# Poster: Twinkle, Twinkle, Streaming Star: Illuminating CDN Performance over Starlink

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## ABSTRACT

Low-Earth-Orbit satellite networks (LSNs) are enabling low-latency high-bandwidth internet connectivity at a global scale. However, majority of the traffic on the Internet is currently handled by Content Delivery Networks (CDNs), which rely on geographical proximity to deliver content. In this work, we examine CDN performance for the commercial largest LSN, i.e. Starlink, by performing active measurements through our web browser plugin and passive analysis of Cloudflare speed tests globally. Comparing this to terrestrial networks, we highlight significant performance degradation for Starlink users due to the asymmetries between satellite and terrestrial infrastructure.

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## 1 INTRODUCTION

Almost 70% of the internet traffic is currently being served by content delivery networks (CDNs) [4]. CDNs operate by localizing users and placing servers in close proximity to deliver geographically popular content by routing users to the "nearest" server using techniques such as *anycast*, IP geolocation, DNS-based redirection. These principles work well when users are connected via traditional terrestrial ISPs as physical proximity largely correlates with lower latency. In LSNs, however, the user traffic traverses a satellite bent-pipe to a ground station (GS), and then terrestrially via an LSN point-of-presence (PoP) to the CDN location. As shown in Figure 1, the user might be connected to a geographically distant PoP with the help of inter-satellite-links (ISL), which can result in fetching content from CDN servers in a different region (different country or continent). Content retrieval in LSNs is thus reliant on its terrestrial deployment. For instance, Starlink users in Bahamas have reported CDN mapping fluctuating between US and UK[1] as the connection switches PoPs. A potential side-effect might be content geo-blocking if the connection is mapped to countries where the requested content is restricted [2].

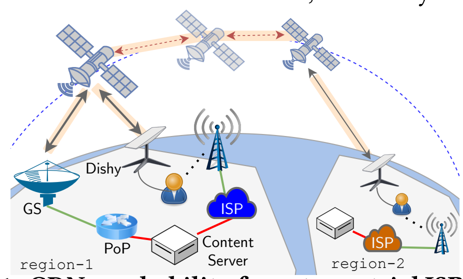


**Figure 1: CDN reachability from terrestrial ISP vs. LSN.**

In this work, we investigate the current state of CDN performance for Starlink network in comparison to terrestrial ISPs globally. Our analysis is based on over 1M+ measurements from 55 countries, which reveals significant degradation in specific regions in retrieving locally popular content from CDNs due to routing inefficiencies in the Starlink network. We highlight a few preliminary results in this paper and plan more comprehensive evaluations targeting CDN-dependant application performance in the future.

## 2 MEASUREMENTS & ANALYSIS

**Global CDN performance.** Open-source Cloudflare Aggregated Internet Measurements (AIM) dataset [1] provides us metrics for Internet connection quality, like download/upload speeds, latency and jitter for end-users. The dataset also includes the location of the mapped CDN server. We filter with ASN 14593 to gather Starlink user measurements. For terrestrial ISP measurements, we include them, if the ASN is classified as "Cable/DSL/ISP" or "NSP" in PeeringDB [6]. Other satellite ISPs are exluded using the Maxmind GeoIP DB [5]. We calculate the median latencies over both Starlink and terrestrial connections from a city to determine the "optimal" CDN server (lowest latency) for that location. We find that terrestrial connections observe lower latencies than Starlink in most countries by ≈ 50 ms. The latencies degrade significantly for Starlink users who are connected

[1]https://www.royalcaribbeanblog.com/2022/06/28/i-tried-elon-musks-starlink-internet-royal-caribbean-cruise-ship


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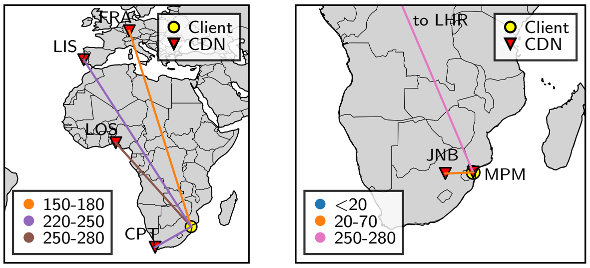


**(a) Starlink ISP** **(b) Terrestrial ISP**

**Figure 2: Median latencies (in ms) to the connected Cloudflare CDN servers from Maputo, Mozambique.**

to PoPs much farther away. Table 1 depicts the distance and minimum round-trip-times (RTTs) to the most optimal CDN server over a terrestrial and a Starlink connection in a few countries. It highlights the sub-optimal CDN server mapping for Starlink users in countries in Africa, Eastern Europe and the Carribean Islands, where the distance to the optimal CDN server is 1000-9000 kms away, often located in another country or continent. For countries where a local PoP is present (e.g. Japan/Spain), latencies >30 ms are observed, as even in the best-case, the bent-pipe link accounts for 25-30 ms [3].

