An Experimental View on Fairness between HTTP/1.1 and HTTP/2

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***Abstract*—As the modern web becomes complicated, HTTP has been upgraded from 1.1 to 2. Many web browsers and servers have adopted HTTP/2 that provides improved performance, security and bandwidth, and they support both HTTP/1.1 as well as HTTP/2 clients for the migration period. In general, HTTP/2 is considered to outperform HTTP/1.1, but it does not always guarantee the enhanced throughput. In this paper, we look into the fairness issue when HTTP/1.1 clients compete with HTTP/2 clients to connect the same web server simultaneously. From the realistic network environments such as WLAN, cellular 3G or LTE networks, we show that the HTTP/2 clients do not achieve the fair network bandwidth allocation when multiple HTTP/1.1 clients are connected to the web server.**

***Index Terms*—HTTP/2, fairness, TCP, page load time, HTTP/1.1**

I. Introduction

Recently, modern web services have begun to migrate their main web protocols from HTTP/1.1 to HTTP/2. It is reported that HTTP/2 accounted for 15% of global web services in August 2017 and about 30% in August 2018 [1]. As web pages become more complex and richer, HTTP/1.1 has shown its performance bottleneck points such as application-layer Head-Of-Line (HOL) blocking and no multiplexing. For example, when a large object of a web page is being sent to the client, it can lead to the sequential delays of the following objects belonging to the same web page. In order to overcome the weaknesses of HTTP/1.1, HTTP/2 has been standardized to support fast downloading of web objects with multiplexing, binary framing, and header compression functions.

Although HTTP/2 achieves the enhanced throughput, it often experiences the low performance. For instance, it is reported that the performance of HTTP/2 can be degraded when the packet loss rate along the end-to-end path is high [2], [3]. A previous study [2] compared Page Load Time (PLT) of HTTP/1.1 and HTTP/2 clients when the loss rate is 0% and 6%. It shows that when the packet loss rate is 6%, the PLT of HTTP/2 exceeds 1.6 times larger than that of HTTP/1.1. The poor PLT of HTTP/2 clients comes from that HTTP/2 uses a single TCP connection that will reduce the congestion window (CWND) under a congestion event, a packet loss. In HTTP/1.1, the maximum number of connections per host varies by different web browsers like Chrome, Firefox, Internet Explorer, Safari, and Opera. Typically, Chrome and Firefox web browsers use the maximum simultaneous connection count in six [4].

Though prior studies [2] show the performance of HTTP/1.1 and HTTP/2 sessions for various network environments, there has been no research that analyzes the fairness view when multiple HTTP/1.1 and HTTP/2 clients access to the destination web server at the same time. Prior studies [5], [6] tackle the unfair allocation of bandwidth in multipath-TCP and HTTP video streaming service. While HTTP/2 is being deployed to web servers and clients, it will take a long time to fully migrate from HTTP/1.1 to HTTP/2. Hence, most web servers support both HTTP/1.1 and HTTP/2 for compatibility, which can trigger the unfairness of performance degradation to HTTP/2 sessions under simultaneous HTTP/1.1 client accesses. That is, we will often meet the situation that HTTP/1.1 and HTTP/2 clients connected to a web server compete for the network resources among them. When HTTP/1.1 and HTTP/2 clients share the same resource along the end-to-end path, they will contend for keeping their own bandwidth. Under the high packet loss rate and the long RTT, an HTTP/2 session using only a single TCP connection cannot achieve the fair network utilization compared with an HTTP/1.1 session that uses multiple TCP connections. Therefore, we need to understand how the HTTP/1.1 and HTTP/2 connections affect each other when multiple HTTP/1.1 and HTTP/2 clients get access to a web server simultaneously.

In this paper, we present the fairness view on multiple HTTP/1.1 and HTTP/2 connections to a web server under varying RTT and loss rates. Especially, we show how the HTTP/1.1 connections affect the HTTP/2 performance degradation. Upon the realistic network environments like wired LAN, WiFi, 3G, and LTE, we run 10 web browsers of different ratio of HTTP/1.1 and HTTP/2 clients and measure their page load time. From experiments, we can know that the fairness between HTTP/1.1 and HTTP/2 connections is not guaranteed under typical network situations with moderate packet loss

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rate and RTT. For instance, in 3G or LTE environments, it is highly probable that HTTP/2 connections receive less than 22% fairness loss.

This paper makes the following contributions.

- We analyze the fairness index between HTTP/1.1 and HTTP/2 clients sharing the same link.
- We investigate the fairness index between HTTP/1.1 and HTTP/2 clients under the loss ratio and the delay of wired and wireless network environments.

