Empirical Characterization of Ookla's Speed Test Platform: Analyzing Server Deployment, Policy Impact, and User Coverage

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***Abstract*—Multiple speed test platforms provide web-based tools for end-users to evaluate their Internet performance. These tests gauge the end-to-end throughput by executing bulk data transfers between the user's browser and one of the globally distributed speed test servers. However, speed test services lack standardization on where and which network to deploy the servers, and how to assign them to users for tests.**

This paper presents the first large-scale empirical characterization of the Ookla, the world's largest speed test platform. We designed novel methods to discover test servers and captured monthly snapshots of their meta-information. We analyzed the deployment in different countries and regions across three years. By correlating the changes with national policies and political incidents, we revealed three key factors influencing Ookla infrastructure deployment: the influence of broadband consumer protection policies encouraging ISPs to operate speed test servers, geopolitical tensions leading to the removal of over 64% of speed test servers from telecommunications companies in response to tensions with Russia, and Ookla's own policies impacting 53% of Japanese customers who lost access to on-net servers.

***Index Terms*—Speed test infrastructure, Policy influence, Ookla.**

I. Introduction

Web-based network throughput tests, commonly known as speed tests, are one of the most popular tools for end-users to appraise Internet performance. Both individuals and content providers utilize speed tests to identify and diagnose network problems [13], [15], [18], [26], [34]. Regulators and researchers also rely on speed tests to validate claims about broadband performance [8], [10]–[12], [19], [21], [22], [31], [38], [39], measure the performance of 5G networks [45], and evaluate the network throughput of public cloud platforms [28]. Speed test platforms include dedicated speed test-only services [34], as well as those operated by Internet Service Providers (ISPs) [15] and content providers [13], [18], [26].

Speed test platforms typically consist of many geographically dispersed test servers, strategically positioned to reduce the latency and shorten the network paths to end-users. Various platforms adopt distinct strategies for building their test infrastructure. For example, M-Lab [25] and Comcast speed test [15] install bare metal machines dedicated for this purpose. Speedof.me [1], Cloudflare speed test [13], and fast.com [18] leverage existing content delivery networks (CDNs). In most cases, the speed test platform has control over the underlying (virtualized) hardware or the network connectivity.

Ookla, currently hosting the largest number of speed test servers, employs a crowdsourcing model to grow its fleet of test servers. Instead of deploying boxes to different locations, network operators use their own hardware to install Ookla's software and submit requests to join the Ookla platform [35]. While this deployment model yields to high diversity in geographical and network location of test servers, it introduces higher variances in the availability of test servers, as server owners may disconnect their servers at anytime. Although the platform could seamlessly redirect users to other available servers to run the tests, the dynamic nature of server availability may introduce variances in measurement results.

The opacity of Ookla speed test platforms poses a major challenge that we have to overcome in this study. In contrast to some other platforms (e.g., M-Lab), Ookla does not provide detailed information (e.g., IP address and geolocation) about their test servers. We tackled this challenge by developing techniques that leverage RESTful APIs on Ookla speed test website (speedtest.net) to discovery speed test servers and their meta information. Our measurement discovered over 12k Ookla speed test servers and their meta-information. This dataset provides a foundation for us to study Ookla's speed test infrastructure.

In this paper, we analyzed the Ookla server lists that we collected over the last 3 years to study the dynamics of the infrastructure. We annotated the data with additional datasets. More specifically, we used ASdb datasets [47] to provide insights on the categories of the owners of autonomous systems (ASes) who deployed Ookla test servers. Recognizing the significance of on-net test servers (within the same ISP as users) in measuring broadband performance [20], we estimated the user coverage of *on-net* Ookla servers using APNIC AS-user population data [4].

We investigated the changes in the infrastructure and summarized the following surprising findings:

- Brazil had the highest number of Ookla speed test servers over the past three years. Many of which were deployed by small regional ISPs, likely driven by government policies on Internet performance.
- Geopolitical tensions contributed to the reduction of test servers in Russia, , with sanctions against major telecommunication companies leading to the removal of over 64% of their speed test servers between 2021 and 2022. Meanwhile, Ukraine only suffered from losing independent operators' speed test servers during the conflict.
- A new Ookla policy that removed test servers hosted by individuals from the platform caused 53% drop in on-net server coverage in Japan.

