



# Adoption, Human Perception, and Performance of HTTP/2 Server Push

Torsten Zimmermann

<https://netray.io>

# Why focus on HTTP/2 (H2) Server Push?

- **H2 major changes over H1**

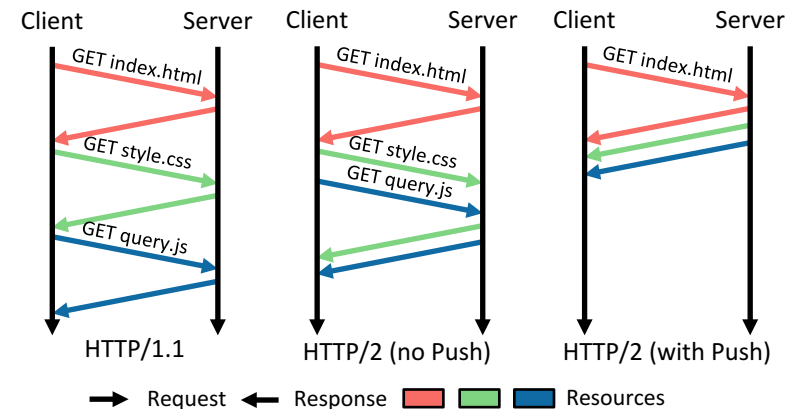
- ▶ Binary, single TCP Connection, (multiplexed) Streams, Header compression

- **Push often regarded as a key feature**

- ▶ Save requests and thus round trips
- ▶ *On paper* great potential to speed up Web

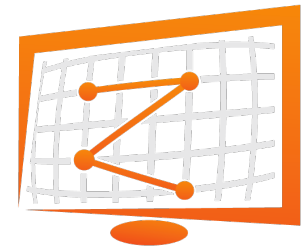
- **No strategy on *what* to push and *when***

- ▶ Standard defines protocol
- ▶ Manual configuration indicator for *true* adoption



→ **Motivation to study the *who*, *what* and *how* of H2 Server Push**

- **Domain Lists accounting for around 50% of domain name space**
  - ▶ Alexa 1M and .com/.net/.org
- **ZMAP: Scan entire IPv4 space**
  - ▶ Explicitly for TLS + ALPN/NPN announcing H2
- **Check for *full* H2 support**
  - ▶ Is the landing page delivered via H2?
  - ▶ Utilize nghttp2 library
    - Try to establish H2 connection (Timeout 10s)
    - Issue GET request for /, follow up to 10 redirects
    - Multiple workers in our network

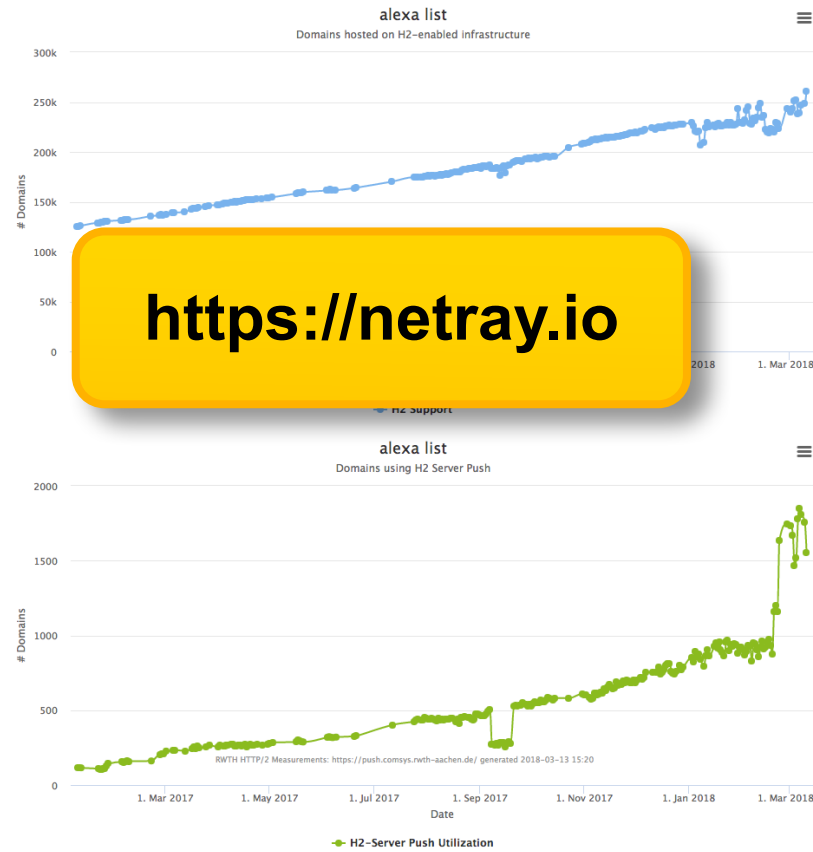


<https://zmap.io>

## HTTP/2 + Push Adoption Measurements

On this page we provide up-to-date information about the HTTP/2 and Server Push Adoption. Please note that we cannot guarantee completeness or accuracy of the information. Depending on the size of the underlying list, e.g., .com or .net, we provide results on a weekly instead of a daily basis.

