# Building *Faster* Mobile Websites

*the nuts and bolts of hitting the **1000 millisecond** "time to glass" target ...*

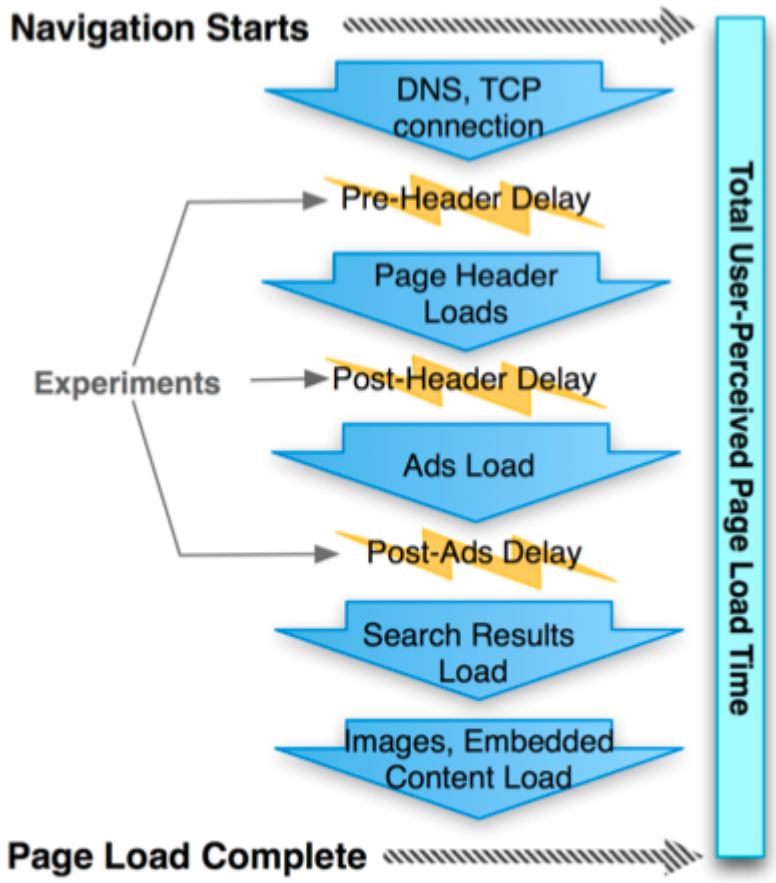
**+Ilya Grigorik** **@igrigorik**
*Make The Web Faster, Google*

**Video of the talk:** http://bit.ly/12GFKDE

# What's the impact of slow sites?

*Lower conversions and engagement, higher bounce rates...*

# Google Web Search Delay Experiment




| Type of Delay | Delay (ms) | Duration (weeks) | Impact on Avg. Daily Searches |
|---|---|---|---|
| Pre-header | 50 | 4 | Not measurable |
| Pre-header | 100 | 4 | **-0.20%** |
| Post-header | 200 | 6 | **-0.59%** |
| Post-header | 400 | 6 | **-0.59%** |
| Post-ads | 200 | 4 | **-0.30%** |

- The cost of delay increases over time and persists
- Delays under half a second impact business metrics
- "Speed matters" is not just lip service

[Performance Related Changes and their User Impact]

# bing Server Delays Experiment

| | Distinct Queries/User | Query Refinement | Revenue/User | Any Clicks | Satisfaction | Time to Click (increase in ms) |
|---|---|---|---|---|---|---|
| 50ms | - | - | - | - | - | - |
| 200ms | - | - | - | -0.3% | -0.4% | 500 |
| 500ms | - | -0.6% | -1.2% | -1.0% | -0.9% | 1200 |
| 1000ms | -0.7% | -0.9% | -2.8% | -1.9% | -1.6% | 1900 |
| 2000ms | -1.8% | -2.1% | -4.3% | -4.4% | -3.8% | 3100 |

- Means no statistically significant change

- Strong negative impacts
- Roughly linear changes with increasing delay
- Time to Click changed by roughly double the delay

[Performance Related Changes and their User Impact]

# How speed affects bounce rate

$y = 0.6517x + 33.682$

$R^2 = 0.91103$


Error pages

Every second = 0.65 increase in bounce rate

# So, how are we doing today?

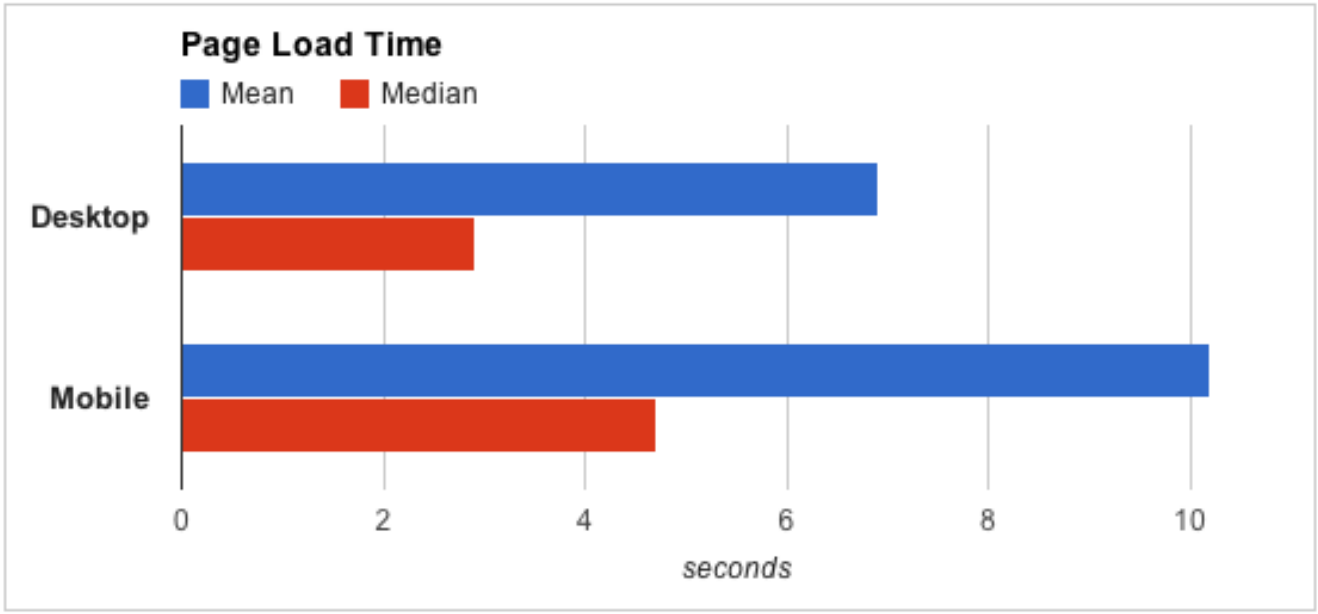
Okay, I get it, speed matters... but, are we there yet?

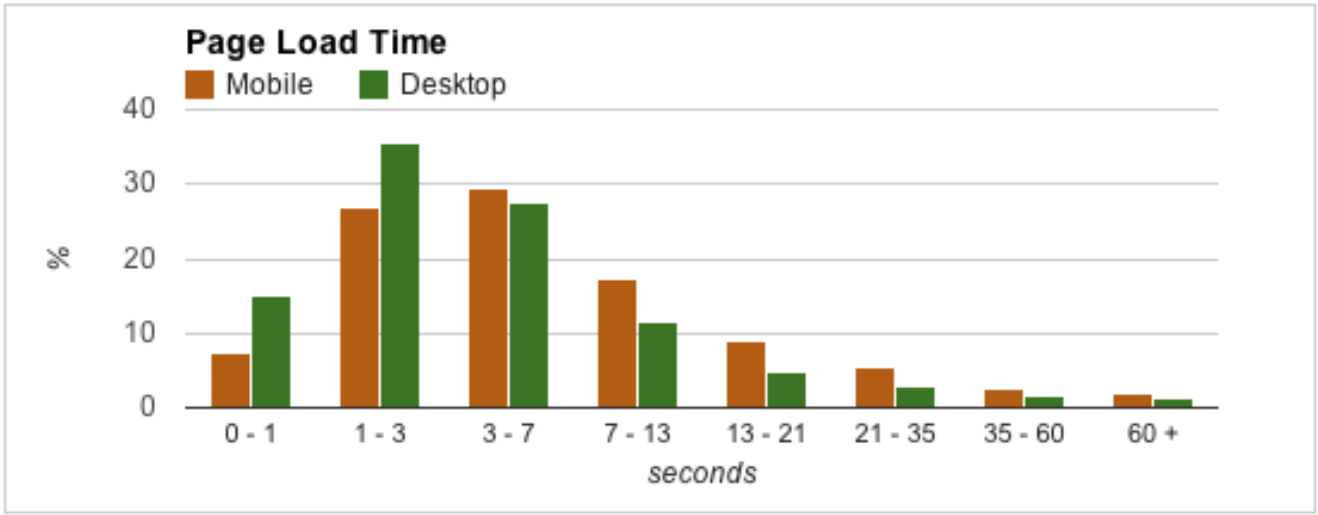
# Usability Engineering 101

| Delay | User reaction |
| --- | --- |
| 0 - 100 ms | Instant |
| 100 - 300 ms | *Feels sluggish* |
| 300 - 1000 ms | Machine is working… |
| 1 s+ | Mental context switch |
| 10 s+ | I'll come back later… |

