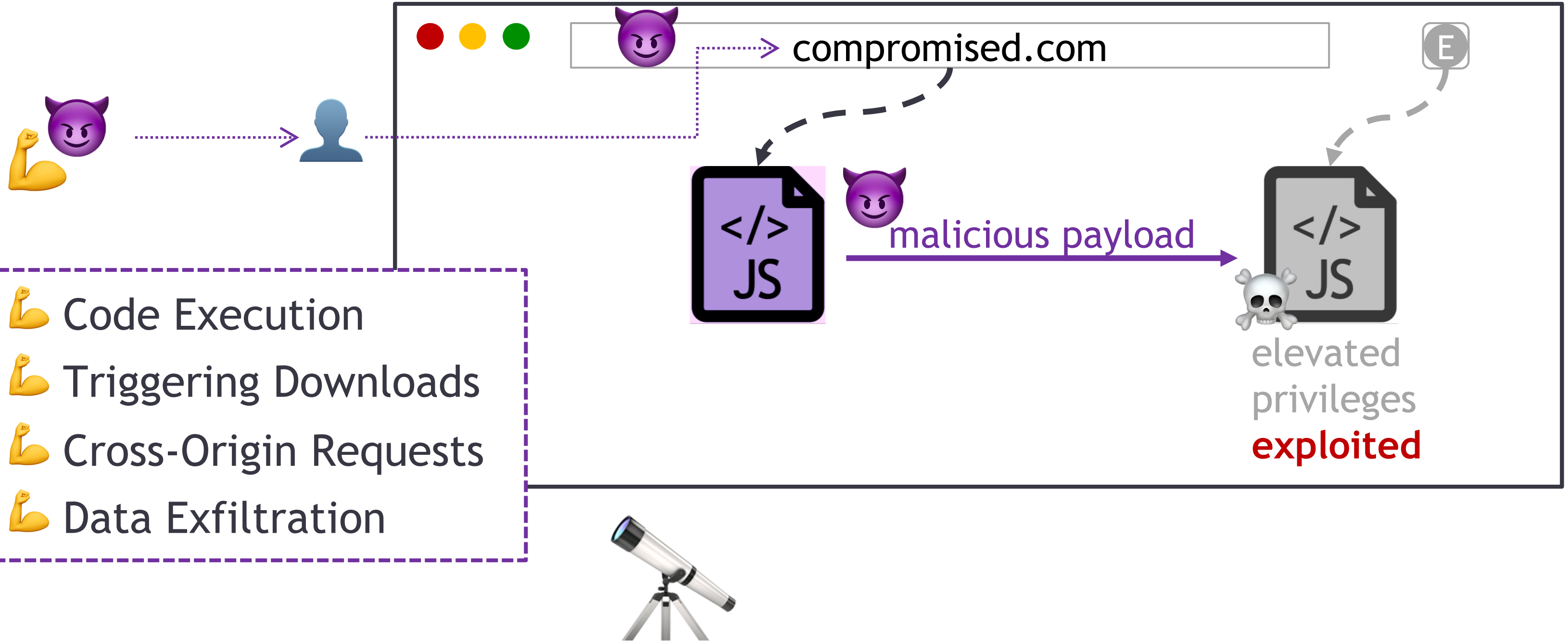
- 💪 Triggering Downloads
- 💪 Cross-Origin Requests
- 💪 Data Exfiltration

Exploiting Vulnerable Extensions



- 💪 Code Execution
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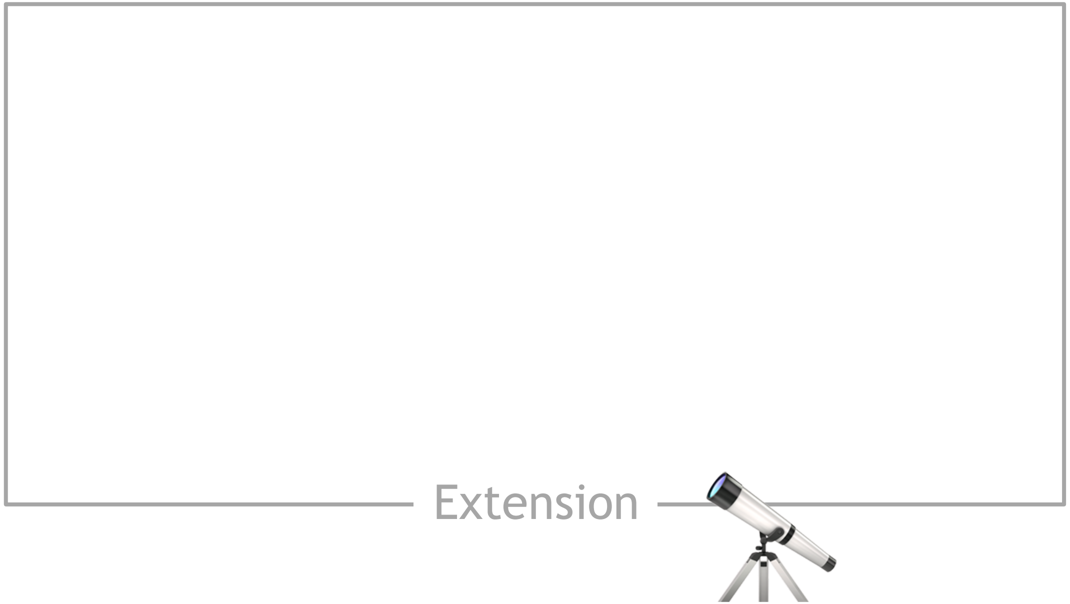
→ **DOUBLEX: detects suspicious data flows from and toward an extension privileged context**

Extension Architecture and Communication



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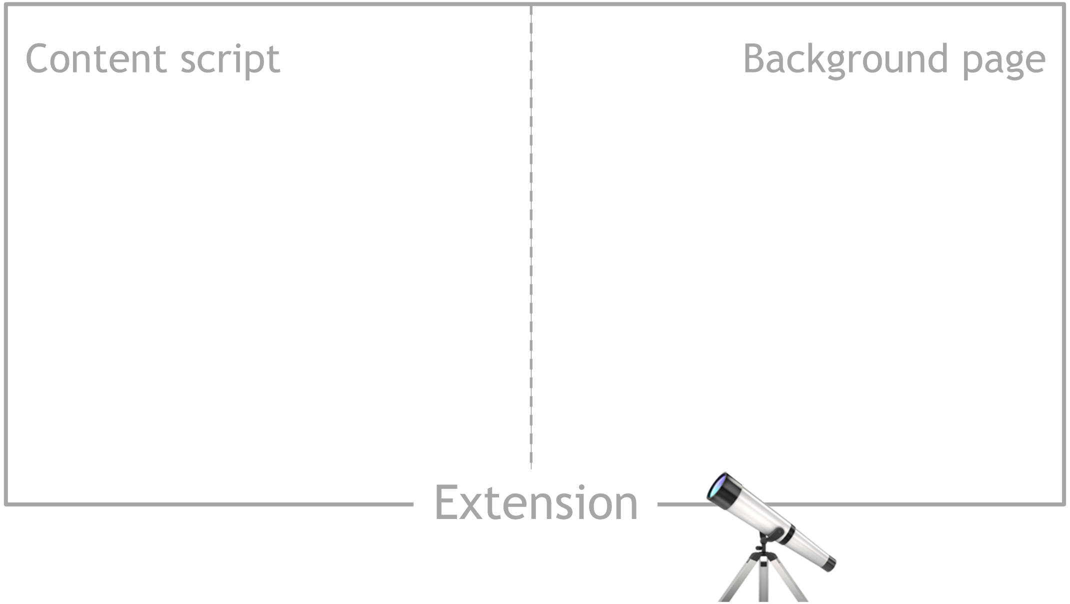
Extension Architecture and Communication



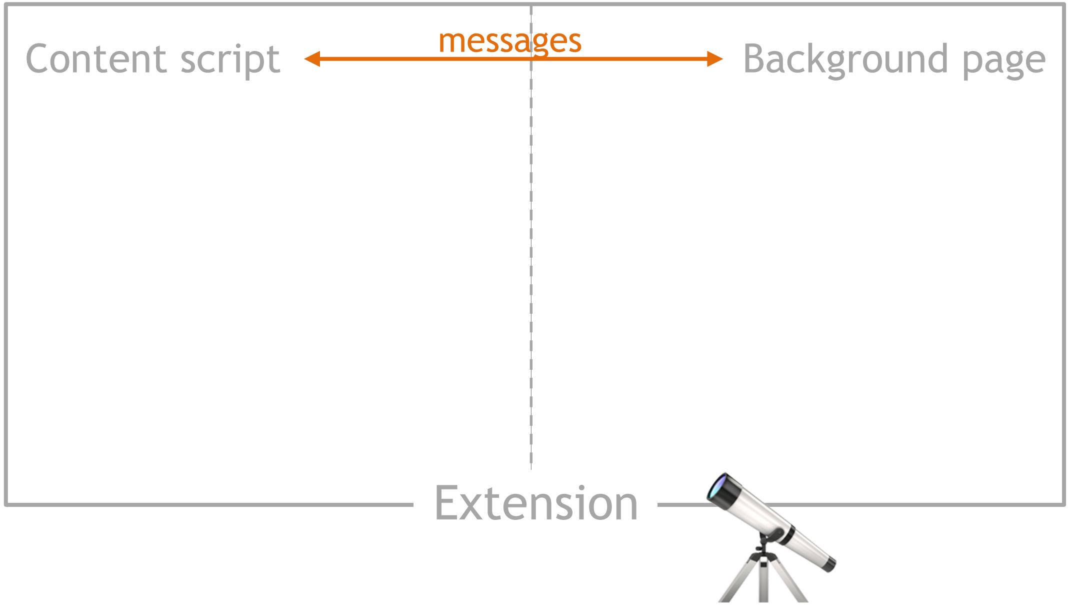
Content script

Background page

Extension

→ **DoubleX: detects suspicious data flows from and toward an extension privileged context**

