



Energy Patterns for Web: An Exploratory Study

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Luis Cruz, Timo Kehrer, Alberto Bacchelli

University of Zurich, Switzerland



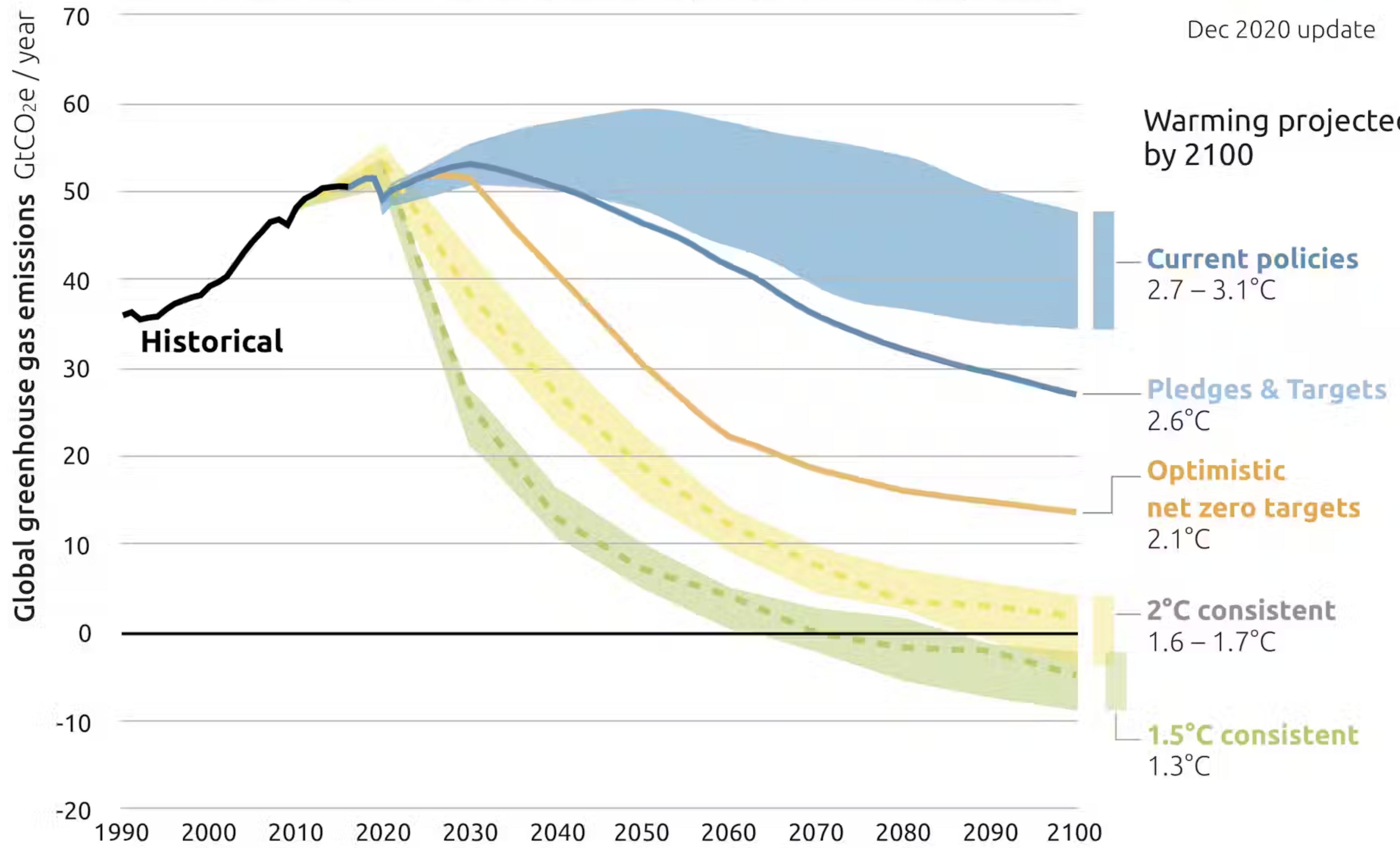
2100 WARMING PROJECTIONS

Emissions and expected warming based on pledges and current policies



Dec 2020 update

Warming projected
by 2100

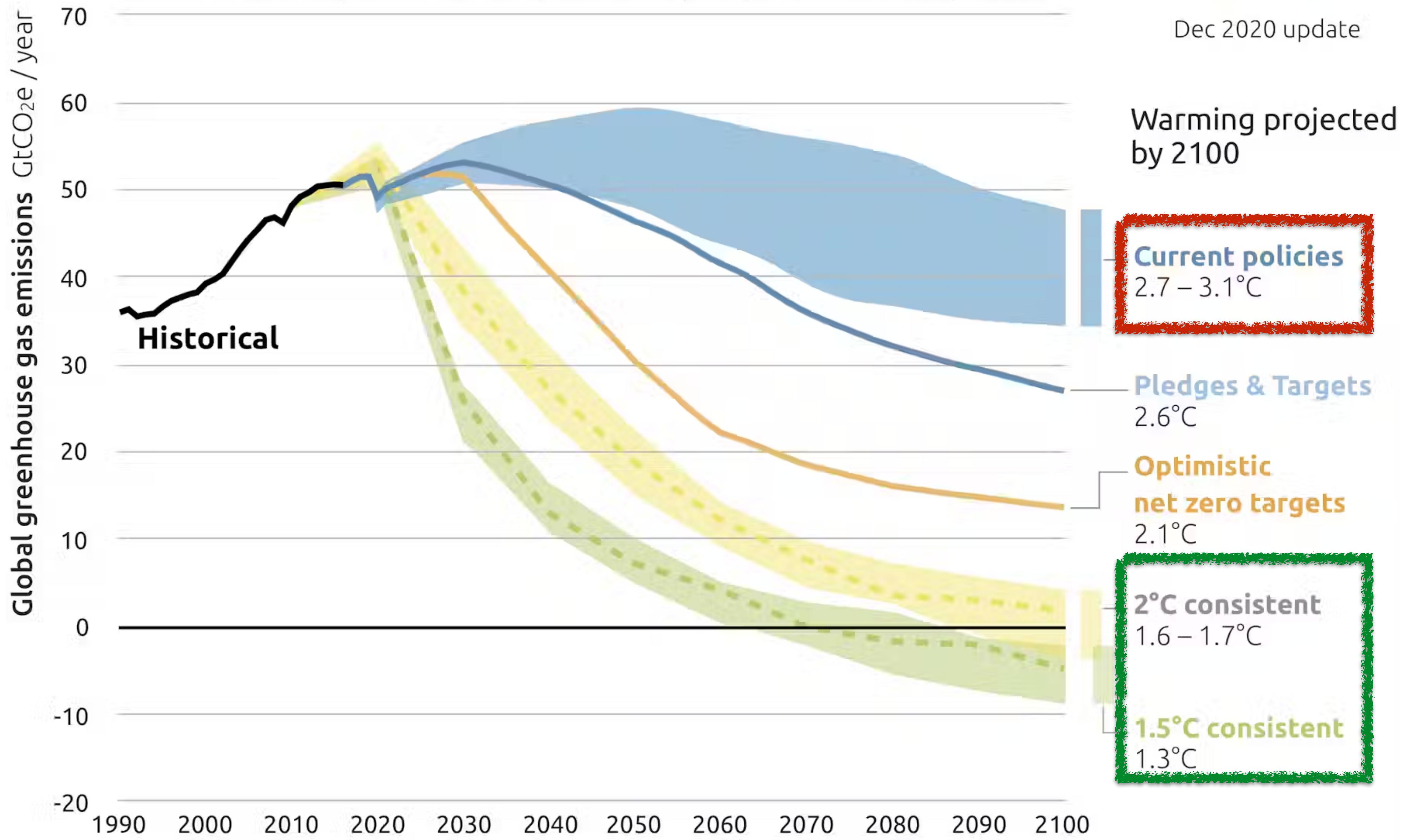


2100 WARMING PROJECTIONS

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Dec 2020 update



Is it our problem?

```
/**  
 * TODO  
 */  
  
public void log(String s) {  
    System.out.println(s);  
}
```



Is it our problem?

Around 4.6 billion people use the internet every day.

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05-09-2019 | CO.DESIGN

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A new study quantifies the environmental footprint of wasteful UI design by tech companies—and proposes a new way of measuring the sustainability of digital interfaces.

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Yes, websites have a carbon footprint

The internet consumes a lot of electricity. 416.2TWh per year to be precise. To give you some perspective, that's more than the entire United Kingdom.

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Globally, the average web page produces approximately 0.8 grams CO₂ equivalent per pageview. For a website with 10,000 monthly page views, that's 102 kg CO₂e per year.

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What can we do?

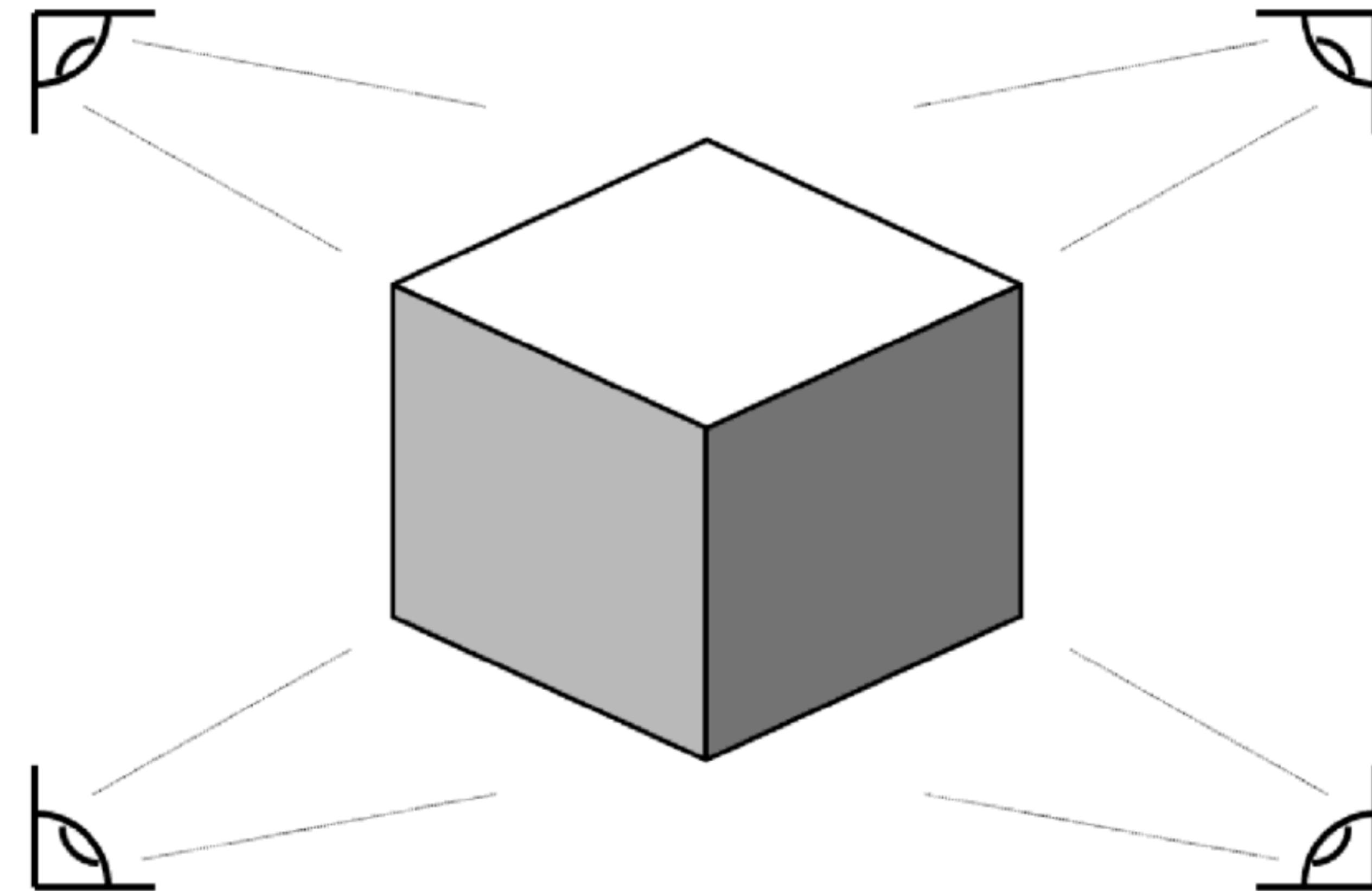
Being aware of energy-related coding practices
in web world can help us make better choices