II. Related work

Prior research on speed tests have investigated the challenges of building and using speed test platforms [5]–[7], [20]. Bauer *et al.* [5] studied five popular speed tests (Ookla, M-Lab NDT, ComScore, Akamai Speed Reports, YouTube Speed numbers) and found significant differences in measurement methods which led to discrepancies in measurement results. The choice of test servers controls the network paths that measurement traffic traverses and thus significantly affects the measurement results [27].

There is no published analysis of speed test servers deployment. And to our best knowledge we establish the first study about how speed test servers will be affected by global policies. Several studies showed the importance of having on-net speed test servers. High-speed residential broadband services (up to 1Gbps) impose new challenges to speed test measurement methods and tools. Test platforms that rely on off-net test servers may underestimate the last-mile capacity of high-speed access links [6]. Other methodological limitations included cross-traffic interference within home networks to the measurement flows [20]. We developed WebTestKit [46] to facilitate the use and analysis of various speed tests for networking research, and showed that unstable test server selection or inaccurate IP geolocation results may lead to highly fluctuated latency/throughput in the test results.

III. Background

Ookla speedtest [34], introduced in 2006, is a popular tool used by users to measure their Internet speed. As of May 2023, Cloudflare Radar [14] ranked the domain (speedtest.net) to be top 501-1000. Similar to other speed test platforms (e.g., [13], [18], [26]), Ookla's test infrastructure comprises multiple test servers deployed across various networks and geographic areas where users access them.

To select a server to perform a speedtest, Ookla chooses a set of 10 servers nearest to the user based on IP geolocation, and conducts ping tests to those servers to use the one with the lowest latency from the users [37]. After that, the test establishes parallel HTTPS/TCP connections with the server to measure latency and download/upload throughput by transferring large amount of data across the Internet.

The placement of these servers affects the use case for the measurements, namely: what bottleneck links the speed test is measuring, and thus how users should interpret their results. Also, the closer to the user, the fewer links that may be a bottleneck that the traffic will encounter. *On-net* in an ISP's regional network, the primary bottleneck link is the last-mile link. Off-net, in an IXP deployment, the links connecting to the IXP can also be bottlenecks, also there may be added latency to reach the IXP [20].

ISPs are incentivized to deploy speed test servers to provide easy-to-use tools for customers to diagnose the network. They may use speed tests to perform quality assurance tests on their network, ensuring compliance with service level agreements (SLAs) and regulatory requirements.Building their own speed test platforms, especially for small ISPs, can be time-consuming and resource-intensive. Ookla tackles this challenge by offering software (a customized web server) that operators can install on their machines to become Ookla speed test servers [35]. Users can then perform speed tests using these servers through Ookla's web interface.

IV. Measurement methodology

In this section, we describe our methodology for acquiring meta-information about Ookla speed test servers, including IP addresses and physical locations. Given Ookla's absence of a publicly accessible server list, obtaining the server list requires reverse-engineering efforts.

We analyzed the web page of Ookla Speedtest and examined the HTTP transactions that occurred prior to the throughput tests. Additionally, we interacted with the "select test server" feature to trigger additional transactions and identified the RESTful APIs that provided server information. Ookla's API allows querying with partial server names, composed of the network name and server location.

To generate queries, we employed a recursive approach to construct query strings. Initially, we enumerated possible combinations of alphabetic characters with a length of 2 (e.g., `aa`–`zz`) and executed the queries. As the API returns a maximum of 100 servers matching the query string, responses containing 100 servers may not include all servers satisfying the query. Subsequent iterations involved increasing the query string length by one to refine results until responses contained fewer than 100 servers.

Each record obtained from the queries includes the sponsor's name (host), IP address, city, country, and coordinates (latitude and longitude) of a test server. To map IP addresses to Autonomous System Numbers (ASNs), we utilized CAIDA's prefix-to-AS dataset [9] at the day performed the crawling. We annotated the ASNs using two datasets–1) ASdb [47], which employs machine learning approaches to analyze data sources, such as WHOIS and organization websites, to classify ASes into 17 industry categories and 95 sub-categories; 2) APNIC AS population [4], which deploys online advertisements to estimate the number of users within each AS.

V. Datasets

We executed our server discovery methods, as described in §IV, on the 1st day of each month from January 2021 to September 2022. Due to technical issues, we temporarily halted the crawling process and conducted an additional download in April 2023. We used the latest prefix-to-AS data at the time the crawling performed to map the IPs to ASNs. We then used ASNs as a key to join the ASdb and APNIC AS population data.

