Advanced Computer Networking

CYBR 230 – Jeff Shafer – University of the Pacific

HTTP/2

Timeline

- **HTTP/0.9 (*not* an RFC: https://www.w3.org/Protocols/HTTP/AsImplemented.html)**
  - Initial version of HTTP — a simple client-server, request-response, telnet-friendly protocol
  - Request nature: single-line (method + path for requested document)
  - Methods supported: `GET` only
  - Response type: hypertext only
  - Connection nature: terminated immediately after the response
  - No HTTP headers (cannot transfer other content type files), No status/error codes, No URLs, No versioning

https://medium.com/platform-engineer/evolution-of-http-69cfe6531ba0

Timeline

- **HTTP/1.0 – RFC 1945 (May 1996)**
  - Browser-friendly protocol
  - Provided header fields including rich metadata about both request and response (HTTP version number, status code, content type)
  - Response: not limited to hypertext (`Content-Type` header provided ability to transmit files other than plain HTML files — e.g. scripts, stylesheets, media)
  - Methods supported: `GET` , `HEAD` , `POST`
  - Connection nature: terminated immediately after the response

https://medium.com/platform-engineer/evolution-of-http-69cfe6531ba0

Timeline

- **HTTP/1.1 – RFC 2068 (January 1997)**
  - Performance optimizations and feature enhancements
    - Persistent and pipelined connections
    - Chunked transfers
    - Compression/decompression
    - Virtual hosting (a server with a single IP address hosting multiple domains)
  - Methods supported: `GET`, `HEAD`, `POST`, `PUT`, `DELETE`, `TRACE`, `OPTIONS`
  - Connection nature: long-lived

https://medium.com/platform-engineer/evolution-of-http-69cfe6531ba0


THE WORLD IS CHANGING

Motivations

- **What's wrong with HTTP/1.1?**
  - Complicated specification
  - Many options / incomplete implementations
  - **Performance limitations**
- **Why does it take so long to load a web page?**
  - https://bagder.gitbooks.io/http2-explained/en/

https://bagder.gitbooks.io/http2-explained/en/part2.html

http archive

REPORTS DISCUSS ABOUT

The **HTTP Archive** Tracks How the **Web is Built.**

We periodically crawl the top sites on the web and record detailed information about fetched resources, used web platform APIs and features, and execution traces of each page. We then crunch and analyze this data to identify trends — learn more about our methodology.

View Reports

Featured Report
State of the Web

This report captures a long view of the web, including the adoption of techniques for efficient network utilization and usage of web standards like HTTPS.

