I FEEL THE NEED FOR WEB PAGE SPEED

VMLY&R

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THINGS PEOPLE WOULD NEVER SAY

"I LOVE AUTOPLAY VIDEOS." – AN ACTUAL MORON

"ADS ARE GOOD AND ALSO RELEVANT TO ME." – PAINT CHIP CONNOISSEUR

"CHROME USING 4GB OF RAM IS GOOD." – A SLACK DEVELOPER

"THIS WEBPAGE LOADS JUST TOO FAST" –DARWIN AWARD WINNER

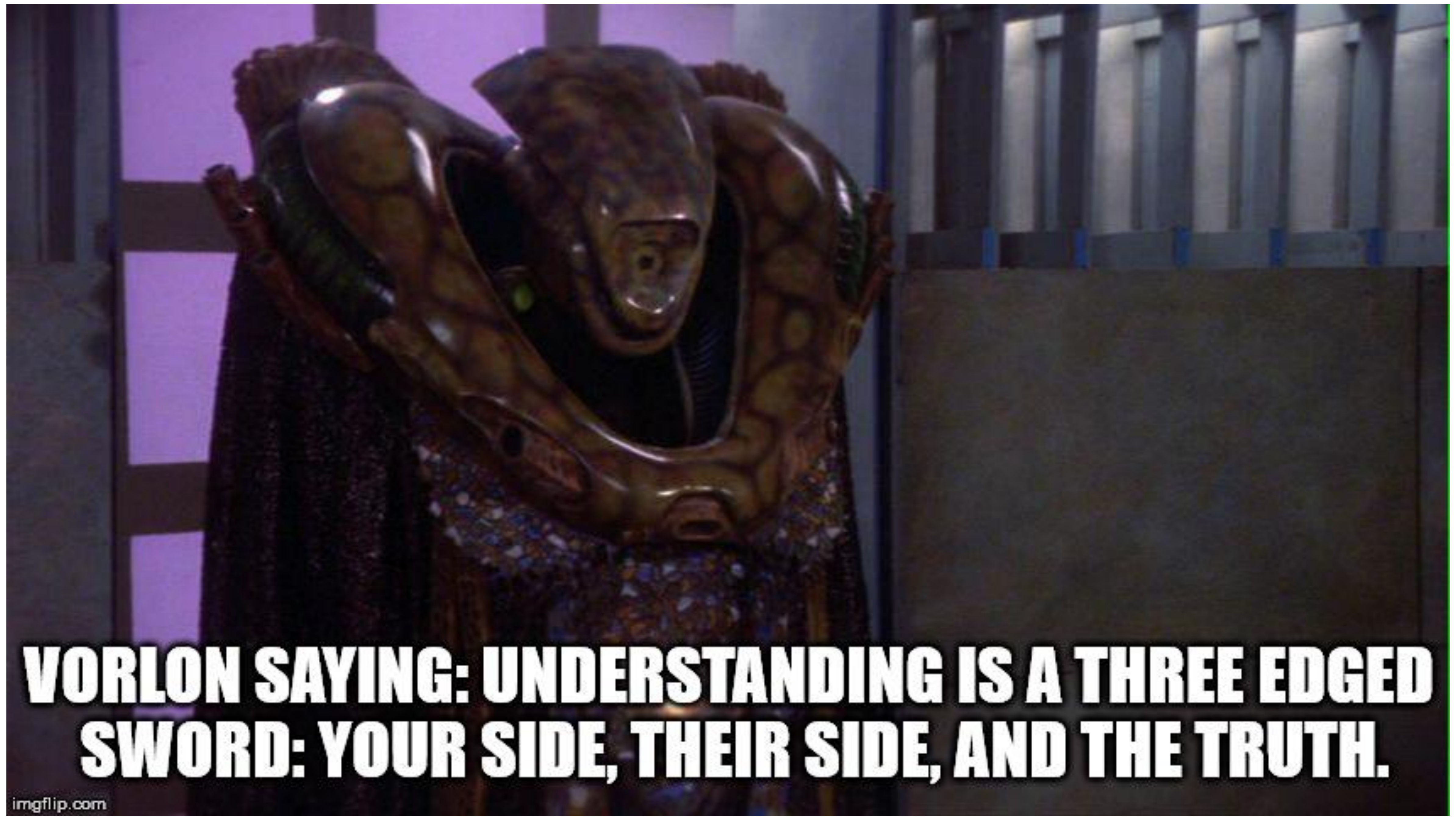
OUR CURRENT GRIMDARK HELLSCAPE OF WEB PERFORMANCE

DESPITE 5G, POCKET SUPERCOMPUTERS AND BILLIONS IN BROWSER DEVELOPMENT WEBPAGES STILL LOAD LIKE ITS 2001 ON MY DAD'S ISDN LINE

WHY IS THIS SO SLOW???

"Byte-for-byte, JavaScript is still the most expensive resource we send to mobile phones, because it can delay interactivity in large ways." – Addy Osmani, Engineering Manager, Chrome.

"My page is perfectly fast if you ignore all this third-party tags and dumb images." – Me, 2017.


VORLON SAYING: UNDERSTANDING IS A THREE EDGED SWORD: YOUR SIDE, THEIR SIDE, AND THE TRUTH.
imgflip.com

THE IMPROVEMENT PATTERN

1. UNDERSTAND THE ARCHITECTURE
2. MEASURE PERFORMANCE
3. OPTIMIZATION TECHNIQUES

1.) UNDERSTAND THE ARCHITECTURE

Understand the Architecture: Critical Rendering Path

The critical rendering path is the minimal set of steps the browser must take to render a webpage.

1.) Construct the Object Model.

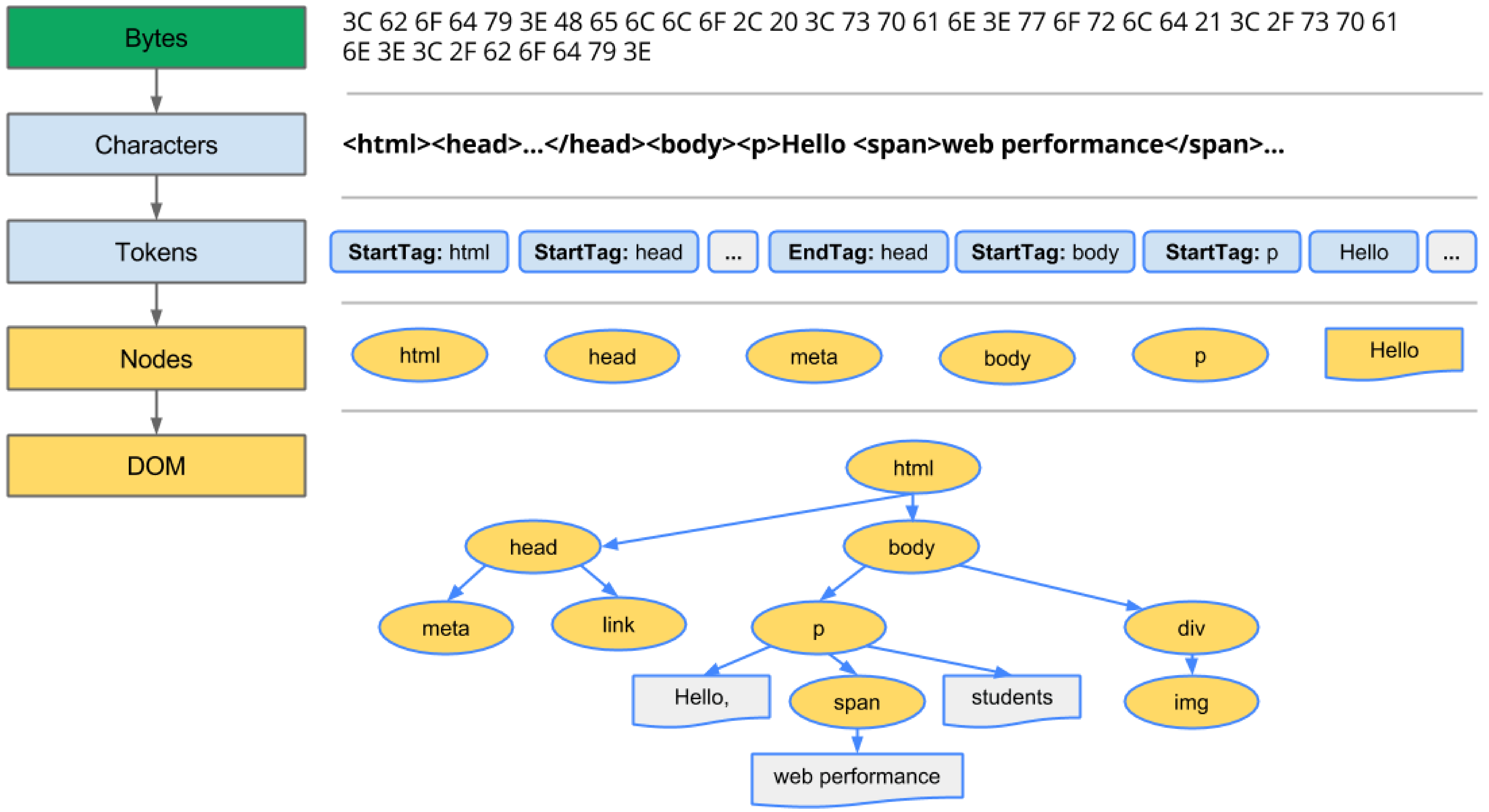
2.) Create a render tree.

3.) Layout.

4.) Paint.

