Comparative Analysis of CDN Performance Between Africa and Europe

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Abstract

This paper investigates round-trip latency and packet routing across African and European Content Delivery Networks (CDNs). The providers considered were AWS, Azure, Google Cloud, and Cloudflare. RIPE Atlas probes were used to gather latency and traceroute data from web applications hosted on the CDNs. Analysis reveals significantly higher latency in Africa, with most traffic routed to European servers despite the presence of African Points of Presence (PoPs). This is in agreement with previous research that identified similar differences in regional web performance. The findings support the case for expanded cloud infrastructure in Africa to improve accessibility and reduce latency for African users.

Keywords

Networking, Internet Measurements, Cloud Computing

1 Introduction

The continuous growth in public cloud adoption has transformed how organizations worldwide deploy and manage their applications. While this digital transformation has been widely embraced across Europe, America, and Asia, Africa presents a unique case study in cloud infrastructure development and performance [3]. With the majority of public cloud infrastructure being outside Africa, this creates significant performance and usability implications for African users. Content Delivery Networks (CDNs) bridge these geographical gaps by hosting cache servers in Points of Presence (PoPs), strategically positioned to reduce latency and enhance user experience [4]. This optimization technique is crucial for organizations organizations seeking to deliver consistent performance across diverse geographical regions. In recent years, major cloud providers have begun establishing presence in Africa. Currently, Amazon Web Services (AWS) maintains datacenters in Cape Town, with PoPs in Cape Town, Johannesburg, and Nairobi. Microsoft Azure has established datacenters in both Cape Town and Johannesburg, complemented by PoPs in these cities as well as in Nairobi and Lagos. While Google Cloud lacks African datacenters, it operates PoPs in Johannesburg, Lagos, and Mombasa. Notably, Cloudflare has achieved the most extensive PoP coverage across the continent, with presence in fourteen African countries including Algeria, South Africa, Senegal, and Morocco.

This study builds upon previous research suggesting the need for expanded cloud infrastructure in Africa [1]. Our investigation focuses specifically on comparing CDN performance metrics between African and European regions, examining the practical implications of current infrastructure distribution. By analyzing latency measurements and network paths across these two distinct markets, we aim to provide insights that can inform both infrastructure providers and organizations in optimizing their cloud strategies. This will be done by addressing the following key questions:

(1) How do CDN latencies compare between African and European clients when accessing major cloud providers' PoPs?
(2) What patterns emerge in the routing paths of traffic from the different regions?
(3) What is the difference in latency between probes making requests to CDN servers and data centers?
(4) How many hops does it take African probes to reach CDN servers?

Through this research, we aim to contribute to the understanding of cloud infrastructure disparities and their practical implications for organizations operating across African and European markets.

2 Background

Previous work done by Chavula et al. [2] has highlighted the challenges faced by African users in accessing cloud services due to the lack of local data-centers. The study found that African users experienced higher latencies and lower throughput when accessing cloud services hosted in Europe and North America. This research underscores the importance of local cloud infrastructure in improving user experience and service delivery across the continent.

3 Methodology

Systematic measurement procedures were employed to analyze CDN performance across the regions. Our measurement methodology focused on collecting latency and routing data using RIPE Atlas measurement infrastructure to evaluate CDN endpoint performance across a limited selection of cloud providers.

3.1 Data Collection

A total of 100 RIPE Atlas probes across Africa and Europe were used as test points during experiments. The host countries of these probes are listed in Table 1. Using the RIPE Atlas platform, we monitored the stability and connectivity of probes in each country. This allowed us to generate a final list of 50 probes for each continent with a minimum 90% up-time in the last month. Figure 1 highlights how the geographic distribution of chosen probes was used to ensure a representative sample of internet performance across each region. We deployed static web applications to activate CDN services across the following major cloud platforms:

- AWS: https://d2idaxovs4aj5h.cloudfront.net
- Azure: https://purple-wave-0cddfaf1e.5.azurestaticapps.net/
- Cloudflare: https://ripe-measurement-demo.pages.dev/
- Google Cloud: https://internet-measurement-495477028753.africa-south1.run.app/ (IP: 35.201.77.206)