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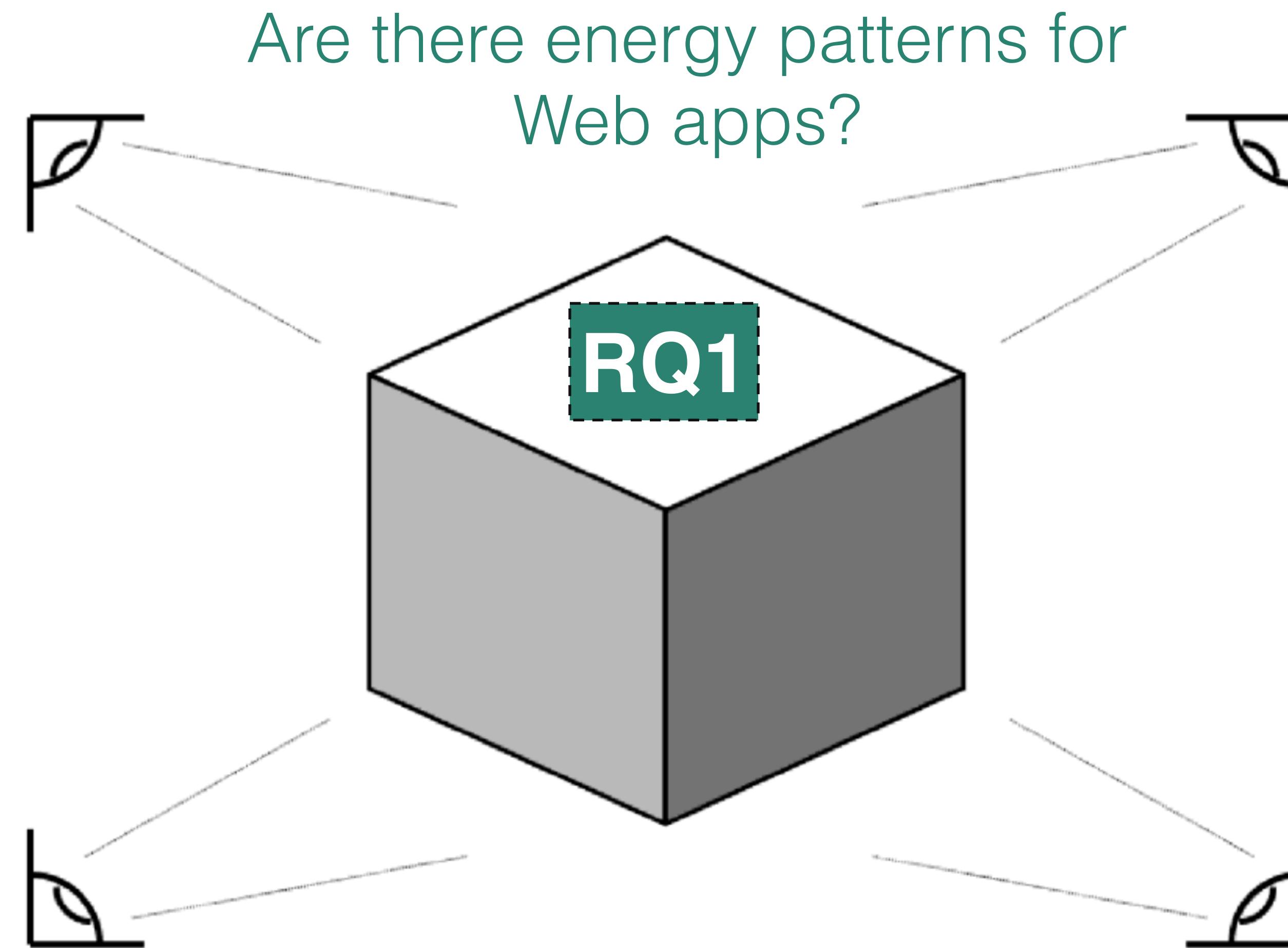
Energy patterns

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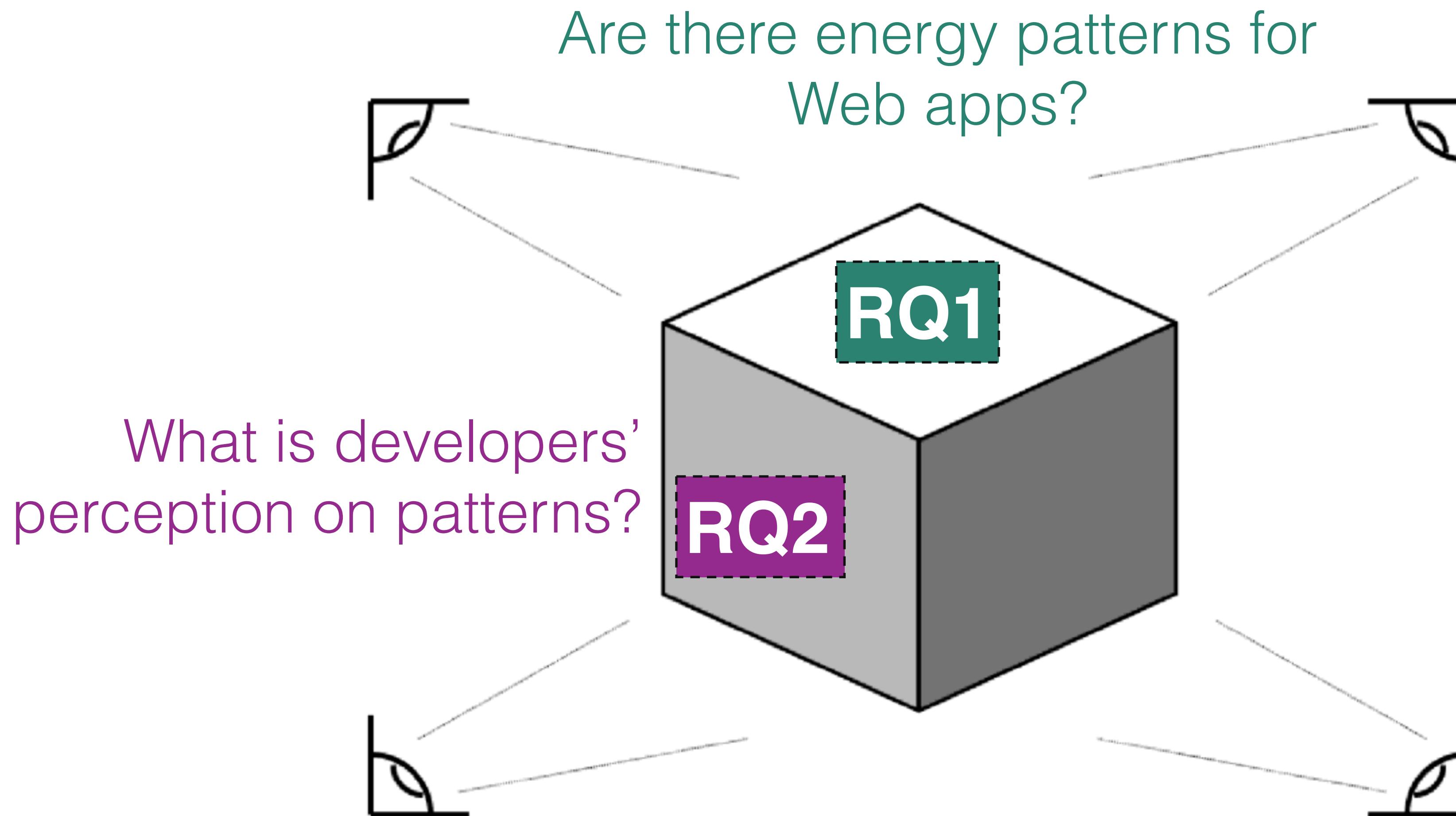
It requires a multi-perspective view



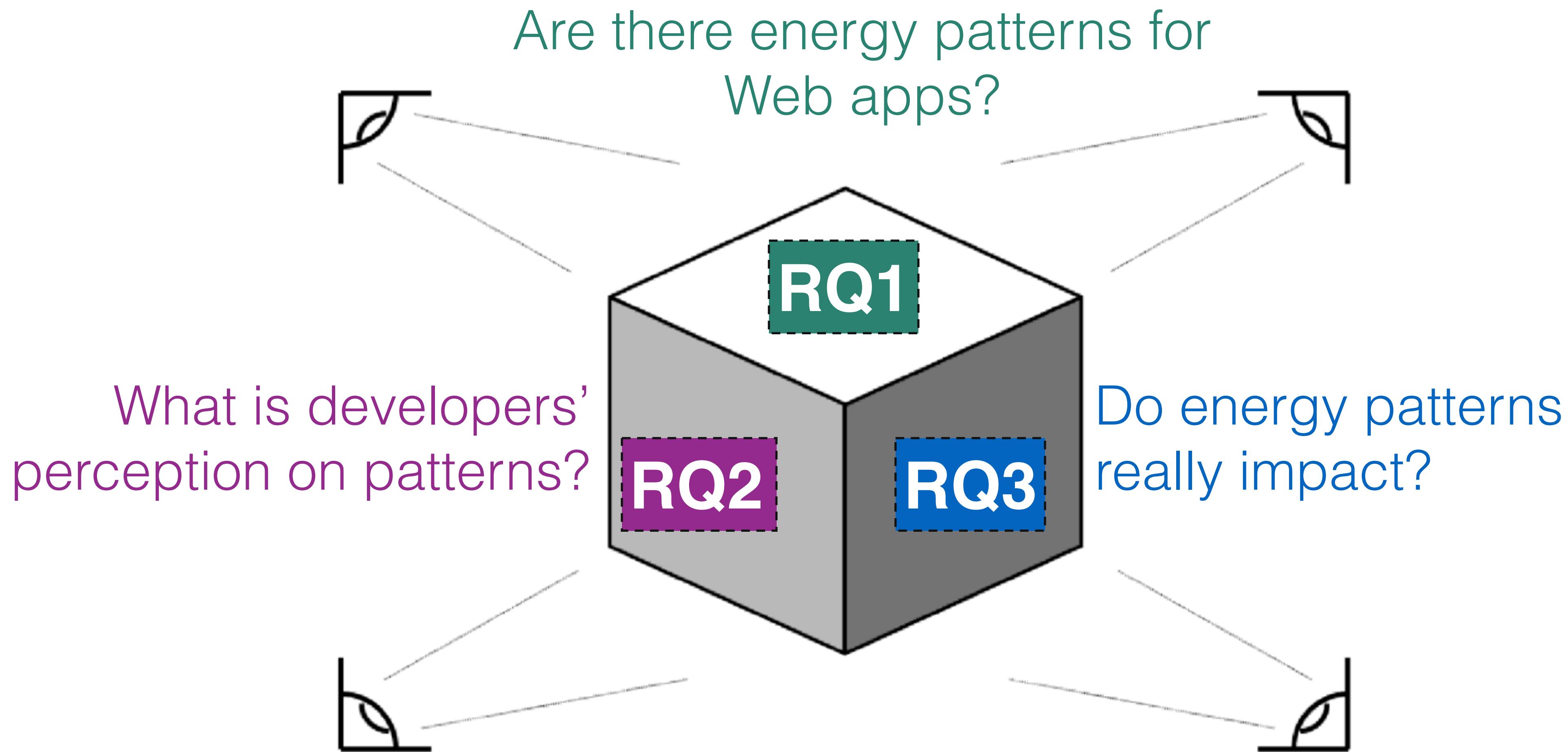
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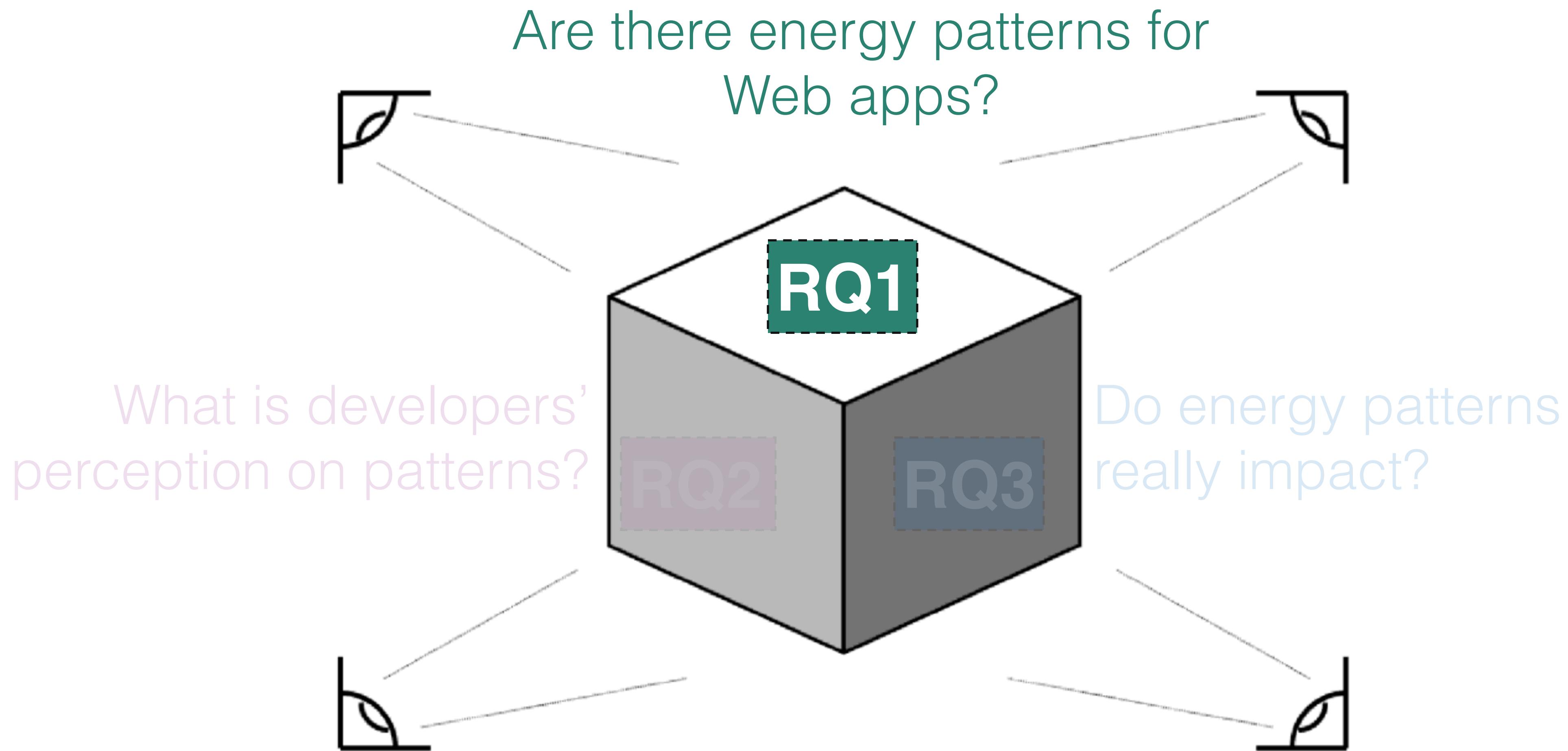
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RQ1: Energy Patterns for the Web

22 Mobile energy patterns

Dark UI Colors

Provide a dark UI colour theme to save battery.

