

# Are 3<sup>rd</sup> Parties Slowing Down the Mobile Web?

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## 1. INTRODUCTION

Content Providers (CPs) such as Facebook, Google, and others desire that their websites attract large user bases and generate high revenue. As a result, CPs strive to develop attractive and interactive websites that keep users engaged. JavaScript libraries from Online Social Networks, advertisements, and user tracking beacons allow CPs to personalize webpages based on end-users' interests, while various CSS frameworks make websites aesthetically pleasing [7, 9]. Further, webpage analytic APIs and performance monitoring tools allow CPs to monitor the user-perceived performance with their websites [8, 11]. However, as CPs continue to evolve their websites with more and more attractive features the webpage load time (PLT) starts to increase, which results in poor user experience with their websites [5, 12, 27].

To speed up Web content delivery to end-users CPs make contracts with Content Delivery Networks (CDNs), such as Akamai. These CDNs are distributed deep inside many last mile wired and mobile ISPs worldwide and thus provide low-latency paths to end-users [24]. Additionally, CDNs are motivated to adopt new and upcoming Internet standards to achieve even faster content delivery for CPs' websites [15, 17, 19, 21]. Although CDNs are effective in reducing download times of Web objects they serve, as CPs continue to enhance their websites by adding *external* APIs and tools it becomes challenging for CDNs to further speed up webpages [5, 12, 27].

We refer to external APIs and tools as *3<sup>rd</sup> Party* assets because the performance of such assets is not under the control of the *1<sup>st</sup> Party* (such as a CDN provider acting as surrogate infrastructure for its CP customers) that serves the base page HTML. In general, we define *3<sup>rd</sup> Party* as any asset embedded in the webpage that is not served by the same infrastructure serving the base page HTML and thus the downloads of such assets cannot be optimized by *1<sup>st</sup> Party*.

In this paper, we take a novel approach to expose the impact of *3<sup>rd</sup> Party* downloads on mobile Web performance. We showcase results from our ongoing investigation to understand whether *3<sup>rd</sup> Party* downloads contribute to critical paths of webpages [26]. Specifically, we make the following three contributions:

**Data Analysis:** We make extensive use of the open-sourced data available at HTTP Archive to expose the characteristics of *3<sup>rd</sup> Party* assets embedded into the top 16,000 Alexa webpages, which we observe to be currently served by four major CDN providers [2, 6]. Specifically, we investigate the number of unique domain names resolved, HTTP requests sent, total bytes, and total uncompressed bytes downloaded for *3<sup>rd</sup> Party* assets for each webpage in our dataset.

**Measurement:** To understand the impact of *3<sup>rd</sup> Party* downloads on PLT, we conduct several active experiments over a period of three months in 2016 using 52 cellular clients of Gomez Mobile testbed [3]. We load 60 real webpages about 400 times each from the production servers of a major CDN provider, where each webpage comprises of several *3<sup>rd</sup> Party* assets. For the purposes of this investigation, we devise a new Web performance metric, **3<sup>rd</sup> Party Trailing Ratio**, that represents the time spent in downloading *3<sup>rd</sup> Party* assets, when no *1<sup>st</sup> Party* asset is downloaded in parallel.

**Inferences Drawn:** Based on our preliminary analysis of *3<sup>rd</sup> Party* download times, we observe that for many webpages *3<sup>rd</sup> Party* downloads contribute to up to 50% of the page load time, in the median case. Additionally, we identify that several *3<sup>rd</sup> Party* vendors do not compress Web objects even when clients show support for compression in HTTP headers.

To the best of our knowledge, there is currently no known best-practice as to how *1<sup>st</sup> Parties* should optimize *3<sup>rd</sup> Party* downloads to mitigate the impact of *3<sup>rd</sup> Party* downloads on the overall PLT. Therefore, in this paper we motivate the need to explore research directions for *1<sup>st</sup> Parties* to enable them reduce PLT currently inflated by various *3<sup>rd</sup> Party* downloads.

## 2. DATA COLLECTION

We now discuss our datasets to investigate the characteristics of *3<sup>rd</sup> Party* assets embedded in different webpages. We then measure the impact that *3<sup>rd</sup> Party* assets make on PLT, by conducting active experiments in real-world cellular networks.

**Understanding webpage structures:** We use the open-sourced HTTP Archive dataset, an initiative by Google, Mozilla, and other industry leaders, to understand structures of different websites [2]. The HTTP Archive data is collected using the WebPageTest framework, where webpages are loaded over several virtual machines inside a datacenter [13]. The page loads are then translated into a format similar to HTTP Archive format (HAR) containing the timing data as well as HTTP request and response headers for each individual HTTP request issued for the webpage under test.

