UNIVERSITY OF CAPE TOWN

DEPARTMENT OF COMPUTER SCIENCE

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INTERNET SYSTEMS ENGINEERING

# A study on cloud latency comparisons between Africa and Europe.


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# Contents

# 1 Introduction

In this project, we build on the findings by Babasanmi and Chavula (2022) [1], who measured cloud latencies in Africa, highlighting that African clients typically connect to CDNs (Content Delivery Networks) located outside the continent, leading to circuitous routing and higher latencies compared to European users. In contrast, European clients benefit from a denser network of CDN PoPs that deliver lower latencies. Babasanmi and Chavula's study underlined the potential for significant latency reductions when African traffic is routed to local CDN PoPs (Points of Presence), proposing that cloud providers should deepen their local infrastructure presence to improve performance for African users. In this study, we deployed a simple React.js website on major cloud service providers like; Cloudflare[1], Amazon Web Services (AWS)[2], Microsoft Azure [3], and Google Cloud [4].
Using the RIPE Atlas platform[5], we investigate latency discrepancies between African and European users accessing the aforementioned cloud service provider's endpoints, applying similar methodologies of ping and traceroute measurements. By analyzing latency accumulation across network hops and comparing endpoint response times between regions, this study aims to validate prior findings and highlight the need for improved cloud infrastructure to support Africa's growing digital presence.

# 2 Methodology

We employed a combination of ping and traceroute measurements using the RIPE Atlas platform to evaluate and compare latencies between Africa and Europe when accessing the different cloud service endpoints. We compiled all our data on a GitHub repository [6]

## 2.1 Data Collection

To ensure broad representation across both continents, we selected RIPE Atlas probes located in multiple countries within Africa and Europe. Probes were chosen based on their availability and geographic spread, covering major regions in each continent. In total, our aim was to access 50 probes per continent (Africa and Europe), bringing them to a grand total of 100 probes. However, we faced challenges in this regard due to some measurements not reaching the probes for some of cloud service providers that we used. Therefore, we chose to increase the number of probes to 132 total, which raised our RIPE Atlas credit usage significantly. This balanced selection facilitated a comparative analysis of the different cloud service provider's performance between the two regions, as we aimed for at least 95% of our original intended probe number.

## 2.2 Measurement Techniques

For measurement, we used a combination of Ping and Traceroute. Ping was used to capture round-trip times (RTT) between probes and the cloud service provider's endpoints. By examining the RTT distribution, we could observe baseline latencies to the cloud services and understand how performance varied between African and European users. Traceroute was used to capture

[1] Cloudflare deployment: https://one-page-sample.pages.dev/
[2] AWS deployment: http://uct2024.s3-website.eu-north-1.amazonaws.com/
[3] Azure deployment: https://black-coast-0499f2610.5.azurestaticapps.net/
[4] Google cloud deployment: https://school-projects-438209.df.r.appspot.com/
[5] RIPE Atlas: https://atlas.ripe.net/
[6] Github repository: https://github.com/ProsperAsiimwe/Measurements

the routing paths and hop-by-hop latencies to the cloud service provider's endpoints, revealing how latency accumulated along each network path. Each probe performed ping and traceroute measurements at regular intervals to account for potential fluctuations in network performance. These measurements were then averaged to provide a more stable representation of latency for each region.

## 2.3 Data Processing

Probe IDs were mapped to their corresponding regions (Africa or Europe) based on probe metadata, allowing us to filter data by geographic location. This step was essential for separating and comparing latency data between Africa and Europe. We did this mapping manually for each individual probe that we used, and created a csv file which we then merged with the RIPE Atlas measurement JSON data to include a key for the continent for each probe we had. To ensure data accuracy, any measurements with missing or extreme outlier values were removed. This step prevented anomalies from skewing the results and enabled a clear analysis of general latency patterns. For ping data, average RTT values were calculated per probe, and these values were then aggregated by region to analyze latency distribution across Africa and Europe. For traceroute data, average latencies were computed for each hop along the route, enabling a visualization of latency progression from the probe to the cloud service provider's endpoints for both regions.

# 3 Data Analysis

## 3.1 Ping Analysis

The ping analysis provides a comparative view of the overall latency distribution between African and European probes. We show the distribution of round-trip times (RTT) to the different cloud service provider endpoints for each region.

