# Inter and Intra Networks Analysis of the African Continent

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## ABSTRACT

The African continent is fairly underdeveloped within the networking world [1] due to economic disadvantage, expensive bandwidth and poor infrastructure [2]. This paper looks studies the ping and traceroutes deployed from Ripe Atlas to determine delays, AS-hops and country-level hops. The paper discovers that the African continent is poorly interconnected between countries, which results in delays and expensive overseas routing. African countries are well intraconnected and have achieved satisfactory delay times on routing packets within the country. There needs to be significant progress within Africa before these inter country latencies will be improved.

## 1 Introduction

The African continent is fairly underdeveloped within the networking world [1] , due to economic disadvantage, expensive bandwidth and poor infrastructure [2]. Improvements in internet performs have been seen over the years, however packet loss is still a major problem, where it remains the highest in the world [2].

This paper aims to study the relationship between how interconnected and intraconnected African countries are by assessing end-to-end delays, AS-level (Autonomous Systems) hops and country level-hops.

This paper is structured in 5 sections. Section 2 covers experimental setup for running the tests. Section 3 provides the results and analyses for inter-country analyses. Section 4 embarks on a discussion around the intra country results and what findings can be drawn from them. Section 5 contains comparison of the inter and intra country results. Finally, section 6 concludes the paper.

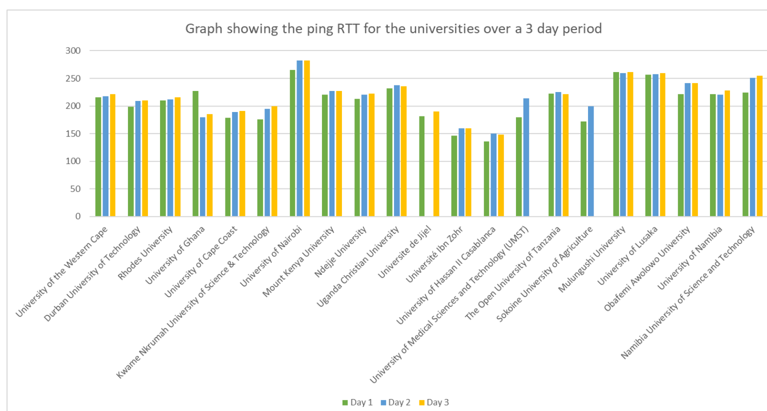
## 2 Experimental Setup

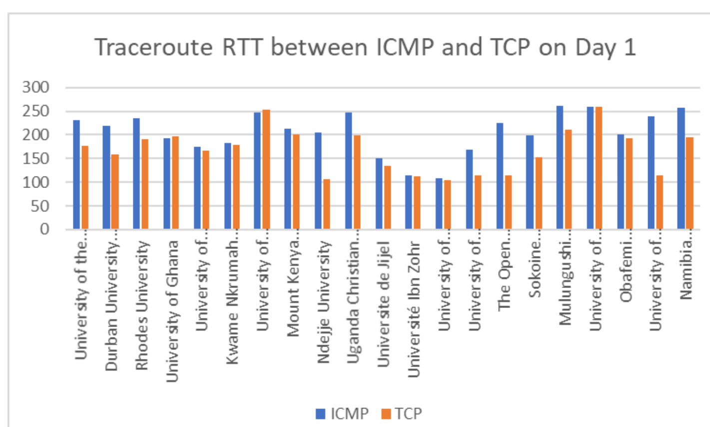
A ping and traceroute was sent to 21 different universities (see Table 1) 3 times a day over a period of 3 days. Each ping and traceroute was sent from 5 different probes – one measurement within the country and another measurement within Africa. The probes for the inter measurements were set in 5 different countries containing sufficient probe access. These countries were Namibia, Ethiopia, Senegal, Gabon and Tunisia. They were selected as no tests were run from those countries and they remained constant for these measurements to accurately compare findings in different countries. Three different traceroutes were sent at each measurement over the different protocols (ICMP, TCP and UDP). Each day's result was aggregated over the day and can be located in file final_results.xlsx. Experiments were run using Ripe Atlas and conducted through the python library Ripe-Atlas-Cousteau. All results were analyzed using Ripe-Atlas-Sagan and API's from api.freegeoip.app. To plot the traceroutes on the map the python libraries: shapely, matplotlib and geopandas were used.

## 3 Inter Country Results

### RTT

Each Ping measurement produces a round trip time (RTT), which measures the duration from the request to the response. It is used as a key element in identifying internet performance. **Figure 1** displays the average RTT over each day for each university. The times are fairly consistent between days, however on 3 occasions the ping failed for different universities. RTT's are long and most of them are around 200ms, which is poor performance in comparison to Europe and North America's Inter country latency [3]. Universities in Kenya and Zambia experience very poor latencies of up to 250ms, whilst Morocco experiences the best performance (150ms), although it is incomparable with European and North American latencies. **Figure 2** displays the RTT for ICMP and TCP measurements. UDP test were also run over the data, however all UDP tests failed. This may be a result of nodes ability to respond from any other address [4]. From **Figure 2**, we can



deduce that ICMP tend to have a longer RTT, however there are some outliers seen specifically for Université Ibn Zohr. **Figure 3** displays this in more detail, this can be attributed to the natural design of IMCP [5].