***Stay under 250 ms to feel "fast".***

***Stay under 1000 ms to keep users attention.***




**Desktop**

Median: ~2.7s

Mean: ~6.9s

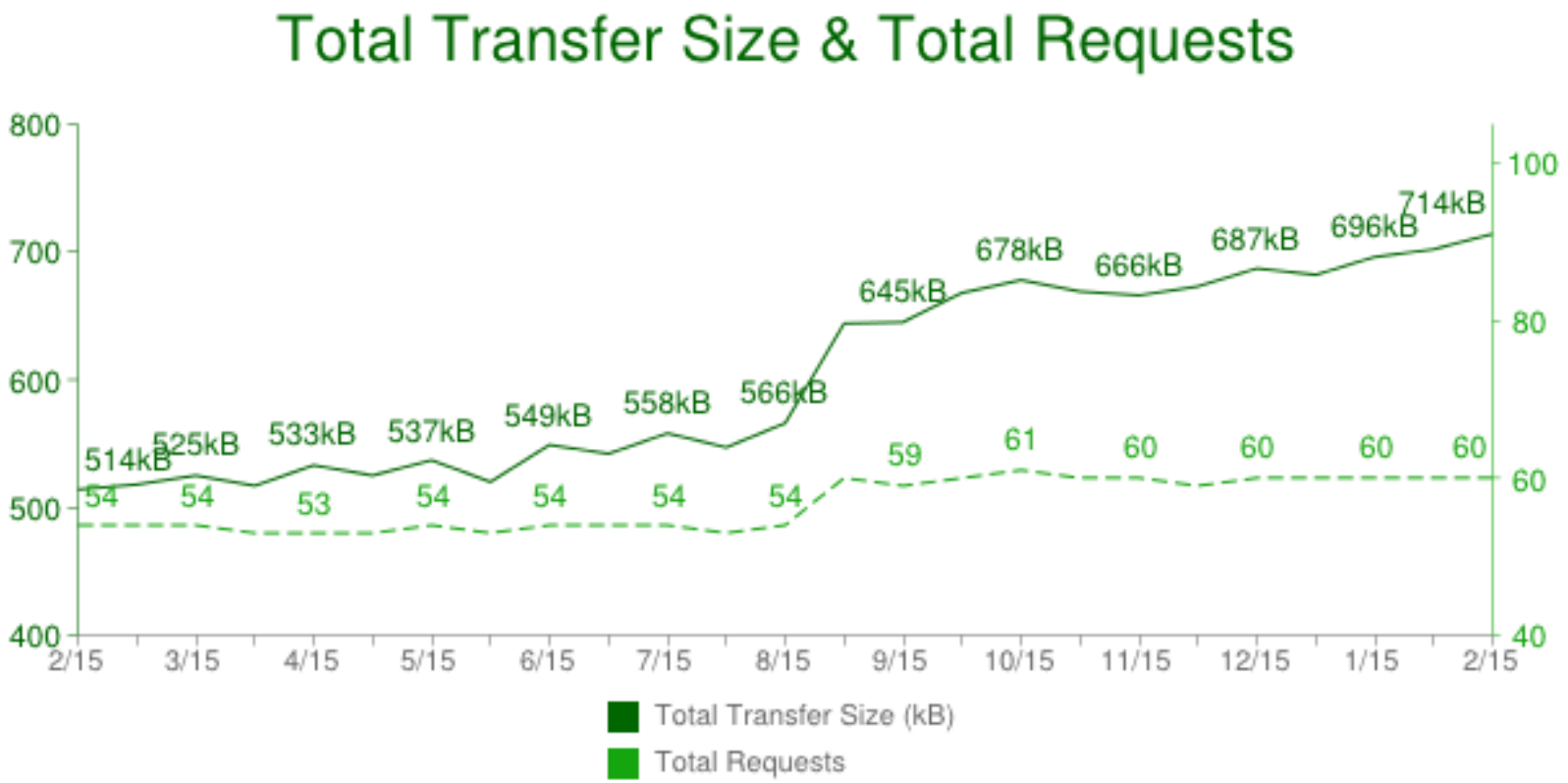
**Mobile** *

Median: ~4.8s

Mean: ~10.2s

* *optimistic*

[How Fast Are Websites Around The World?](#) - Google Analytics Blog




| Content Type | Avg # of Requests | Avg size |
|---|---|---|
| HTML | 6 | 39 kB |
| Images | **39** | **490 kB** |
| Javascript | **10** | **142 kB** |
| CSS | 3 | 27 kB |

HTTP Archive - Mobile Trends (Feb, 2013)

# For many, mobile is the one and only internet device!

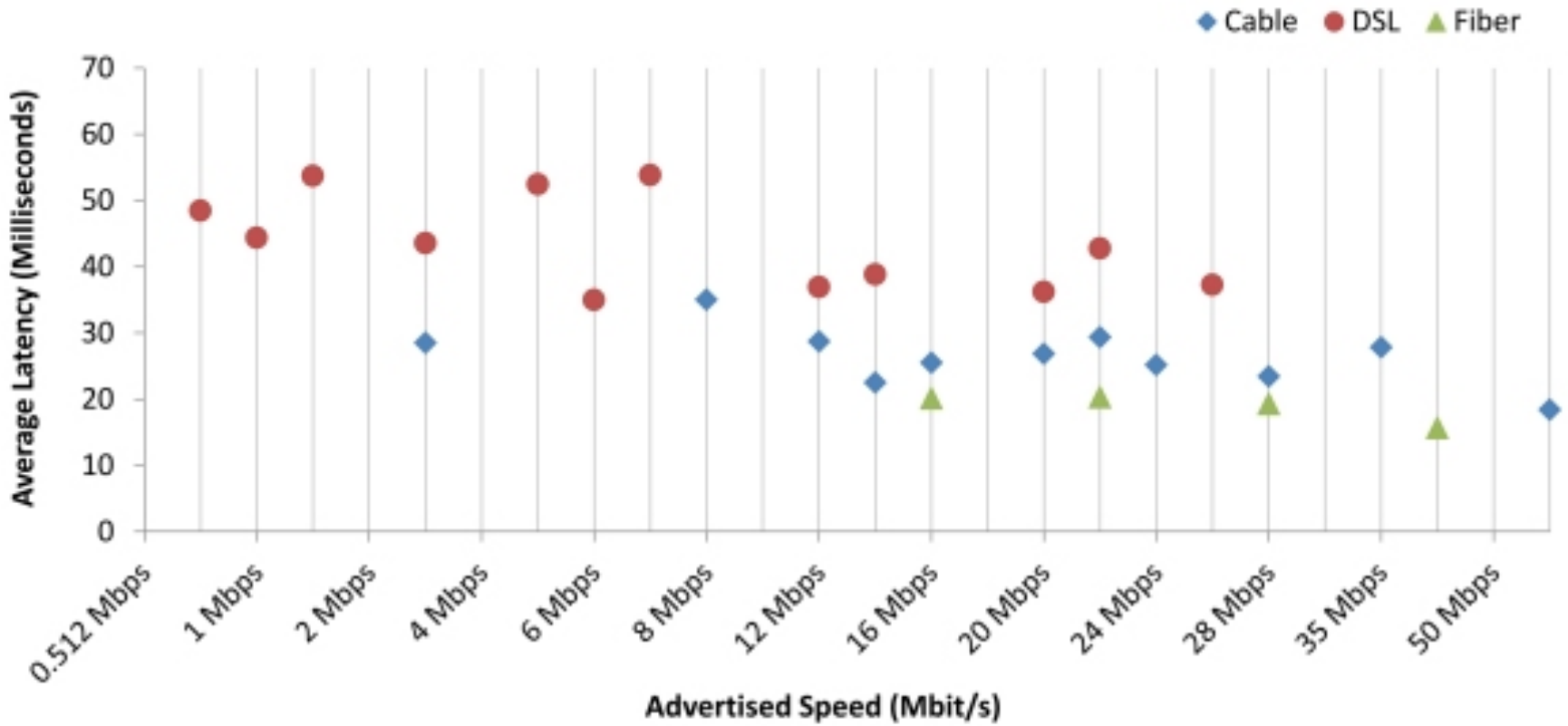

| Country | Mobile-only users |
|---|---|
| Egypt | 70% |
| India | 59% |
| South Africa | 57% |
| Indonesia | 44% |
| United States | 25% |

*onDevice Research*

# The network will save us!

***1000 ms is plenty of time.. 4G will fix everything! Right, right?***

* Nope.




***Fiber-to-the-home*** *services provided* ***18 ms*** *round-trip latency on average, while* ***cable-based*** *services averaged* ***26 ms****, and* ***DSL-based*** *services averaged* ***43 ms****. This compares to 2011 figures of 17 ms for fiber, 28 ms for cable and 44 ms for DSL.*

Measuring Broadband America - July 2012 - FCC

# Mobile, oh Mobile...

*"Users of the **Sprint 4G network** can expect to experience average speeds of 3 Mbps to 6 Mbps download and up to 1.5 Mbps upload with an **average latency of 150 ms**. On the **Sprint 3G** network, users can expect to experience average speeds of 600 Kbps - 1.4 Mbps download and 350 Kbps - 500 Kbps upload with an **average latency of 400 ms**."*

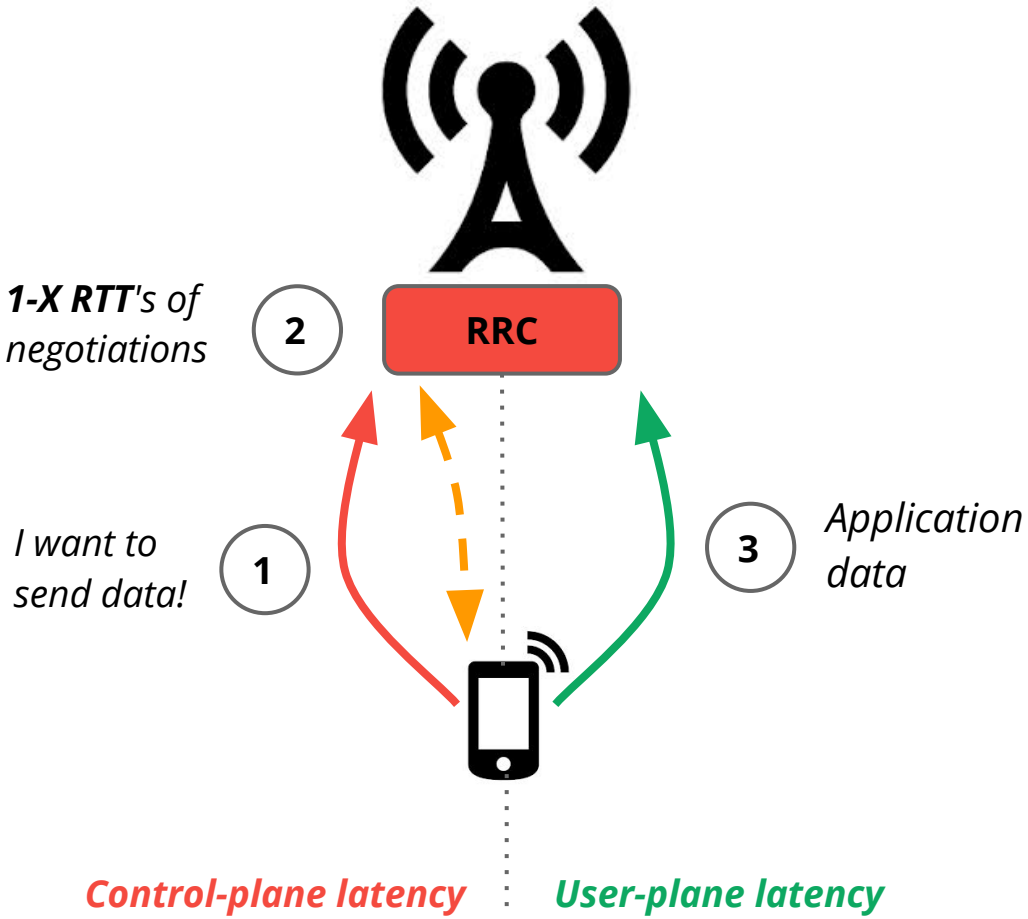
| | 3G | 4G |
|---|---|---|
| **Sprint** | 400 ms | 150 ms |
| **AT&T** | 150 - 400 ms | 100 - 200 ms |


AT&T

# Mobile design constraint: Battery life

- Radio is the **second most expensive** component (after screen)
- Limited amount of available power (as you well know...)

