Loophole: Timing Attacks on Shared Event Loops in Chrome

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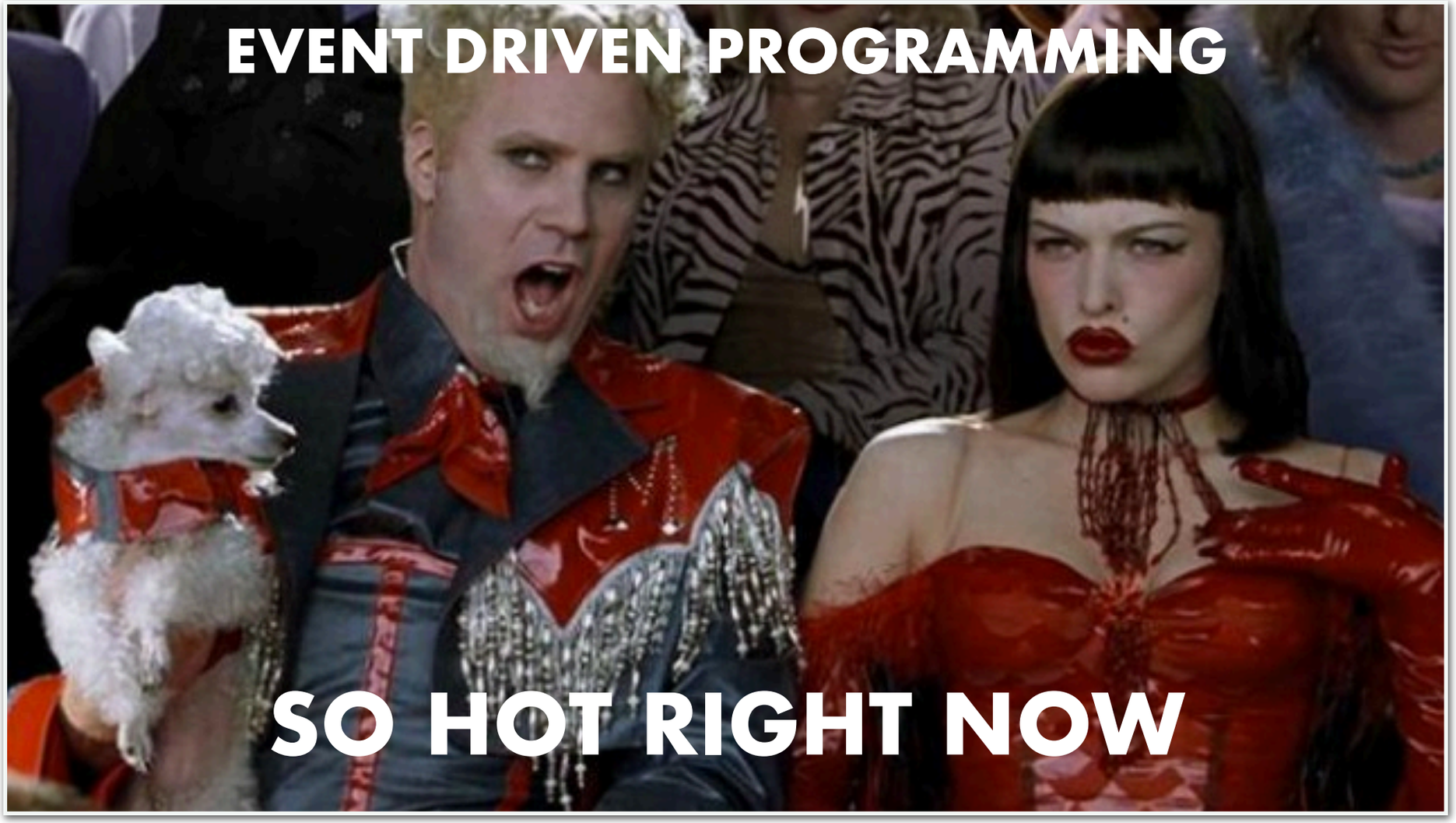
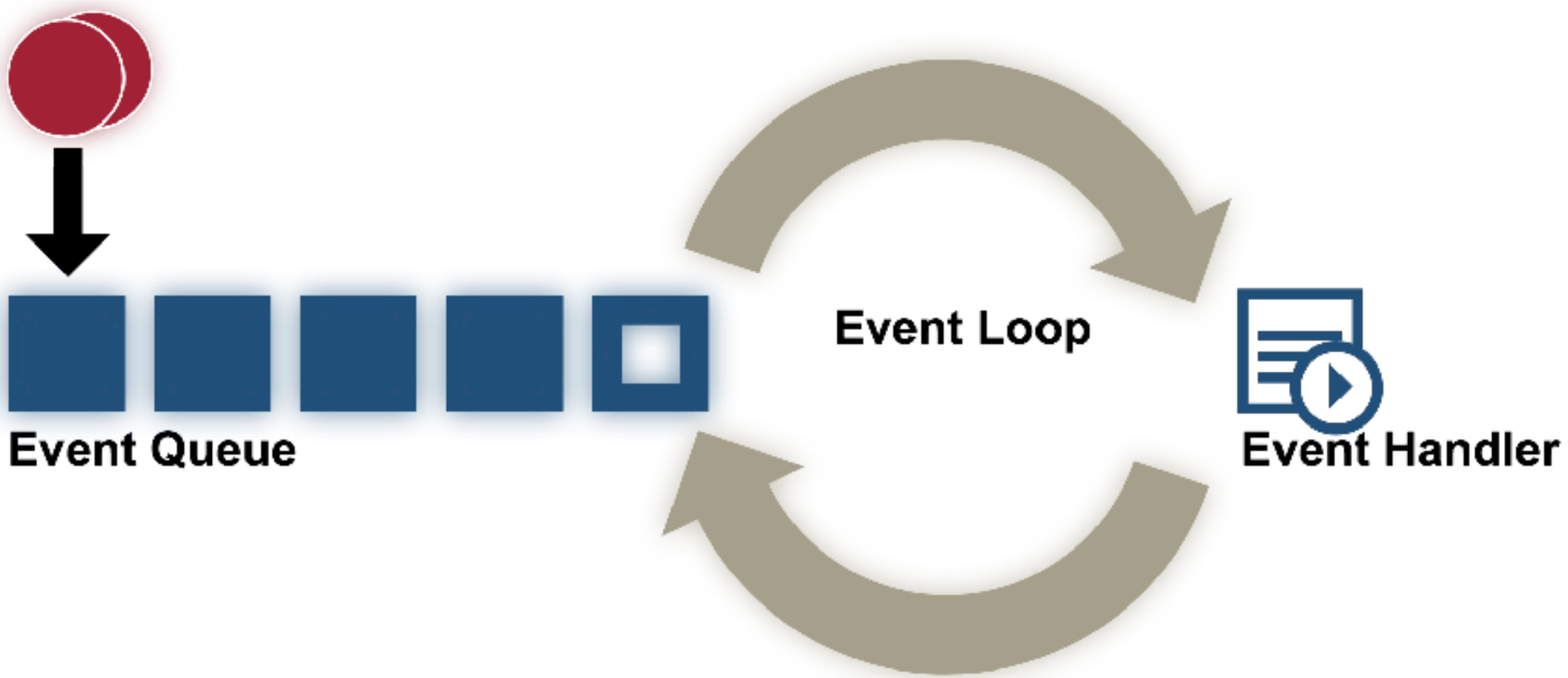
github.com/cgvwzq


EVENT DRIVEN PROGRAMMING
SO HOT RIGHT NOW

HTML

NGINX

node



Source: http://berb.github.io/diploma-thesis/original/042_serverarch.html

We exploit 2 different shared Event Loops in Chrome:

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I/O's of the **Host Process**

Main thread's of **Renderers**

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And implement 3 different attacks:

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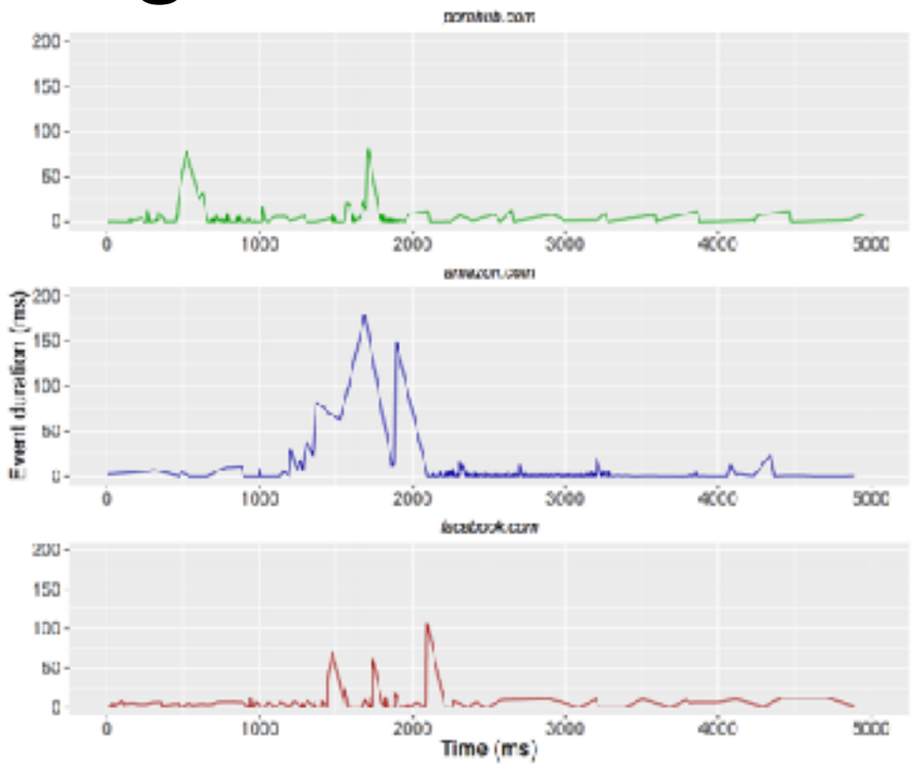
Page Identification



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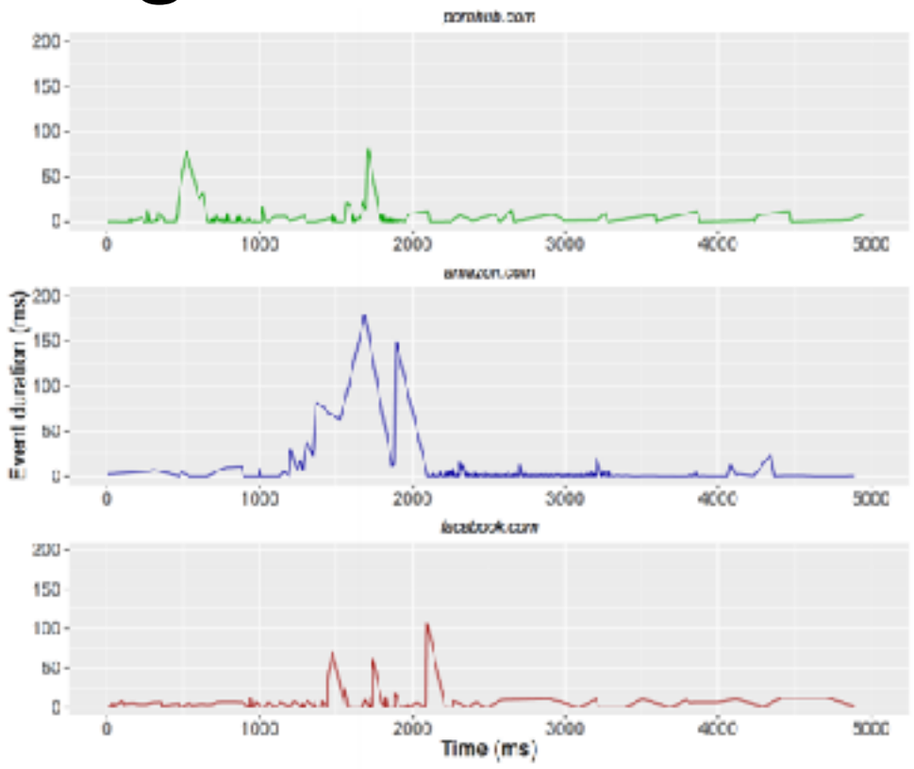
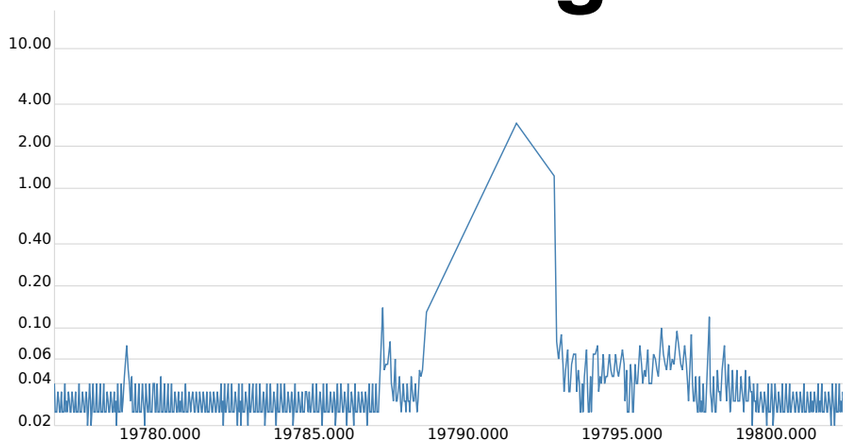