II. FAIRNESS BETWEEN HTTP/1.1 AND HTTP/2 CLIENTS

If HTTP/1.1 and HTTP/2 clients send requests to a web server concurrently, HTTP/2 clients could not fully utilize the end-to-end bandwidth. In general, a web server should provide the fair resource allocation so that every web client experiences the fair network performance such as the page download time (PLT). However, when RTT and loss rate become high like in cellular networks, HTTP/2 clients often receive unfair resource allocation. This unfairness is caused by the number of TCP connections that HTTP/1.1 and HTTP/2 clients use.

In general, in HTTP/1.1, a web browser creates six TCP connections to a server in maximum. On the other hand, in HTTP/2, a web browser opens only a single TCP connection. When a packet loss event occurs, a TCP sender triggers the congestion control algorithm to reduce the CWND size. However, this is fatal to the HTTP/2 session using a single TCP connection. When many web objects in a web page are multiplexed and transmitted at the same time, if the CWND size is reduced, it will take longer to download all objects along a single TCP connection.

We use the Jain's fairness index [7]. Jain's fairness index is a metric to measure how equally clients share bandwidth. x_i is the normalized throughput of the i-th HTTP session. The index value ranges from $1/N$ to 1. If all clients use the same bandwidth, the value would be 1. When we compare the fairness between HTTP/1.1 and HTTP/2, the exact bandwidth sharing will be 1. If the fairness index is lower than 1, it means that HTTP/1.1 takes more resources than HTTP/2.

$$I = \frac{(\sum_{i=1}^{n} x_i)^2}{n \cdot \sum_{i=1}^{n} (x_i)^2} \tag{1}$$

III. PERFORMANCE EVALUATION

A. Experimental environment

We examine how the fairness metric varies in a typical network environment such as wired LAN, cellular 3G, wireless LAN, and LTE. Table I shows the RTT and loss rate values in typical networks [8].

Figure 1 shows the experimental test network environment. We run 10 web clients on Ubuntu 16.04.4 with 1.30GHz Intel Celeron CPU and 4GB memory and a web server on Ubuntu 16.04.4 with 3.40GHz Intel Core i7-3770 CPU and 4GB memory. The clients and the server are connected with 100 Mbps Ethernet hub. In order to simulate the delay and loss rate of LAN, LTE, WiFi, and 3G, we configure

TABLE I
TEST NETWORK CASES: RTT(MS) AND LOSS RATE (%)

LAN		LTE		WiFi		3G	
10ms	0%	100ms	0%	150ms	0%	200ms	0%
10ms	0.5%	100ms	0.5%	150ms	0.5%	200ms	0.5%
10ms	1%	100ms	1%	150ms	1%	200ms	1%
10ms	3%	100ms	3%	150ms	3%	200ms	3%
10ms	5%	100ms	5%	150ms	5%	200ms	5%

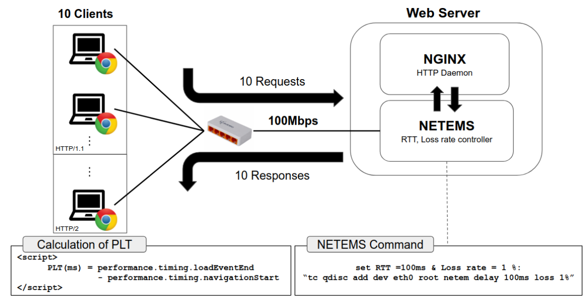


Fig. 1. Experimental environment where 10 clients access to a web server.

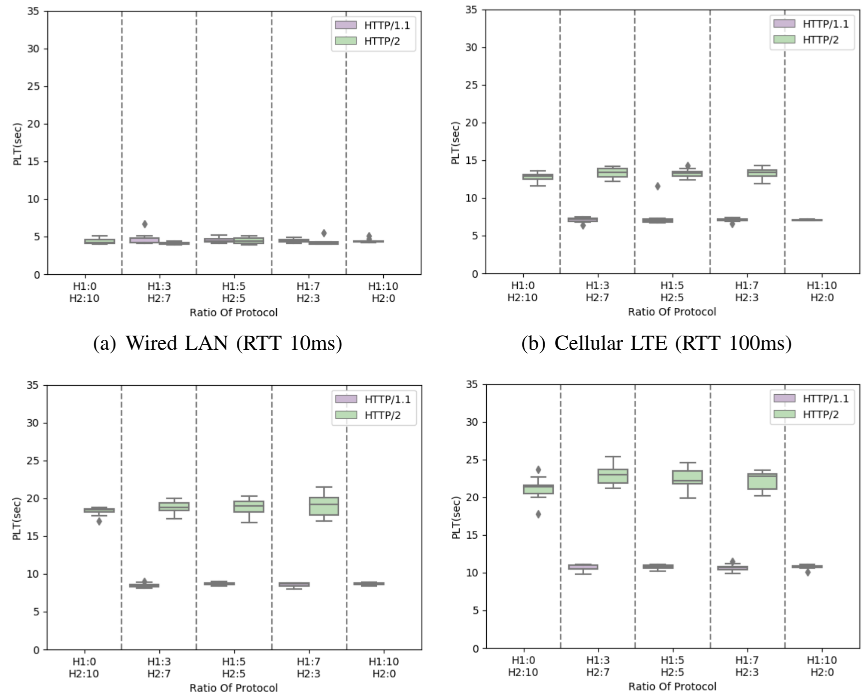
`Netem` on the web server and invoke all clients to connect the server simultaneously with `crontab`. We use Chrome 66.0.3359.170 and repeat 10 tests. For the web server, we selected a representative shopping mall website, eBay. The eBay web page consists of 171 objects and its total size is 2.5MB. To compare the performance, we computed the page loading time (PLT) that is the time difference between the `loadEventEnd` event and the `navigationStart` event of the `JavaScript` Navigation Timing API and the fairness index.