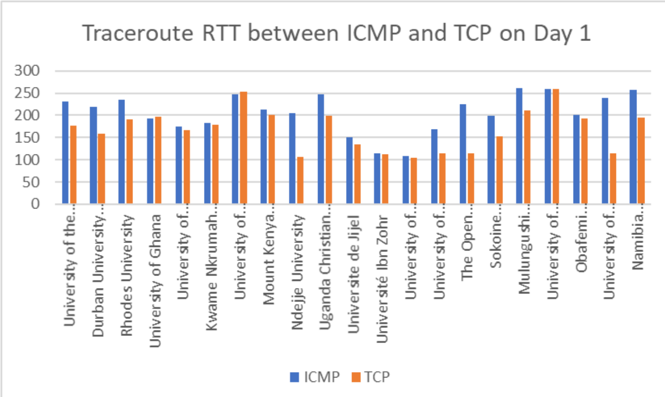



*Figure 3: Traceroute RTT for day 1*

**Hops**

Traceroutes can be used effectively to analyze the hops between AS-levels and inter country hops. **Figure 4** demonstrates the intercountry hops for the traceroutes from the University of the Western Cape. We can see that the routes within Africa are not well established and traffic needs to be routed through Europe or North America before it can be routed to South Africa. Even the traceroute sent from South Africa's neighboring country Namibia is first routed through Senegal before reaching South Africa. This is most likely to contribute to the large inter country latencies discussed in the previous paragraph. The number of AS hops remains fairly consistent throughout the data, which indicated that traffic is routed is a similar fashion, however

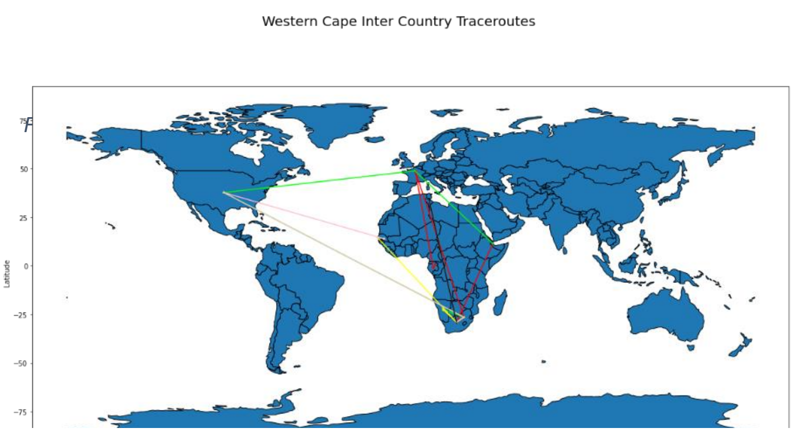



*Figure 4: Western Cape University Inter Country Traceroutes*

routing traffic through different paths where necessary. This may experience a more drastic change at different hours of the day. However, this cannot be deducted from the aggregated day approach and would need to undergo further investigation.

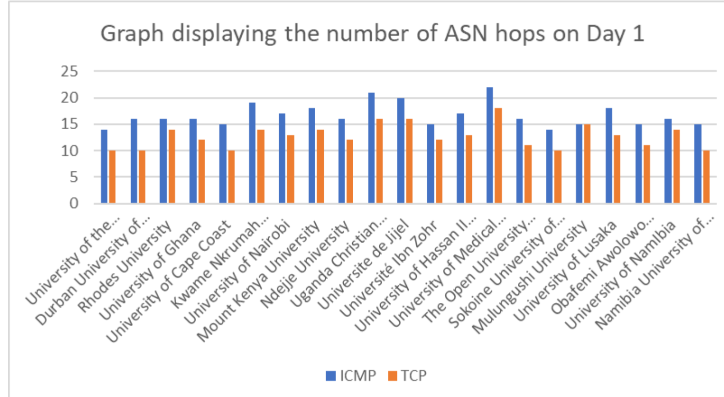



*Figure 5: Graph of ASN hops on Day 1*

**Figure 5** displays the difference between the number of AS hops on day 1. It is clear that TCP has a more direct route and thus experiences much lower AS hops per university. This is elaborated on in [6] that states TCP is 20-30% more accurate than ICMP, which is synonymous with our findings. As our results show that TCP hops are 24% lower than ICMP hops. **Figure 6** displays the intercountry hops, which remain fairly constant only deviating from the mean by 1 unit. For most universities a unit decrease in intercounty hops is most likely seen from the TCP measurements, however the University of Medical Sciences and Technology is the outlier on day 2. As previously discussed the inter country networks in Africa are poor, thus this indicated why there are a large number of inter country hops. These hops are displayed in **Figure 7**, which is a traceroute of all universities from the probe located in Namibia. This figure is very congested with all the traceroutes, although we can make some observations. Traffic routed through Europe is evenly spread among the entire continent. However, traffic routed to North America is fairly concentrated within Missouri.

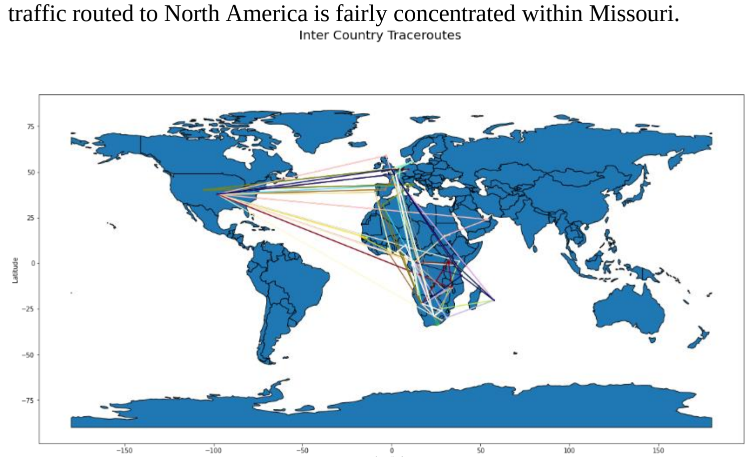



*Figure 7: Intercountry Traceroutes displayed on map*

## 4 Intra Country Results

**RTT**

The Intra Country results follow a similar pattern to the Inter country results, however the probes are located within the country. Looking at **Figure 8**, we can immediately deduce that the ping intra delays are significantly shorter than the inter delays, averaging around 10ms per request. However, these test immediately pointed out an outlier of Mount Keya University, which is hosted in America and not in Kenya, thus has been removed from the following tests. Despite South Africa placing third in South Africa for highest grossing GDP [7], it displays the highest consistent ping delay. Obafemi Awolowo University has not been included in **Figure 8**, as it has disproportionally high delays with an average of 140ms. This could indicate poor intraconnectivity within Nigeria. However, Nigeria is the country with the highest GDP in Africa [7], thus this indicates that both Nigeria and South Africa most likely experience more traffic than other African countries. However, Nigeria handles this traffic more poorly than in South Africa. Countries that indicate very good intraconnectivity are Zambia, Ghana and Sudan.