# Control and User plane latencies

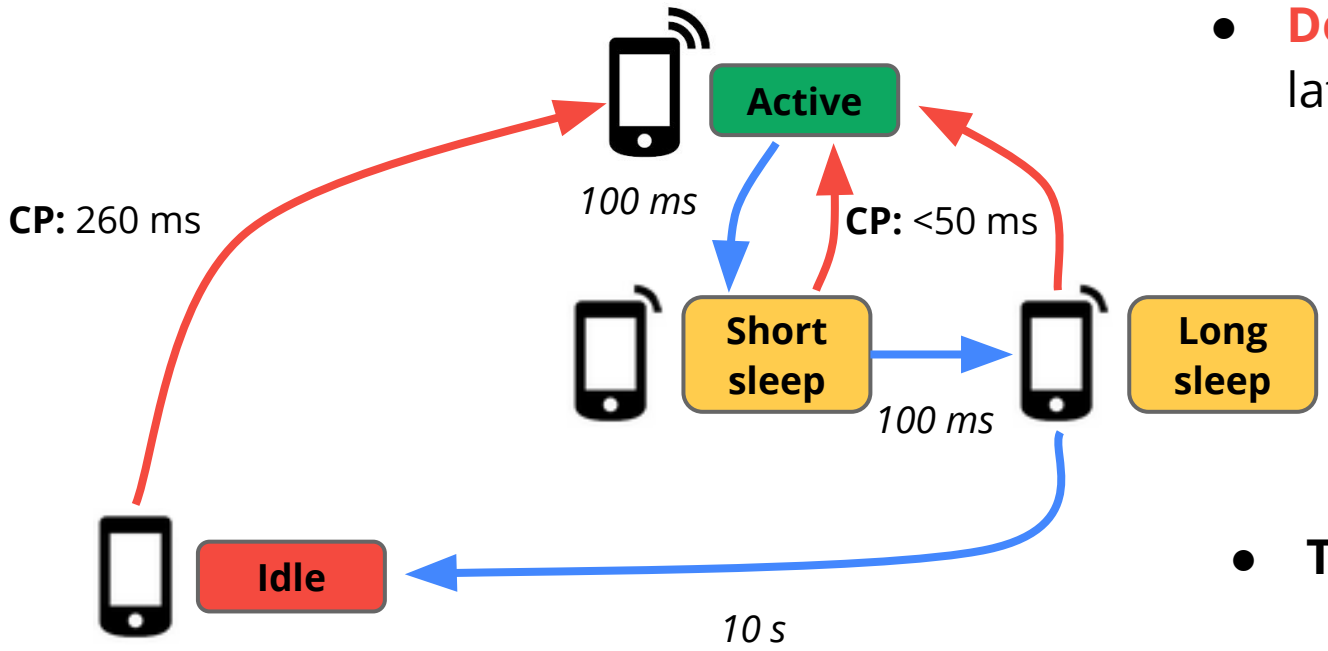



- There is a **one time** cost for control-plane negotiation
- **User-plane latency** is the one-way latency between packet availability in the device and packet at the base station

| | LTE | HSPA+ | 3G |
|---|---|---|---|
| Idle to connected latency | < 100 ms | < 100 ms | **< 2.5 s** |
| User-plane one-way latency | < 5 ms | < 10 ms | < 50 ms |

*Same process happens for incoming data, just reverse steps 1 and 2*

# LTE power state transitions (AT&T)

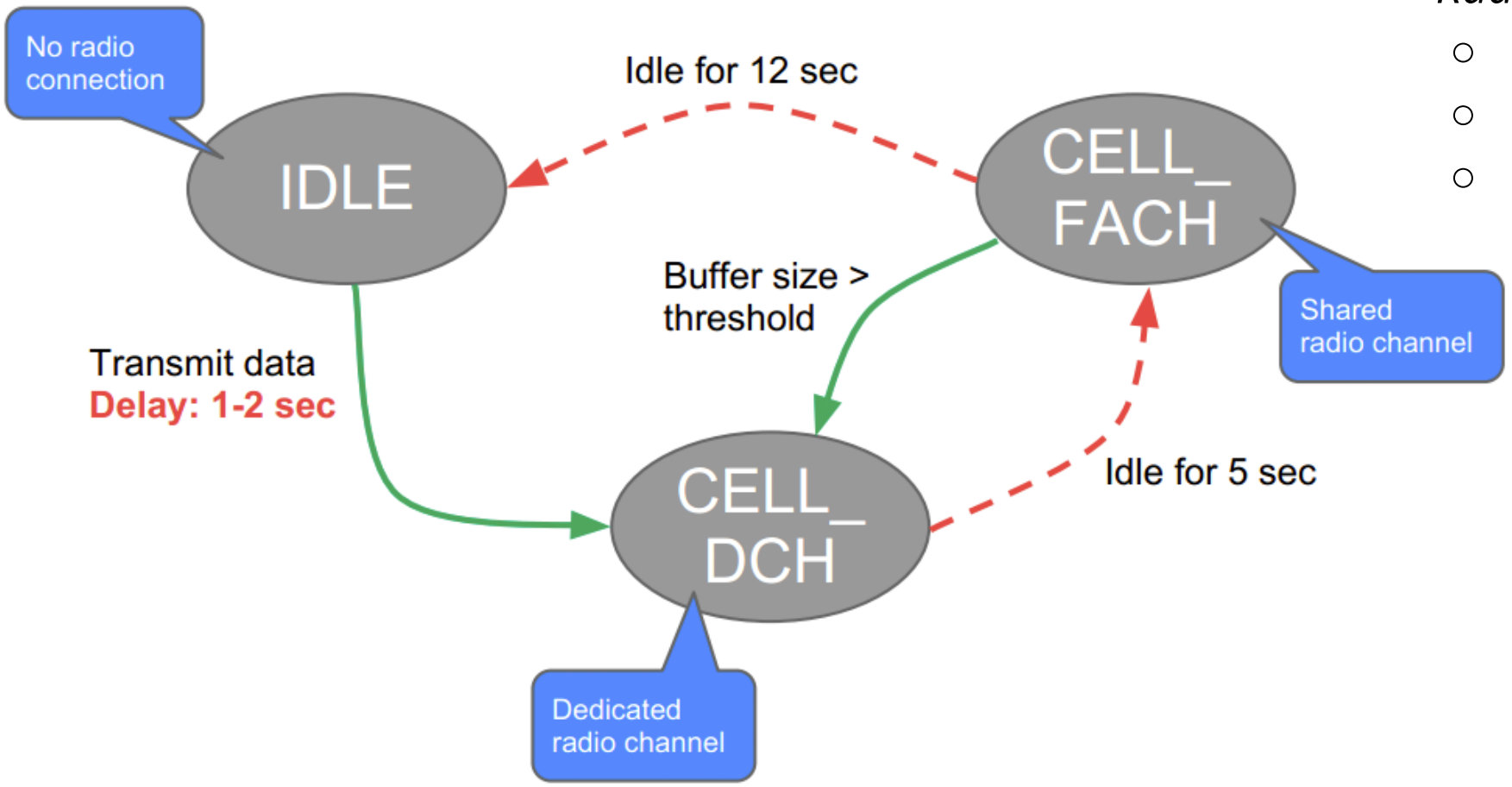



- **Idle to Active:** 260 ms control-plane latency
- **Dormant to Active:** <50 ms control-plane latency (spec)

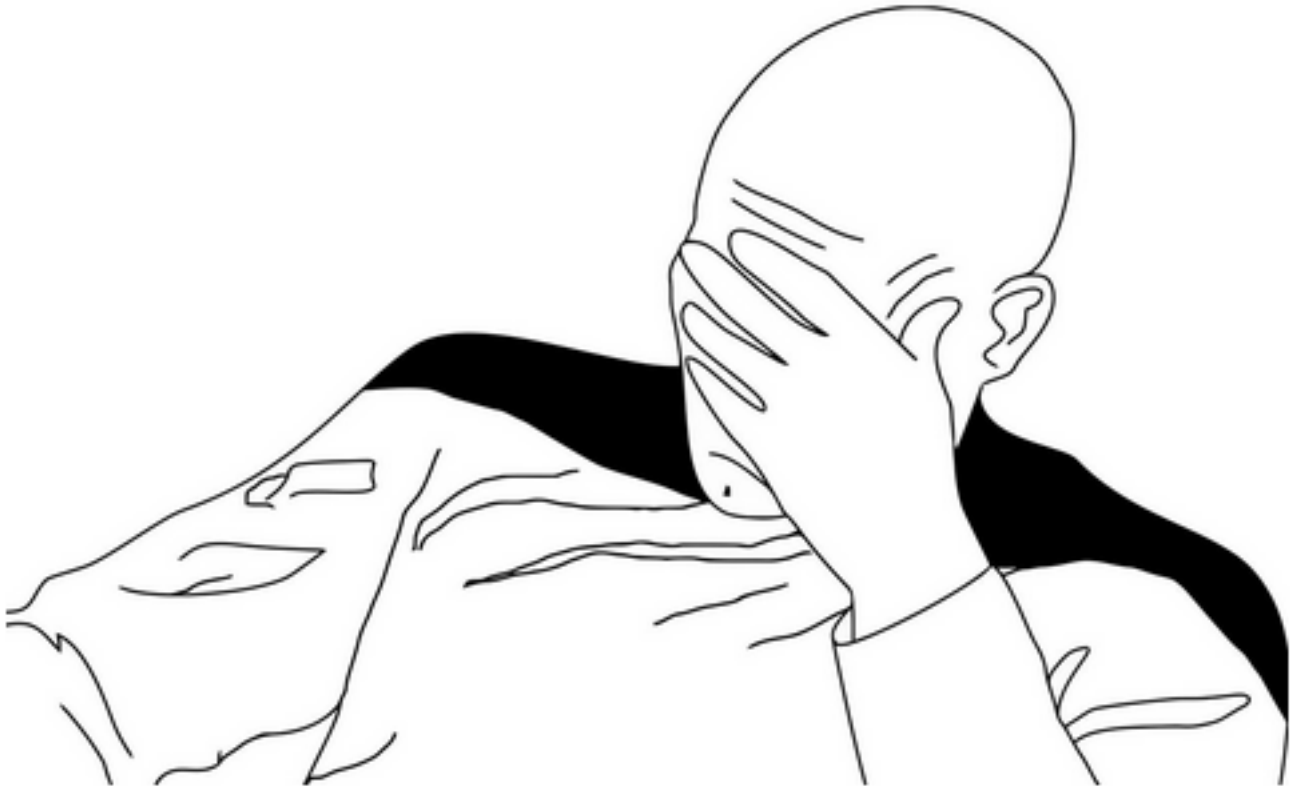
- **Timeout driven** state transitions back to idle
  - 100 ms, 100 ms, 10 s > Idle
- Similar state machine for 3G devices
  - Except CP latencies are ***much higher***

https://github.com/attdevsupport/ARO/blob/master/ARODataAnalyzer/src/lte.conf

# 3G power state transitions (AT&T)




- *Radio cycles between 3 states*
  - ***Idle***
  - *Low TX power (**FACH**)*
  - *High TX power (**DCH**)*