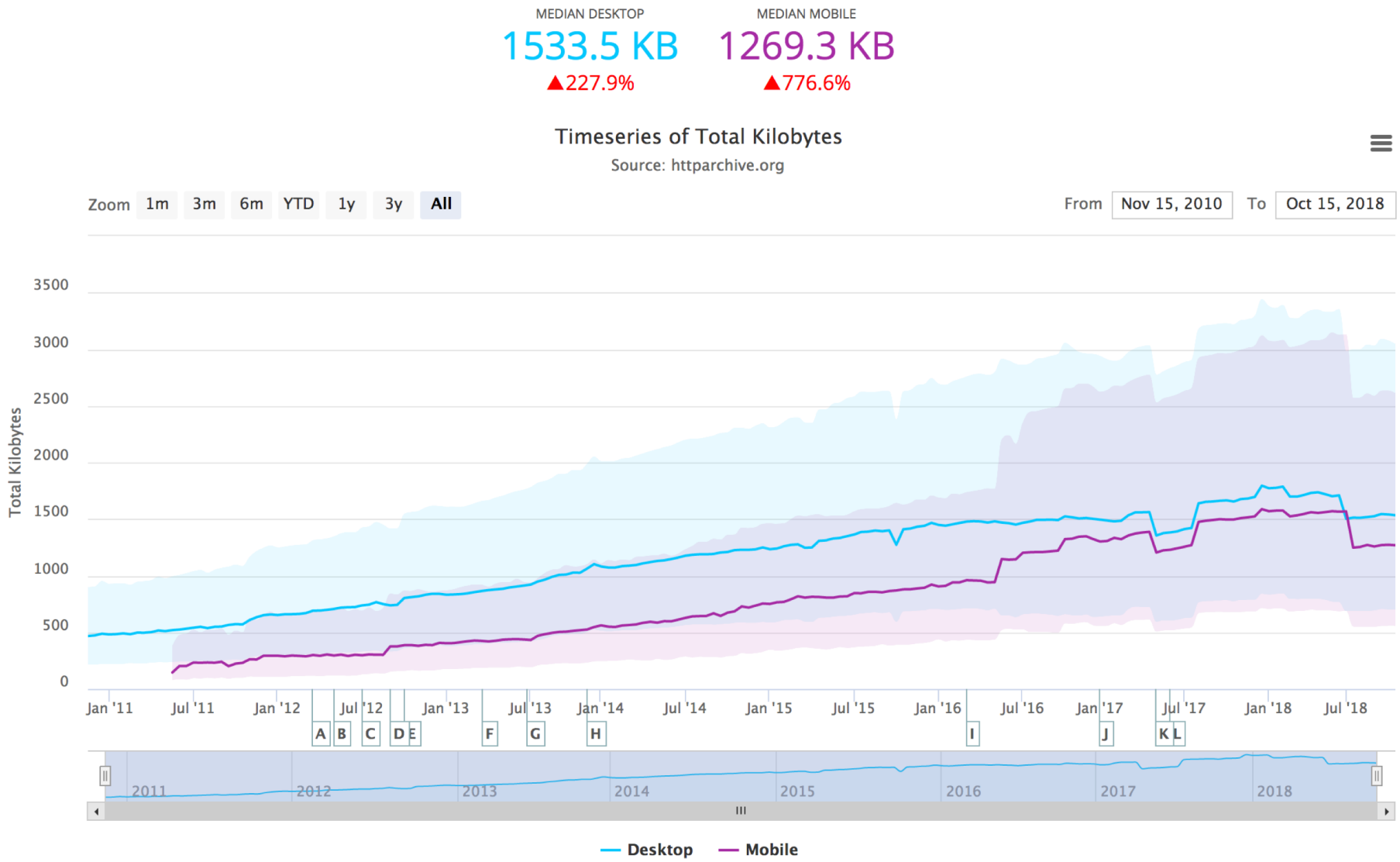
View The Report

https://httparchive.org/

Total Kilobytes

The sum of transfer size kilobytes of all resources requested by the page.

See also: Page Weight

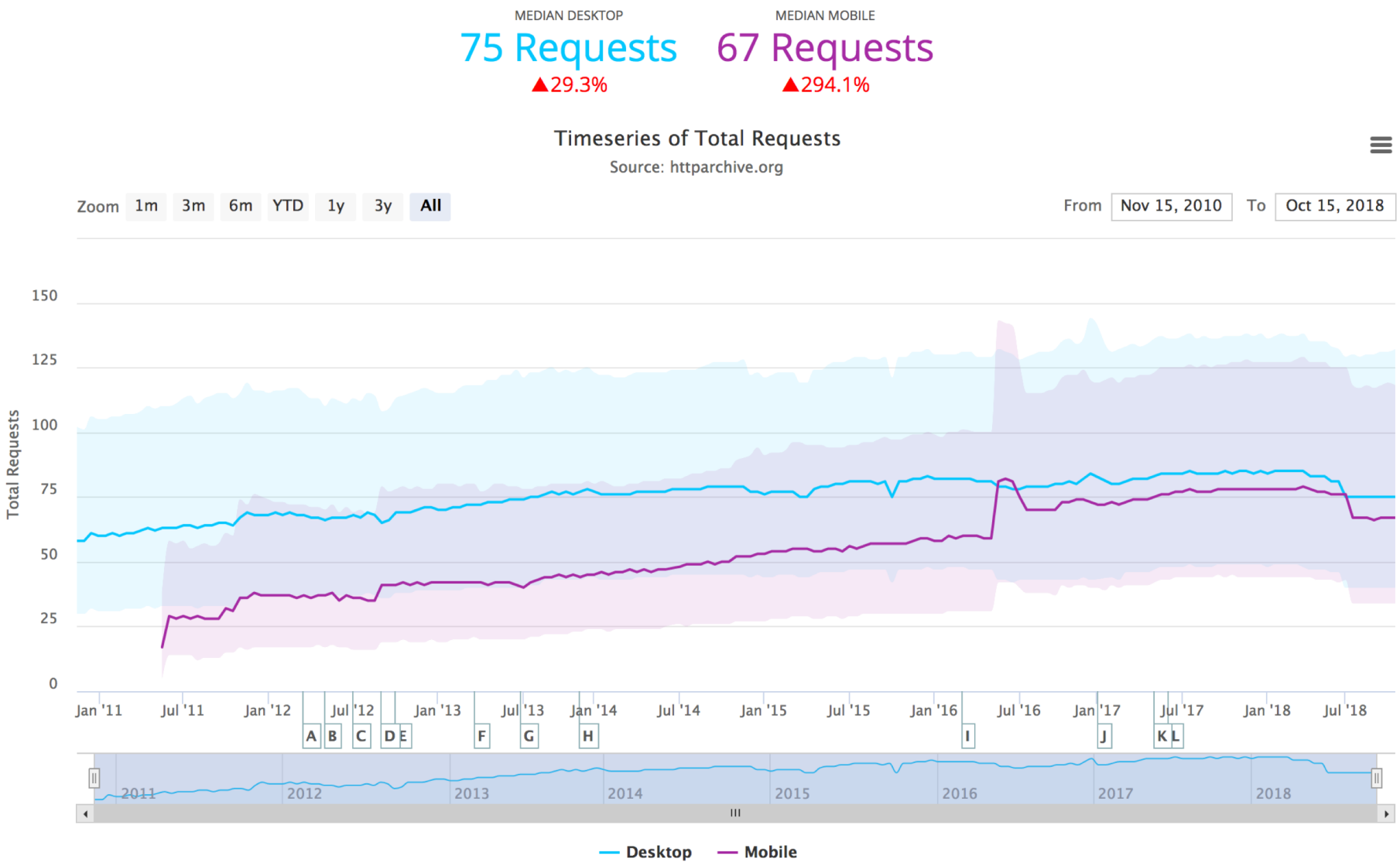


https://httparchive.org/reports/state-of-the-web

Total Requests

The number of resources requested by the page.