Extension Architecture and Communication



Content script

messages

Background page

Extension

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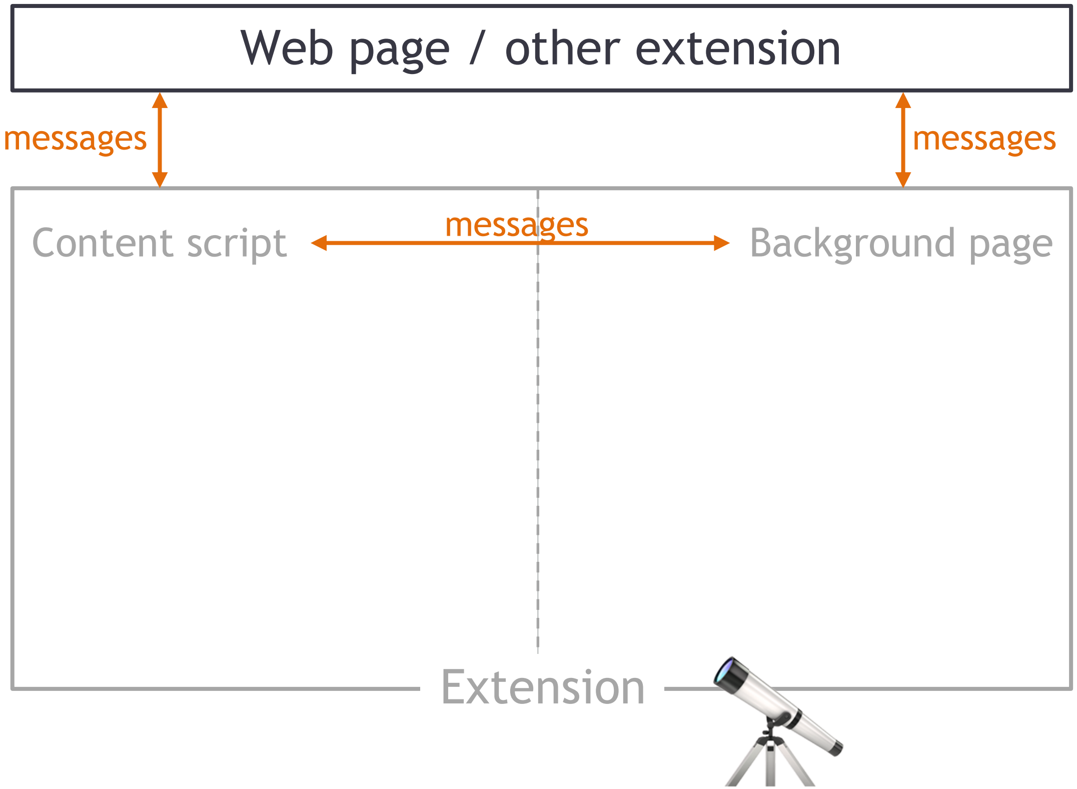
Extension Architecture and Communication



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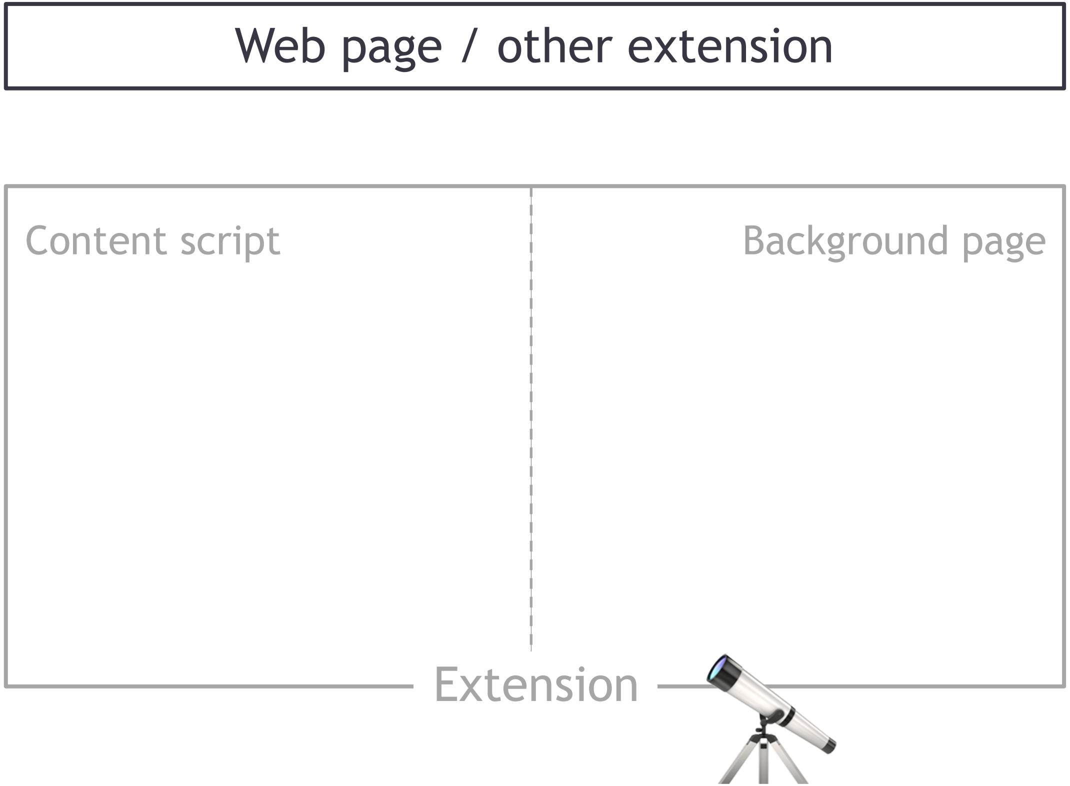
DoubleX: Suspicious Data Flow Detection



Web page / other extension

Content script

Background page

Extension

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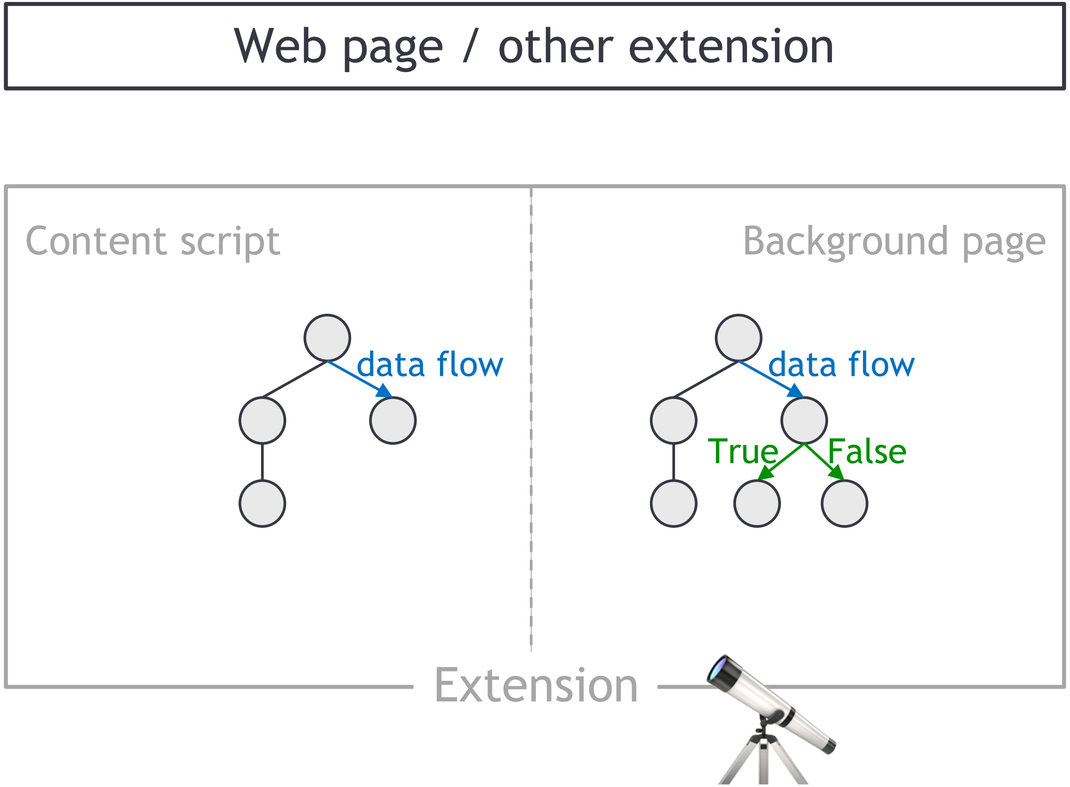
DOUBLEX: Suspicious Data Flow Detection



Per-component JS code abstraction

- AST
- Control flow
- Data flow
- Pointer analysis

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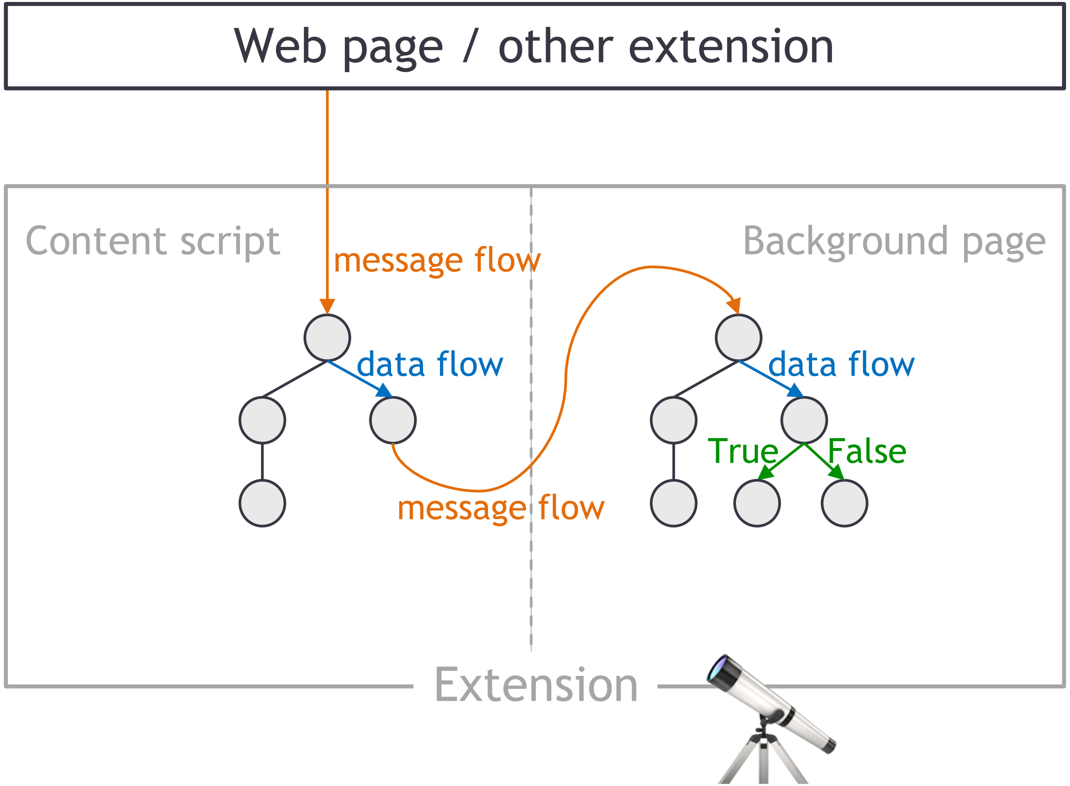
DOUBLEX: Suspicious Data Flow Detection