Inter-keystroke Timing



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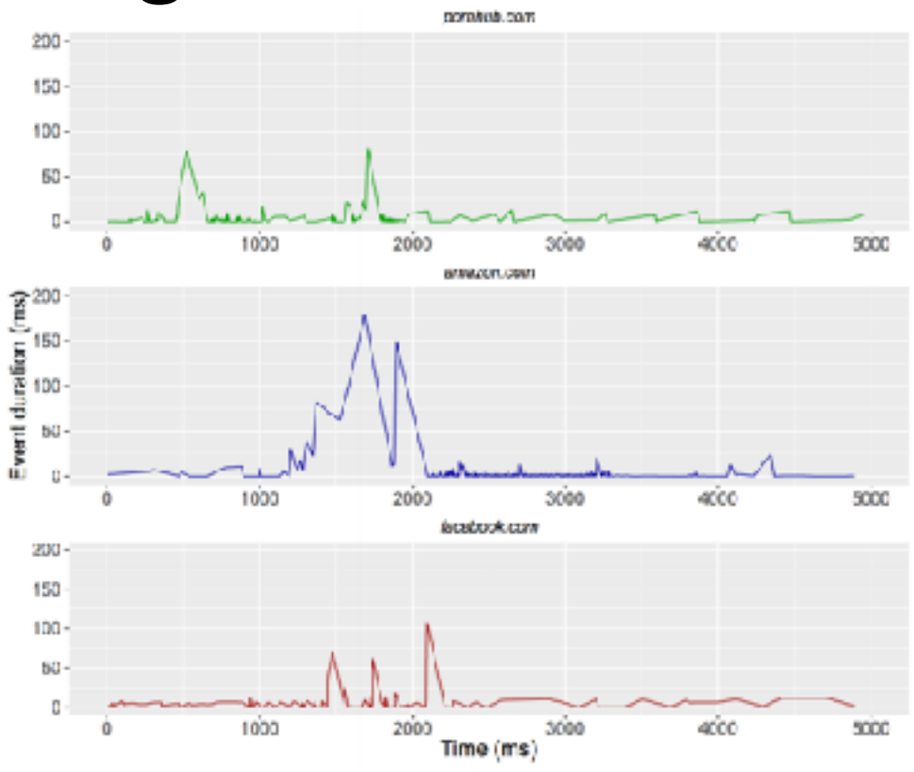

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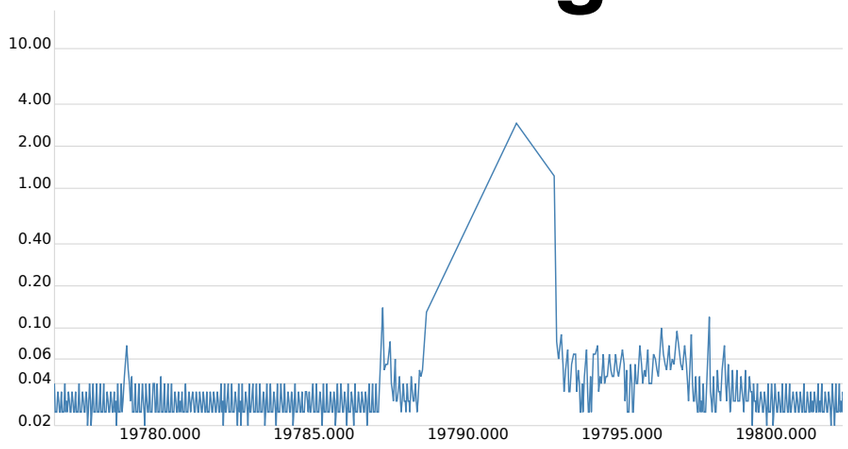
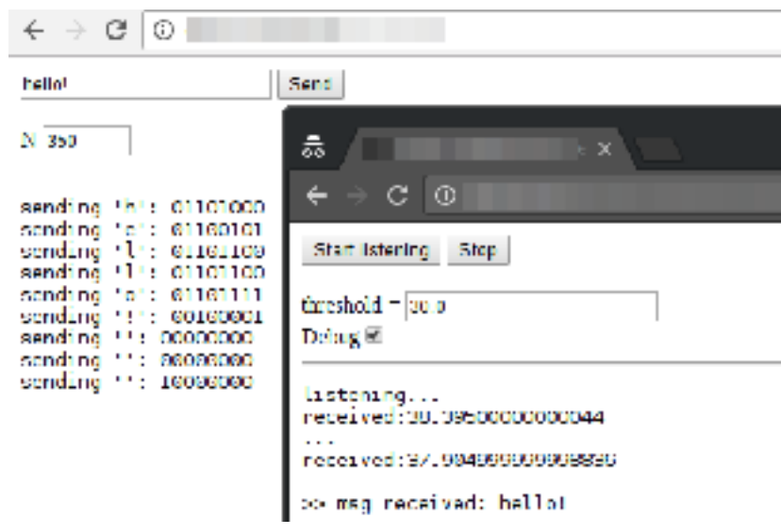
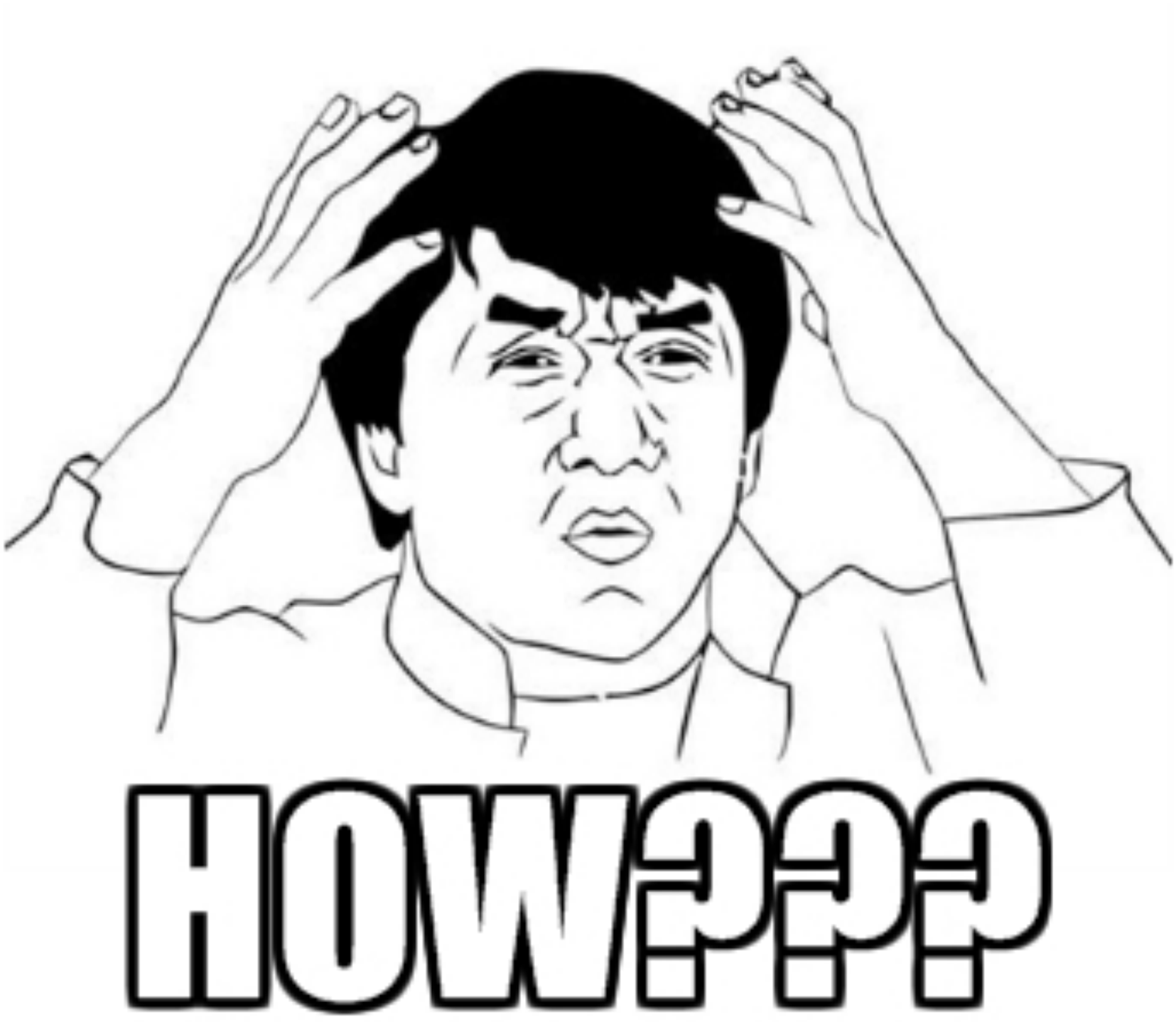


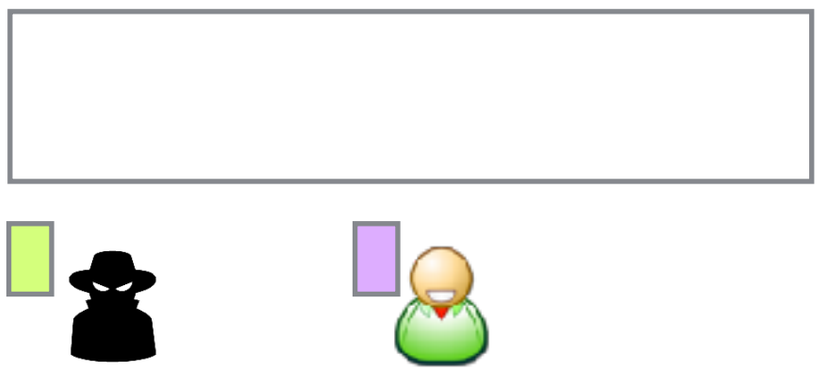
Covert Channel




HOW???