We downloaded the ASdb dataset released on December 2022 on the project website [43]. We then categorized the AS owners that hosted the speed test servers. For the APNIC AS population dataset, the website [4] only provided the most recent data. To account for the population changes in ASes, we contacted APNIC to obtain three historical snapshots (April 1st 2021-2023).

VI. Results

In this section, we first present an overview of the distribution of Ookla Speedtest servers that we have discovered over the past three years. We used the annotated datasets to shed light on different characteristics of Ookla's infrastructure (§VI-A). We further identified and investigated how the deployment of Ookla speed test servers and influenced user coverage was possibly affected by three different factors (§VI-B1—§VI-B2).

A. Evaluating the coverage of Ookla speed test platform

We illustrate the location of 12,955 Ookla speed test servers we discovered on April, 2023 (Figure 1). Some regions in North/South America, Europe, and Southwest Asia had dense server deployment (yellow in the map). Meanwhile, the server distribution in regions such as Africa, Australia, and Southeast Asia was relatively sparse (purple in the map).

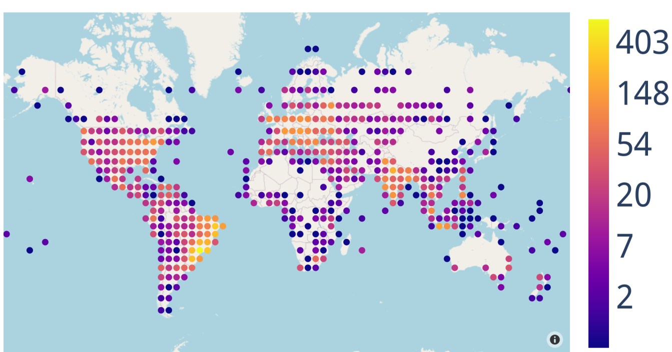

Figure 1: Distribution of Ookla speed test servers around the world. We aggregated the locations of servers by rounding the latitude/longitude to one 5x5 point. The color of bubbles is proportional to the number of servers in the area (log scale).

To delve deeper, we investigated the number of speed test servers in each country on April 2023 (Figure 2). Focusing on the top 10 countries/regions by population, we found that Brazil (BR) had the highest number (∼3,300) of speed test servers, followed by the United States (US) and European Union (EU) (both had ∼1500 servers). Meanwhile, China (CN) and Japan (JP) had relatively low number (>30) of servers .

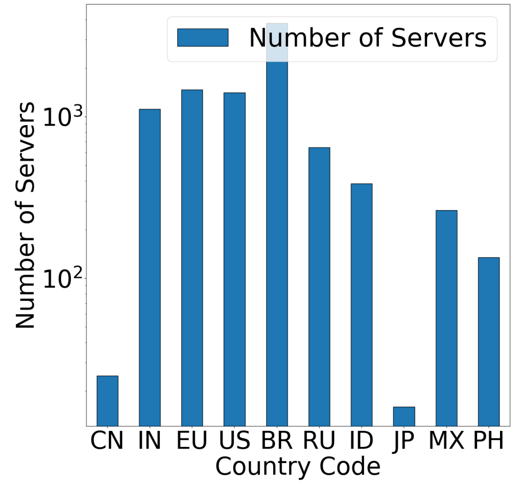

Figure 2: Number of speed test servers in top 10 countries/regions. Populated countries (e.g., CN and JP) had very few test servers.

1) Population coverage: By combining the Ookla server list with APNIC AS population data, we estimated the percentage of the population in each country/region with at least one on-net server. Figure 3 shows the top 10 countries by population and their corresponding on-net server population coverage percentages [1]. The consistently high population coverage is attributed to the preference of ISPs and many networks operate their own speed test servers, offering on-net servers for their customers. For example, Comcast deployed both their own speed test platform [15] and test servers on Ookla. ISPs often recommends these servers their web pages. Despite Mexico (MX), and Philippines (PH) had relatively small number of speed test servers, the coverage of both countries was nearly 100%. In contrast, BR, with the largest number of servers, reported the second-lowest population coverage ranked the 8th in population coverage.