Dynamic Retry Delay

Whenever an attempt to access a resource has failed, increase the interval of time waited before asking it

Open Only When Necessary

Open/start resources/services only when they are strictly necessary.

Push Over Poll

Use push notifications to receive updates from resources instead of actively querying resources (polling)

Power Awareness

Have a different behavior when device is connected/disconnected to a power station

Wifi Over Cellular

Delay or disable heavy data connections until the device is connected to a WiFi network

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energy patterns



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RQ2: Developers' Perception on Patterns

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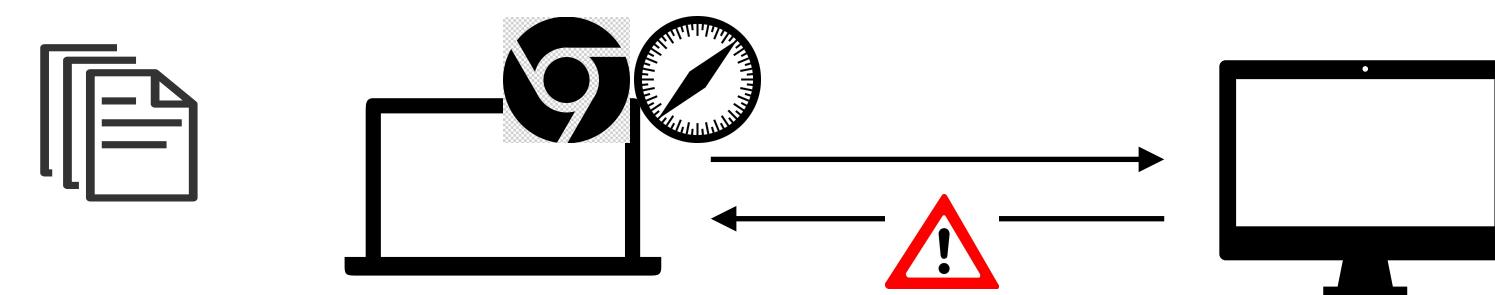
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RQ2: Developers' Perception on Patterns

Dynamic Retry Delay

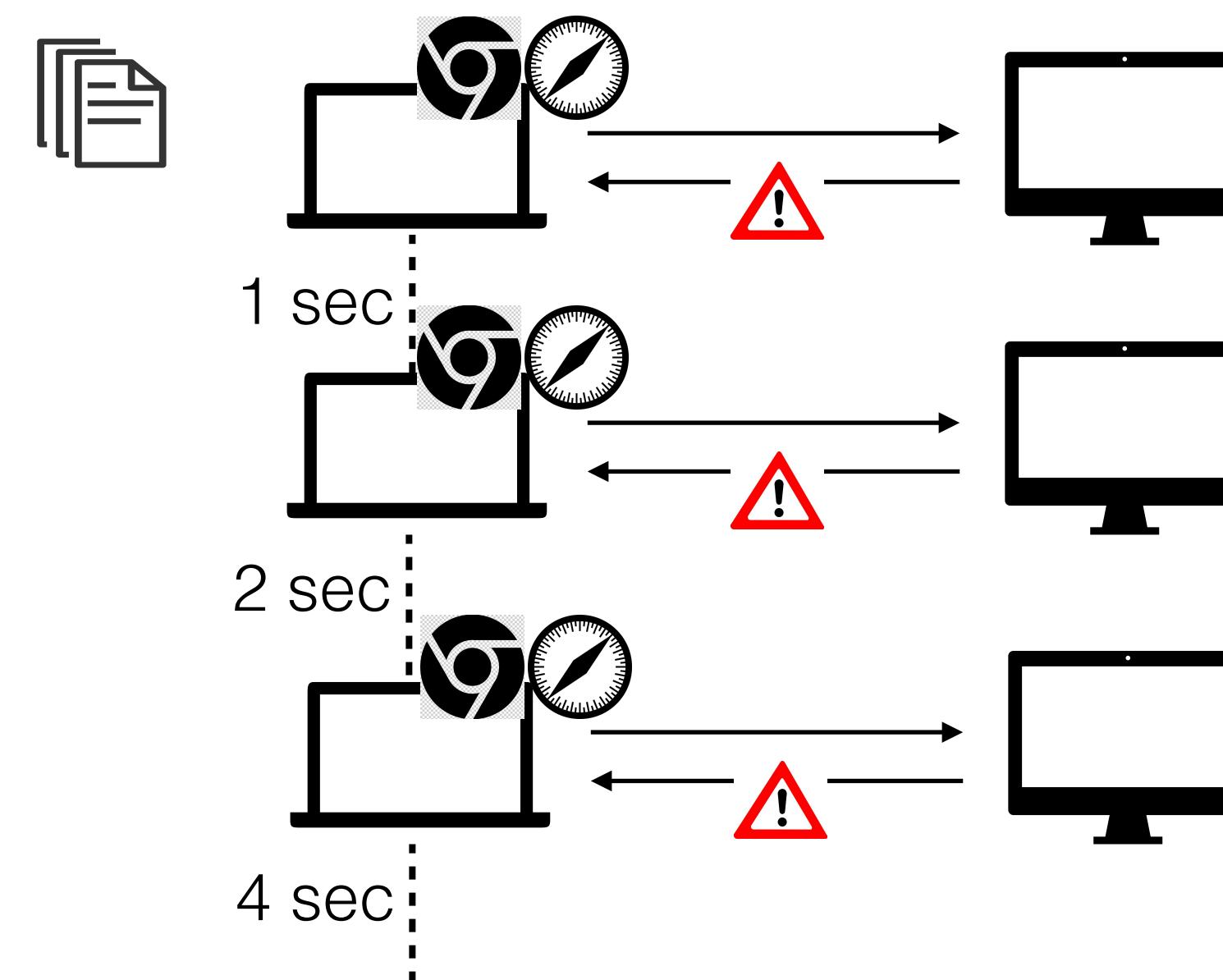
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RQ2: Developers' Perception on Patterns

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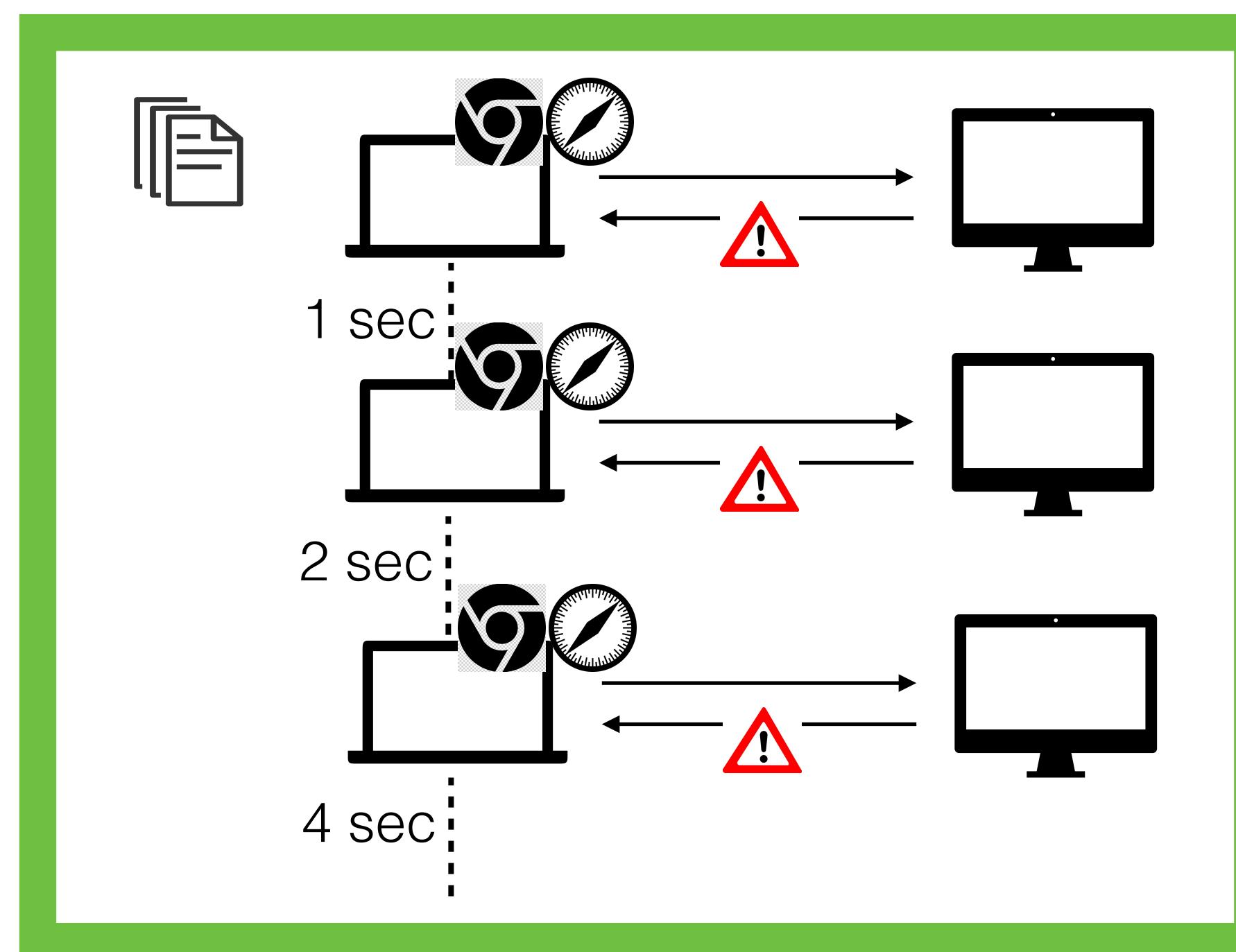
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RQ2: Developers' Perception on Patterns

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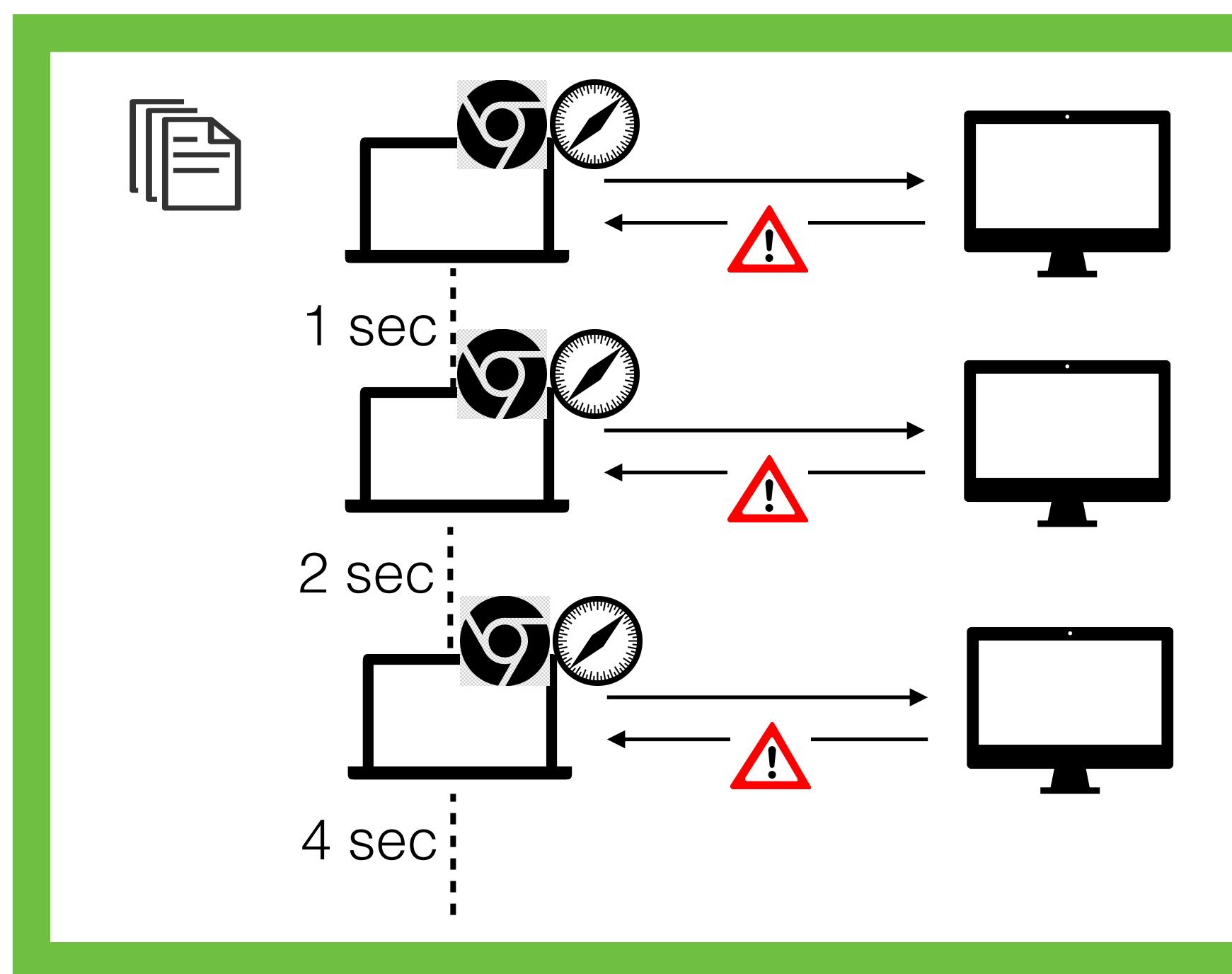


