

From HTTP 1.1 to HTTP 2.0

# Bandwidth and Latency

## Bandwidth

*In computing, bandwidth is the bit-rate of available or consumed information capacity expressed typically in metric multiples of bits per second. Various, bandwidth may be characterized as network bandwidth, data bandwidth, or digital bandwidth.*

## Latency

*Latency is a time interval between the stimulation and response, or, from a more general point of view, as a time delay between the cause and the effect of some physical change in the system being observed.*

| Delay        | User reaction                 |
|--------------|-------------------------------|
| 0 - 100ms    | Instant                       |
| 100 - 300ms  | Slight perceptible delay      |
| 300 - 1000ms | Task focus, perceptible delay |
| 1 s+         | Mental context switch         |
| 10 s+        | I'll come back later...       |

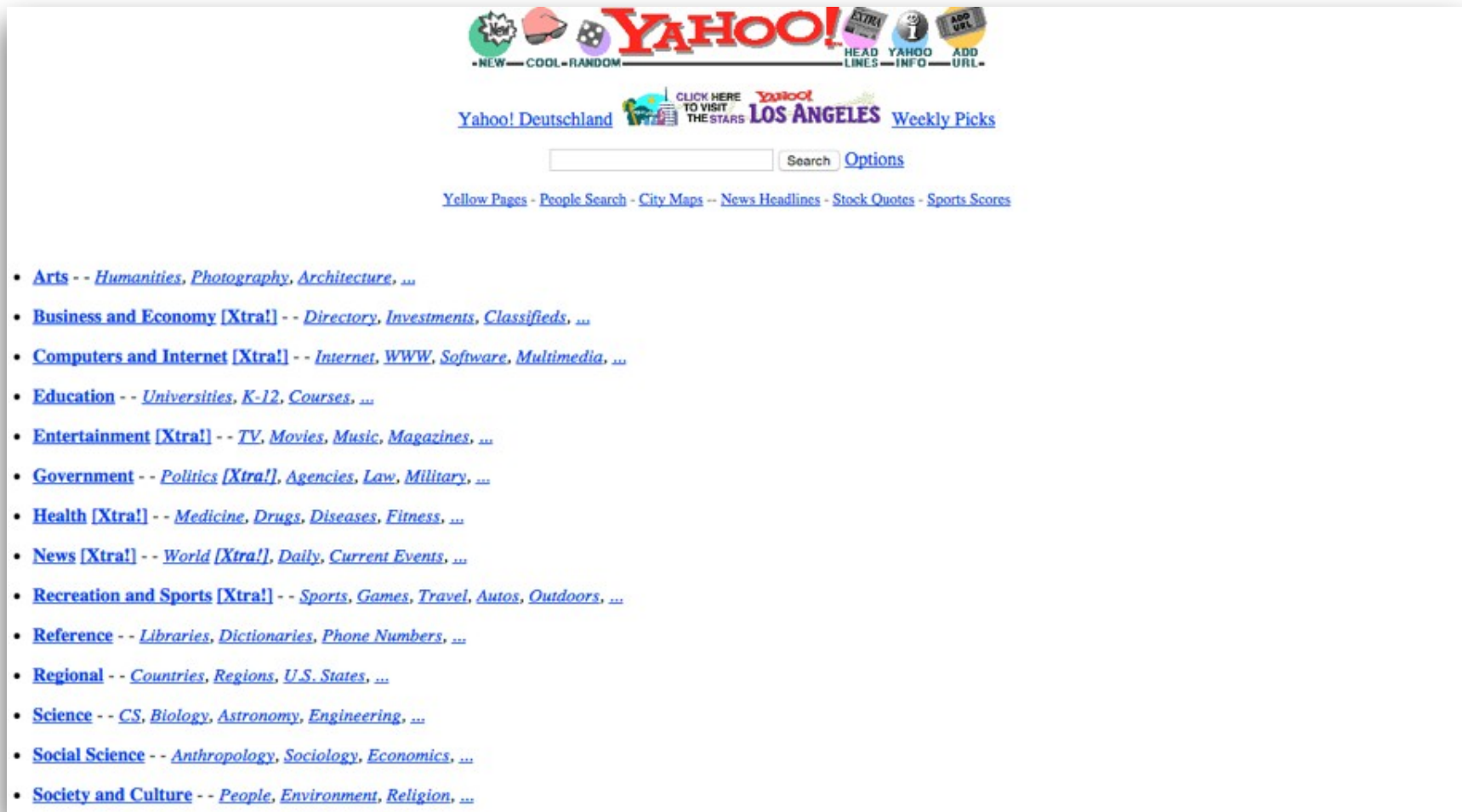


**"1000 ms  
time to  
glass  
challenge"**

- *Simple user-input must be acknowledged within ~100 milliseconds.*
- *To keep the user engaged, the task must complete within 1000 milliseconds.*

***Ergo, our pages should render within 1000 milliseconds.***

# The World Wide Web in 1996



The screenshot shows the Yahoo! homepage with the following elements:

- Header:** The word "YAHOO!" in large red letters. To the left are icons for "NEW", "COOL", and "RANDOM". To the right are icons for "HEAD LINES", "YAHOO! INFO", and "ADD URL".
- Navigation:** Links for "Yahoo! Deutschland", "CLICK HERE TO VISIT THE STARS", "LOS ANGELES", and "Weekly Picks".
- Search:** A search bar with a "Search" button and a link to "Options".
- Footer:** A row of links: "Yellow Pages", "People Search", "City Maps", "News Headlines", "Stock Quotes", and "Sports Scores".
- Directory:** A list of categories with sub-links:
  - Arts** - - [Humanities](#), [Photography](#), [Architecture](#), ...
  - Business and Economy [Xtra!]** - - [Directory](#), [Investments](#), [Classifieds](#), ...
  - Computers and Internet [Xtra!]** - - [Internet](#), [WWW](#), [Software](#), [Multimedia](#), ...
  - Education** - - [Universities](#), [K-12](#), [Courses](#), ...
  - Entertainment [Xtra!]** - - [TV](#), [Movies](#), [Music](#), [Magazines](#), ...
  - Government** - - [Politics \[Xtra!\]](#), [Agencies](#), [Law](#), [Military](#), ...
  - Health [Xtra!]** - - [Medicine](#), [Drugs](#), [Diseases](#), [Fitness](#), ...
  - News [Xtra!]** - - [World \[Xtra!\]](#), [Daily](#), [Current Events](#), ...
  - Recreation and Sports [Xtra!]** - - [Sports](#), [Games](#), [Travel](#), [Autos](#), [Outdoors](#), ...
  - Reference** - - [Libraries](#), [Dictionaries](#), [Phone Numbers](#), ...
  - Regional** - - [Countries](#), [Regions](#), [U.S. States](#), ...
  - Science** - - [CS](#), [Biology](#), [Astronomy](#), [Engineering](#), ...
  - Social Science** - - [Anthropology](#), [Sociology](#), [Economics](#), ...
  - Society and Culture** - - [People](#), [Environment](#), [Religion](#), ...

# The World Wide Web Today

**YAHOO!**

Buscar en la Web

Iniciar sesión

Correo

Correo

Noticias

Deportes

Finanzas

Celebrity

Vida y Estilo

Cine

Horóscopo

Videos

Más >

eBay

Amazon

Meetic

Al utilizar Yahoo, aceptas que nosotros y nuestros socios podamos definir cookies para distintos fines, tales como personalizar el contenido y la publicidad.