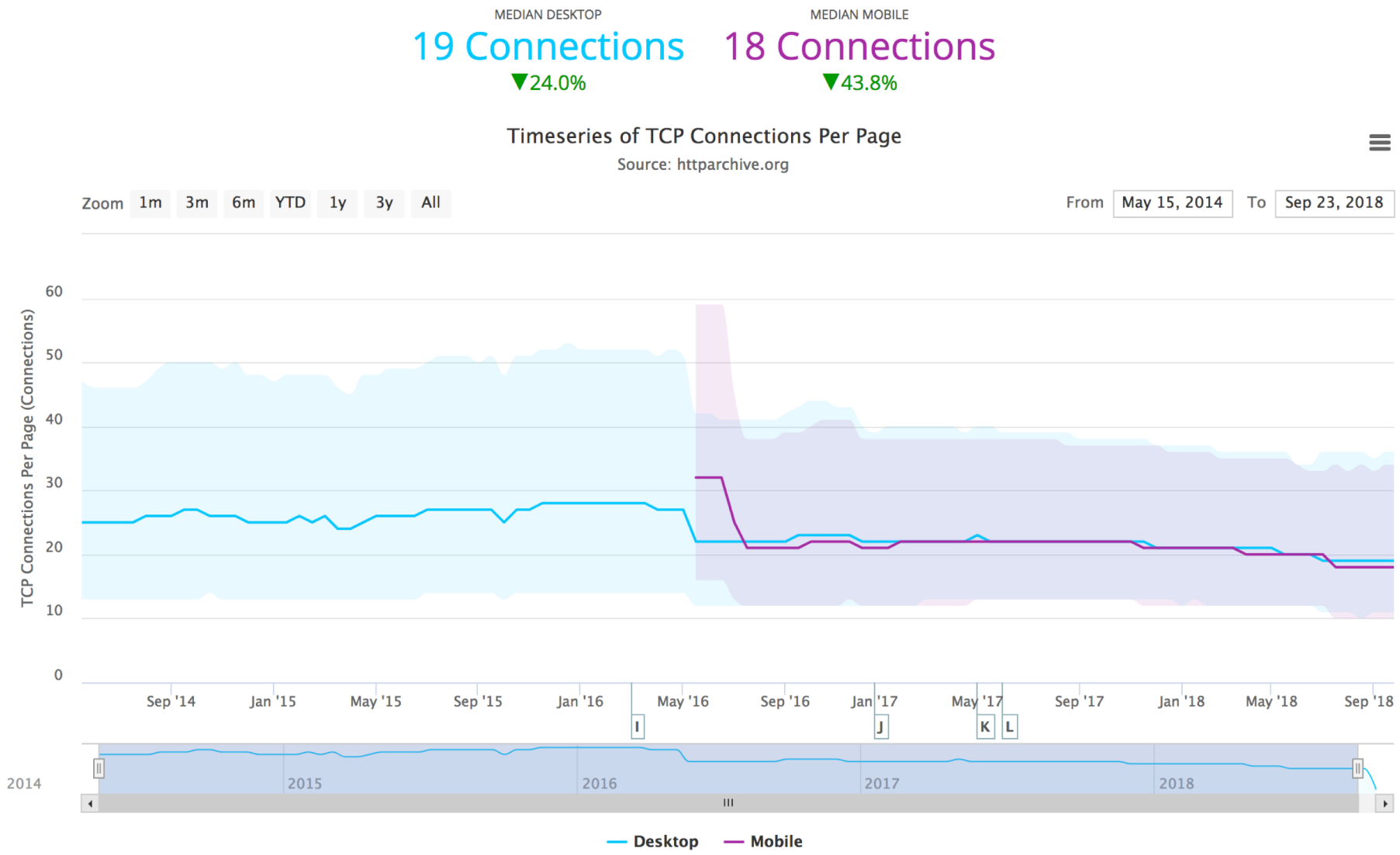
See also: Page Weight



https://httparchive.org/reports/state-of-the-web

TCP Connections Per Page

The number of TCP connections per page.



https://httparchive.org/reports/state-of-the-web

Performance

- Many files (Median of ~75 in 2018)
  - Some files are large, some files are small
- Many TCP sockets (Median of ~19 in 2018)
  - More than one file per socket
  - Resource penalty + time penalty to just open yet more sockets
- Problems
  - **Latency between requests**
    - HTTP Pipelining typically disabled by default
  - **Head-of-line blocking**
    - Multiple requests over same socket, large file blocks small file
    - **Not solved** by HTTP Pipelining