Pattern

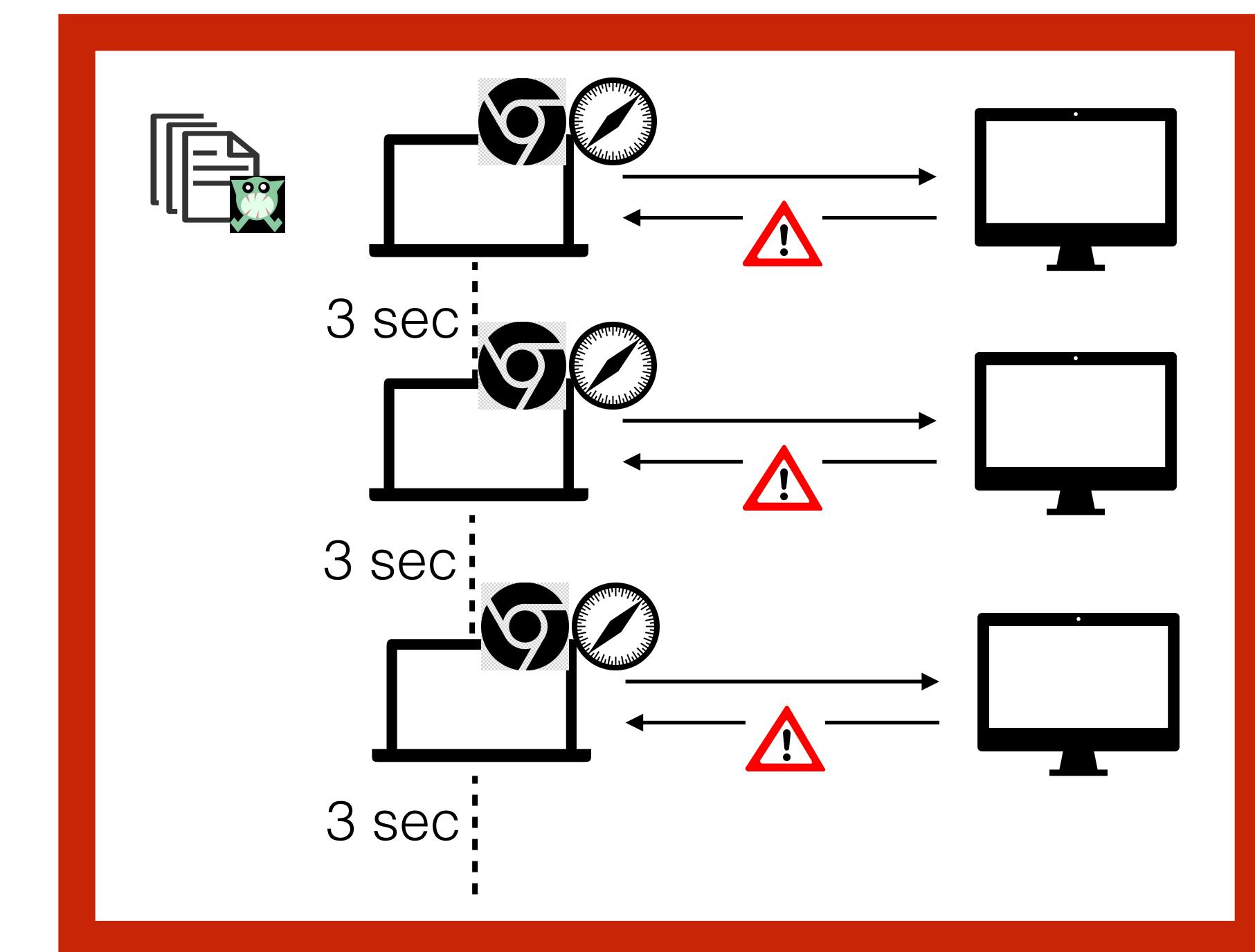
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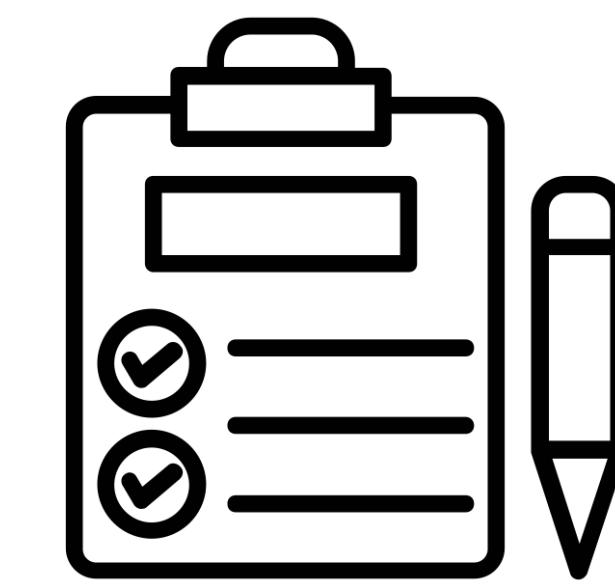
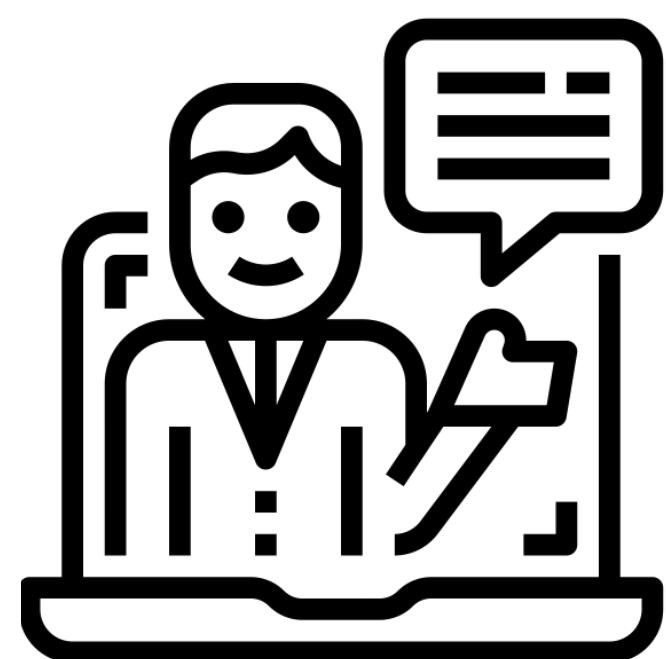


Pattern



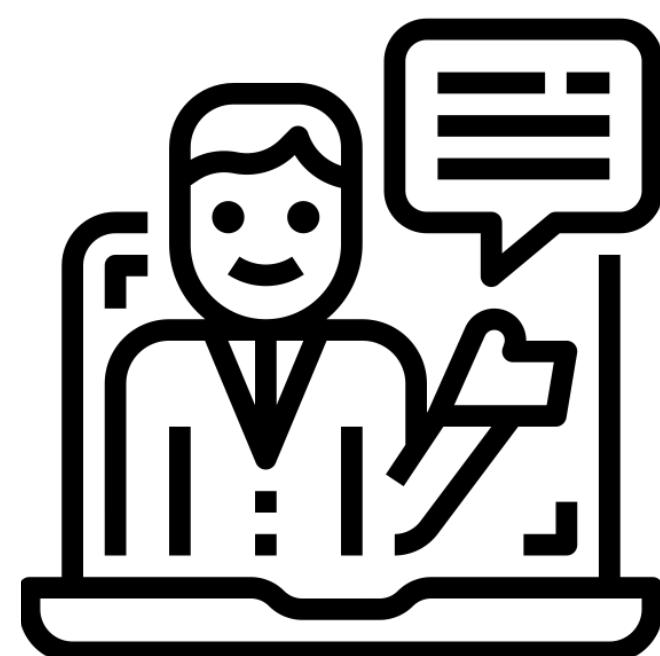
(Anti)pattern

RQ2: Developers' Perception on Patterns

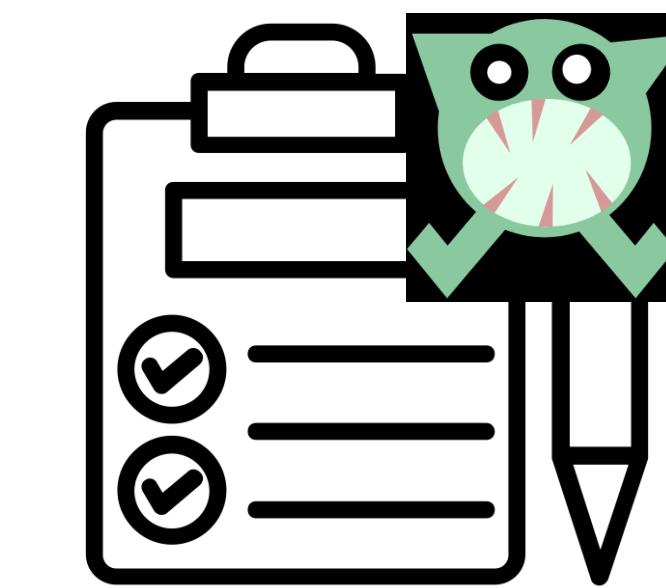


familiarity
on patterns

RQ2: Developers' Perception on Patterns

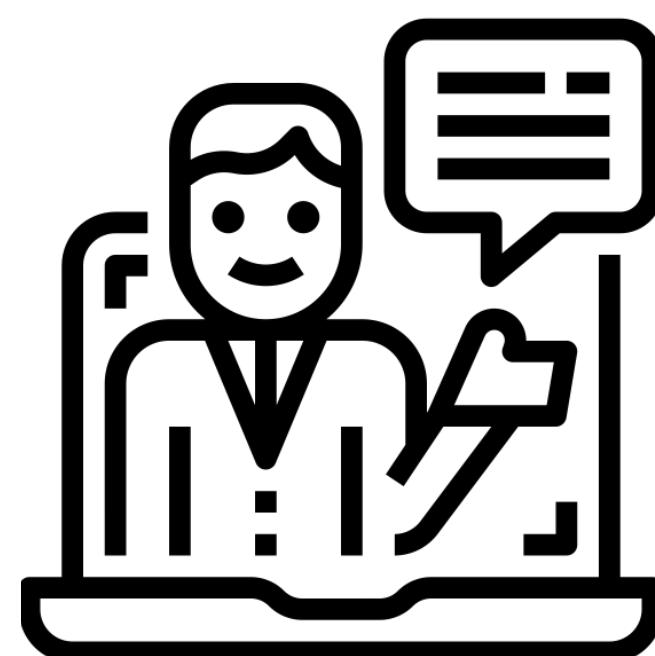


familiarity
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Concerns on
antipatterns

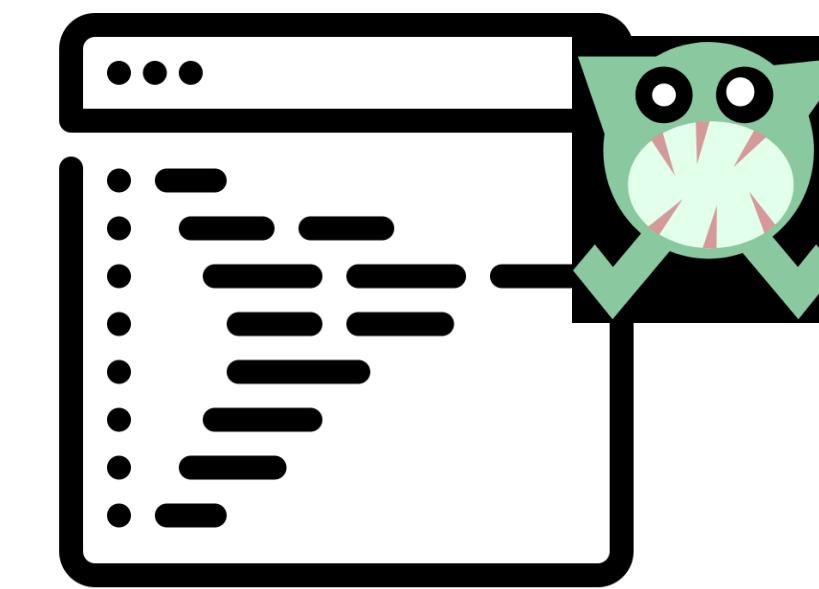
RQ2: Developers' Perception on Patterns



familiarity
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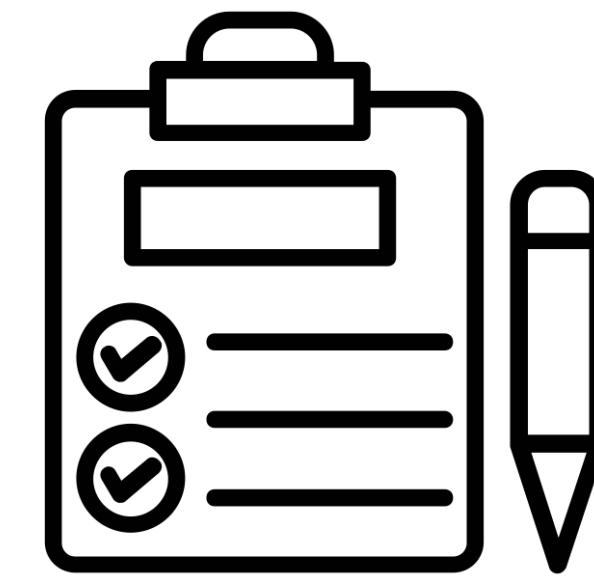