### 3.1.1 Google Cloud: 142.251.47.244

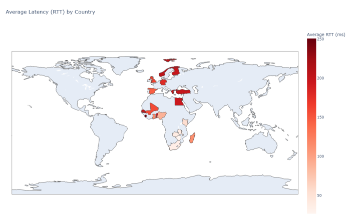


Figure 1: Average latency RTT by country

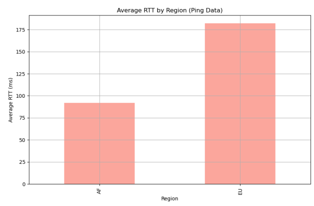


Figure 2: Average latency RTT by region

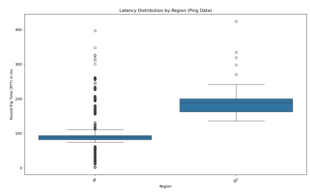


Figure 3: Latency distribution by region

Figure 1 shows the average round-trip latency times for Google Cloud's endpoint across different countries in Europe and Africa. Which are color coded to show the intensity of RTT values per country. African countries in general, more specifically countries in the Southern part of Africa exhibit significantly lower RTT values compared to European countries, suggesting that there is a denser and more direct network routing available in the southern part of Africa. In Europe, the latencies are higher, even though some African countries show high values, on average, Africa performed better than Europe. This indicates infrastructure constraints and less efficient routing paths in Europe for google cloud. In Figure 2 and Figure 3 African probes recorded lower latencies as compared to European probes, as was reflected in Figure 2. Even though the average RTTs for Africa is narrow in Figure 3, there are too many outliers that suggests the inconsistencies of RTTs across different African countries. Europe has a wider average range with very few outliers due to the continent's balanced speed levels. Africa RTTs, however, has extreme outliers in the distribution. regardless, it still has a lower average RTTs compared to Europe. Contrary to what one will generally expect, Africa probes have shown a lower RTTs on google cloud than Europe for this particular test conducted. This somewhat suggests that maybe google has well localized cloud infrastructure in Africa than in Europe, which could be because google cloud services are tailored specifically for the African continent.

#### 3.1.2 Cloudflare: 172.66.44.140

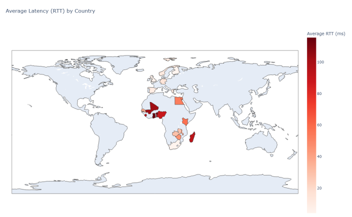


Figure 4: Average latency RTT by country

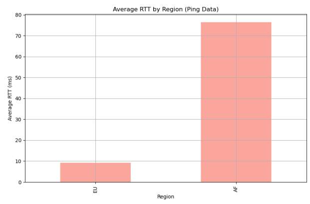


Figure 5: Average latency RTT by region

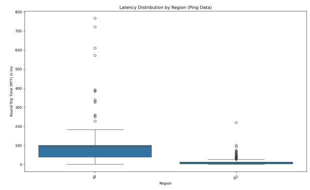


Figure 6: Latency distribution by region

In Figure 4, the average round-trip latency times for Cloudflare's endpoint across various countries in Europe and Africa are displayed, which indicates that European countries consistently experience lower RTT values than African countries.

Figure 5 compares the average RTT by region, highlighting a pronounced disparity between Africa and Europe. European users have a significantly lower latency that averages below 10ms, demonstrating the effectiveness of Cloudflare's network architecture in Europe. African RTT values remain significantly higher, with an average of almost 76ms, reflecting the limited cloud flare infrastructure and challenges on the continent. The lack of nearby data centers and the dependence on international backbone routes contribute to higher latencies for African users when accessing Cloudflare services.

In Figure 6 ,Europe exhibits a narrow latency range, clustered around lower values, indicating consistent, efficient routing within the region. In Africa, RTT latencies are more widely spread with a number of extreme outliers, showing significant variance due to diverse infrastructure quality and route dependency on distant PoPs. This could be because European countries benefit from Cloudflare's extensive network of data centers and Points of Presence (PoPs), which significantly reduces latency by shortening the physical distance and improving routing efficiency. In contrast, African countries face higher latencies, which can be attributed to limited local PoPs and reliance on international routes that increase RTT.