HTTP Performance Hacks

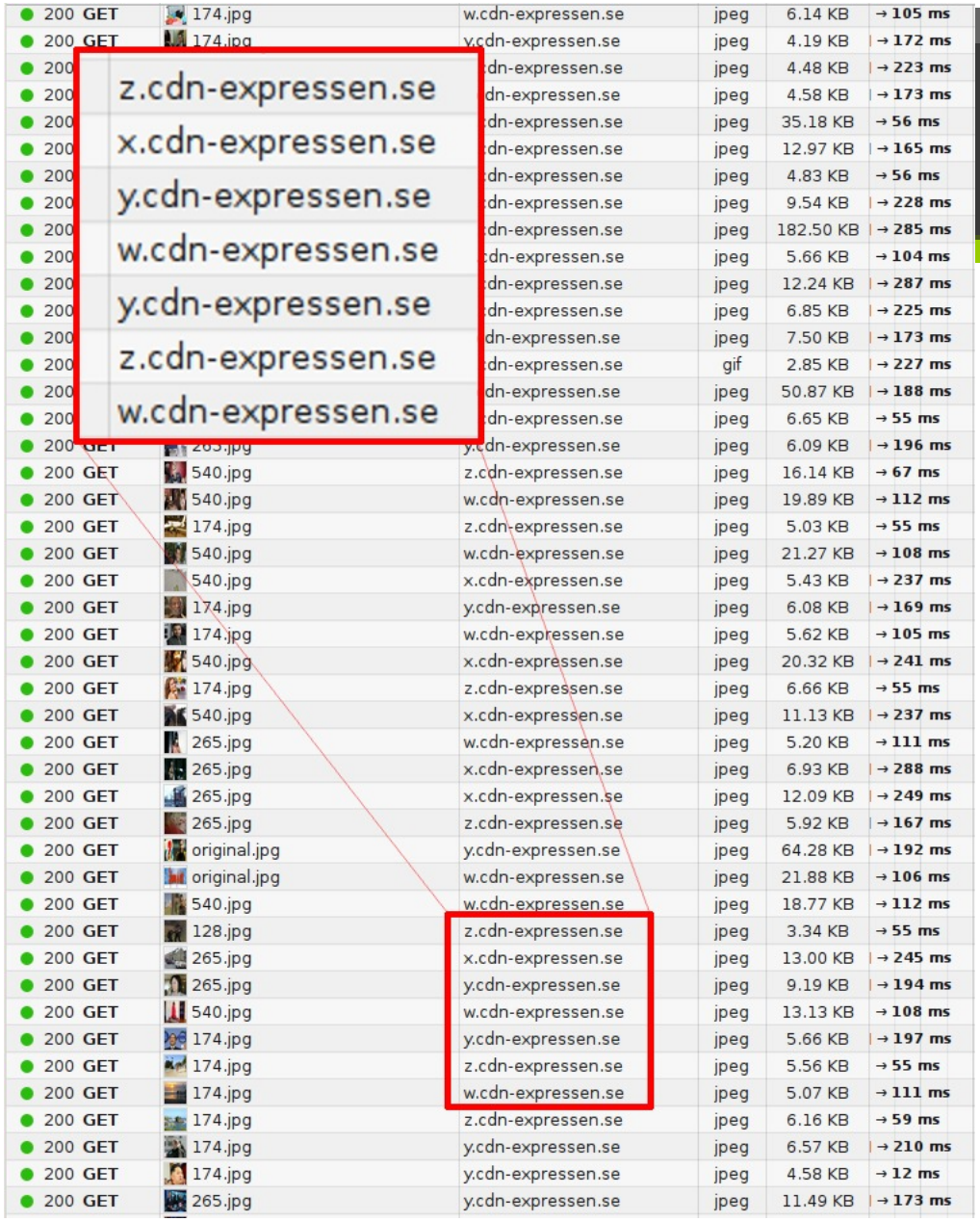
- **Sprite Sheets**
- Instead of sending many tiny images, send one big image and use JavaScript/CSS to pull out the desired pieces
- Inefficient if only a few pieces are needed

HTTP Performance Hacks

```
.icon1 {
  background:
url(<data>)
no-repeat;
}

.icon2 {
   background:
url(<data>)
no-repeat;
}
```

- **Inlining**
  - Embed data inside the CSS file instead of as separate files
- **Concatencation**
  - Combine multiple JS / CSS files into megafiles before sending to client



HTTP Hacks

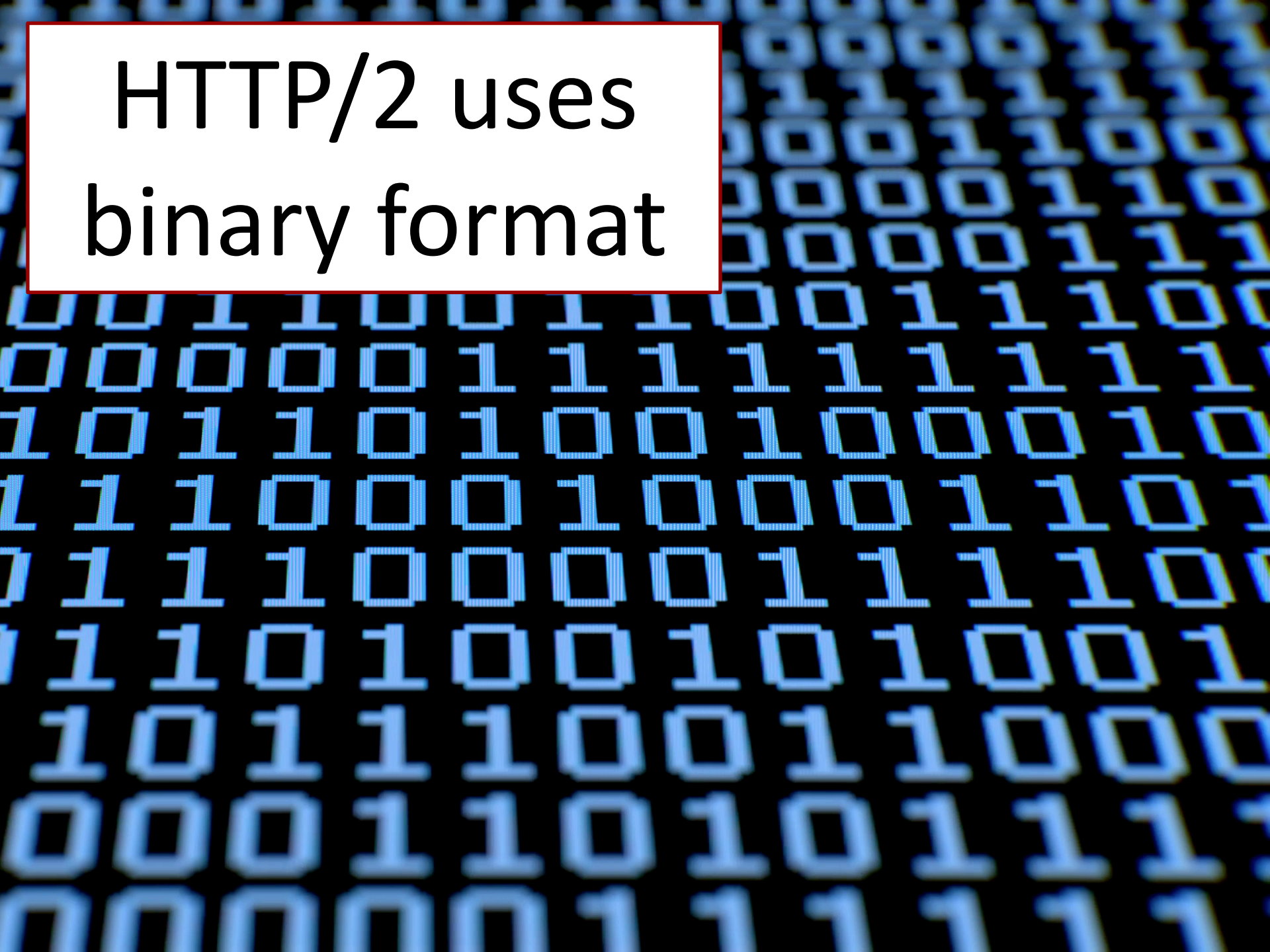
- **Domain Sharding**
- Avoid per-host limits on # of connections by spreading website across many "separate" hostnames
- How does the browser (or OS) prioritize these connections?