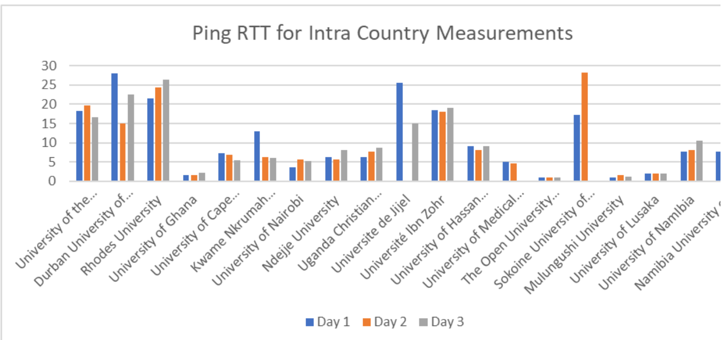



*Figure 8: Ping RTT for Intracountry measurements*

**Figure 9** echoes a similar pattern to the ping RTT although the traceroute delays do for Obafemi are not as long. In these measurements TCP and ICMP see similar delays and are almost on par.

**Hops**

The number of intracountry hops at AS level vary widely depending on the university (see **Figure 10**). Countries with the lowest number of hops are Ghana and Algeria. Ghana's good performance is likely to do with excellent intraconnectivity that is paired with effective traffic routing. Algeria has a very low number of AS-level hops that could indicate the university is in close proximity to the probes. South Africa and Namibia, display the higher number of AS-level hops.

For Inter country hops most countries stayed within their borders as they operate through their own ISP's. Durban University of Technology's intra traffic is routed through Mauritius, which can be seen in **Figure 11** by the purple line near the bottom of Africa. A number of South African measurements are traced to other parts of the continent such as Morocco. Kenya intra traceroute goes through Europe for certain measurements and Nigeria's intra measurements go through the Netherlands. As Kenya's traceroutes do not consistently go through Europe, we can assume it is trying to balance for the amount of traffic it is receiving. We cannot declare that Nigeria has poor intra connectivity as it is only represented by one country, thus more tests need to be run to determine its status. A number of countries go through other countries in Africa, with Ghana appearing as a central destination for multiple traceroutes.

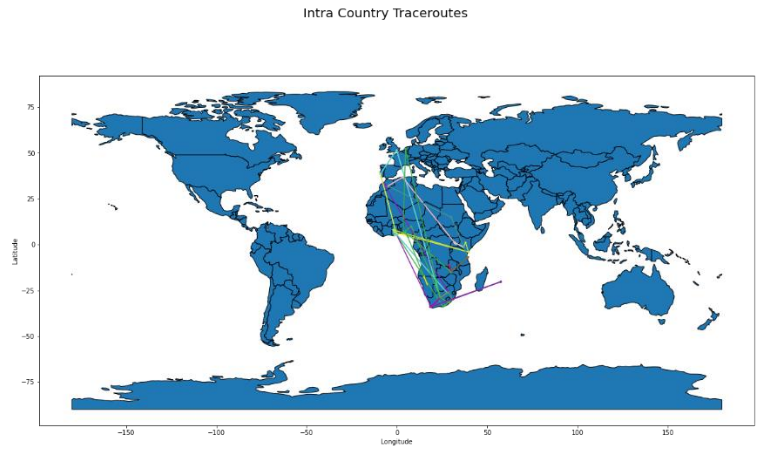



*Figure 11: Mapping all Intracountry Traceroutes*

## 5 Comparison between Inter and Intra Country Results

We aim to observe the key differences between the Inter and Intra country measurements.

| | Inter (average) | Intra (average) |
|---|---|---|
| **Ping RTT** | 214.56 | 14.66 |
| **Traceroute RTT ICMP** | 211.37 | 14.27 |
| **Traceroute RTT TCP** | 193.67 | 15.32 |
| **Traceroute Hops ICMP** | 16.95 | 8.18 |
| **Traceroute Hops TCP** | 14.33 | 8.30 |
| **Traceroute Inter Country Hops ICMP** | 4.63 | 1.17 |
| **Traceroute Inter Country Hops TCP** | 4.14 | 1.28 |

*Table 2: Showing the average differences between Intra and Inter measurements*

Comparing the delays one can identify that there is a large difference in latencies. As discussed, these latencies indicate proficient intra connectivity and poor inter connectivity. For intercountry traceroutes, TCP is the better performing measurement as it produces shorter RTT, fewer AS-level hops and fewer inter-country hops. However, the opposite is seen for intraconnectivity. Although there is a small difference, ICMP has shown to perform better in these instances.

## 6 Conclusion

This paper aimed to study the relationship between how interconnected and intraconnected African countries are by assessing end-to-end delays, AS-level (Autonomous Systems) hops and country level-hops. After implementing tests and analysing the results, we can conclude that there is insufficient infrastructure to interconnect countries within the African continent and traceroutes need to be routed through Europe or North America to produce the best results.

## REFERENCES

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[3] Agustin Formoso, Josiah Chavula, Amreesh Phokeer, Arjuna Sathiaseelan, Gareth Tyson. 2017. Deep Diving into Africa's Inter-Country Latencies. IEEE INFOCOM 2018 - IEEE Conference on Computer Communications. DOI: 10.1109/INFOCOM.2018.8486024

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## APPENDIX

An appendix has been included with larger figures of the ones seen in the paper as with some figures that were too small to insert into the paper.