### 10 trucos para acelerar tu metabolismo

No tienes que pasarte el día en el gimnasio, basta con entrenamientos en intervalos de alta intensidad para quemar calorías, y sin dieta. [Maneras rápidas de perder peso](#) »

Narcogram' en Internet

¿Qué fue de su vida?

Malas noticias para Mayweather Jr.

Trucos para estar en forma

Hay algo raro en esta foto

Titulares

Noticias

Deportes

Finanzas

Celebrity



### Liga - De Gea-United 2019: Algunas sorprendentes preguntas sin respuesta

El portero David de Gea ha renovado su contrato con el Manchester United y pone punto y final a uno de los grandes culebrones de los últimos tiempos.

Eurosport

### Los 10 lugares donde mejor se come de España

Desde Sevilla a San Sebastián haciendo parada en Caceres, Madrid o Segovia, nos vamos a comer el país, bocado a bocado

Skyscanner Patrocinado



Lo más buscado

1 [Liga BBVA](#)

2 [US Open](#)

3 [Casas rurales](#)

4 [Eurobasket 2015](#)

5 [Horóscopo](#)

6 [Oferta hoteles](#)

7 [Lionel Messi](#)

8 [Vestidos mujer](#)

9 [Floyd Mayweather](#)

10 [Previsión tiempo](#)

NUEVO FORD ECOSPORT

>Apertura Sin Llave

Desde 12.990€



Descúbrelo

Go Further

29660, Marbella (Ubicación actual)

27°F | °C

Buen tiempo

Hoy

Lu.

Ma.

29° 19°

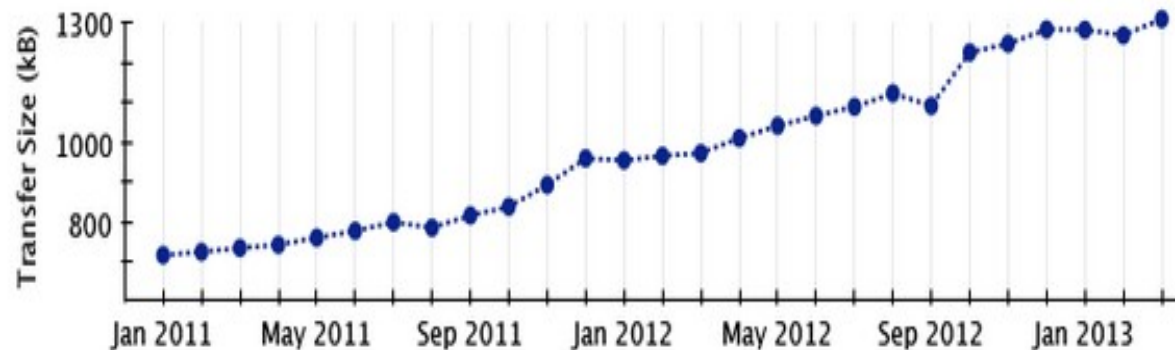
29° 19°

28° 18°

Ver más »

Establecer YAHOO! como página de inicio

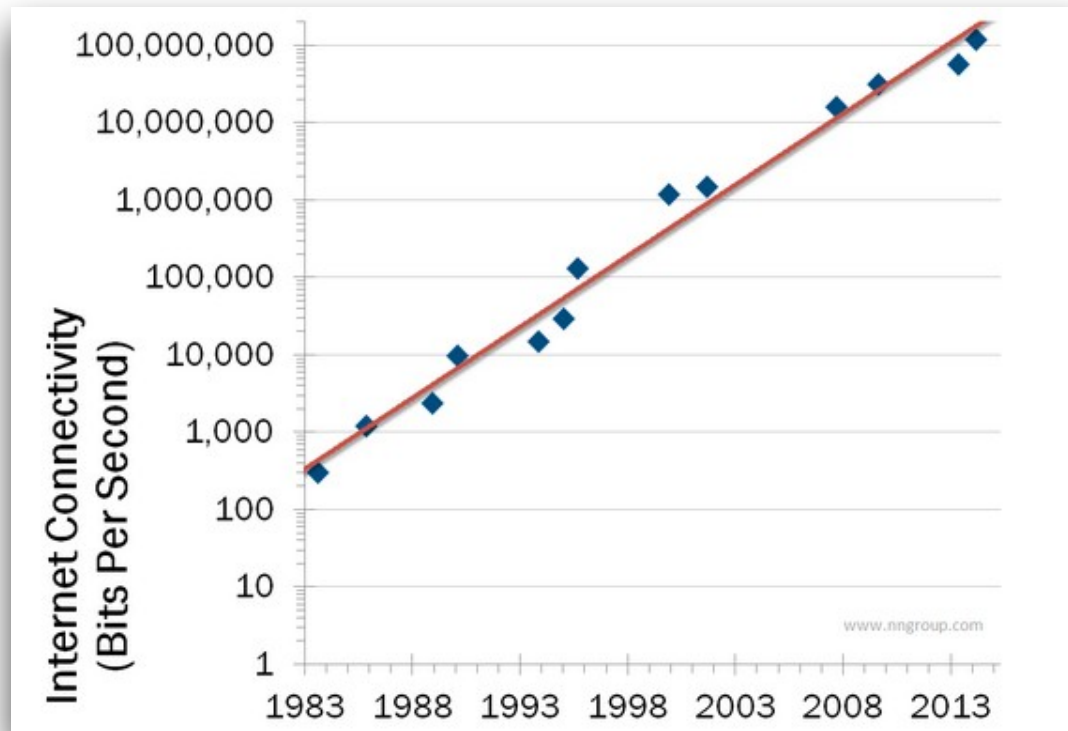
# Our applications are complex, and growing...



| Content Type | Desktop           |          | Mobile            |          |
|--------------|-------------------|----------|-------------------|----------|
|              | Avg # of requests | Avg size | Avg # of requests | Avg size |
| HTML         | 10                | 56 KB    | 6                 | 40 KB    |
| Images       | 56                | 856 KB   | 38                | 498 KB   |
| Javascript   | 15                | 221 KB   | 10                | 146 KB   |
| CSS          | 5                 | 36 KB    | 3                 | 27 KB    |
| Total        | 86+               | 1169+ KB | 57+               | 711+ KB  |

← Ouch!

# Nielsen's Law of Bandwidth



1984 - 300 bps

50% Growth per Year

# Bandwidth by Country

| Position | Country       | Speed (Mbps) |
|----------|---------------|--------------|
| 1        | South Korea   | 25.3         |
| 2        | Hong Kong     | 16.3         |
| 3        | Japan         | 15           |
| 4        | Switzerland   | 14.5         |
| ...      | ...           | ...          |
| 12       | United States | 11.5         |
| 13       | Belgium       | 11.4         |
| ...      | ...           | ...          |
| 24       | Germany       | 8.7          |
| ...      | ...           | ...          |
| 28       | Spain         | 7.8          |
| ...      | ...           | ...          |
| 30       | Australia     | 6.9          |
| 31       | France        | 6.9          |
| ...      | ...           | ...          |
| 55       | Bolivia       | 1.1          |