Shared Event Loop

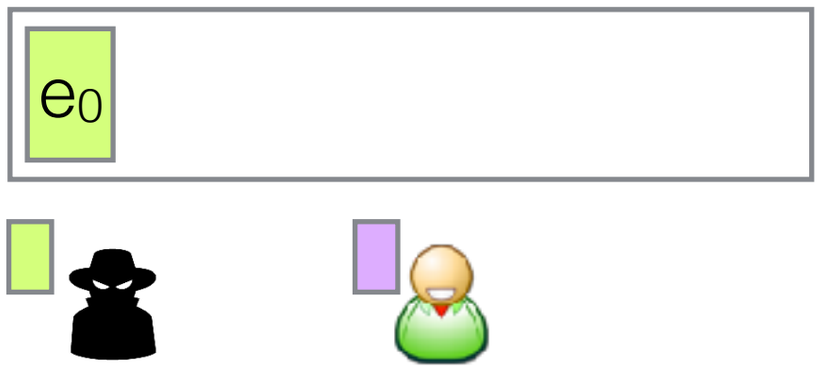
FIFO queue



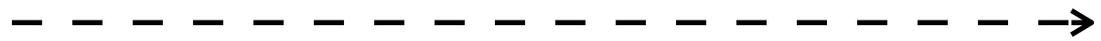
Dispatcher

Shared Event Loop

FIFO queue

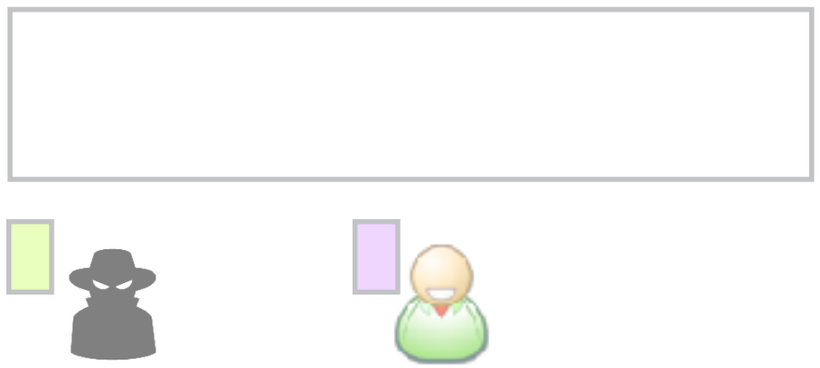


Dispatcher 



Shared Event Loop

FIFO queue

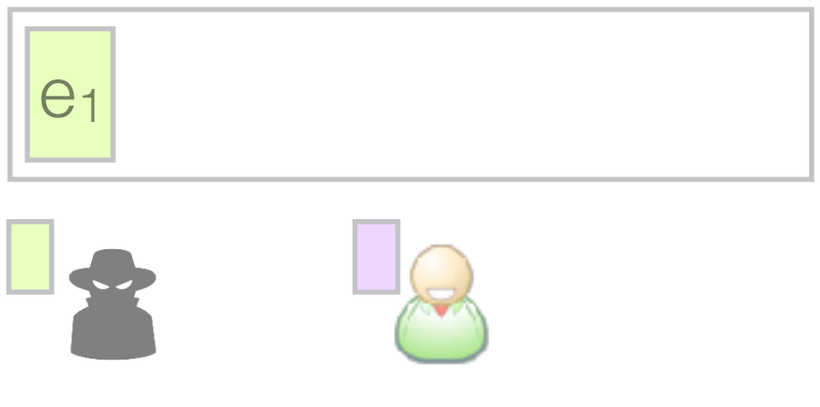


Dispatcher 

e_0

Shared Event Loop

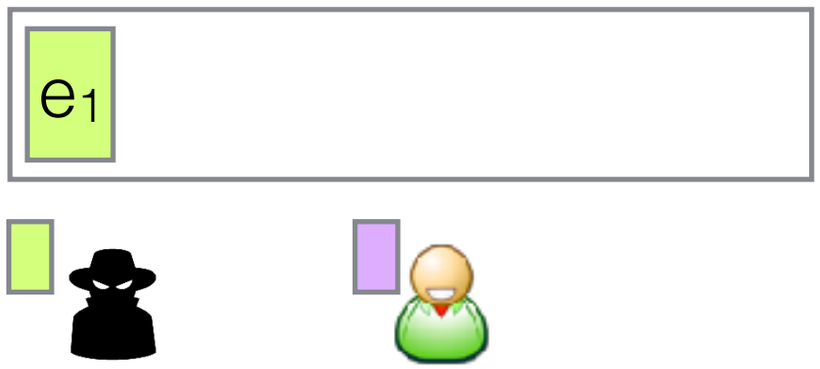
FIFO queue



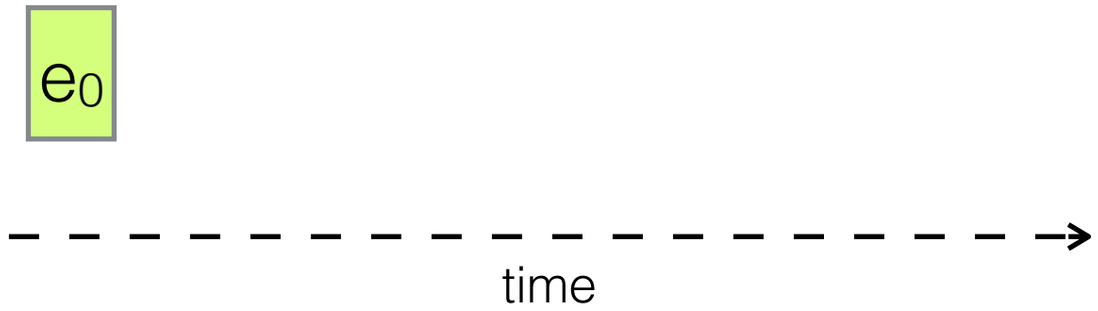
Dispatcher 

Shared Event Loop

FIFO queue

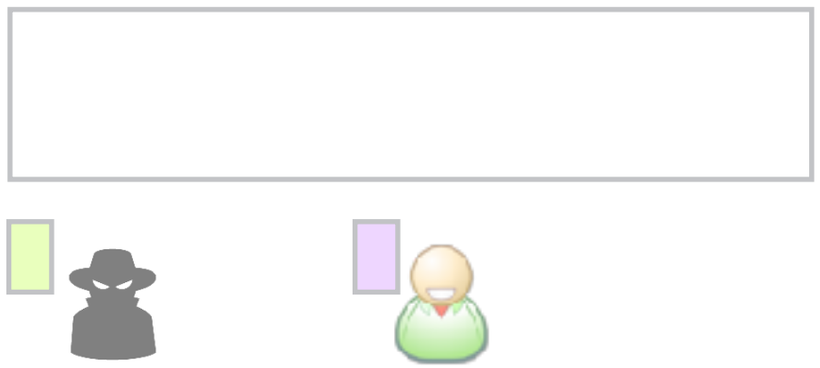


Dispatcher 



Shared Event Loop

FIFO queue



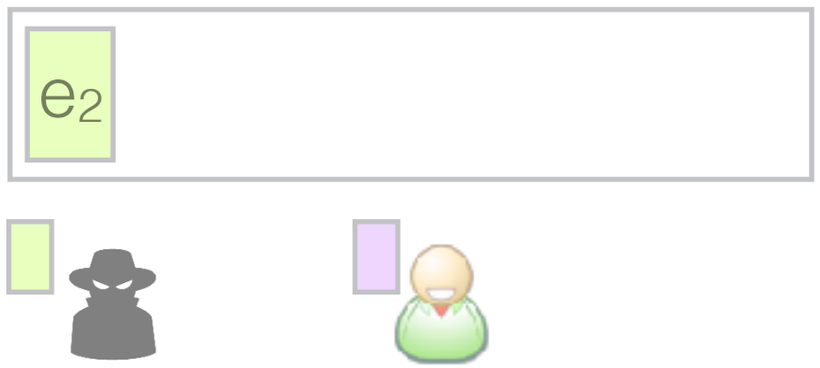
Dispatcher

e_1

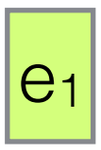
e_0

Shared Event Loop

FIFO queue

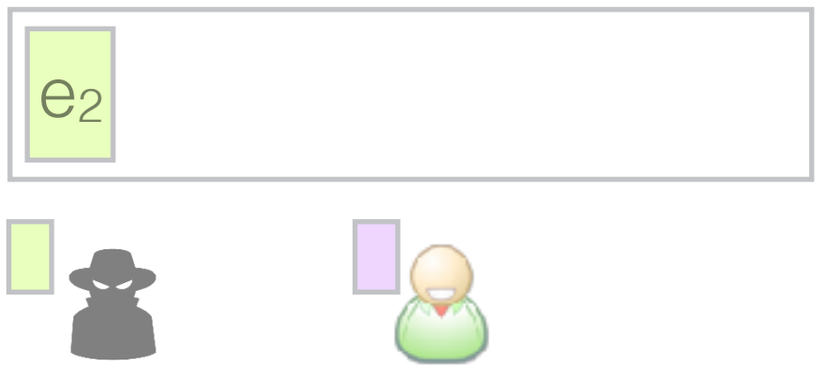


Dispatcher

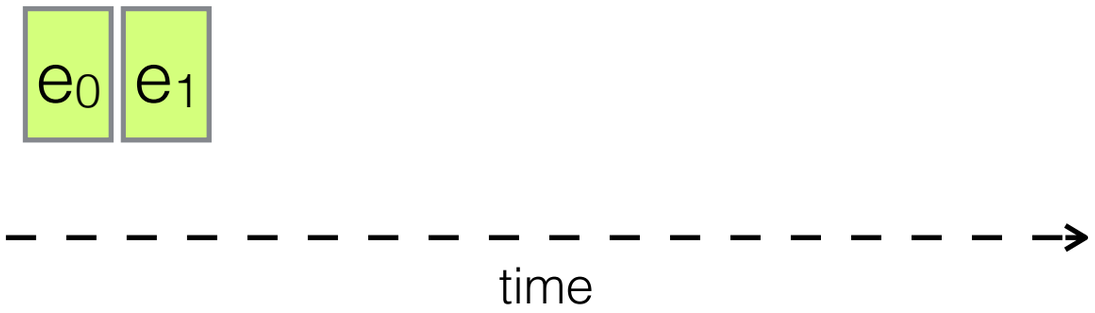


Shared Event Loop

FIFO queue

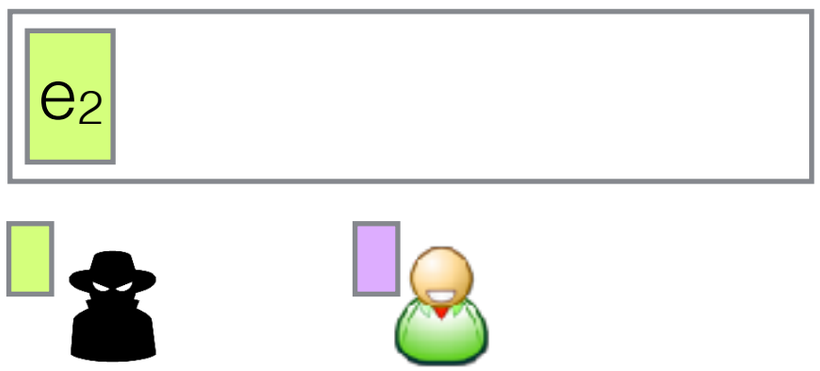


Dispatcher

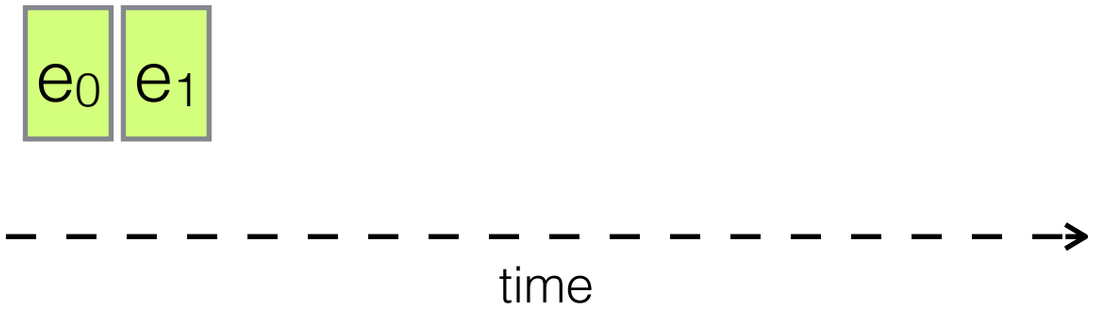


Shared Event Loop

FIFO queue



Dispatcher



Shared Event Loop

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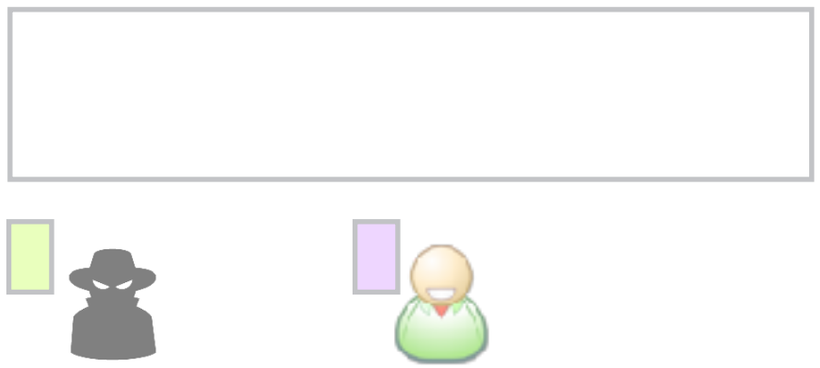


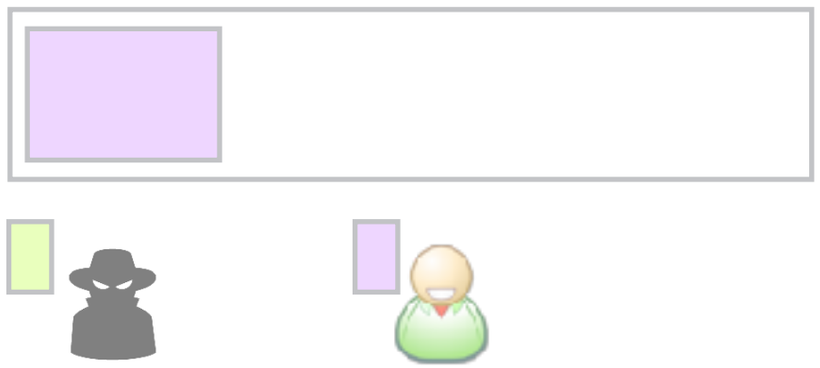
Dispatcher

e_2

e_0 e_1

Shared Event Loop

FIFO queue



Dispatcher

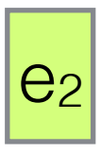
e_2

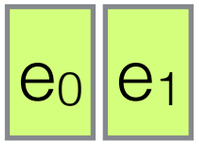
e_0 e_1

Shared Event Loop

FIFO queue

Dispatcher





Shared Event Loop

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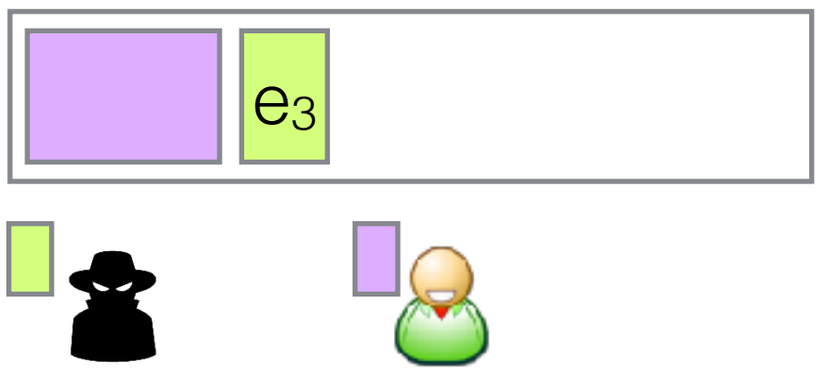

