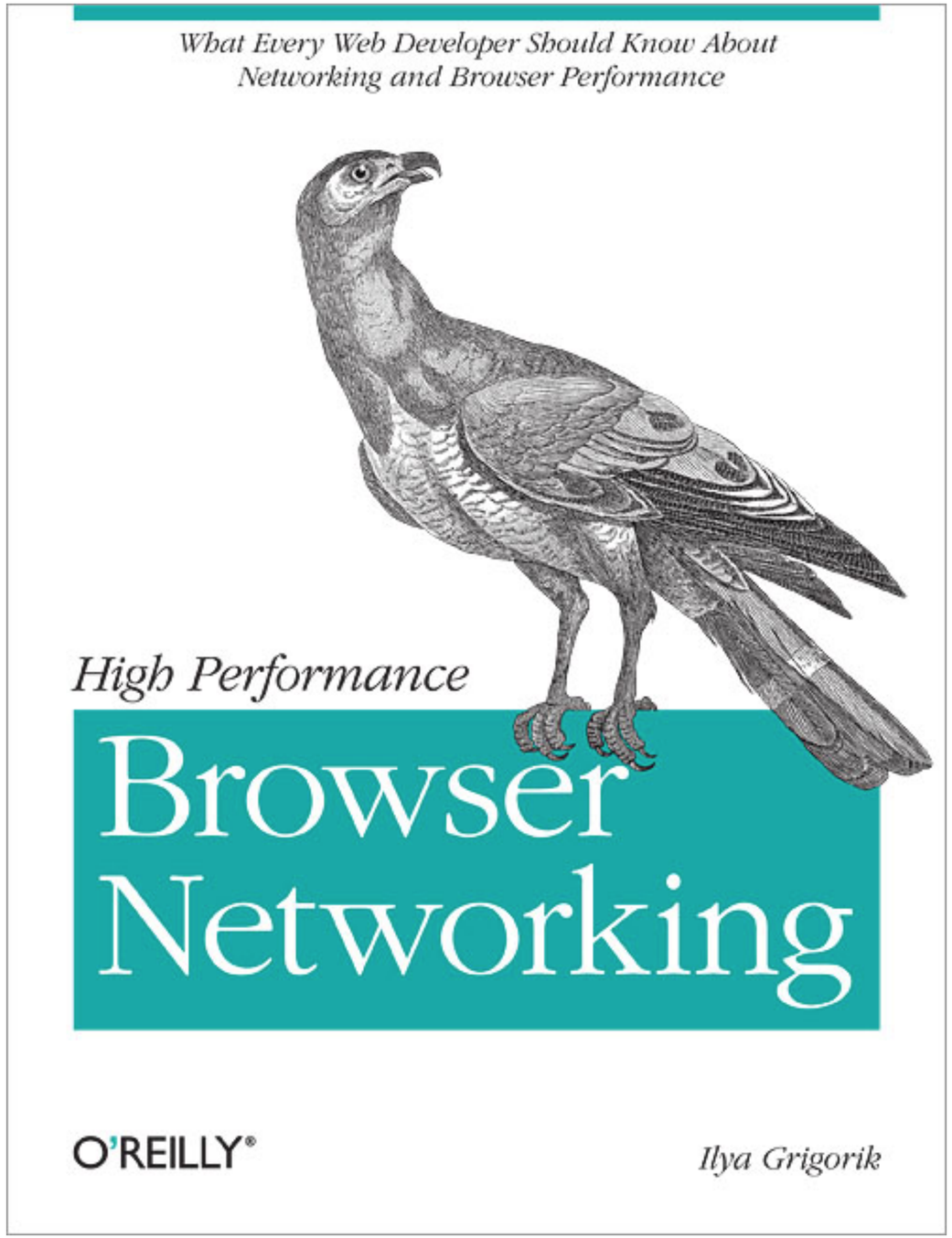
Demystifying SPDY and HTTP/2

Jonathan Klein
@jonathanklein
April 21, 2015

Slides, Links
jkle.in/http2

H/2 == HTTP/2



Figures from this book

About Me

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- Formerly a performance engineer at Etsy

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- Started the Boston Web Perf Meetup Group
- Former CTO at a pre-product startup in Boston
- Planned on launching with HTTPS everywhere and H/2 support

SPDY

Experimental protocol developed at Google

SPDY

Experimental protocol developed at Google

H/2

Official second major version of HTTP, based on SPDY

SPDY's Future, H/2 Status

SPDY's Future, H/2 Status

- H/2 approved by the IETF for publication as standards-track RFCs

SPDY's Future, H/2 Status

- H/2 approved by the IETF for publication as standards-track RFCs

- Chrome removing SPDY support in 2016

mnot's blog

"Design depends largely on constraints." — Charles Eames

Wednesday, 18 February 2015

HTTP/2 is Done

The IESG has formally approved the HTTP/2 and HPACK specifications, and they're on their way to the RFC Editor, where they'll soon be assigned RFC numbers, go through some editorial processes, and be published.

We should have an official entry about this up soon over at the IETF blog, but I want to recognise a few people specifically:

- Mike Belshe and Roberto Peon brought SPDY to the IETF to standardise it. While a few have painted Google as forcing the protocol upon us, anyone who actually interacted with Mike and Roberto in the group knows that they came with the best of intent, patiently explaining the reasoning behind their design, taking in criticism, and working with everyone to evolve the protocol. Roberto also served alongside Herve Ruellan as editor of HPACK, after they merged their competing proposals for header compression.
- Martin Thomson is a fantastic editor, and we couldn't have had such a high-quality document (read the IESG reviews) without his tireless work.
- Barry Leiba is our Area Director and supported this work within the IESG, doling out wisdom and advice to me along the way.

Hi, I'm Mark Nottingham. I currently chair the IETF HTTP Working Group and am a member of the W3C TAG. I usually write here about the Web, protocol design, HTTP, and caching. Once in a while, I'll write about economics, travel or living in Australia. Find out more.

Follow @mnot 4,590 followers

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HTTP/2 protocol / SPDY - OTHER

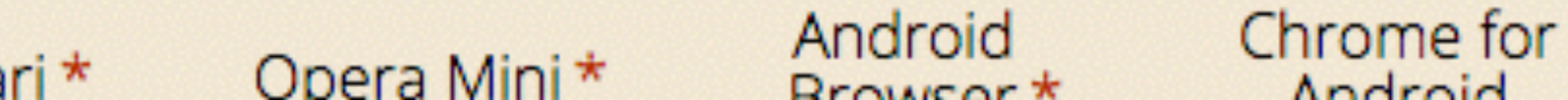
Global 72.15% + 7.98% = 80.13%

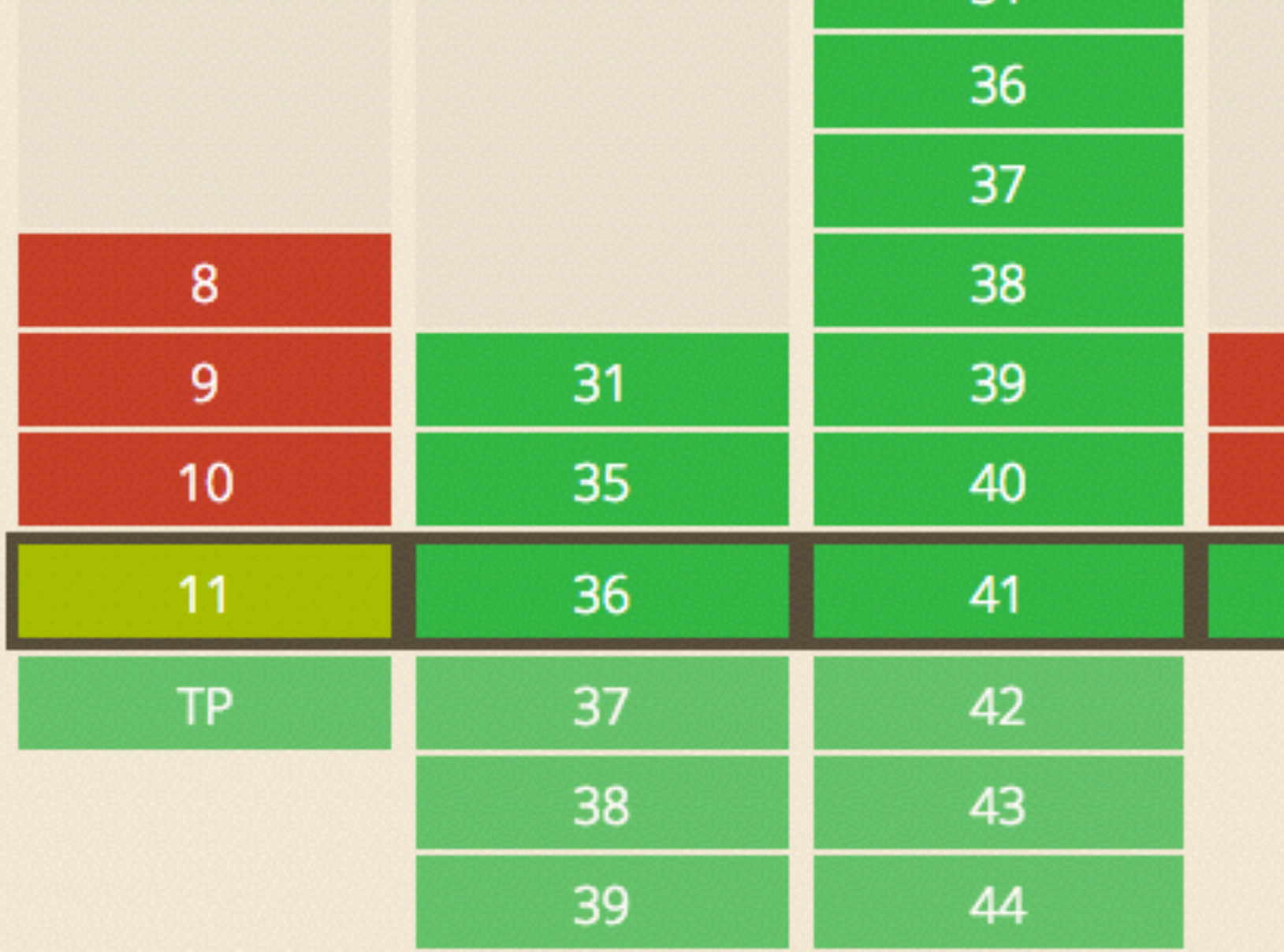
Networking protocol for low-latency transport of content over the web. Originally started out from the SPDY protocol, now standardized as HTTP version 2.

Current aligned | Usage relative | Show all

IE	Firefox	Chrome	Safari	Opera	iOS Safari *	Opera Mini *	Android Browser *	Chrome for Android
		31					4.1	
		36					4.3	
		37					4.4	
8		38					4.4.4	
9	31	39	7		7.1			
10	35	40	7.1					
11	36	41	8	27	8.1	8	37	41
TP	37	42		28				
	38	43		29				
	39	44						