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Extension Dependence Graph (EDG)

➢ Message interactions

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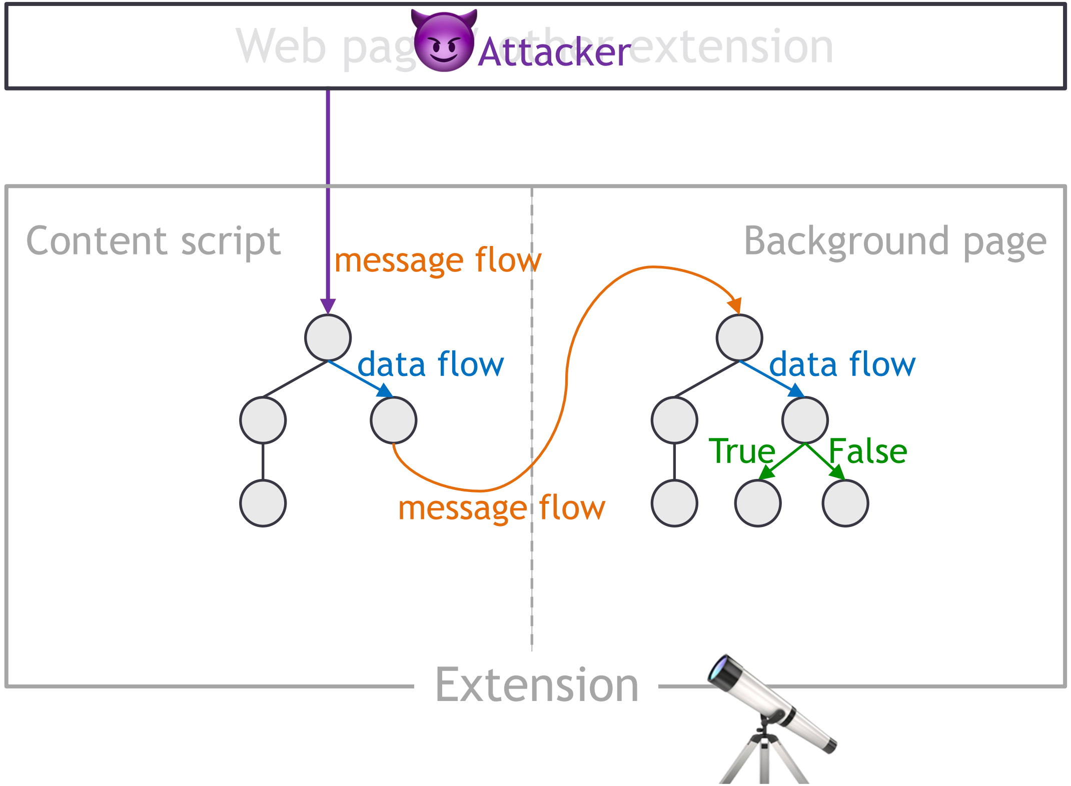

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Suspicious data flow tracking

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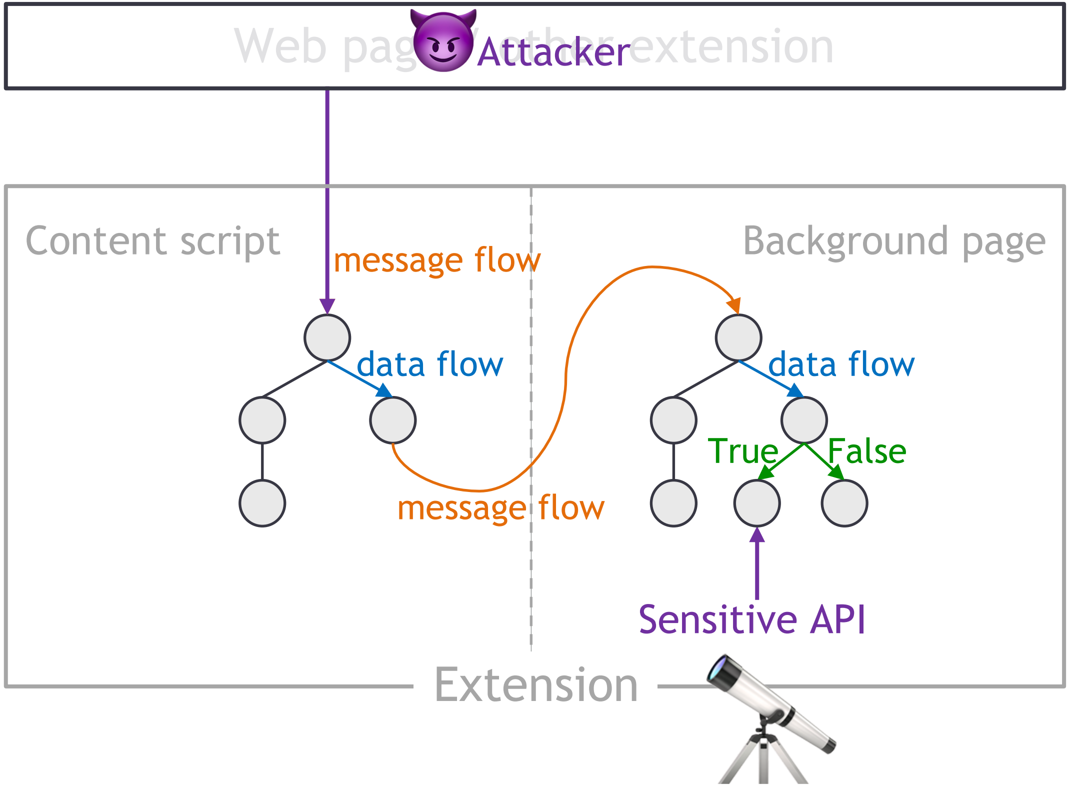

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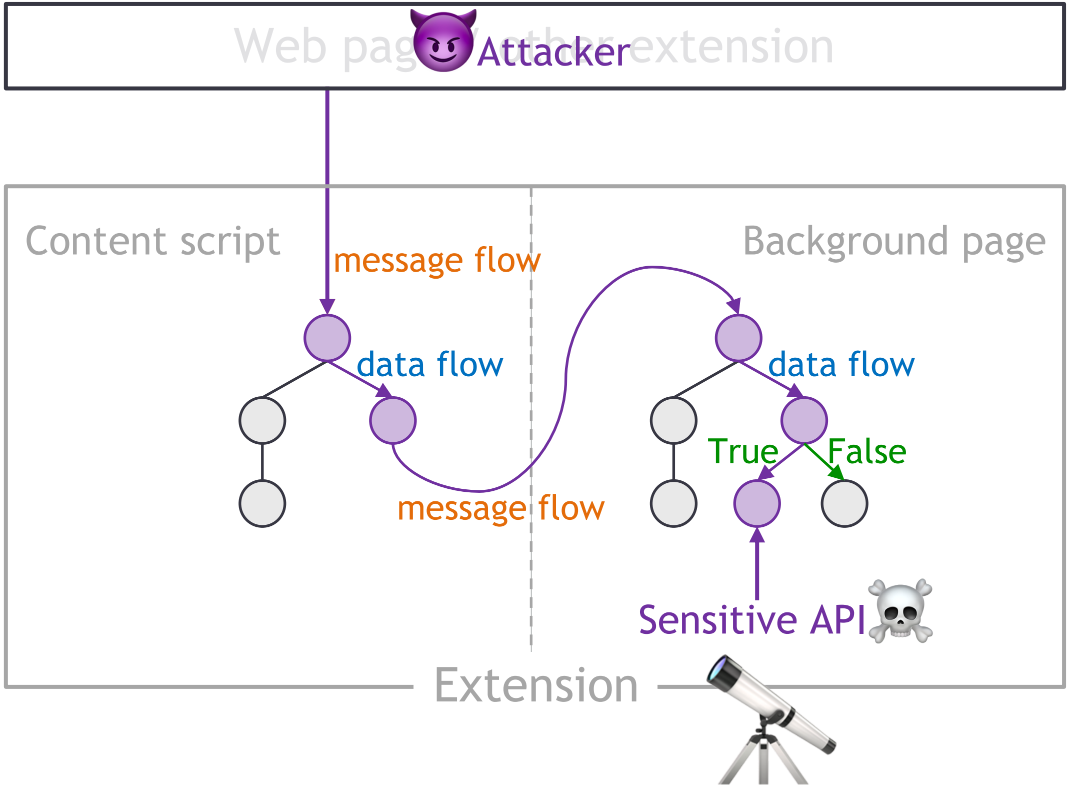

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Extension Dependence Graph (EDG)