#### 3.1.3 Amazon Web Services (AWS): 16.12.11.4

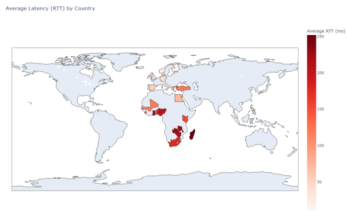


Figure 7: Average latency RTT by country

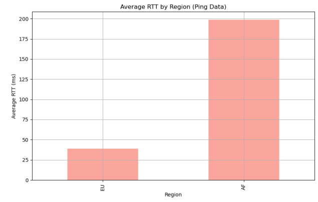


Figure 8: Average latency RTT by region

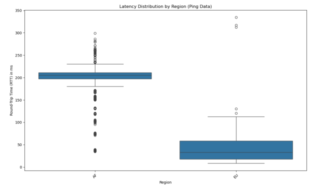


Figure 9: Latency distribution by region

In this Figure 7 we see the average round-trip latency (RTT) for AWS endpoints across various countries, as we compare their performance. Latency values for European countries remain low and consistent, a reflection of AWS's extensive European infrastructure. Conversely, African countries experience significantly higher RTT, indicating greater distance and reliance on intercontinental routing. The significantly high latencies in African countries, such as Ghana, Nigeria and Kenya among others, highlights the challenges in connecting to AWS endpoints. In Figure 8 we can see European users benefit from lower latency due to AWS's strategically positioned data centers across Europe, while African users face higher latencies. Figure 9 also shows European RTT values which are tightly clustered at low latency levels, indicating a highly reliable and efficient network structure within Europe. African RTT values, however, are more spread out and skewed towards higher latencies. This wider latency range suggests inconsistencies in network performance across Africa, where users depend on varied and sometimes suboptimal international routes to reach AWS services. The limited number of PoPs in Africa forces traffic to be routed through distant regions, resulting in a notable performance gap. This discrepancy highlights the infrastructural gap AWS must address to offer equitable service access across continents.

#### 3.1.4 Microsoft Azure: 20.69.151.16

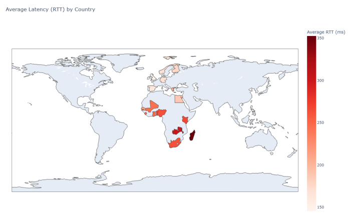


Figure 10: Average latency RTT by country

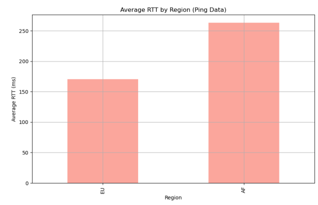


Figure 11: Average latency RTT by region

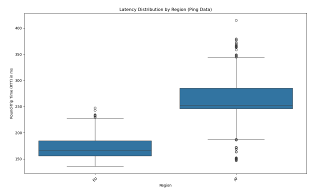


Figure 12: Latency distribution by region

Figure 10 shows the average round-trip latency (RTT) for Microsoft Azure endpoints across various African and European countries. European countries consistently report lower RTT values, however, Africa shows a considerable increase in latency.

In Figure 11 the comparison between Europe and Africa illustrates that European regions maintain low and stable latency due to Azure's robust infrastructure across the continent. African regions, by contrast, experience significantly higher RTT values. These findings emphasize the need for Azure to extend its network within Africa to reduce latency for local users and align with the performance levels observed in Europe.

We continue to see Europe outperforme African in Figure 12. As seen from the chart, European RTT values are tightly grouped around low latency, reflecting consistent and efficient network performance. In contrast, the African RTT distribution is more spread out, showing a wider range of latency values due to inconsistent network routes and fewer PoPs within Africa. The broader latency spread in Africa suggests varied performance reliability, with Azure's current network setup limiting accessibility for African users. Investing in additional Azure PoPs within Africa would likely improve RTT consistency and lower latency, facilitating better service quality for users across the African continent.

## 3.2 Traceroute Analysis

The traceroute measurements offer a detailed look at how latency accumulates at each network hop, providing insights into the efficiency of routing paths in each region.