Table 1:

| | Country | Country Code | University | IP Address |
|---|---|---|---|---|
| 1 | South Africa | ZA | University of the Western Cape | 154.0.173.19 |
| 2 | South Africa | ZA | Durban University of Technology | 196.2.164.249 |
| 3 | South Africa | ZA | Rhodes University | 146.231.128.43 |
| 4 | Ghana | GH | University of Ghana | 197.255.125.213 |
| 5 | Ghana | GH | University of Cape Coast | 156.38.97.106 |
| 6 | Ghana | GH | Kwame Nkrumah University of Science & Technology | 129.122.16.228 |
| 7 | Kenya | KE | University of Nairobi | 41.89.94.20 |
| 8 | Kenya | KE | Mount Kenya University | 208.109.41.232] |
| 9 | Uganda | UG | Ndejje University | 216.104.200.12 |
| 10 | Uganda | UG | Uganda Christian University | 102.220.200.167 |
| 11 | Algeria | DZ | Universite de Jijel | 193.194.69.172 |
| 12 | Morocco | MA | Université Ibn Zohr | 196.200.181.122 |
| 13 | Morocco | MA | University of Hassan II Casablanca | 196.200.165.54 |
| 14 | Sudan | SD | University of Medical Sciences and Technology (UMST) | 197.251.68.25 |
| 15 | Tanzania | TZ | The Open University of Tanzania | 196.216.247.18 |
| 16 | Tanzania | TZ | Sokoine University of Agriculture | 41.73.194.141 |
| 17 | Zambia | ZM | Mulungushi University | 41.63.16.3 |
| 18 | Zambia | ZM | University of Lusaka | 41.63.7.238 |
| 19 | Nigeria | NG | Obafemi Awolowo University | 196.27.128.12 |
| 20 | Namibia | NA | University of Namibia | 41.205.129.157 |
| 21 | Namibia | NA | Namibia University of Science and Technology | 196.216.167.71 |