Timeline

- IETF HTTPbis working group
  - Formed in 2007
  - Finalized HTTP/2 – **RFC 7540 (May 2015)**
  - Finalize HPACK – **RFC 7541 (May 2015)**
  - Heavily derived from Google SPDY work
  - **https://http2.github.io/**
- Google SPDY
  - Released in Chrome in 2010
  - Withdrawn in Chrome in 2016

HTTP/2

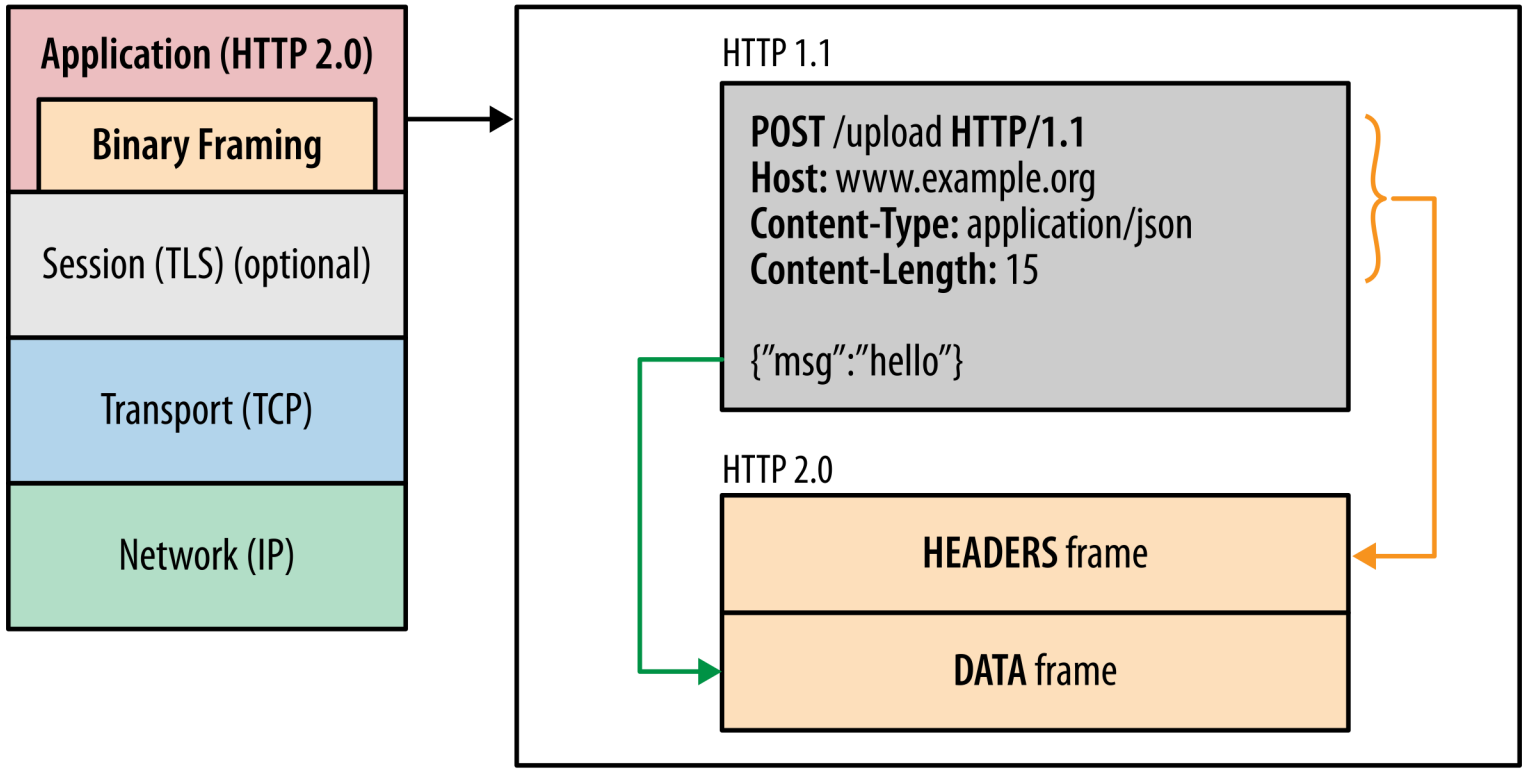
- Make the web faster *and* eliminate the design hacks
- Maintain high-level compatibility with HTTP/1.1
  - Methods, status codes, URIs, …
  - No changes to web pages, web apps, …
- Reduce Latency -> Reduce Page Load Times
  - Compress headers
  - Server Push
  - No head-of-line blocking
  - Request pipelining
  - Request multiplexing over single connection