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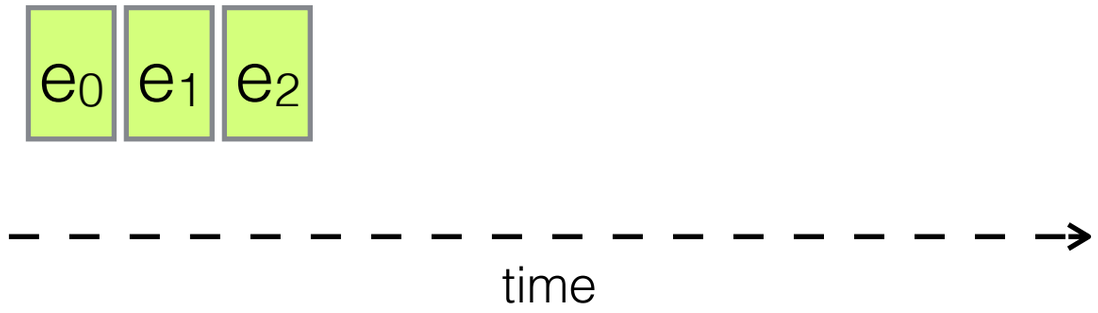

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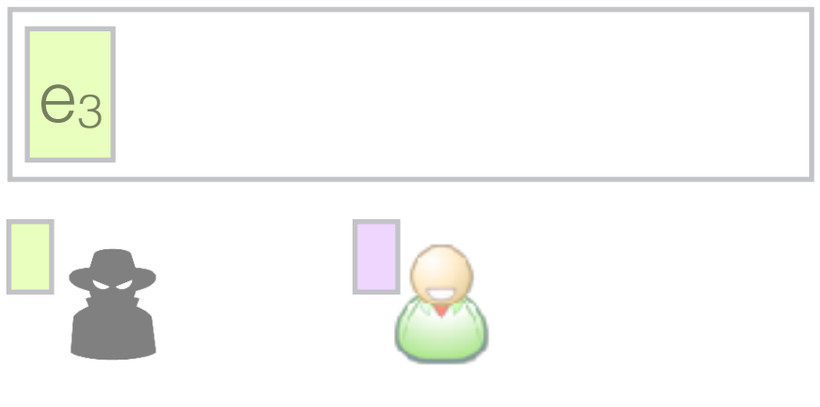

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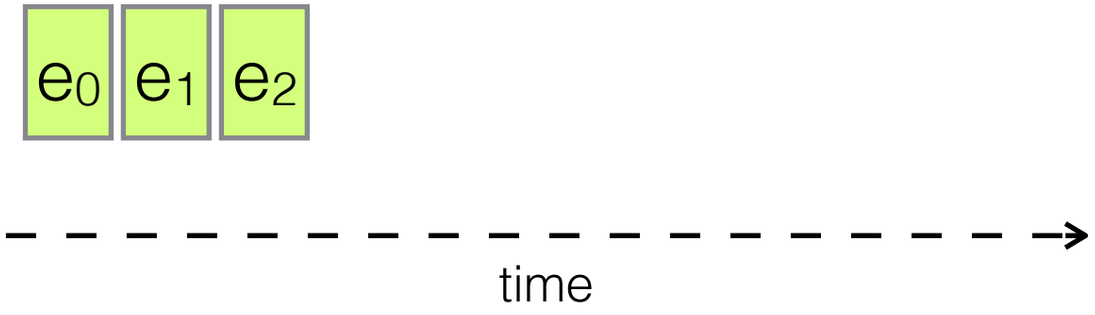
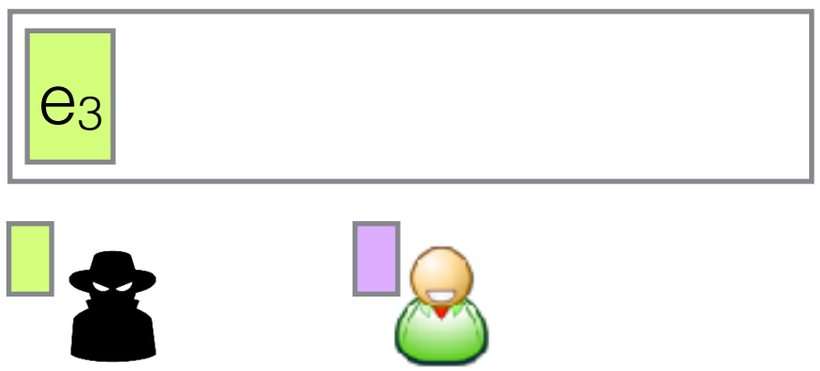


Shared Event Loop

FIFO queue



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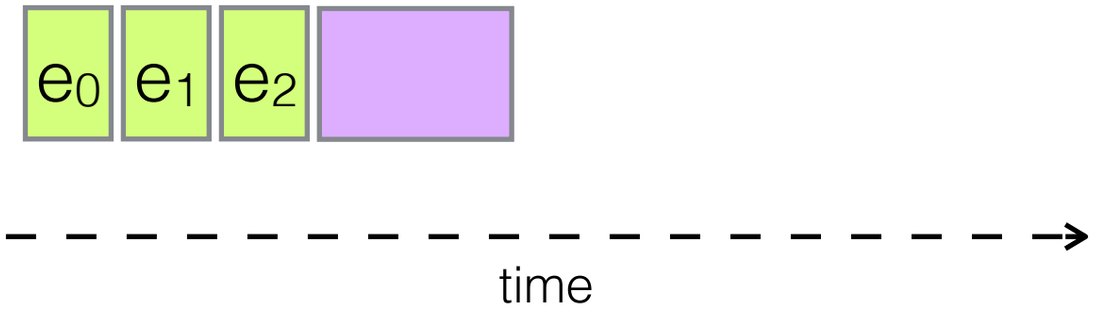
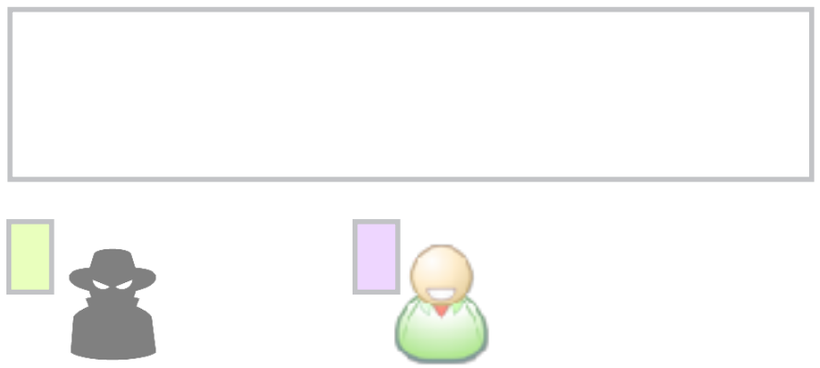