Figure 1

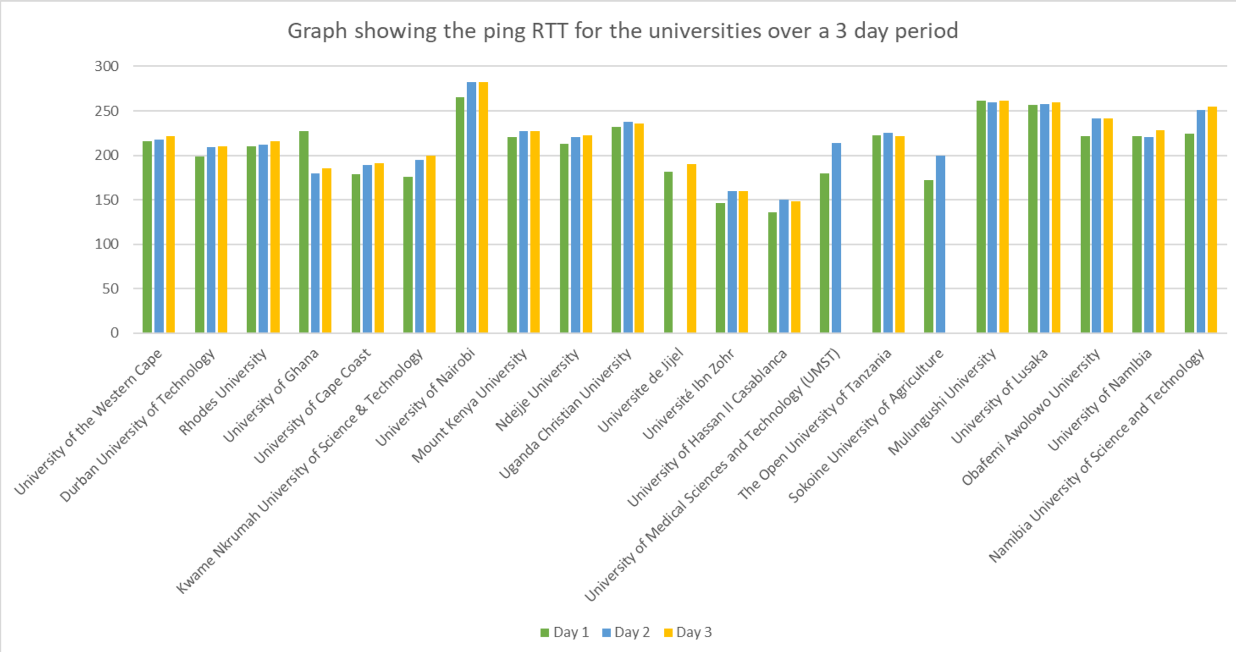



Figure 2

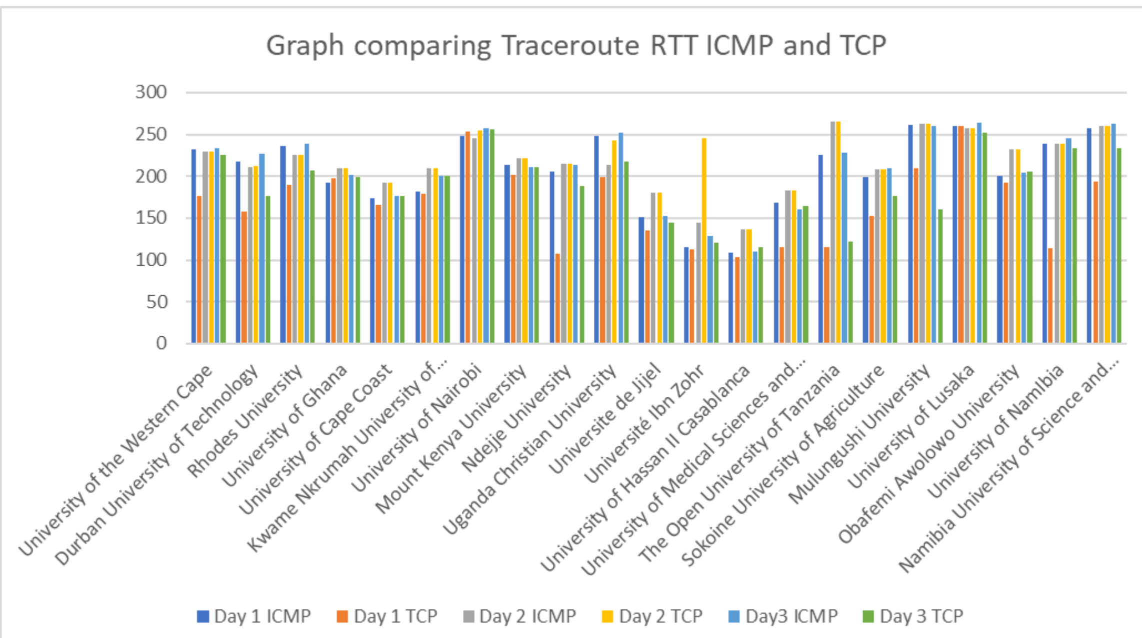


Figure 3

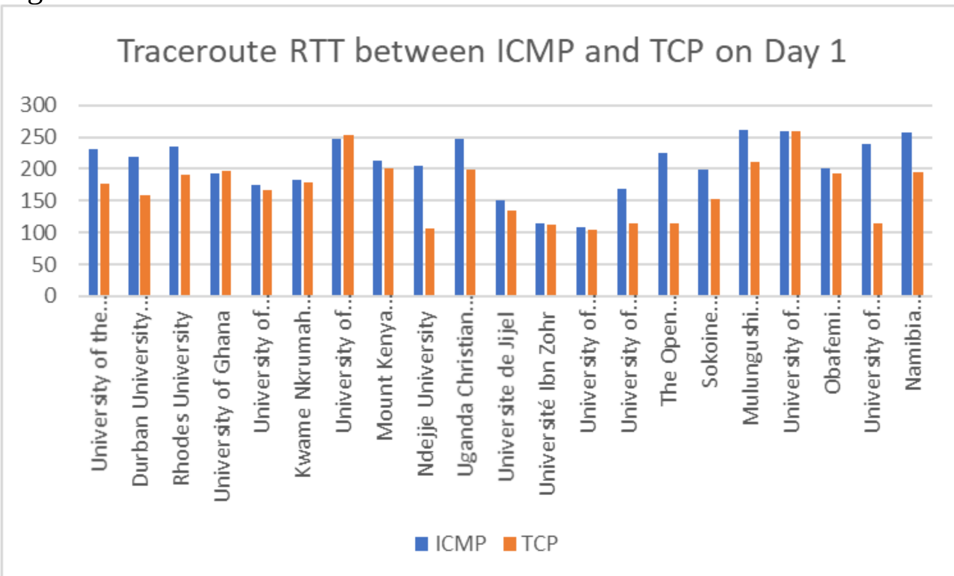



Figure 4