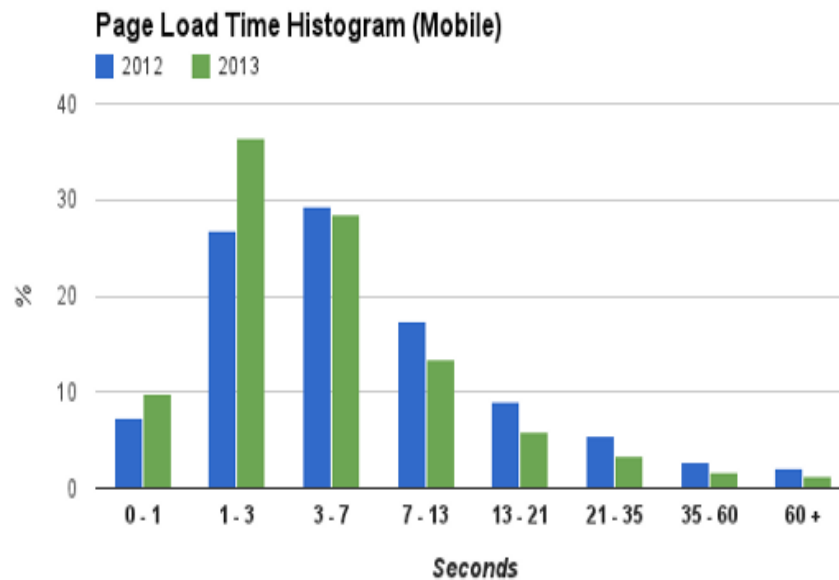
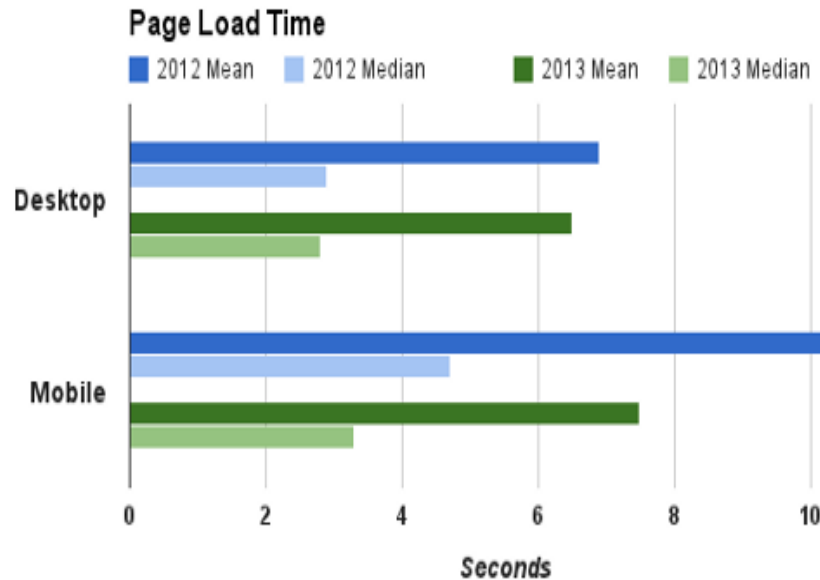


# Mobile Networks

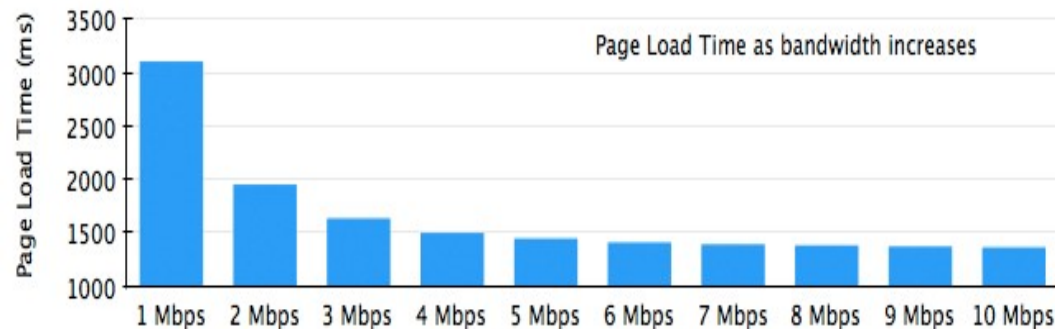
| Region        | Average Speed (Mbps) |
|---------------|----------------------|
| Europe        | 20.4                 |
| North America | 9.6                  |
| Asia Pacific  | 8.8                  |
| South America | 7.0                  |
| Africa        | 4.8                  |

Desktop: ~3.1 s

Mobile ~3.5 s



# Latency vs. Bandwidth impact on Page Load Time



*Single digit  
perf  
improvement  
after 5 Mbps*



Average household is running on a **5 Mbps+** connection. Ergo, **average consumer would not see an improvement in page loading time by upgrading their connection.**

(doh!)  
[Bandwidth doesn't matter  
\(much\)](#) - Google

- Improving bandwidth is "easy" ...
  - 60% of new capacity through upgrades in past decade + unlit fiber
  - *"Just lay more fiber..."*
- **Improving latency is expensive... impossible?**
  - Bounded by the speed of light - oops!
  - We're already within a small constant factor of the maximum
  - *"Shorter cables?"*



**\$80M /  
ms**

Latency is the new Performance  
Bottleneck

@igrigo  
rik

And latency is per connection

# Typical Web Page

| Name                                                                                                                     | Method | Status | Type       | Initiator                        | Size         | Time   | ▲ |
|--------------------------------------------------------------------------------------------------------------------------|--------|--------|------------|----------------------------------|--------------|--------|---|
|  comunes.css                            | GET    | 200    | stylesheet | (index):37                       | (from cache) | 42 ms  |   |
|  pxlctl2.gif?r=2&m=1&s=25c10673e...     | GET    | 302    | gif        | http://pxlctl.elpais.com/pxlc... | 508 B        | 58 ms  |   |
|  advert.gif?648618153                   | GET    | 200    | gif        | (index):164                      | 392 B        | 59 ms  |   |
|  caja_tlife.css                         | GET    | 200    | stylesheet | (index):1619                     | 793 B        | 70 ms  |   |
|  pxlctl2.gif?m=1&r=2&w=2123515          | GET    | 302    | gif        | http://elpais.com/pxlctl.gif?... | 347 B        | 80 ms  |   |
|  ?script=0&random=4019638651&ip...      | GET    | 200    | gif        | http://www.google.com/ads...     | 343 B        | 94 ms  |   |
|  gpt.js                                 | GET    | 304    | script     | pbs.slots.js:1                   | 363 B        | 95 ms  |   |
|  rta.js?netId=4045&cookieName=crt...    | GET    | 200    | script     | pbs.slots.js:1                   | 457 B        | 118 ms |   |
|  pxlctl.gif?m=1&r=2&w=2123515           | GET    | 302    | text/html  | (index):164                      | 241 B        | 121 ms |   |
|  elpais.com                             | GET    | 200    | document   | http://www.elpais.es/            | 61.9 KB      | 123 ms |   |
|  ?script=0&random=4019638651            | GET    | 302    | text/html  | http://googleads.g.doublecli...  | 380 B        | 138 ms |   |
|  rep.gif?ver=1&typ=pgv&rnd=iemvn...     | GET    | 200    | gif        | (index):165                      | 404 B        | 147 ms |   |
|  bid?src=3226&u=http%3A%2F%2Felp...    | GET    | 200    | script     | amzn_ads.js:1                    | 217 B        | 191 ms |   |
|  s64909375414717?AQB=1&pccr=tr...     | GET    | 302    | text/plain | http://prisacom.112.2o7.net...   | 811 B        | 213 ms |   |
|  ?value=0&guid=ON&script=0            | GET    | 302    | gif        | (index):164                      | 651 B        | 226 ms |   |
|  ?idsite=255&url=http%3A%2F%2Felp...  | GET    | 200    | xhr        | vrs.20150907.js:6                | 337 B        | 355 ms |   |
|  ?transport=jsonp&idsite=255&url=h... | GET    | 200    | xhr        | vrs.20150907.js:6                | 1.1 KB       | 369 ms |   |
|  s64909375414717?AQB=1&ndh=1&...      | GET    | 302    | text/plain | (index):165                      | 1.8 KB       | 432 ms |   |
|  ads?gdfp_req=1&correlator=231131...  | GET    | 200    | script     | pubads_impl_72.js:189            | 29.4 KB      | 528 ms |   |

# Optimization Possibilities with HTTP 1.1

# Optimizations...

## **Reduce DNS lookups**

Every hostname resolution requires a network roundtrip, imposing latency on the request and blocking the request while the lookup is in progress.