Patterns in
source code

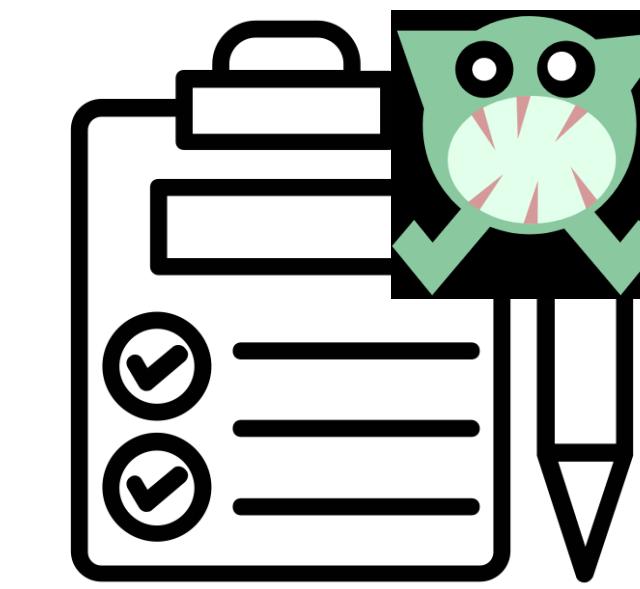
RQ2: Developers' Perception on Patterns



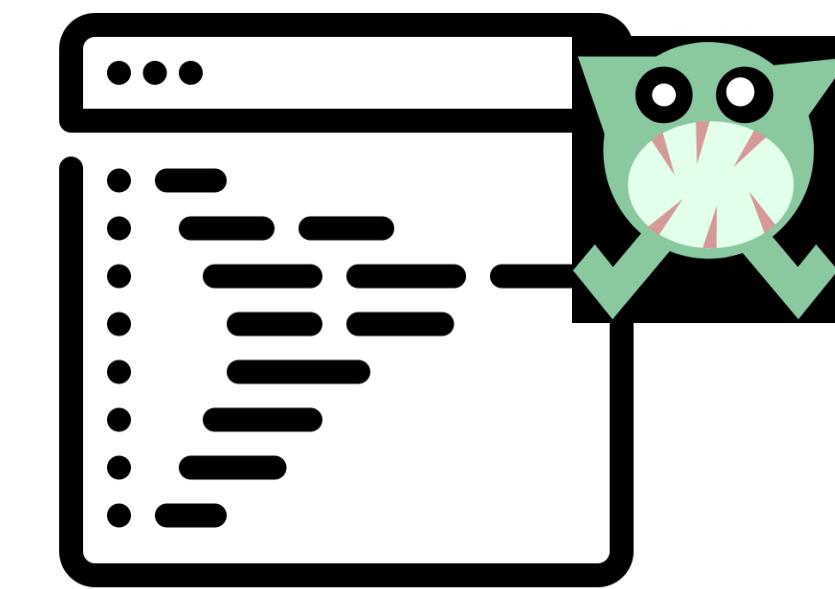
Case study with 6
web developers



familiarity
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Concerns on
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Patterns in
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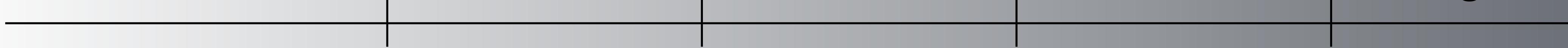