### Alexa Top 1M List



# Adoption at a glance

| Varvello [VSN <sup>+</sup> 16] |          |          |                       |          | Alexa 1M |          |          |          |
|--------------------------------|----------|----------|-----------------------|----------|----------|----------|----------|----------|
|                                | Sep. '16 |          | Jan. '17 <sup>†</sup> |          | Jan. '17 |          | Jan. '18 |          |
| #                              | 241.9K   |          | 241.9K                |          | 1M       |          | 1M       |          |
| H2                             | 165.6K   | (69.97%) | 168.4K                | (69.62%) | 125.4K   | (12.54%) | 226.6K   | (22.66%) |
| Push (rel. H2)                 | 98       | (0.06%)  | 100                   | (0.06%)  | 117      | (0.09%)  | 928      | (0.4%)   |
| No H2 neg.                     | 1.4K     | (0.6%)   | 6K                    | (2.5%)   | 521.1K   | (52.11%) | 446.4K   | (44.64%) |
| Con. timeout                   | 1.6K     | (0.66%)  | 1.7K                  | (0.71%)  | 71.9K    | (7.19%)  | 82K      | (8.2%)   |
| Con. failed                    | 183      | (0.08%)  | 1.4K                  | (0.58%)  | 131.7K   | (13.17%) | 85.6K    | (8.56%)  |
| TLS error                      | 361      | (0.15%)  | 2.5K                  | (1.04%)  | 68.4K    | (6.84%)  | 54.1K    | (5.41%)  |
| Redirect H1                    | 62.3K    | (26.32%) | 53.5K                 | (22.12%) | 40.7K    | (4.07%)  | 42.4K    | (4.24%)  |
| DNS failed                     | 203      | (0.09%)  | 3.5K                  | (1.44%)  | 37.2K    | (3.72%)  | 48.1K    | (4.81%)  |
| App. timeout                   | 3K       | (1.26%)  | 2.8K                  | (1.14%)  | 1.5K     | (0.15%)  | 2.2K     | (0.22%)  |
| Miscellany                     | 2.1K     | (0.87%)  | 2.1K                  | (0.86%)  | 2K       | (0.2%)   | 11.6K    | (1.16%)  |

| .com/.net/.org |          |          |          |          | ZMap IP  |         |          |          |
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|                | Jan. '17 |          | Jan. '18 |          | Jan. '17 |         | Jan. '18 |          |
| #              | 151.4M   |          | 155M     |          | 849K*    |         | 2.4M*    |          |
| H2             | 5.3M     | (3.47%)  | 11.8M    | (7.63%)  | 766.6K   | (90.3%) | 2M       | (80.81%) |
| Push (rel. H2) | 7K       | (0.13%)  | 5K       | (0.04%)  | 118      | (0.02%) | 447      | (0.02%)  |
| No H2 neg.     | 43.8M    | (28.92%) | 38.1M    | (24.6%)  | 5.1K     | (0.6%)  | 18K      | (0.74%)  |
| Con. timeout   | 38.8M    | (25.65%) | 45.1M    | (29.07%) | 4.7K     | (0.56%) | 67.3K    | (2.76%)  |
| Con. failed    | 29.7M    | (19.61%) | 25.1M    | (16.19%) | 971      | (0.11%) | 4.7K     | (0.19%)  |
| TLS error      | 13.9M    | (9.16%)  | 13.4M    | (8.62%)  | 1.9K     | (0.22%) | 5.3K     | (0.22%)  |
| Redirect H1    | 1M       | (0.67%)  | 1.4M     | (0.92%)  | 46.3K    | (5.45%) | 237K     | (9.73%)  |
| DNS failed     | 18.8M    | (12.45%) | 17.4M    | (11.22%) | 3K       | (0.35%) | 7.7K     | (0.32%)  |
| App. timeout   | 82.7K    | (0.05%)  | 295.7K   | (0.19%)  | 4.8K     | (0.56%) | 34.9K    | (1.43%)  |
| Miscellany     | 40.9K    | (0.03%)  | 2.4M     | (1.55%)  | 15.7K    | (1.85%) | 92.8K    | (3.81%)  |