## **Make fewer HTTP requests**

No request is faster than a request not made:  
eliminate unnecessary resources on your pages.

## **Use a Content Delivery Network**

Locating the data geographically closer to the client can significantly reduce the network latency of every TCP connection and improve throughput.



# Optimizations...

## Add an Expires header and configure Etags

An Expires header can be used to specify the cache lifetime of the object, allowing it to be retrieved directly from the user's cache and eliminating the HTTP request entirely.

ETags and Last-Modified headers provide an efficient cache revalidation mechanism—effectively a fingerprint or a timestamp of the last update.

### Response Headers

- . **Access-Control-Allow-Origin:\***
- . **Cache-Control:max-age=604800**
- . **Connection:keep-alive**
- . **Date:Wed, 2 Mar 2016 19:56:34 GMT**
- . **ETag:"~~13630e1-b438-524daace96280~~"**
- . **Expires:Mon, 30 Nov 2015 19:56:34 GMT**
- . **Last-Modified:Thu, 16 Apr 2015 10:26:33 GMT**
- . **Link:https://domain.com/foobar.css**
- . **X-Edge-Location:usch**

# Optimizations...

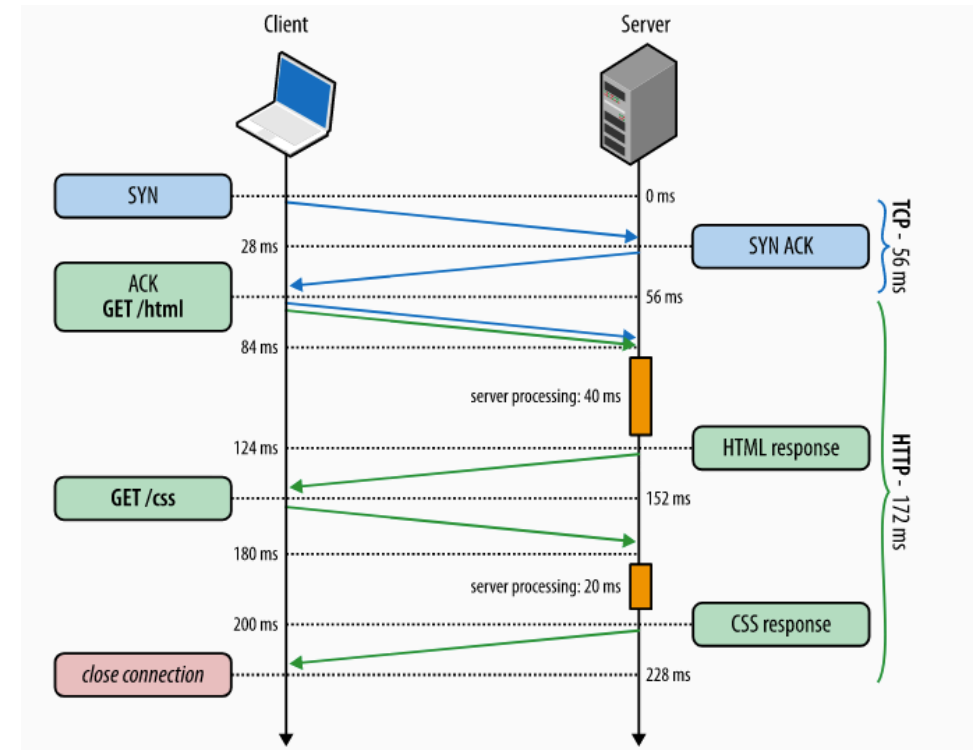
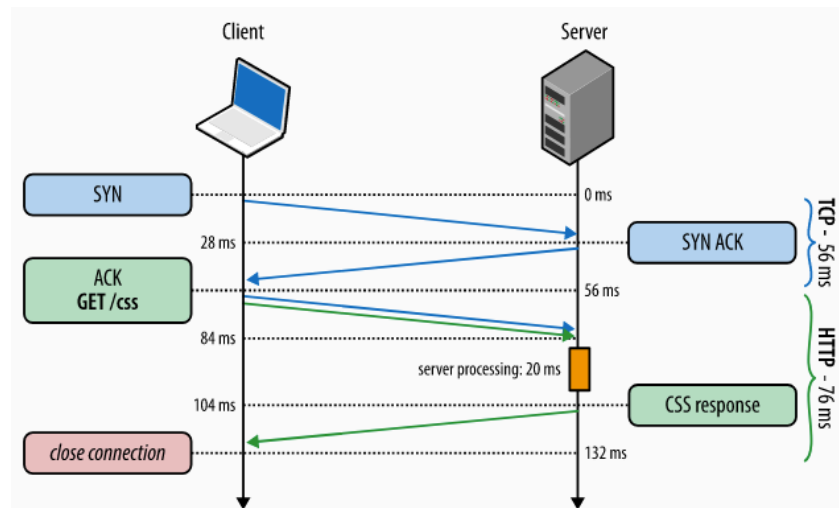
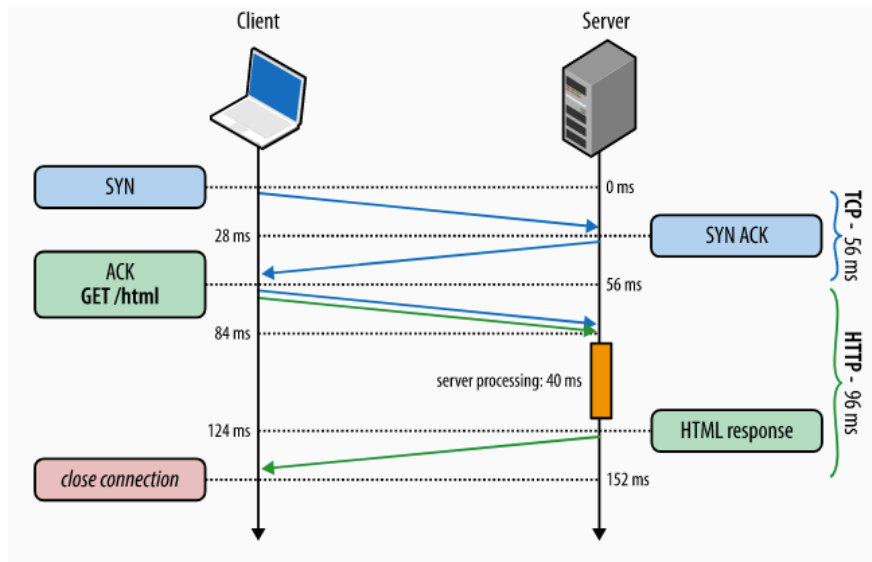
## **Gzip assets**

All text-based assets should be compressed with Gzip when transferred between the client and the server.