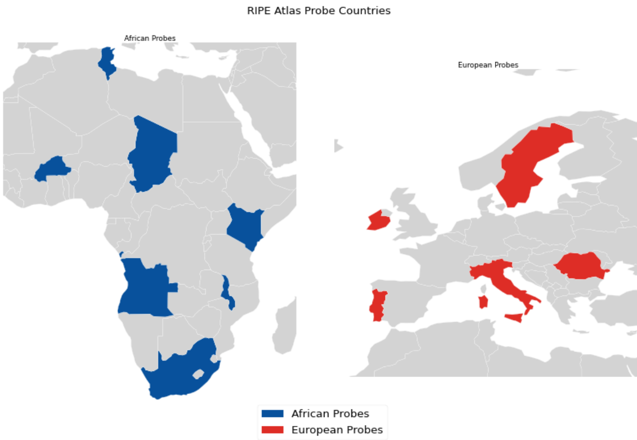

Figure 1: RIPE Probe host countries

Region	Countries
Africa	South Africa, Malawi, Tunisia, Kenya, Angola, Mauritius, Chad, Burkina Faso, Namibia
Europe	Sweden, Ireland , Ireland, Portugal, , Italy

Table 1: Distribution of RIPE Atlas probes across Africa and Europe

Measurements were executed every 3 hours over a three day period starting 21st October 2024. Two measurement types were used:

- **PING** - Ping measurements were used to record round trip latency. These were sent over ICMP with a 1000ms interval between packets. Each ping used a 48 byte payload with 3 packets sent for each measurement.
- **Traceroute** - UDP packets were sent over port 80 to trace the path to a destination. A maximum of 32 hops with a maximum of 3 packets per hop were sent. Each packet was set to 48 bytes with fragmentation allowed to reduce bandwidth impact. A response timeout of 4 seconds was used to determine a request's time to live. The duplicate timeout of 10 milliseconds helps to identify and handle duplicate packets, which could arise in high-latency environments.

Results from these measurements included the final destination IP address for each packet. These addresses were used to determine the geographical distribution of CDN endpoints through passive geolocation. In particular, the Maxmind and ip-api.com GeoIP databases.

3.2 Inability to Use Azure CDN

The Azure website was not able to be distributed to the CDN servers due to limitations on the features available for a Microsoft student account. As a result, the website was hosted as a static web app and Microsoft placed it on a server in the Netherlands, which is where all requests resolved to from all probes in both Africa and Europe.

4 Data Analysis

The data that was collected was then analyzed in the following fashion.

- **Latency analysis**: The mean RTT values for ping measurements from the selected probes to the cloud providers were collected and aggregated by country. So cloud provider performance in each country could be compared. This was done for countries in both Africa and Europe. Country names were determined using the IP-API[1], which uses an IP-geolocation table.
- **Geo-location of CDN servers:** Using the final destination of the trace-route measurements collected by the probes. We produced a collection of the CDN servers that traffic was most commonly redirected to. Country names were once again determined using the IP-API.
- **Measuring Hops:** Each measurement contains a list mapping the route from source to destination. We utilized these lists to determine the median number of hops to CDN servers for each provider, by country.

	AWS	Azure	Cloudflare	Google
African PING	80602536	80602888	80602405	80604371
African Traceroute	80602537	80602889	80602406	80604372
European PING	80604435	80604447	80603189	80604391
European Traceroute	80604436	80604448	80603190	80604392

Table 2: RIPE Atlas measurement links for PING and Traceroute tests conducted on AWS, Azure, Cloudflare, and Google CDNs in African and European regions

5 Results and Discussion

5.1 Latency from Africa and Europe to CDN Servers

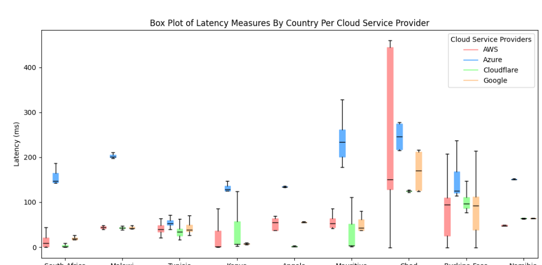

Figure 2: African Latency Measurements

This experiment delves into the latency measurements of pings from the various probes from countries in both Africa and Europe.