For the purposes of this work, we extract only the HTTP request and response headers pertaining to the top 16,000 Alexa webpages,

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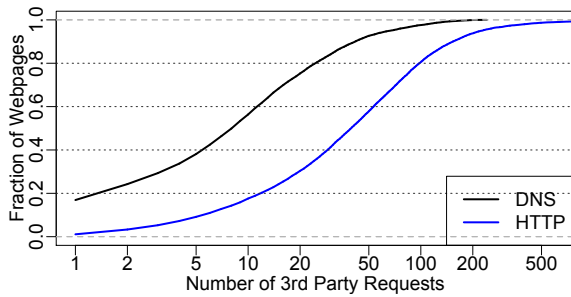


Figure 1: Distribution of the number of DNS lookup and HTTP requests made to download  $3^{rd}$  Party assets.

which we observe are currently served to Android mobile devices by four major CDN providers. In particular, for each requested object we extract headers indicating the response size, hostname associated with the download, and whether the response was compressed by the  $3^{rd}$  Party server. Since many  $3^{rd}$  Party assets often load after the *onLoad* event triggered by the Web browser and since we only focus on understanding how much  $3^{rd}$  Party downloads impact the PLT, we consider the measurement data for objects loaded only until the *onLoad* event. Our total dataset consists of about 16,000 webpages requesting a total of 1.6M objects, out of which about 525 K objects belong to  $3^{rd}$  Party vendors.

Next, for each hostname we perform a `dig` operation to check whether the hostname resolves to a canonical name (CNAME) associated with any of the four CDN providers used in this study. If a hostname for an object does not resolve to a CNAME associated to the  $1^{st}$  Party serving the base page HTML, we consider that object as a  $3^{rd}$  Party asset, with respect to the  $1^{st}$  Party under analysis. Additionally, if the hostname does not resolve to any CNAME, we consider that hostname as  $3^{rd}$  Party for all four  $1^{st}$  Party CDN providers we consider in this study.

Finally, for each webpage we calculate the total number of domain names resolved and HTTP requests sent for objects that we label as  $3^{rd}$  Party assets. We also calculate the total number of bytes, as well as the total number of uncompressed bytes delivered by various  $3^{rd}$  Party vendors even when mobile clients indicate support for compression in HTTP requests.

**Measurement data for  $3^{rd}$  Party impact:** To collect Web performance data pertaining to mobile page loads, we conduct several active experiments on Gomez Mobile testbed to download 60 different webpages served by the production servers of a major CDN provider [1, 3]. Next, we configure Gomez Mobile clients to load each website about 400 times and record Navigation and Resource Timing data for each page load [4, 10]. The Navigation and Resource Timing data we obtain consists of timestamps when the page load starts, timestamps when each object starts and finishes loading (including the time to perform DNS lookup, TCP handshake time, SSL handshake time, time to receive the first bit, and the object download time), and the timestamp when *onLoad* event is triggered by the Web browser. Our configured Gomez clients also record the hostname associated to each requested object, which we use to identify whether or not the object is downloaded from a  $3^{rd}$  Party vendor, similarly to how we identify this using the HTTP Archive data.

### 3. RESULTS

In Figure 1, we show the distribution of the number of unique domain names resolved and total number of HTTP requests issued to download  $3^{rd}$  Party assets for webpages served by the four major CDN providers used in this study. In general, we observe that

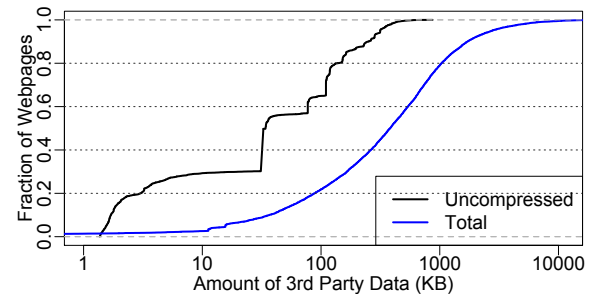


Figure 2: Distribution of total bytes and uncompressed bytes downloaded from  $3^{rd}$  Party vendors.

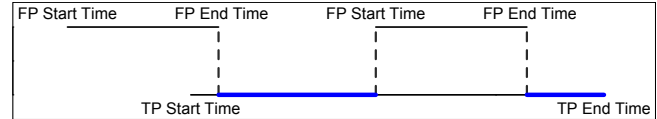


Figure 3: An example waterfall diagram showing one  $3^{rd}$  Party and two  $1^{st}$  Party downloads during page load.

in the median case, webpages resolve about 10 unique  $3^{rd}$  Party domain names and issue about 50 HTTP requests to download  $3^{rd}$  Party assets. For mobile clients where radio latency and the latency to cellular DNS servers is a few hundred milliseconds, we speculate that resolving multiple  $3^{rd}$  Party domain names could introduce significant latency to the overall PLT [20, 19, 25]. Additionally, such a large number of domain name lookups could potentially result in establishing many new TCP connections, negatively affecting the object downloads as each connection to  $3^{rd}$  Party server has to go through a TCP slow start phase.