*I just wanted to make a **fast** mobile app.....*

# Uh huh… Yeah, tell me more…

1. **Latency variability can be very high on mobile networks**

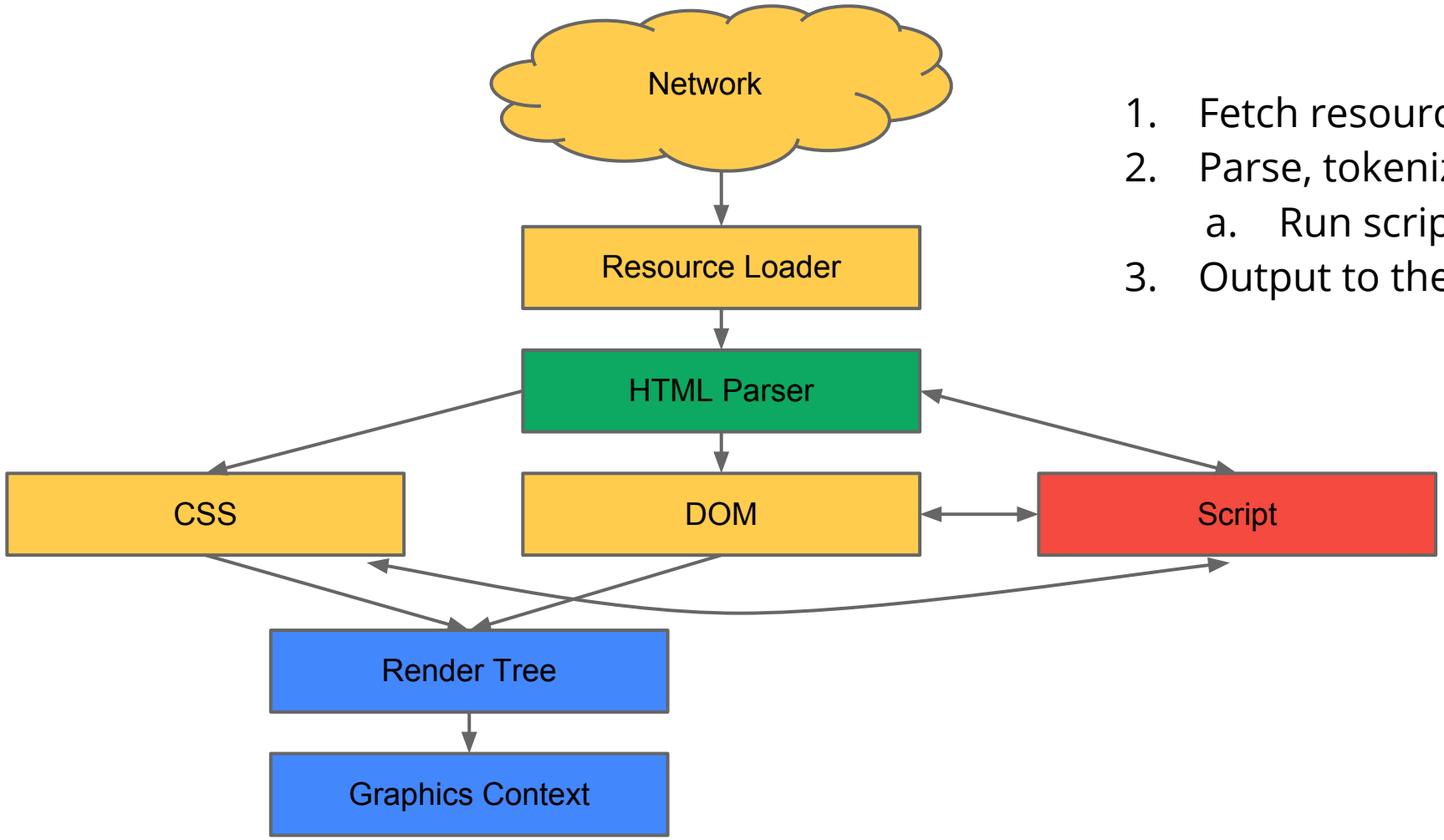
2. **4G networks will improve latency, but…**
   a. We still have a long way to go until everyone is on 4G - *a decade!*
   b. And 3G is definitely not going away anytime soon
   c. Ergo, latency and variability in latency ***is a problem***

3. **What can we do about it?**
   a. Re-use connections
   b. Download resources in bulk, avoid waking up the radio
   c. Compress resources
   d. Cache

# How do we render the page?

*we're getting bytes off the wire... and then what?*

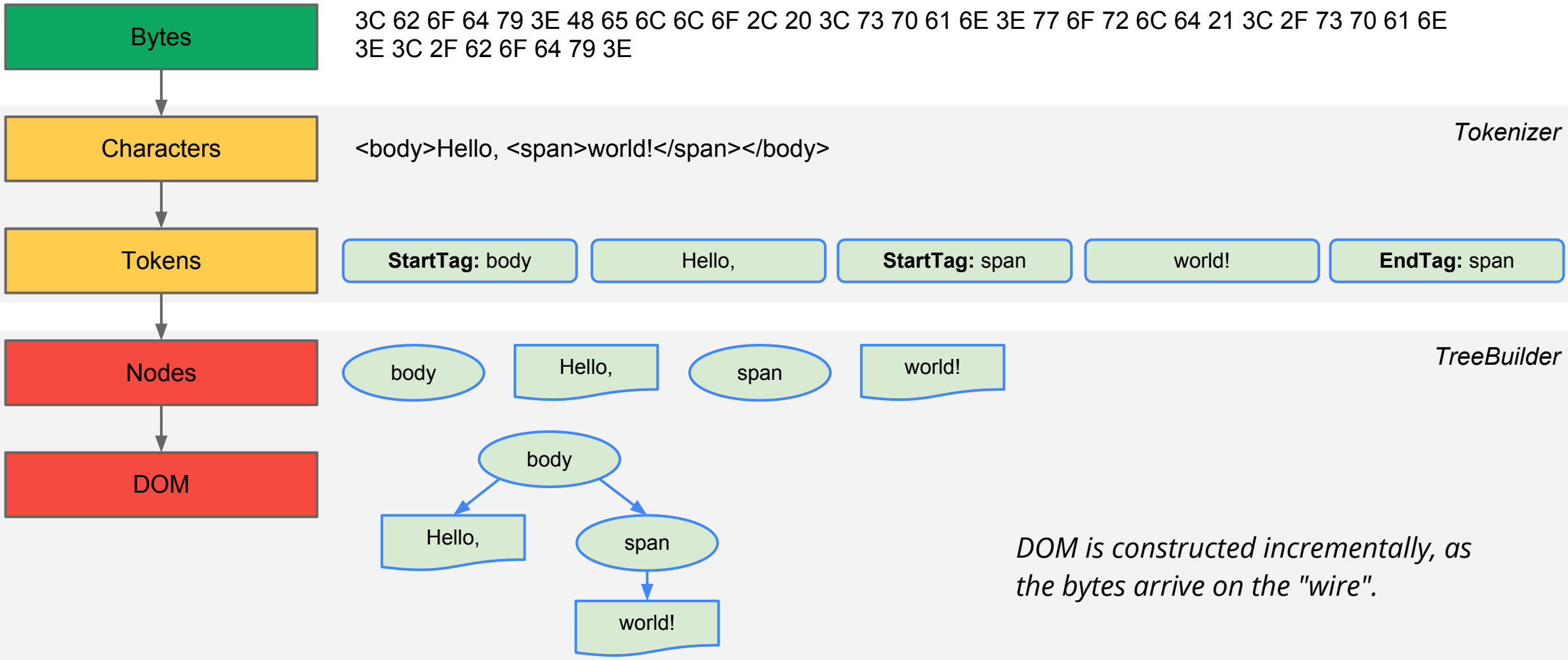
# Life of a web-page in the browser...



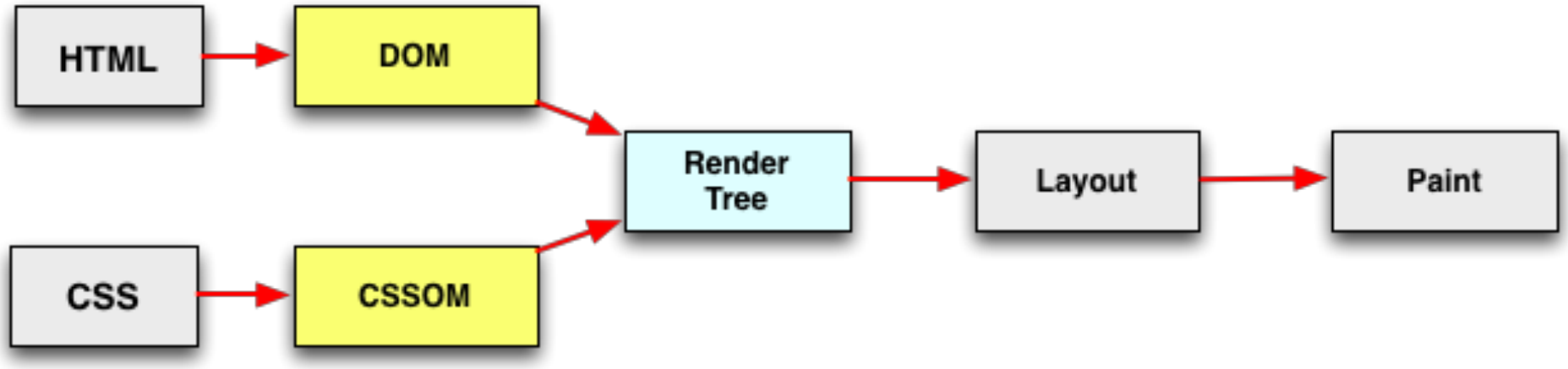

1. Fetch resources from the network
2. Parse, tokenize, construct the DOM
   a. Run scripts...
3. Output to the screen

[How WebKit works](#) - Adam Barth

# The HTML5 parser at work...



# Deciphering the Critical Rendering Path




- HTML > Document Object Model - incremental parsing
- CSS > CSS Object Model

- Rendering is blocked on **CSSOM and DOM**

# The HTML5 parser at work...

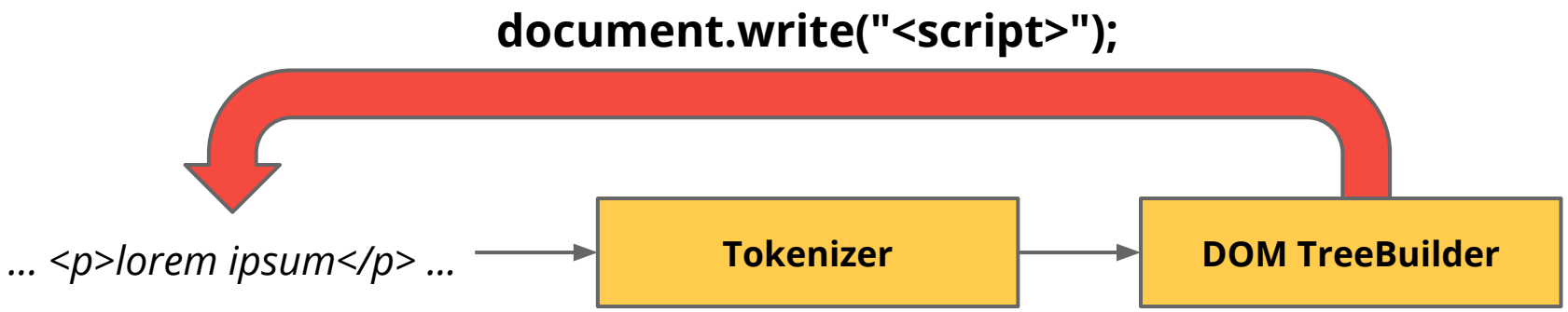
```
<!doctype html>
<meta charset=utf-8>
<title>Awesome HTML5 page</title>

<script src=application.js></script>
<link href=styles.css rel=stylesheet />

<p>I'm awesome.
```

HTMLDocumentParser begins parsing the received data ...

```
HTML
  - HEAD
    - META charset="utf-8"
    - TITLE
      #text: Awesome HTML5 page
    - SCRIPT src="application.js"
      ** stop **
```

**Stop.** Dispatch request for application.js. Wait...

# (1) Scripts can block the document parser…




JavaScript can **block** DOM construction.