[VSN<sup>+</sup>16] M. Varvello et. al., Is The Web HTTP/2 Yet?, PAM 2016, <sup>†</sup>Latest data from November 2016, \*>50M TLS enabled

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| No H2 neg.                     | 1.4K     | (0.6%)   | 6K                    | (2.5%)   | 521.1K   | (51.1%)  | 185.6K   | (44.64%) |
| Con. timeout                   | 1.6K     | (0.66%)  | 1.7K                  | (0.71%)  | 71.9K    | (7.07%)  | 18.2K    | (8.2%)   |
| Con. failed                    | 183      | (0.08%)  | 1.4K                  | (0.58%)  | 131.7K   | (13.17%) | 85.6K    | (8.56%)  |
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H2 x1.8  
Push x7.9

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Domain Parker  
Template (~6.5K)  
w/o: 563 (0.01%)

[VSN<sup>+</sup>16] M. Varvello et. al., Is The Web HTTP/2 Yet?, PAM 2016, <sup>†</sup>Latest data from November 2016, \*>50M TLS enabled

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H2 x1.8  
Push x7.9

**Rising adoption of H2 across data sets.  
Usage of Server Push orders of magnitude lower.**

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# Case Study - Adoption on Alexa 1M

- Who drives the adoption?

| AS           | Share   |
|--------------|---------|
| Cloudflare   | 34.65 % |
| Google       | 7.96 %  |
| Amazon       | 6.34 %  |
| OVH (FR)     | 3.65 %  |
| UnifiedLayer | 2.37 %  |

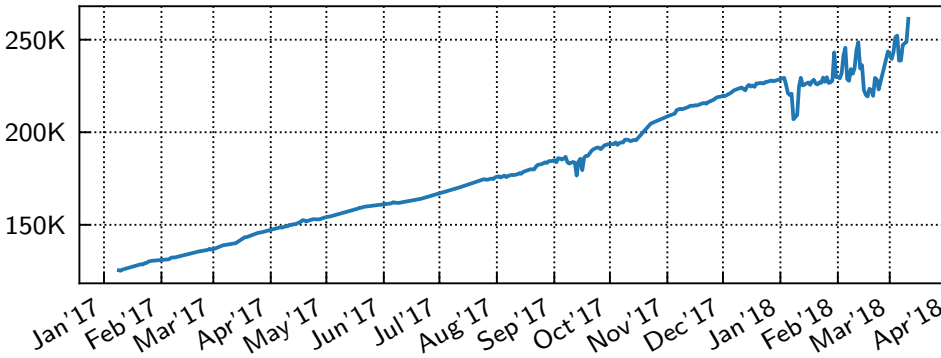
a) H2

| AS           | Share   |
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| Cloudflare   | 40.52 % |
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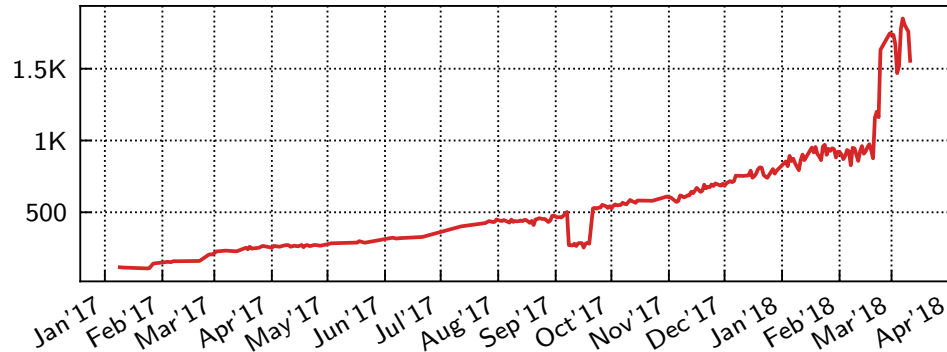
b) H2 Server Push