Our investigation found that the size of networks in MX and PH was small, with only 441 and 352 ASes, respectively. With most of the eyeball networks/ISPs equipped with Ookla test servers, these counties achieved high population coverage. Large number of ASes in BR (7844 ASes) made deploying test servers for high network/population coverage challenging. Furthermore, we could not find test servers in two major Brazilian ISPs (Telefônica Brasil and Claro), which served 9.1% of customers in total. JP had the least number of speed test servers and population coverage. We will present an in-depth investigation in §VI-B2.

2) AS classification of the hosts of speed test servers: We used ASdb [43] to categorize the ASes hosting speed test servers. Figure 4 shows the percentage of servers in top

[1] During our analysis, we found Russia's population data from APNIC in 2022 and 2023 was not accurate due to low impression (hit rate) of the measurement ad. Google have been suspending online advertisement business in Russia since March 2022 [44]. We found that the AS population did not significantly change throughout the 3 years, we used the 2021 version of data instead to estimate the user coverage of Russia's on-net speed test server.

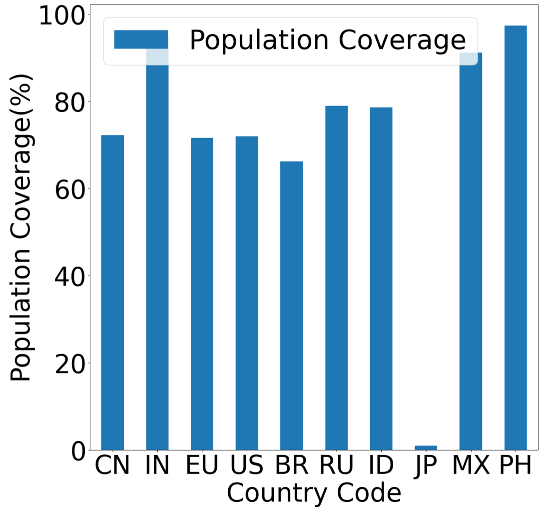

Figure 3: Population coverage of on-net speed test servers. All countries except JP had coverage over 60%.

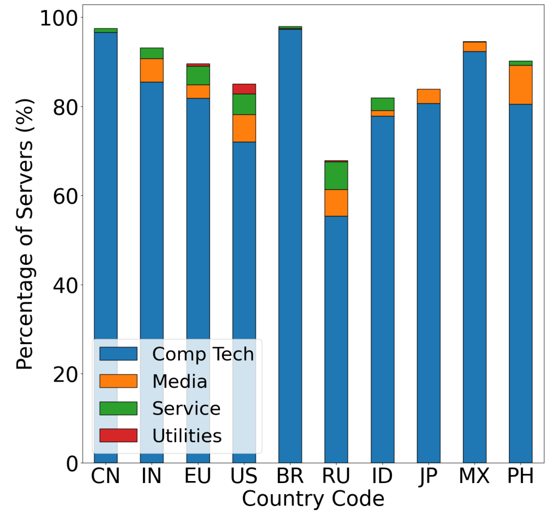

Figure 4: Classification of ASes. Most servers in BR and CN were hosted by ISPs (Comp Tech).

four industry categories in each country. The category 'Comp Tech', short for 'Computer and Information Technology', predominantly comprises ISPs offering telecommunication services. 'Media' refers to entities primarily engaged in providing online music and video streaming services, motivated to provide speed test services for users to assess network quality between users and their servers. The 'Service' category encompasses business and consulting service firms, providing their speed test platform for their clients. Lastly, 'Utilities' includes essential infrastructure providers such as electricity generation and water supply companies. Monitoring network quality is critical for the remote control and management of their infrastructure, such as smart grids.

Over 90% of Brazilian and Chinese test servers were hosted by ISPs (belonged to Comp Tech category), while other countries had more diverse types of hosts. We will explain this phenomenon in §VI-B2. Interestingly, our analysis revealed that Russia (RU) exhibited relatively low percentage of servers within the top four main categories. We manually examined the classification results of Russian ASes. We found that ASdb labeled 14.9% of test server hosting ASes 'construction' or 'retail'. We believe that ASdb erroneously classified some Russian ASes. For example, AS42742 (InterkamService LLC) is a Russian ISP, according to [41], but was incorrectly labeled as 'retail' by ASdb.

3) Server deployment trend: We conducted a comparative analysis of Ookla server lists captured between April 2021 and 2023. Our examination involved calculating the average rate of server loss and gain in the top 10 countries/regions over the span of three years. We defined servers present in the current year but absent in the subsequent year as 'loss', while those not detected in the current year but discovered in the next year were labeled as 'gain'. The 'loss/gain rate' was determined by dividing the number of 'loss/gain' servers by the total number of servers in the current year, resulting in the 'loss/gain rate'. We then average the 'loss/gain rate' for the years 2021-2022 and 2022-2023 in each country to derive their 'Average loss/gain rate'.