Script execution can change the input stream.

Hence we **must wait for script to execute**.

# Sync scripts block the parser...

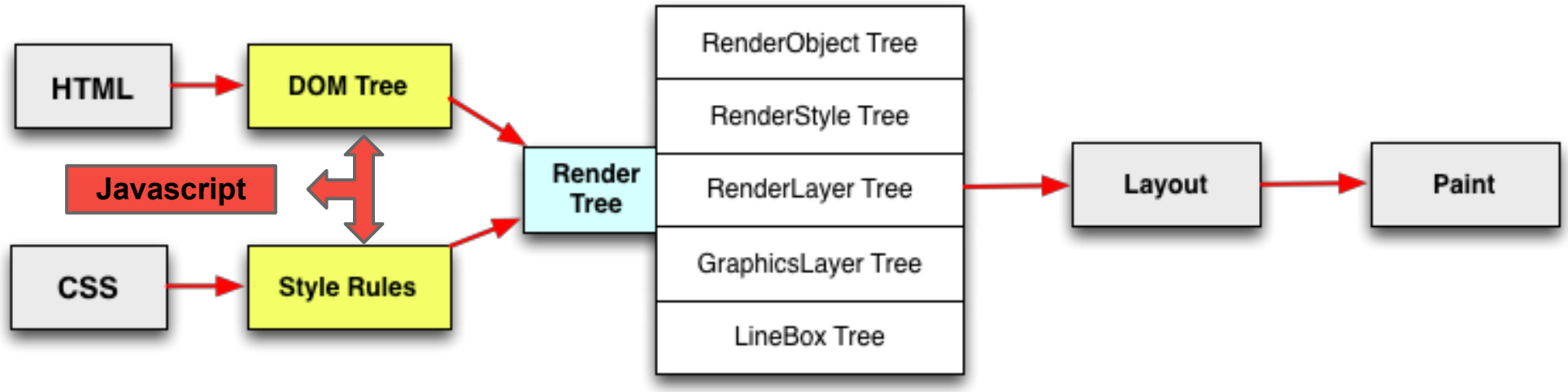
Sync script **will block** the rendering of your page:

```
<script type="text/javascript"
        src="https://apis.google.com/js/plusone.js"></script>
```

Async script **will not block** the rendering of your page:

```
<script type="text/javascript">
  (function() {
    var po = document.createElement('script'); po.type = 'text/javascript';
    po.async = true; po.src = 'https://apis.google.com/js/plusone.js';
    var s = document.getElementsByTagName('script')[0];
    s.parentNode.insertBefore(po, s);
  })();
</script>
```

# (2) Javascript can query CSS, which means...



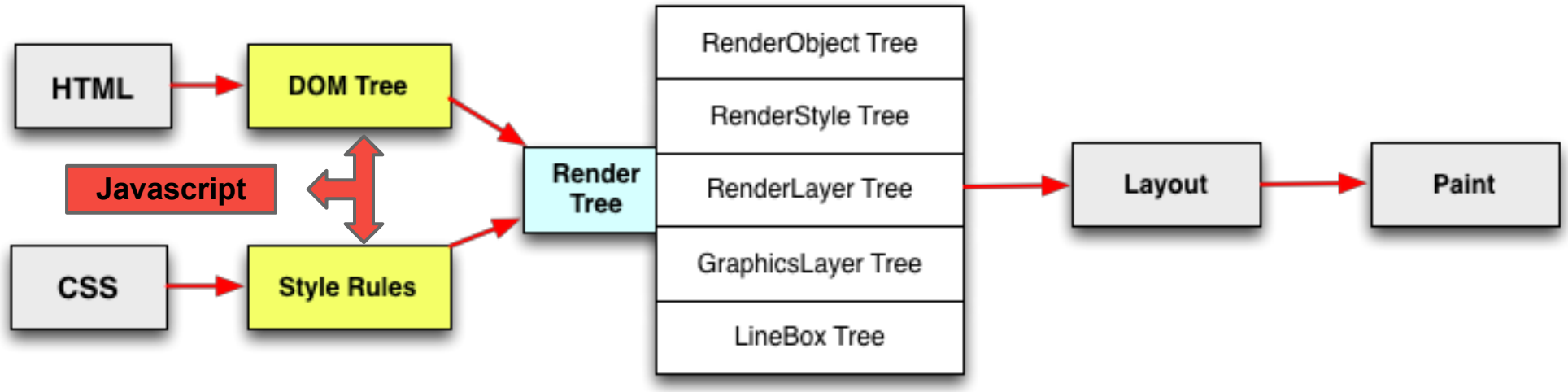

JavaScript can **block on CSS**.

DOM construction can be blocked on Javascript, which can be blocked on CSS

- *ex: asking for computed style, but stylesheet is not yet ready...*

*At least CSS can't query javascript.. phew!*

# (3) Rendering is blocked on CSS...




CSS must be fetched & parsed before Render tree can be painted.

Otherwise, the user will see "flash of unstyled content" + reflow and repaint when CSS is ready

*At least CSS can't query javascript.. phew!*

# Performance rules to keep in mind...

**(1)** JavaScript can **block the DOM** construction

**(2)** JavaScript can **block on CSS**

**(3)** Rendering is **blocked on CSS**...

## Which means...

**(1) Get CSS down to the client as fast as you can**

- *Unblocks paints, removes potential JS waiting on CSS scenario*

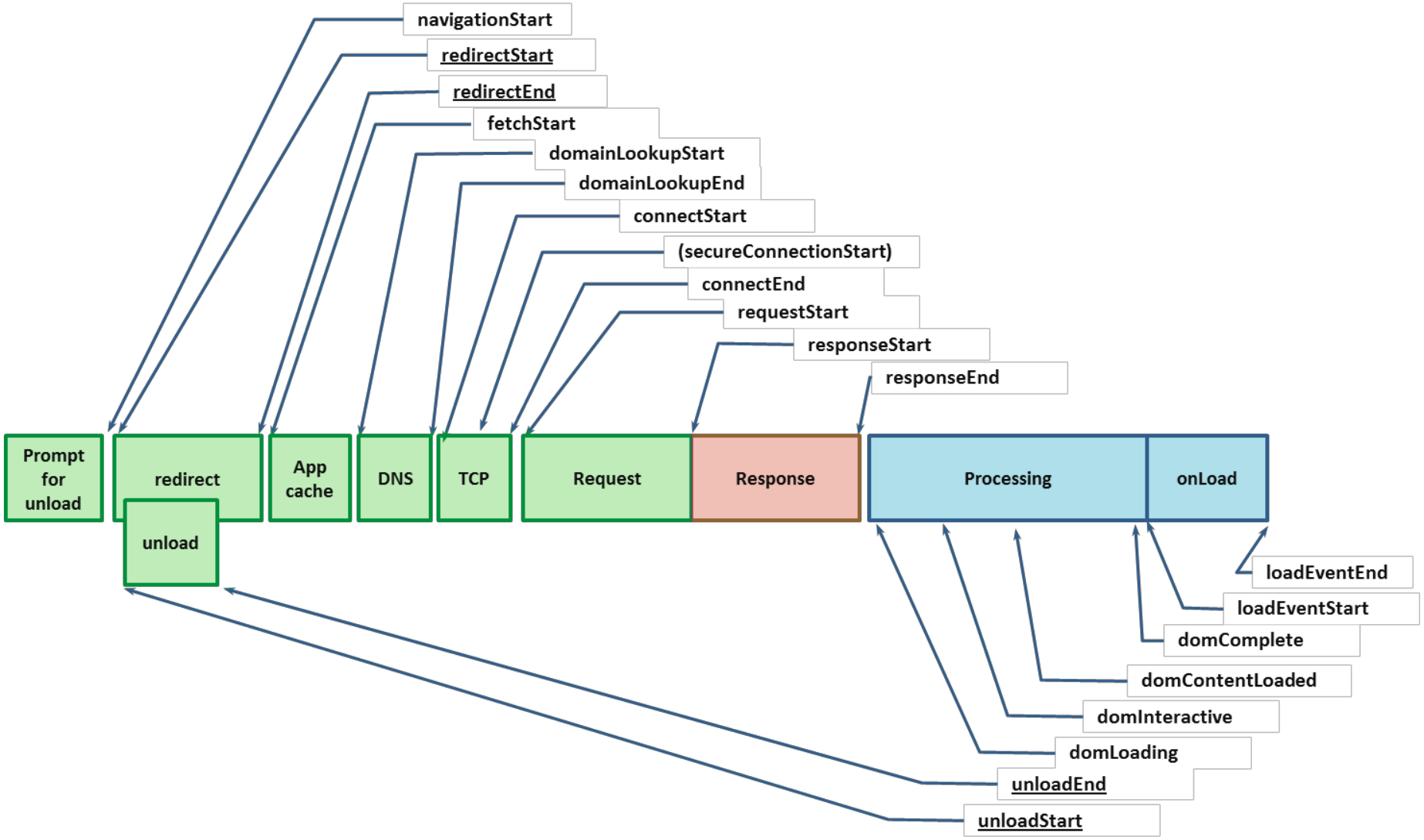
**(2) If you can, use async scripts + avoid doc.write at all costs**

- *Faster DOM construction, faster DCL and paint!*
- *Do you need scripts in your critical rendering path?*