Step #1: Construct the Object Model

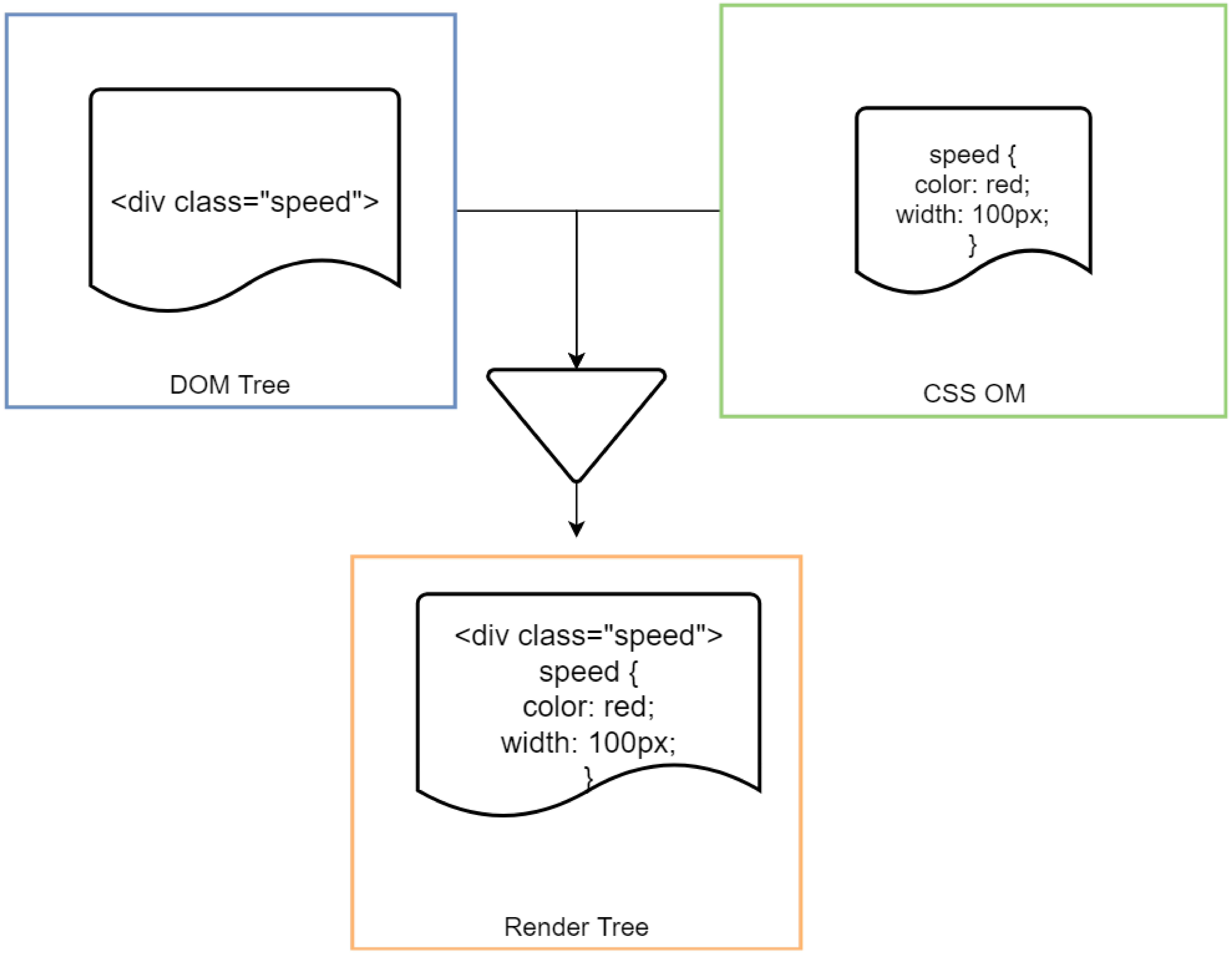
Two-part process to fetch and parse HTML (to turn into the DOM) and CSS (to turn into the CSSOM).



https://developers.google.com/web/fundamentals/performance/critical-rendering-path/constructing-the-object-model

Step #2: Create the Render Tree

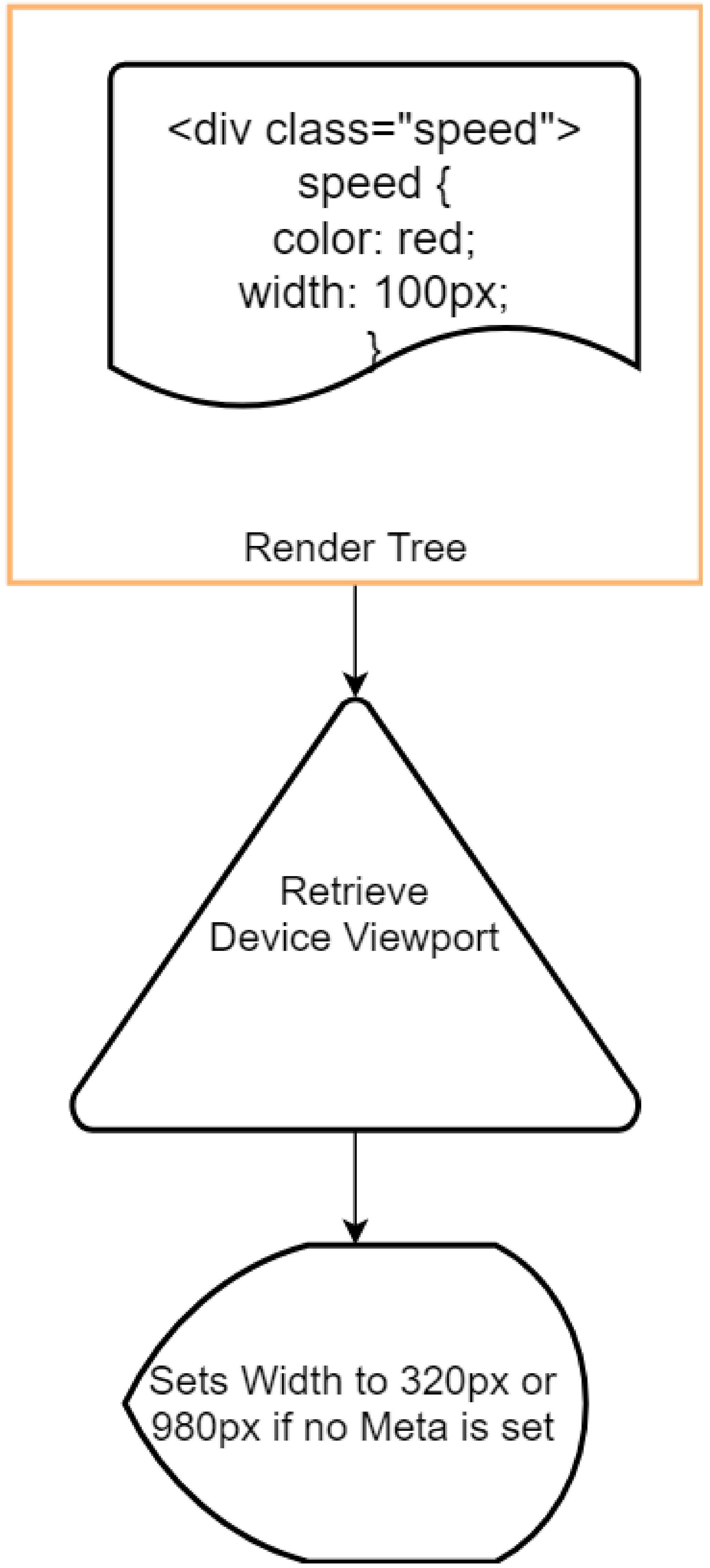
Combines the CSSOM & DOM into one tree structure. Only consists of *visible* elements.

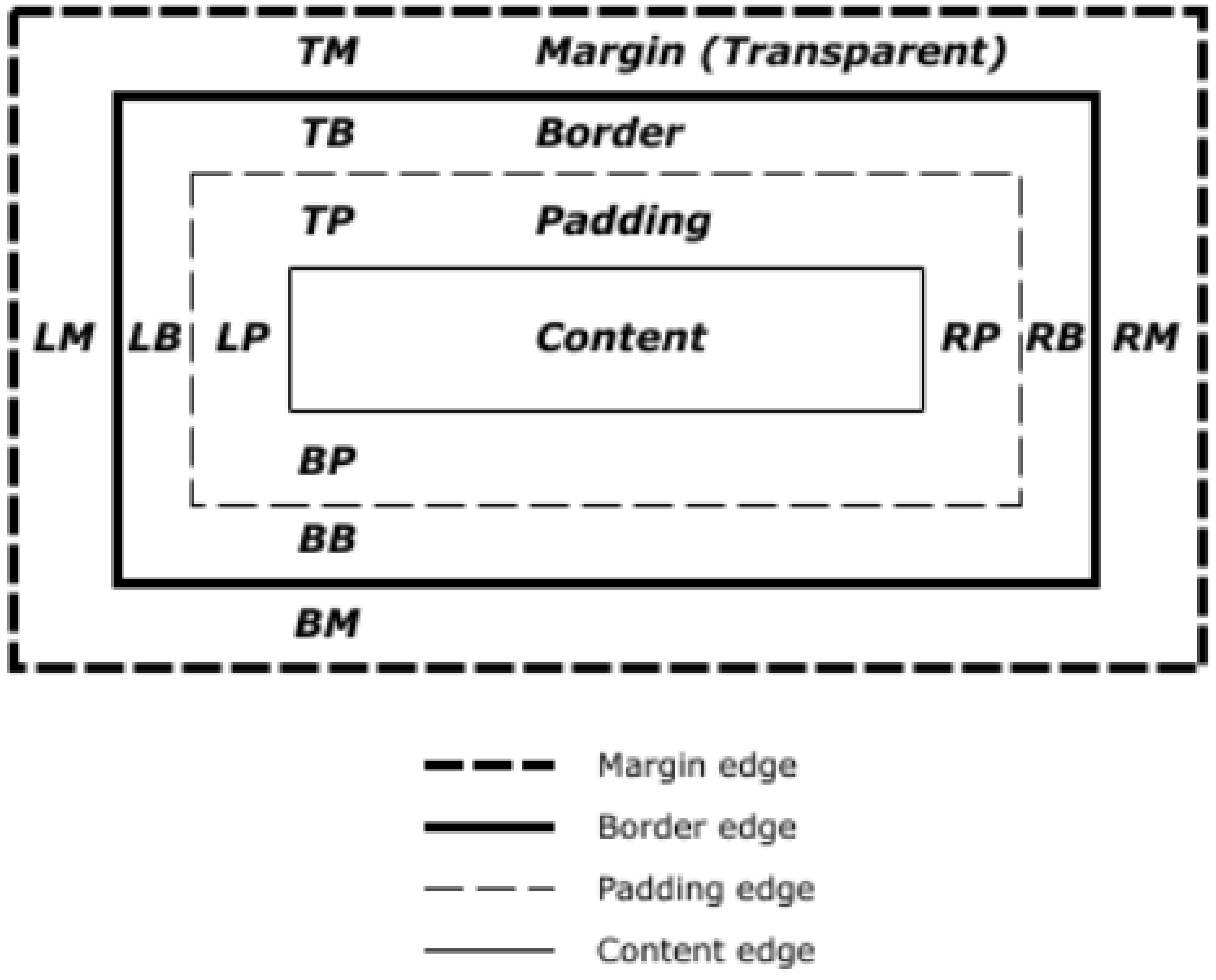


Understand the Architecture: Critical Rendering Path

Step #3: Layout

Determines size and placement (width/height/float) of elements on the page.





https://www.w3.org/TR/CSS21/box.html#box-dimensions

Step #4: Paint

Actually rendering the pixels onto the screen.
In modern browsers, typically will make use of
the GPU if present to speed up render.