Figure 5 shows that most countries had a slight gain of servers, indicating a growing trend of Ookla infrastructure. Indonesia (ID), MX and PH had significantly higher growth rates than loss rates. The gain and loss rates in EU were comparable. In contrast, Russia (RU), JP and CN faced a more substantial loss in servers. These results motivated us to further investigate the factors that influence the deployment of speed test servers in different countries.

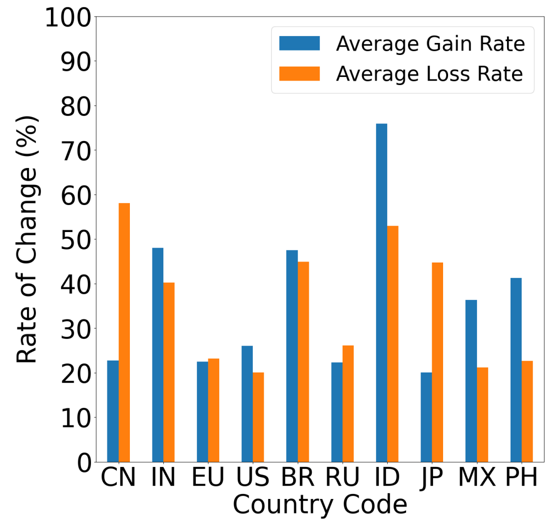

Figure 5: Number of speed test servers changing rate during 2021 to 2023 in top 10 countries with the largest populations.

B. *Contributing factors to the dynamics of Ookla infrastructure*

This section provides in-depth investigation into three factors/events that were correlated with the changes in speed test server deployment in some countries.

1) Geopolitical tensions: We found that geopolitical tensions could influence the deployment of speed test servers. A notable example is the conflict between Russia and Ukraine started on January 31st, 2022. Multiple studies have shown severe disruption on Internet throughput [22], routing and latency [24], and service availability [42] in Ukraine. On the policy prospective, the United States and Europe implemented sanctions on Russian telecommunications companies from March [2] to April 2022 [3]. We subsequently observed a large drop in the number of speed test servers in Russia within a month (from 775 to 603, -22%).

Our investigation revealed a significant decline in the servers associated with companies under sanction [33] (Figure 6). Specifically, the number of Rostelecom's speed test servers decreased from 81 to 29 (-64.1%). Net by Net Holding LLC (a subsidiary of Megafon) declined from 18 to 1 server (-94.6%). However, Beeline and MTS did not have any reduction in its number of servers. Lastly, the number of servers in DOM.RU (a subsidiary of ER-telecom) only decreased from 40 to 30 (-25%). Apart from the five large telecommunication companies, Ookla lost approximately 158 companies/organizations that hosted speed test servers, possibly a consequence either directly or indirectly linked to the conflict. This resulted in a loss of on-net speed test servers for 11.1% of the population in Russia.

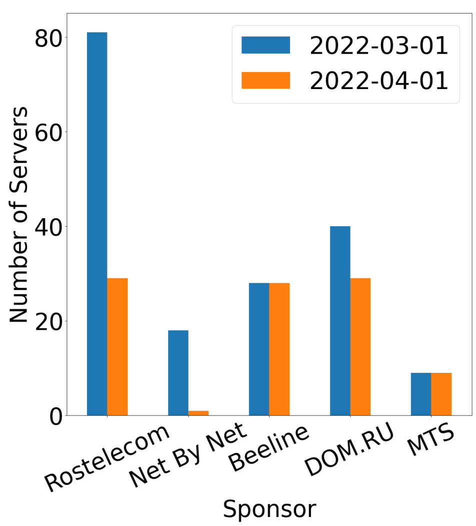

Figure 6: Number of speed test servers owned by Russian telecommunication companies in March 2022 and April 2022.

On the other hand, Ukraine also suffered from the loss of servers. We observed a decline in the servers from 355 (February 2022) to 269 (May 2022) (-24.3%). Consequently, the population coverage decreased from 75.4% to 61.1%. We correlated the geographic distribution of the lost servers in that three months with the progression of the conflict. We discovered that a significant portion of the lost servers was located in the Eastern and Southern parts of Ukraine, particularly in the areas controlled by Russia (Fig 7).