A case-study on the CDN mappings for Internet users in Maputo, Mozambique is highlighted in Figure 2. We observe for Starlink connections that Frankfurt CDN server, almost 9000 kms away is the optimal and frequent choice, with latencies ≈ 160 ms (Figure 2a). This leads us to believe the LSN PoP is in Frankfurt, consistent with observations made in previous works [3]. While connecting to other CDN servers in Europe and Africa, much higher latencies of 220-280 ms are observed due to the longer terrestrial paths from the PoP to the CDN. This might degrade application performance when fetching geographically popular content from African CDNs. However, Figure 2b shows a contrasting picture for terrestrial ISP users in Maputo. In this case, the optimal and frequently chosen CDN location is Maputo itself, reachable under 20 ms. While Maputo to other African CDN locations (e.g. Johannesburg) observe latencies within ≈ 70 ms.

**Web Measurements.** We design and develop a Chromium based browser plugin which periodically fetches the top-20 popular websites in the Tranco list [7] served by Cloudflare or Cloudfront CDN. Through advertisement campaigns over Reddit and mailing lists, we recruit 21 Starlink users from North America, Europe, Africa and Oceania and 35 terrestrial ISP users from North America, Europe, Africa and Asia to install the plugin. No sensitive user information except public IP is extracted. We collect ≈ 5K measurements related to web browsing metrics, mainly HTTP response time (HRT), First Contentful Paint time (FCP) etc. Figure 3 illustrates the difference in HRT for both networks. Terrestrial users observe lower HRT by ≈ 20-50 ms, sometimes even upto 100 ms. Interestingly, 60% of the time Starlink users in Nigeria receive faster responses as connections are routed through the nearby PoP, skipping the still under-developed terrestrial infrastructure. Furthermore, FCP being a better indicator of quality of experience (QoE), we observe even higher differences ≈ 200 ms between both the networks (plot not shown), as this might entail a few web requests before the first content of the webpage is rendered.

**Table 1: The average geographical distance (in kms) to the best (= lowest latency) CDN server, indicating the sub-optimal CDN mapping for Starlink users.**

| Country | Terrestrial ISP | | Starlink | |
|---|---|---|---|---|
| | Distance (km) | minRTT (ms) | Distance (km) | minRTT (ms) |
| Guatemala | 6.9 | 7 | 1220.9 | 44.2 |
| Mozambique | 5.0 | 7.2 | 8776.5 | 138.7 |
| Haiti | 6.1 | 1.5 | 2063.2 | 50 |
| Kenya | 197.5 | 16 | 6310.8 | 110.9 |
| Lithuania | 168.6 | 12.4 | 1243.2 | 40 |
| Spain | 375.3 | 14.3 | 13.4 | 33 |
| Japan | 253 | 9 | 57.0 | 34 |

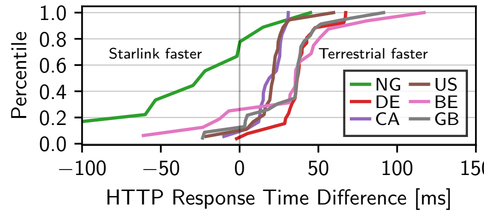


**Figure 3: The difference in HTTP response times for Starlink and terrestrial ISPs from selected countries.**

## 3 CONCLUSION

Our study highlights the critical differences in a terrestrial versus Starlink network with respect to CDN mapping and its performance implications. Although Starlink enables broadband connectivity in remote regions, the CDN performance over Starlink is highly dependant on its terrestrial footprint. Our analysis shows that Starlink network lags behind those of terrestrial ISPs in content delivery, which is the most prominent use-case of the internet. We plan to expand our measurements for other application scenarios (e.g. live video streaming via CDN relay points) to gain further insight in relevant content delivery and QoE over Starlink network.

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