HTTP/2 uses
binary format

HTTP/2 Binary

- Advantages of Binary
  - Simplifies parsing (~~Case? Line endings? Whitespace?~~)
  - Compact representation
  - Simplifies multiplexing and prioritization
  - Impact: Reduces latency, improves throughput
- Disadvantages of Binary
  - Can't fire up Telnet to port 80 and demonstrate HTTP any more
    (couldn't do that with HTTPS anyway…)

HTTP/2 Protocol

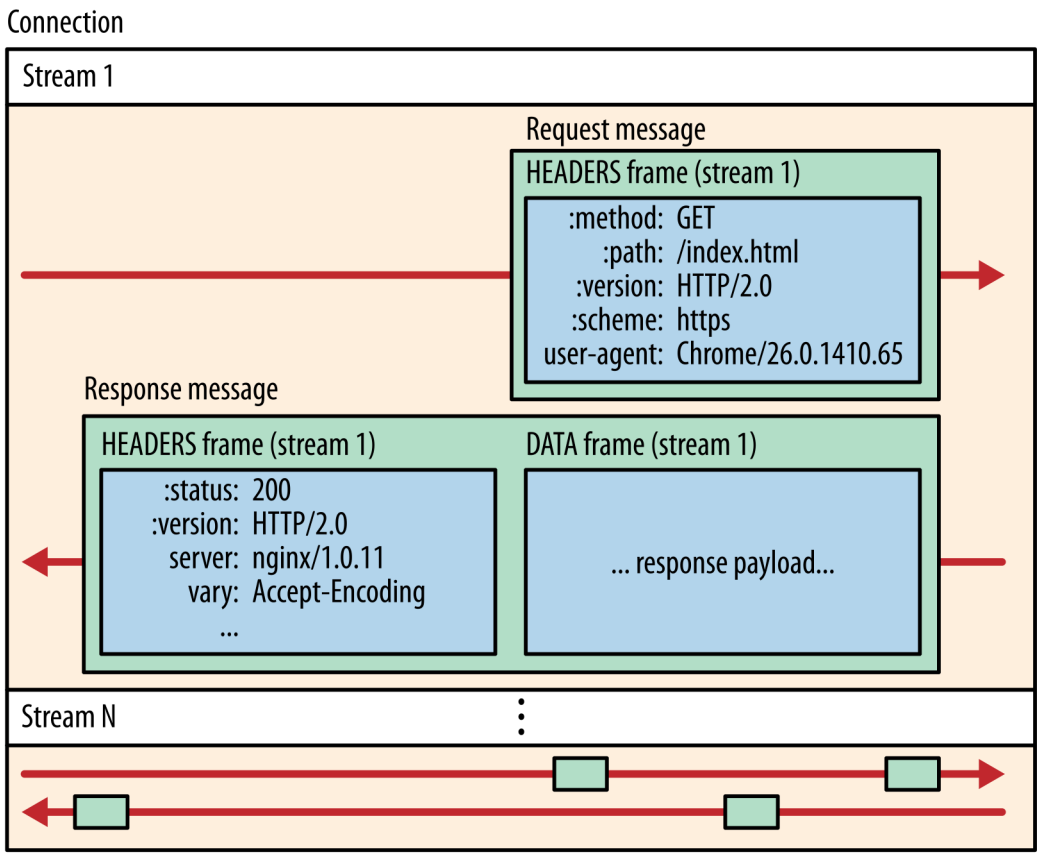


https://developers.google.com/web/fundamentals/performance/http2/

HTTP/2 Protocol

- **Stream** = Bidirectional flow of data
  - Streams can carry 1 or more messages
  - Binary format allows multiple streams to exist over single TCP connection
- **Message** = Collection of frames that, combined, form a *request* or *response* message
- **Frame** = Fundamental unit of communication
  - *Note that these are frames* inside *the TCP connection, not Ethernet frames…*

HTTP/2 Protocol



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HTTP/2 Protocol

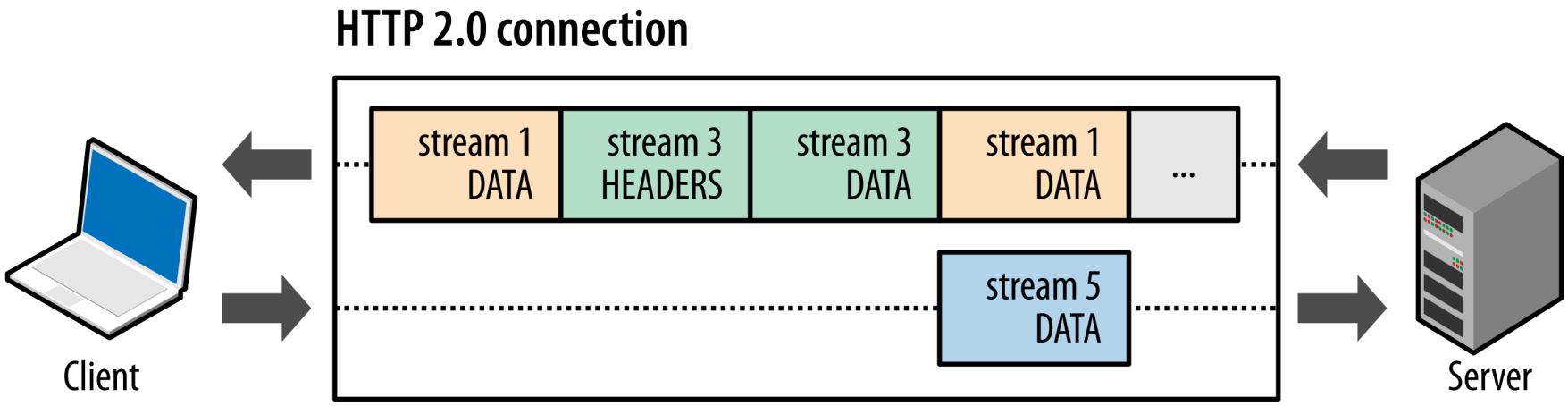
Frame Format

- Length
- Type
- Flags
- Stream Identifier
- *Payload*

Frame Types

- DATA
- HEADERS
- PRIORITY
- PUSH_PROMISE
  - Server push
- WINDOW_UPDATE
  - Flow control
- *(10 frame types in total)*