➢ Message interactions

Suspicious data flow tracking

➢ Detects any path between an attacker & sensitive APIs

↓

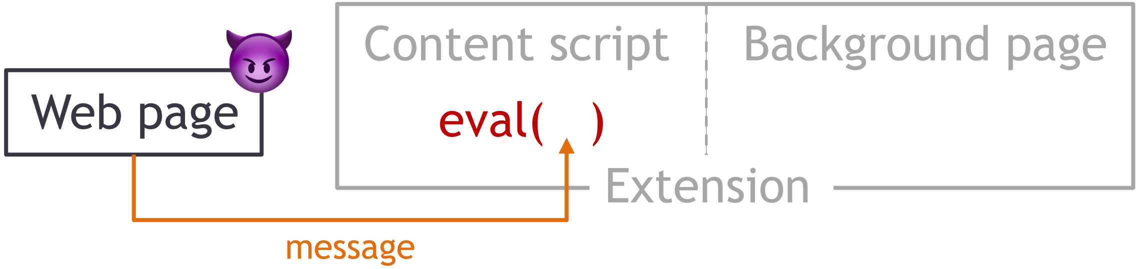
Data flow report

Per-Component JS Code Abstraction

```
// Content script code
window.addEventListener("message", function(event) {

    eval(event.data);

})
```



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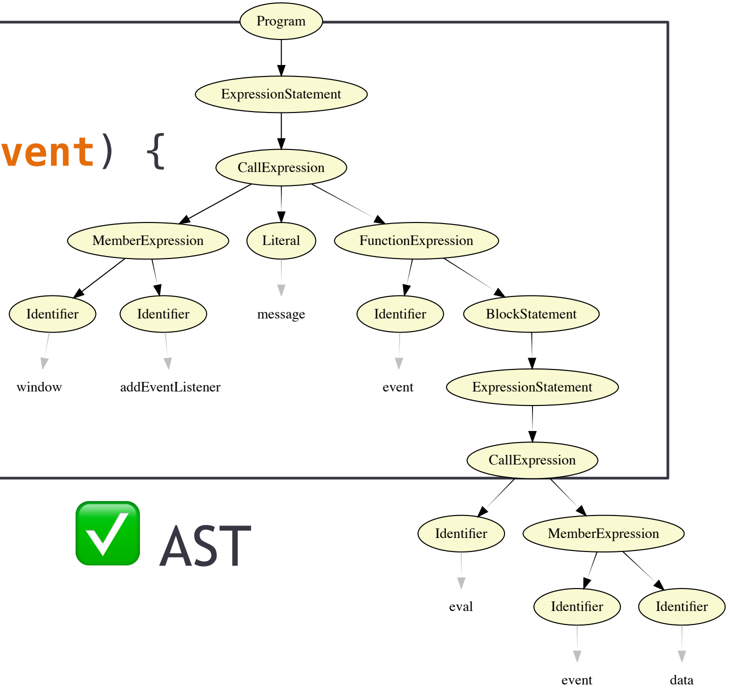
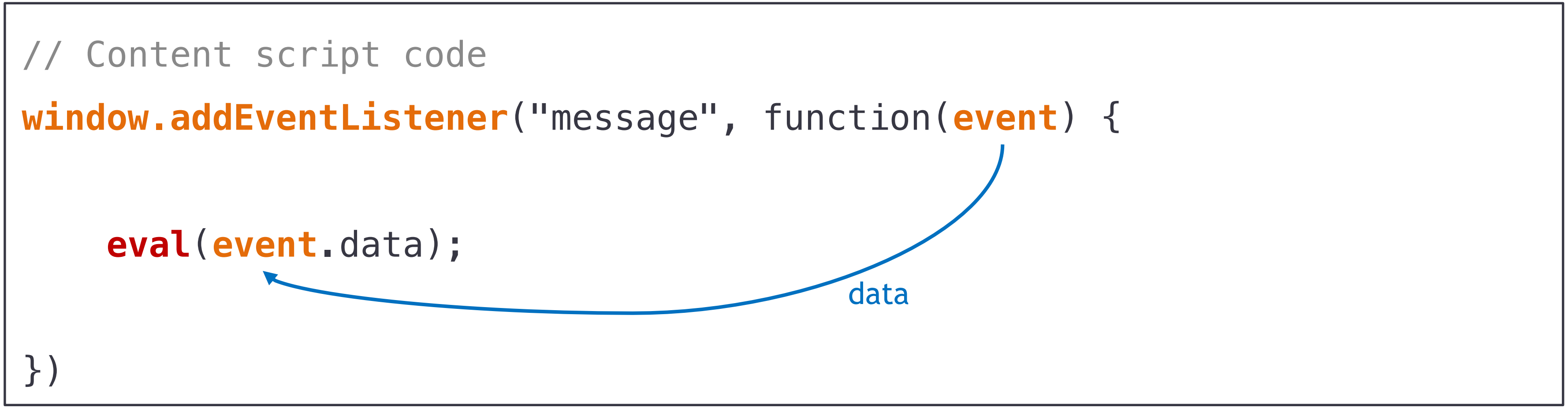


Abstract code representation → ✅ AST

Per-Component JS Code Abstraction



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Abstract code representation → ✅ AST