Global	72.15%	+ 7.98% =	80.13%




36
37
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TP
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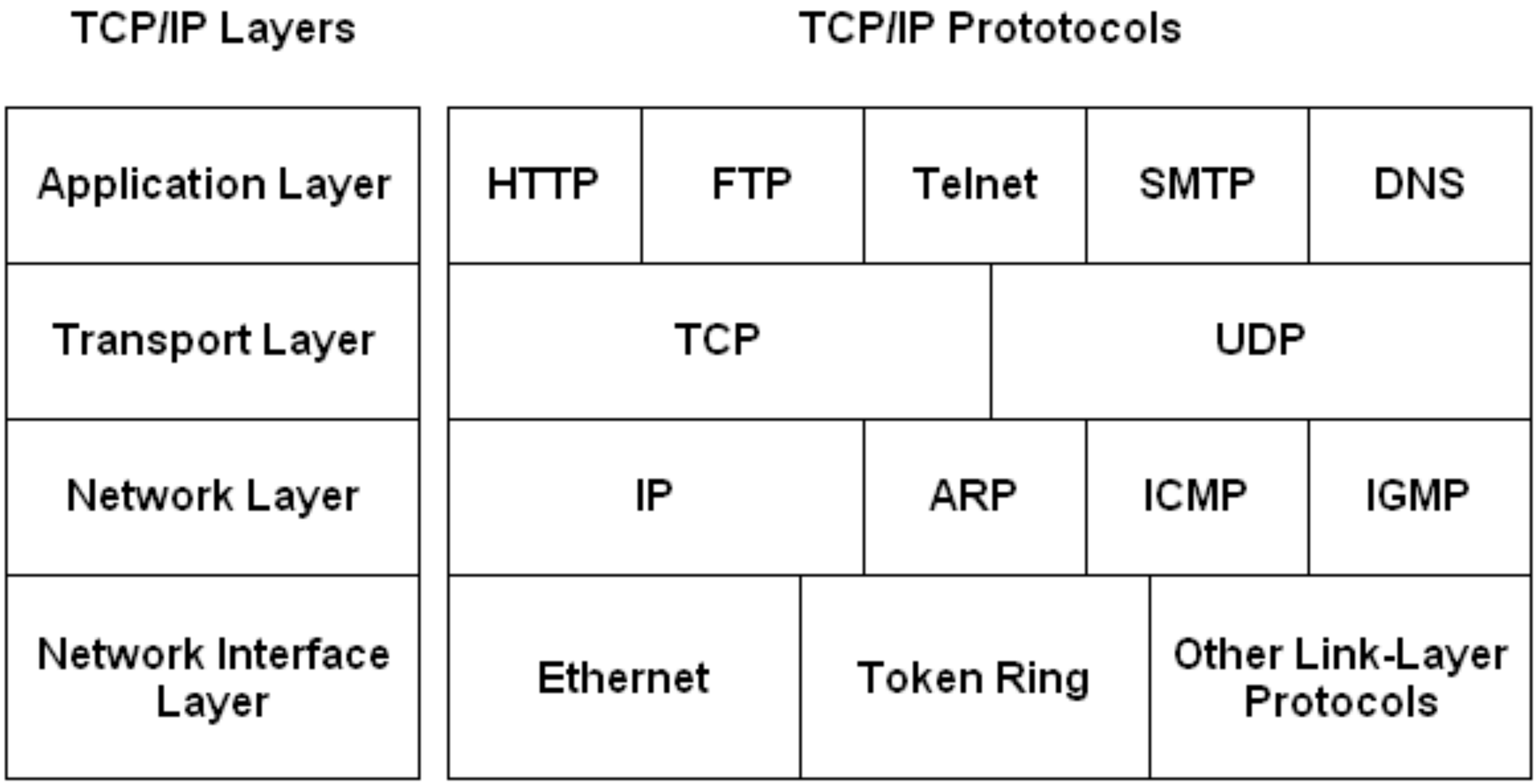
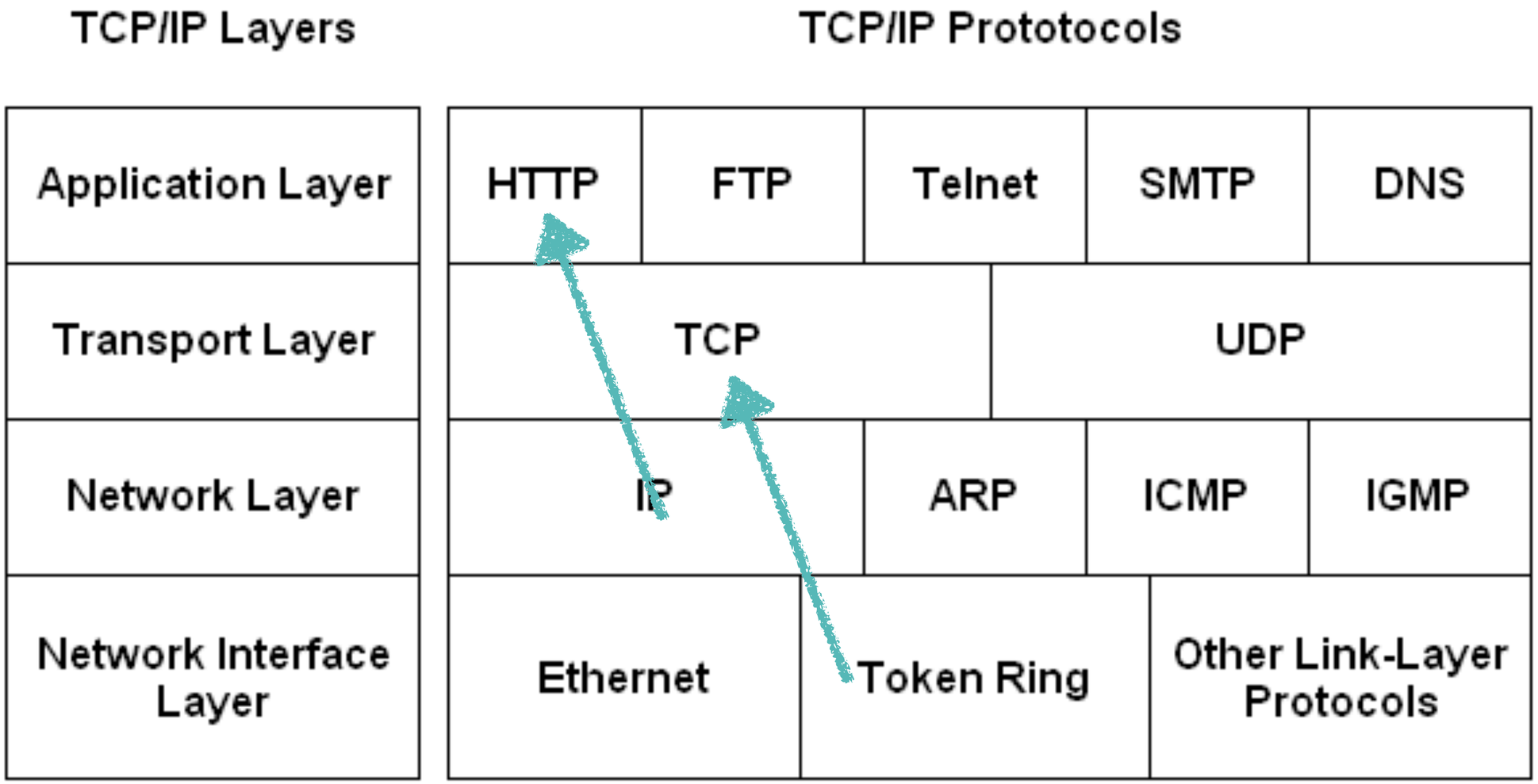
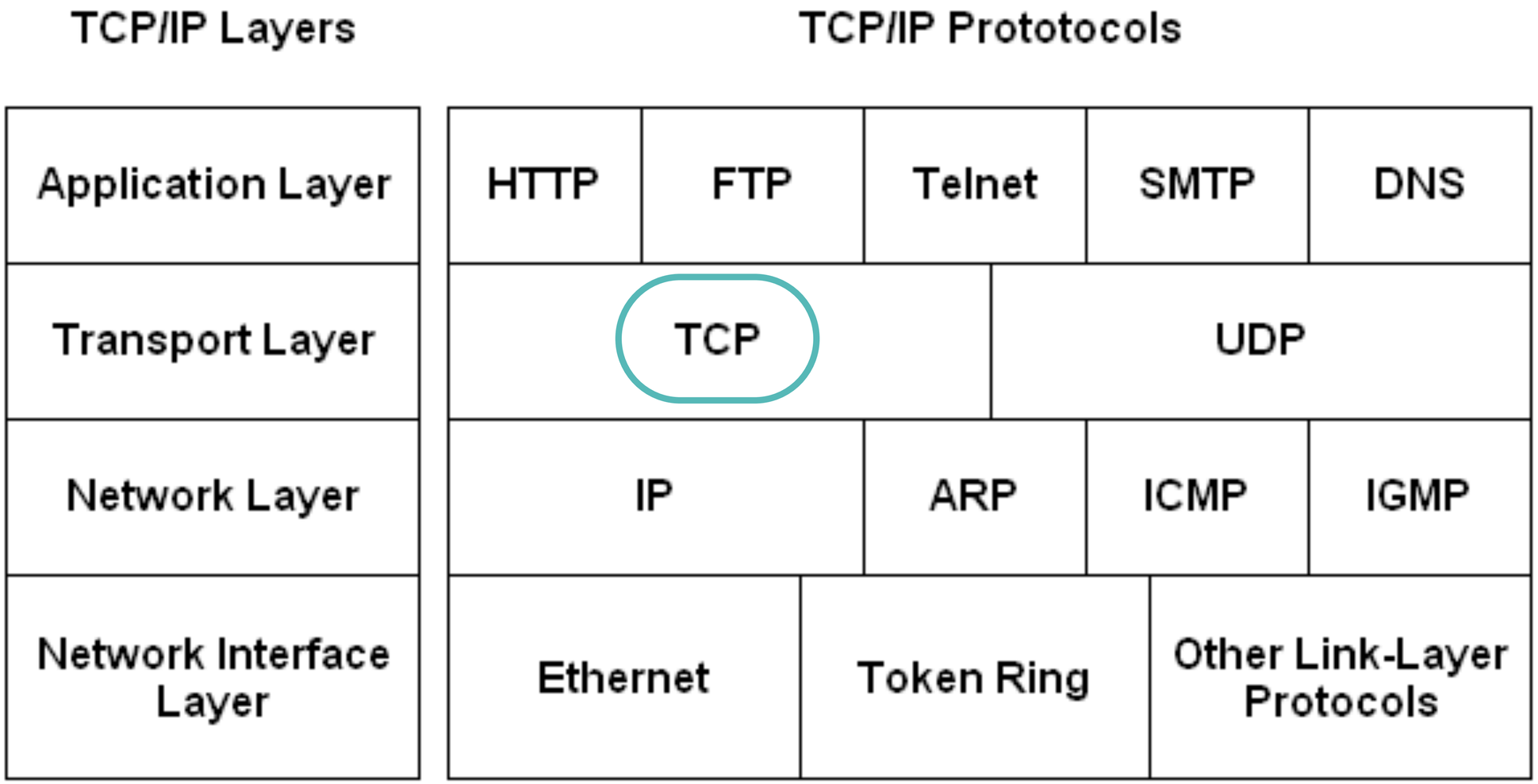
TCP/IP Network Model