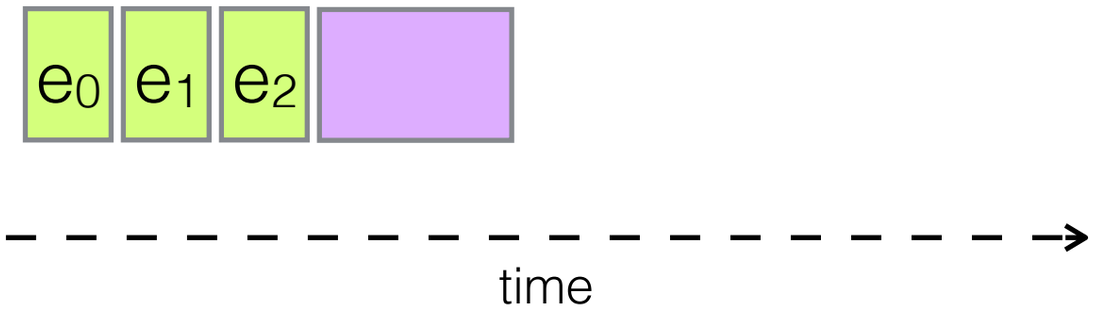
Shared Event Loop

FIFO queue



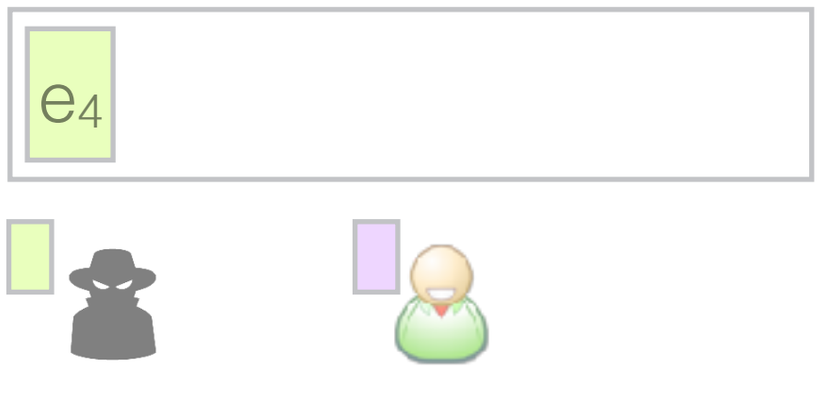
Dispatcher

e_3

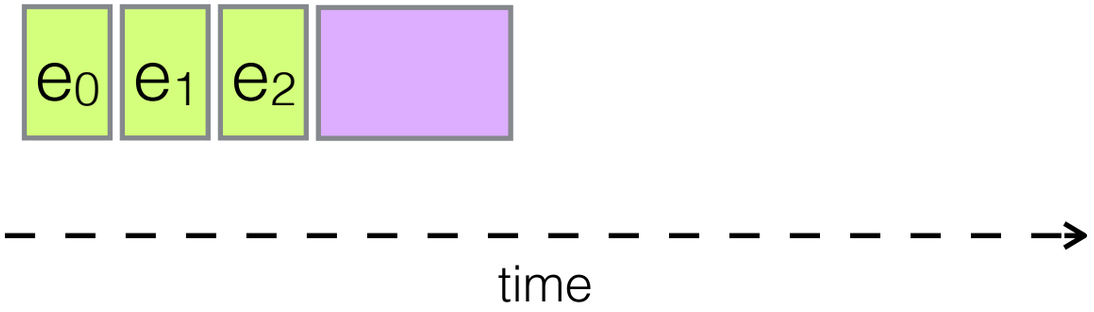


Shared Event Loop

FIFO queue

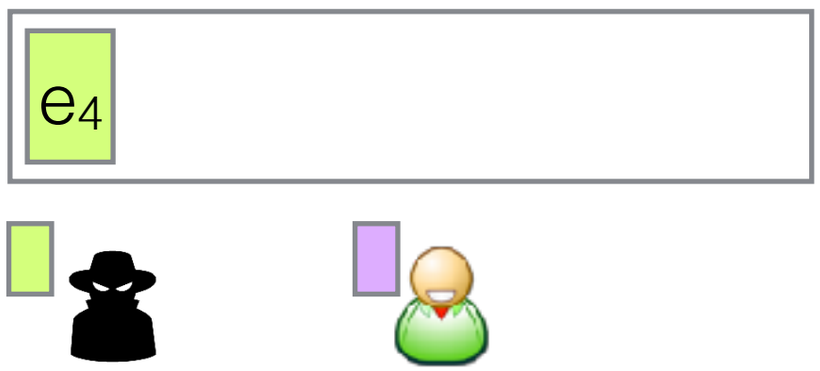


Dispatcher

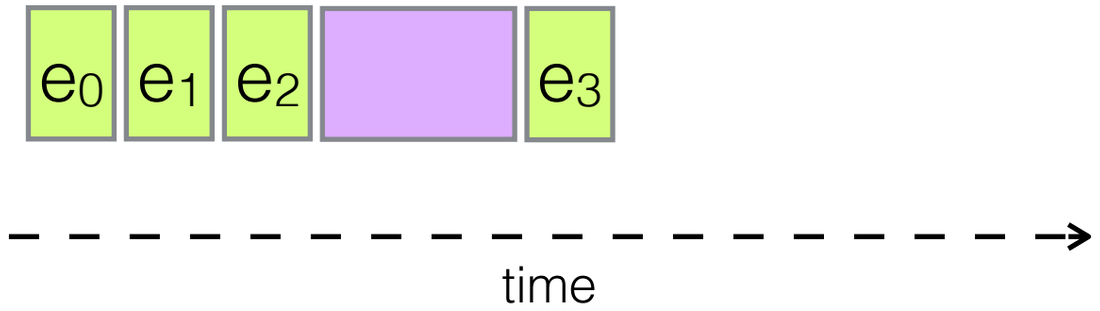


Shared Event Loop

FIFO queue

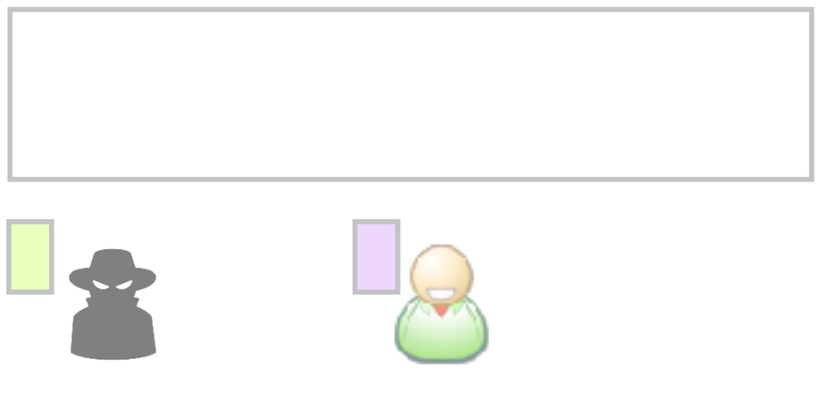


Dispatcher



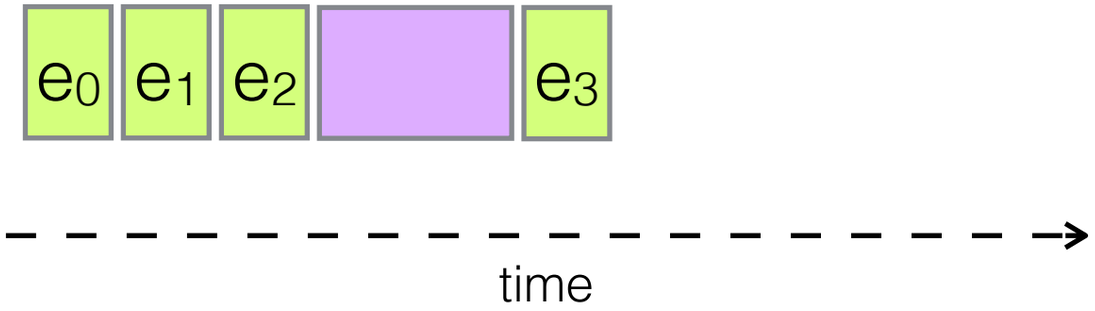
Shared Event Loop

FIFO queue



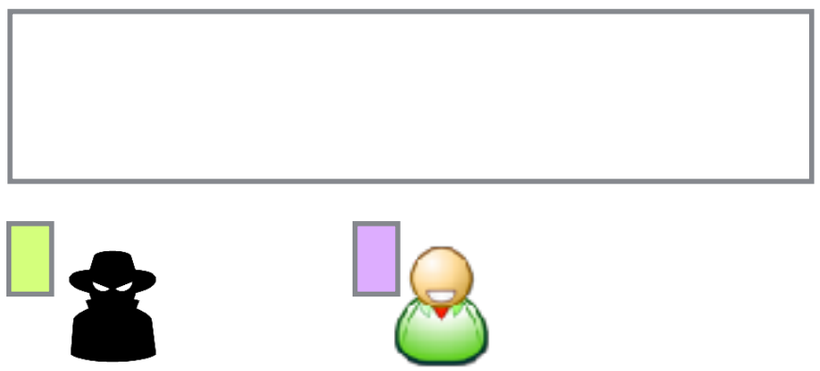
Dispatcher

e_4

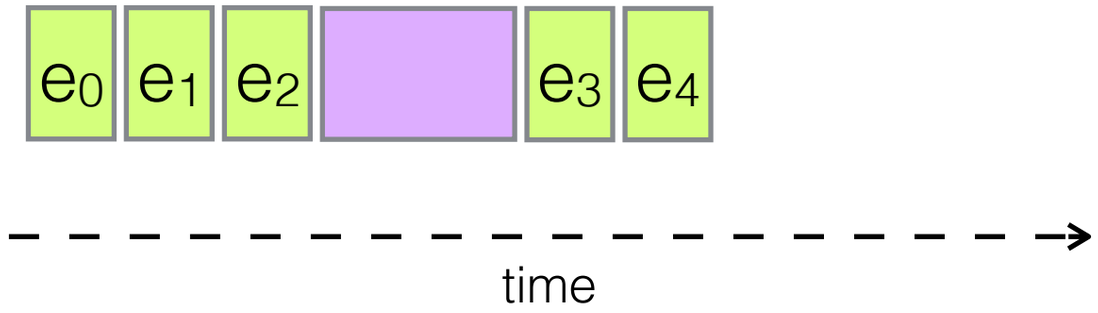


Shared Event Loop

FIFO queue

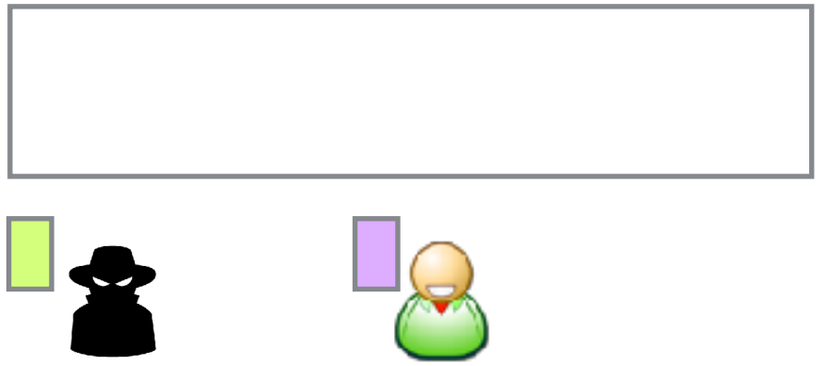


Dispatcher

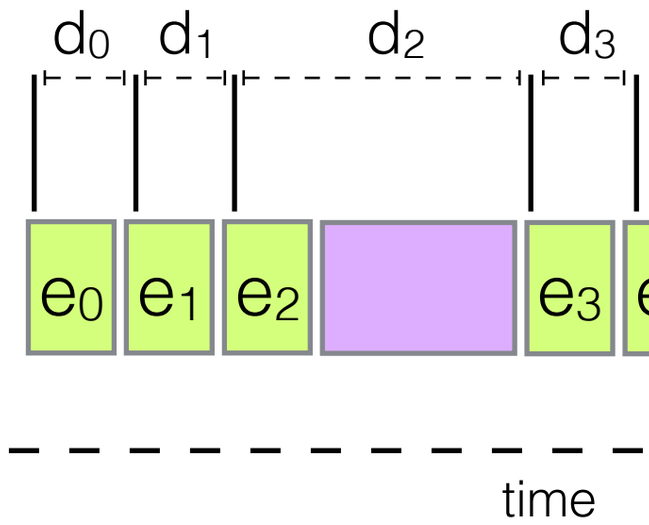


Shared Event Loop

FIFO queue

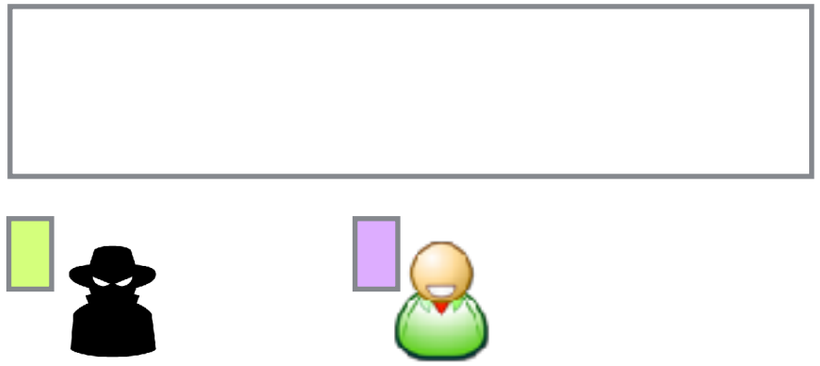


Dispatcher



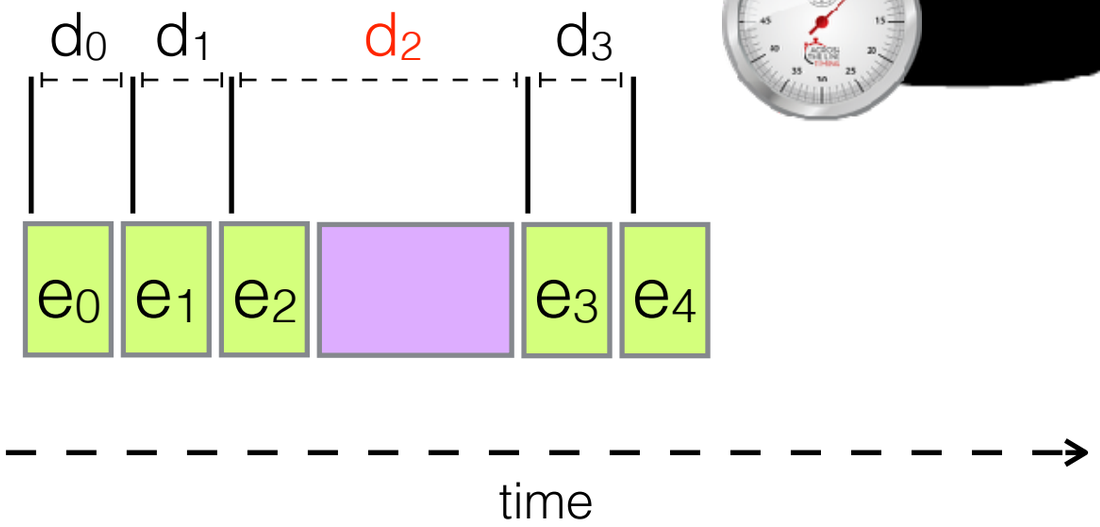
Shared Event Loop

FIFO queue

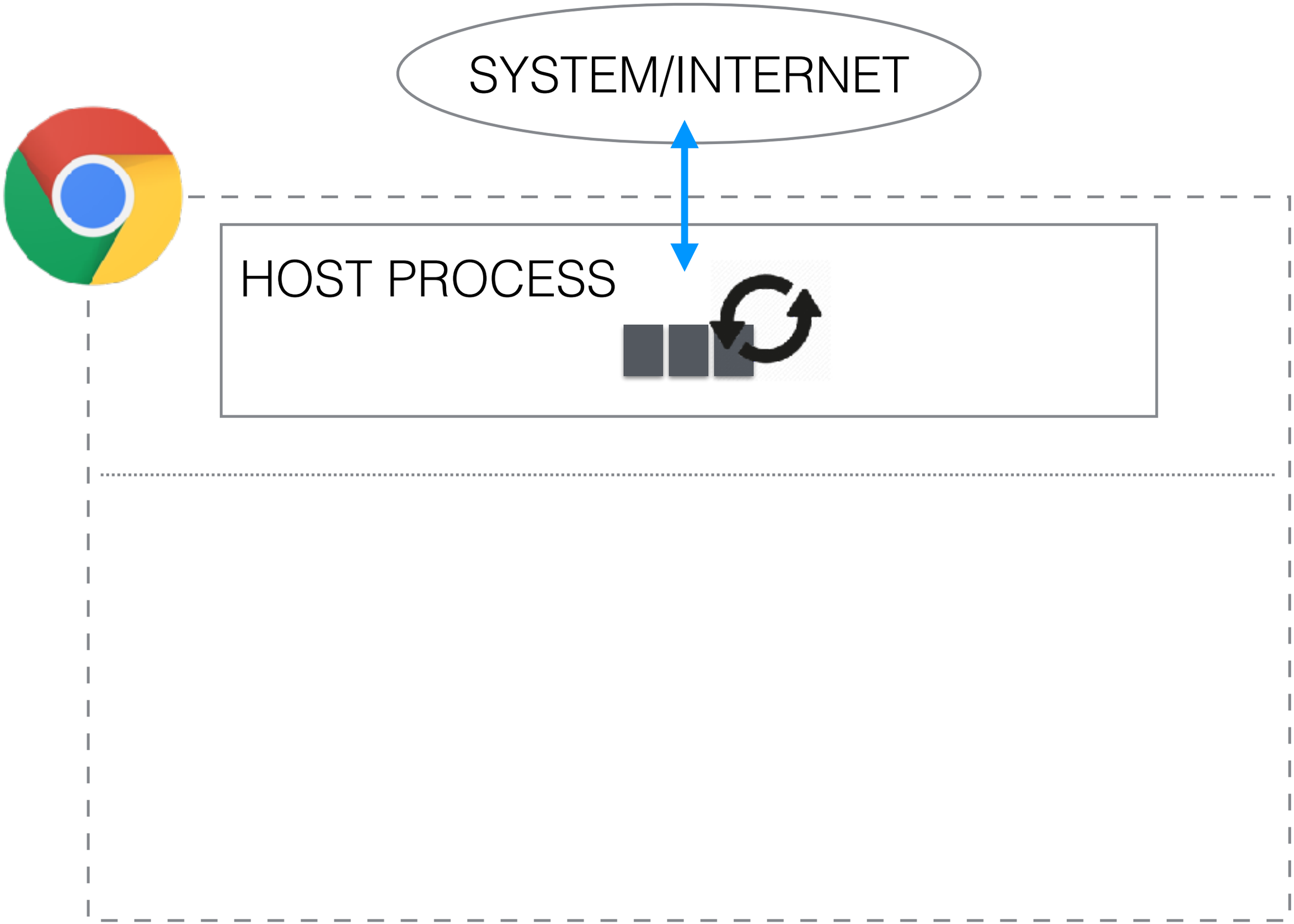


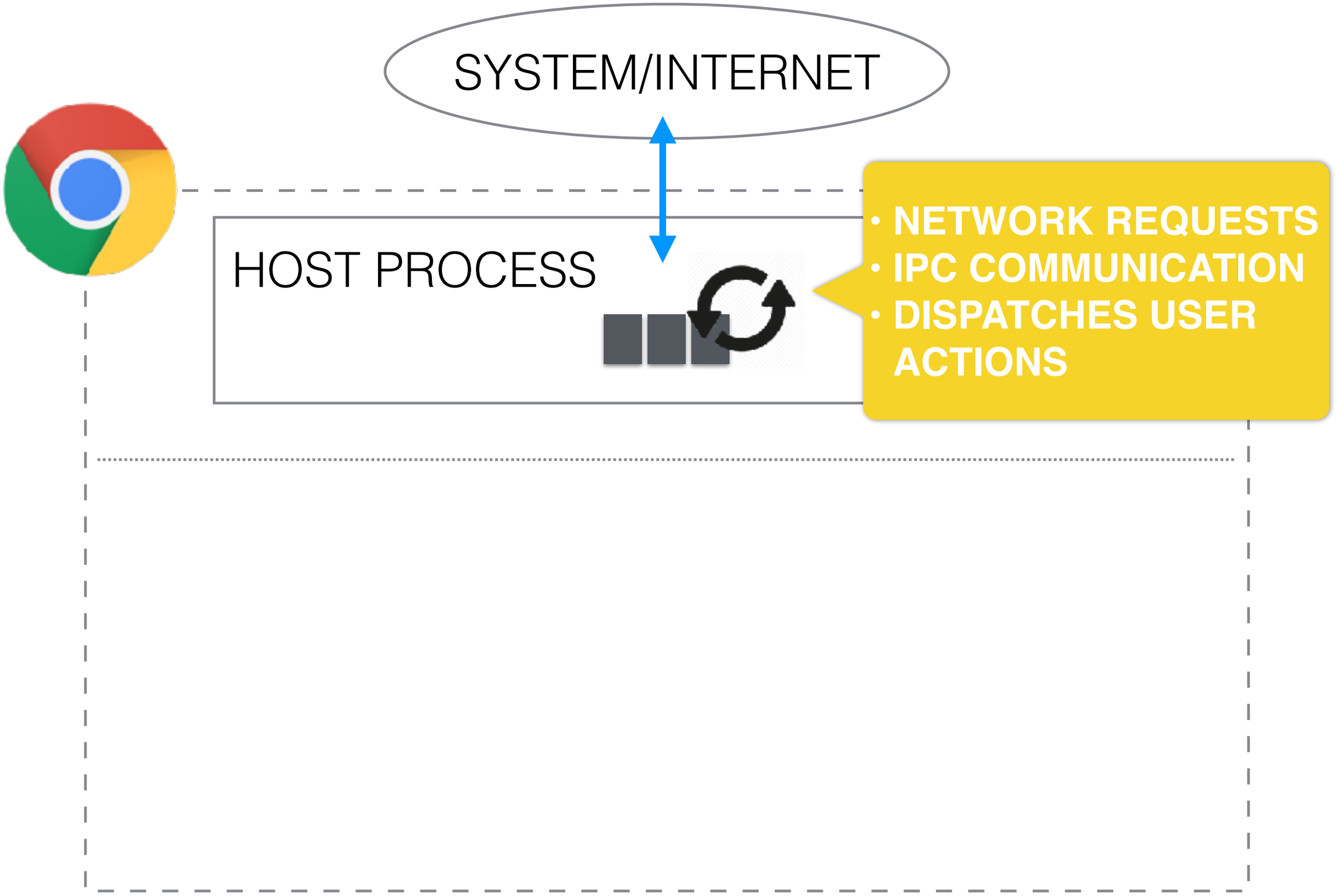
Dispatcher

Event-delay trace



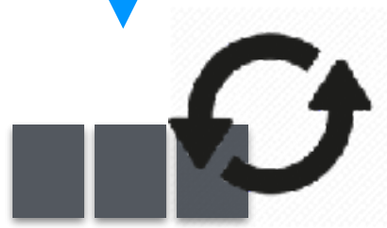
SYSTEM/INTERNET


SYSTEM/INTERNET
HOST PROCESS


SYSTEM/INTERNET
HOST PROCESS
• NETWORK REQUESTS
• IPC COMMUNICATION
• DISPATCHES USER ACTIONS

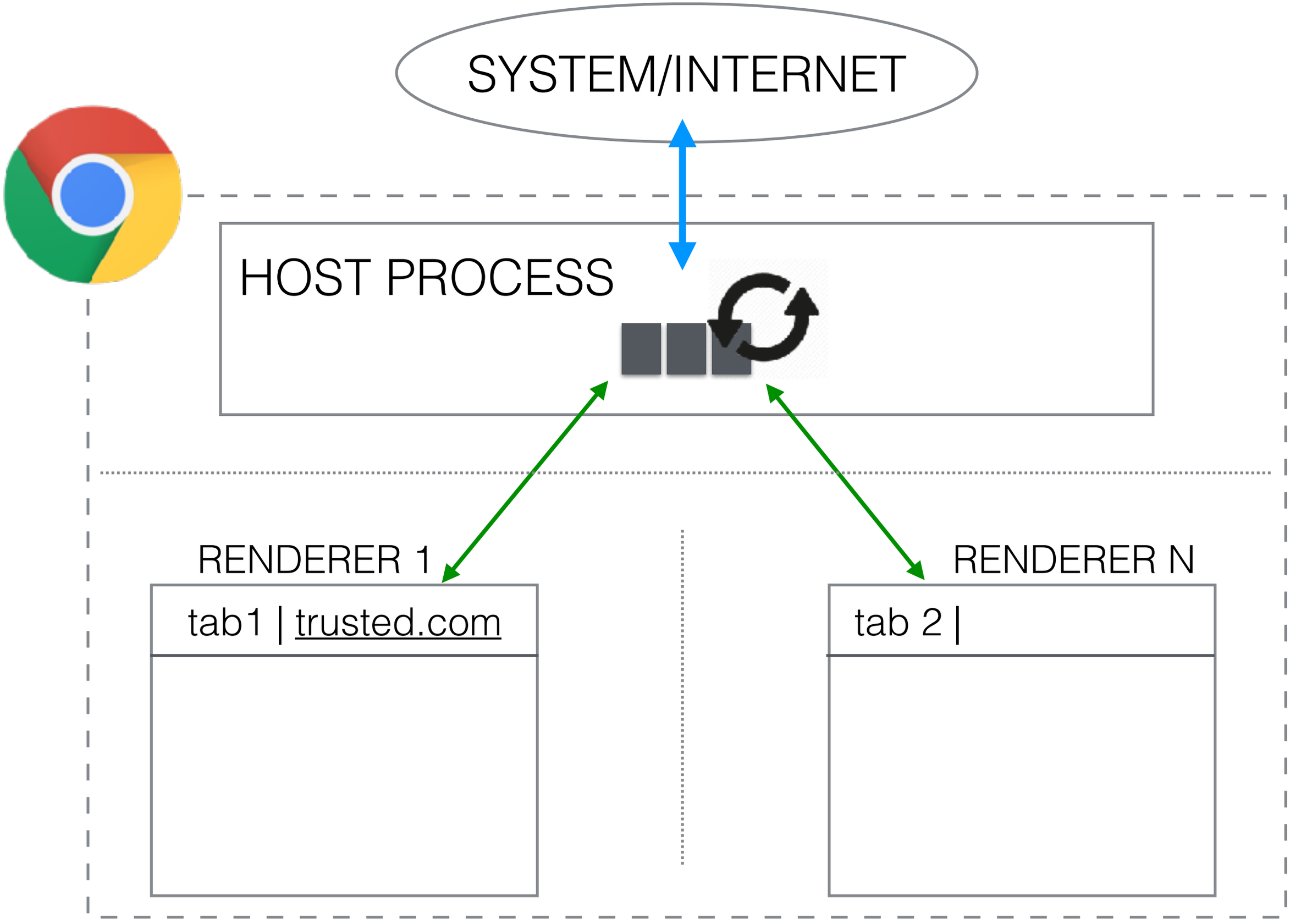
SYSTEM/INTERNET

HOST PROCESS



- **NETWORK REQUESTS**
- **IPC COMMUNICATION**
- **DISPATCHES USER ACTIONS**

SHARED BETWEEN ALL RENDERERS


SYSTEM/INTERNET
HOST PROCESS
RENDERER 1
tab1 | trusted.com
RENDERER N
tab 2 |

SYSTEM/INTERNET

HOST PROCESS

SANDBOXED PROCESSES

RENDERER 1

tab1 | trusted.com

RENDERER N

tab 2 |

SYSTEM/INTERNET