[1] https://ip-api.com/

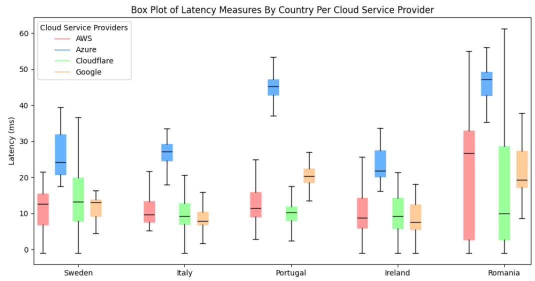

Figure 3: European Latency Measurements

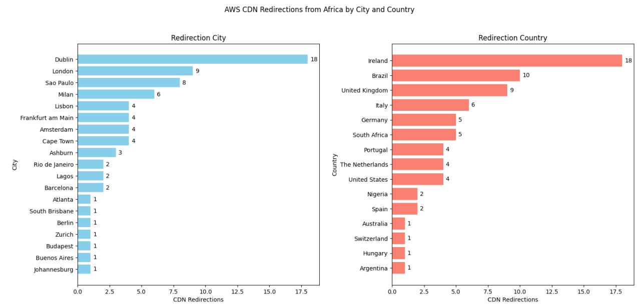

Figure 4: AWS CDN Redirection in Africa

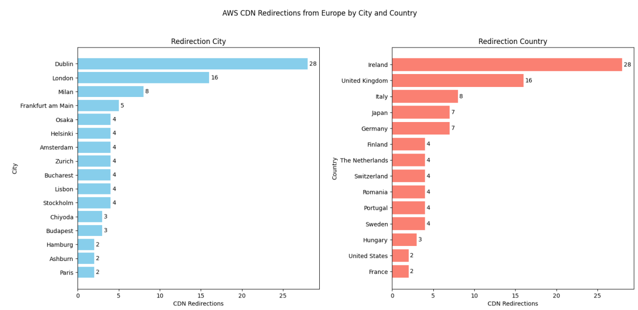

Figure 5: AWS CDN Redirection in Europe

Previous work by Chavula et. al [2] found that there was a much higher latency to services when comparing Africa and Europe. This paper found the same results, with African latency measurements being significantly higher than that of measurements from European probes.

When comparing the latency measurement results for both Africa and Europe, we can see from Figure 3 that Europe had much more consistent performance, with all countries having a latency less than 60 ms. Countries in Africa had a far greater range. Figure 2 illustrates measurements for AWS in Chad exceeding 450 ms and across most countries having latency measures that fluctuate drastically, when compared to that of the stable European internet performance.

We also found that despite all cloud services being slower in Africa, Azure was on average the slowest. We attribute this to the fact our site was unable to be placed on a CDN, as discussed in Section 3.2. This emphasizes the benefits of using a CDN stated by Akhtar et. al [1]. While market demands suggest a greater infrastructural roll out is needed in African countries, the available CDNs still provide performance improvements over accessing a website where it is being hosted. In this case, this would be the Netherlands datacentre.

It should also be noted that Namibia was one of the countries identified as having probes that were used in the experiment, although no Namibian probes were selected. This was traced back to one probe, that upon further inspection using the Maxmind Geomap tool in RIPE Atlas, that was said to be located in multiple countries. This may be due to historical data in the geolocation database or the use of a proxy server by the probe host.

5.2 Geolocation of CDN Servers

We identified all unique destination IPs accessed by the probes and used the IP-API tool to determine the locations of CDN endpoints. This was done for the static website hosted on AWS. Google Cloud and Cloudflare CDN endpoints could not be identified using the geolocation tools. This is because they utilize anycast for their CDNs, routing requests from a single public IP address to the nearest PoP. The use of a single anycast IP address makes it impossible to determine the locations of the CDN servers. Additionally, geolocation tools were not used for the static website hosted on Microsoft Azure, as it consistently resolved to the same server in the Netherlands.

From Figure 4, we can see 73 unique CDN server IPs were accessed by the African probes. Similarly to Chavula et al. [2] we observe that 69% of the unique IP addresses accessed by probes in Africa belonged to CDN endpoints in Europe, with Ireland having the highest number (25%) of endpoints accessed by probes. South America and the United States accounted for 16% and 5% of the IP addresses access by the probes respectively. Lastly, 10% of the IP addresses were located in Africa, with 5 from South Africa (Cape Town and Johannesburg) and 2 from Nigeria (Lagos). The percentage of IPs located in Africa represents an increase of 5% compared to the results obtained by Chavula et al [2]. However, we note that no requests were sent to the Kenyan AWS PoPs despite 9 probes being located in Kenya.
When observing where the European requests are redirected to, we see from Figure 5 that 98% of the traffic is directed to CDN endpoints in Europe, with the remaining requests being sent to endpoints in the US. This provides a reason for the lower latencies observed in European countries, indicating that the requests are being routed to nearby CDN servers, decreasing the RTT.

As noted above, the African probes routed a significant number (69%) of requests to European CDN servers. We investigated this by examining the endpoints that requests were being routed to from Angola, Mauritius and Kenya. Angola and Mauritius were selected as they are significantly closer to South Africa (which has AWS PoPs) than Europe. Kenya was selected as Nairobi has AWS