- Over Time

HTTP/2



HTTP/2 Server Push





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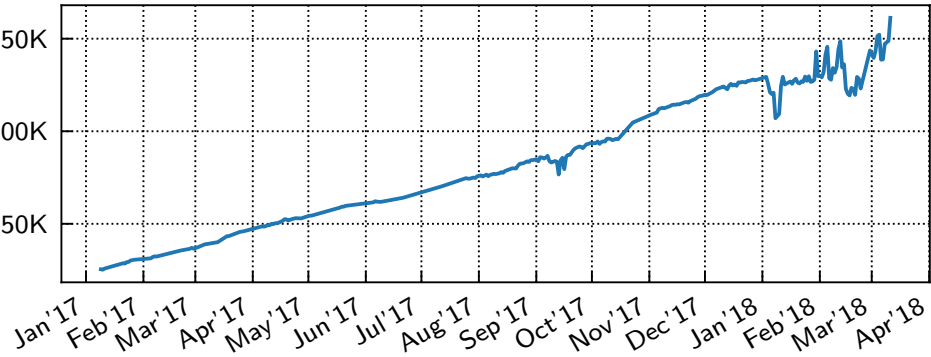
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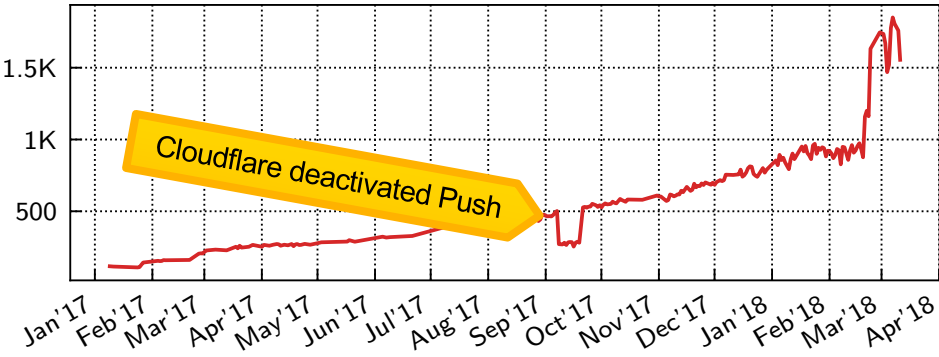
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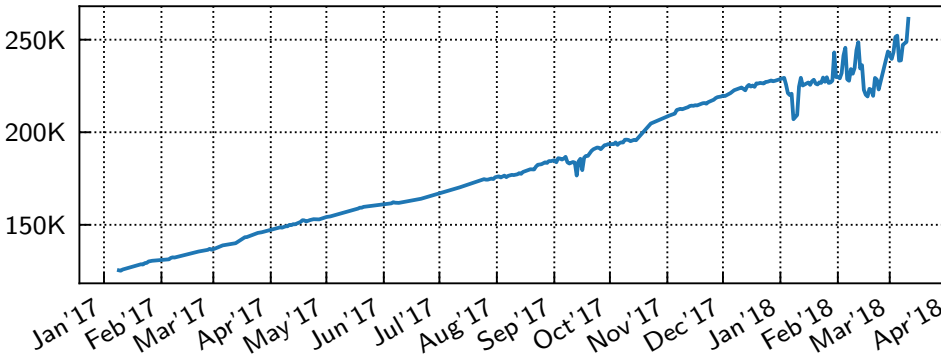
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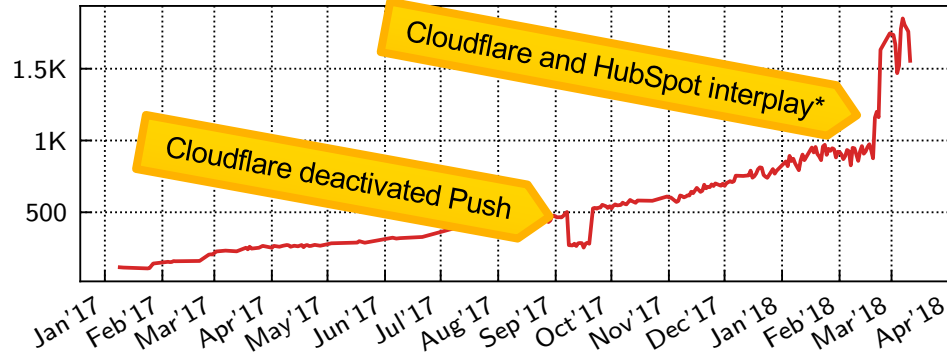
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HTTP/2 Server Push