Additionally, in Figure 2, we show the distribution of the total amount of data downloaded from  $3^{rd}$  Party servers, as well the total number of uncompressed bytes transmitted by  $3^{rd}$  Party servers even when clients indicate support for compression in the HTTP requests. Finally, similarly to Agababov *et al.*, we observe that several  $3^{rd}$  Party vendors do not compress objects even when clients indicate support for compression in HTTP request headers [14].

Although  $3^{rd}$  Party assets embedded on a webpage may require multiple domain name lookups and download of hundreds of kilobytes of data, we argue that  $3^{rd}$  Party assets that do not lie on a webpage’s critical path will not impact the PLT. Therefore, we now focus on quantifying the time spent by  $3^{rd}$  Party downloads on the critical path of the webpage. Specifically, we devise a new Web performance metric,  **$3^{rd}$  Party Trailing Ratio (TPTR)**, to reflect time spent by  $3^{rd}$  Party downloads during which no  $1^{st}$  Party asset is being downloaded. For example, consider the example waterfall chart in Figure 3, where we show the start and end timestamps of one  $3^{rd}$  Party and two  $1^{st}$  Party object downloads during a webpage load [22]. We define **TPTR** as the total time spent by  $3^{rd}$  Party downloads during which no  $1^{st}$  Party download is overcasting the  $3^{rd}$  Party download in the waterfall chart, as denoted by the two thick solid blue lines.

To calculate **TPTR**, we employ a two step process as follows: First, using start and end timestamps of all object downloads, we calculate all non-overlapping time intervals of  $1^{st}$  Party and  $3^{rd}$  Party downloads [18]. Second, using above intervals, for each  $3^{rd}$  Party interval we identify whether there is any  $1^{st}$  Party interval that intersects the  $3^{rd}$  Party interval. We then calculate the  $3^{rd}$  Party time interval that does not overlap with any  $1^{st}$  Party interval. The sum of all such intervals results to the **TPTR**.

In Figure 4, we show the distribution of **TPTR** for 60 webpages served by a major CDN provider, each loaded 400 times from Gomez Mobile clients connected to cellular networks. For figure

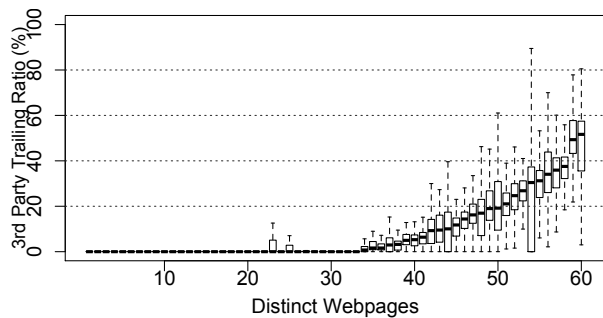


Figure 4: Distributions of 3<sup>rd</sup> Party Trailing Ratio across 60 webpages served to cellular clients.

clarity, we sort pages on x-axis based on the median **TPTR** value across different webpages. In general, we observe that 3<sup>rd</sup> Party downloads do not impact PLT for about half of the webpages in our dataset. With these webpages, when 3<sup>rd</sup> Party assets are being downloaded, one or more longer 1<sup>st</sup> Party assets are also being downloaded in parallel. Therefore, for these webpages, the 3<sup>rd</sup> Party downloads do not lie on critical path. However, for other webpages, 3<sup>rd</sup> Party downloads contribute to up to 50% of the total PLT, in the median case. For these webpages, when 3<sup>rd</sup> Party assets are being downloaded one or more 1<sup>st</sup> Party downloads overlap at most a small fraction of 3<sup>rd</sup> Party download time. Therefore, for these webpages, 3<sup>rd</sup> Party downloads lie on the webpage critical path and thus introduce additional latency to the overall PLT.

#### 4. FUTURE RESEARCH DIRECTIONS

Our study exposes the impact of 3<sup>rd</sup> Party object downloads on mobile Web performance. We argue that the research community should invest effort to develop techniques that mitigate such demonstrated 3<sup>rd</sup> Party impact. In our ongoing work, we plan to investigate if and how 1<sup>st</sup> Party could safely redirect 3<sup>rd</sup> Party downloads onto their infrastructures. One option to achieve this would be to rewrite 3<sup>rd</sup> Party URLs to URLs associated to 1<sup>st</sup> Party hostnames, such that any request to download a 3<sup>rd</sup> Party asset could be delivered by 1<sup>st</sup> Party servers, to which the clients are already connected.

Additionally, such URL rewriting would allow 1<sup>st</sup> Party to use well-thought content delivery protocols, such as HTTP/2, IPv6, caching and pre-fetching static resources to deliver 3<sup>rd</sup> Party assets. Alternatively, one could potentially coalesce TCP connections to 3<sup>rd</sup> Party content serves onto the existing connection to the 1<sup>st</sup> Party server [23]. In fact, a recent Internet draft by Microsoft and Mozilla details how to present additional certificates during an existing connection and serve content for the domains referenced in the additional certificates [16].

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