On average, Gzip will reduce the file size by 60–80%, which makes it one of the simpler (configuration flag on the server) and high-benefit optimizations you can do.

## **Avoid HTTP redirects**

HTTP redirects can be extremely costly, especially when they redirect the client to a different hostname, which results in additional DNS lookup, TCP connection latency, etc.



# Using Keep-Alive

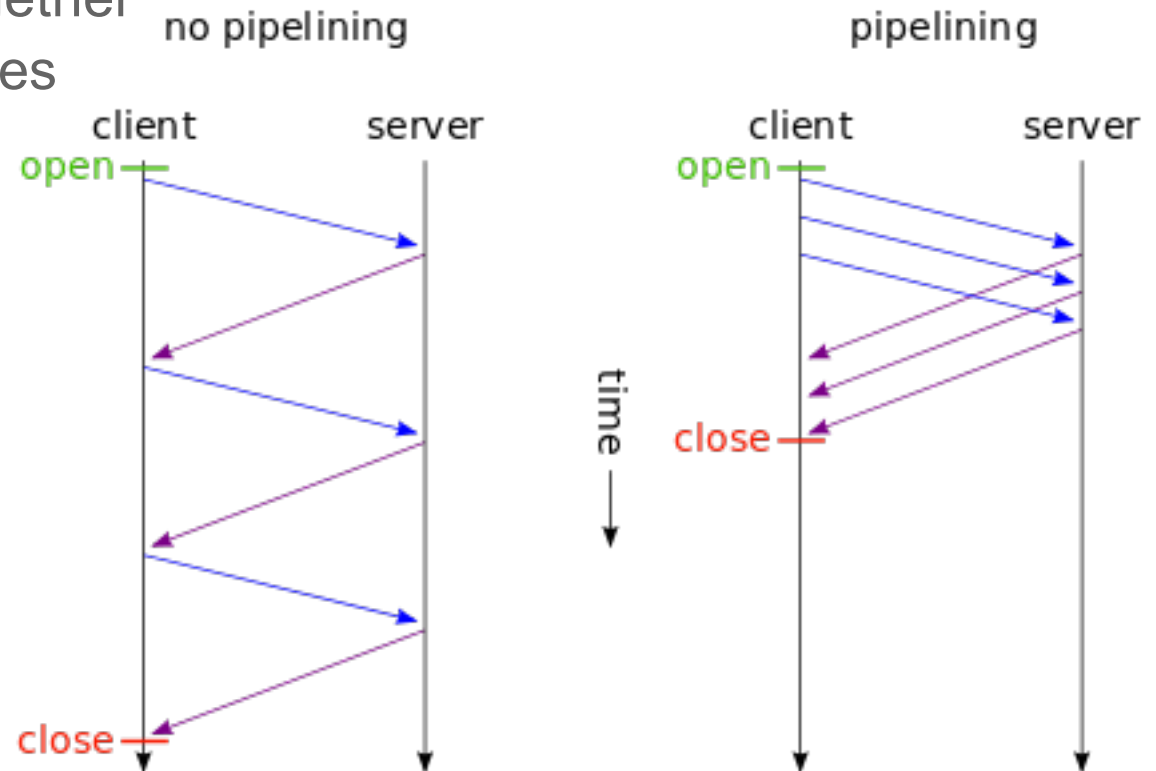
# Keep Alive-Pipelining

Using a single connection to send multiple successive requests

Pipelining Requests

Send several requests together

Head of line blocking issues



# Keep-alive + pipelining

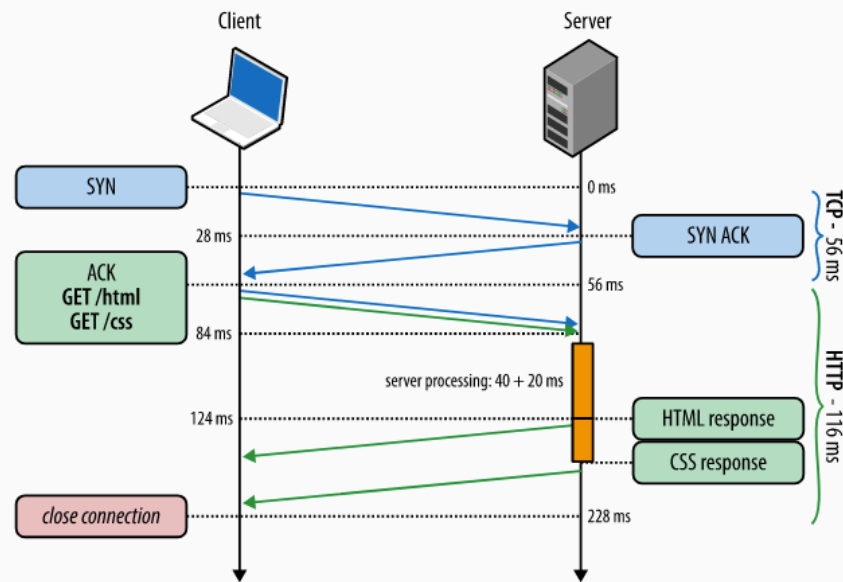


Figure 11-3. Pipelined HTTP requests with server-side FIFO queue

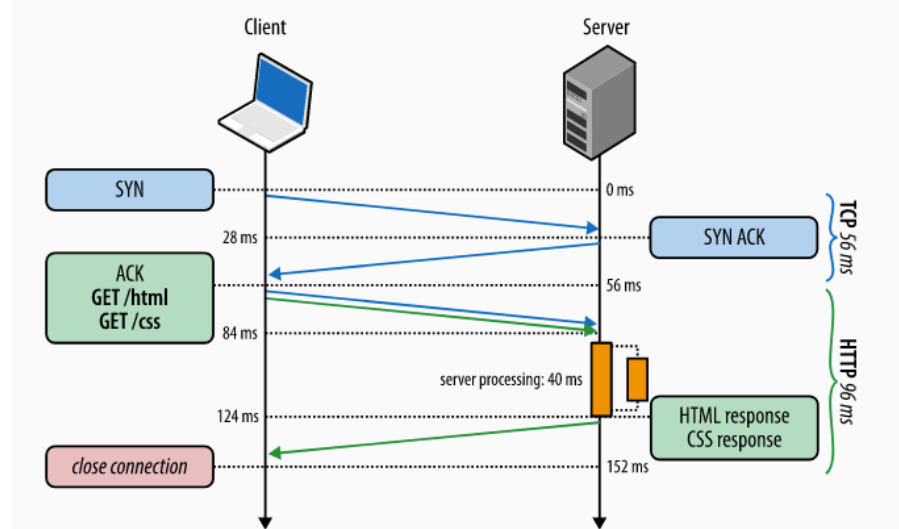


Figure 11-4. Pipelined HTTP requests with parallel processing

# Keep Alive-Pipelining

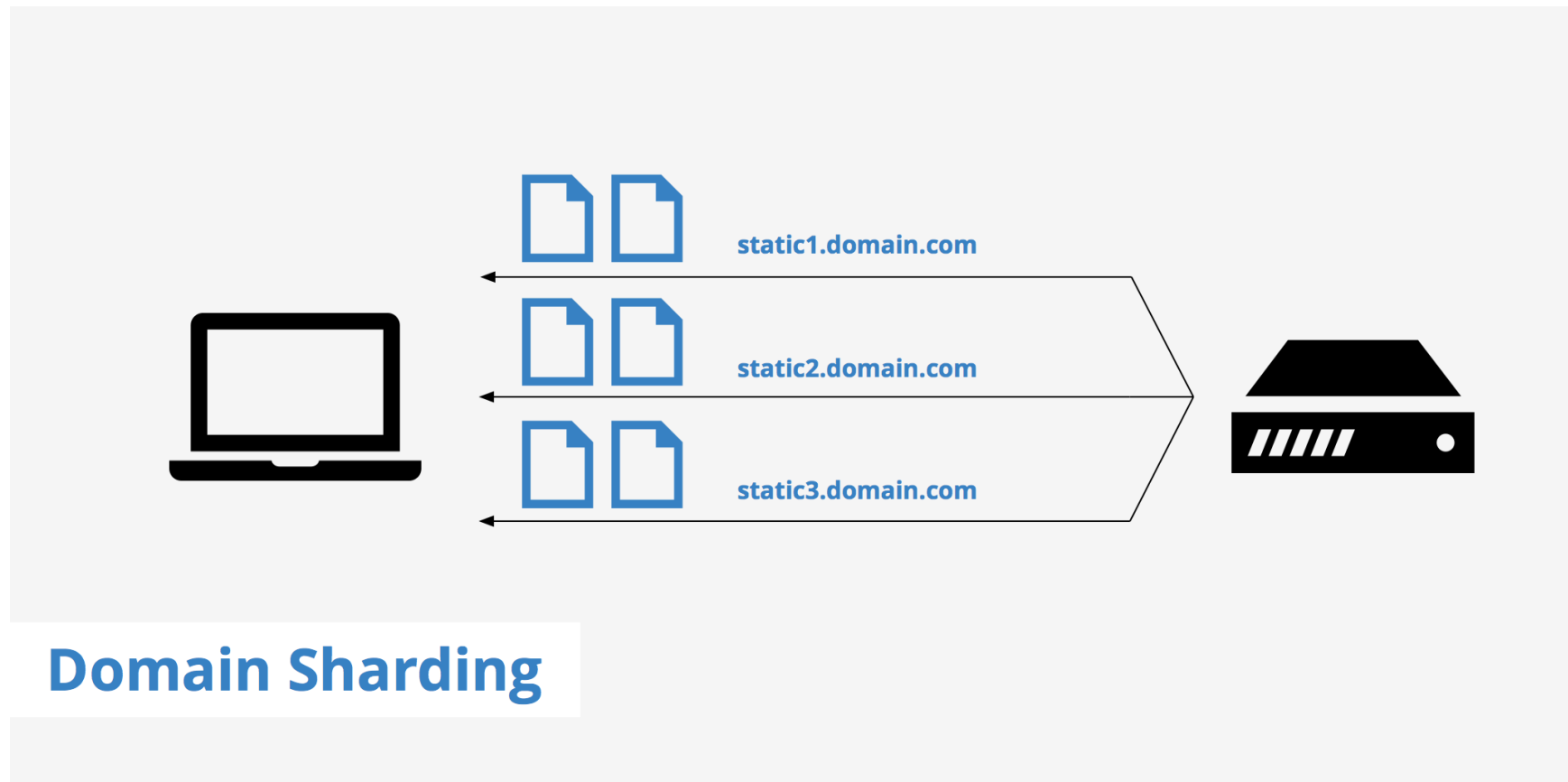