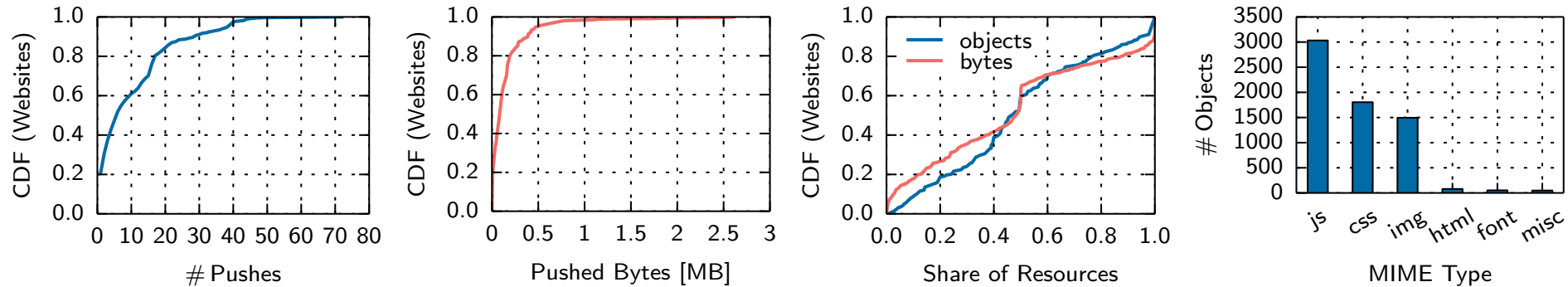


\*HubSpot CMS adds preload  
Cloudflare pushes these over H2

# What is pushed?

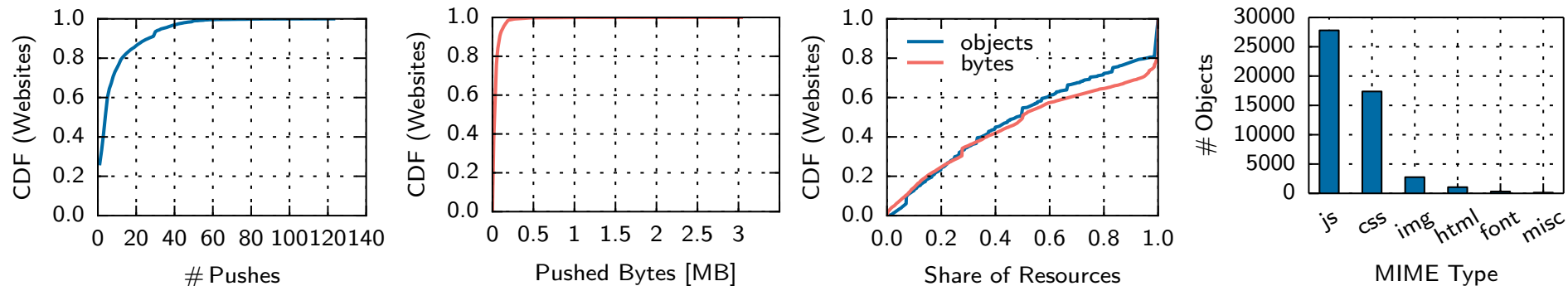
- January 2017

- ▶ 595 websites utilizing push



- January 2018

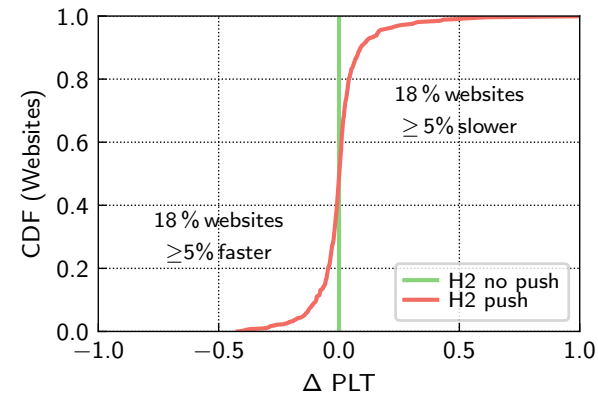
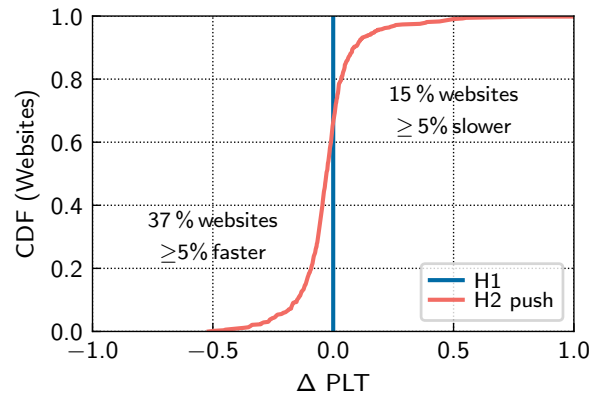
- ▶ 5549 websites utilizing push