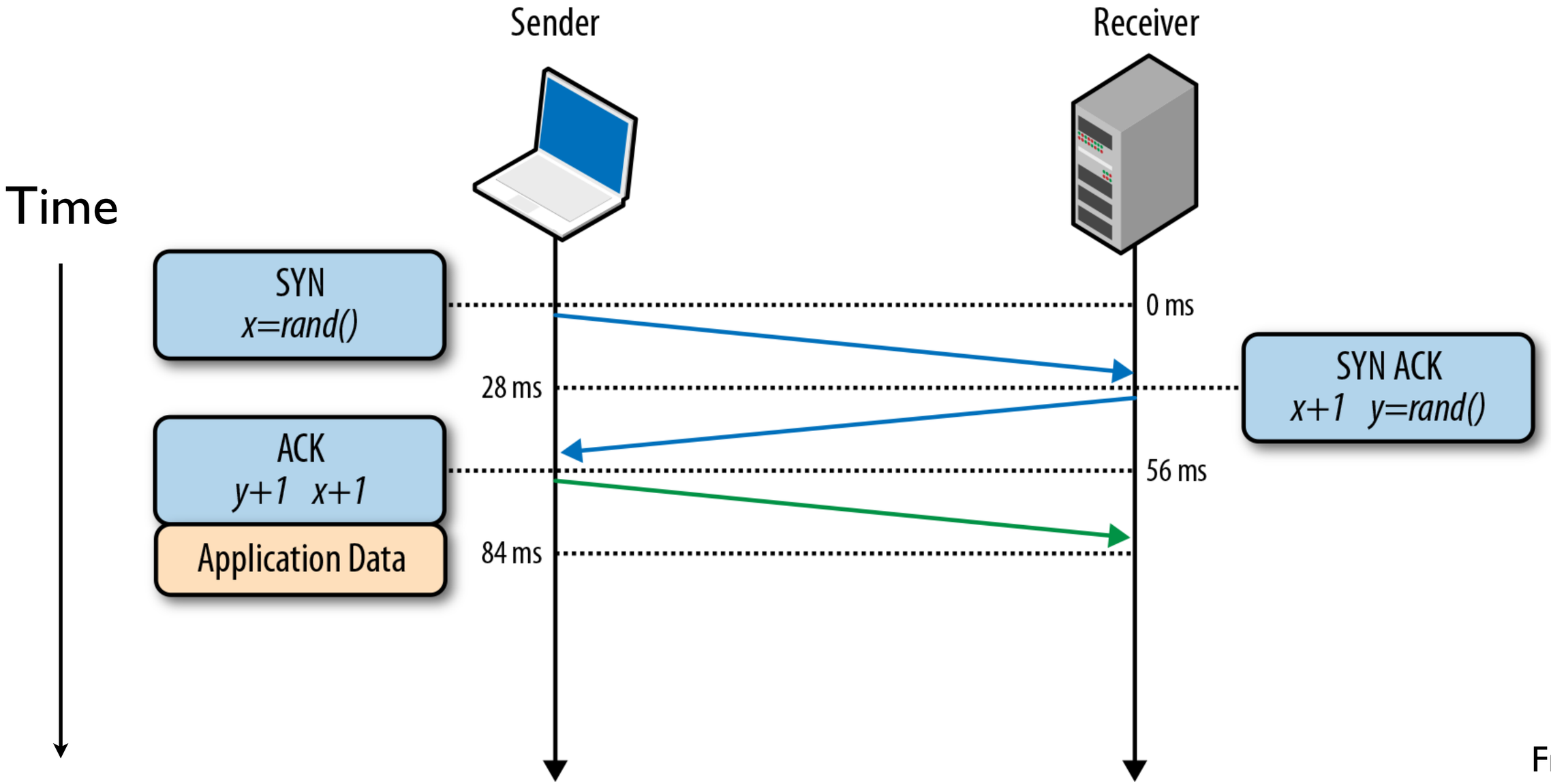
TCP/IP Network Model



TCP/IP Network Model

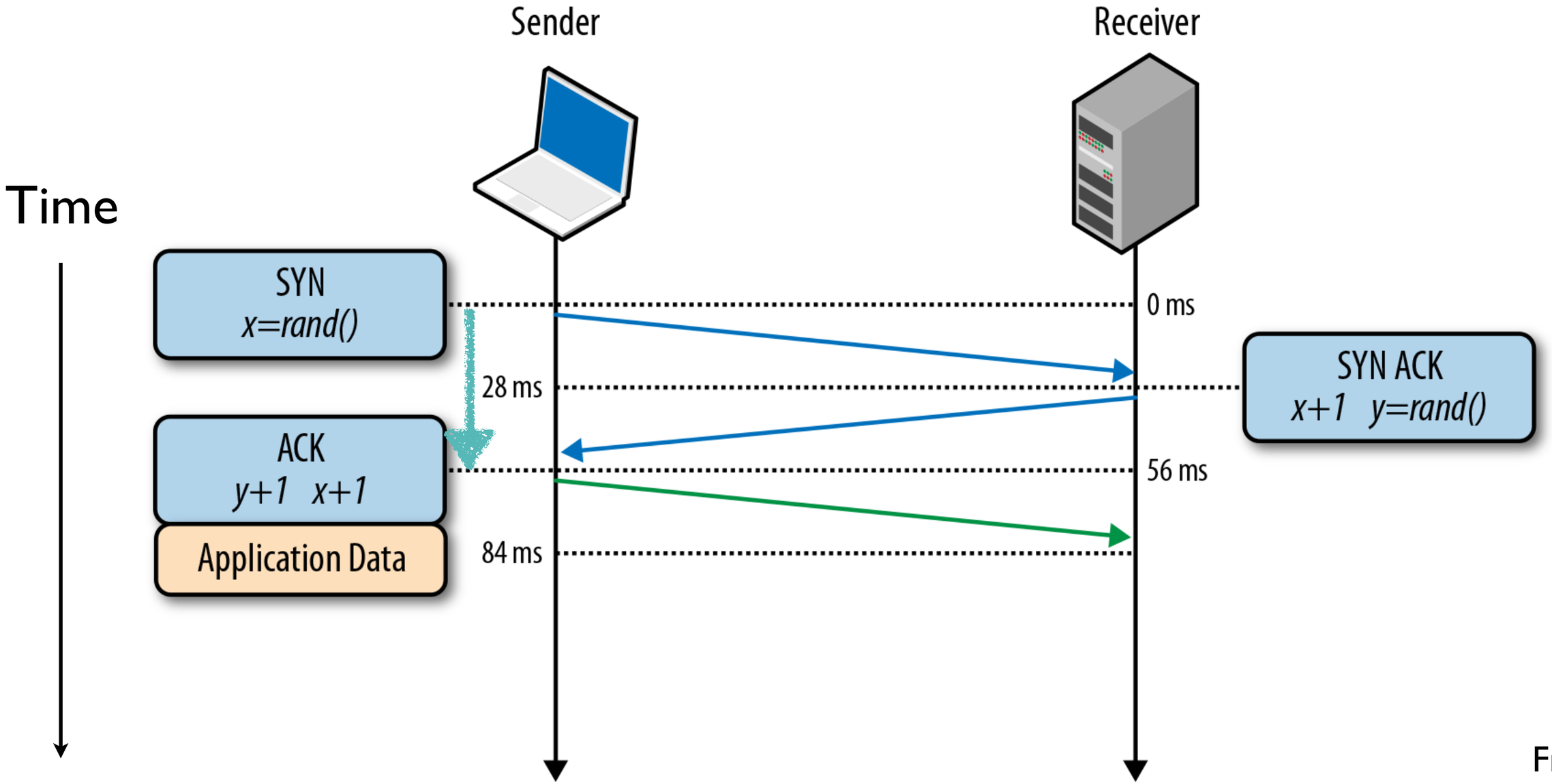


TCP Three Way Handshake

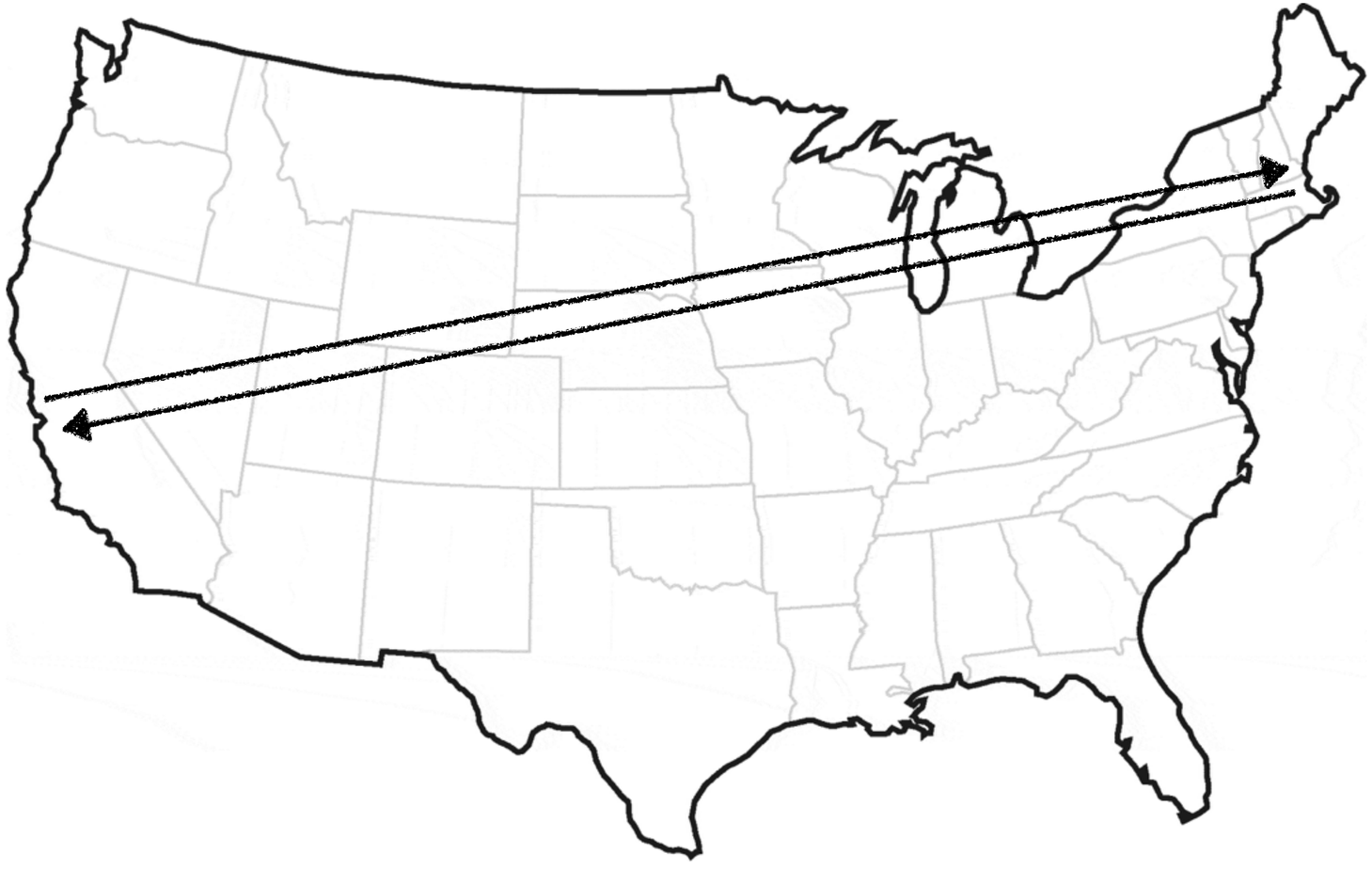


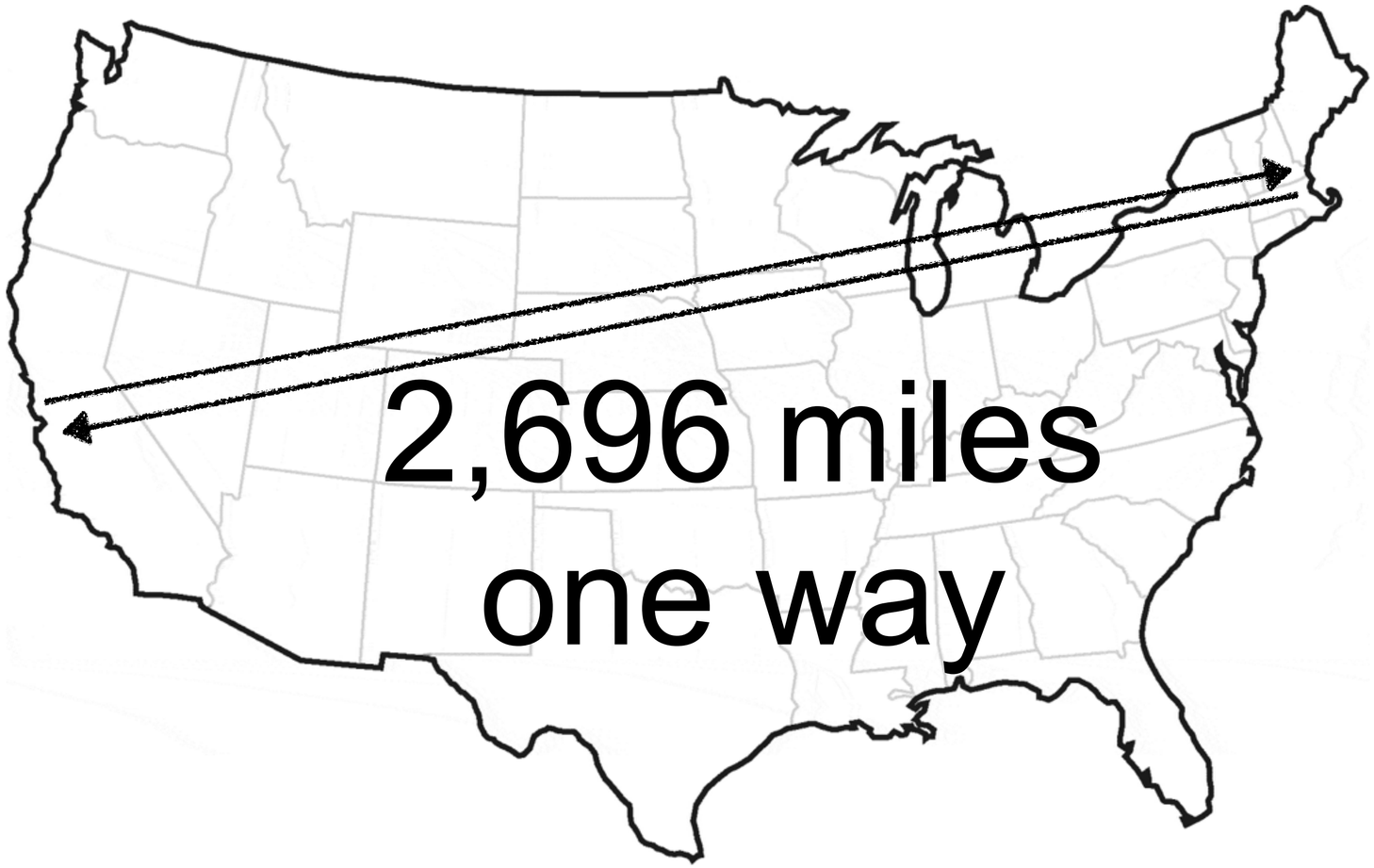
From HPBN

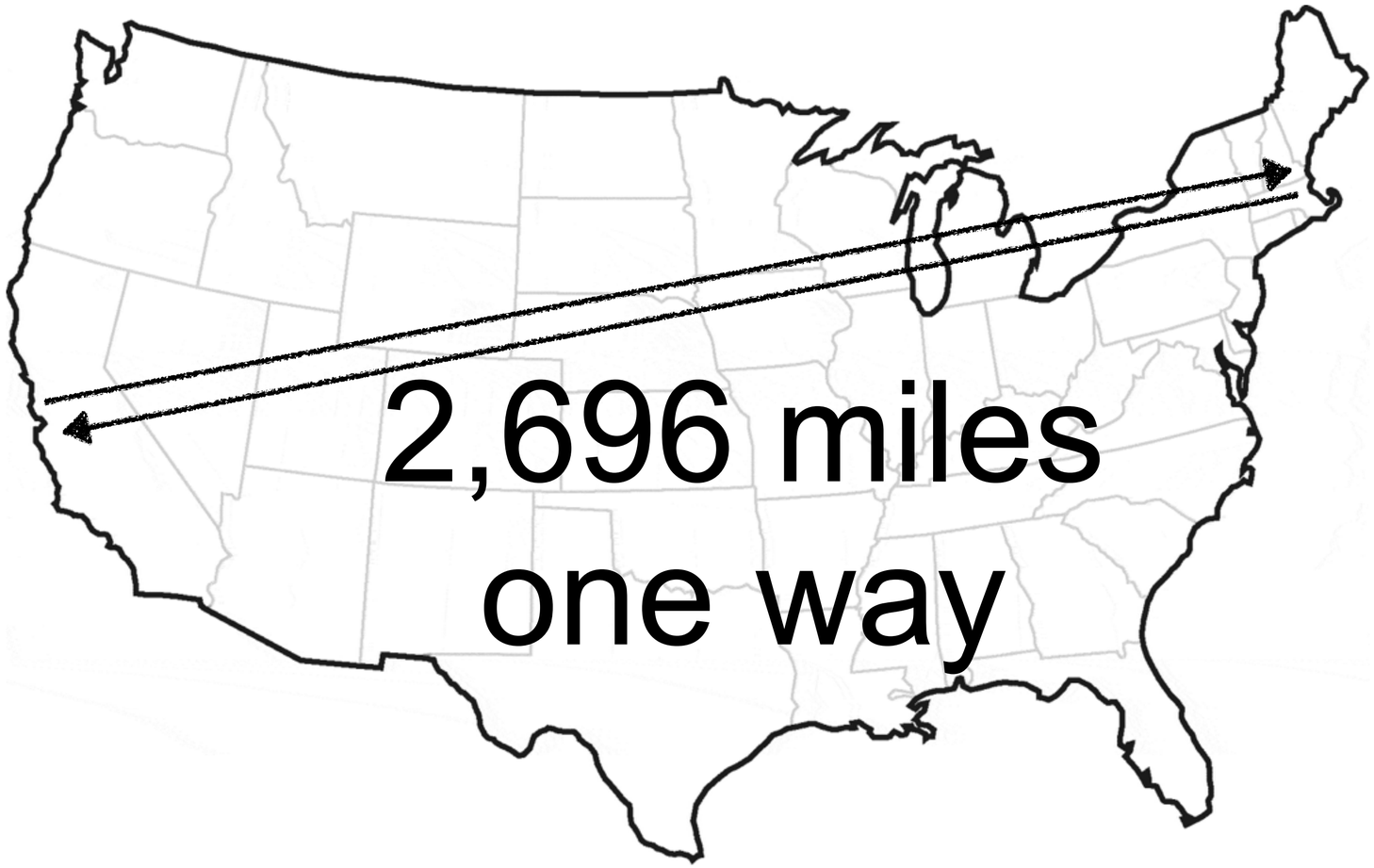
TCP Three Way Handshake



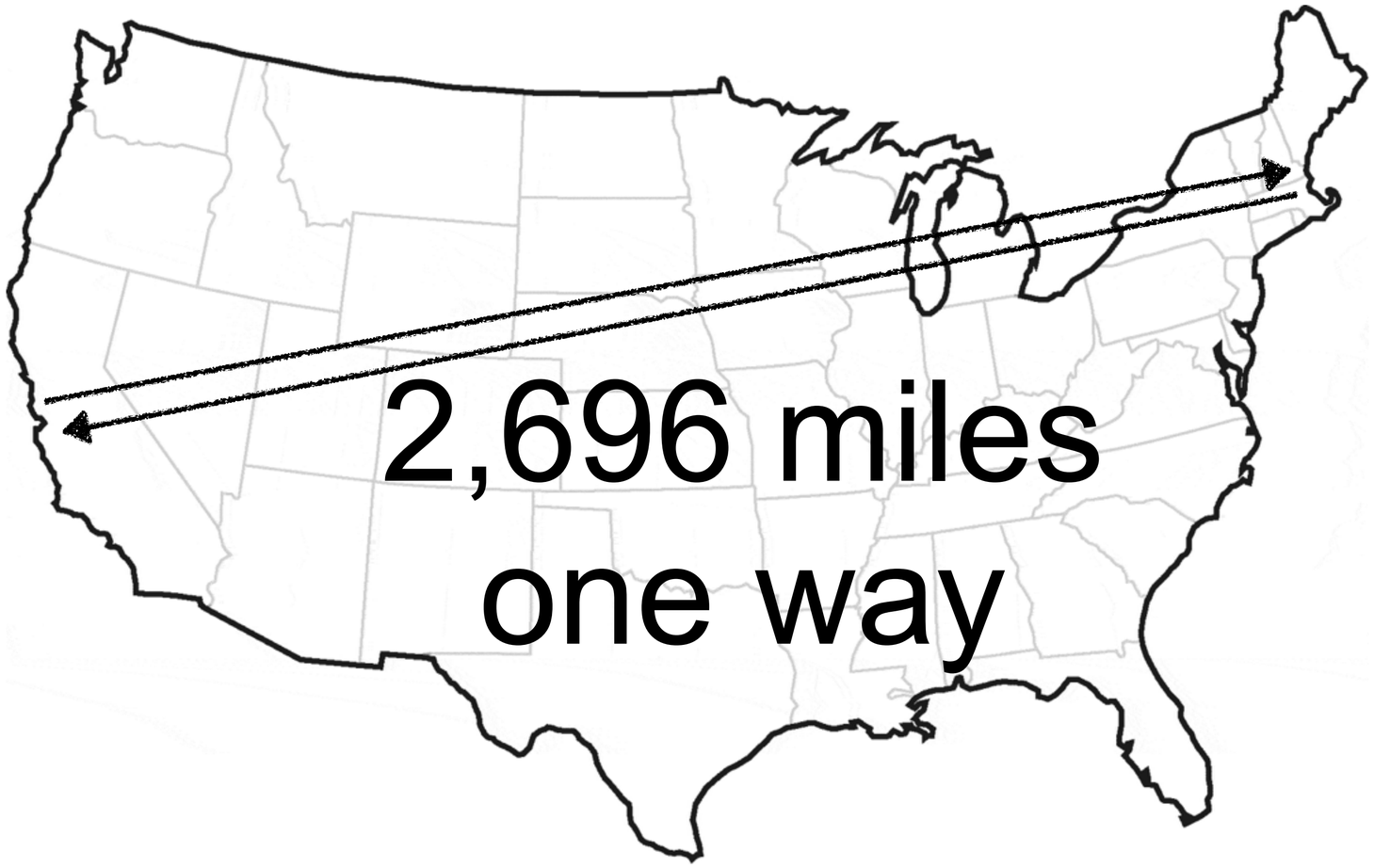
From HPBN




2,696 miles
one way



Speed of Light = 186,000 miles / sec

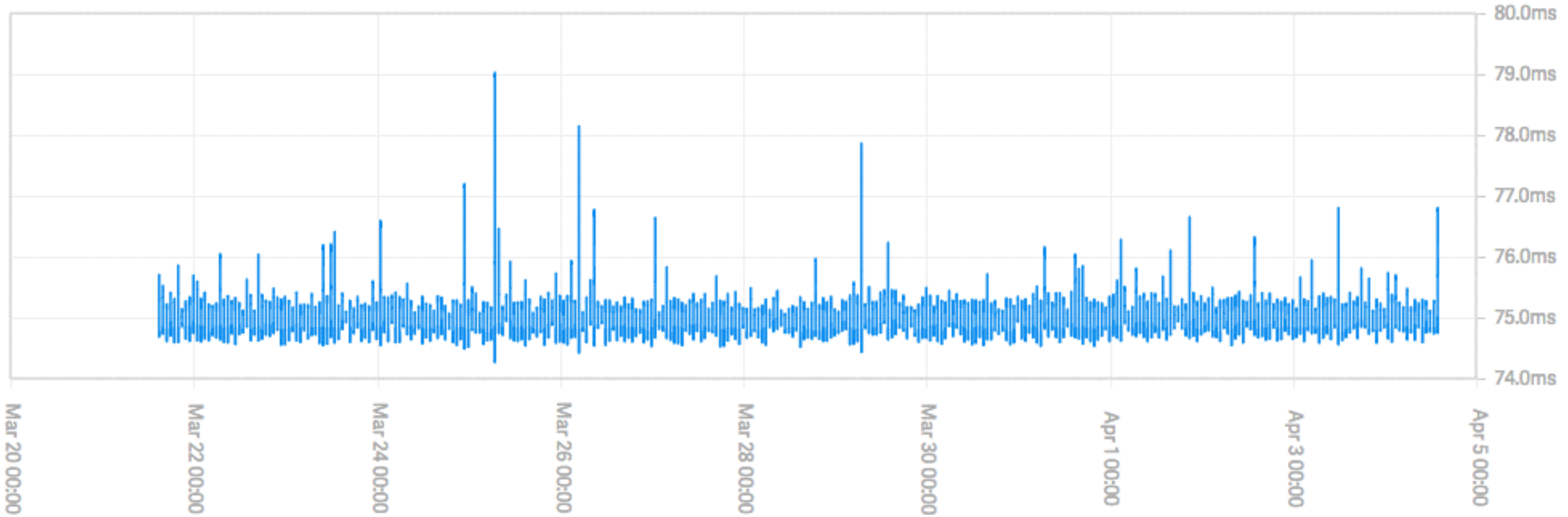


Speed of Light = 186,000 miles / sec

Assumed RTT = 28ms

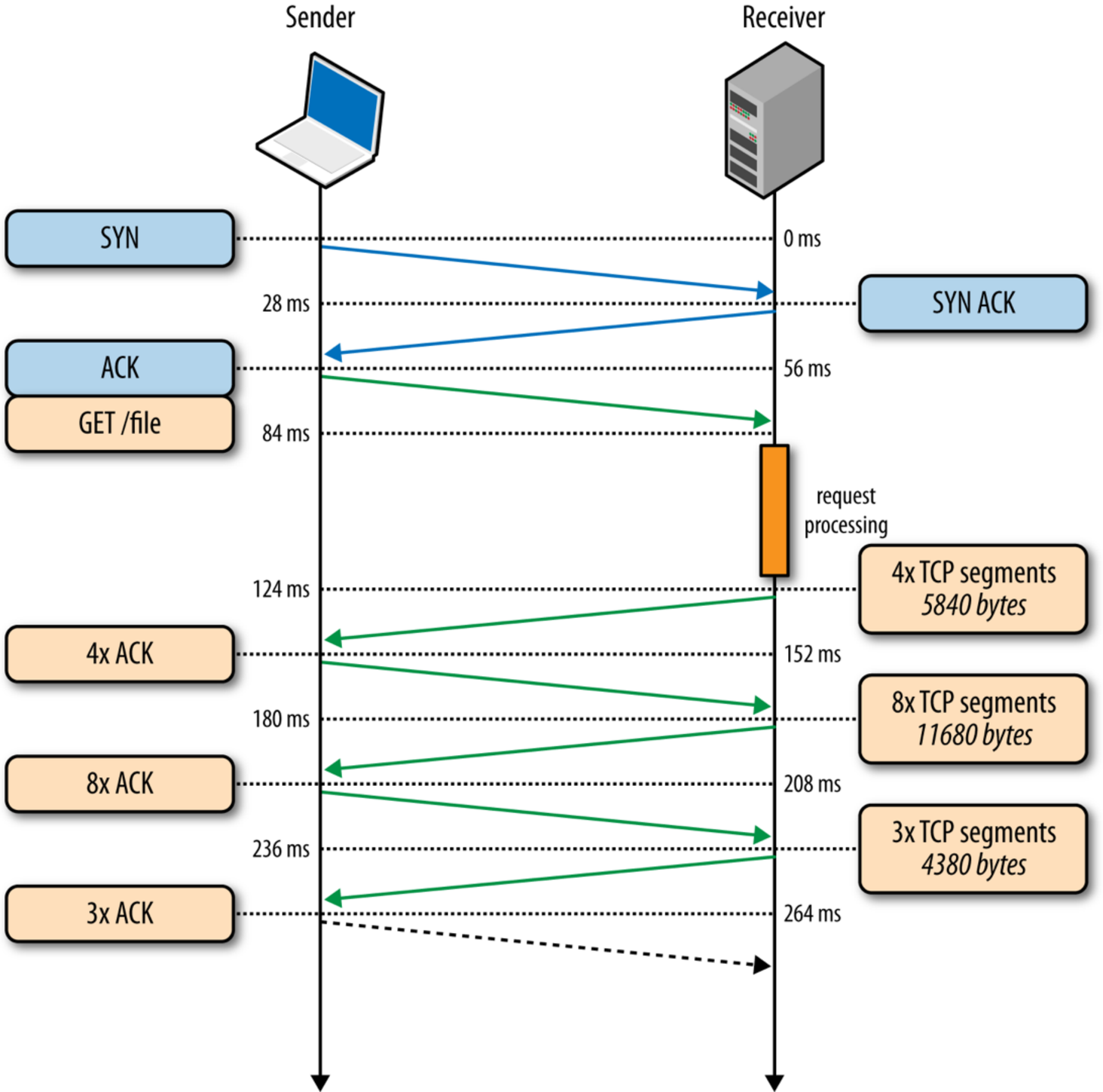
Global Ping Statistics → Boston and San Francisco