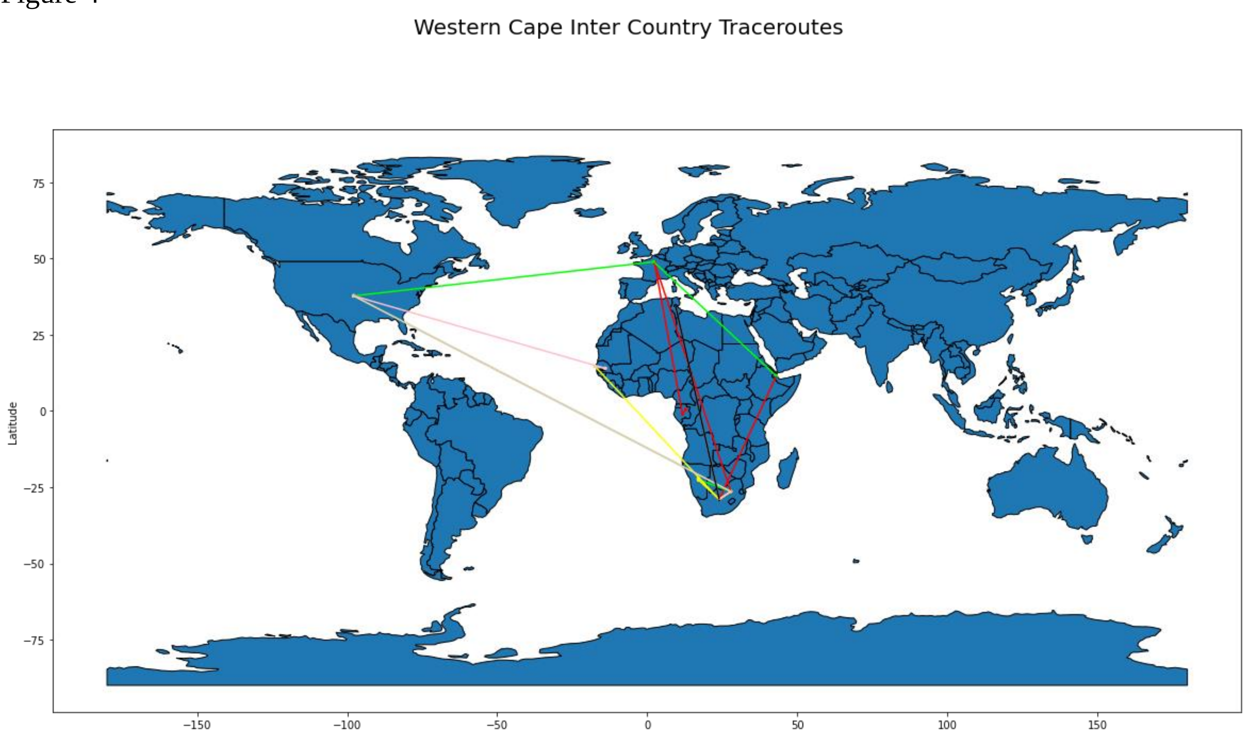


Figure 5

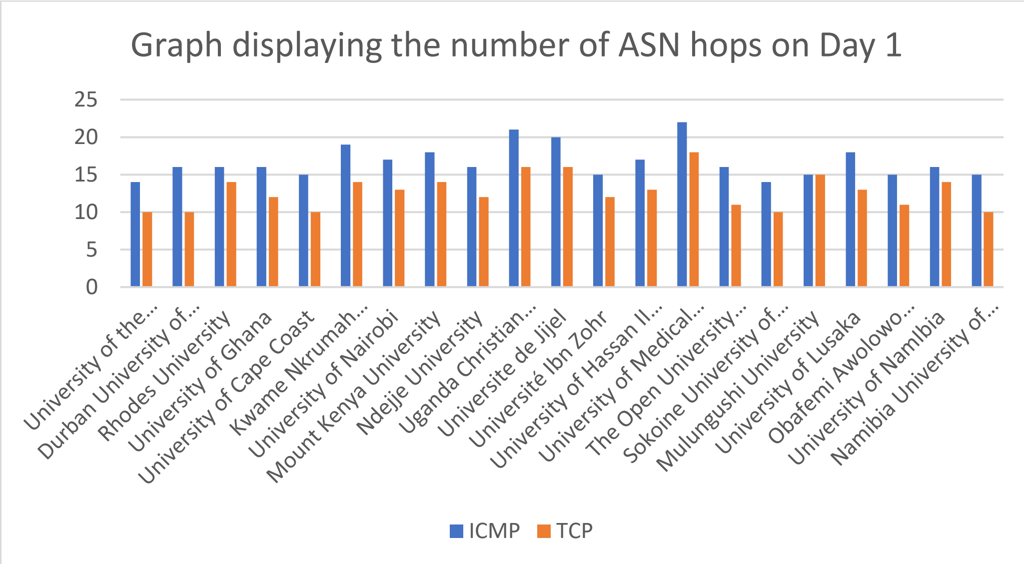



Figure 6

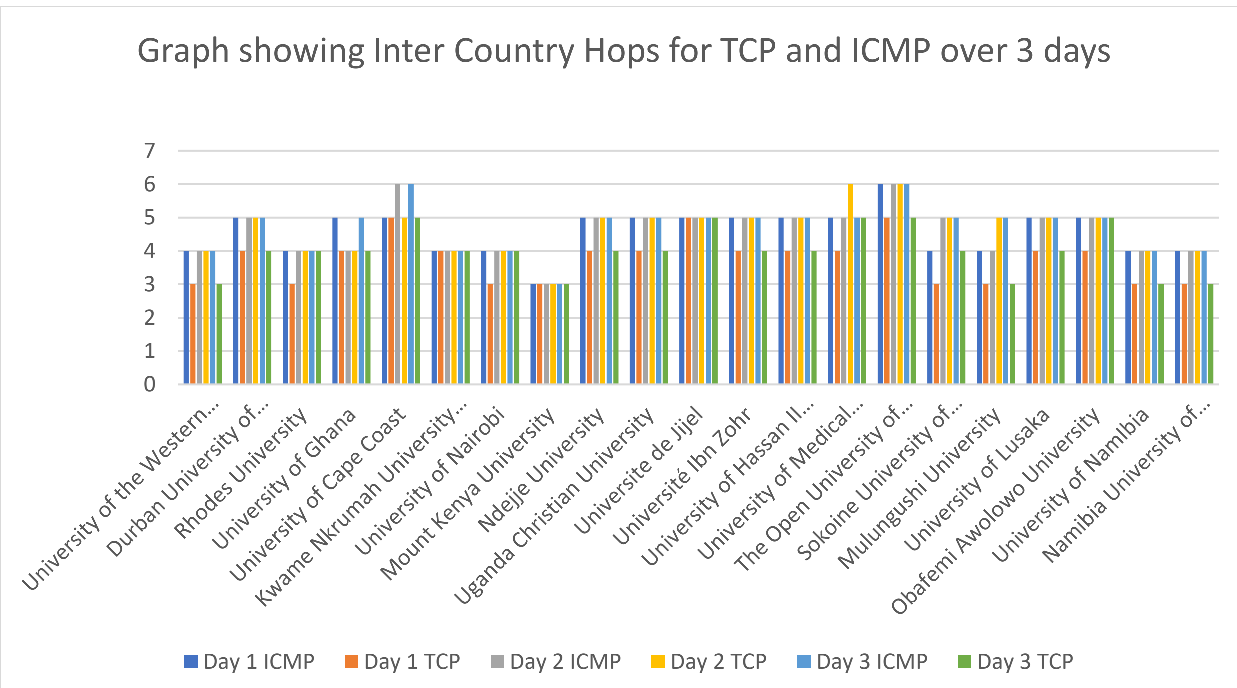


Figure 7