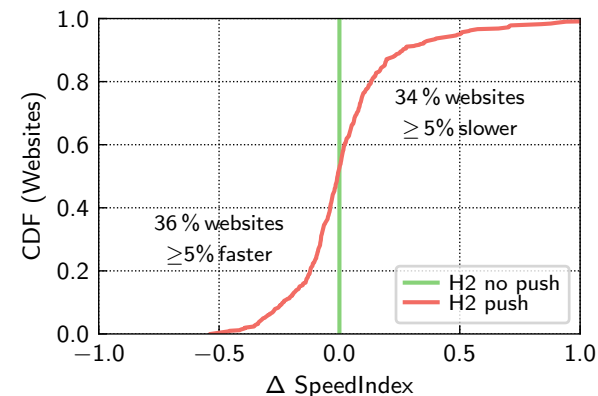
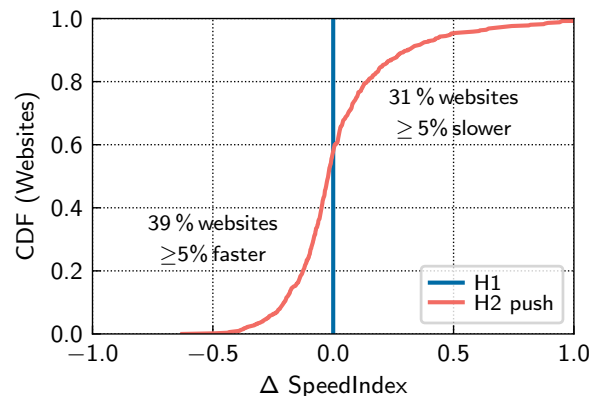
T. Zimmermann et. al., How HTTP/2 pushes the Web: An empirical study of HTTP/2 Server Push, NETWORKING 2017

# Analysis of performance impact of Server Push

- **January 2017, automate Chrome to repeatedly visit websites**
  - ▶ 16 Mbit/s Down, 1 Mbit/s Up, 50 ms symmetric delay
  - ▶ Page Load Time: time between connectEnd and loadEventStart