The pipelining of requests results in **a dramatic improvement] in the loading times of HTML pages**, especially over high latency connections such as satellite Internet connections.

The speedup is less apparent on broadband connections, as the limitation of HTTP 1.1 still applies: **the server must send its responses in the same order that the requests were received — so the entire connection remains first-in-first-out and Head Of Line blocking can occur.**

# Domain sharding

- Web browsers traditionally place limits on the amount of concurrent downloads allowed for each domain (between 2-16). This limit was put in place by the Internet Engineering Task Force and is mentioned in the HTTP/1.1 specification. It was recommended in order to reduce Internet congestion and web server overloading.

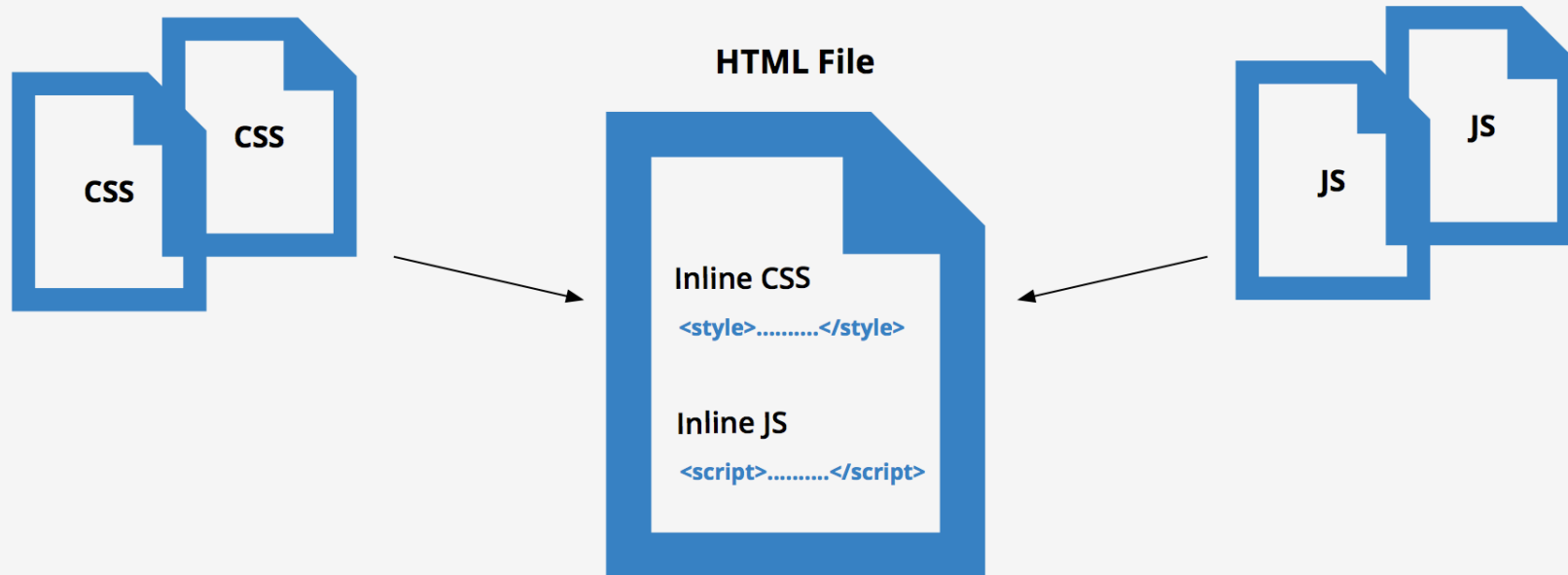
# Domain sharding





# Inlining

- Inline Small CSS and Javascript



**Inline Small CSS and Javascript**

# Spriting

- Multiple images are combined into a larger, composite image.