# Let's put it all together now

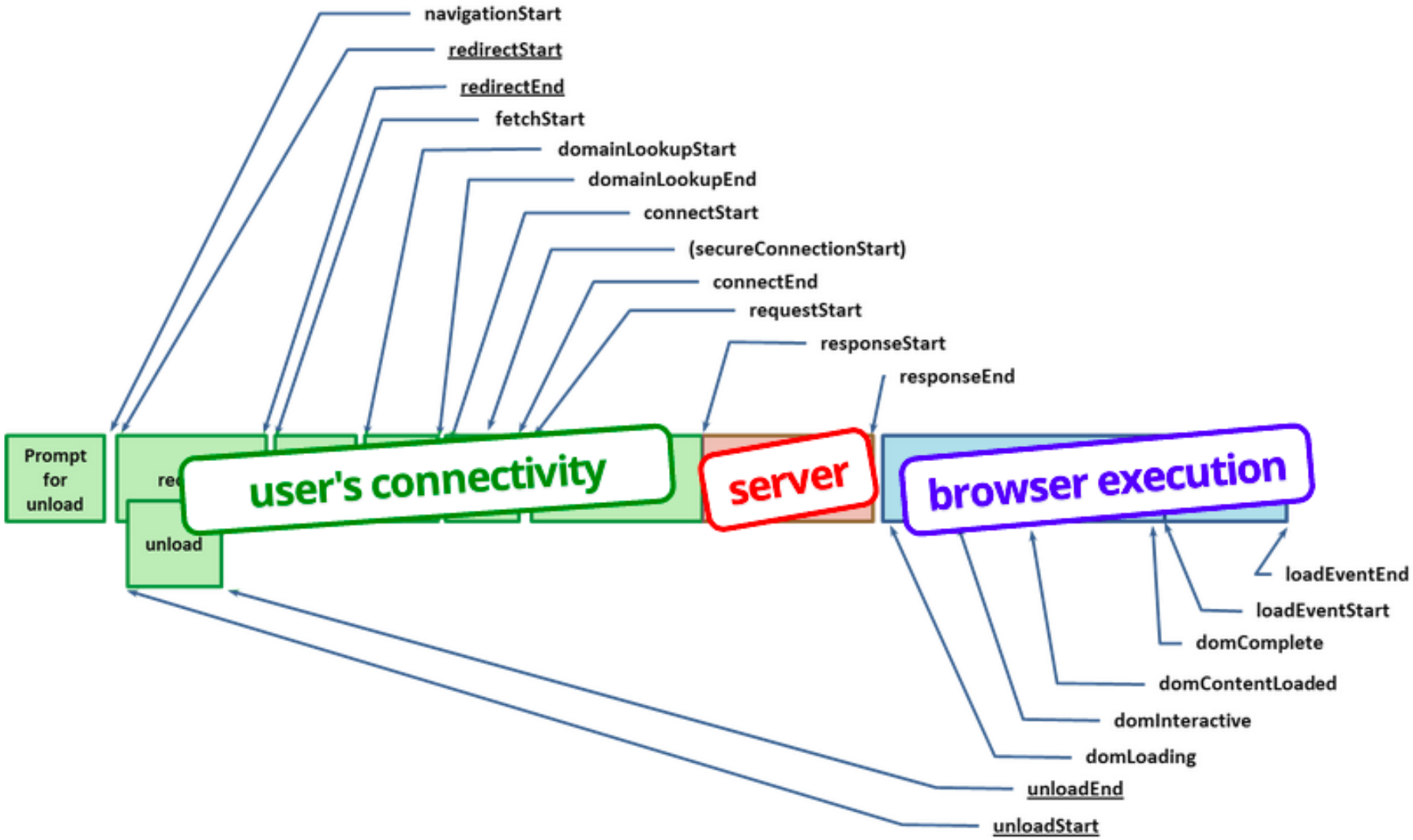
*network, browser rendering pipeline, and the rest...*

# Navigation Timing (W3C)



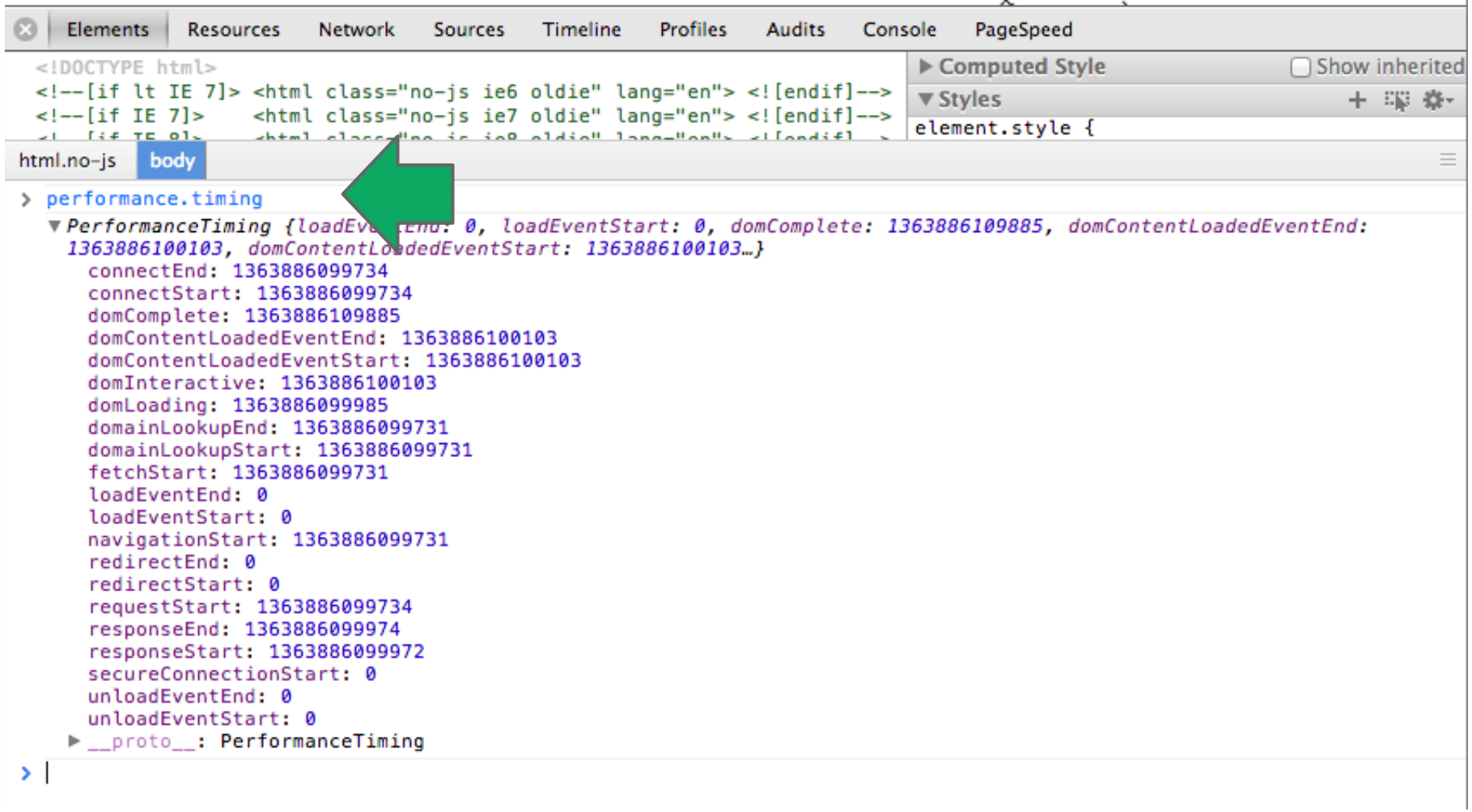

[Navigation Timing spec]

# Navigation Timing (W3C)




## W3C Navigation Timing

If we want to see the end-user perspective, then we need to instrument the browser to give us this information. Thankfully, the W3C Web Performance Working Group is ahead of us: Navigation Timing. The spec is still a draft, but Chrome, Firefox and IE have already implemented the proposal.