COOL COOL COOL. WHAT ABOUT JAVASCRIPT??

Understand the Architecture: JavaScript Execution

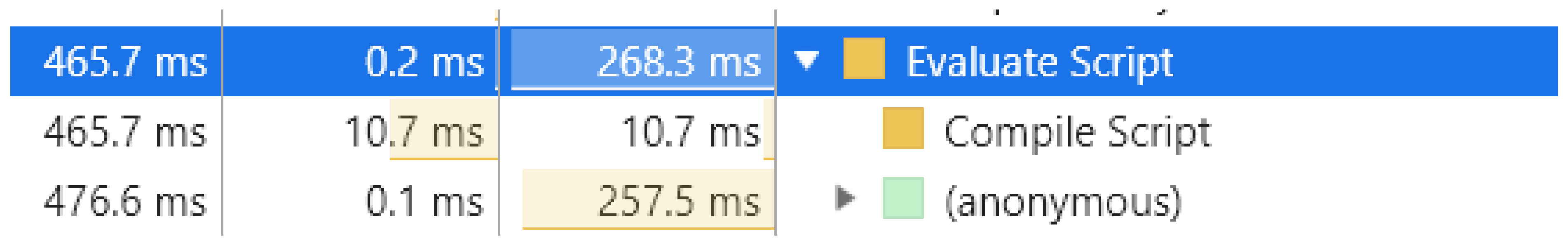
Four steps to run JavaScript once it is encountered

1.) Download
2.) Parse
3.) Compile
4.) Execute

Understand the Architecture: JavaScript Execution

1.) Download – Network Bound
2.) Parse – CPU Bound.
3.) Compile – CPU Bound.
4.) Execute – CPU Bound.

JavaScript execution speed is mainly CPU bound!



465.7 ms	0.2 ms	268.3 ms	▼ Evaluate Script
465.7 ms	10.7 ms	10.7 ms	Compile Script
476.6 ms	0.1 ms	257.5 ms	▶ (anonymous)

DEMO: GMAIL

LIKE CSS BY DEFAULT JAVASCRIPT BLOCKS RENDER UNTIL ALL 4 STEPS HAVE BEEN COMPLETED!

Understand the Architecture: JavaScript Execution

… Although there are some caveats

JS	Blocks Render?	Network Load Priority
Inline JS, i.e <script> Console.log('hello world'); </script>	Yes	N/A
<script async src="https://www...>	No	Medium/High
<script defer src="https://www">	No	Lowest
<script> in head	Yes	Highest
<script> in body	No	Medium/High

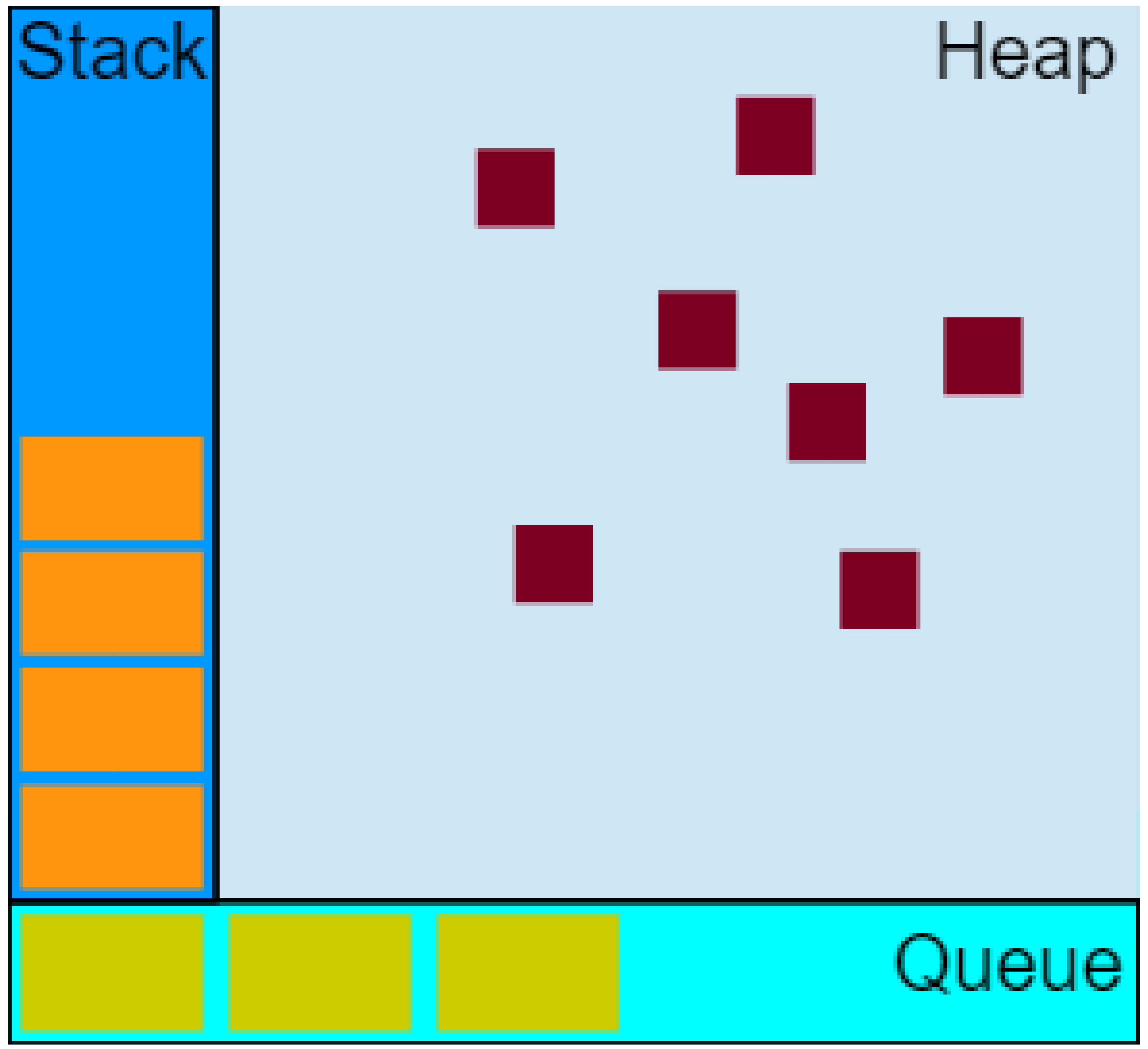
Source: bit.ly/script-scheduling

JavaScript Event Loop and its Friends.

Stack: A stack of Functions and their arguments. When a function is called it is added to the top of the stack when it returns it is popped off the top and next function down is executed.

Heap: Where objects get stored in memory.

Queue: A queue of messages (events, promises, functions) to process



Source: https://developer.mozilla.org/en-US/docs/Web/JavaScript/EventLoop#Visual_representation

Understand the Architecture : JavaScript Threading

Code:

```
function callingMe(first,second) {
   console.log(`Calling me with ${first}
   and ${second}`);
}

function doingThing() {
   callingMe('hello', 'world');
}

function startMeUp(param) {
   console.log(`starting up my program
   for ${param}`);
   doingThing()
}

startMeUp('KCDC 2019’);
```

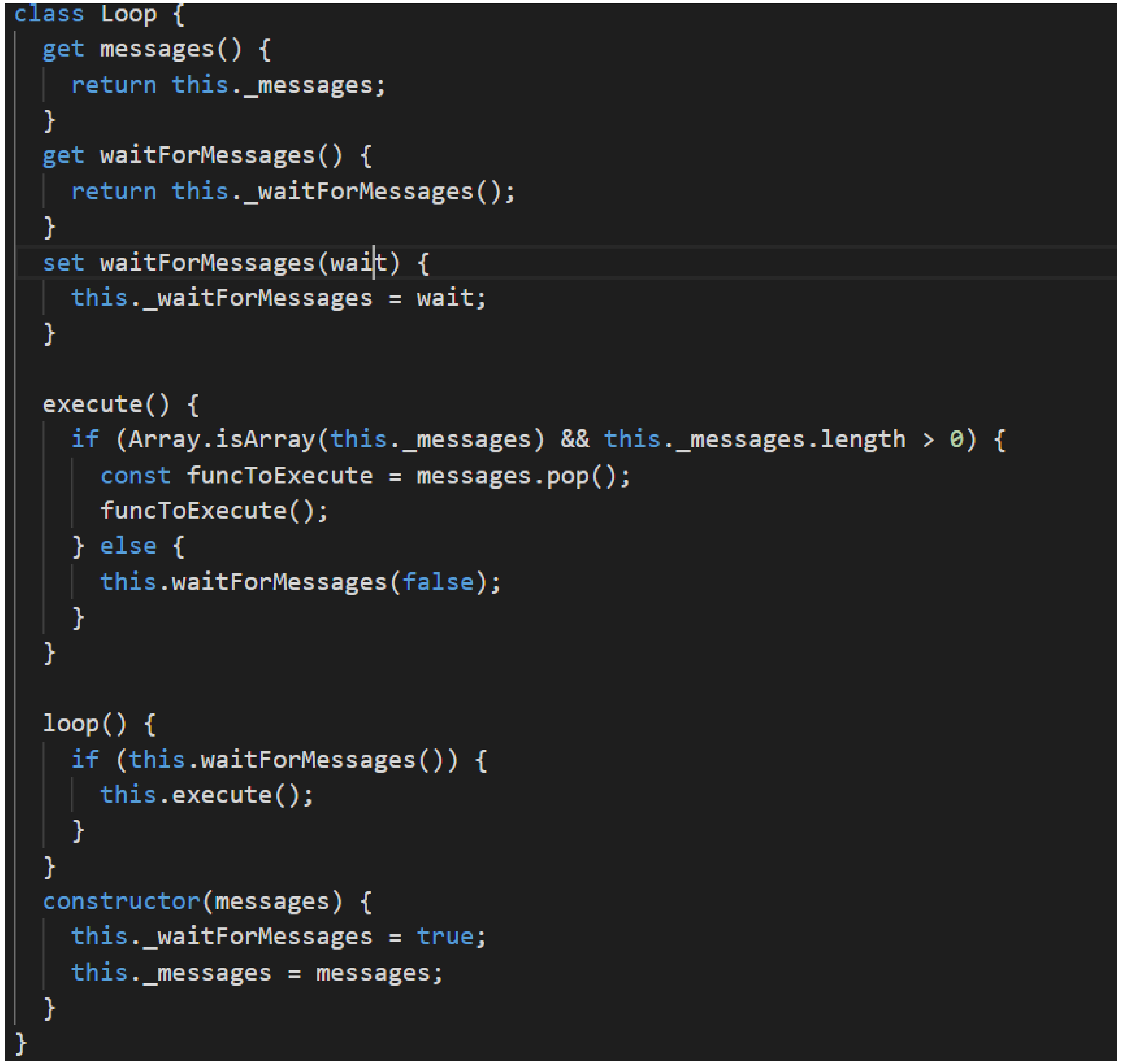
Stack:

```
1.)callingMe('first','second’)
2.)doingThing()
3.)startMeUp(‘KCDC 2019')
```