– variable dependencies → ✅ data flow

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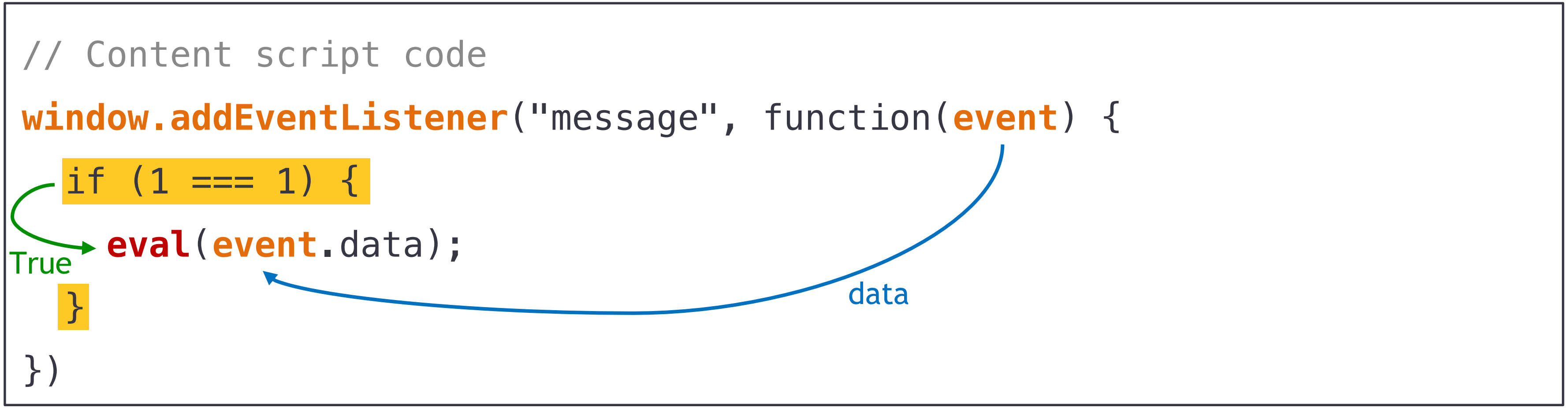

```
// Content script code
window.addEventListener("message", function(event) {
   if (1 === 1) {
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```
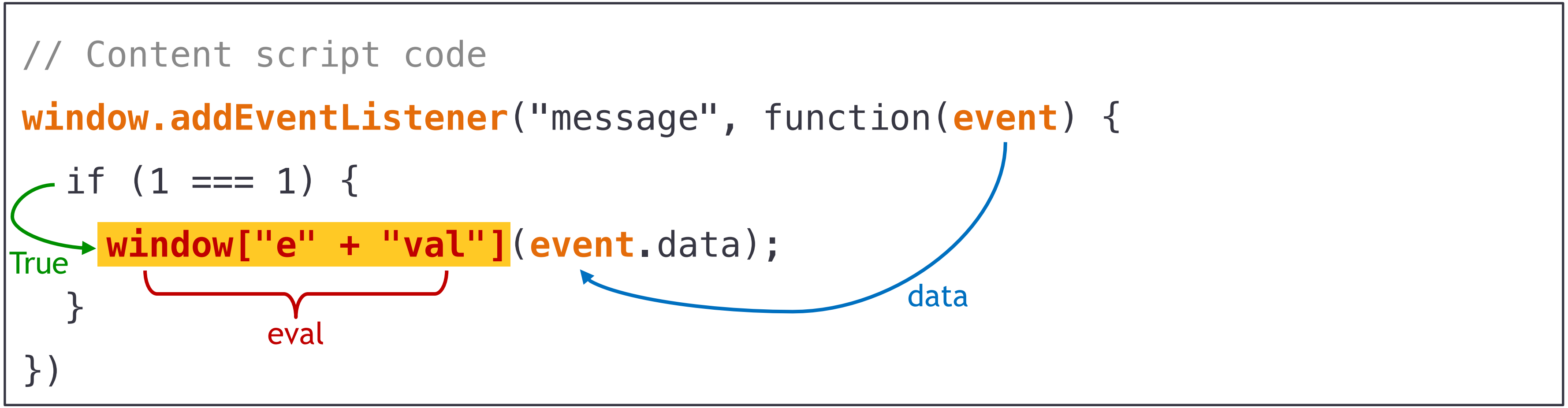

Abstract code representation → ✓ AST

- conditions → ✓ control flow
- variable dependencies → ✓ data flow

Per-Component JS Code Abstraction



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```

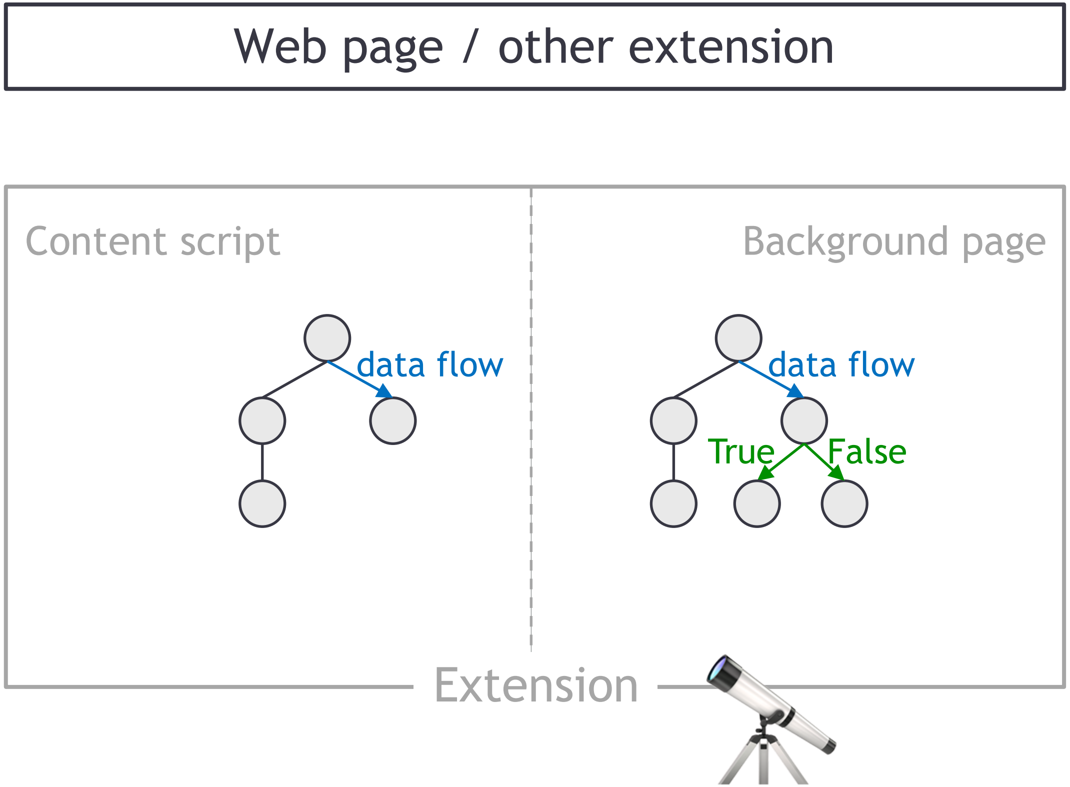
Abstract code representation → ✅ AST

– conditions → ✅ control flow

– variable dependencies → ✅ data flow

– variable values → ✅ pointer analysis

DoubleX: Suspicious Data Flow Detection



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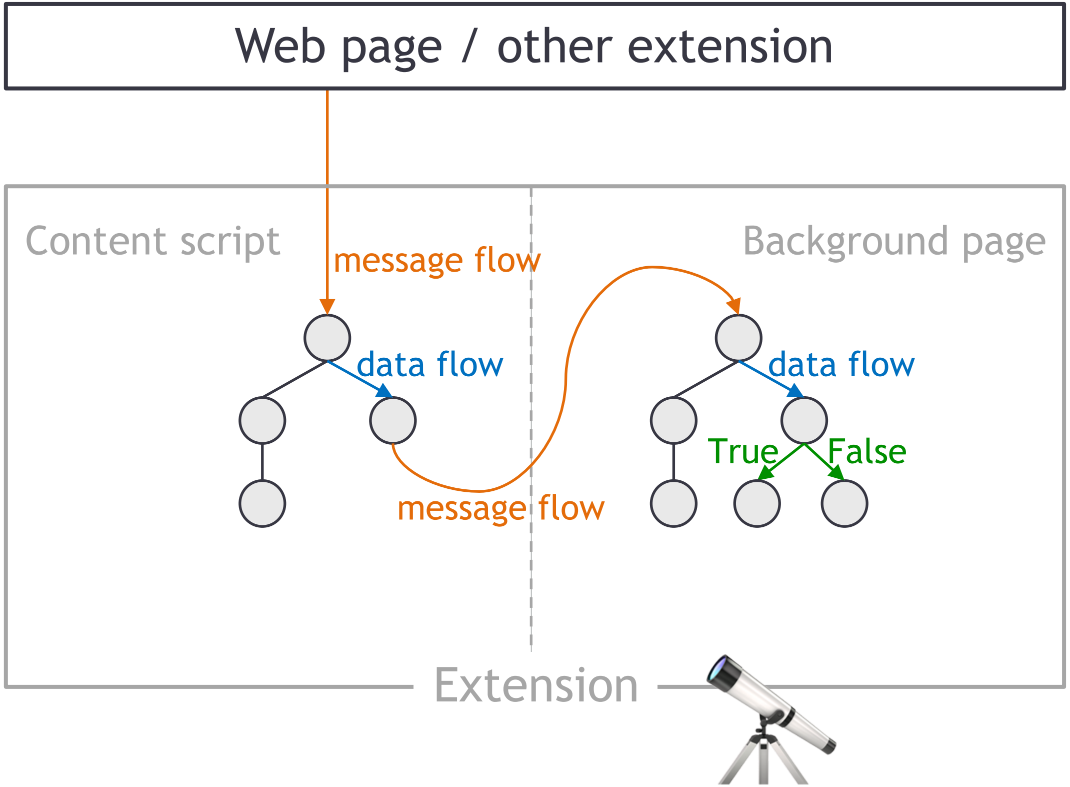

Web page / other extension

Content script

Background page

message flow

data flow

message flow

data flow

True

False

Extension

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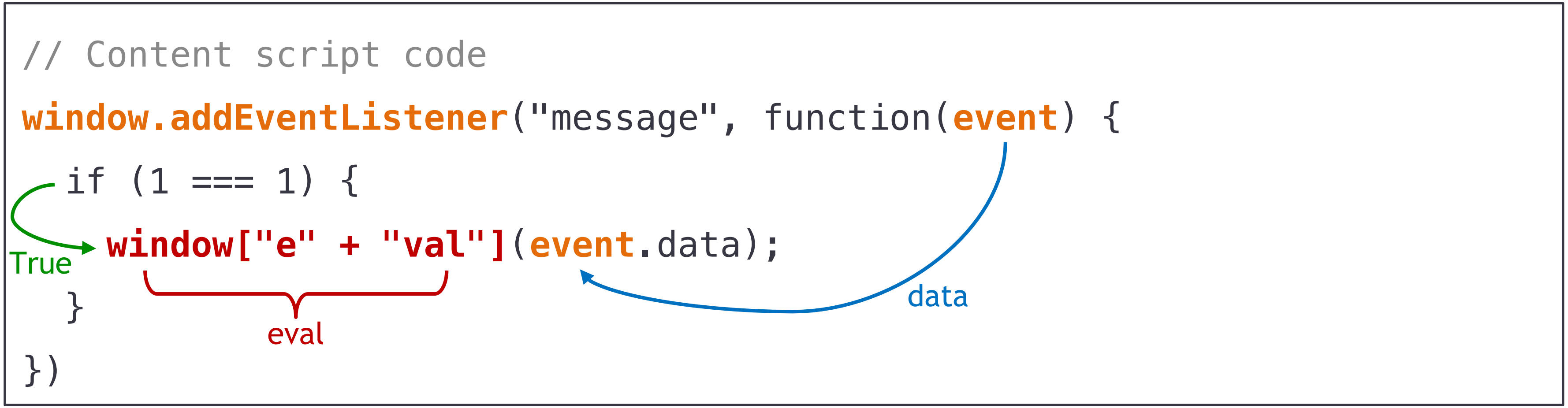

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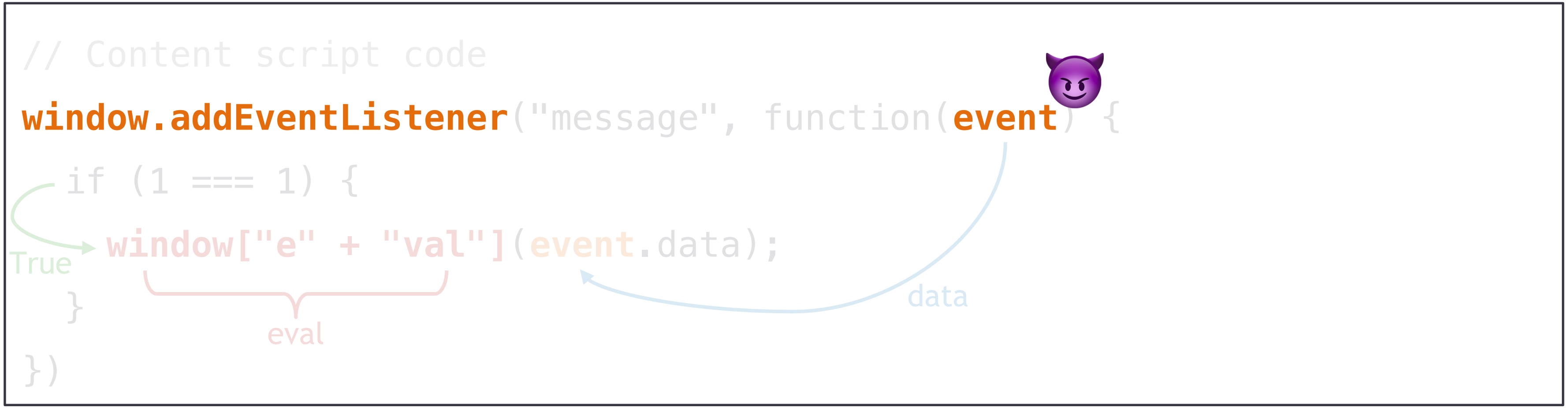
- external messages
- internal messages

Extension Dependence Graph



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- external messages ✅
- internal messages

Extension Dependence Graph

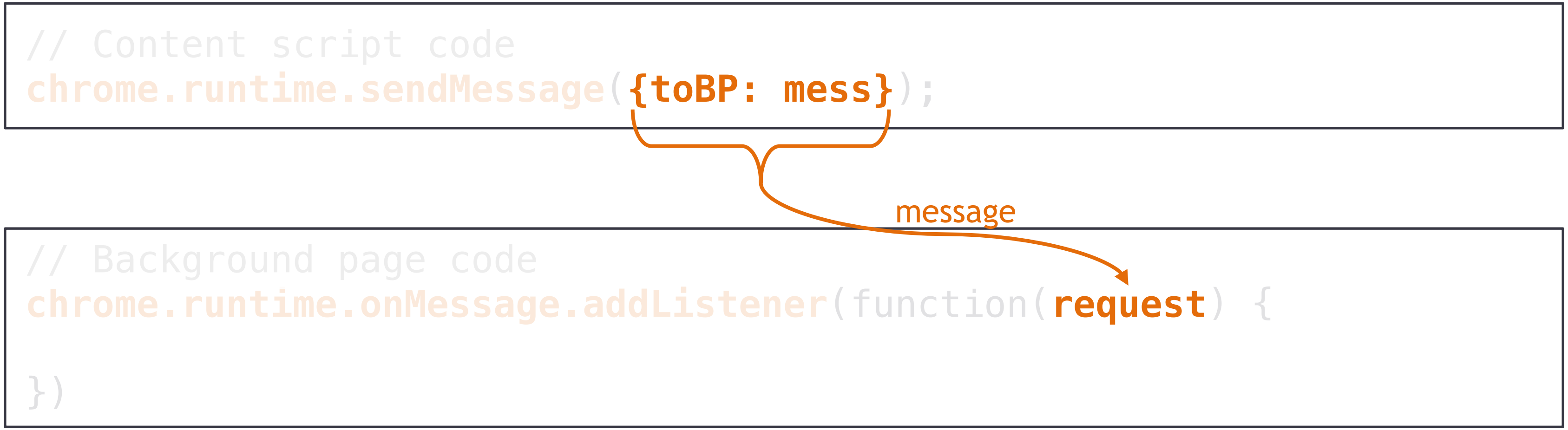
```
// Content script code
chrome.runtime.sendMessage({toBP: mess});
```