B. Fairness between HTTP/1.1 and HTTP/2

We investigate how fairness among web clients is not guaranteed as the number of HTTP/1.1 and HTTP/2 clients is changed. We measure and compare the PLT under the different ratio of HTTP/1.1 and HTTP/2 clients.

Figure 2 presents the PLT plots of HTTP/1.1 and HTTP/2 sessions in wired LAN, LTE, WiFi, and 3G networks. We assume 1% of the packet loss rate and the latency of 10ms for wired LAN, 100ms for LTE, 150ms for WiFi, and 200ms for 3G. It is reported that the probability of a packet loss rate less than 1% on 2.5MB page loading is about 62% [9]. In wired LAN with 10ms, PLT for HTTP/1.1 and HTTP/2 shows no difference. In LTE with 100ms, HTTP/2 experiences the increased PLT of 13 seconds, whereas HTTP/1.1 has the low PLT of 7 seconds. In addition, in WiFi and cellular 3G networks (150ms and 200ms), the PLT of HTTP/2 becomes larger than that of HTTP/1.1. In WiFi and 3G networks, the clients using HTTP/2 experience 2.2 times more PLT than clients using HTTP/1.1.

To examine how the loss rate and RTT variations affect the fairness, we measured the fairness index under the different latency and loss rate values. Figure 3 shows the fairness index under the various latency and loss rate configurations assuming



(a) Wired LAN (RTT 10ms)

(b) Cellular LTE (RTT 100ms)

(c) WiFi (RTT 150ms)

(d) Cellular 3G (RTT 200ms)

Fig. 2. PLT of HTTP/1.1 and HTTP/2 sessions on various network cases with 1% packet loss rate

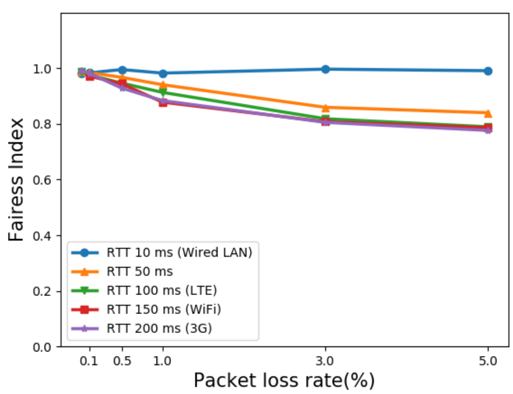


Fig. 3. The fairness index in different network environments with various RTT and loss rates.

LAN, LTE, WiFi, and 3G cellular networks. The ratio of HTTP/1.1 and HTTP/2 connections is 5:5. In the wired LAN with low RTT (10ms), the fairness index does not change for different loss rates. However, when RTT becomes moderate like 50ms, the fairness index decreases even for the low packet loss rate. In networks with 0.1% packet loss rate, the fairness index is well maintained around 0.98. However, as the packet loss rate kicks in from 0.5% to 5%, the fairness index begins to be noticeably reduced: 0.95 for 0.5% packet loss rate;0.87 for 1% loss rate; 0.8 for 3% loss rate; 0.75 for 5% loss rate. Under the packet loss rate larger than 0.5%, the RTT value also contributes to the unfairness. This is because HTTP/2 is sensitive to the packet loss rate which decreases the sender congestion window size.

IV. Conclusion

In this paper, we present how the fairness between HTTP/1.1 and HTTP/2 session is not well maintained in realistic network environments. Though HTTP/2 supports the overall performance enhancement of modern web pages, it does not always provide the fair throughput for simultaneous HTTP/1.1 and HTTP/2 sessions to a web server.

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