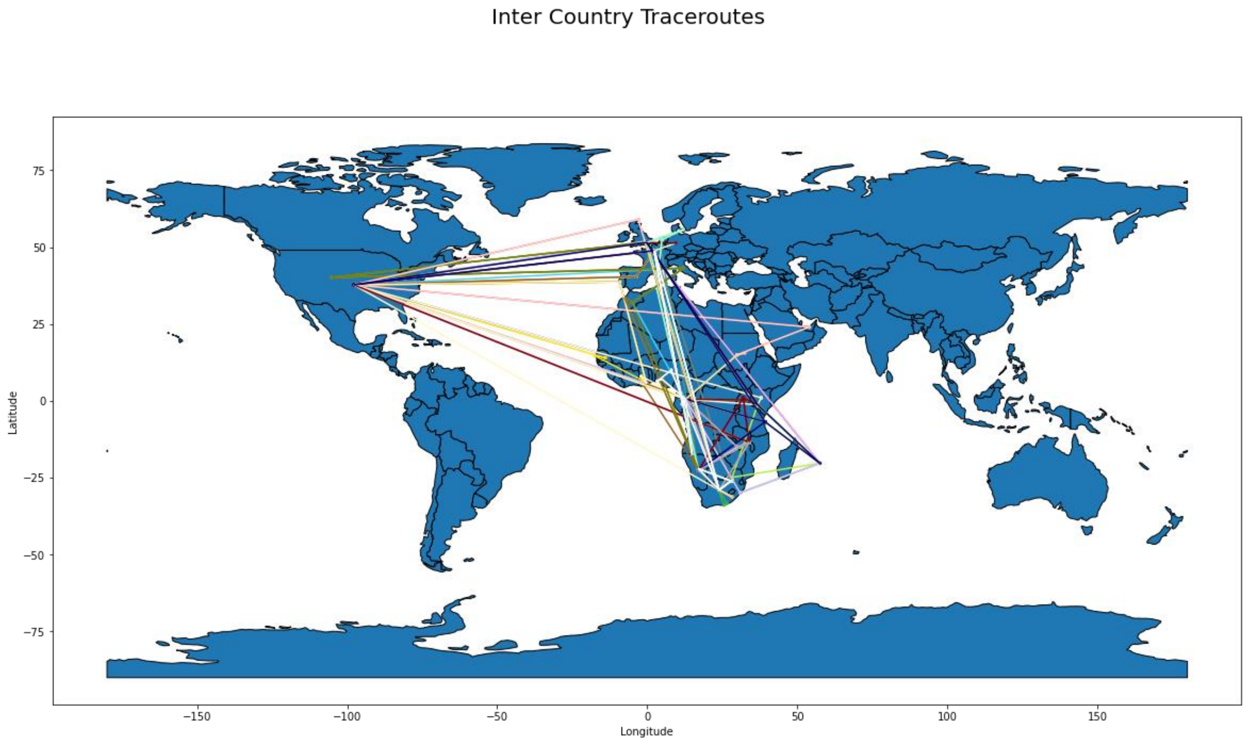



Figure 8

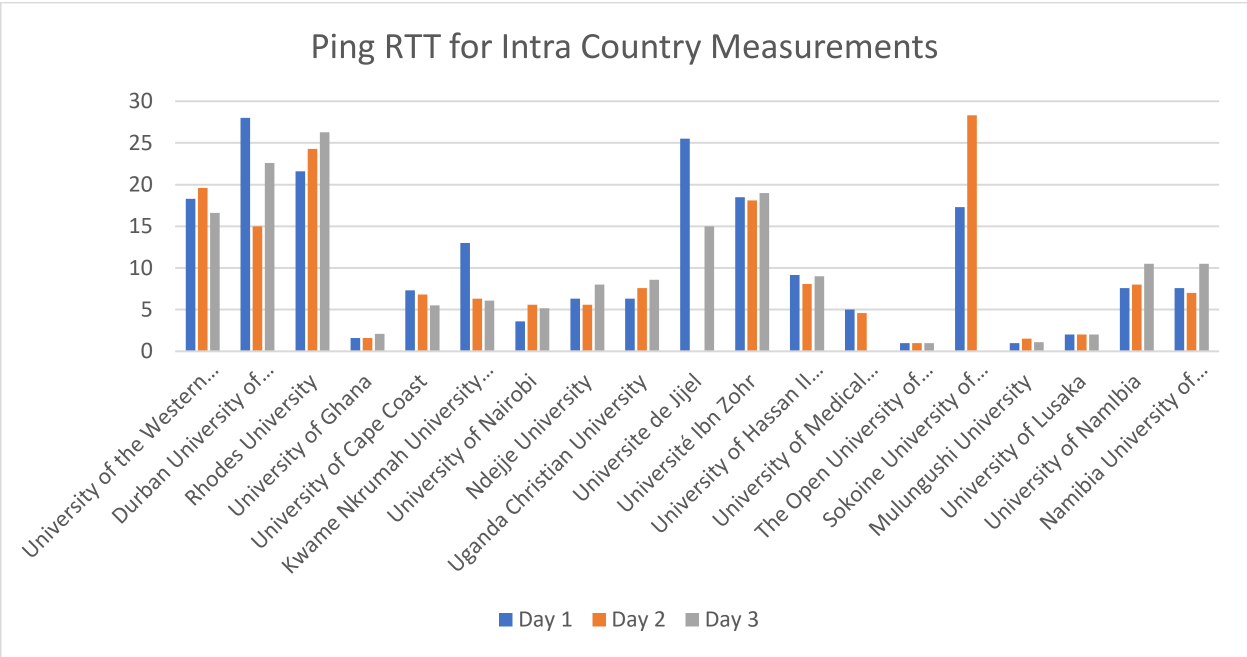


Figure 9

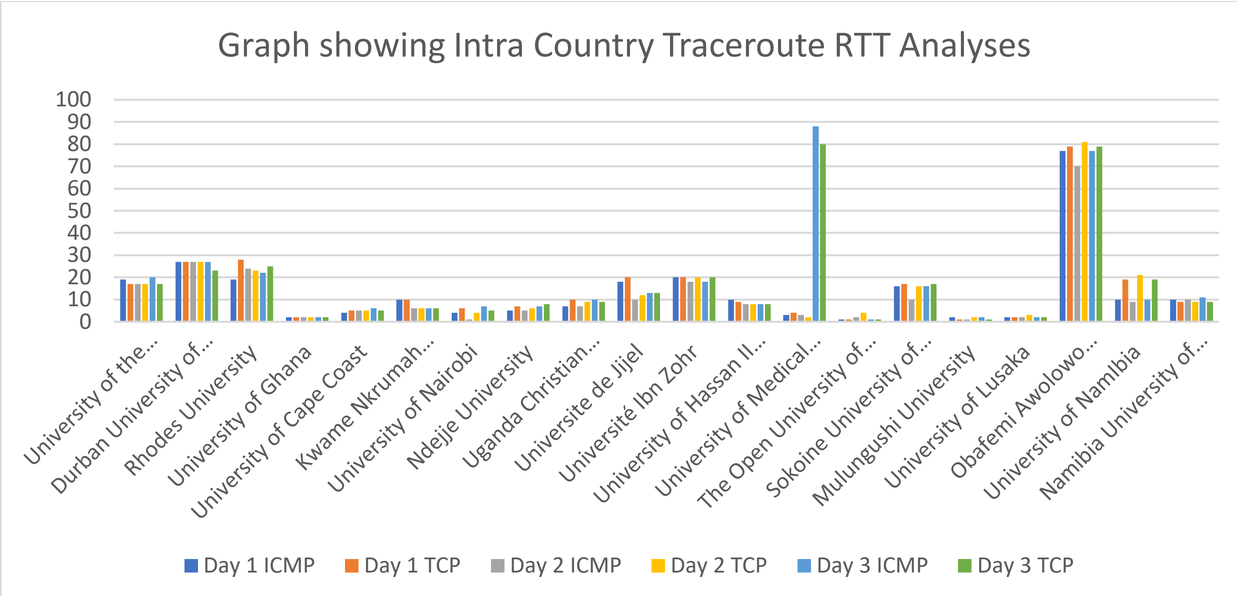



Figure 10