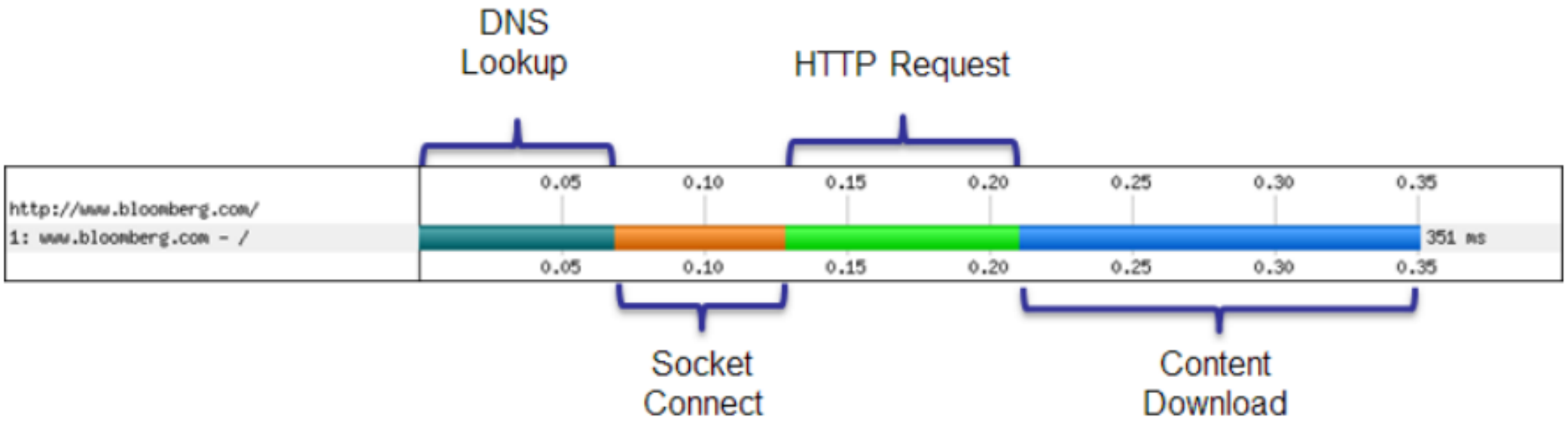



## Available in...

- IE 9+
- Firefox 7+
- Chrome 6+
- Android 4.0+

caniuse.com/nav-timing

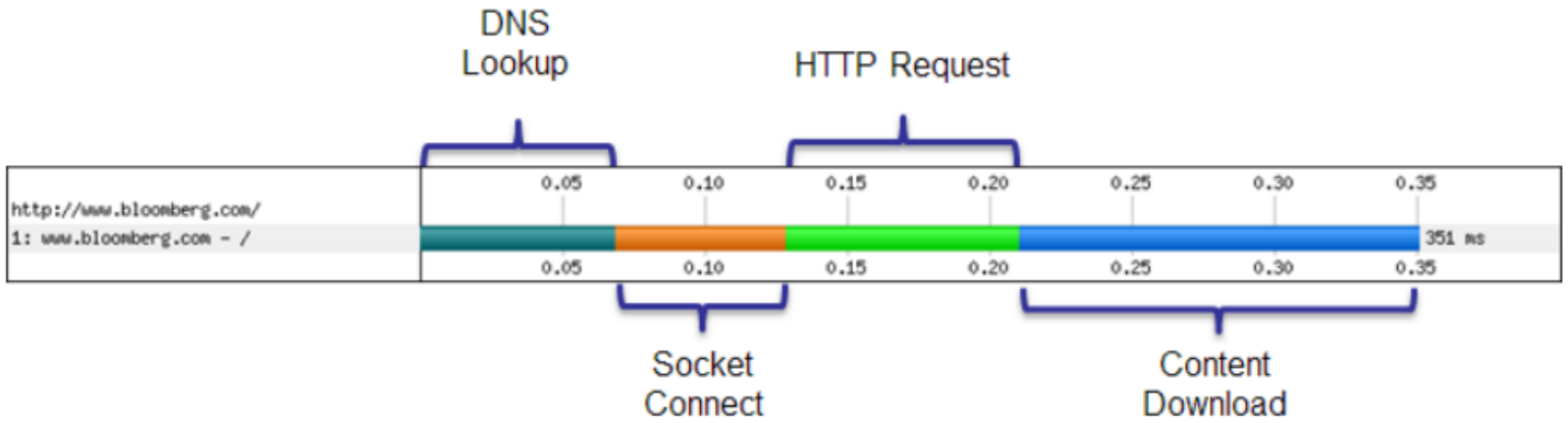
# The *(short)* life of a web request




- *(Worst case)* **DNS lookup** to resolve the hostname to IP address
- *(Worst case)* **New TCP connection**, requiring a full roundtrip to the server
- *(Worst case)* **TLS handshake** with up to two extra server roundtrips!

- **HTTP request**, requiring a full roundtrip to the server
- **Server processing time**

# The (short) life of our *1000 ms budget*




| | **3G** *(200 ms RTT)* | **4G** *(80 ms RTT)* |
|---|---|---|
| *Control plane* | *(200-2500 ms)* | *(50-100 ms)* |
| DNS lookup | 200 ms | 80 ms |
| TCP Connection | 200 ms | 80 ms |
| *TLS handshake* | *(200-400 ms)* | *(80-160 ms)* |
| HTTP request | 200 ms | 80 ms |
| **Leftover budget** | **0-400 ms** | **500-760 ms** |

***Network overhead of one HTTP request!***

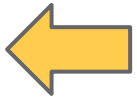

***Our mobile apps and pages are not single HTTP requests… are they?***

*But, perhaps they {could, should} be?*

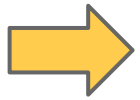
| | **3G** *(200 ms RTT)* | **4G** *(80 ms RTT)* |
|---|---|---|
| Leftover budget | **0-400 ms** | **500-760 ms** |

*~400 ms of budget left for...*

Should be **<100 ms**



- **Server processing time**
  - *what is your server processing time?*
- **Client-rendering**
  - *what does it take to render a page?*



Reserve **100 ms** for layout, rendering

**200 ms**

*JavaScript execution and an extra request if we're lucky!*

*Breaking the **1000 ms** time to glass mobile barrier... **hard facts:***

1. **Majority of time is in network overhead**
   - *Leftover budget is ~400 ms on average*
2. **Fast server processing time is a must**
   - *Ideally below 100 ms*
3. **Must allocate time for browser parsing and rendering**
   - *Reserve at least 100 ms of overhead*

***Therefore...***

*Breaking the **1000 ms** time to glass mobile barrier... **implications:***

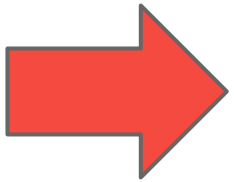
1. **Inline just the required resources for above the fold**
   - *No room for extra requests... unfortunately!*
   - *Identify and inline critical CSS*
   - *Eliminate JavaScript from the critical rendering path*
2. **Defer the rest until after the above the fold is visible**
   - *Progressive enhancement...*
3. ...
4. *Profit*

Make your mobile pages render in under one second

# A simple example in action...

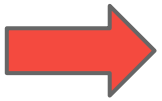
*network, browser rendering pipeline, and the rest...*

```
<html>

<head>
 <link rel="stylesheet" href="all.css">
 <script src="application.js"></script>
</head>

<body>
 <div class="main">
   Here is my content.
 </div>
 <div class="leftnav">
   Perhaps there is a left nav bar here.
 </div>
 ...
</body>
</html>
```

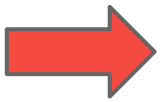


1. Split **all.css**, inline AFT styles
2. Do you need the JS at all?
   - Progressive enhancement
   - Inline AFT JS code
   - Defer the rest

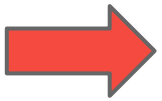
```
<html>
<head>

 <style>
   .main { ... }
   .leftnav { ... }
   /* ... any other styles needed for the initial render here ... */
 </style>

 <script>
   // Any script needed for initial render here.
   // Ideally, there should be no JS needed for the initial render
 </script>

</head>
<body>
 <div class="main">
   Here is my content.
 </div>
 <div class="leftnav">
   Perhaps there is a left nav bar here.
 </div>

 <script>
    function run_after_onload() {
      load('stylesheet', 'remainder.css')
      load('javascript', 'remainder.js')
    }
 </script>

</body>
</html>
```



Above the fold CSS



Above the fold JS
*(ideally, none)*

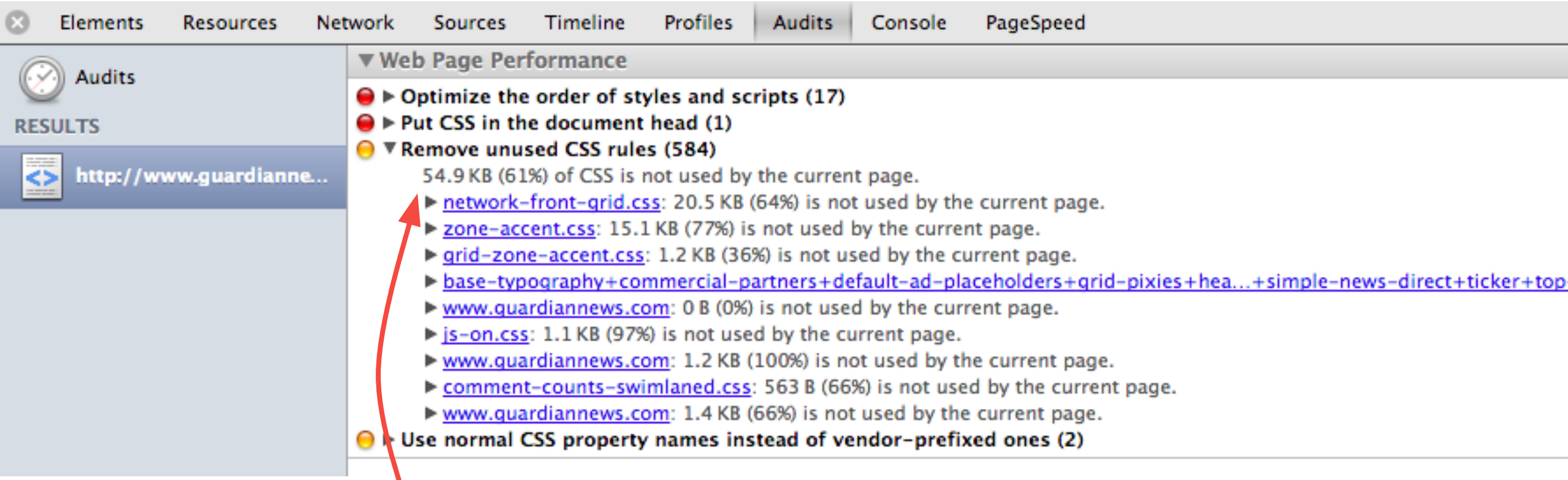


Paint the above the fold, then fill in the rest

# A few tools to help you...

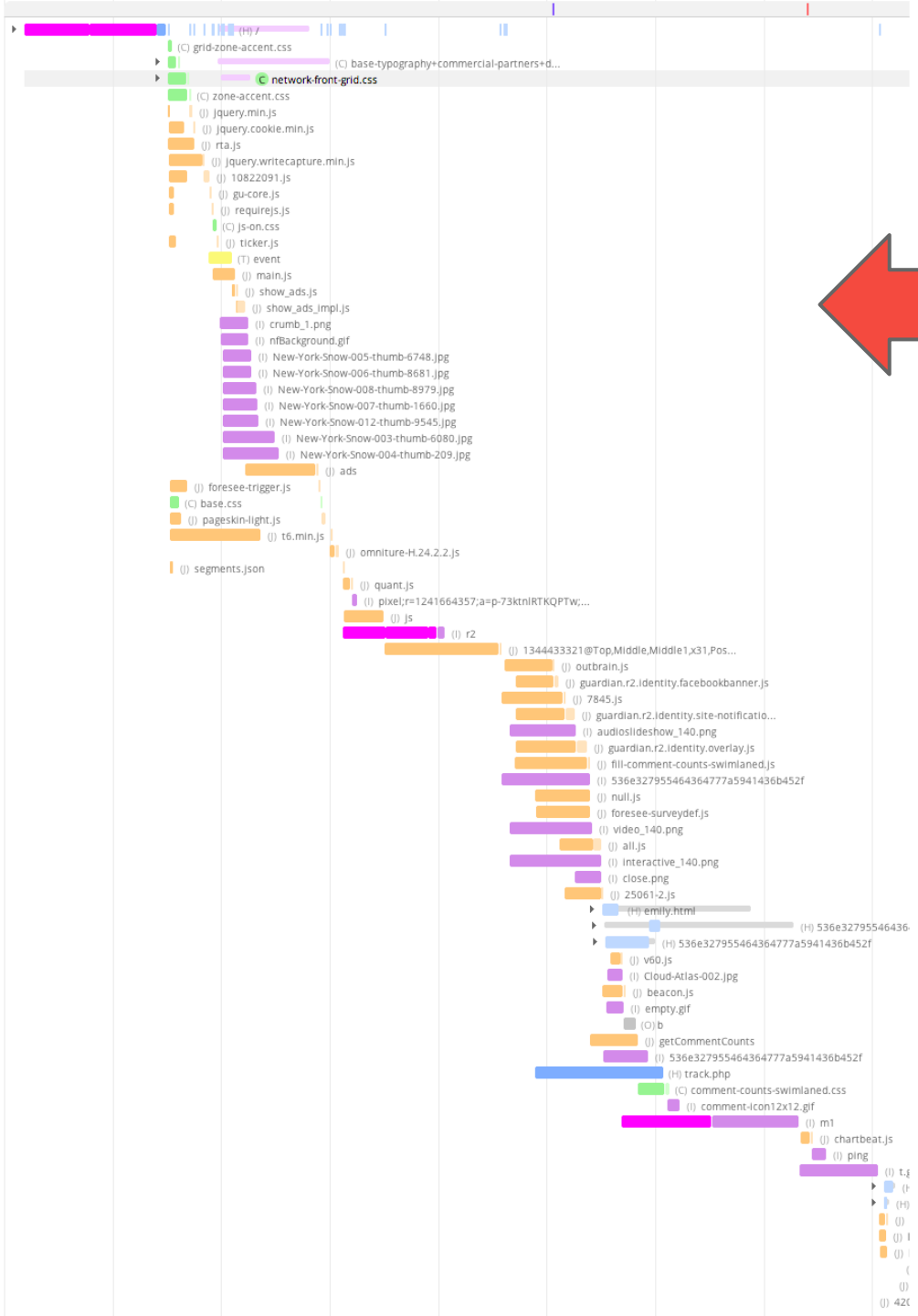
*How do I find "critical CSS" and my critical rendering path?*