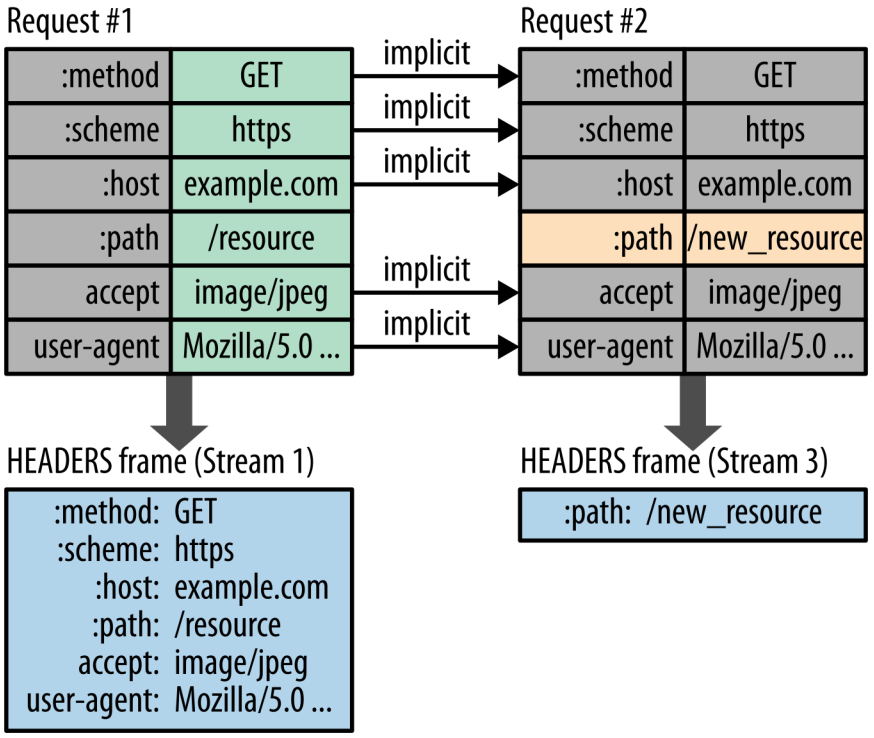
HTTP/2 Multiplexing



https://developers.google.com/web/fundamentals/performance/http2/

- Interleave multiple requests / responses without head-of-line blocking
  - Ability for client or server to prioritize frames
- Single TCP connection to each "origin" (host)
  - Connection overhead and initial latency (especially TLS) is amortized over multiple file transfers
  - More efficient than opening multiple connections

HTTP/2 Compression



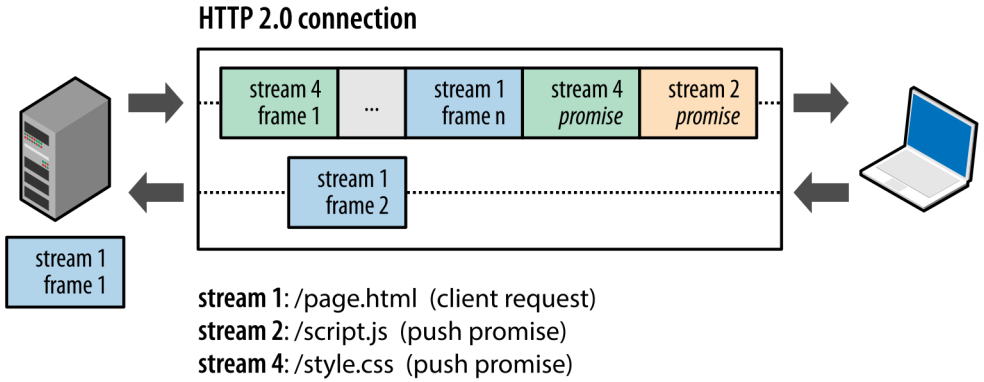
- **HPACK Header Compression (RFC 7541)**
- Fields can be encoded with static Huffman code
  - Reduces transfer size
- Client and server maintain list of previously-seen fields
  - No need to re-transmit duplicate values (refer to them by index number)
- Operates with bounded memory requirements (i.e. embedded systems)
- Resistant to security flaws (e.g. CRIME – Compression Ratio Info-leak Made Easy)
  - Steal HTTP cookies from TLS connection by observing impact of random payloads on compressed ciphertext length

https://developers.google.com/web/fundamentals/performance/http2/

HTTP/2 Compression

- **Is header compression worth the code?**
- Typical page
  - ~75 assets
  - ~1400 bytes per request (referrer tag, cookies, …)
- 7-8 round trips just to transmit requests
- Limited by TCP slow start congestion control
  - Can only have a few outstanding packets until ACKs begin returning
- Benefits increase the greater your network latency
  - Mobile LTE latency: 100+ ms (best case)