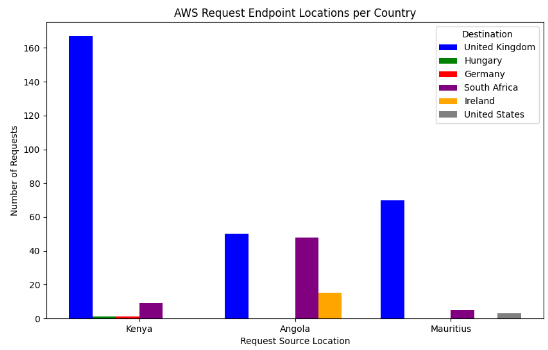

Figure 6: AWS Request Endpoint Locations

CDN PoPs, however the earlier findings indicate that none of the requests are sent to endpoints in Kenya. Figure 6 shows where the destination IPs of the requests from Angola, Kenya, and Mauritius are geolocated. We see that although the UK is nearly 3 times the distance from Angola compared to South Africa, more than half the requests are sent to CDN servers in the UK. This behaviour is also observed in Mauritius. These results indicate that requests are not being optimally routed, which was also found by Chavula et al. [2]. This is likely a result of weak peering relationships between ISPs or ineffective routing policies [6]. The lack of requests to the AWS PoPs in Nairobi is further evidence of suboptimal routing, as none of the 9 Kenyan probes made requests to the Kenyan CDN servers.

5.3 Hops from African Probes to CDN Servers

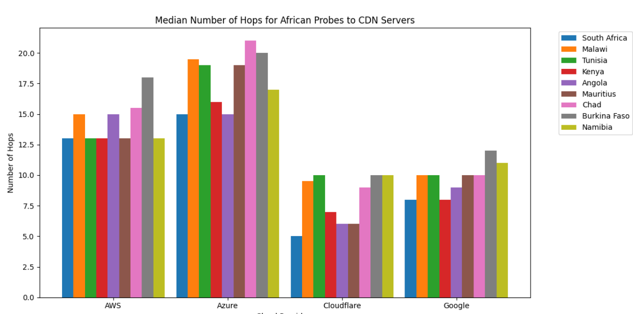

Figure 7: Caption

Figure 7 shows the median number of hops from the African probes to the CDN servers. The South African probes achieved the lowest number of hops when accessing the website on the Cloudflare CDN. The probes in Burkina Faso acheived the largest number of hops when accessing the website on the AWS CDN (Azure was not considered as the content was not on the Azure CDN). However, when considering the latency measurements (Figure **??**), we observe that the number of hops is not indicative of performance. Notably, while AWS often has more hops than Cloudflare and Google, the median latencies achieved by AWS are very similar to Google and Cloudflare.

5.4 Latency Comparison between CDNs and Datacentres

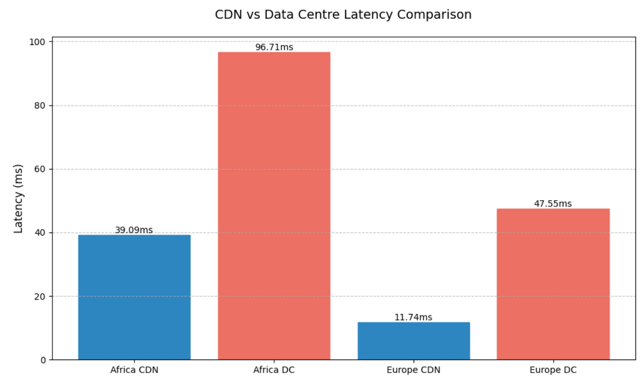

Figure 8: Latency comparison between accessing data-centres and connecting to a CDN

Figure 8 compares latency between CDNs (Content Delivery Networks) and data centers (DCs) in Africa and Europe, measured in milliseconds (ms). The results reveal a significant disparity between the regions. For African users, average latency is much higher when accessing data centers (96.71 ms) than when accessing CDNs (39.09 ms). In Europe, both latency values are lower, with CDN latency at 11.74 ms and data center latency at 47.55 ms. This indicates that CDNs provide a more efficient method of content delivery in both regions, but the latency gap between CDNs and data centers is particularly pronounced in Africa [5]. These findings highlight the impact of infrastructure limitations on latency, especially in African regions, where fewer local data centers lead to increased reliance on more distant facilities, resulting in higher latency.

6 Conclusion

This study provides valuable insights into the performance differences of CDNs in different regions. Our results corresponded with previous experiments that observed African clients experiencing notably higher CDN latency than European clients when accessing major cloud providers' PoPs. African latency measurements often exceeded 100 ms, in contrast to more consistent and lower latencies (under 50 ms) observed across European countries. This performance difference highlights the ongoing need for improved cloud infrastructure in Africa.

Our redirection analysis further revealed patterns of suboptimal routing for African requests. Though the chosen service providers have PoPs in regions like South Africa and Kenya, a large portion of African traffic was routed through Europe. Servers in Ireland and the UK were prominently featured in the paths of traffic originating from Africa. This routing inefficiency exacerbates latency issues and indicates how underutilized PoPs within Africa are.

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