HOST PROCESS

RENDERER 1

tab1 | trusted.com

RENDERER N

tab 2 | evil.com

Spying on the Host

```
<script>
function loop () {
    save(performance.now());
    fetch(new Request("http://0/"))
        .catch(loop);
}
loop();
</script>
```

Timing resolution of ~500 µs

Spying on the Host

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<script>
function loop () {
    save(performance.now());
    fetch(new Request("http://0/"))
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}
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```

~~Timing resolution of ~500 µs~~

With some smarter techniques we obtain <100 µs
(see the paper)

SYSTEM/INTERNET

HOST PROCESS

RENDERER 1

tab1 | trusted.com

SYSTEM/INTERNET

HOST PROCESS

RENDERER 1

tab1 | trusted.com

- **JAVASCRIPT EXECUTION**
- **RESOURCE PARSING**
- **LAYOUT & RENDERING**

SYSTEM/INTERNET

HOST PROCESS

RENDERER 1

tab1 | trusted.com

iframe |

SHARED BETWEEN IFRAMES, POPUPS, MAX #RENDERER EXCEEDED…

SYSTEM/INTERNET

HOST PROCESS

RENDERER 1

tab1 | trusted.com

iframe | evil.co

Spying on the Renderer

```
<script>
function loop() {
    save(performance.now());
    self.postMessage(0, "*");
}
self.onmessage = loop;
loop();
</script>
```

Timing resolution of <25 µs

Duration of Events

µ-arch events	?	**loop()**	Mouse movement	GC scavenge	JS event handlers
<5µs	…	**25 µs**	100 µs	<1 ms	>2 ms

Duration of Events

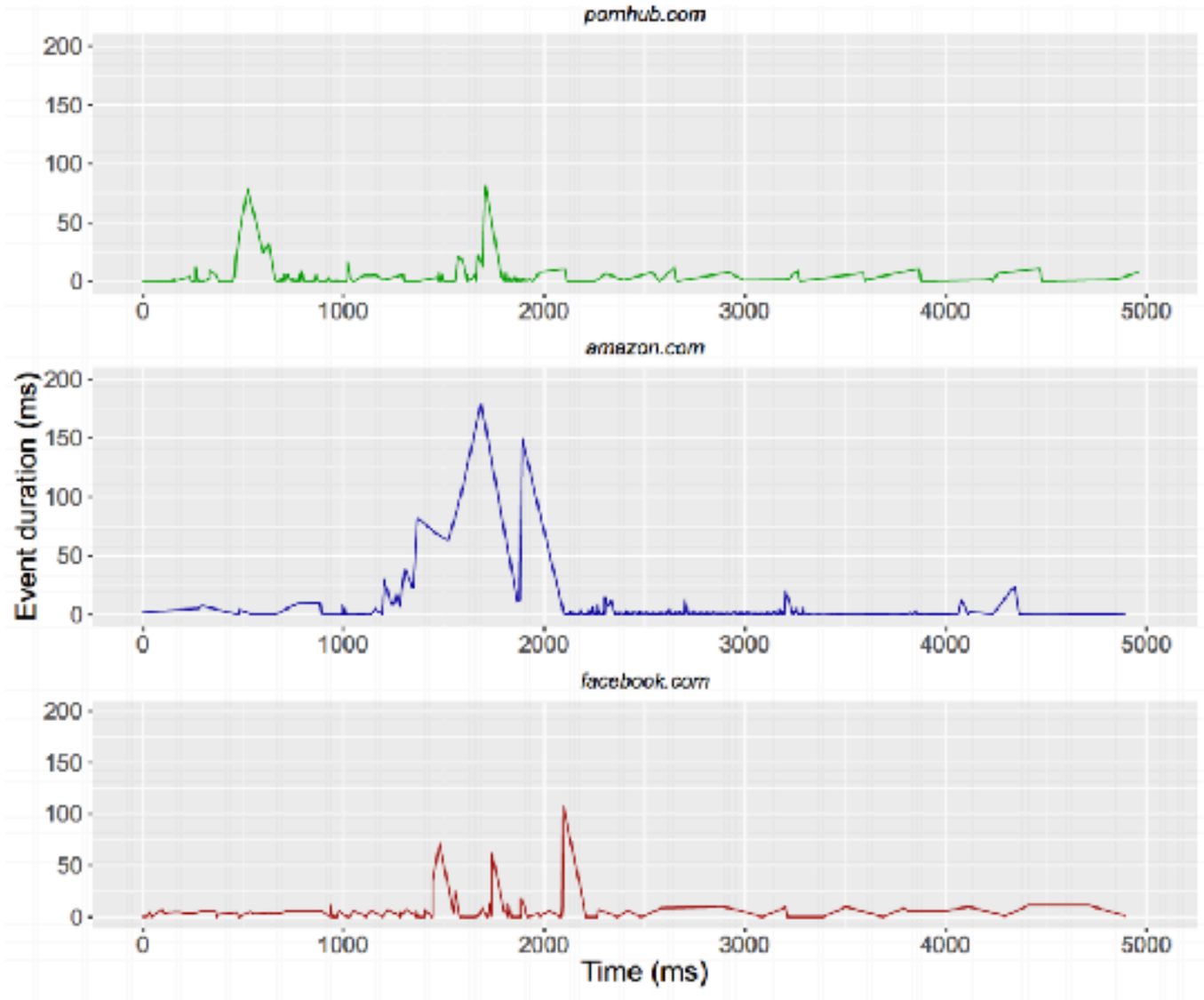
µ-arch events	?	**loop()**	Mouse movement	GC scavenge	JS event handlers
<5µs	…	**25 µs**	100 µs	<1 ms	>2 ms