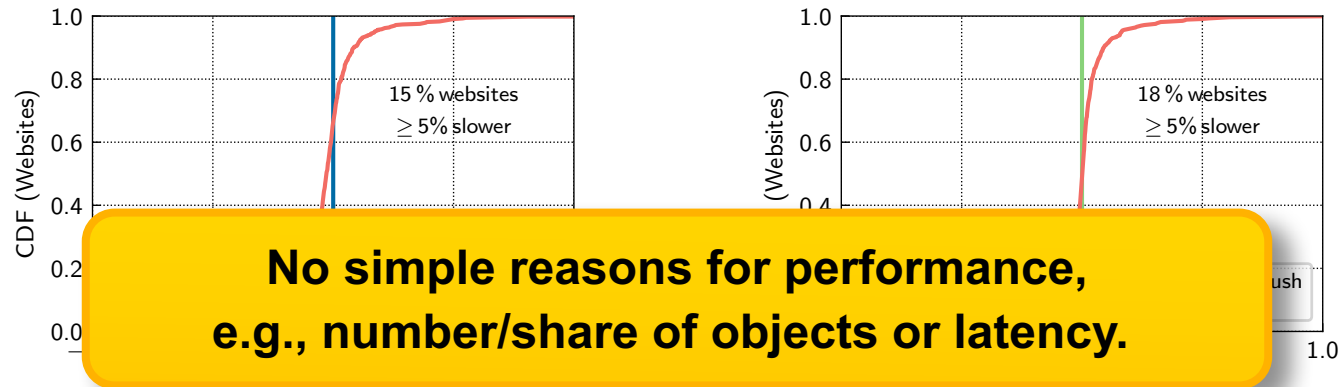


- ▶ SpeedIndex: measures how quickly page contents are visually populated

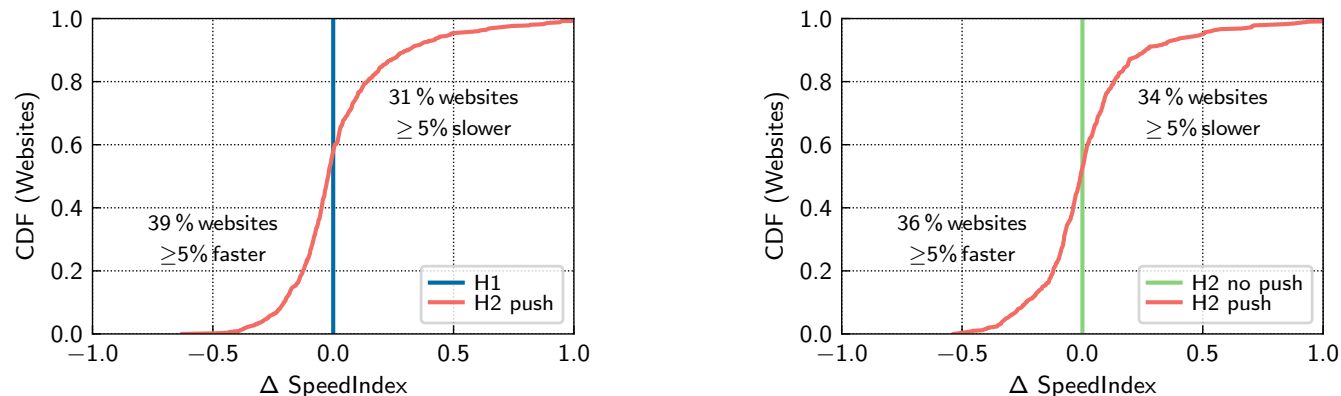


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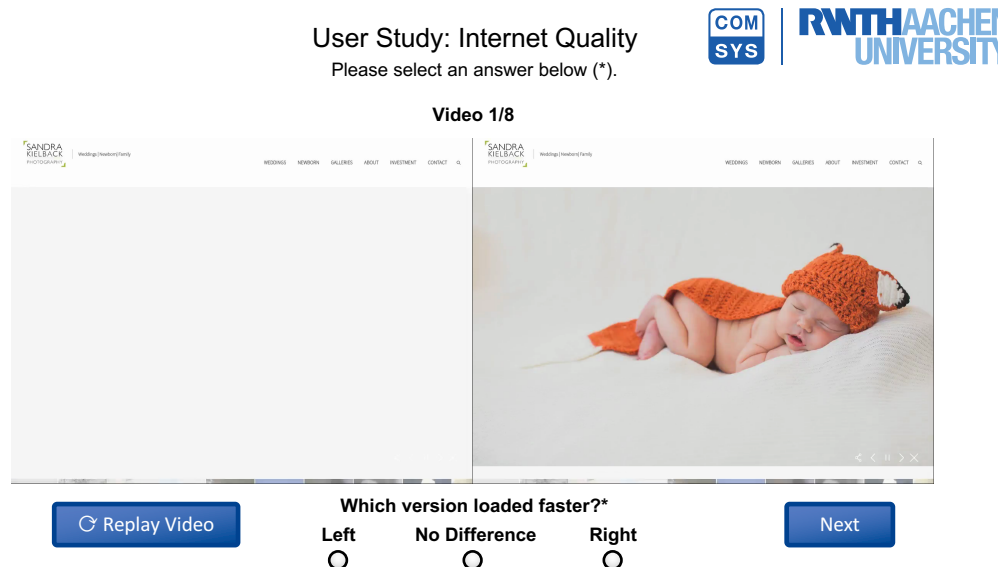


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# A QoE Perspective on Server Push

- **Standardization sufficient to optimize the browsing experience?**
  - ▶ Up to now, focused on technical metrics → might be misleading
  - ▶ Do people even notice?
- **Conduct a user study (28 lab + 323 crowd participants)**
  - ▶ Pairwise comparison → User vote which version of a website loaded faster
    - Conditions: H1 vs. H2, H2 vs. H2 without Server Push, H1 vs. H2 w/o Server Push



T. Zimmermann et. al., A QoE Perspective on HTTP/2 Server Push, Internet-QoE 2017

# User Study – Key Results

- **Voting behavior**

- ▶ E.g., in 58% of scenarios,  $\geq 75\%$  in favor of one version
- ▶ For 36% of websites,  $> 80\%$  of votes towards Push variant
  - However, for 18% of websites,  $> 80\%$  in favor of H2 without Push

**Server Push *can* lead to human-perceivable negative performance!**

- **Reasons for decision *highly* website specific (examples)**

- ▶ Some benefits based on other H2 features, e.g., multiplexed streams
- ▶ Pushing too early might delay basic document → delay resource discovery
- ▶ Pushing hidden resources *can* help (e.g., discovered after JS execution)
  - Lead to faster rendering in the browser
- ▶ Pushing not referenced resources also improved some websites
  - Cold connection → enlarges CWND

**Know your website, browser, and server!**

# What impacts the performance? – Sneak Peak

- **Analyze Server Push in controlled testbed**
  - ▶ Goal to remove variability
  - ▶ Test various strategies (e.g., amount and type) for *real-world* websites
  - Don't push everything, (some) images are bad, fill network idle time
- **Alternative scheduler for H2 webserver**
  - ▶ Push *right* resources at the *right* time
    - Resources that contribute for above-the-fold viewport
    - *Interleaved* with the base HTML document
  - ▶ Can lead to promising results for some websites in our testbed
    - Depending on the overall structure, third party content, browser behavior

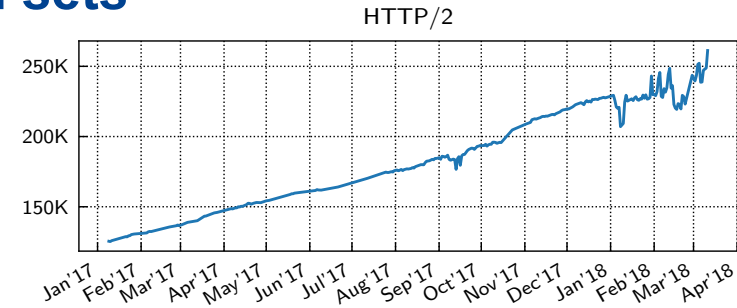
**No single generic guideline for Server Push.  
Requires website-specific tuning and configuration.**