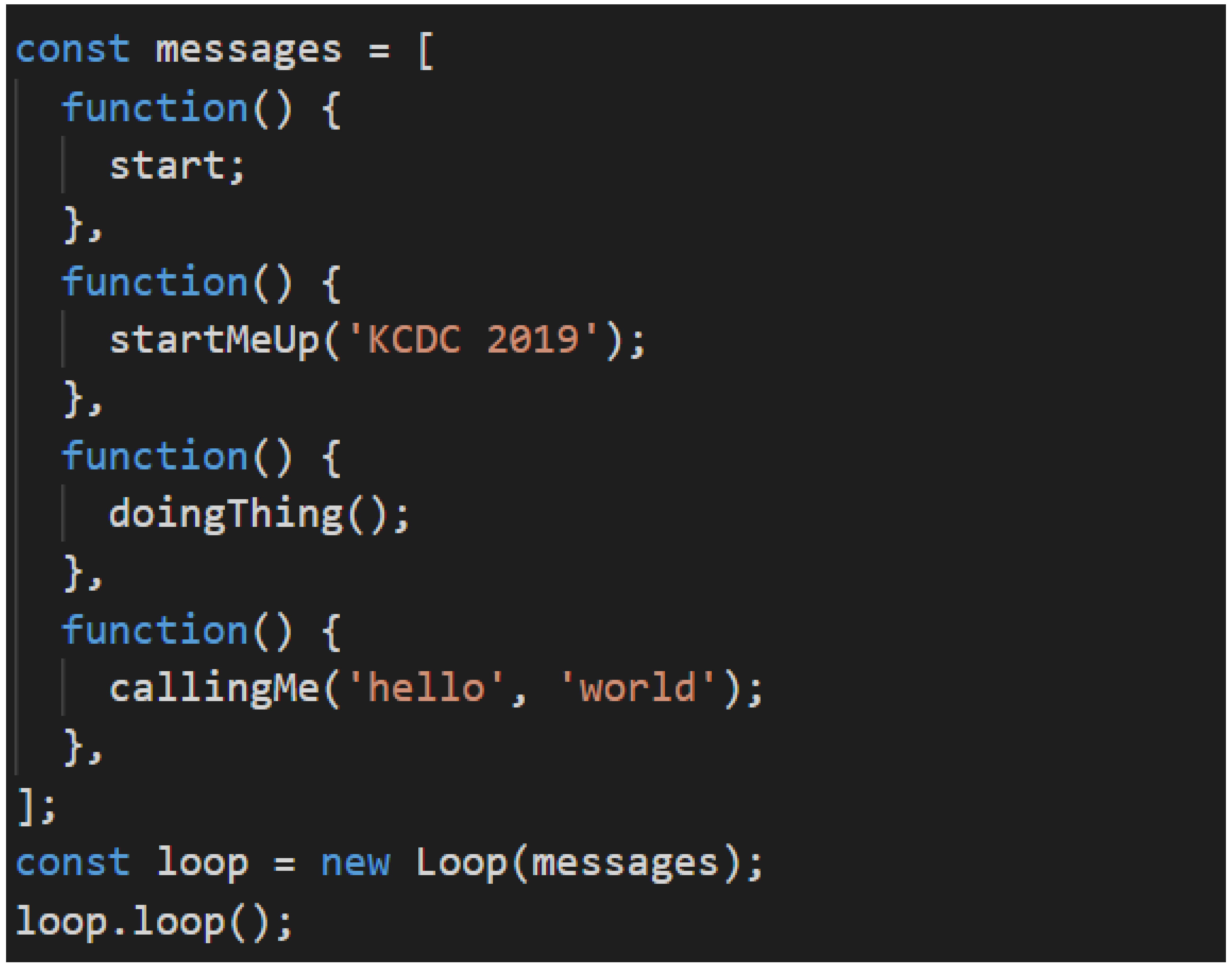
The *stack* runs from top to bottom and executes until completion.

Understand the Architecture : JavaScript Threading

Event loop implementation: example



```javascript
class Loop {
  get messages() {
    return this._messages;
  }
  get waitForMessages() {
    return this._waitForMessages();
  }
  set waitForMessages(wait) {
    this._waitForMessages = wait;
  }

  execute() {
    if (Array.isArray(this._messages) && this._messages.length > 0) {
      const funcToExecute = messages.pop();
      funcToExecute();
    } else {
      this.waitForMessages(false);
    }
  }

  loop() {
    if (this.waitForMessages()) {
      this.execute();
    }
  }
  constructor(messages) {
    this._waitForMessages = true;
    this._messages = messages;
  }
}
```



```javascript
const messages = [
  function() {
    start;
  },
  function() {
    startMeUp('KCDC 2019');
  },
  function() {
    doingThing();
  },
  function() {
    callingMe('hello', 'world');
  },
];
const loop = new Loop(messages);
loop.loop();
```

YOU GET TO DO ONE THING AT A TIME… WHICH IS WHERE THE QUEUE COMES IN

Queue: handles non-blocking code and works with the event loop.

Examples of non-blocking code include things like setTimeout, setInterval, event handlers, and most I/O related things in JavaScript such as ajax calls.

Technically not part of the JavaScript spec, rather implemented by the various engines (Node, V8, etc) to offload I/O and not block the event loop.

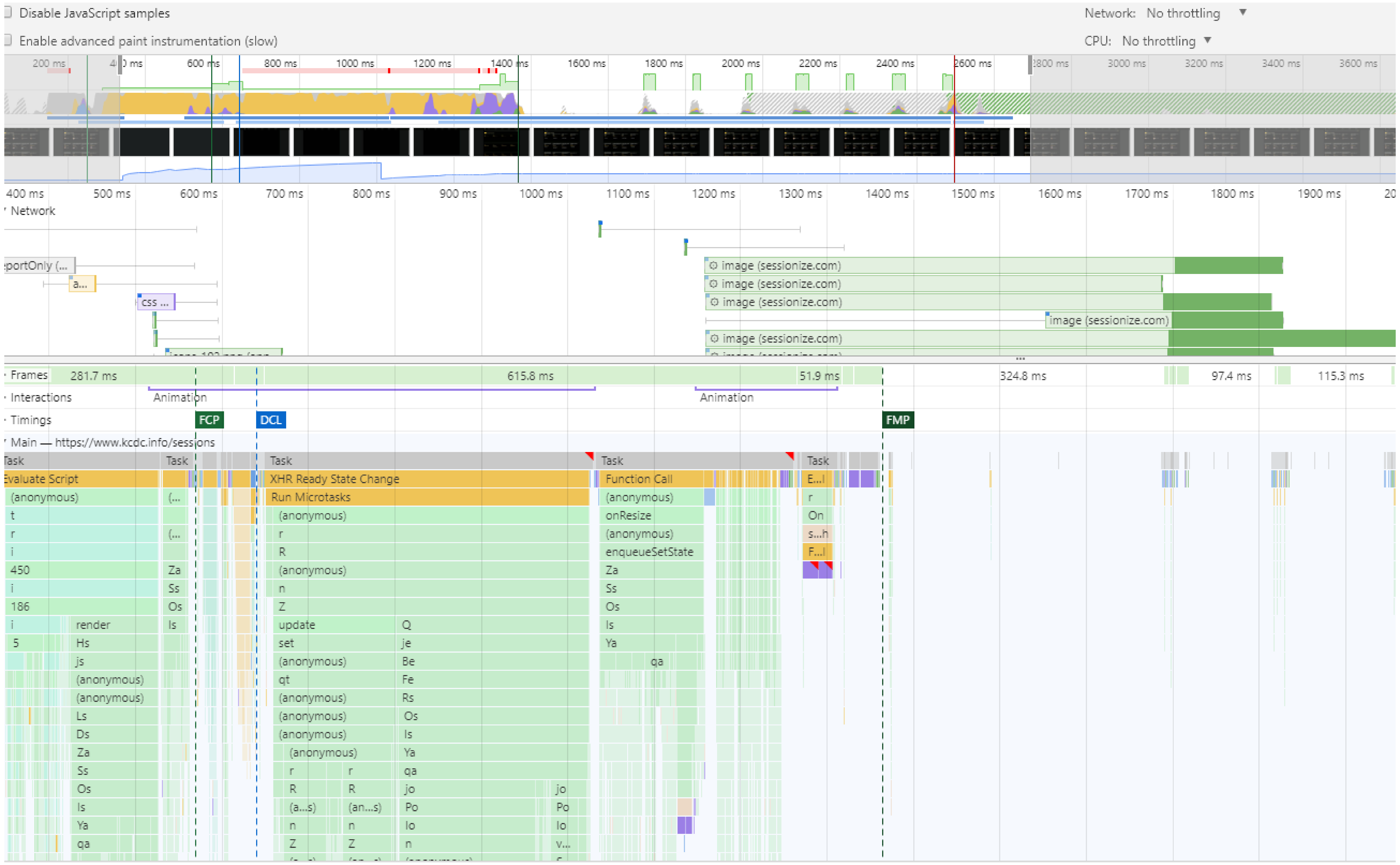
Queue: Quiz Time!

```javascript
const XMLHttpRequest = require('xmlhttprequest').XMLHttpRequest;

try {
  console.log('Starting our program.');
  const request = new XMLHttpRequest();
  request.onloadend = () => {
    console.log('Non Blocking complete!');
  };
  request.open('GET', 'https://jsonplaceholder.typicode.com/comments', true);
  request.send();
  console.log('Out of try block.');
} catch (err) {
  console.log('Error found.', err);
} finally {
  console.log('Finally thats done');
}
```

DEMO: BLOCKING/NON BLOCKING I/O

2.) MEASURE PERFORMANCE

Chrome & Firefox both ship with great performance monitoring tools



Disable JavaScript samples

Enable advanced paint instrumentation (slow)

Network: No throttling

CPU: No throttling

DEMO: CHROME PERFORMANCE TOOLS

Real User Monitoring

- Important to capture & collect statistics from a wide array of devices, countries, regions, network conditions, etc.
- Collect *meaningful* stats and send them to a centralized analytics store for analysis.
- Third party paid tools are available (Tealeaf, New Relic, Dynatrace).