HTTP/2 Server Push



- Client requests Resource X
- Server anticipates that Resource Y will be requested next
  - Perhaps Resource Y is a dependency?
- Server pushes Resource Y to client despite never being requested
  - Client saves Resource Y in cache
- Client can elect not to accept pushed resources at all or limit total number/size

https://developers.google.com/web/fundamentals/performance/http2/

HTTP/2 Security

- HTTP/2 standard (RFC 7540) supports unencrypted connections
- Subject of much debate! (Should encryption be mandatory?)
  - Pros:
    - Security security security
    - Prevents tampering from *annoying* middleboxes assuming anything over port 80 is plain HTTP/1.1
  - Cons:
    - Not all content has to be encrypted
    - Performance / latency / etc…

HTTP/2 Security

- HTTP/2 standard (RFC 7540) supports unencrypted connections
  - Client starts with HTTP/1.1 and sends header: `Upgrade: h2c`
  - Server responds with `HTTP 101 Switching Protocol` status code
  - Rare in wild! (*curl?*)
- **Major browser implementations (Firefox, Chrome, Safari, etc…) only support HTTP/2 over TLS connections**
  - Consistent with overall design philosophy of HTTPS everywhere: New features only enabled over HTTPS

HTTP/2 Protocol

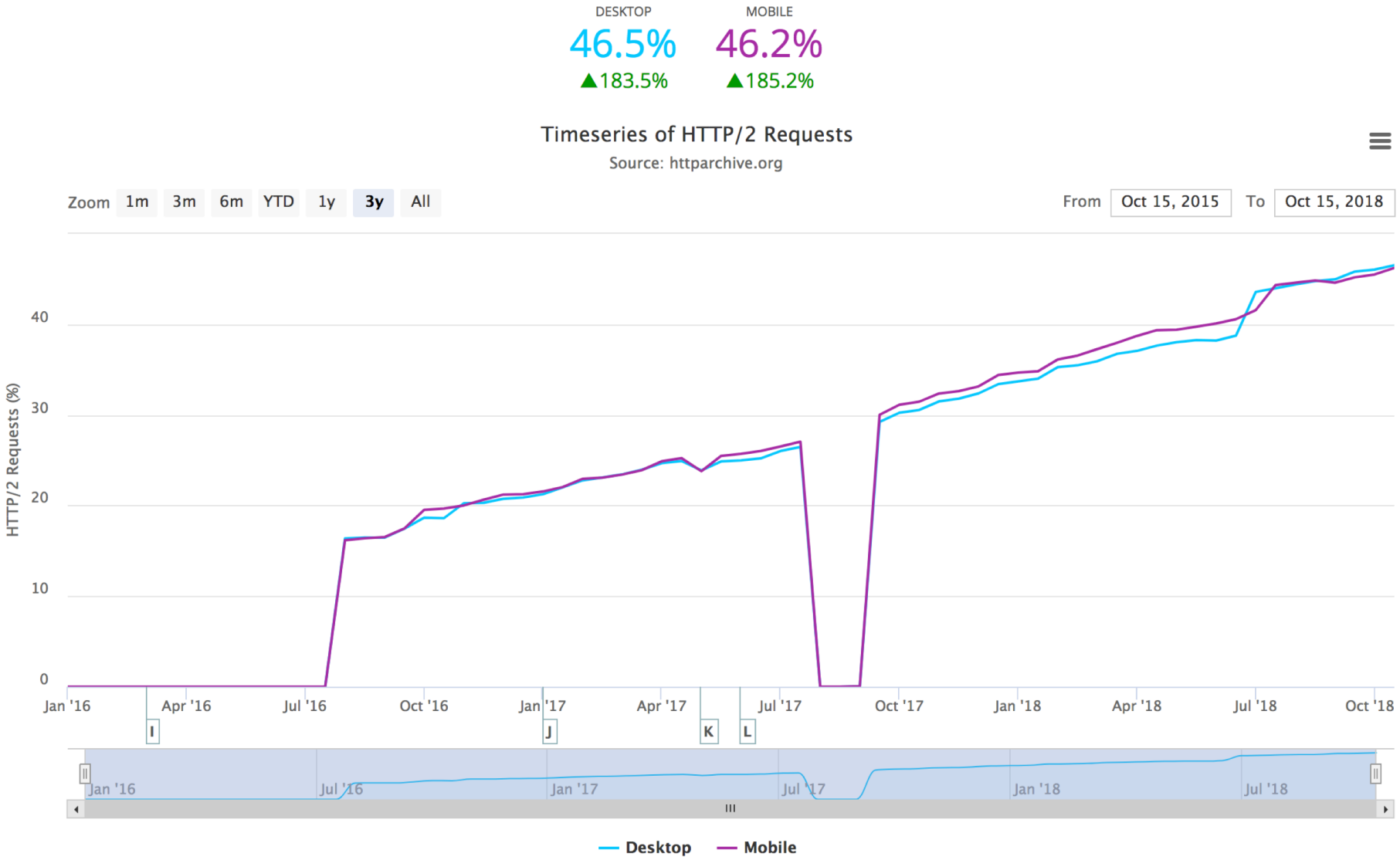
- How to “enable” HTTP/2?
- Application Layer Protocol Negotiation (ALPN) – RFC 7301
  - Part of TLS handshake
  - Client provides server with list of protocols it supports
  - Server picks one it prefers
  - Performance optimization that avoids additional roundtrip of starting with HTTP/1.1 and upgrading to HTTP/2

HTTP/2 Adoption

- **Widespread support!**
- Web browsers
  - Chrome, Safari, Firefox, Edge, …
- Web servers
  - Apache, nginx, IIS, …
- Content delivery networks
  - Akami, Azure, Cloudflare, AWS CloudFront, …

HTTP/2 Requests

The percent of all requests in the crawl using HTTP/2.



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