Other
questions



Familiar with Energy Patterns

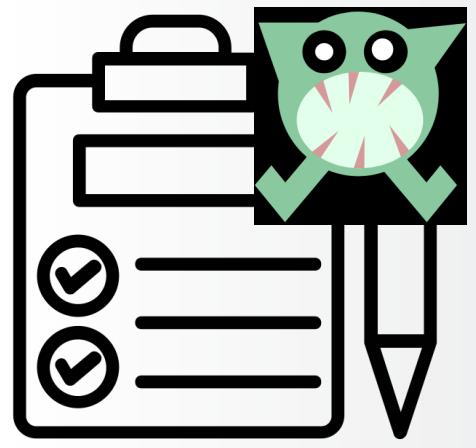
Never heard



17%

66%

17%



Concerns about Anti-patterns

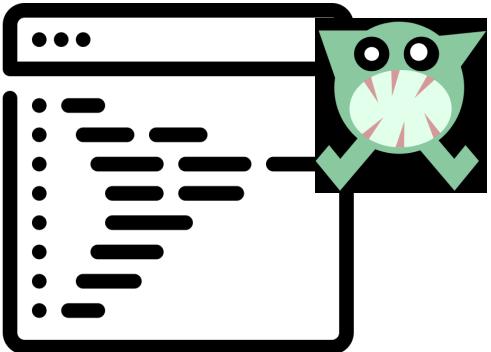


Dynamic Retry Delay

17% 17% 66%

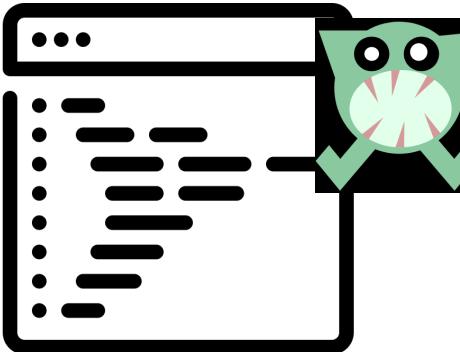
Open Only When Necessary

17% 33% 50%



Energy Patterns in Source code

```
503             message -  
504         if not hasattr(self, '_headers_buffer'):  
505             self._headers_buffer = []  
506         self._headers_buffer.append(("%s %d %s\r\n" %  
507             (self.protocol_version, code, message)).encode(  
508             'latin-1', 'strict'))  
509  
510     def send_header(self, keyword, value):  
511         """Send a MIME header to the headers buffer."""  
512         if self.request_version != 'HTTP/0.9':  
513             if not hasattr(self, '_headers_buffer'):  
514                 self._headers_buffer = []  
515             self._headers_buffer.append(  
516                 ("%s: %s\r\n" % (keyword, value)).encode('latin-1', 'strict'))  
517  
518         if keyword.lower() == 'connection':  
519             if value.lower() == 'close':  
520                 self.close_connection = True  
521             elif value.lower() == 'keep-alive':  
522                 self.close_connection = False  
523
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```

✓ 9 patterns found in code

✓ 11 anti patterns in code

✗ 4 not applicable to code

RQ3: Impact of Energy Patterns

Dark UI Colors

Provide a dark UI colour theme to save battery.

Dynamic Retry Delay

Whenever an attempt to access a resource has failed, increase the interval of time waited before asking it



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Power Awareness

Have a different behavior when device is connected/disconnected to a power station

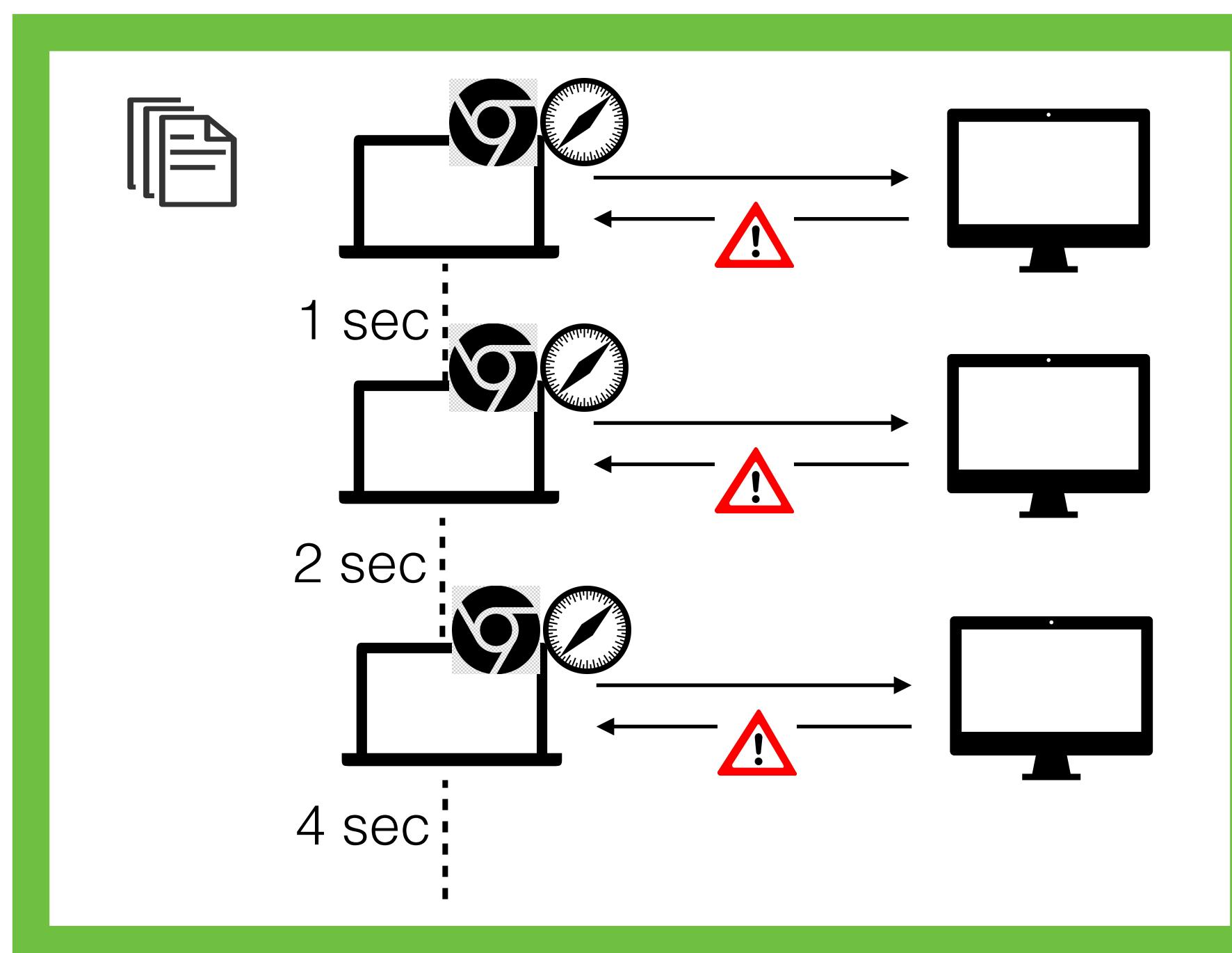