Built in Events

- domInteractive - When the browser has finished parsing the document.
- domContentLoaded – browser has finished parsing the document (DOM construction complete). Scripts such as defer and inline have finished parsing and executing.
- domComplete – All scripts run and all dependent resources (styles, images) finished downloading.
- First Paint – first time the browser rendered something after navigation, the first time anything on the screen changes from what was on the screen prior to the navigation.
- First Contentful paint – first time the browser renders any text, image, non-white canvas or SVG from the DOM.

Performance APIs: Monitoring Crack

A series of high-resolution timers & observers built around navigation, resources, and your own custom events.

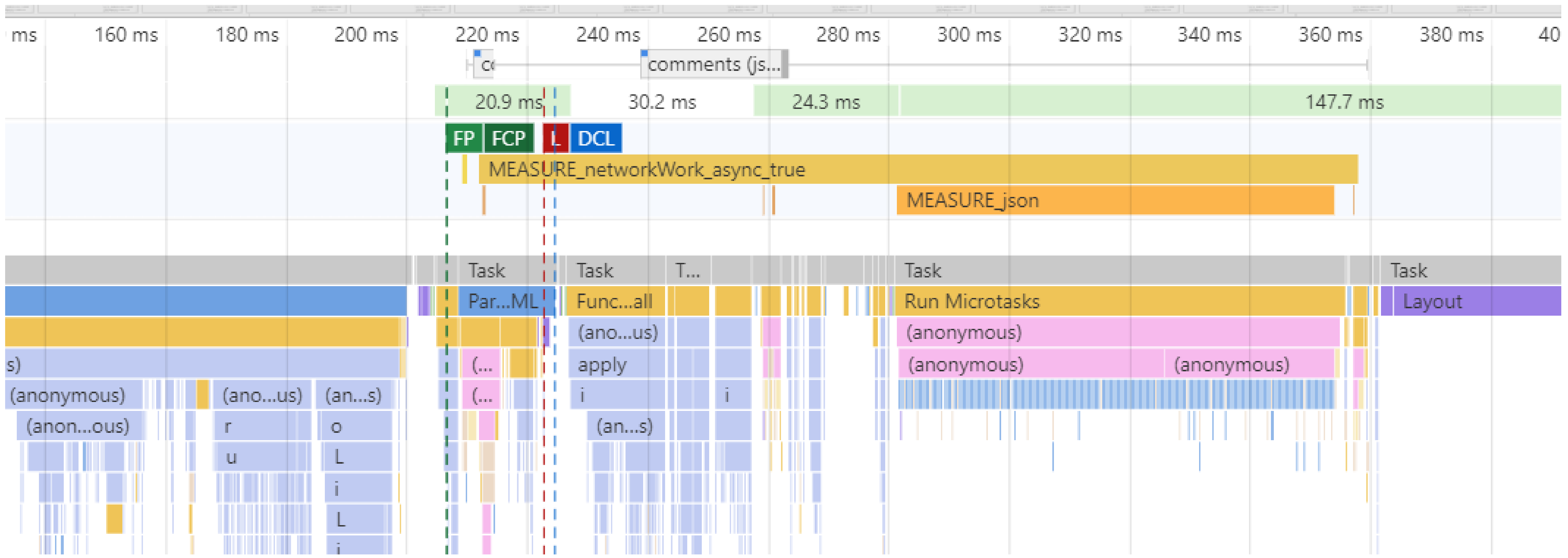
Type	API	Example	Use
Performance	Window.Performance	Window.performance.navigation	Legacy APIs and root interface all others inherit from
Navigation Timing	Window.performance.timing	domInteractive, loadEventEnd, connectEnd	Built in events created by the browser.
User Timing	Window.performance.mark, window.performance.measure	N/A	For you to create and use.
Resource Timing	Window.performance.getEntriesByType('resource')	Any external resource (Script, SVG, CSS, XHR)	Retrieving detailed performance report on connection times.
Performance Timeline	window.performance.Observe	Window.performance.observer('resource')	Performance observers

Measure Performance: Webpage test

Instrument your app for insights!

```
const registerPerformance = function(markName) {
  const endName = `END_${markName}`;
  const measureName = `MEASURE_${markName}`;
  window.performance.mark(markName);

  return () => {
    window.performance.mark(endName);
    window.performance.measure(measureName, markName, endName);
    console.log(window.performance.getEntriesByName(measureName, 'measure'));
  };
};
```

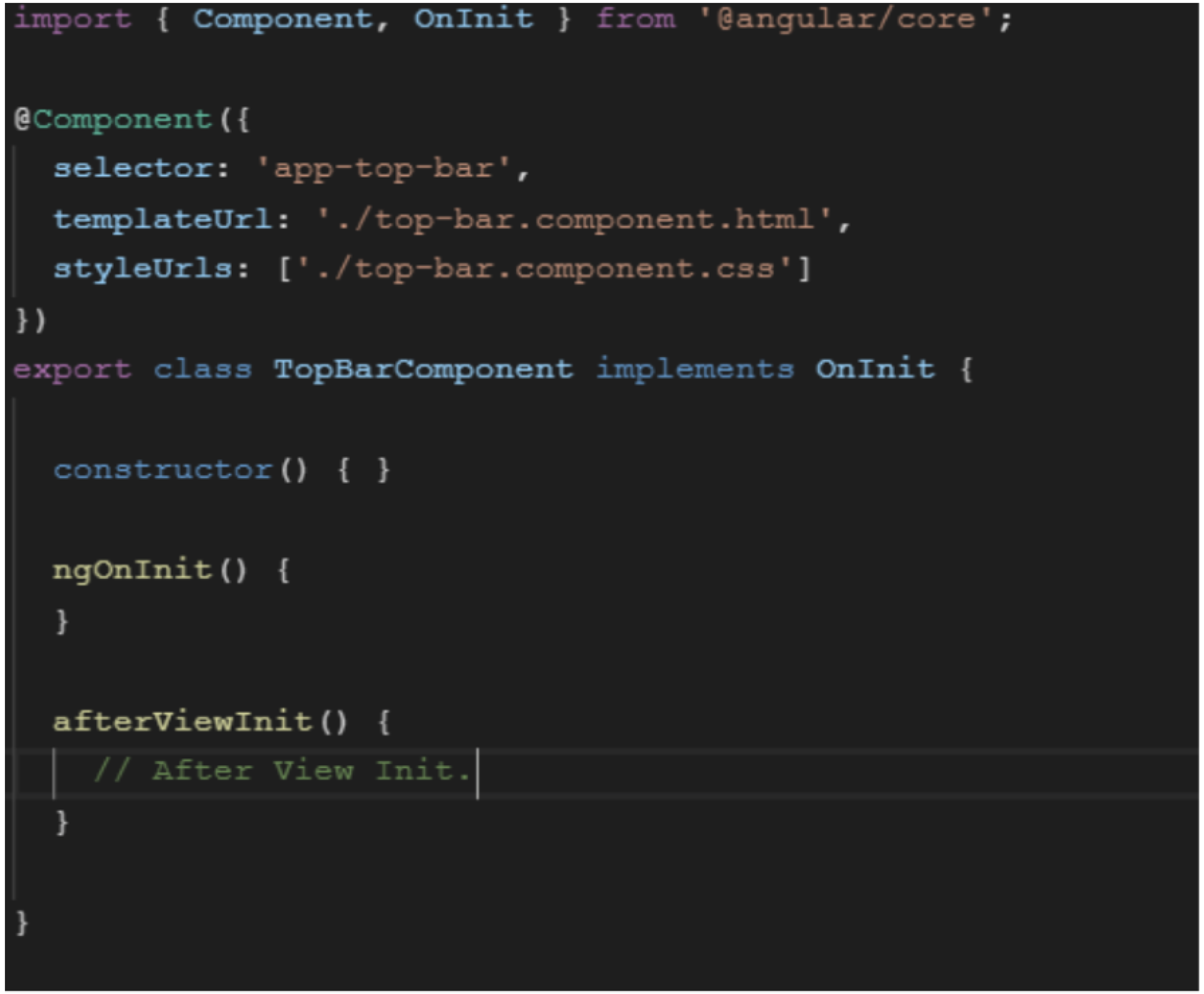
1.) Create a Mark.
2.) Create a end mark.
3.) Add a Measure.
4.) User timings will display in chrome dev tools.
5.) Can also report them to your favorite analytics service for real time user monitoring.



YEAH SURE WHAT ABOUT A REAL SITE?
DEMO TIME!!!!