```
// Background page code
chrome.runtime.onMessage.addListener(function(request) {

})
```

- external messages ✅
- internal messages

Extension Dependence Graph



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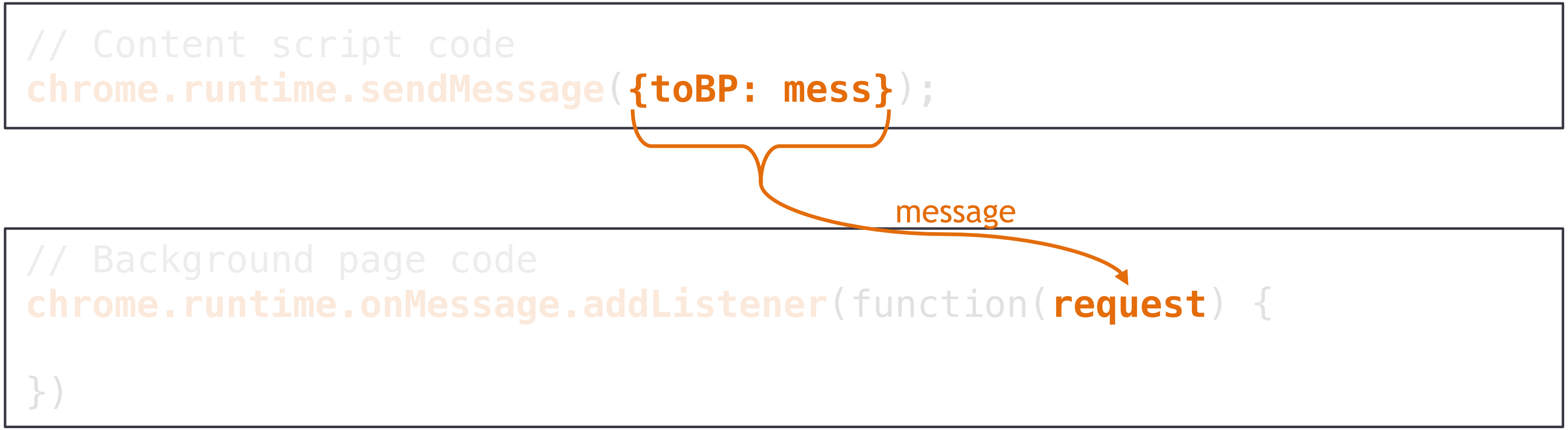

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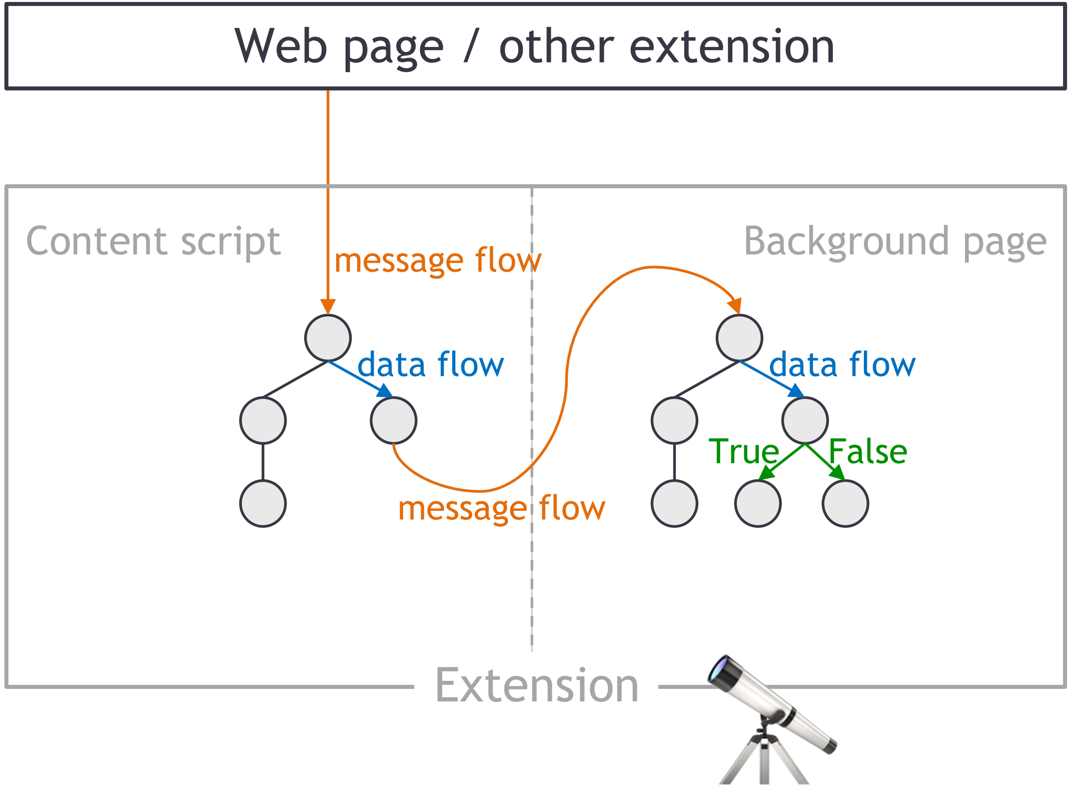
– external messages ✅

– internal messages ✅

➢ Models message interaction within and outside of an extension

DoubleX: Suspicious Data Flow Detection



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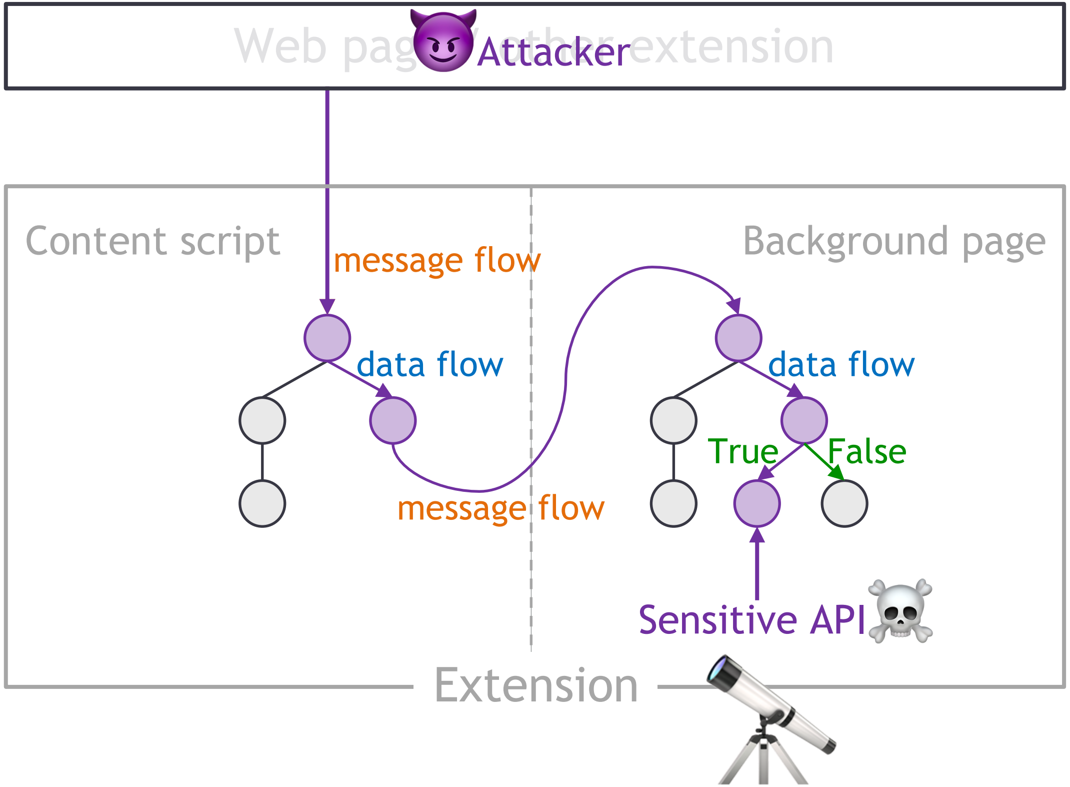

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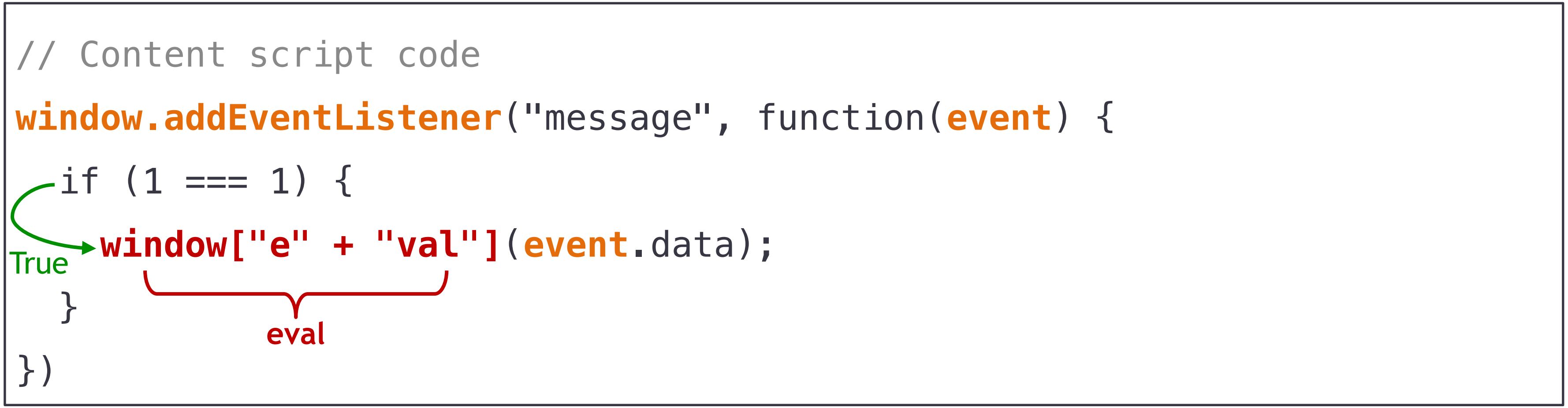
Data flow report

Suspicious Data Flow Tracking