Showing historical ping data between major cities. Bar shows Average ± Median Deviation.



Actual RTT ~ 75ms

TCP SLOW START


Sender
Receiver
SYN
0 ms
28 ms
SYN ACK
ACK
56 ms
GET /file
84 ms
request
processing
4x TCP segments
5840 bytes
124 ms
4x ACK
152 ms
8x TCP segments
11680 bytes
180 ms
8x ACK
208 ms
3x TCP segments
4380 bytes
236 ms
3x ACK
264 ms

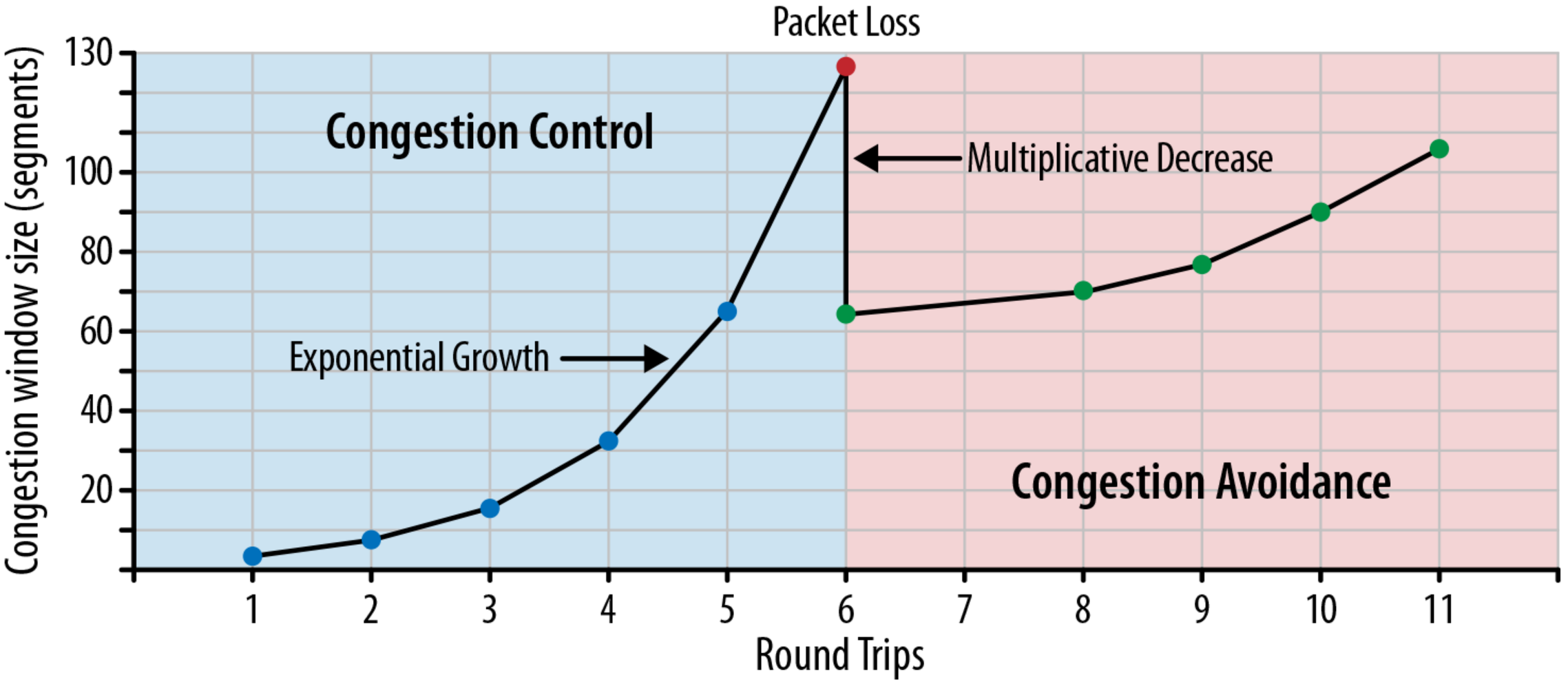
From HPBN

Congestion Collapse

“This condition is stable. Once the saturation point has been reached, if the algorithm for selecting packets to be dropped is fair, the network will continue to operate in a degraded condition.”