### 3.2.1 Google Cloud: 142.251.47.244

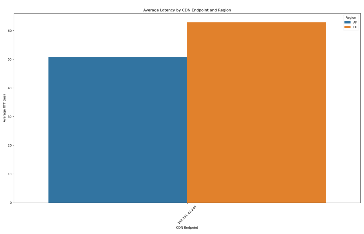


Figure 13: Average latency by CDN endpoint and region

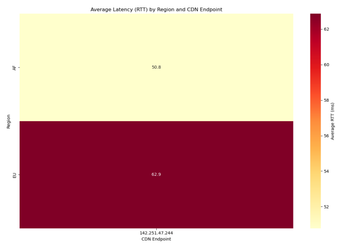


Figure 14: Average latency (RTT) by region and CDN endpoint

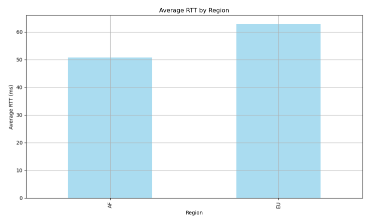


Figure 15: Average RTT by region

Figure 13 shows the average latency progression across CDN endpoints for Google Cloud, categorized by region. Arican paths exhibit lower cumulative latencies. However in Europe, the latency levels are more prominent as data packets travel from one endpoint to the other. These latency values shows a higher cumulative RTT for European users. Figure 14 also further highlights the cumulative RTT for each Google Cloud CDN endpoint when accessed from African and European regions. African paths demonstrate a gradual increase in latency, with each hop contributing minimally to the overall RTT. In contrast, European paths show steeper latency increases due to additional and distant network hops, amplifying RTT. In Figure 15 we observe that the average RTT by region captured shows an aggregate latency impact of each trace-route hop. African users experience minimal RTT accumulation, which suggests an optimized routing paths and closer proximity to Google's infrastructure. European users, however, face higher cumulative RTT values due to extended routing paths and additional network hops. These findings suggest that Google Cloud's infrastructure distribution heavily favors Africa than Europe.

### 3.2.2 Cloudflare: 172.66.44.140

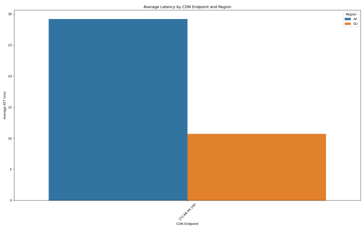


Figure 16: Average latency by CDN endpoint and region

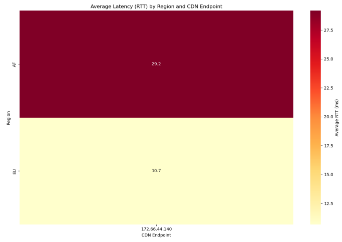


Figure 17: Average latency (RTT) by region and CDN endpoint

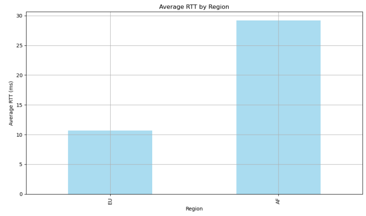


Figure 18: Average RTT by region

Figure 16 shows the average latency per hop when accessing Cloudflare CDN endpoints, grouped by Africa and Europe regions. European traceroutes display lower cumulative latency and optimized paths through Cloudflare's network. African traceroutes show significantly higher cumulative RTT, which could be as a result of additional international hops and less direct routing paths in Africa. Figure 17 also further illustrates the cumulative RTT across Cloudflare's CDN endpoints for African and European regions. European routes maintain low latency, and eficient data flow in Cloudflare's infrastructure. African routes, however, accumulate latency more rapidly, particularly at international gateway hops, where RTT spikes significantly due to less optimal network paths. From Figure 18, we notice that in Europe, RTT remains stable, reflecting efficient routing across Cloudflare's European infrastructure. For African users, RTT still increases significantly across multiple hops, pointing to the inefficiency of international routing paths and the lack of nearby CDN infrastructure. This RTT disparity illustrates how the current Cloudflare network setup disproportionately affects African users. This difference highlights the limitations African networks face in achieving low latency, with Cloudflare's CDN endpoints predominantly located outside Africa, increasing RTT for African users.