```
// Content script code
window.addEventListener("message", function(event) {
  if (1 === 1) {
   window["e" + "val"](event.data);
  }
})
```

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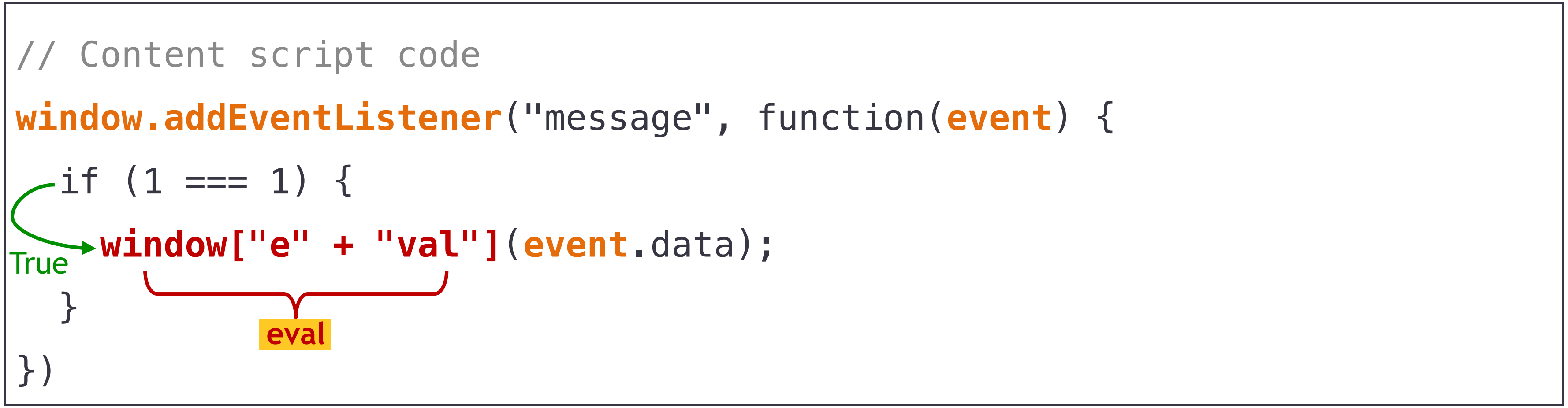

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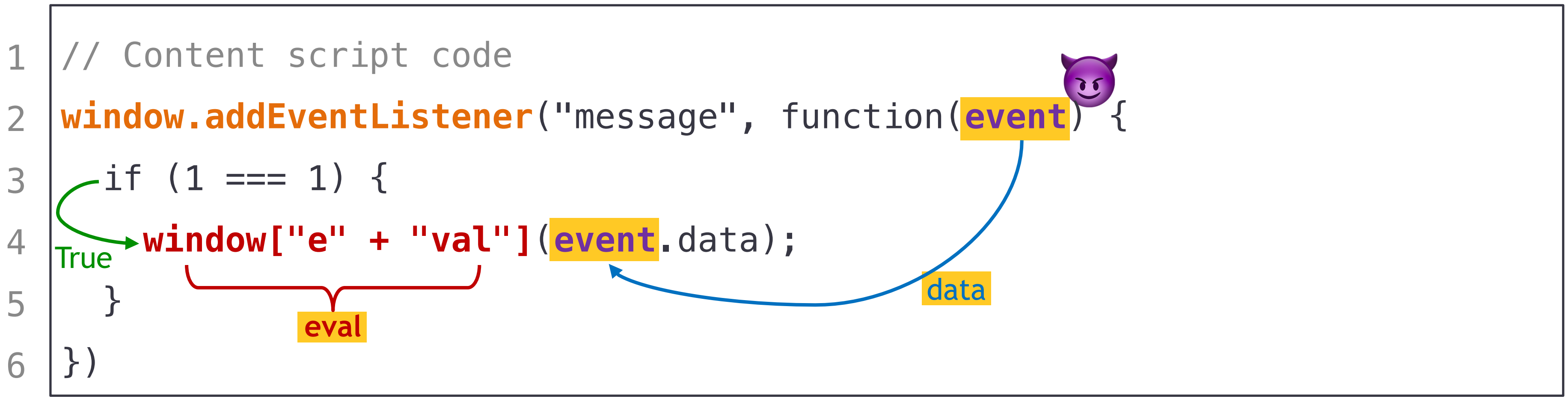

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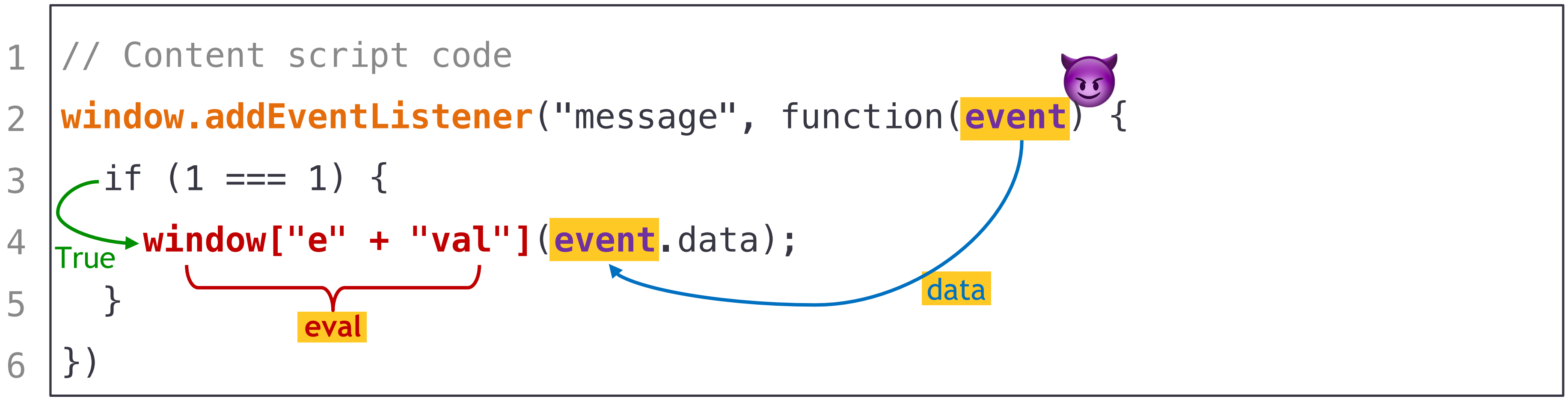

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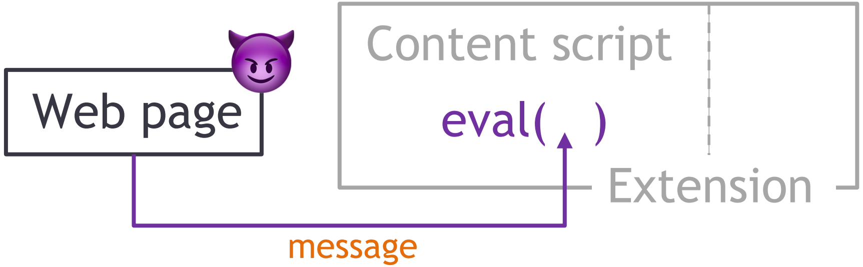

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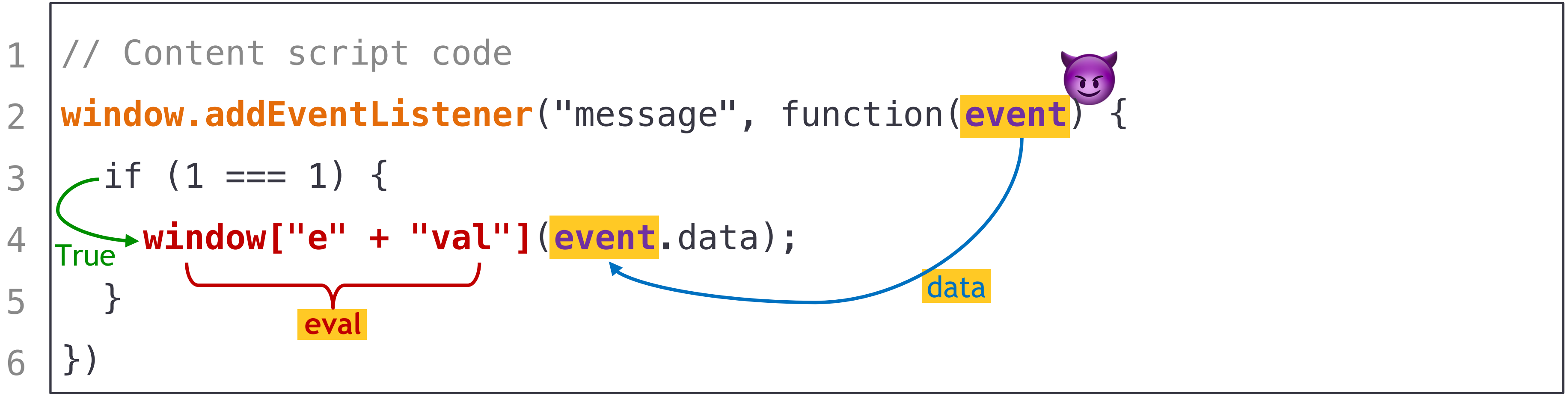

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1 // Content script code
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3   if (1 === 1) {
4     window["e" + "val"](event.data);
5   }
6 })
```
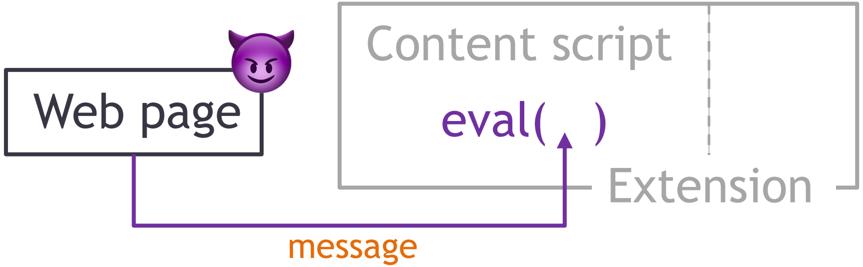
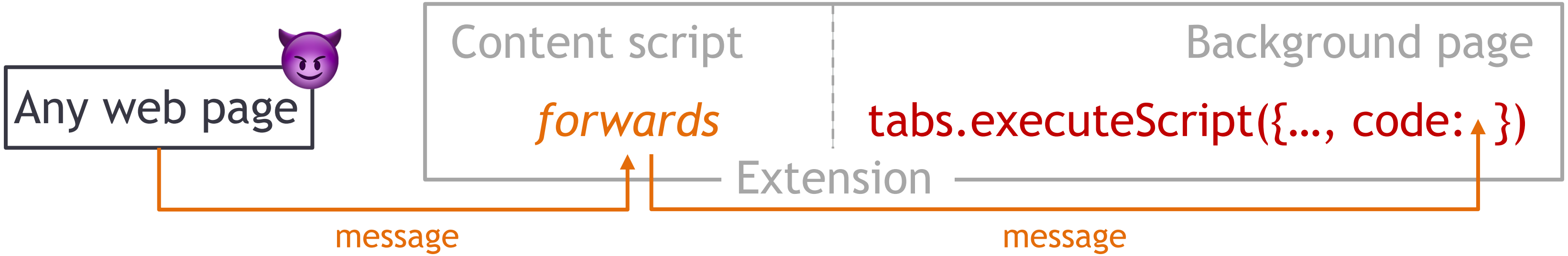



```
// Data flow report
{"direct-danger1": "eval",
"value": "eval(event.data)",
"line": "4 - 4",
"dataflow": true,
"param1": {
  "received": "event",
  "line": "2 - 2"}}
```