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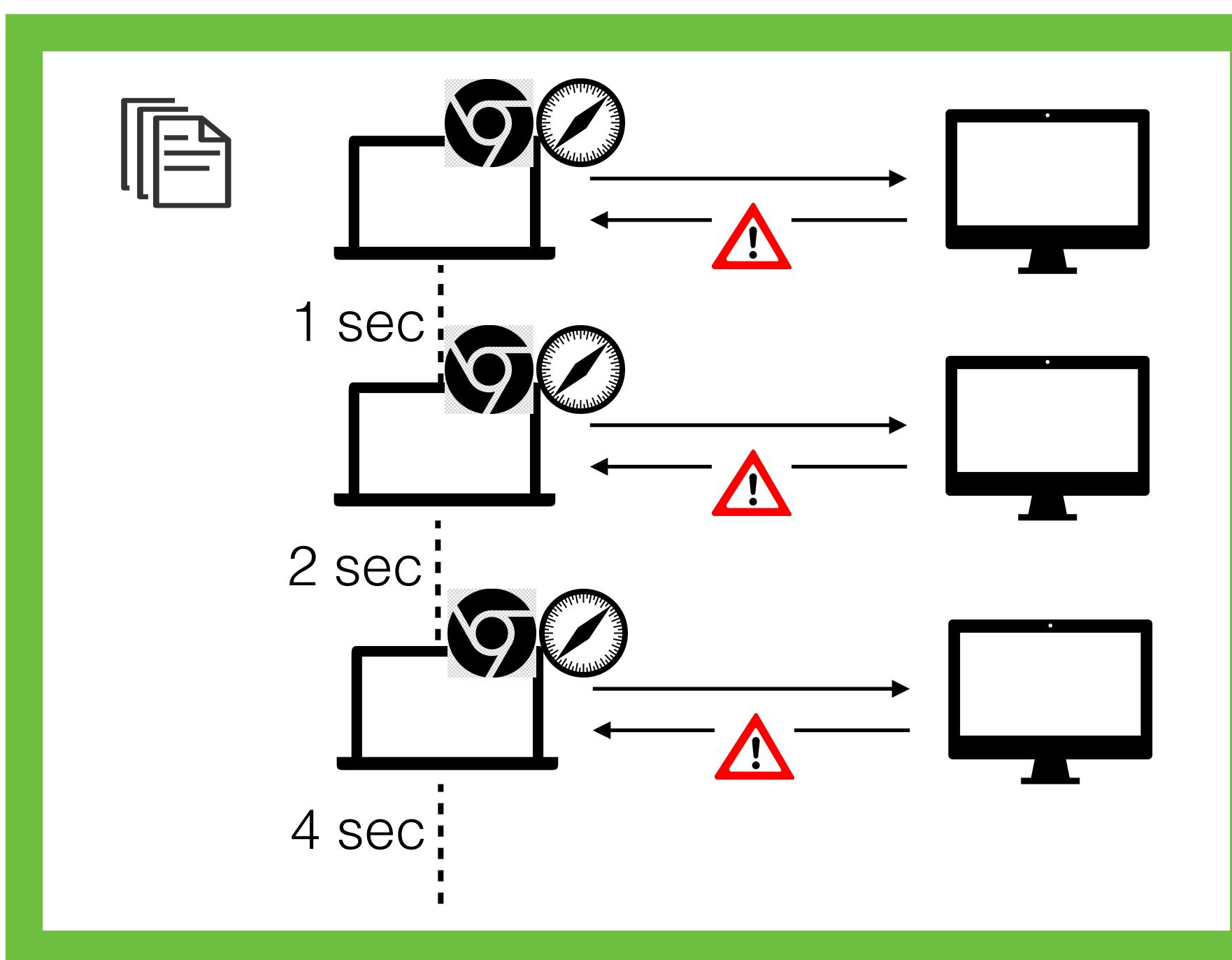


Pattern

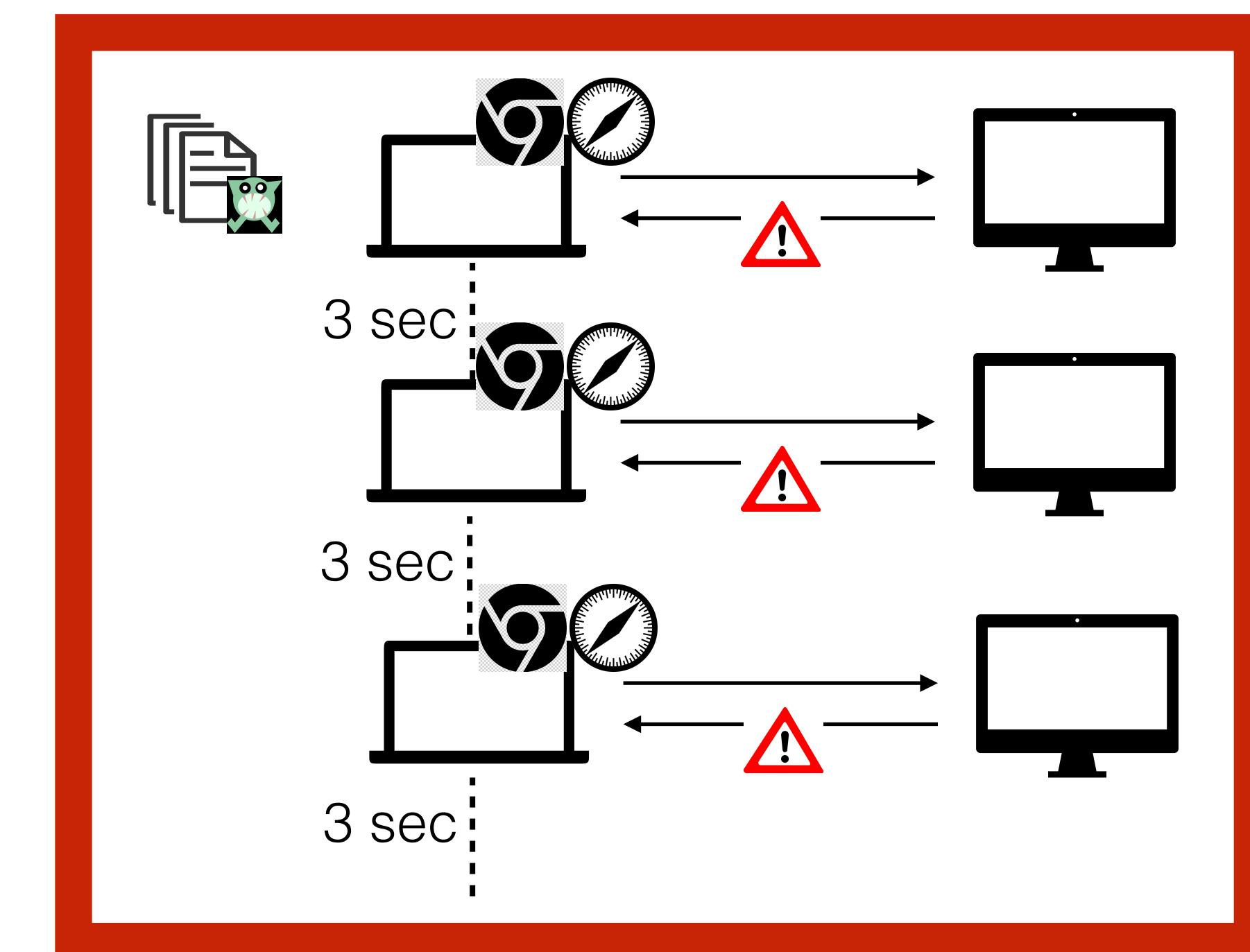
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Pattern

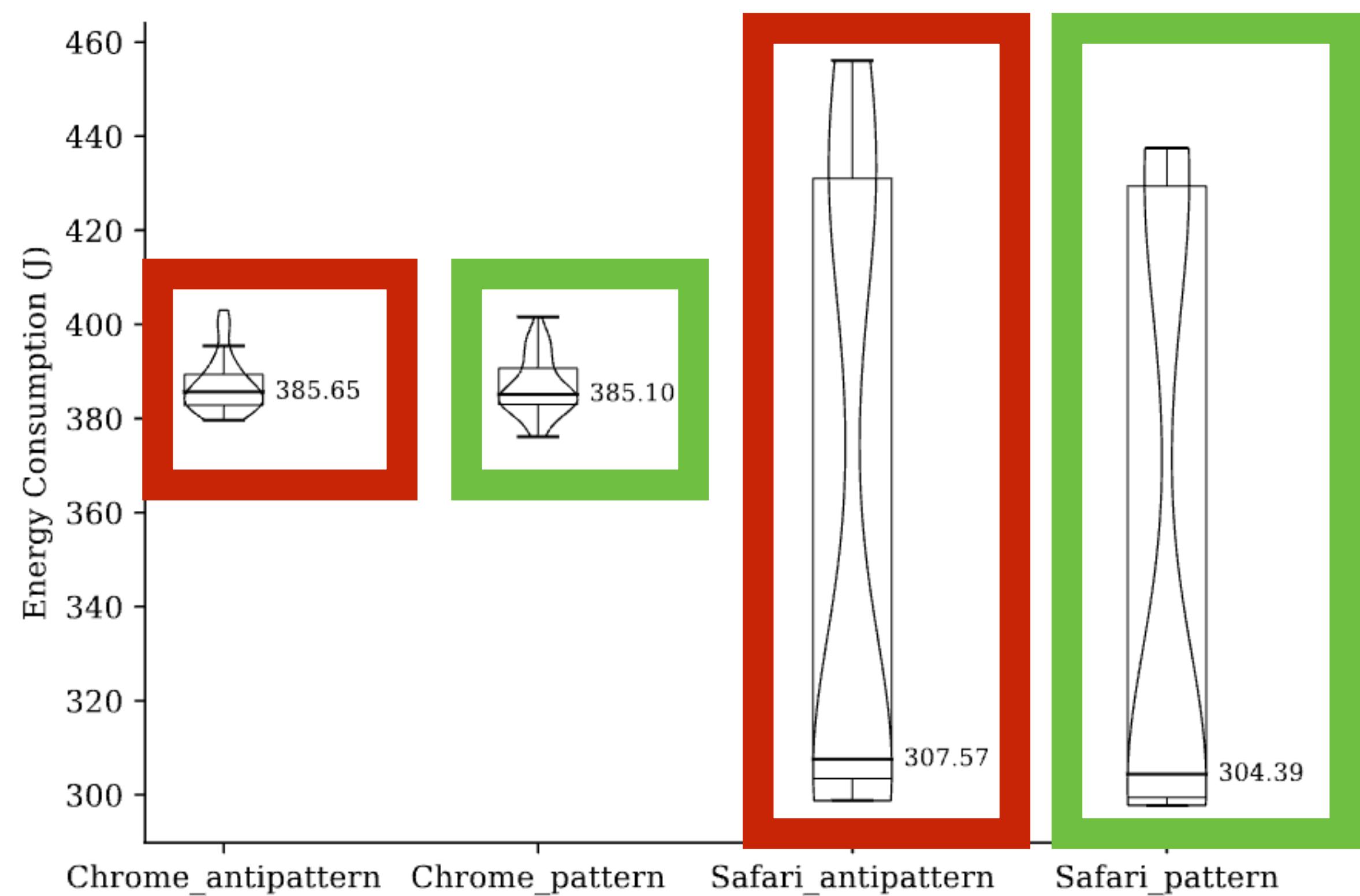


(Anti)pattern

RQ3: Impact of Energy Patterns

Dynamic Retry Delay

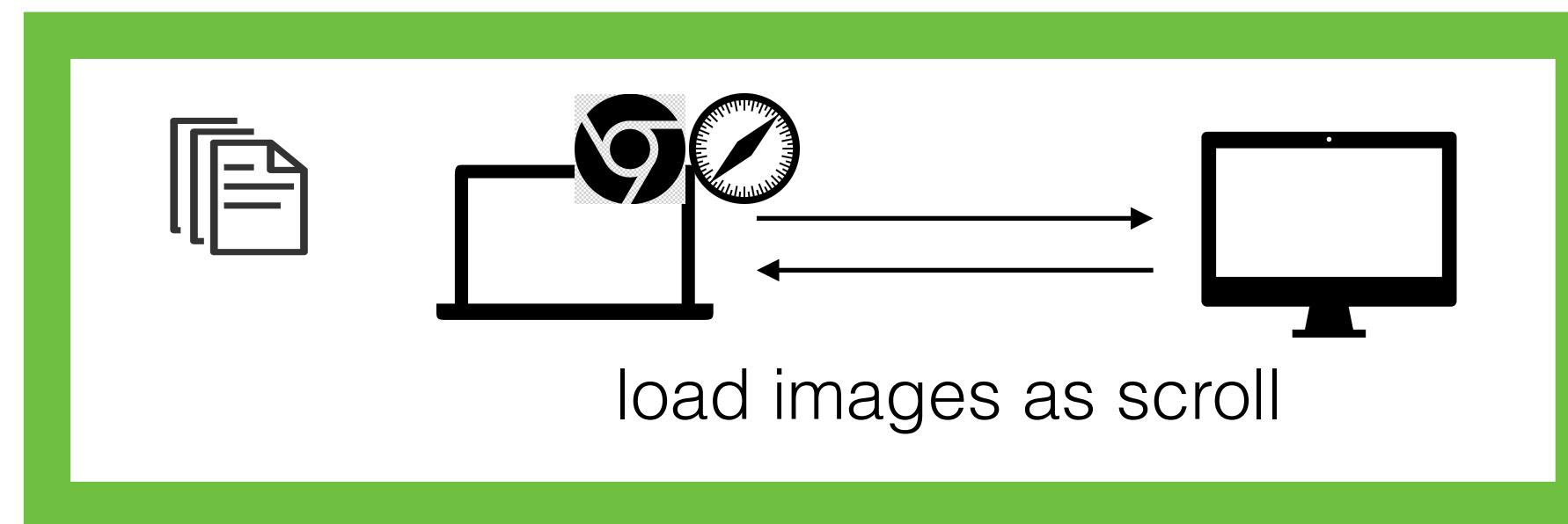
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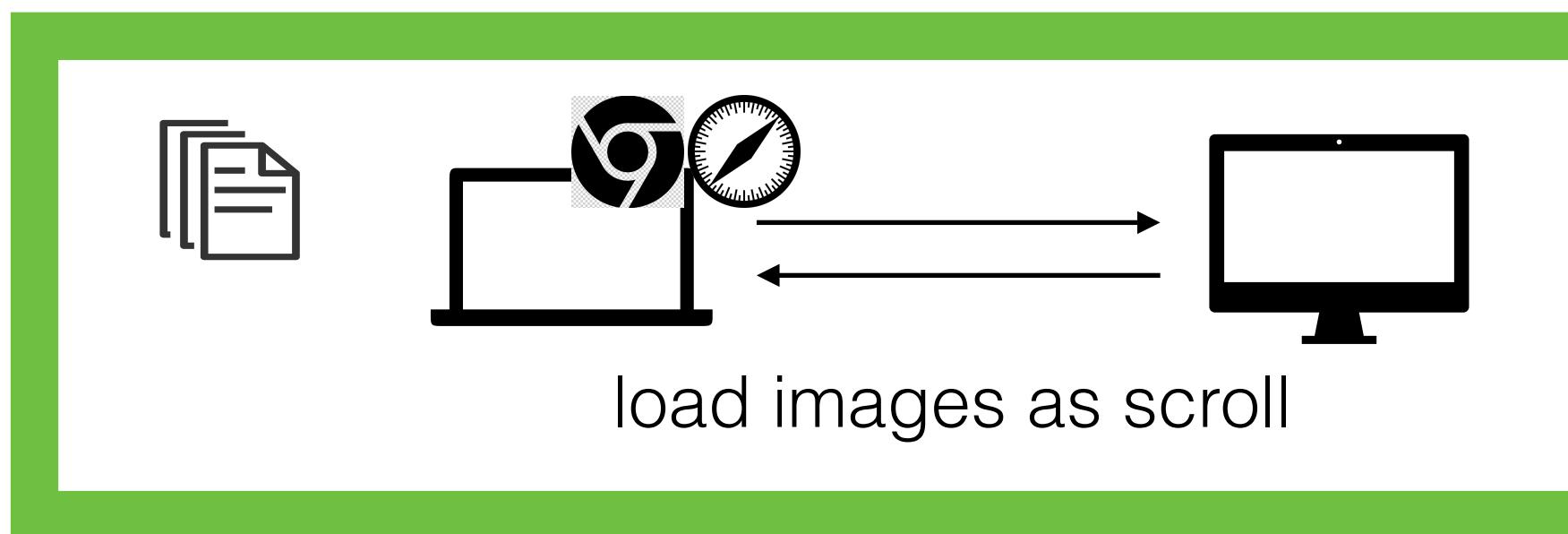


Pattern

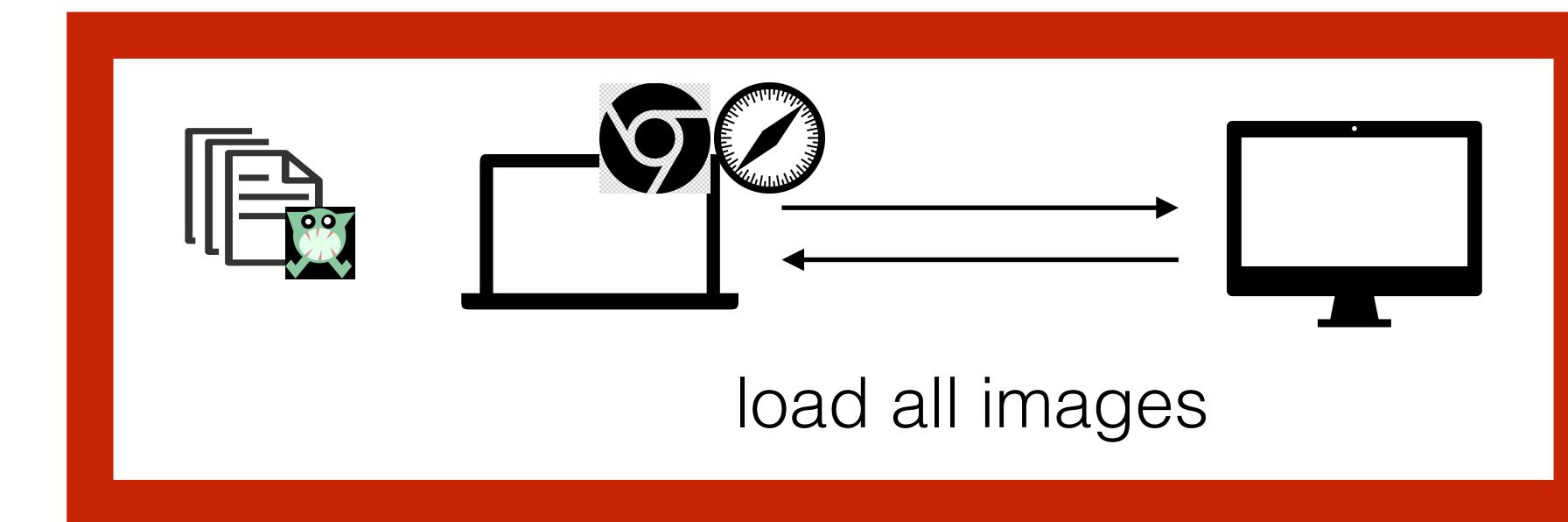
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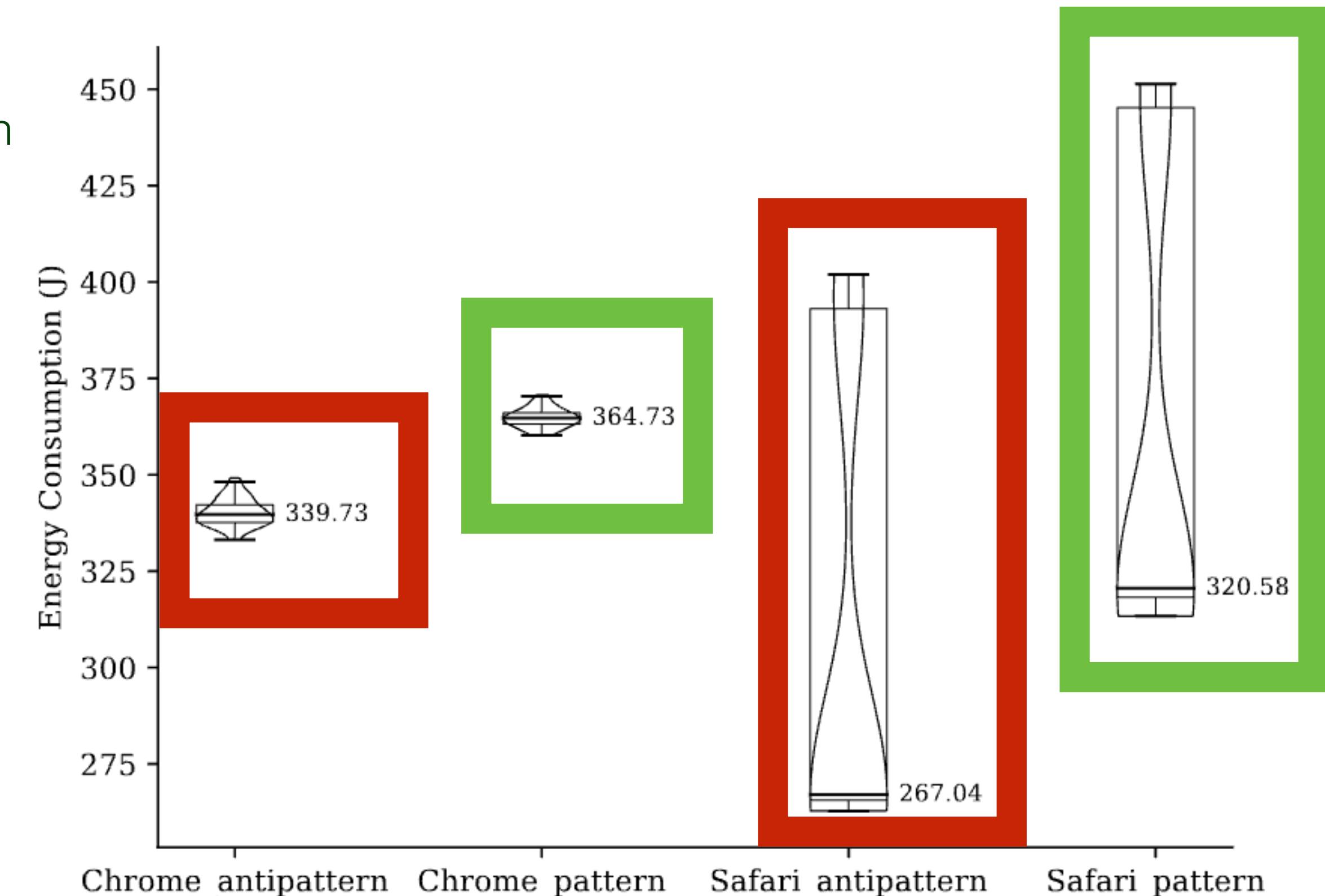


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Takeaways

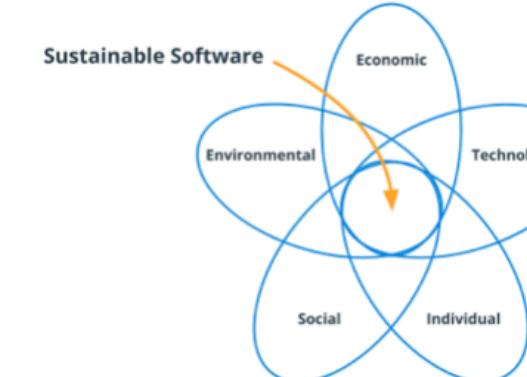
- 83% developers are not familiar with energy patterns.
- Developers are concerned about many anti patterns.
- They could find 16 (anti) patterns in source code.
- Energy impact of energy patterns vary.

Is it my problem?



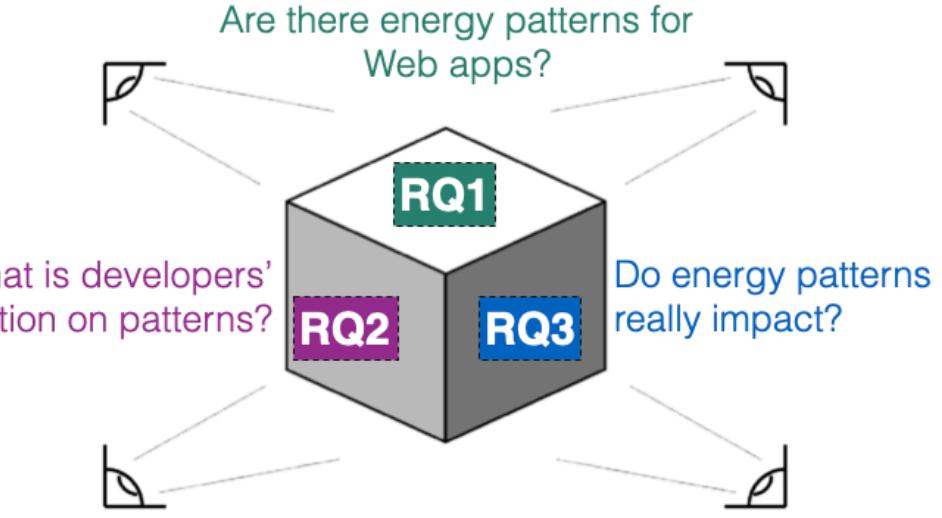
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/** * TODO */  
public void log(String s) {  
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```

“Sustainability means meeting our own needs without compromising the ability of future generations to meet their own needs.” (McGill University, 2013)



7

It requires a multi-perspective view



9

RQ1: Energy Patterns for the Web

20 web
energy patterns

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✓ 20

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✗ 2

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Power Awareness

Have a different behavior when device is connected/disconnected to a power station

Wifi Over Cellular

Delay or disable heavy data connections until the device is connected to a WiFi network

13



<https://torg.github.io/energy-patterns/#/>

Energy Patterns in Source code