### 3.2.3 Amazon Web Services (AWS): 16.12.11.4

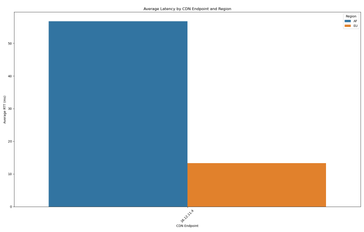


Figure 19: Average latency by CDN endpoint and region

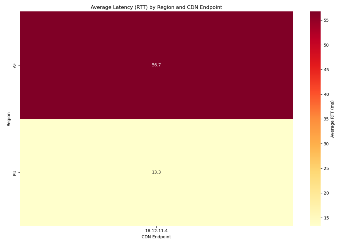


Figure 20: Average latency (RTT) by region and CDN endpoint

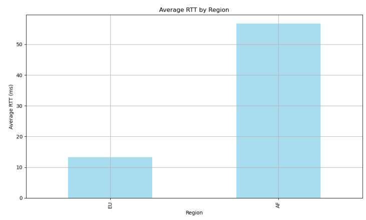


Figure 21: Average RTT by region

Figure 19 displays the average latency per network hop for AWS endpoints, separated by region. European routes to AWS endpoints exhibit lower cumulative latency due to efficient and direct paths through AWS's comprehensive European network. African routes, in contrast, experience higher cumulative RTT due to indirect routing paths that involve several international hops. Figure 20 also illustrates the cumulative RTT by region for AWS CDN endpoints, highlighting a significant disparity between African and European routes. European routes maintain lower RTT throughout each hop. African routes, however, accumulate latency sharply, especially at gateway hops leading out of Africa, reflecting AWS's efficient, well-connected network within Europe. Again, Figure 21 shows the average RTT by region for AWS endpoints, capturing cumulative latency across all hops. European routes continue to demonstrate stable, low-latency RTT values, while African RTT values, are more varied and higher due to increased hop count and extended routing paths. This latency buildup underscores the challenges African users face in reaching AWS endpoints and highlights the need for more AWS data centers or PoPs within Africa to reduce RTT.

#### 3.2.4 Microsoft Azure: 20.69.151.16

We had challenges with traceroute measurements for our Azure cloud service because out of all the measurements performed, this was the only one where we did not receive any feedback from all the 132 probes. We tested this on several measurements but all yielded a similar outcome, with no response from any of the probes.

# 4 Findings and Discussion

## 4.1 Research Questions

1 What are the differences in internet latencies between African clients for AWS, Cloudflare, Azure, and Google Cloud CDN PoPs compared to European clients?

African clients face higher latencies to AWS, Cloudflare and Azure. However it outperforms Europe on Google Cloud PoPs. Europes general outperformance of Africa is largely due to the lack of nearby CDN nodes for AWS, Cloudflare and Azure cloud services. European clients benefit from lower and more consistent latencies, thanks to a denser infrastructure network. But as seen on tests conducted on Google Cloud, African outperforms Europe in both PING and Traceroute tests.

2 How do these latencies vary when accessing AWS, Cloudflare, Azure and Google cloud nodes within Africa versus from Europe?

Accessing nodes within Africa reduces latency for African clients, but the limited number of local PoPs restricts the impact. However Google cloud gives lower letencies for all hops for African probes, which is the only Cloud service where Africa outperforms Europe. European clients maintain low latencies overall, espercially in AWS, Cloudflare and Azure, due to their closer proximity to a larger network of PoPs. This further encouraging the need for more CDN nodes within Africa to improve accessibility and performance for AWS, Cloudflare and Azure cloud services.

## 4.2 Comparison with Prior Research

Our findings generally echo the results of Babasanmi and Chavula's study, which highlighted that African users often connect to CDN nodes located outside the continent. This issue leads to higher latencies for African users as opposed to their European counterparts, who benefit from denser, local CDN networks. Both studies show that local CDN infrastructure significantly reduces latency, with our analysis indicating similar trends aside Google Cloud but, across AWS, Cloudflare and Azure. Babasanmi and Chavula also observed the impact of routing inefficiencies, with African traffic often taking circuitous routes that increase latency. Our traceroute analysis confirms this pattern, showing higher latency buildup across hops in African routes compared to European routes.

### 4.3 Implications

We believe that relevant authorities and stakeholders need to expand cloud infrastructure in Africa for AWS, Cloudflare and Azure services, by investing in building and installation of additional PoPs and data centers across the African continent, as we believe this would greatly improve service accessibility and bring latency down for African users. If building new infrastructure is too expensive, these cloud service providers could partner with local ISPs to use their existing infrastructure for this purpose.

## 5 Conclusion and Recommendations

With the help of Babasanmi and Chavula's study and with our own findings, even though for Google Cloud, African probes had lower latencies than European probes, In general African probes performed significantly poorer on cloud services like AWS, Cloudflare and Azure. Therefore, we believe that cloud access in Africa is hindered by a lack of nearby infrastructure and inefficient routing , resulting in higher latencies than those experienced by European users. We encourage cloud providers to prioritize establishing additional PoPs and data centers within Africa, which would reduce physical distances and latency. As a more attainable alternative to building new infrastructure, they can strike deals with already established local ISPs like the popular MTN, Vodacom, Airtel and many others to improve routing paths and make the experience for clients on the African continent on level with the European clients.

## References

[1] Opeoluwa Babasanmi and Josiah Chavula. Measuring cloud latency in africa. pages 61–66, 11 2022.