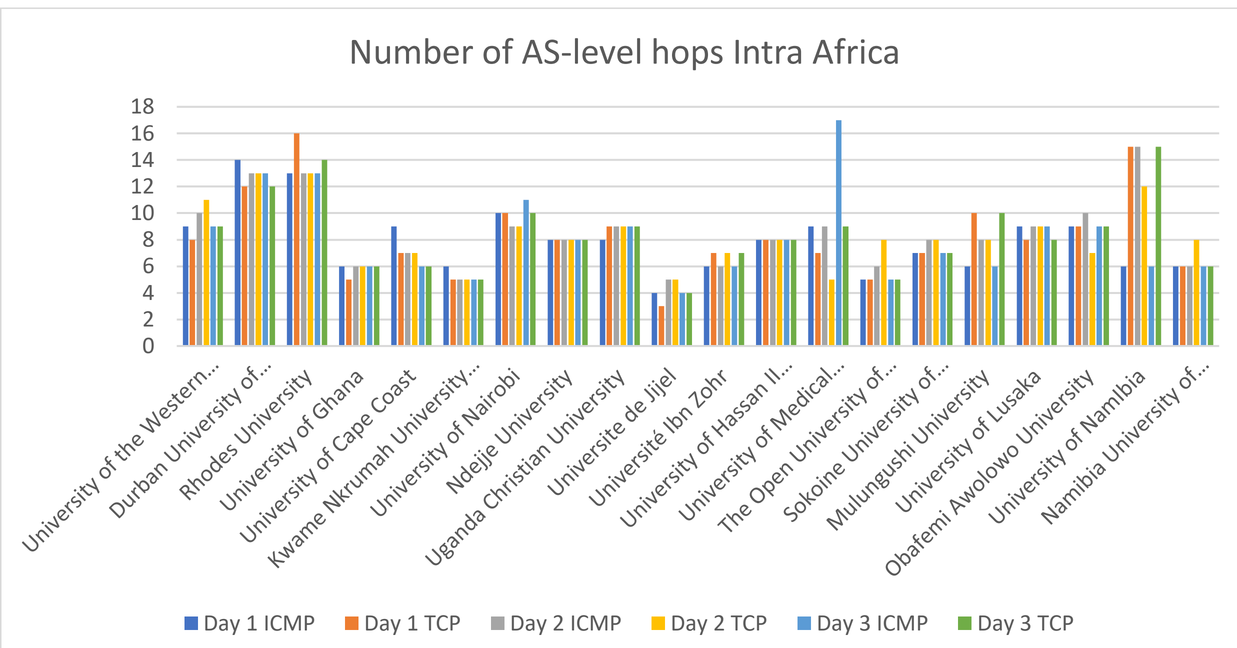
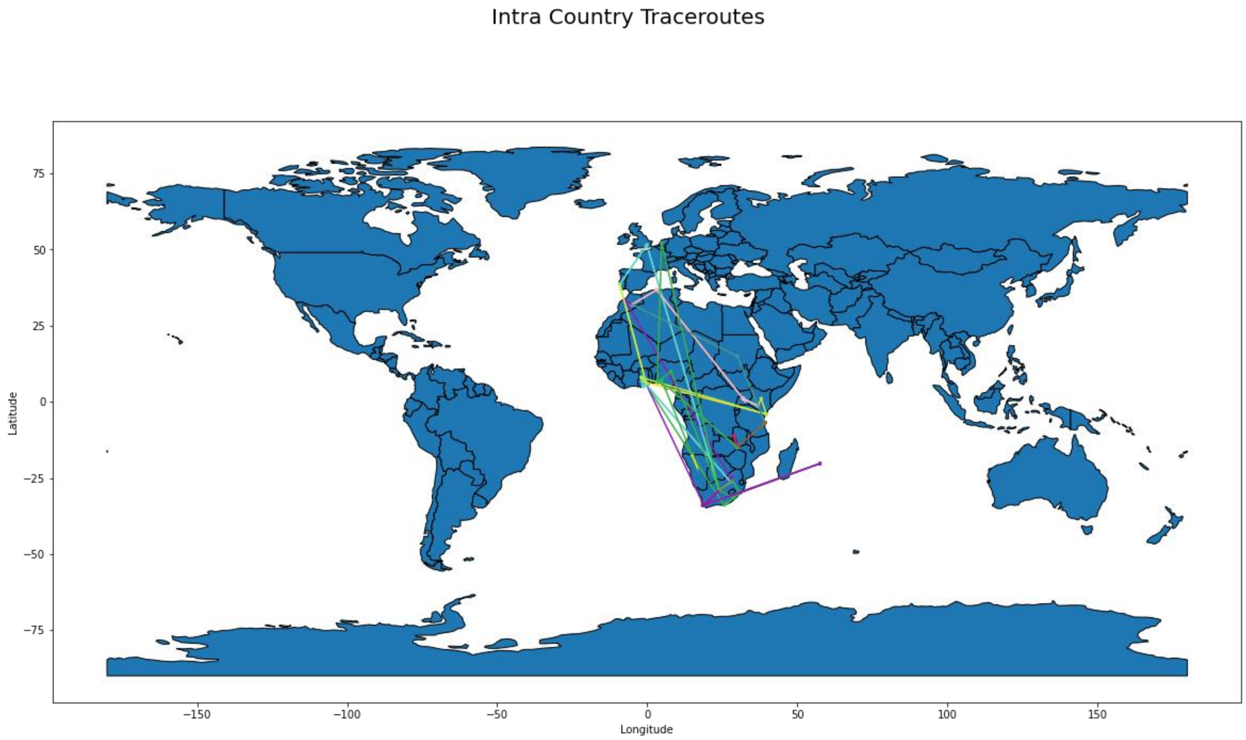


Figure 11


Intra Country Traceroutes
Latitude
Longitude
75
50
25
0
−25
−50
−75
−150
−100
−50
0
50
100
150