Measure Performance: Angular + Performance API

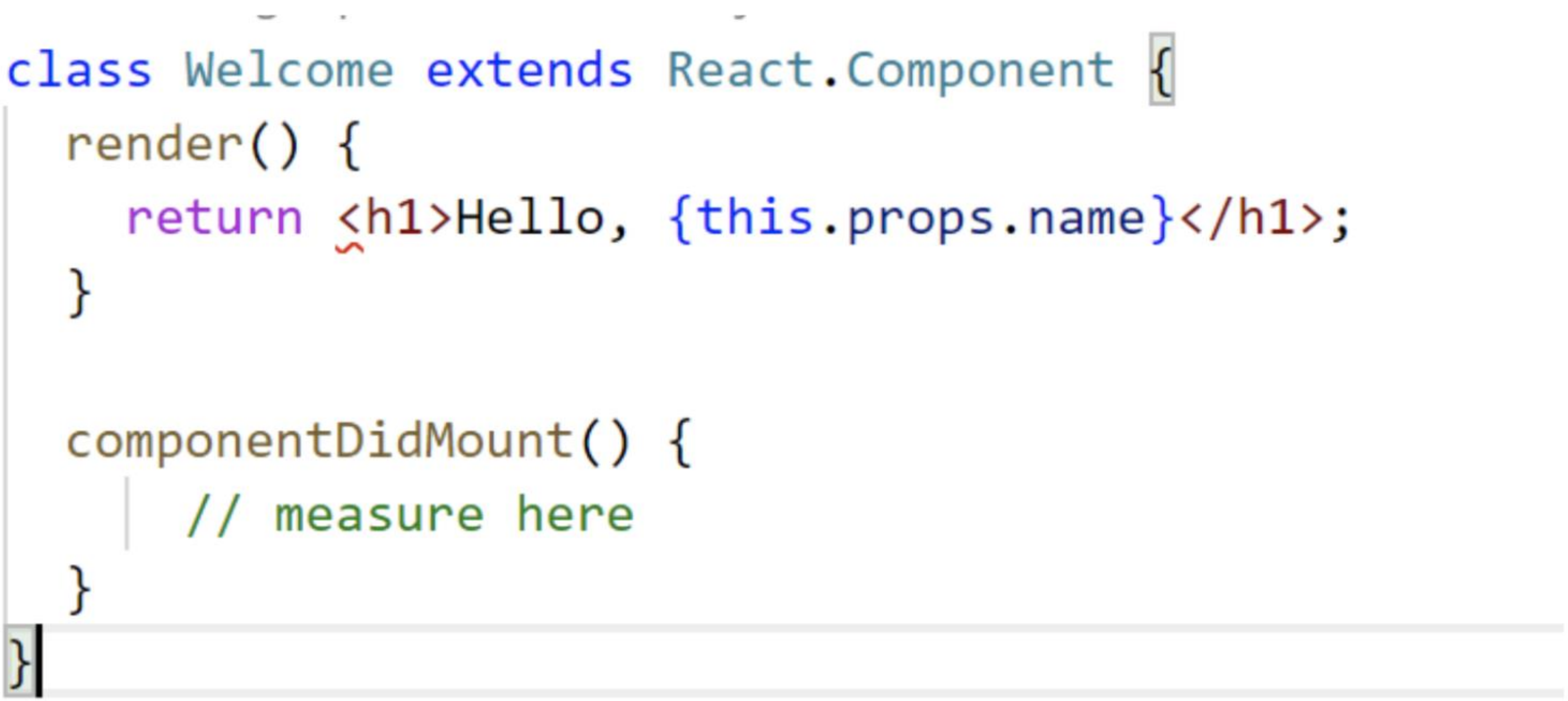
Instrument Angular



```
import { Component, OnInit } from '@angular/core';

@Component({
  selector: 'app-top-bar',
  templateUrl: './top-bar.component.html',
  styleUrls: ['./top-bar.component.css']
})
export class TopBarComponent implements OnInit {

  constructor() { }

  ngOnInit() {
  }

  afterViewInit() {
    // After View Init.
  }

}
```

Measure Performance: React + Performance API

Instrument React



```
class Welcome extends React.Component {
  render() {
    return <h1>Hello, {this.props.name}</h1>;
  }

  componentDidMount() {
    // measure here
  }
}
```

WebPage Test

- Free, open source project that supports user focused performance metrics.
- Website (https://www.webpagetest.org) as well as standalone docker containers
- Supported primarily by google, but wide array of industry backers.
- Integrate into your CI/CD pipeline.

Web Vitals Metrics

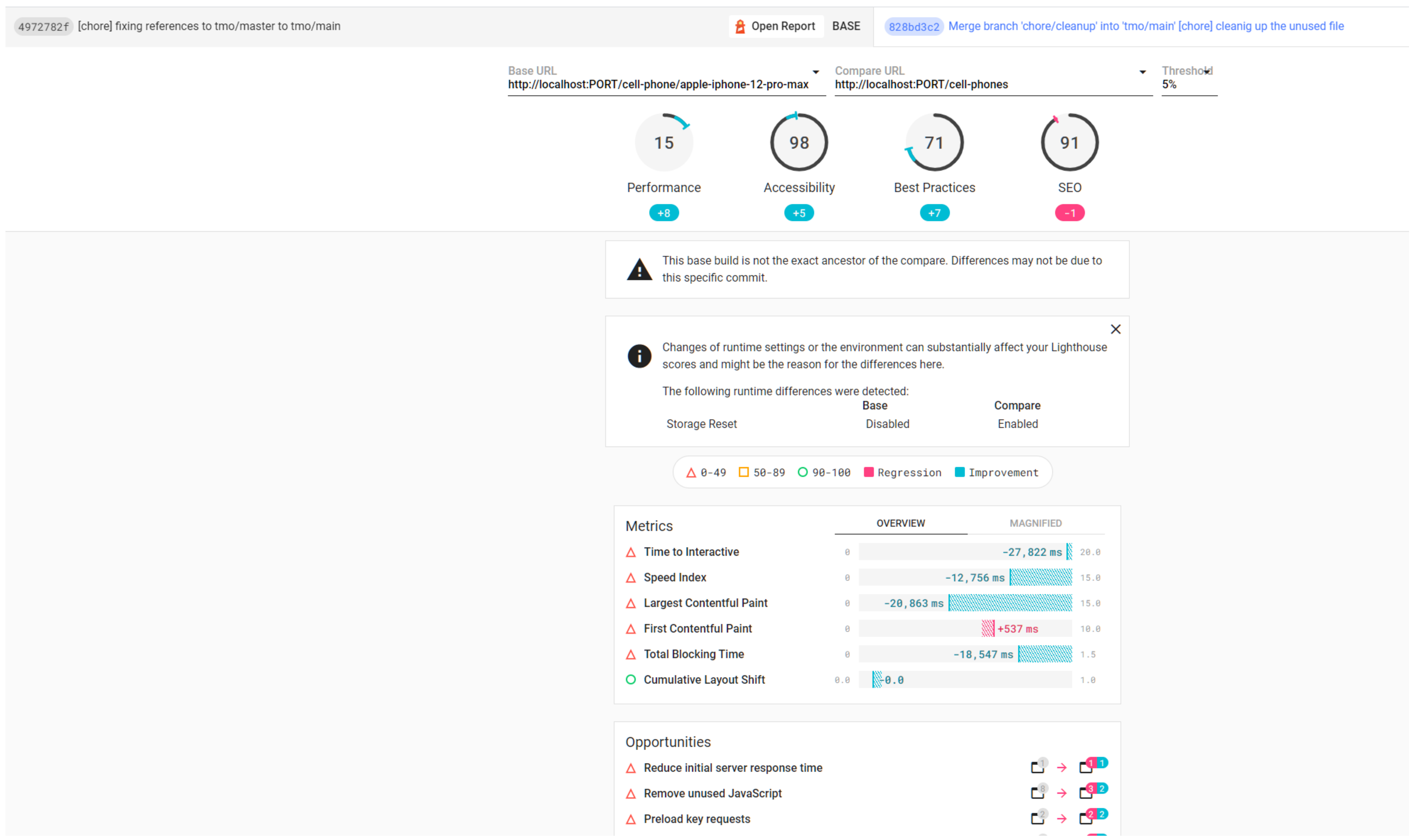
Google’s “helpful” metrics

LCP Largest Contentful Paint
FID First Input Delay
CLS Cumulative Layout Shift

Measure Performance: Lighthouse

Lighthouse & Lighthouse CI

Tools from Google, free can integrate them into your CI Pipeline
(https://github.com/GoogleChrome/lighthouse-ci)



4972782f [chore] fixing references to tmo/master to tmo/main   Open Report   BASE   828bd3c2 Merge branch 'chore/cleanup' into 'tmo/main' [chore] cleanig up the unused file

Base URL http://localhost:PORT/cell-phone/apple-iphone-12-pro-max
Compare URL http://localhost:PORT/cell-phones
Threshold 5%

15	98	71	91
Performance	Accessibility	Best Practices	SEO
+8	+5	+7	-1

This base build is not the exact ancestor of the compare. Differences may not be due to this specific commit.

Changes of runtime settings or the environment can substantially affect your Lighthouse scores and might be the reason for the differences here.

The following runtime differences were detected:

	Base	Compare
Storage Reset	Disabled	Enabled

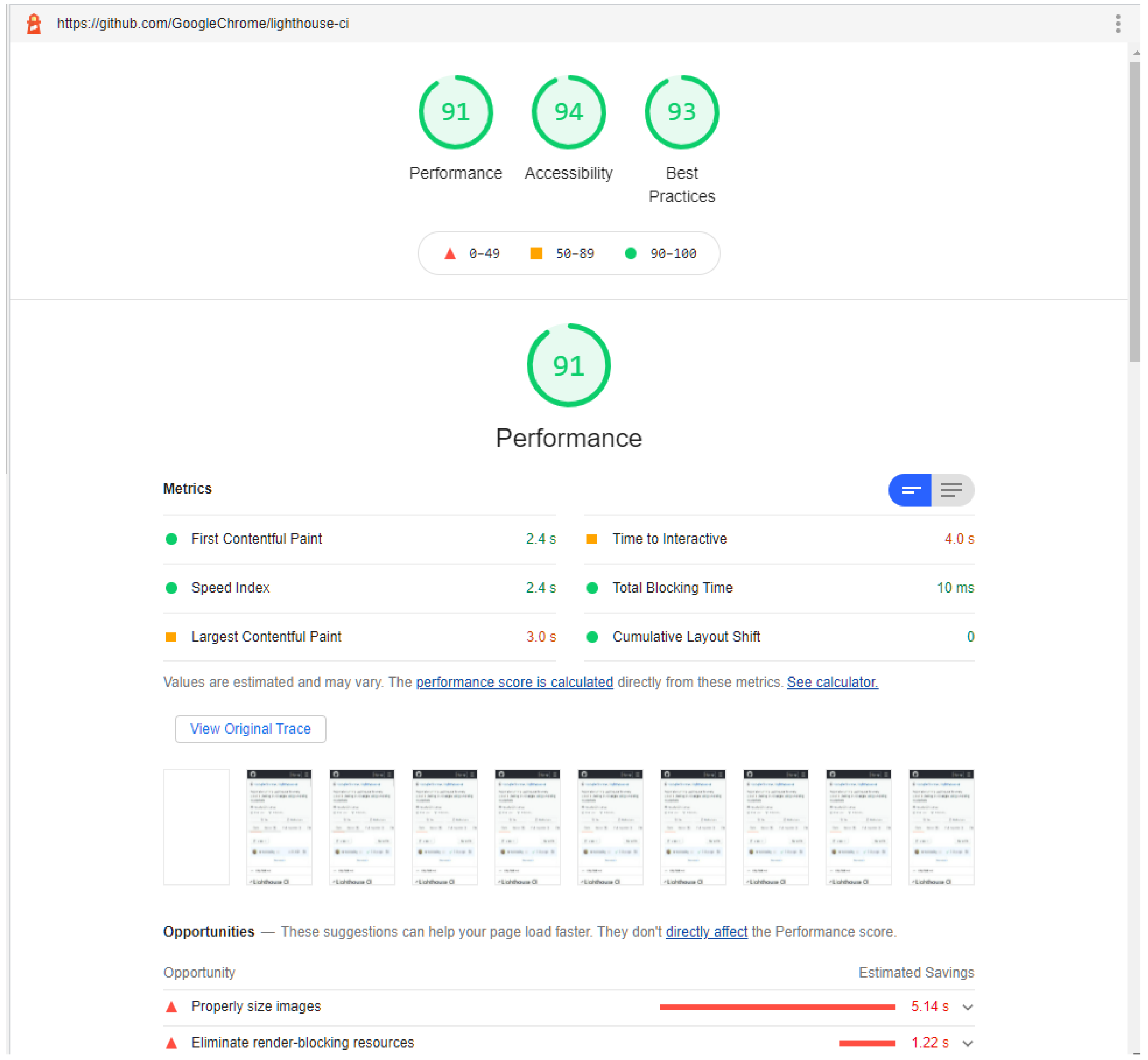
△ 0-49 □ 50-89 ○ 90-100 🟥 Regression 🟦 Improvement

Metrics   OVERVIEW   MAGNIFIED

△ Time to Interactive	0	-27,822 ms	20.0
△ Speed Index	0	-12,756 ms	15.0
△ Largest Contentful Paint	0	-20,863 ms	15.0
△ First Contentful Paint	0	+537 ms	10.0
△ Total Blocking Time	0	-18,547 ms	1.5
○ Cumulative Layout Shift	0.0	-0.0	1.0

Opportunities

△ Reduce initial server response time	1	1 1
△ Remove unused JavaScript	8	3 2
△ Preload key requests	2	2 2



https://github.com/GoogleChrome/lighthouse-ci

91	94	93
Performance	Accessibility	Best Practices

▲ 0-49 ■ 50-89 ● 90-100

91
Performance

Metrics

● First Contentful Paint	2.4 s	■ Time to Interactive	4.0 s
● Speed Index	2.4 s	● Total Blocking Time	10 ms
■ Largest Contentful Paint	3.0 s	● Cumulative Layout Shift	0

Values are estimated and may vary. The performance score is calculated directly from these metrics. See calculator.

View Original Trace

Opportunities — These suggestions can help your page load faster. They don't directly affect the Performance score.

Opportunity	Estimated Savings
▲ Properly size images	5.14 s
▲ Eliminate render-blocking resources	1.22 s

Measure Performance: RAIL

RAIL Model

Use your new instrumentation to understand performance from a *user* perspective in these 4 scenarios

Render
Animation
Idle
Load

OPTIMIZATION TECHNIQUES

Optimization Techniques: Overview

Once you measure… follow this convenient flowchart

1.) Establish a performance budget (https://www.performancebudget.io/)

2.) Are your file sizes too large?
3.) Is render performance / CPU usage the issue?

Webpack: Code Splitting, Minification, Tree Shaking

Code Splitting – Don't ship one gigantic bundle of code. Conditionally load separate bundles.

Minification – let webpack reduce size of JavaScript by shortening variable names, removing comments, etc

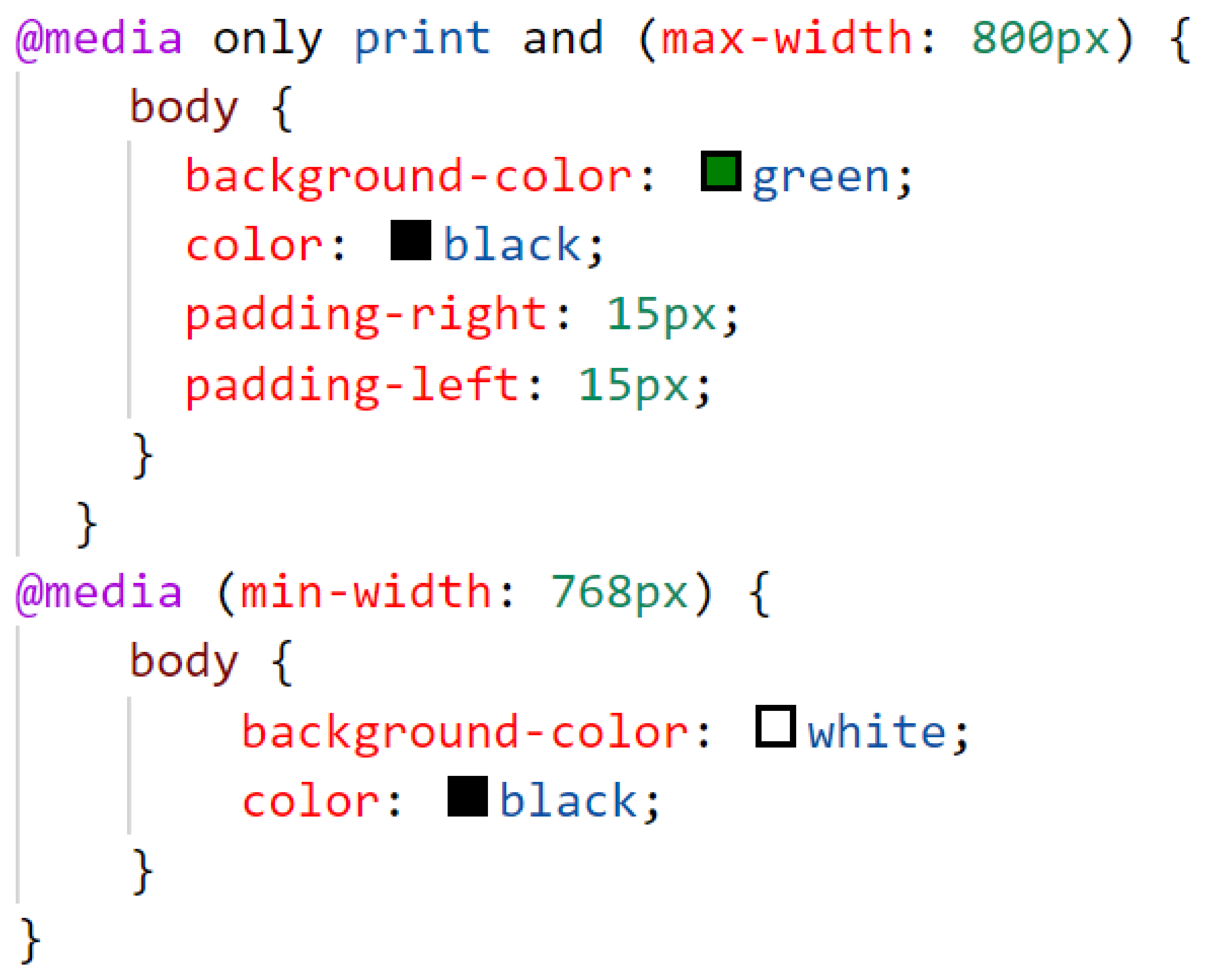
Tree Shaking – parses code and removes uncalled functions.

Webpack Stats (analyzer) – visual graph of the size of your JS

Media Queries in CSS

Use Media Queries to scope your styles, allows much faster construction of CSSOM, Render Tree & Layout steps.

Has built in support for match syntax (only, not, and) as well as different media types (print, screen) as well as supporting resolution/grid/width of viewport sizes.



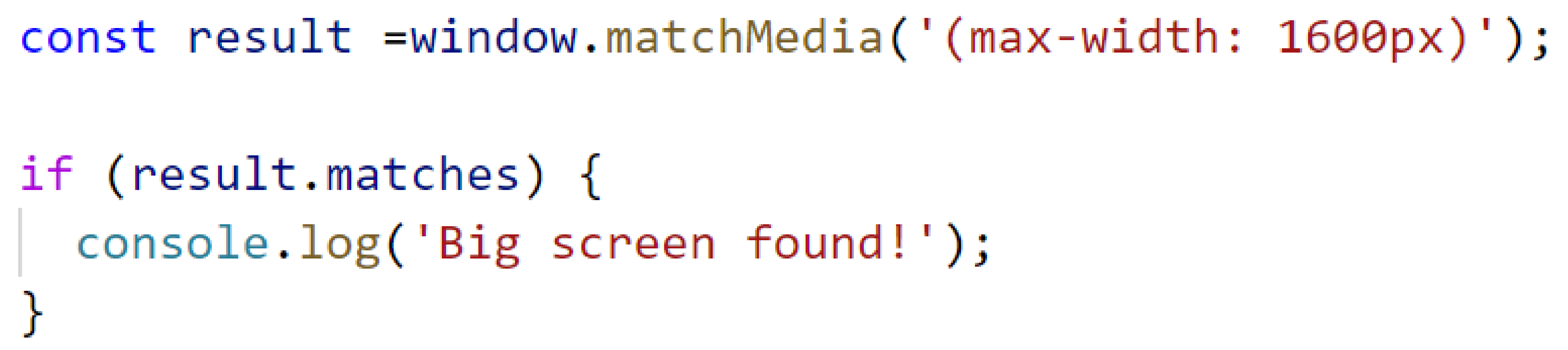
```css
@media only print and (max-width: 800px) {
    body {
      background-color: green;
      color: black;
      padding-right: 15px;
      padding-left: 15px;
    }
  }
@media (min-width: 768px) {
    body {
        background-color: white;
        color: black;
    }
}
```

Reflow: Avoid like the plague

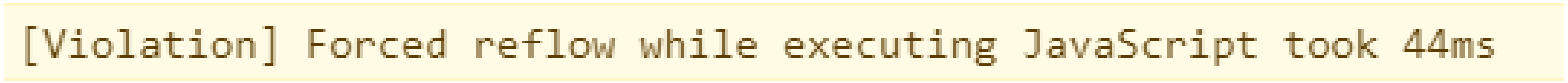
Reflow: Anything that forces the browser to recalculate the layout of the page, forcer the render tree & layout steps to re-run.