## **Concatenating files (JavaScript, CSS)**

- Reduces number of downloads and latency overhead
- Less modular code and expensive cache invalidations (e.g. app.js)
- Slower execution (must wait for entire file to arrive)

## **• Spriting images**

- Reduces number of downloads and latency overhead
- Painful and annoying preprocessing and expensive cache invalidations
- Have to decode entire sprite bitmap - CPU time and memory

## **• Domain sharding**

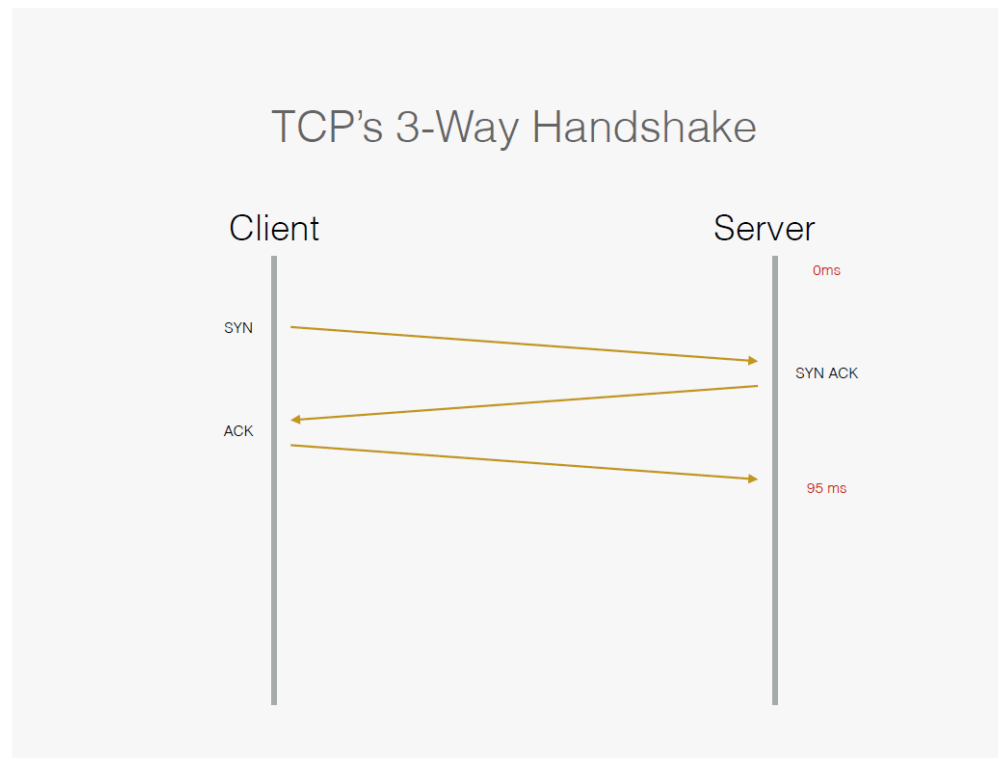
- TCP Slow Start? Browser limits, Nah... 15+ parallel requests -- *Yeehaw!!!*
- Causes congestion and unnecessary latency and retransmissions

## **• Resource inlining**

- Eliminates the request for small resources
- Resource can't be cached, inflates parent document
- 30% overhead on base64 encoding

# The culprit is HTTP on TCP

Http 1.1 chatty - TCP is not made for chatty protocols  
TCP has slow start and head of line blocking



Most HTTP transfers are short and bursty, whereas TCP is optimized for long-lived, bulk data transfers

# SPDY

an experimental protocol, developed at Google and announced in mid-2009

primary goal: to try to reduce the load latency of web pages

- Target a 50% reduction in page load time (PLT).
- Avoid the need for any changes to content by website authors.
- Minimize deployment complexity, avoid changes in network infrastructure.
- Develop this new protocol in partnership with the open-source community.
- Gather real performance data to (in)validate the experimental protocol.

*"a protocol designed for **low-latency transport of content** over the World Wide Web"*

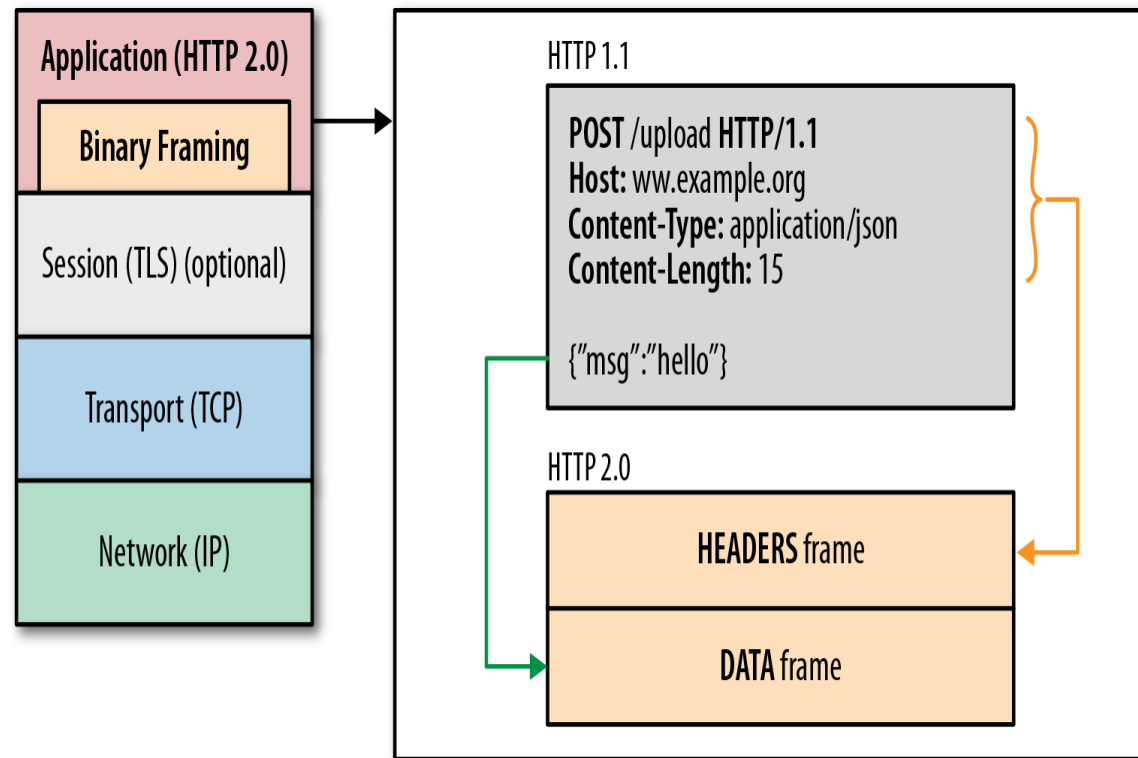
- Improve end-user perceived latency
- Address the "head of line blocking"
- Not require multiple connections
- Retain the semantics of HTTP/1.1

**HTTP 2.0**  
**goals**



# HTTP 2.0 in a nutshell

- One TCP connection
- Request = Stream
  - Streams are multiplexed
  - Streams are prioritized
- (New) binary framing layer
  - Prioritization
  - Flow control
  - Server push
- Header compression



*“... **we’re not replacing all of HTTP** — the methods, status codes, and most of the headers you use today will be the same. Instead, **we’re re-defining how it gets used “on the wire” so it’s more efficient**, and so that it is more gentle to the Internet itself ....”*

- Mark Nottingham  
(chair)





# All frames have a common 8-byte header

| Bit | +0..7         |                   | +8..15 | +16..23 | +24..31 |
|-----|---------------|-------------------|--------|---------|---------|
| 0   | Length        |                   |        | Type    | Flags   |
| 32  | R             | Stream Identifier |        |         |         |
| ... | Frame Payload |                   |        |         |         |

- Length-prefixed frames
- **Type** indicates ...type of frame
  - *DATA, HEADERS, PRIORITY, PUSH\_PROMISE, ...*
- Each frame may have custom **flags**
  - e.g. *END\_STREAM*
- Each frame carries a **31-bit stream identifier**
  - After that, it's frame specific payload...