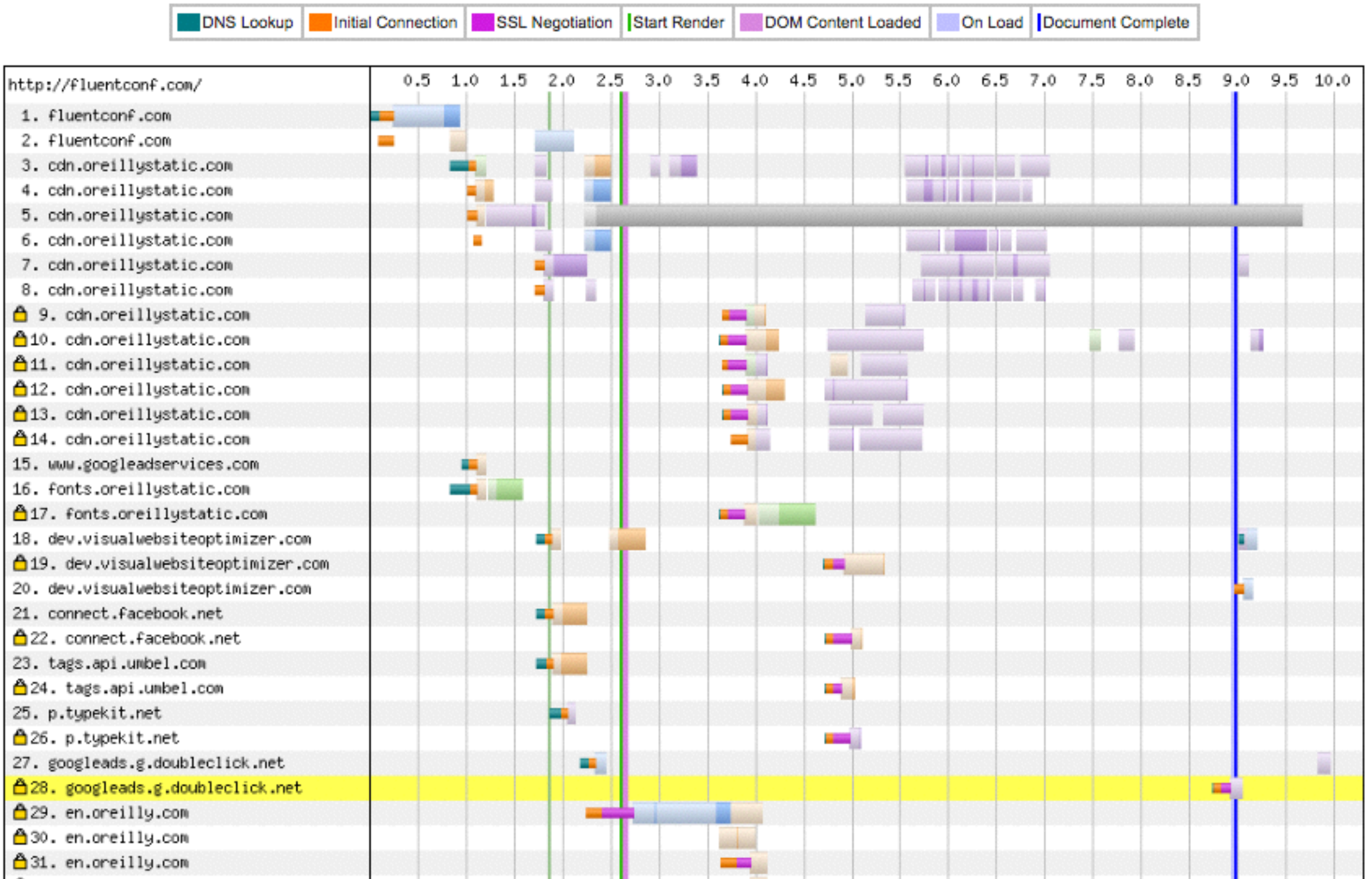
- RFC 896

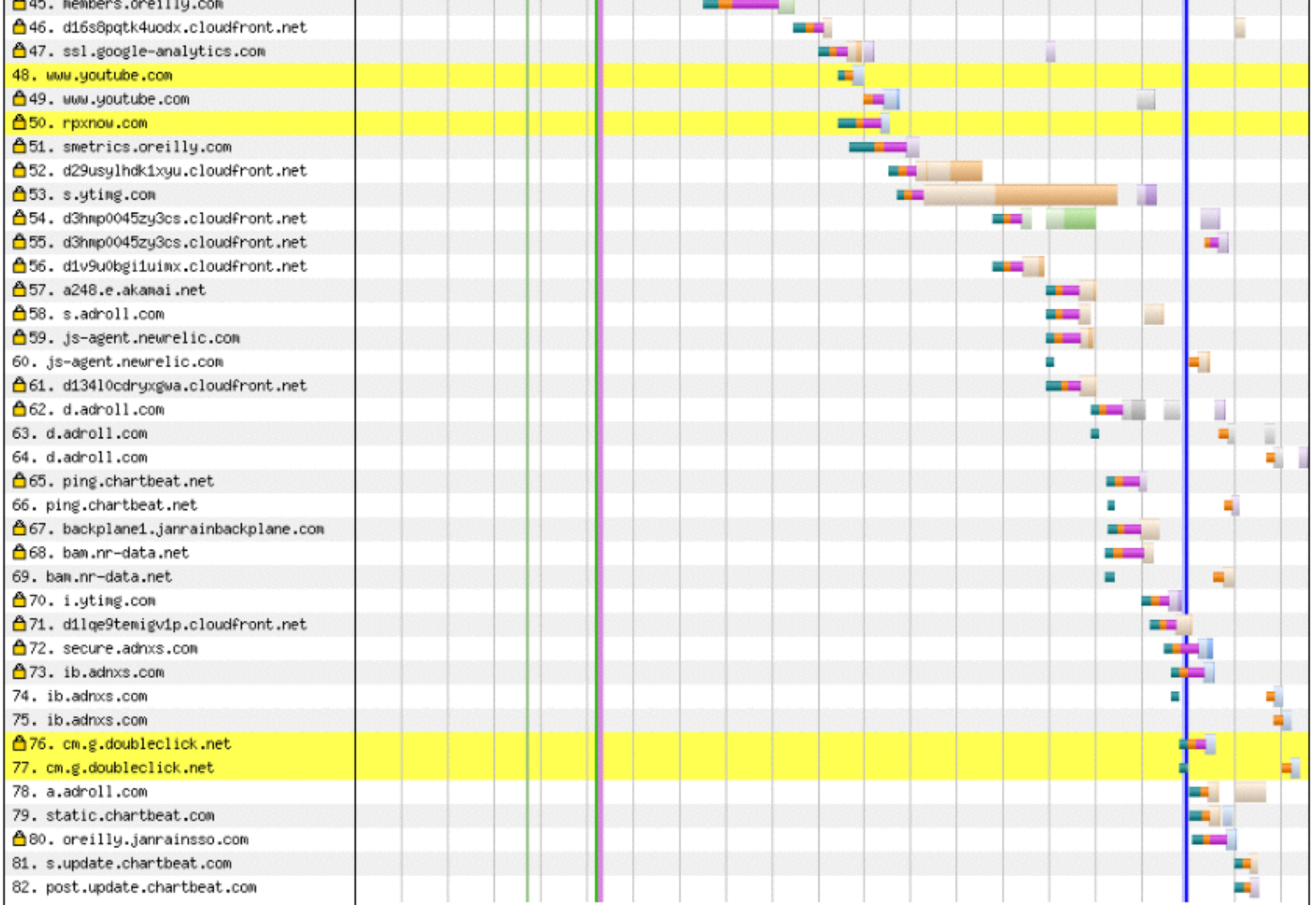
GEORGE BRAZIL
Plumbing · Heating
Air Conditioning
SERVING YOUR COMMUNITY
24 HRS. A DAY
TIP
TRANSPORT INTERNATIONAL POOL
TRAILER
RENTAL
Motor Cargo
SOUTH
5


Packet Loss
Congestion Control
Multiplicative Decrease
Exponential Growth
Congestion Avoidance
Congestion window size (segments)
130
100
80
60
40
20
1
2
3
4
5
6
7
8
9
10
11
Round Trips

From HPBN

Connection View




45. members.oreilly.com
46. d16s8pqtk4uodx.cloudfront.net
47. ssl.google-analytics.com
48. www.youtube.com
49. www.youtube.com
50. rpxnow.com
51. smetrics.oreilly.com
52. d29usylhdk1xyu.cloudfront.net
53. s.ytimg.com
54. d3hmp0045zy3cs.cloudfront.net
55. d3hmp0045zy3cs.cloudfront.net
56. d1v9u0bgi1uimx.cloudfront.net
57. a248.e.akamai.net
58. s.adroll.com
59. js-agent.newrelic.com
60. js-agent.newrelic.com
61. d1341ocdryxgwa.cloudfront.net
62. d.adroll.com
63. d.adroll.com
64. d.adroll.com
65. ping.chartbeat.net
66. ping.chartbeat.net
67. backplane1.janrainbackplane.com
68. bam.nr-data.net
69. bam.nr-data.net
70. i.ytimg.com
71. d1lqe9temigv1p.cloudfront.net
72. secure.adnxs.com
73. ib.adnxs.com
74. ib.adnxs.com
75. ib.adnxs.com
76. cm.g.doubleclick.net
77. cm.g.doubleclick.net
78. a.adroll.com
79. static.chartbeat.com
80. oreilly.janrainsso.com
81. s.update.chartbeat.com
82. post.update.chartbeat.com

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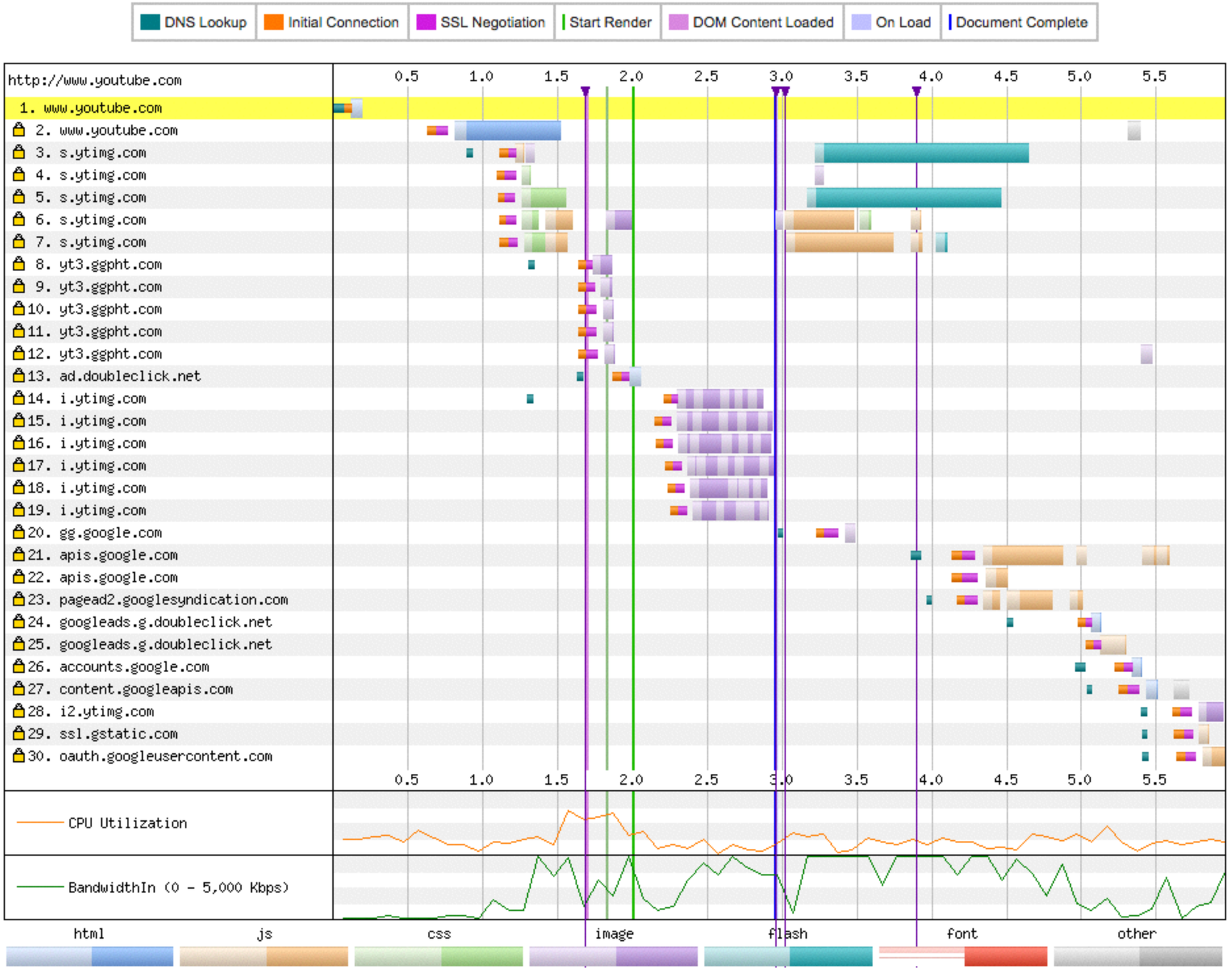