The majority of the lost speed test servers hosted by small companies rather than major telecommunication companies.

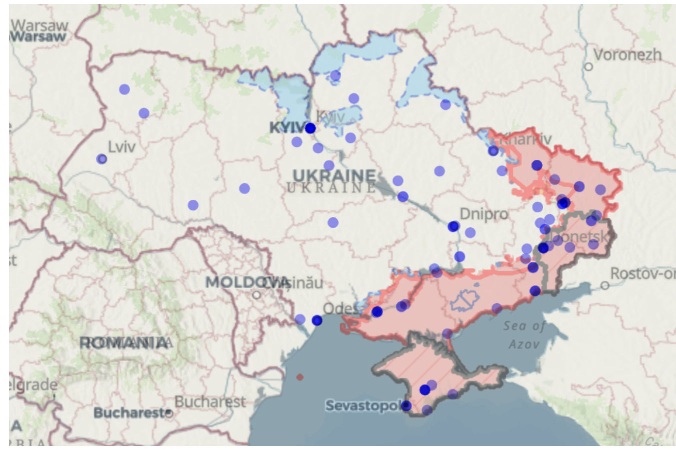

Figure 7: Ukraine's speed test servers loss graph during the war against Russia. Each light blue dot represent a server lost in the location and dark blue dot indicates there are more than one speed test server lost. The high light area are the major conflicts happened.

For example, speed test servers hosted by Kyivstar, a major Ukrainian telecommunication company, were barely affected. These Ukrainian ISPs maintained their speed test services, providing an adequate number of servers to monitor network quality. Our evidence showed that the effects of the sanctions imposed on Russia have had a more substantial impact on speed test servers than that of Ukraine.

2) Ookla server deployment policy: During the period of 2021-2022, the population coverage of speed test servers in Japan experienced a significant decline of 53.3%. This decline continued until 2023, reaching a low of 1.97%. The timing of the decline correlated with the release of a new Ookla policy that prohibited individual users from operating speed test servers [30]. As a result, 40% (12 servers) of individually operated servers in Japan disappeared between 2021 and 2023.

In our analysis of each speed test server and its associated AS (Table I), we observed that five AS lost their on-net Ookla speed test servers due to the prohibition of individual speed test servers. Notably, three major ASes in Japan—KDDI, Softbank, and NTT Communications—accounted for significant population coverage, with 21.07%, 18.37%, and 13.37% of the Japanese population covered, respectively.

Through conversations with researchers in Japan, we learned that Ookla was a popular platform used by customers to conduct speed tests in the country. The policy implemented by Ookla, which removed individually operated speed test servers, had the consequence of customers being unable to find a third-party platform with on-net servers to measure their network services. The impact of Ookla's policy in Japan highlights the significance of accessible and diverse speed test server options for customers. On the other hand, we found that major Japanese ISPs hosted their proprietary speed test platforms [23], [32], which only can conduct tests from their networks. The measurement methods of these tests could be different from each other. Customers may be hard to correctly compare and interpret the results.

Table I: Number of speed test servers and their population coverage in each Japanese AS during 2021 to 2023.

ASN	Number of speed test servers			Population coverage (%)
	2021	2022	2023	
2516	6	0	0	21.1%
17676	1	0	0	18.4%
4713	2	0	0	13.4%
2527	2	1	0	3.99%
138384	1	0	1	1.0%
2497	1	0	0	1.0%
2914	1	0	0	0.09%
55900	7	7	7	0.065%
63772	1	0	0	0.008%
18978	1	1	1	0.002%
17932	1	0	0	0.001%
63770	1	2	1	0.001%
59103	2	1	1	0.0001%
17661	1	0	0	0.0003%

3) National broadband policies: We conducted an investigation into the change in population coverage of speed test servers in the top 10 countries/regions (Figure 8) across the pass three years. We clustered these countries into three distinct groups.

The first group is located in the top right quadrant, including countries such as BR, IN, US, EU, and RU. These countries exhibited a high and stable number of speed test servers and sufficient population coverage. Notably, each country in this group had a designated commission responsible for overseeing the network quality of service. For instance, in the US, the Federal Communications Commission (FCC) administered the Measuring Broadband America program [19], which performs throughput tests from SamKnows [40] vantage points to evaluate ISPs' performance. Similarly, the Body of European Regulators for Electronic Communications (BEREC) had established guidelines for measuring broadband service performance, encompassing parameters like speed, measurement methods, and data processing.