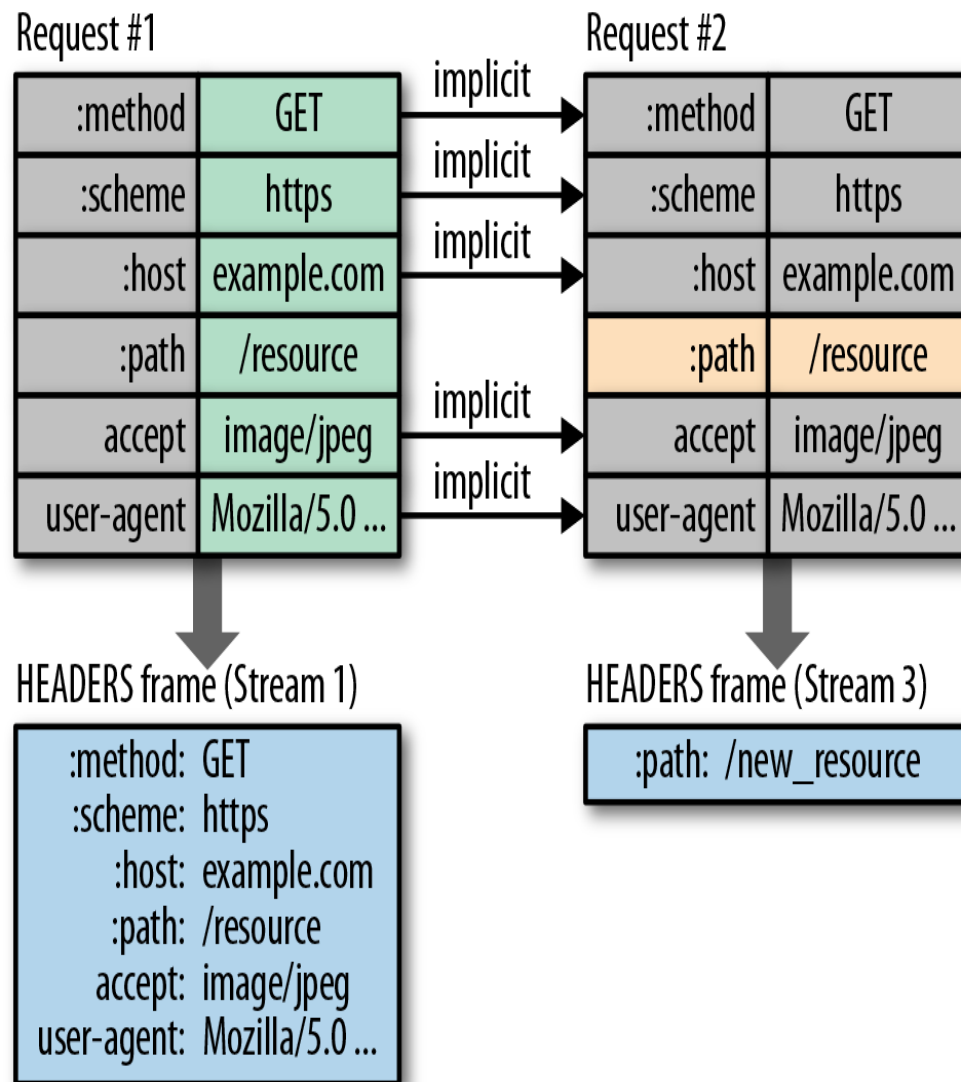
```
frame =  
buf.read(8)  
if  
frame_i_care  
_about  
do_someth  
ing_smart  
else  
buf.skip(fram
```

# Opening a new stream with HTTP 2.0 (HEADERS)

| Bit | +0..7        |                   | +8..15 | +16..23  | +24..31 |
|-----|--------------|-------------------|--------|----------|---------|
| 0   | Length       |                   |        | Type (1) | Flags   |
| 32  | R            | Stream Identifier |        |          |         |
| 64  | X            | Priority          |        |          |         |
| ... | Header Block |                   |        |          |         |

- Common 8-byte header
- Client / server allocate new stream ID
  - *client: odd, server: even*
- Optional 31-bit stream priority field
  - *Flags indicates if priority is present*
  - *2<sup>31</sup> is lowest priority*
- HTTP header payload
  - see [header-compression-01](#)

# HTTP 2.0 header compression (in a nutshell)



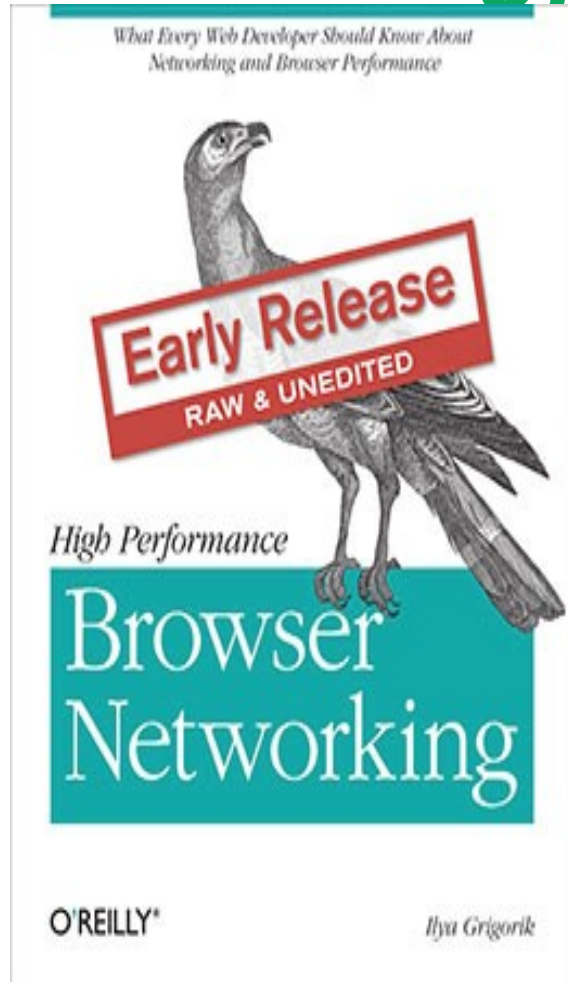
- Each side maintains “header tables”
- Header tables are initialized with common header key-value pairs
- New requests “toggle” or “insert” new values into the table
- New header set is a “diff” of the previous set of headers
- *E.g. Repeat request (polling) with exact same headers incurs no overhead (sans frame header)*

# Sending application data with ...DATA frames.

| Bit | +0..7        |                   | +8..15 | +16..23  | +24..31 |
|-----|--------------|-------------------|--------|----------|---------|
| 0   | Length       |                   |        | Type (0) | Flags   |
| 32  | R            | Stream Identifier |        |          |         |
| ... | HTTP payload |                   |        |          |         |

- Common 8-byte header
- Followed by application data...
- In theory, max-length =  $2^{16}-1$
- To reduce head-of-line blocking: **max frame size is  $2^{14}-1$**  (~16KB)
  - Larger payloads are split into multiple DATA frames, last frame carries "END\_STREAM" flag

*For an in-depth discussion on all  
of the above...*



<http://hpbn.co>

- Optimizing **TCP** server stacks
- Optimizing **TLS** deployments
- Optimizing for **mobile** networks
- HTTP 2.0 features, framing, deployment...
- XHR, SSE, WebSocket, WebRTC, ...