Includes many commonly used methods such as innerHeight, innerText, focus, scroll, etc.

Instead of checking window height, use the matchMedia interface!



```
const result =window.matchMedia('(max-width: 1600px)');

if (result.matches) {
  console.log('Big screen found!');
}
```



```
[Violation] Forced reflow while executing JavaScript took 44ms
```

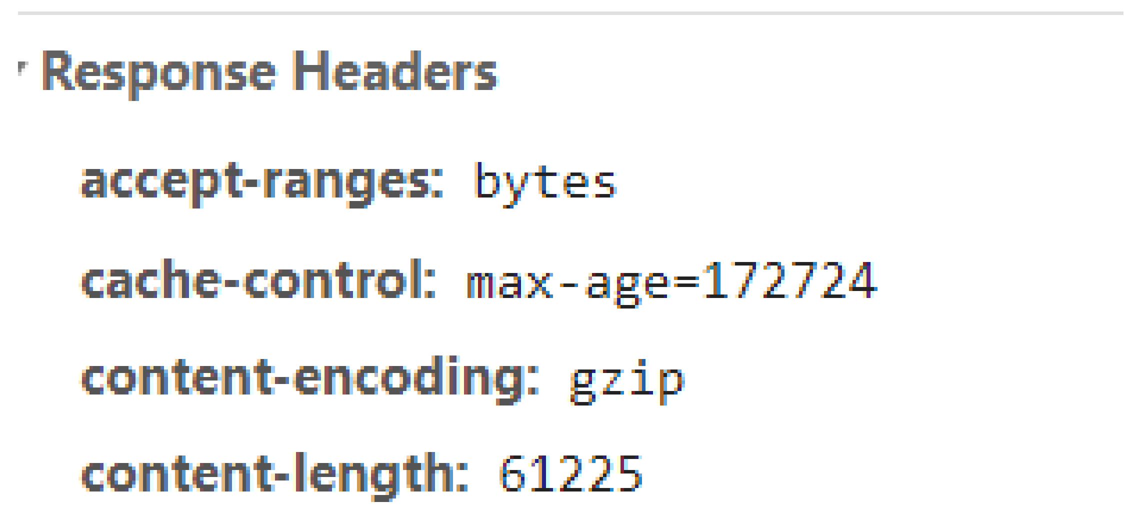
[https://gist.github.com/paulirish/5d52fb081b357 0c81e3a](https://gist.github.com/paulirish/5d52fb081b3570c81e3a)

Network Optimization Techniques

HTTP/2 – requires HTTPS and somewhat modern web servers, much more efficient at handling multiple requests.

GZIP – natively gzip's files on the server reducing file size in exchange for minimal CPU overhead.

CDN – Content Delivery Network, handles delivering assets to users
With many data centers across the world, reducing transmission
delays.



```
Response Headers
   accept-ranges: bytes
   cache-control: max-age=172724
   content-encoding: gzip
   content-length: 61225
```

Etags – A specification around hashing content and allowing browser
To check if the local copy cache is valid by only sending the hash to the server.

Cache-Control directives – allows on disk caching by the browser itself.

TTFB – Time to first byte, long delay time indicates overwhelmed servers, misconfigured servers, or network bottleneck.

Cookies: STOP USING COOKIES FOR EVERYTHING! Get sent with *every* request! Adds up.

Service & Web Workers

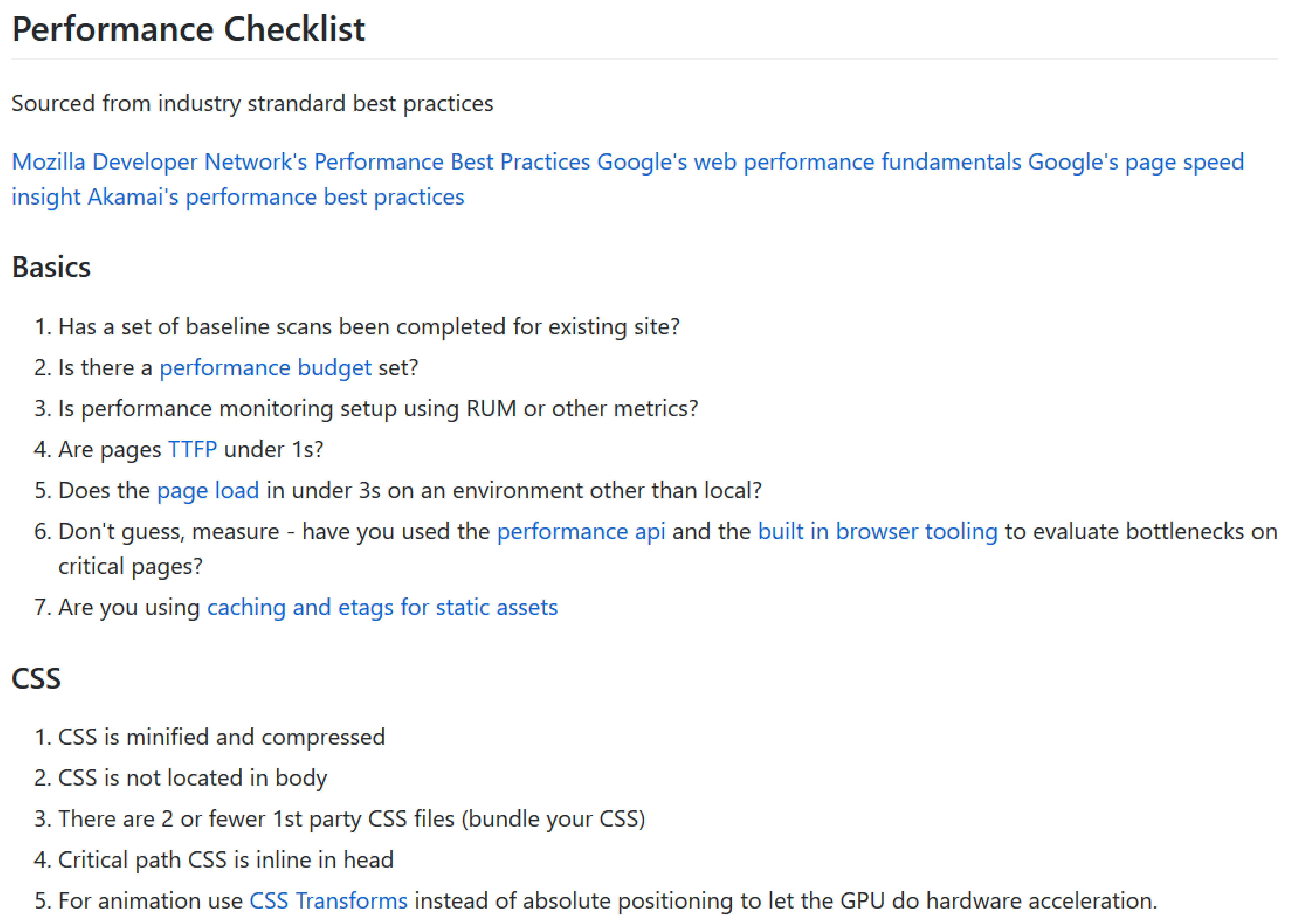
Service Workers – a separate thread that you can queue work onto that does not take up the main UI thread. Intercepts network traffic leaving the browser and allows you to modify it without the main program necessarily knowing. Think offline requests, caching, and pre-fetching.

Web Workers - A script initiates an XHR request and handles the response back from the server. Response is set to another thread (the web worker). Good use case would be any XHR request that when the response comes back requires heavy CPU such as a large JSON payload

Optimization Techniques: Performance Checklist

All collected into one central location

https://github.com/BillDinger/WebPageSpeed/blob/master/performance_checklist.md



Performance Checklist

Sourced from industry standard best practices

Mozilla Developer Network's Performance Best Practices Google's web performance fundamentals Google's page speed insight Akamai's performance best practices

Basics

1. Has a set of baseline scans been completed for existing site?
2. Is there a performance budget set?
3. Is performance monitoring setup using RUM or other metrics?
4. Are pages TTFP under 1s?
5. Does the page load in under 3s on an environment other than local?
6. Don't guess, measure - have you used the performance api and the built in browser tooling to evaluate bottlenecks on critical pages?
7. Are you using caching and etags for static assets

CSS

1. CSS is minified and compressed
2. CSS is not located in body
3. There are 2 or fewer 1st party CSS files (bundle your CSS)
4. Critical path CSS is inline in head
5. For animation use CSS Transforms instead of absolute positioning to let the GPU do hardware acceleration.

RESOURCES

The Cost of JavaScript in 2019: https://v8.dev/blog/cost-of-javascript-2019

The JavaScript event loop: https://developer.mozilla.org/en-US/docs/Web/JavaScript/EventLoop#Event_loop

Google Web Fundamentals: Critical Rendering Path
https://developers.google.com/web/fundamentals/performance/critical-rendering-path/

What causes reflow: https://gist.github.com/paulirish/5d52fb081b3570c81e3a

Script scheduling: bit.ly/script-scheduling

HTML parsing spec: https://html.spec.whatwg.org/multipage/parsing.html#the-end

RAILs monitoring: https://developers.google.com/web/fundamentals/performance/rail

Browser Caching: https://tools.ietf.org/html/rfc7234

Service Workers: https://developer.mozilla.org/en-US/docs/Web/API/Service_Worker_API/Using_Service_Workers

Google's Core Web Vitals help: https://web.dev/

Jon Mill's talk on service workers: https://www.youtube.com/watch?v=C6S-SOqAX-k

THANK YOU.

https://github.com/BillDinger/WebPageSpeed

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