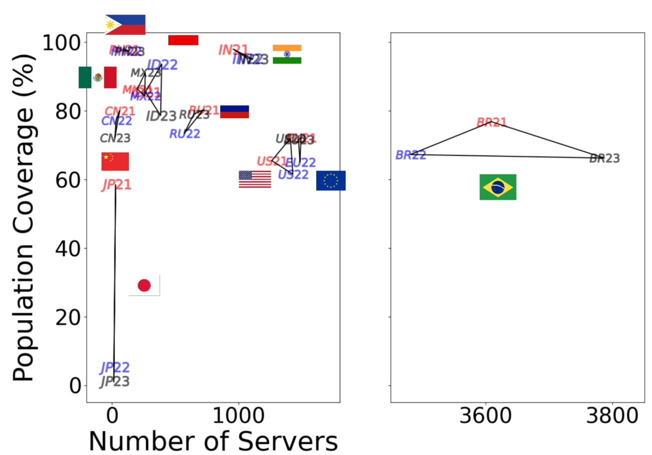

Figure 8: Changes in population coverage percentage and the number of speed test servers in 10 countries over three years.

The second group of countries is situated in the top left quadrant, including CN, ID, MX, and PH. These countries had fewer speed test servers but still maintained adequate population coverage, due to the presence of only a few large, often state-owned, ASes in these countries. Moreover, we were unable to identify effective policies in these nations aimed at regulating network quality. Consequently, the lack of motivation among individuals to deploy speed test servers contributes to the limited server presence.

Finally, the bottom left quadrant includes countries, such as Japan[2]. These countries exhibited a relatively low number of speed test servers and population coverage. However, we discovered that these countries have adopted a strategy of establishing speed test servers within each ISP. Nevertheless, these ISPs' speed test servers tend to be exclusive, catering only to their respective customers, and the collected data is typically not publicly available.

VII. Discussion

Significance of on-net server deployment. On-net servers could be important for policy-making for the residential broadband market. A number of recent policies and programs in the United States, including FCC Broadband Consumer Labels [16], the new FCC broadband maps [17], and NIST's Broadband Equity, Access, and Deployment (BEAD) [29], proposed to use network performance (throughput and latency) to regulate the broadband marketplace and distinguish unserved/under-served communities in broadband coverage. Measuring throughput using on-net servers could mitigate noise from other networks and provide a better view of the last-mile performance.

Geographical distance between users and test servers. Our country-level analyses did not account for the physical distance between end-users and test servers within the same country. In countries covering a vast geographical area, network latency could be significant, particularly when on-net test servers are physically distant from users. For instance, the round-trip delay between the East and West coasts of the U.S. within the same ISP could exceed 50ms, potentially impacting network throughput.

Completeness of the server lists. We may only obtain an incomplete list of servers using our method in §IV. The reason is that we noticed that some Ookla servers are only visible to clients in the same network. We usually found these restricted servers in mobile ISPs, such as AT&T mobile and T-mobile. In the future, we will use diverse vantage points to conduct the crawling for a more comprehensive results.

VIII. Conclusion and Future Work

Our research studied the evolution of Ookla, one of the largest speed test platform in the world, over the past 3 years. We developed techniques to periodically crawl a relatively complete list of servers, which allowed us to gain valuable insights into the geographical distribution of these widely used yet opaque speed test servers.

Our analysis shed light on how the number of speed test servers varies across different countries and over time. We

[2]This group also includes South Korea, Japan, the United Kingdom, and Thailand. We did not show them in the figure due to space.

observed the impact of conflicts between countries on the change of server deployment. Additionally, we highlighted the consequences of Ookla's new policy, which prohibits individual users from operating speed test servers and has resulted in a 53% reduction in on-net server coverage among the total population. We only picked several countries as example to present our observations.

In the future, we will enhance our analysis by coordinating with diverse vantage points to conduct active measurements on these speed test servers. To this end, we will leverage RIPE Atlas nodes, which will enable us to investigate the geographical distribution and network positioning of these servers. We will evaluate the effectiveness and accuracy of these speed test servers in providing reliable results to customers. We will use the Ookla's open datasets [36] to study how the changes in Ookla test infrastructure potentially affects the global Internet performance observed by the Ookla.

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