Case Studies of Vulnerable Chrome Extensions

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

- Arbitrary code execution (*cdi…*, 4k+ users)



Any web page 😈

Content script

forwards

Background page

tabs.executeScript({…, code: })

Extension

message

message

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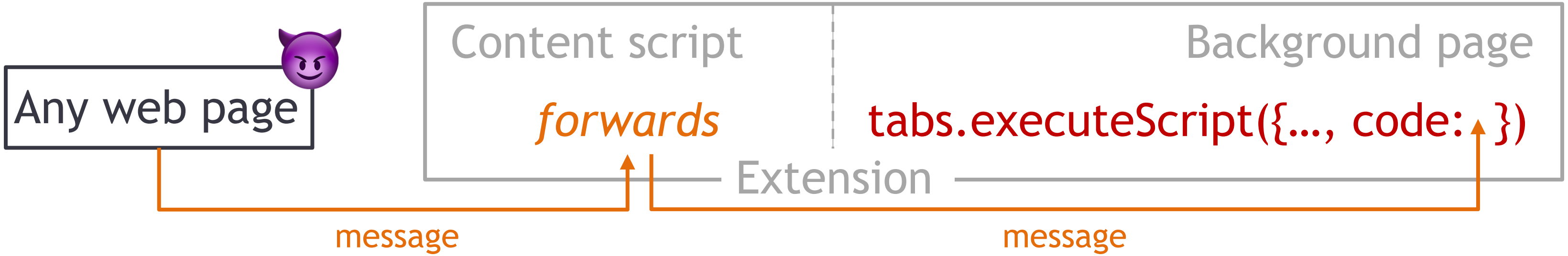
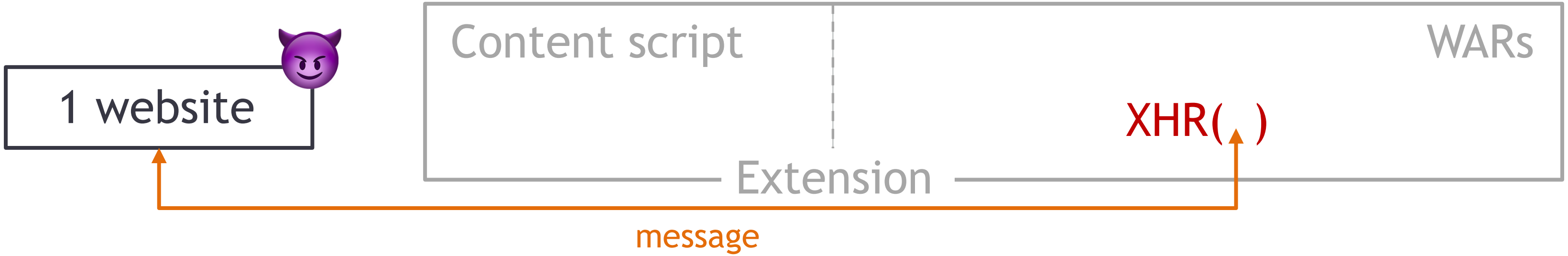


- Cross-origin requests (*koh*…, 200k+ users)



Large-Scale Analysis of Chrome Extensions

- Analyzed 155k Chrome extensions from 2021 with DOUBLEX
  - 278 suspicious extensions reported (309 suspicious data flows)

    → **Precision: 89%** (manually) verified dangerous data flows (275 / 309)

Attacker capabilities	#Reports	#Verified data flow	#Exploitable
Code Execution	113	102	63
Triggering Downloads	21	21	21
Cross-Origin Requests	95	75	49
Data Exfiltration	80	77	76
Sum	309	275	209

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  → **184 confirmed vulnerable extensions**
    - 2.4 – 2.9 million users impacted
    - 36% can be exploited by *any* websites or extensions

- Analyzed known vulnerable extensions with DOUBLEX [5]
  - → **Recall: 93%** of known vulnerabilities are detected (151 / 163)

[5] Somé, IEEE S&P 2019

Life Cycle of Vulnerable Chrome Extensions

- Analyzed 165k extensions from 2020 with DOUBLEX
  - 193 vulnerable extensions (184 in 2021)
  - vulnerability disclosure for 35 extensions (48 extensions when including 2021)

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  - not in the Store anymore: 30 / 193
  - vulnerability fixed: 3 / 193
  - turned vulnerable: 5 / 184
  - new vulnerable: 19 / 184
  - ➢ **still vulnerable: 160 (87%!)**

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➢ **still vulnerable: 160 (87%!)** ➢ **Need to prevent vulnerable extensions from entering the Store → DOUBLEX**

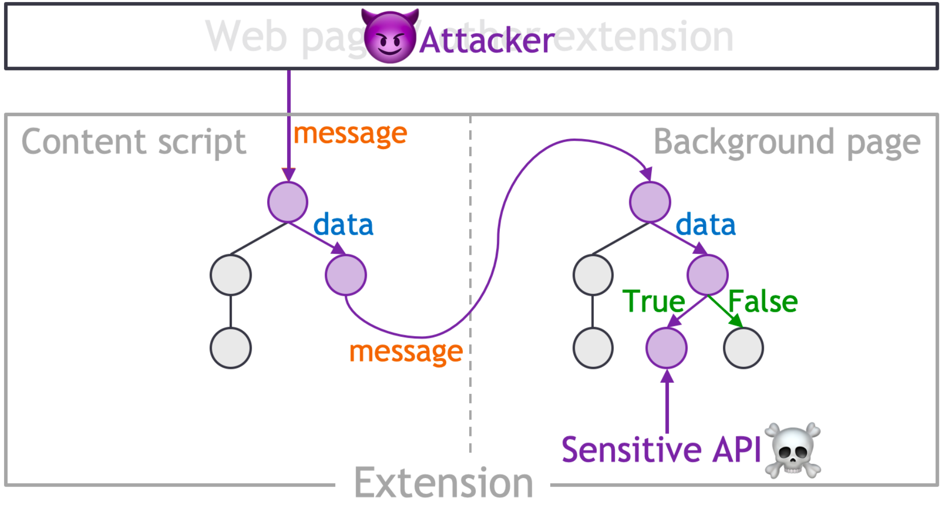
Takeaway

unintentionally

Extensions are popular… but may introduce security & privacy threats

→ Because **highly privileged**

→ Due to their **communication with websites** / other extensions



DoubleX: detects suspicious data flows in extensions

- 184 vulnerable extensions (87% already vulnerable the year before)
- **Precision: 89%**
- **Recall: 93%**

Aurore54F/DoubleX

@AuroreFass

Fork 9 ▾ ☆ Star 47 ▾