# Identify critical CSS via an Audit



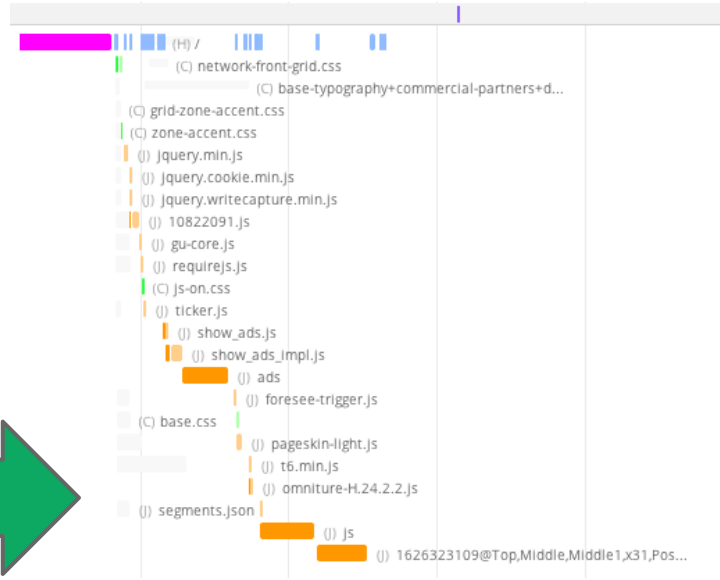

DevTools > Audits > Web Page Performance

# guardian.co.uk




**Full Waterfall**

**Critical Path**




***Critical Path Explorer*** ***extracts the subtree*** *of the waterfall that is in the "**critical path**" of the **document parser and the renderer**.*

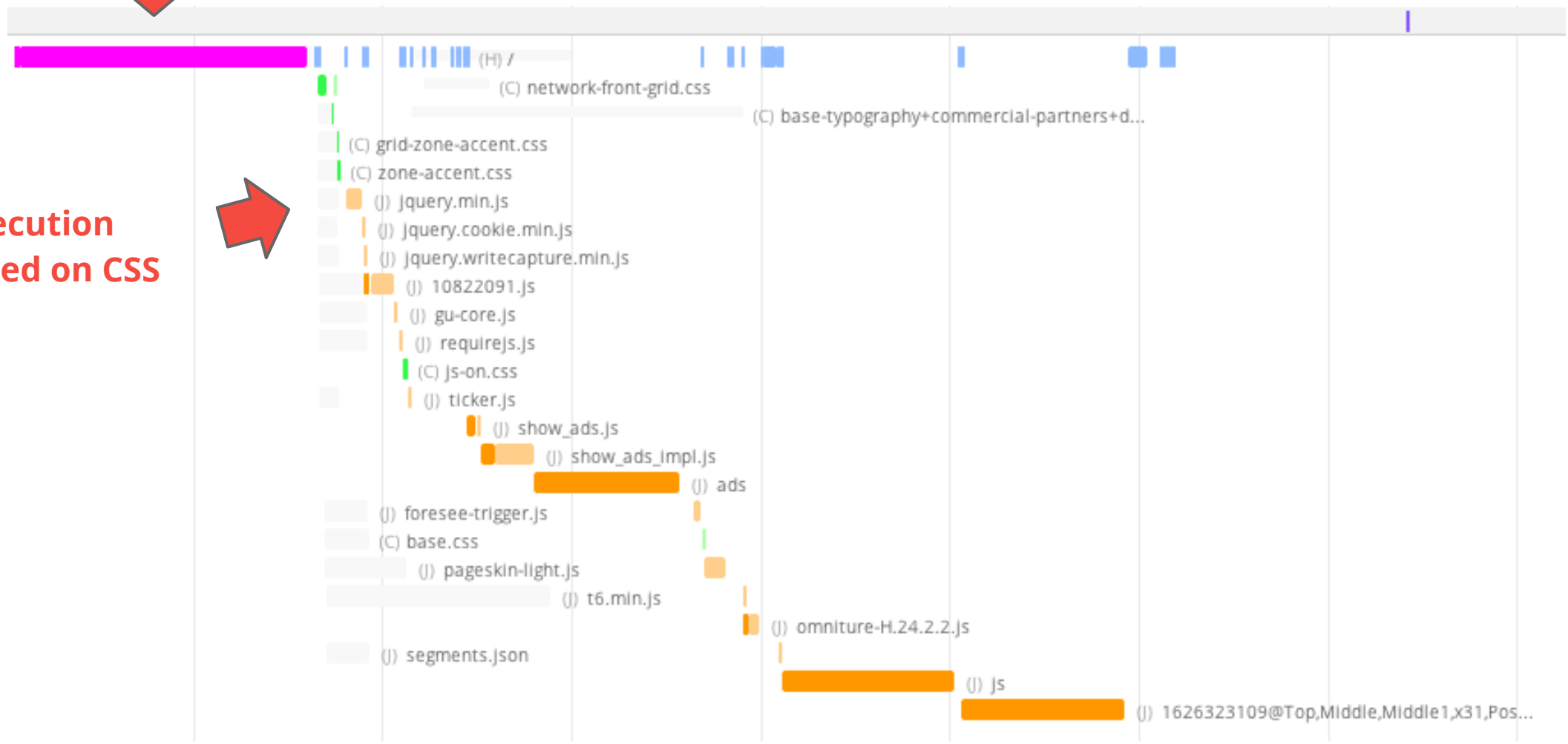
*(automation for the win!)*

300 ms redirect!

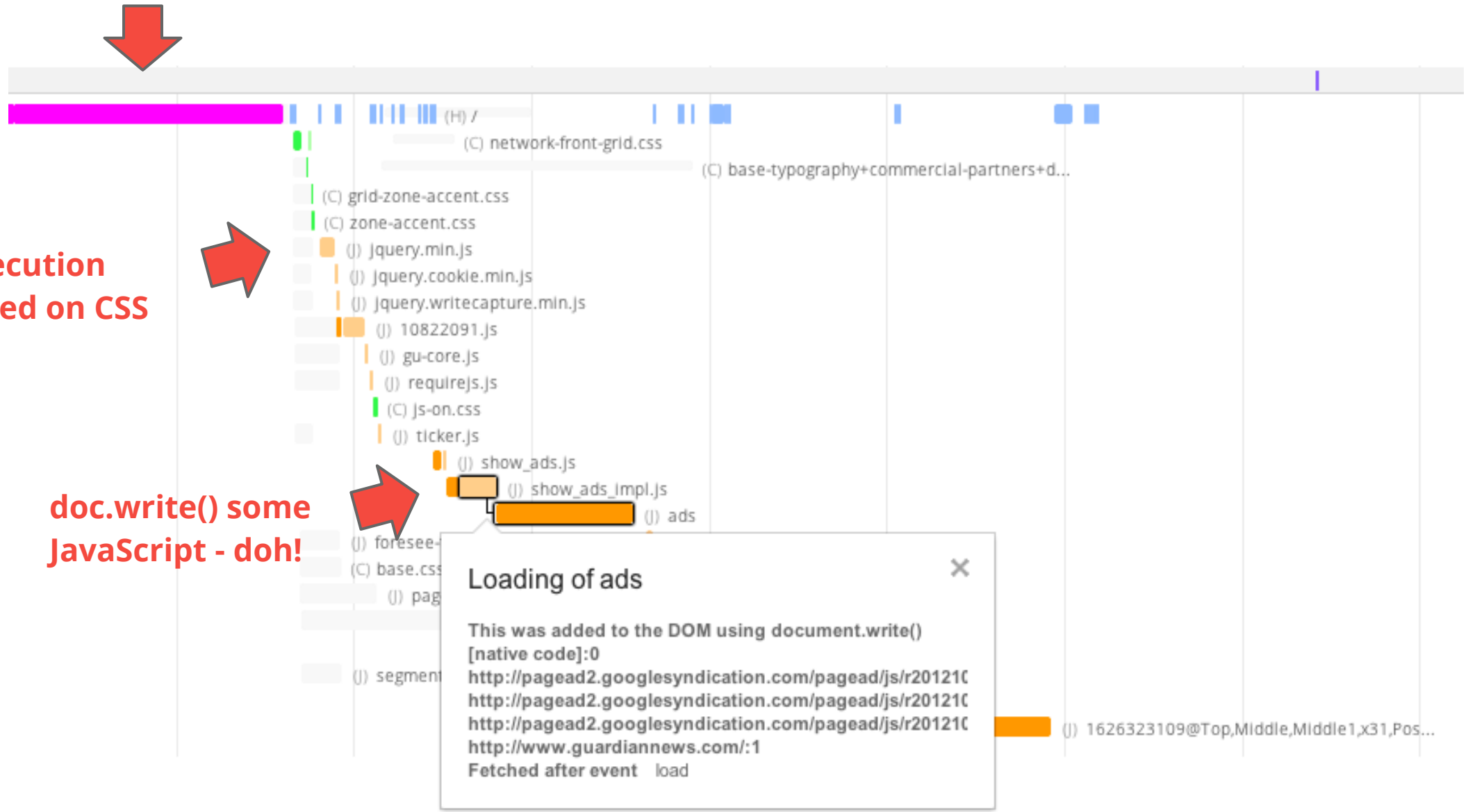
DCL.. no defer


**300 ms redirect!**

**JS execution blocked on CSS**




300 ms redirect!




JS execution blocked on CSS

doc.write() some JavaScript - doh!

300 ms redirect!


JS execution blocked on CSS

doc.write() some JavaScript - doh!

long-running JS

# *One request. Inline. Defer the rest.*

*It's not as crazy, or as hard as it sounds:* ***investigate your critical rendering path****.*

# Thanks! Questions?

- *1000 ms total budget*
  - 600 ms in network overhead
  - 400 ms for server processing and browser rendering
    - **aim for <100 ms server response**
    - **reserve 100 ms for browser rendering**

- **To beat 1000 ms time to glass barrier**
  - Inline critical CSS (no room for other requests)
  - Eliminate JavaScript from critical rendering path

**Slides @ bit.ly/mobile-barrier**
**Video @ bit.ly/12GFKDE**

**+Ilya Grigorik** - igrigorik@google.com - @igrigorik


**bit.ly/browser-networking**