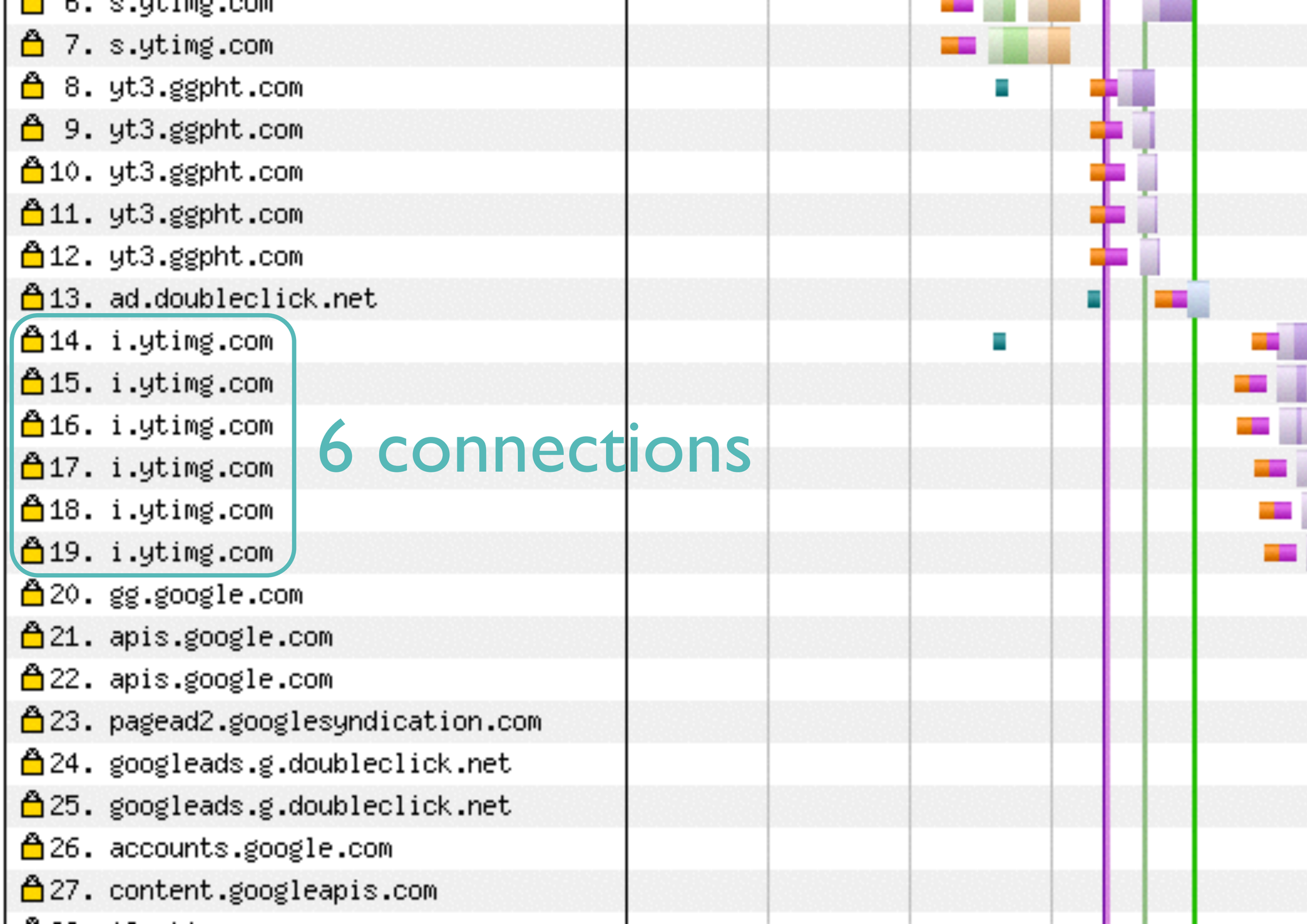
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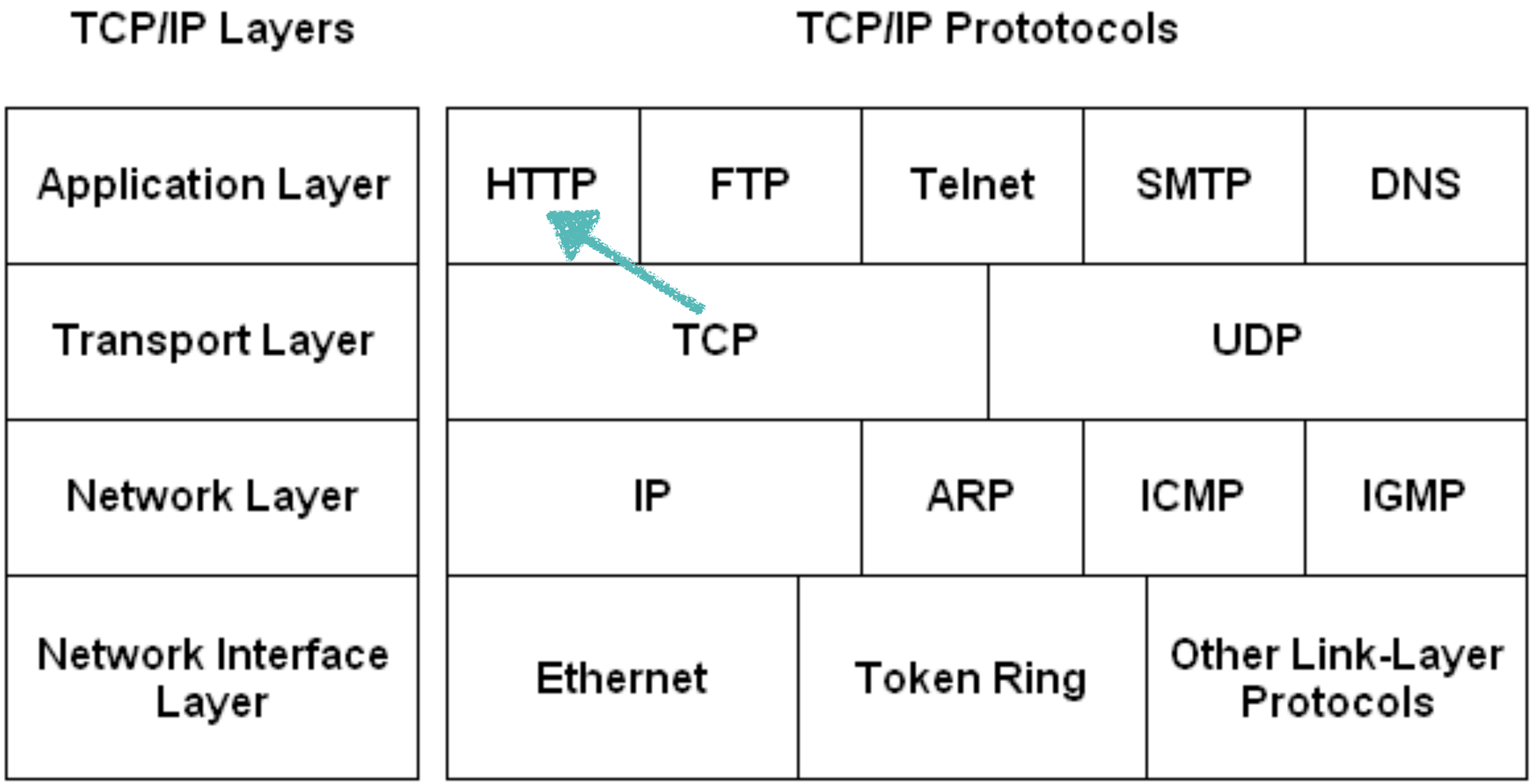
17. i.ytimg.com
18. i.ytimg.com
19. i.ytimg.com
20. gg.google.com
21. apis.google.com
22. apis.google.com
23. pagead2.googlesyndication.com
24. googleads.g.doubleclick.net
25. googleads.g.doubleclick.net
26. accounts.google.com
27. content.googleapis.com
6 connections

HTTP Head-of-line Blocking

A single slow response blocks all requests behind it.

Reusable Water Bottles

TCP/IP Network Model



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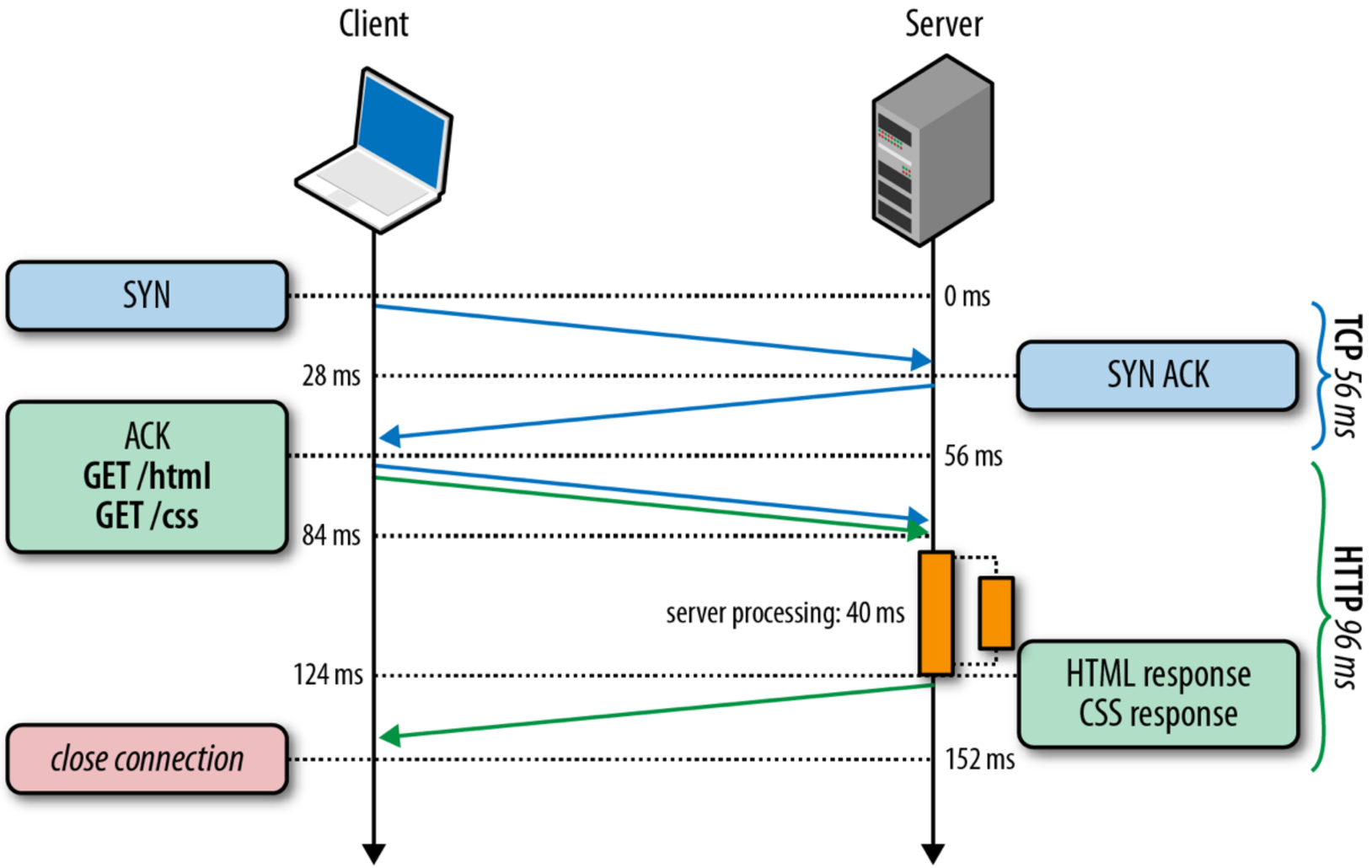
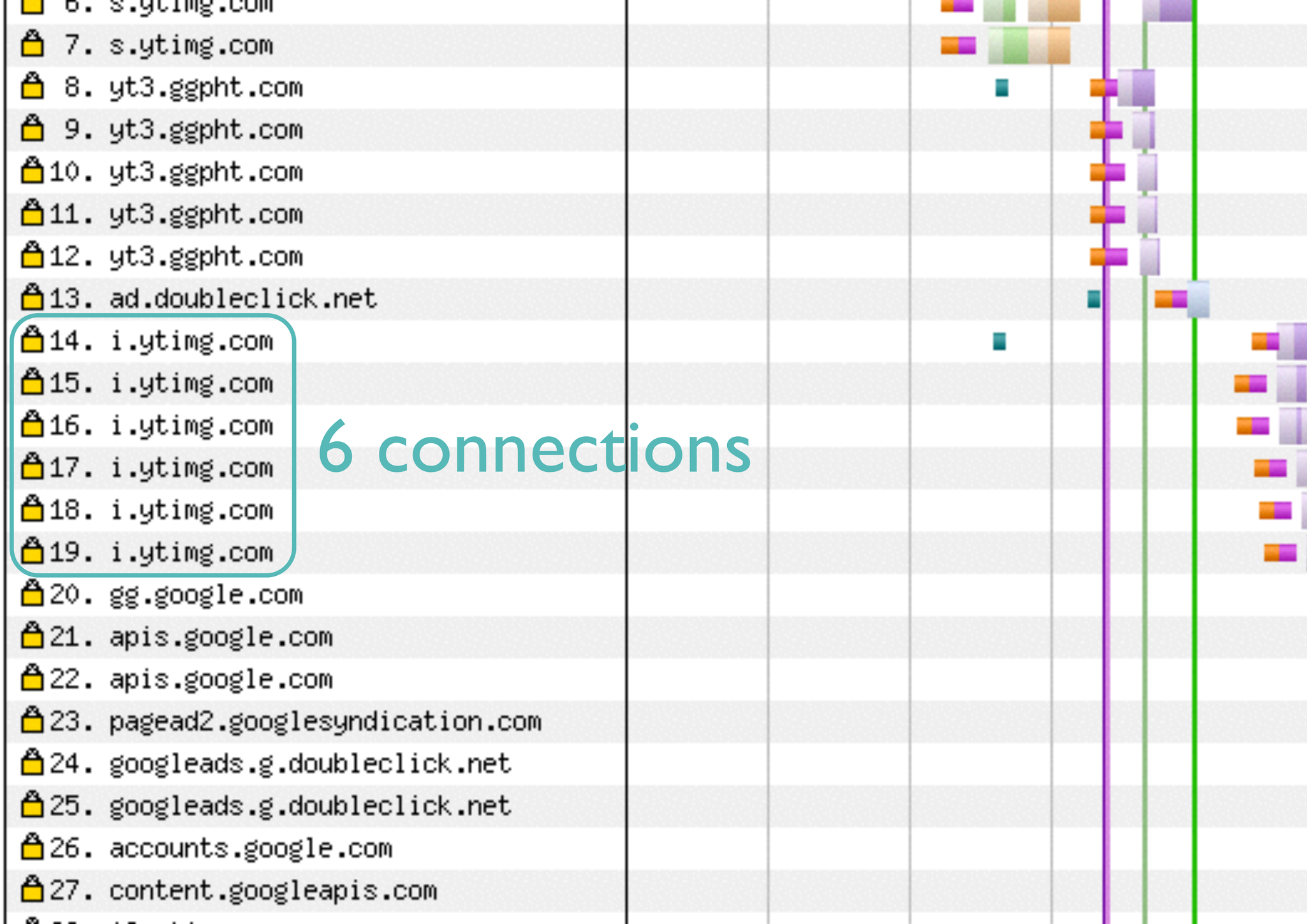


From HPBN

What About HTTP Pipelining?