Good vs. badly coded web pages

Web Page Identification

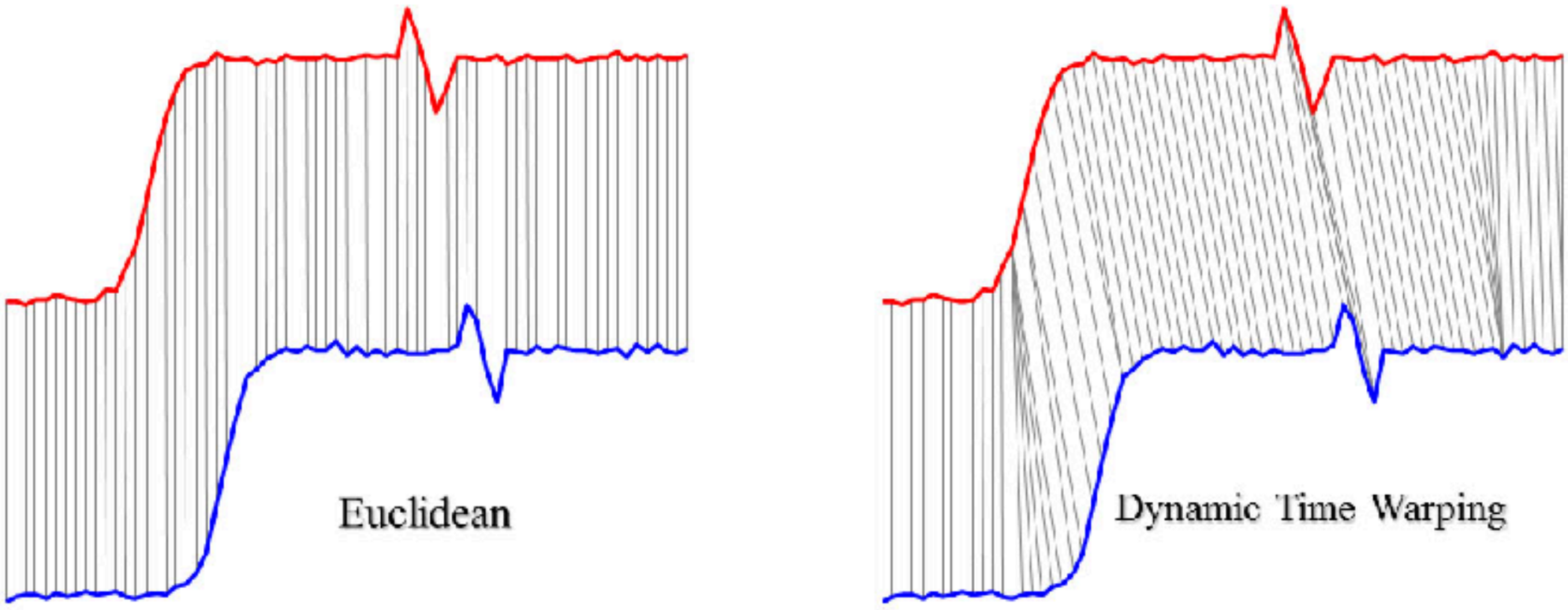
& Inter-keystroke Timing

Web Page Identification



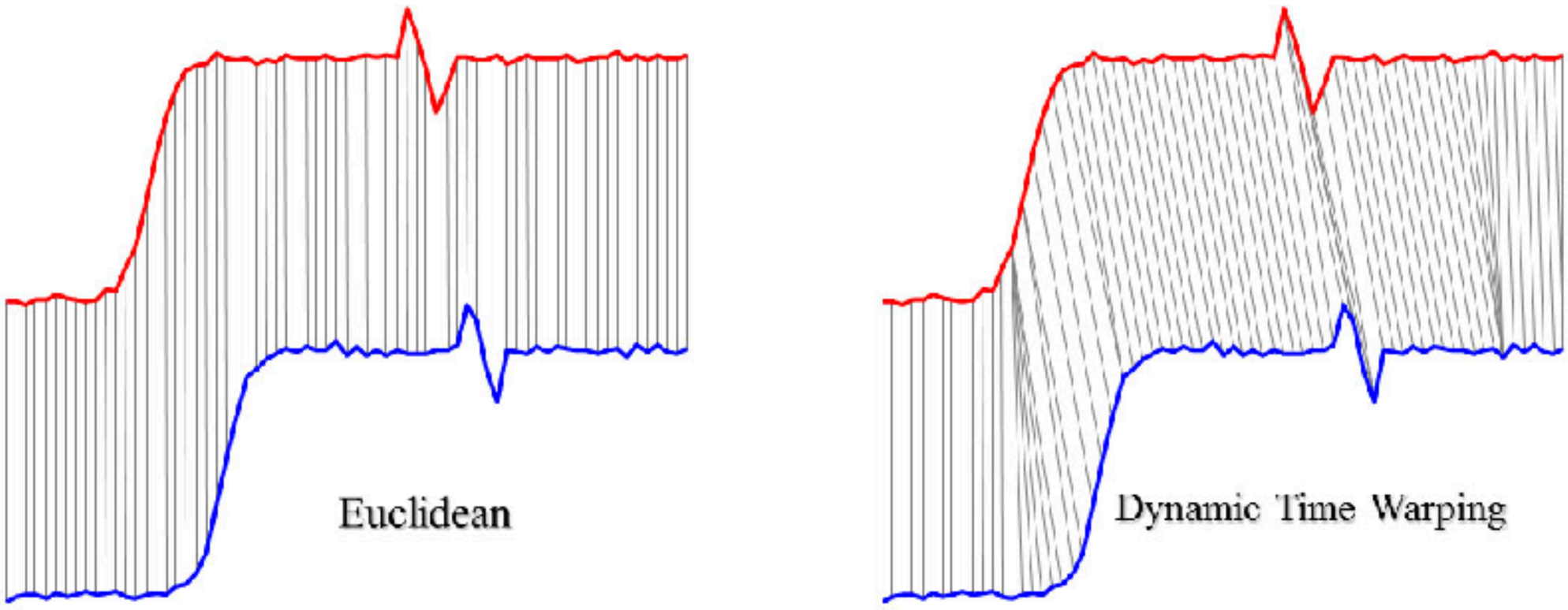
Monitor the EventLoop while page loading

Dynamic Time Warping



DTW is resistant to delays in the occurrence of events

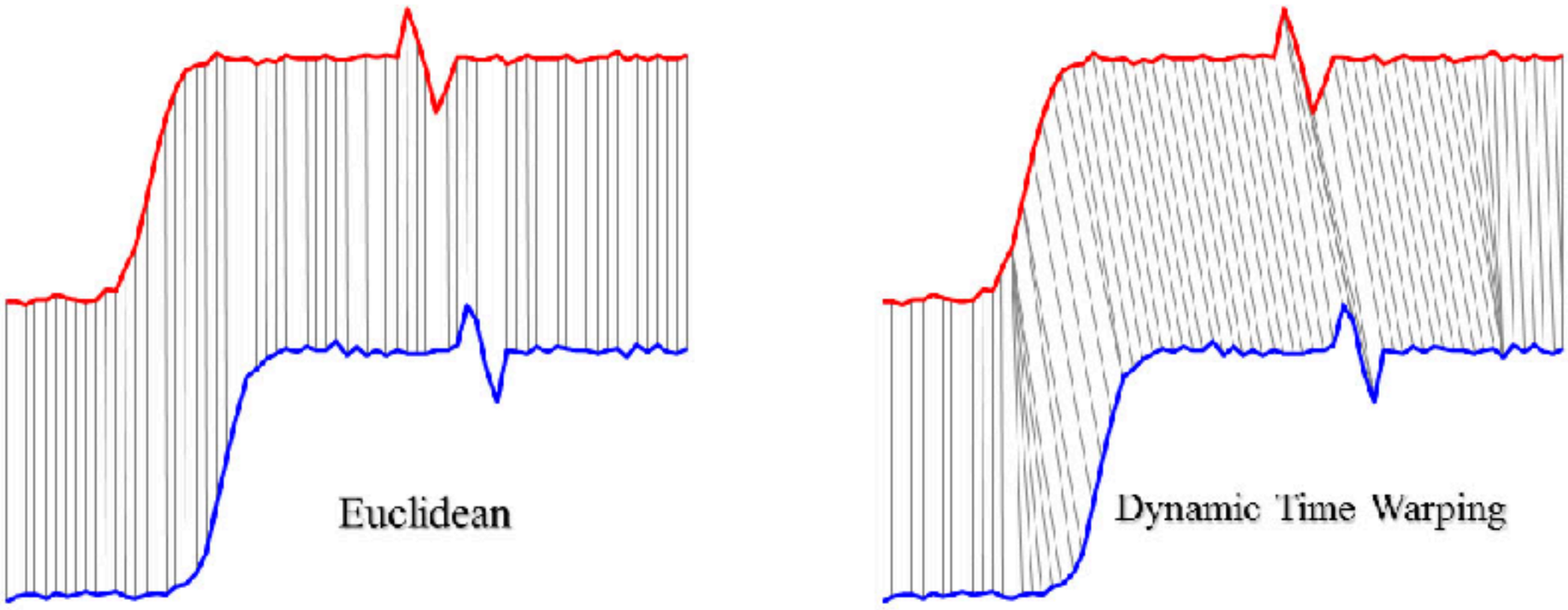
Dynamic Time Warping



DTW is resistant to delays in the occurrence of events

2-4 seconds of measuring

Dynamic Time Warping



DTW is resistant to delays in the occurrence of events

2-4 seconds of measuring

One trace for training

Web Page Identification

500 pages x 30 traces x 3 machines x 2 event loops

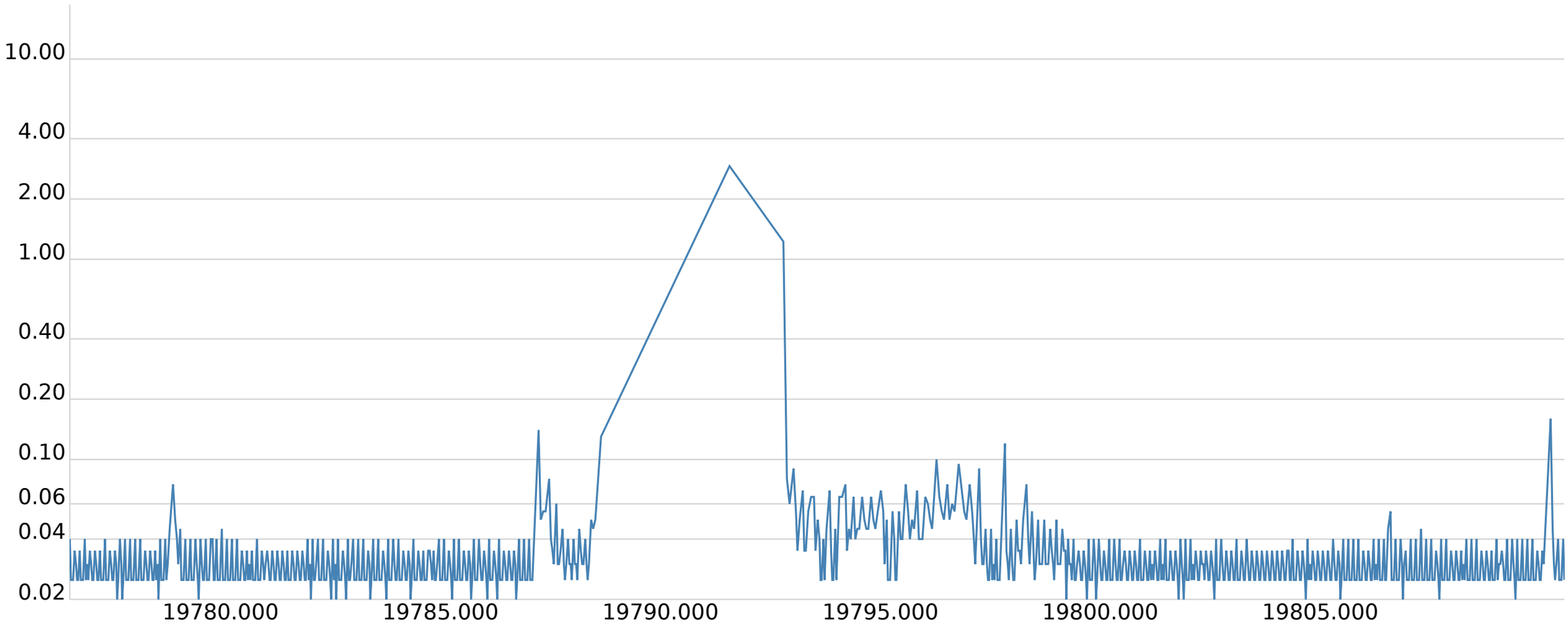
Renderer's main thread: **75%** (Linux desktop)