```
if (methodId == 0) {  
    if (methodId >= 0) {  
        self->methodId = methodId;  
        self->methodBuffer = 0;  
        self->methodSize = 0;  
        self->methodMode = 0;  
        self->methodVersion = 0;  
  
        self->methodHeader = 0;  
        self->methodHeaderSize = 0;  
        self->methodHeaderMode = 0;  
        self->methodHeaderVersion = 0;  
  
        self->methodHeaderSize = 0;  
        self->methodHeaderMode = 0;  
        self->methodHeaderVersion = 0;  
    }  
}  
  
if (methodHeader != 0) {  
    if (methodHeader >= 0) {  
        self->methodHeader = methodHeader;  
        self->methodHeaderSize = methodHeaderSize;  
        self->methodHeaderMode = methodHeaderMode;  
        self->methodHeaderVersion = methodHeaderVersion;  
    }  
}
```

✓ 9 patterns found in code

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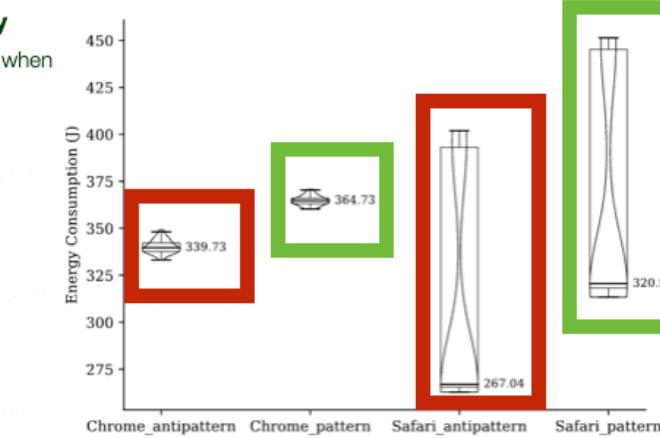
✗ 4 not applicable to code

21

RQ3: Do Energy Patterns impact?

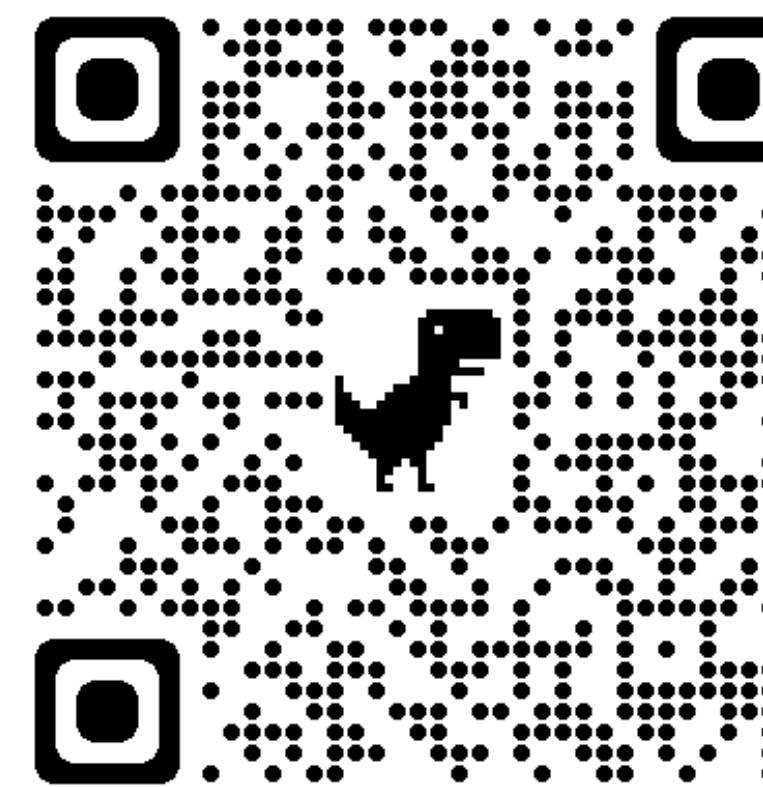
Open Only When Necessary

Open/start resources/services only when



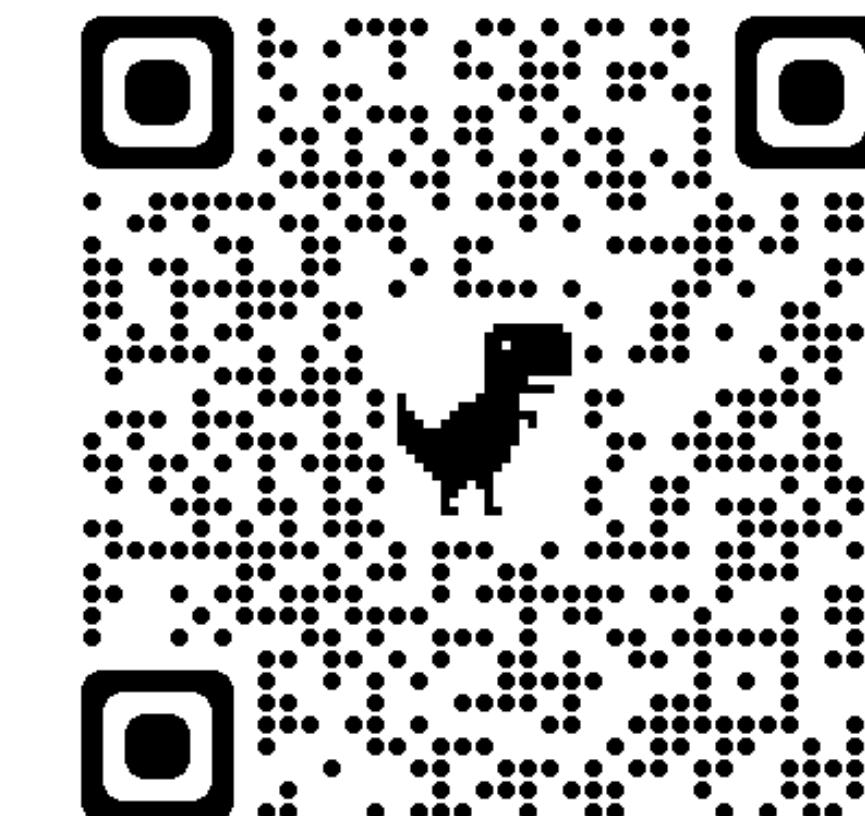
26

<https://torg.github.io/energy-patterns/#/>

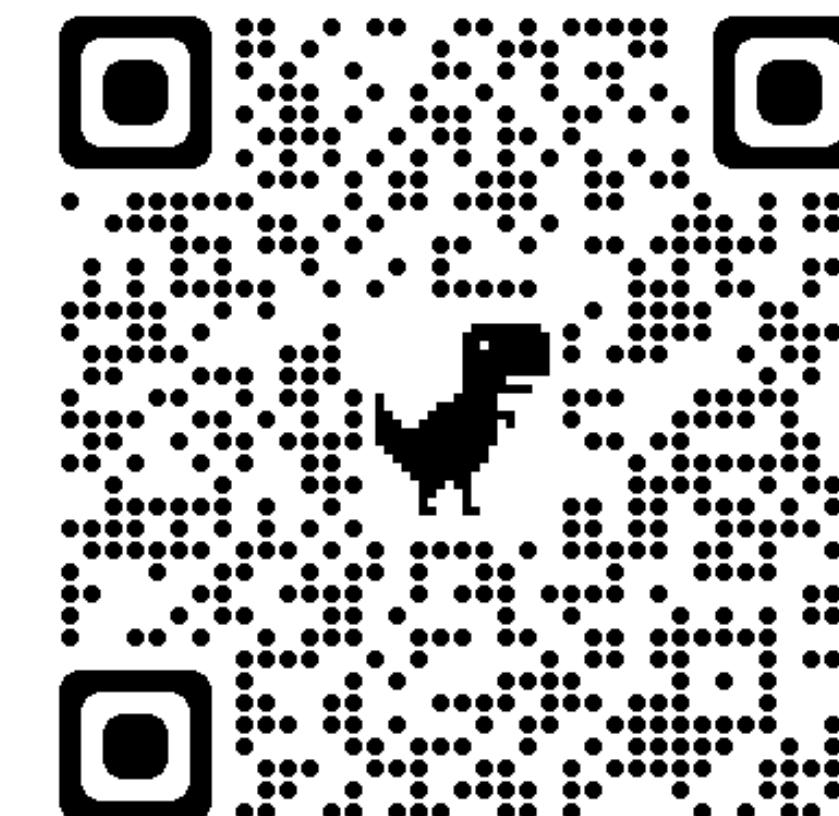


39

My profile



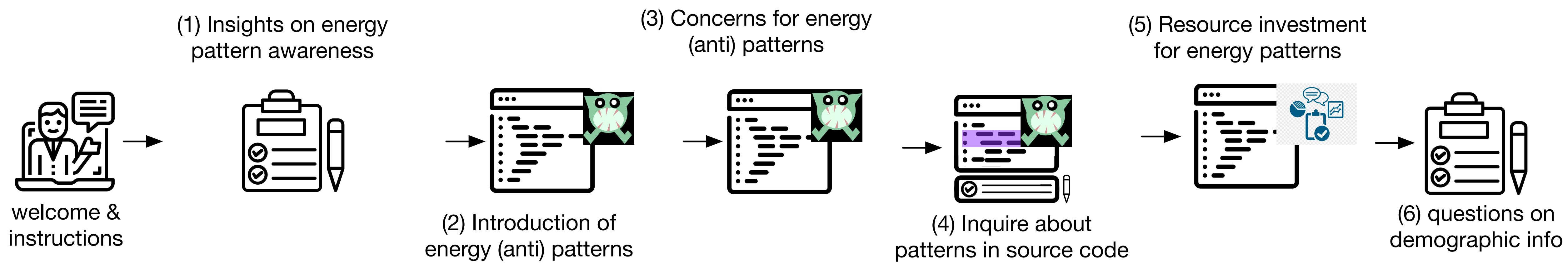
Replication Package



Paper

More Curious?

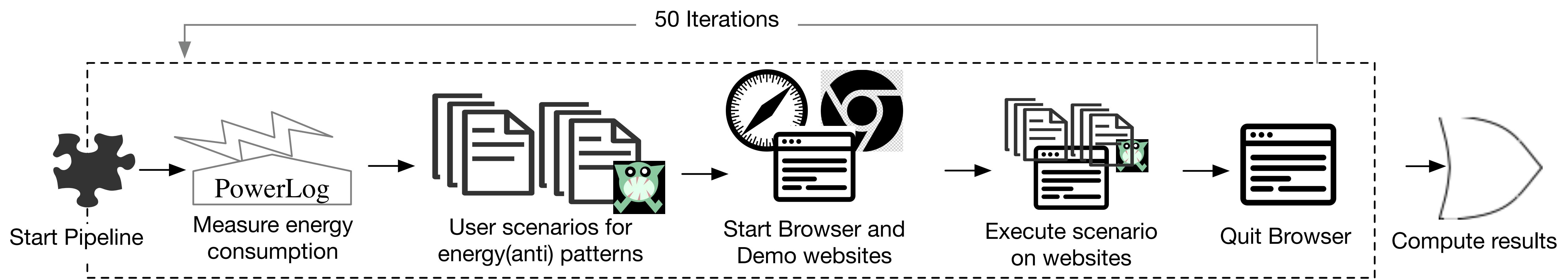
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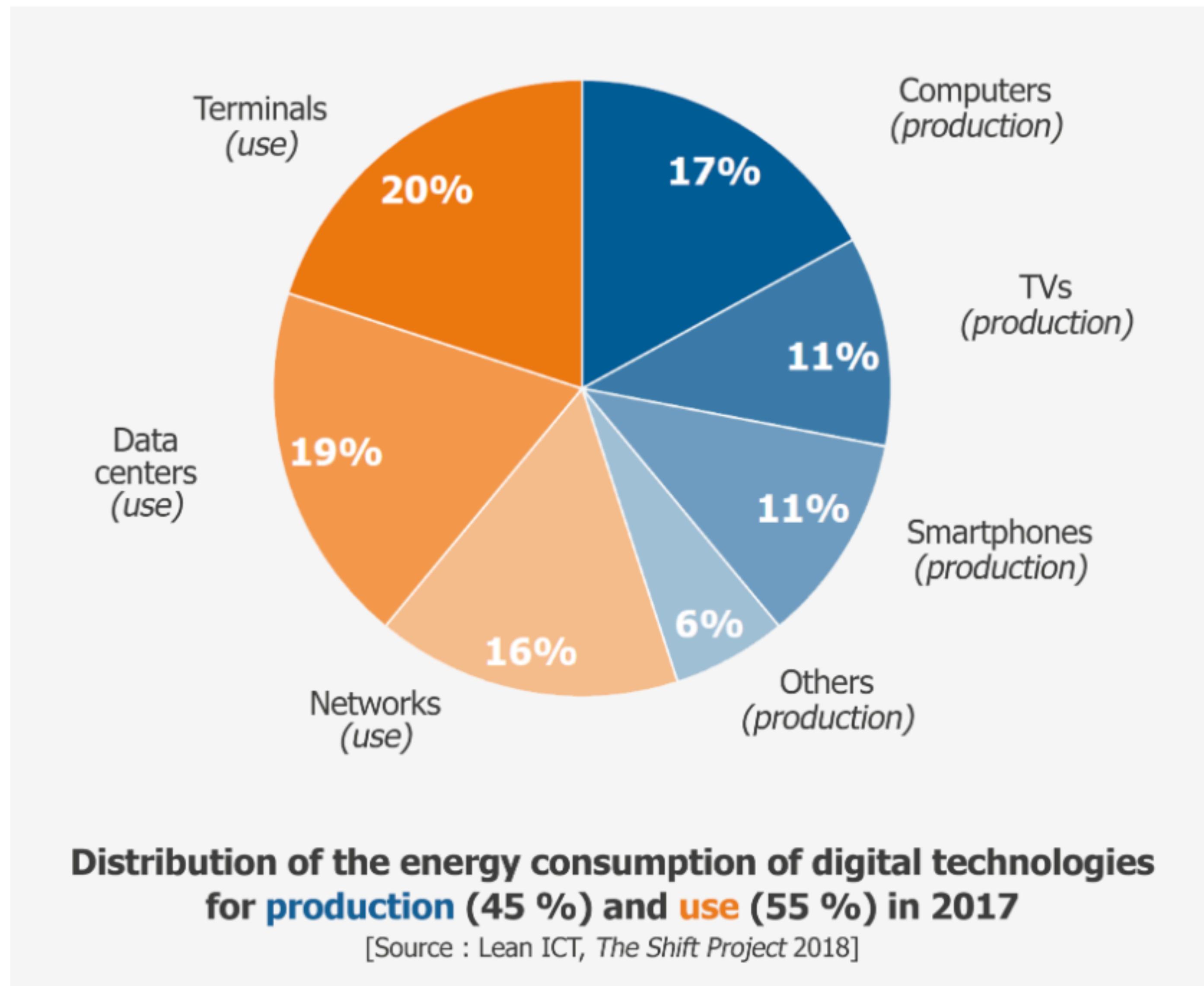


Case study with 3 web developers from a energy-grid based company

3 developers from other companies

RQ3: Impact of Energy Patterns





Technologies disappear, software updates, increasing development costs due to technical debt, high-performance systems that need high power.

Saputri and Lee, 2021, Integrated framework for incorporating sustainability design in software engineering life-cycle: An empirical study