"…if the web browser is the primary delivery vehicle for your web application, then we can't count on HTTP pipelining to help with performance."

- High Performance Browser Networking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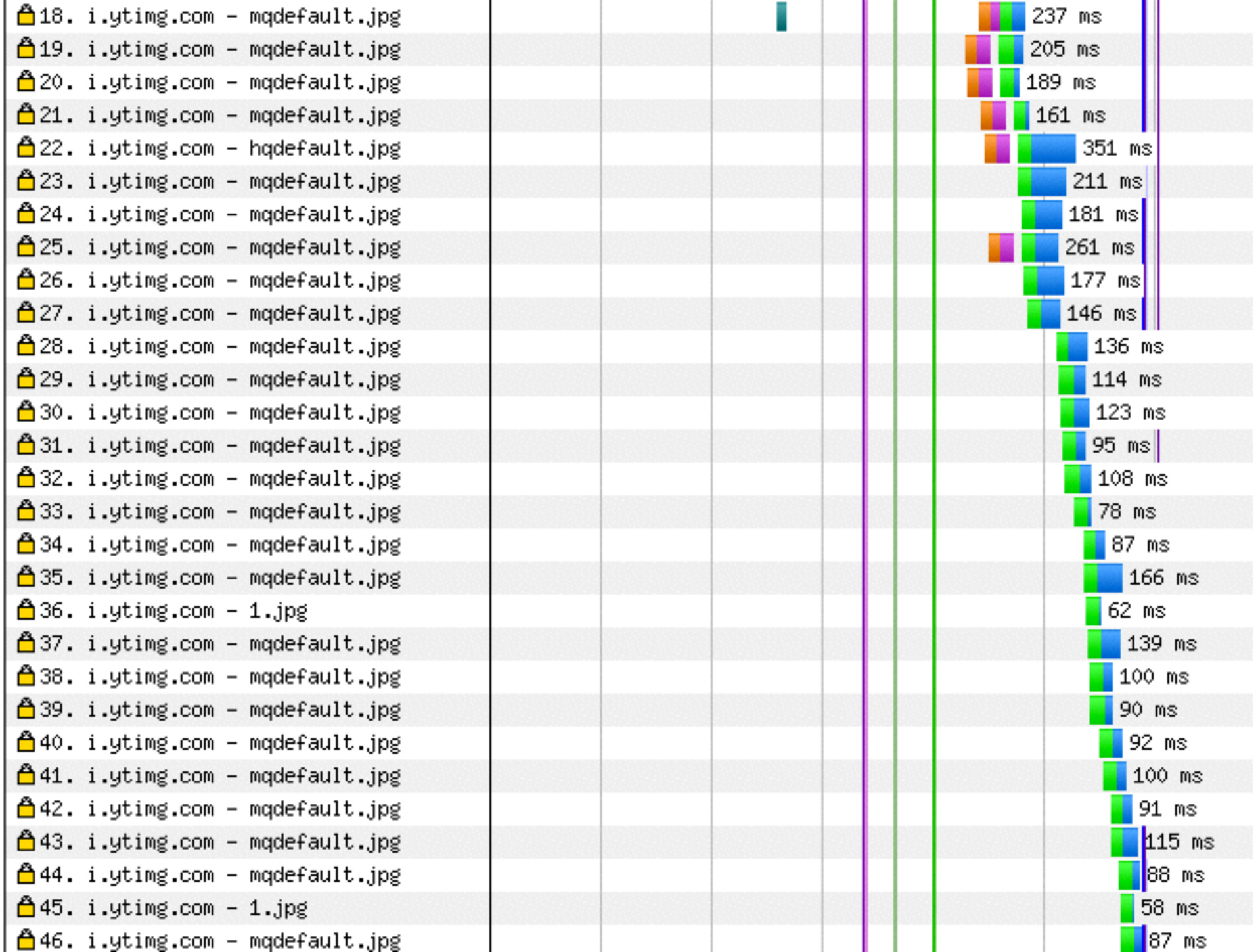
17. i.ytimg.com
18. i.ytimg.com
19. i.ytimg.com
20. gg.google.com
21. apis.google.com
22. apis.google.com
23. pagead2.googlesyndication.com
24. googleads.g.doubleclick.net
25. googleads.g.doubleclick.net
26. accounts.google.com
27. content.googleapis.com
6 connections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19. i.ytimg.com – mqdefault.jpg 205 ms
20. i.ytimg.com – mqdefault.jpg 189 ms
21. i.ytimg.com – mqdefault.jpg 161 ms
22. i.ytimg.com – hqdefault.jpg 351 ms
23. i.ytimg.com – mqdefault.jpg 211 ms
24. i.ytimg.com – mqdefault.jpg 181 ms
25. i.ytimg.com – mqdefault.jpg 261 ms
26. i.ytimg.com – mqdefault.jpg 177 ms
27. i.ytimg.com – mqdefault.jpg 146 ms
28. i.ytimg.com – mqdefault.jpg 136 ms
29. i.ytimg.com – mqdefault.jpg 114 ms
30. i.ytimg.com – mqdefault.jpg 123 ms
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32. i.ytimg.com – mqdefault.jpg 108 ms
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34. i.ytimg.com – mqdefault.jpg 87 ms
35. i.ytimg.com – mqdefault.jpg 166 ms
36. i.ytimg.com – 1.jpg 62 ms
37. i.ytimg.com – mqdefault.jpg 139 ms
38. i.ytimg.com – mqdefault.jpg 100 ms
39. i.ytimg.com – mqdefault.jpg 90 ms
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44. i.ytimg.com – mqdefault.jpg 88 ms
45. i.ytimg.com – 1.jpg 58 ms
46. i.ytimg.com – mqdefault.jpg 87 ms

Workarounds and Downsides

Workarounds and Downsides

- Multiple TCP Connections

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- Multiple TCP Connections
  - Extra resource utilization

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Workarounds and Downsides

- Multiple TCP Connections
  - Extra resource utilization
  - Bandwidth competition
- Domain Sharding
  - Extra DNS Lookup(s)
  - Implementation complexity

H/2 Multiplexing

H/2 Multiplexing

From HPBN

H/2 Multiplexing

- Interleave multiple requests/responses on the same connection

From HPBN

H/2 Multiplexing

- Interleave multiple requests/responses on the same connection
- No more head-of-line blocking!

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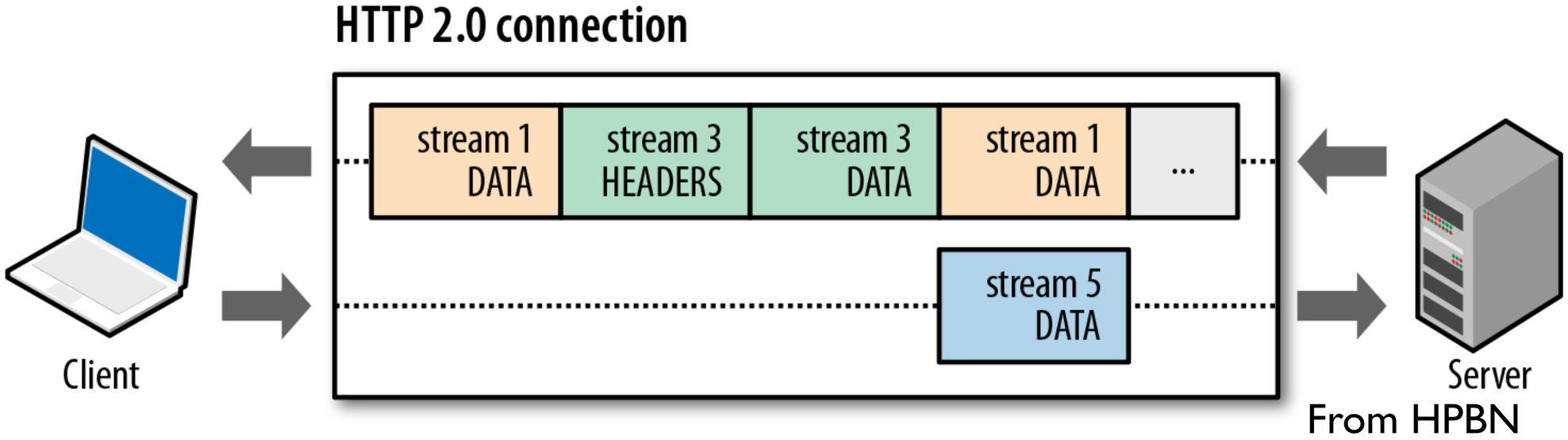


From HPBN

Forget about…

Forget about…

- Combining CSS and JS files

Forget about…

- Combining CSS and JS files
- Inlining small CSS/JS

Forget about…

- Combining CSS and JS files
- Inlining small CSS/JS
- Using image sprites

Forget about…

- Combining CSS and JS files
- Inlining small CSS/JS
- Using image sprites
- Using DataURIs

Forget about…

- Combining CSS and JS files
- Inlining small CSS/JS
- Using image sprites
- Using DataURIs
- Domain sharding

What About HTTP Headers?

Request Headers

```
GET /ajax/libs/jquery/1.7.2/jquery.min.js HTTP/1.1
Host: cdn.oreillystatic.com
Connection: keep-alive
Pragma: no-cache
Cache-Control: no-cache
Accept: */*
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10_10_2)
AppleWebKit/537.36 (KHTML, like Gecko) Chrome/41.0.2272.118 Safari/
537.36
Referer: http://fluentconf.com/javascript-html-2015
Accept-Encoding: gzip, deflate, sdch
Accept-Language: en-US,en;q=0.8
```

Response Headers

```
HTTP/1.1 200 OK
Server: Apache
Vary: Accept-Encoding
Last-Modified: Thu, 02 Aug 2012 22:41:31 GMT
Accept-Ranges: bytes
Content-Encoding: gzip
Content-Length: 33622
Content-Type: application/javascript
Cache-Control: max-age=2236992
Expires: Thu, 30 Apr 2015 17:21:11 GMT
Date: Sat, 04 Apr 2015 19:57:59 GMT
Connection: keep-alive
```

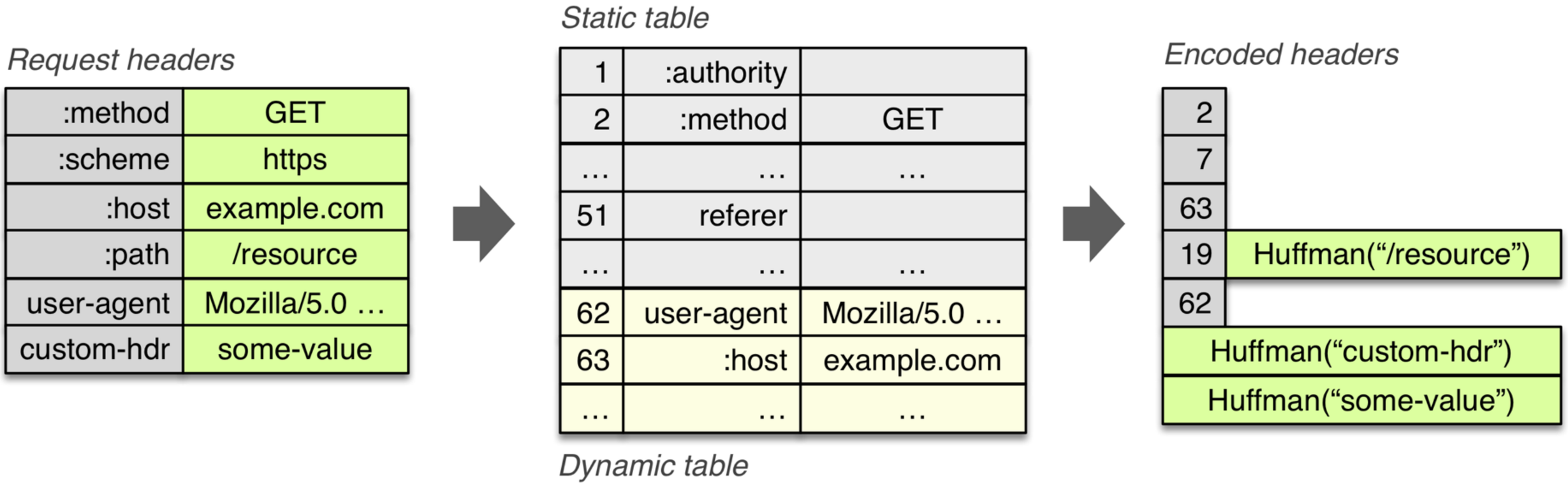
Request Headers

```
GET /en/assets/1/eventprovider/1/lazyload_min_v3.js HTTP/1.1
Host: cdn.oreillystatic.com
Connection: keep-alive
Pragma: no-cache
Cache-Control: no-cache
Accept: */*
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10_10_2)
AppleWebKit/537.36 (KHTML, like Gecko) Chrome/41.0.2272.118 Safari/
537.36
Referer: http://fluentconf.com/javascript-html-2015
Accept-Encoding: gzip, deflate, sdch
Accept-Language: en-US,en;q=0.8
```

Request Headers

```
GET /en/assets/1/eventprovider/1/lazyload_min_v3.js HTTP/1.1
Host: cdn.oreillystatic.com
Connection: keep-alive
Pragma: no-cache
Cache-Control: no-cache
Accept: */*
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10_10_2)
AppleWebKit/537.36 (KHTML, like Gecko) Chrome/41.0.2272.118 Safari/
537.36
Referer: http://fluentconf.com/javascript-html-2015
Accept-Encoding: gzip, deflate, sdch
Accept-Language: en-US,en;q=0.8
```