# Conclusion

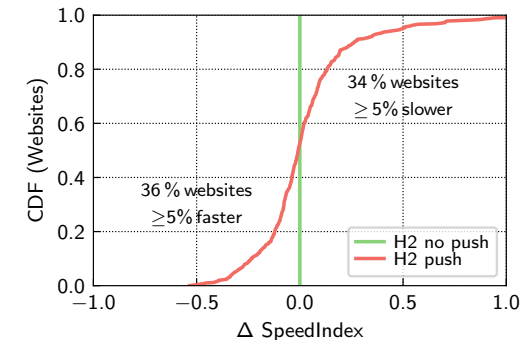
- **Increasing H2 Adoption on large domain sets**

- ▶ > 20% of Alexa 1M, ~ 8 % of .com/.net/.org
- ▶ Can drastically increase by server update
  - All major browsers support it



- **Adoption and Utilization of H2 Server Push**

- ▶ Rising, but orders of magnitude lower than H2
- ▶ Needs *active* configuration
- ▶ Has *great* potential! However,...
  - ... it is no silver bullet to improve the performance
  - ... its usage *can* lead to human-perceivable negative performance impacts
  - ... requires deep understanding of page load and rendering process



**We need best practices/guidelines for Server Push!**

- **Acknowledgements**

- ▶ Benedikt Wolters, Jan Rüth and Oliver Hohlfeld
- ▶ This work has been funded by the DFG as part of the CRC 1053 MAKI

- **Publications**

- ▶ *How HTTP/2 Pushes the Web: An Empirical Study of HTTP/2 Server Push*
  - IFIP NETWORKING 2017
- ▶ *A QoE Perspective on HTTP/2 Server Push*
  - ACM Internet-QoE 2017

- **Live results of measurement studies @COMSYS**

- ▶ <https://www.netray.io>

**Thank you for your attention!**

# Appendix - HTTP/2 (H2) in a nutshell

- **One TCP Connection (!)**

- ▶ Better utilization

- **Streams**

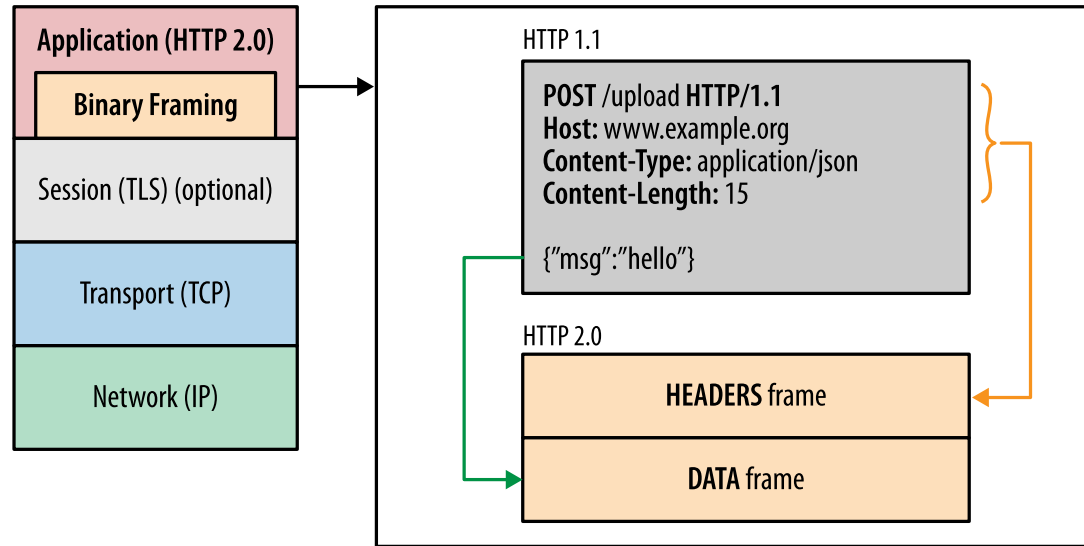
- ▶ Multiplexing
- ▶ Prioritization

- **Additional Features**

- ▶ Flow Control, Header Compression, Server Push

- **Improved parallelism → H1 hacks become obsolete**

- ▶ Domain sharding, inlining, image spriting, concatenation



Sources: Ilya Grigorik, High Performance Browser Networking, <https://hpbnp.co>