Host's I/O thread: **23%** (Macbook Pro)

(recognition rates below 5% across machines)

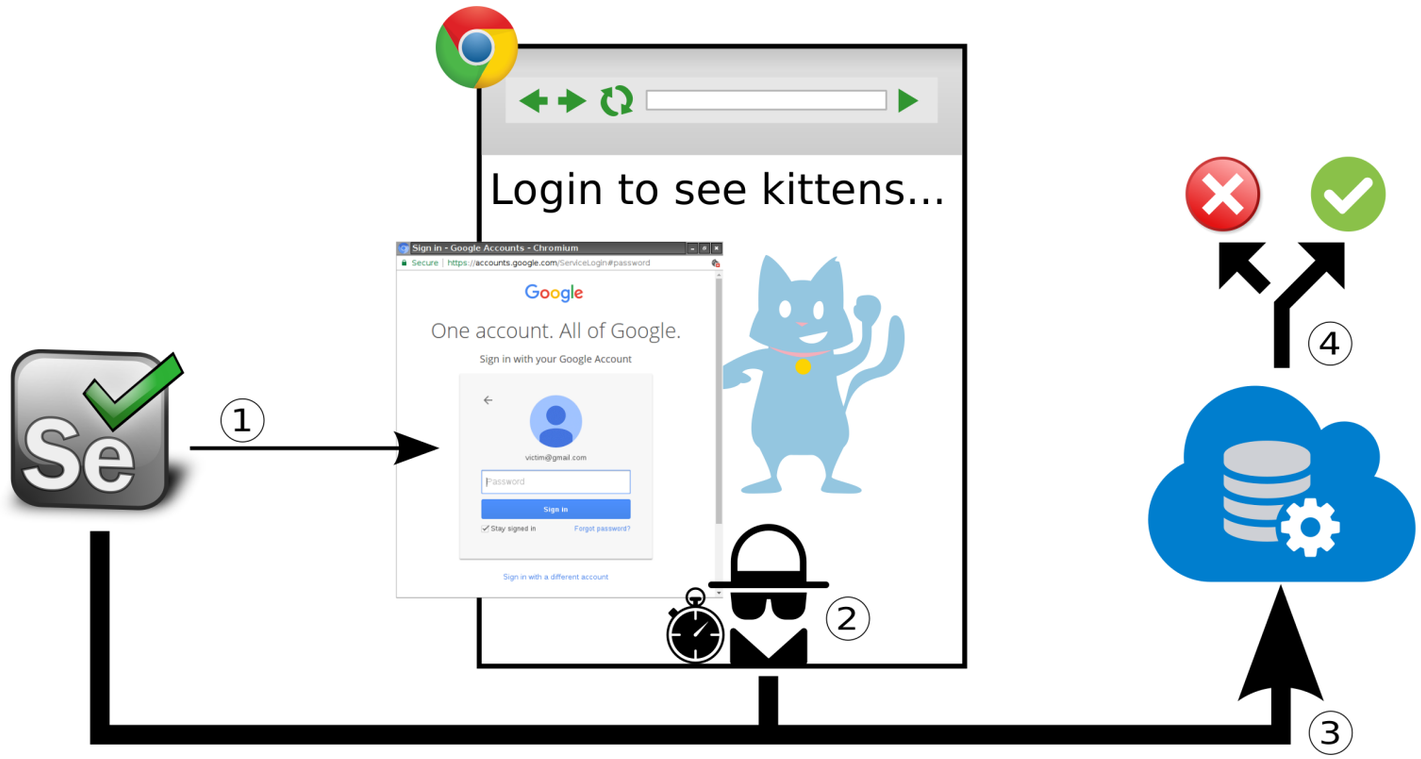
R-library and datasets:
https://github.com/cgvwzq/rlang-loophole

Inter-keystroke Timing



We obtain the password length and time between consecutive pressed keys

Inter-keystroke Timing

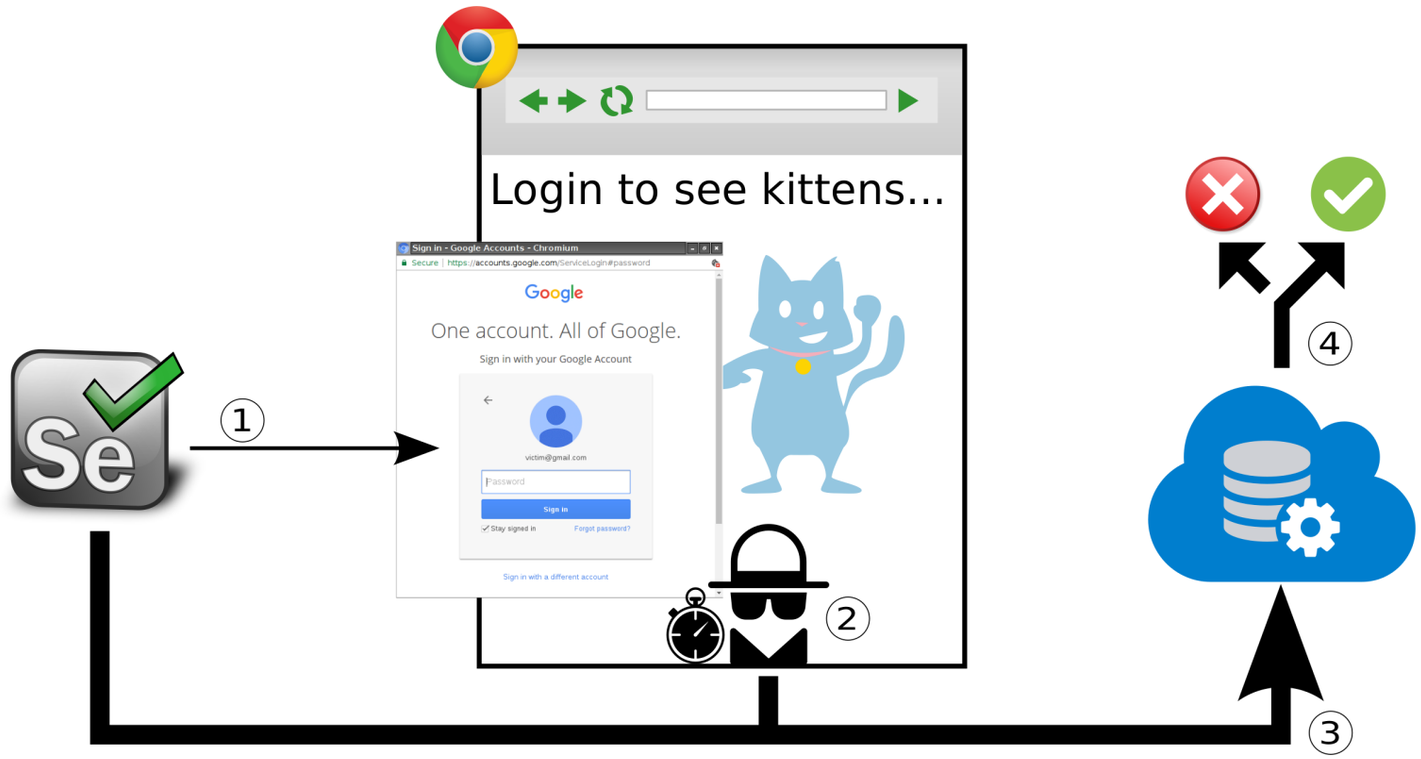


10.000 passwords

90% accuracy

precision: σ = 6.1 ms

Inter-keystroke Timing



10.000 passwords

90% accuracy

precision: σ = 6.1 ms

More precision than network based attacks.

Less noise than in micro-architectural attacks.

No privileges. No training.

Countermeasures

- Reduce clock resolution
- Site Isolation Project
- CPU Throttling

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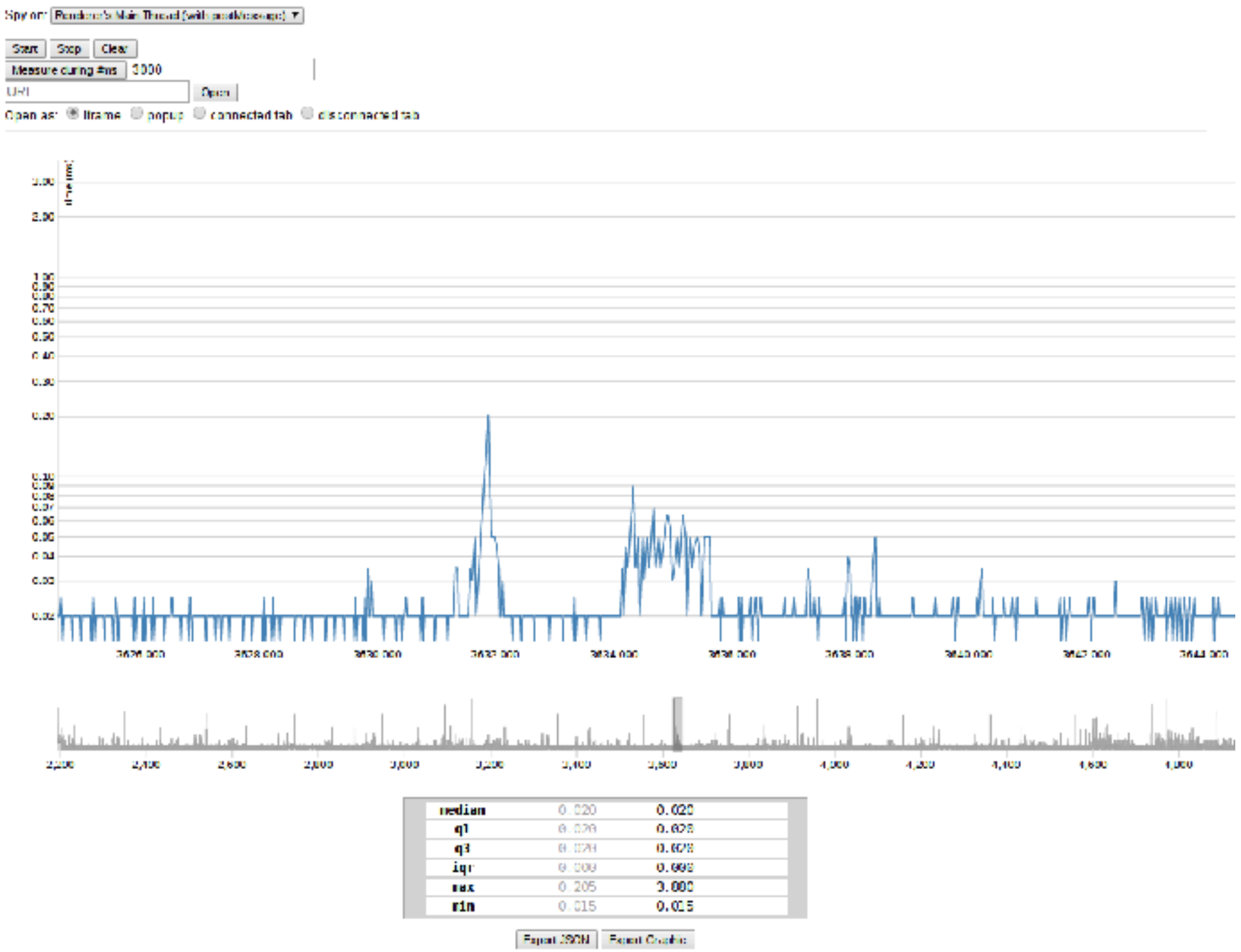
Conclusions

- Shared event loops in Chrome are vulnerable to timing side-channels
- We systematically study how this channel can be used for different attacks
- Fundamental design issues that need to be addressed

Thank you! :)

Questions?

You can visualise the congestion of event loops with our LoopScan tool



https://github.com/cgvwzq/loopscan