HPACK

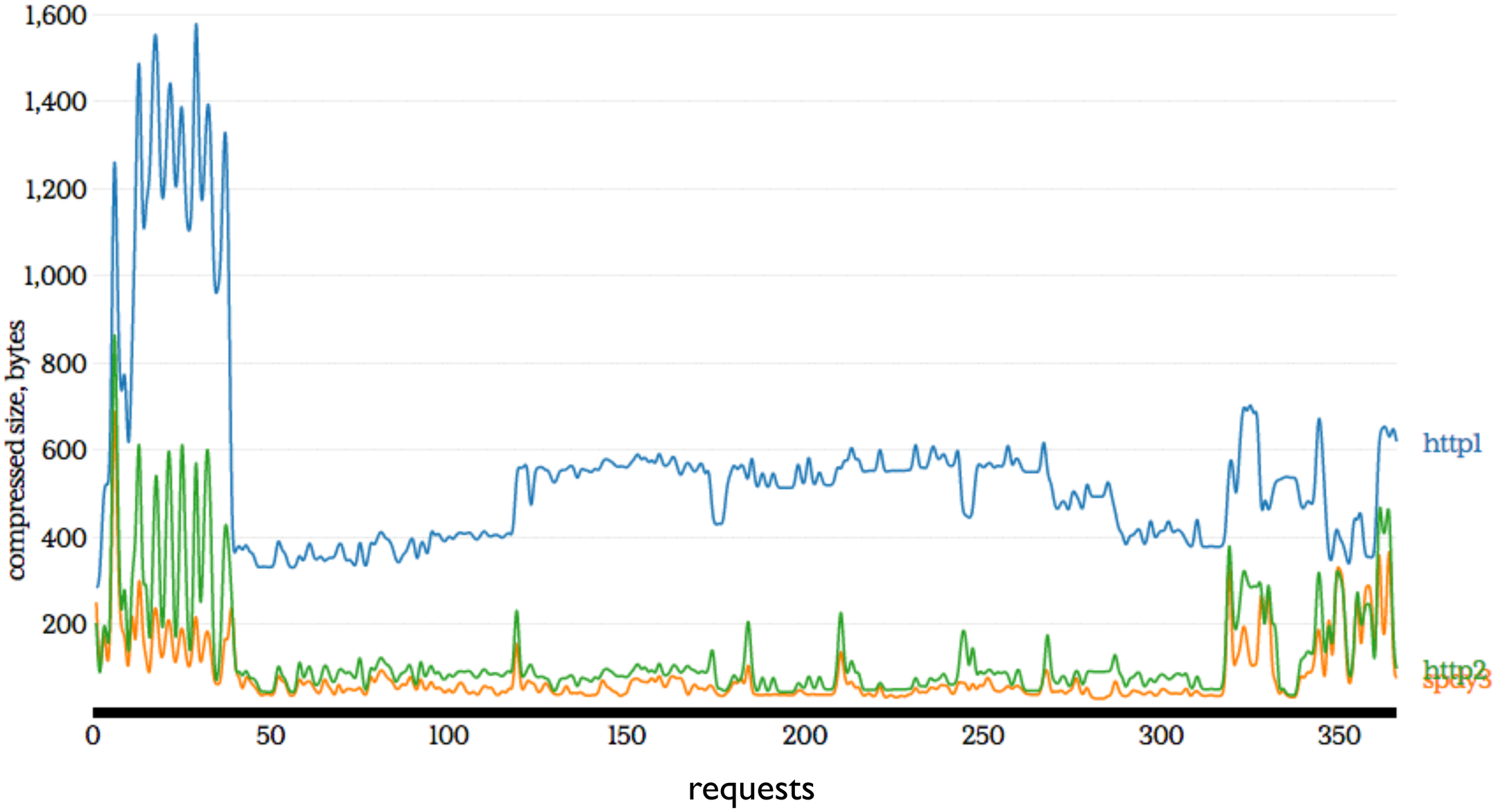


From HPBN

Why HPACK and not zlib?

- CRIME attack
  - zlib + encryption = session hijacking

- HPACK: New, header specific compression algorithm



https://www.mnot.net/talks/http2-expectations/#/tsv

Request Prioritization and Server Push

Server Push

Server Push

- Resources can be…

Server Push

- Resources can be…
  - Cached by client

Server Push

- Resources can be…
  - Cached by client
  - Declined by client

Server Push

- Resources can be…
  - Cached by client
  - Declined by client
  - Multiplexed

Server Push

- Resources can be…
  - Cached by client
  - Declined by client
  - Multiplexed
  - Prioritized by server

Server Push

- Resources can be…
  - Cached by client
  - Declined by client
  - Multiplexed
  - Prioritized by server
- Must obey same-origin policy

IS IT REALLY
FASTER?

Data From Google

	Google News	Google Sites	Google Drive	Google Maps
Median	-43%	-27%	-23%	-24%
5th percentile (fast connections)	-32%	-30%	-15%	-20%
95th percentile (slow connections)	-44%	-33%	-36%	-28%

time from first request byte to the onload event

YourLogoHere

SEARCH

Cart (empty)

Welcome | Login

Home | iPods | Accessories

TAGS

ipod apple superdrive Ipod touch nano shuffle

CATEGORIES

- iPods
- Accessories
- Laptops

MANUFACTURERS

- Apple Computer, Inc
- Shure Incorporated

All manufacturers

SUPPLIERS

- AppleStore
- Shure Online Store

All suppliers

INFORMATION

- Delivery
- Legal Notice

FEATURED PRODUCTS

iPod Nano

New design. New features. Now in 8GB and 16GB. iPod nano...

iPod shuffle

iPod shuffle, the world's most wearable music player, now...

MacBook

MacBook makes it easy to hit the road thanks to its tough...

iPod touch

Revolutionary Multi-Touch interface 3.5-inch widescreen...

SPECIALS

iPod Nano -5%

~~$166.39~~

$158.07

» All specials

OUR STORE(S)!

» Discover our store(s)!

CONTACT US

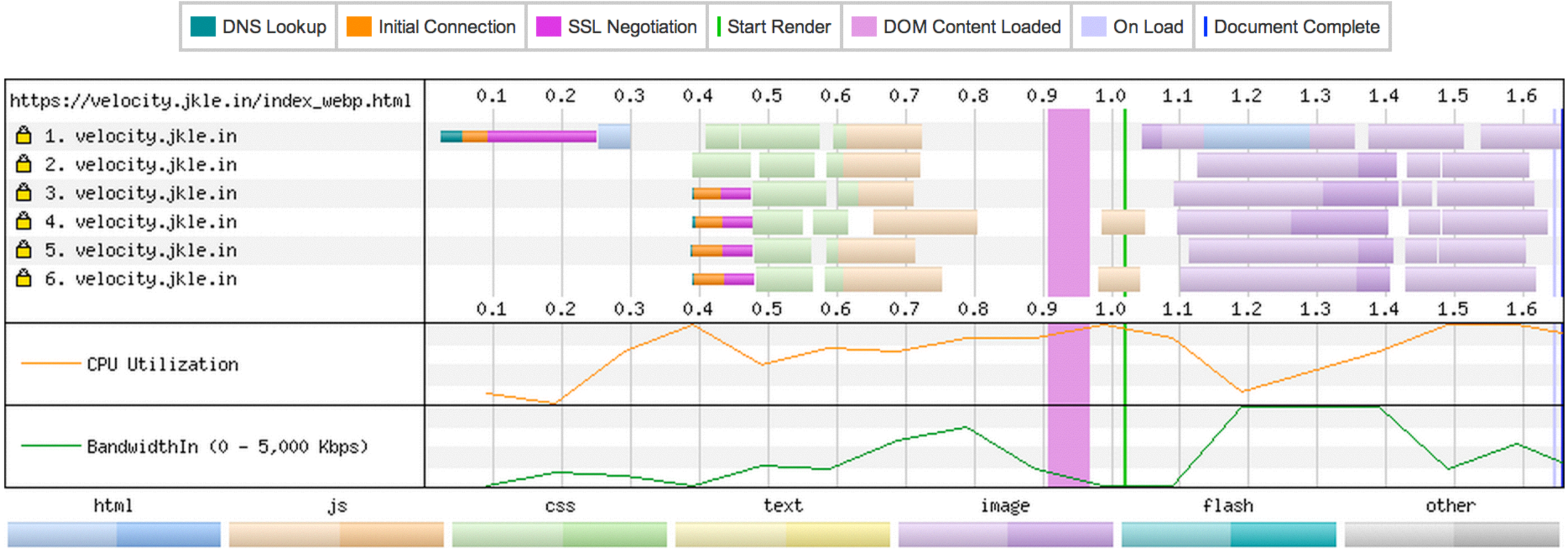
Our support hotline is available 24/7.

0123-456-789

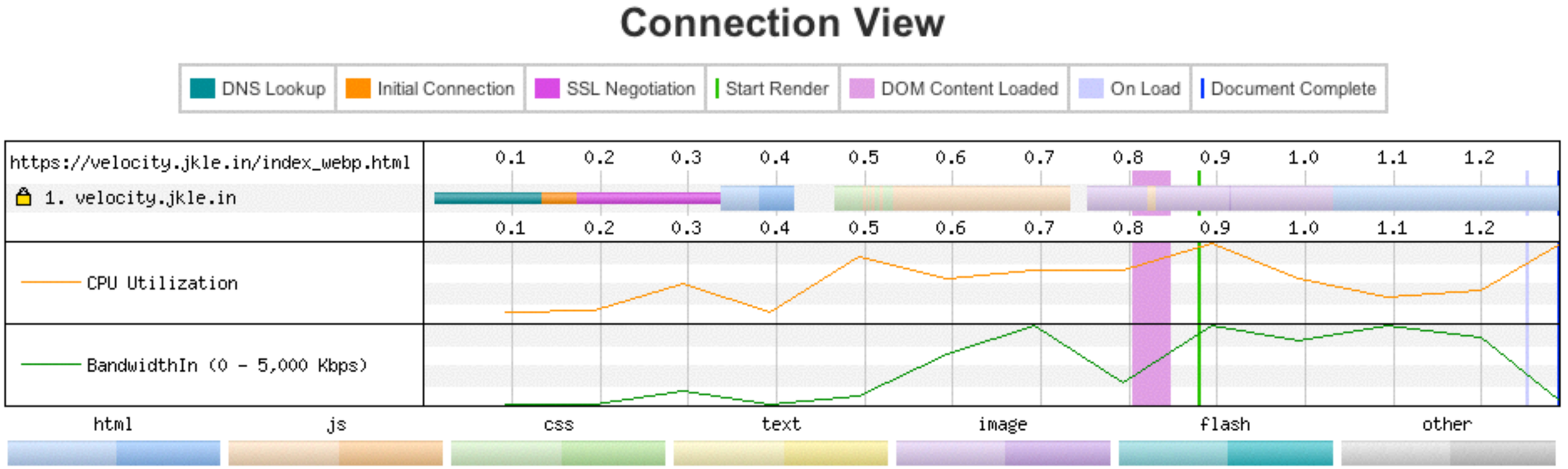
CONTACT OUR EXPERT SUPPORT TEAM!

H/1

Connection View



H/2


Connection View
DNS Lookup
Initial Connection
SSL Negotiation
Start Render
DOM Content Loaded
On Load
Document Complete
https://velocity.jkle.in/index_webp.html
1. velocity.jkle.in
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
CPU Utilization
BandwidthIn (0 - 5,000 Kbps)
html
js
css
text
image
flash
other

Key Stats

	H/1	H/2	Difference
Bytes	387KB	387KB	-
Start Render	1019ms	972ms	-5%
Speed Index	1278ms	1108ms	-14%

What About HTTPS?

Not required by spec, but
Firefox and Chrome will require it

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Criticism

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“It was rushed, we wanted more”

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- Something good now > something perfect in 5 years

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“Why does it require TLS?”

Criticism

“It was rushed, we wanted more”

- Something good now > something perfect in 5 years

“Why does it require TLS?”

- The spec doesn’t, some browsers do

HATERS GONNA HATE

Implementation

Webservers

	Session identifiers	Session tickets	OCSP stapling	Dynamic record sizing	ALPN / NPN	Forward secrecy	SPDY & HTTP/2
Apache	yes	yes	yes	no	no*	yes	mod_spdy
ATS	yes	yes	yes	dynamic	yes	yes	spdy/3.1
bud	no	yes	yes	static	yes	yes	no
F5 BIG-IP	yes	yes	yes	no	yes	yes	spdy/3.1, http/2.0
HAProxy	yes	yes	yes	dynamic	yes	yes	no
IIS	yes	yes	yes	no	yes	yes	no
NetScaler	yes	no	no	no	yes	yes	spdy/3.0
NGINX	yes	yes	yes	static	yes	yes	spdy/3.1
node.js	yes	no	no	no	yes	no	spdy/3.1

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CDN Support

	Session identifiers	Session tickets	OCSP stapling	Dynamic record sizing	ALPN / NPN	Forward secrecy	SPDY & HTTP/2
Akamai	yes	yes	yes	configurable (static)	yes	yes	spdy/3 spdy3.1 (opt-in)
CloudFlare	yes	yes	yes	4KB (static)	yes	yes	spdy/3.1
AWS ELB	yes	yes	no	no	no	yes	no
AWS CloudFront	no	yes	yes	no	yes	yes	no
EdgeCast	no	yes	yes	no	no	yes	no
Fastly	yes	yes	yes	no	no	yes	no
Google App Engine	yes	yes	no	dynamic	yes	yes	spdy/3.1
Heroku	yes	yes	no	no	no	yes	no
Instart Logic	yes	yes	no	configurable (static)	yes	yes	spdy/3.1
Limelight	yes	yes	no	no	no	yes	no
MaxCDN	yes	yes	no	no	yes	no	spdy/3.1

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Handling Both H/1 and H/2 Clients

Okay to Keep	Stop
Combining CSS/JS	Domain Sharding
Spriting	Inlining Content

Global	72.15% + 7.98% = 80.13%

Wrapping Up

Wrapping Up

- H/2 is here

Wrapping Up

- H/2 is here
- H/2 is fast

Wrapping Up

- H/2 is here
- H/2 is fast
- H/2 is supported

Wrapping Up

- H/2 is here
- H/2 is fast
- H/2 is supported

… go implement it!

Thanks!

http://jkle.in/http2

@jonathanklein