State of Internet Measurement in Africa - A Survey

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Abstract. This paper presents the results of a survey aimed at understanding the status of Internet measurement platforms usage, deployment and capabilities in Africa. It presents findings related to prevalence of measurement in the region, the reasons why the different business categories investigated conduct Internet measurement as well as the metrics of interest to these entities. The survey also looked at the popular measurement platforms that the respondents use in their measurement activities as well as the platforms that are hosted by businesses and users in the African region. The survey also recorded responses related to data handling and privacy considerations. A total of 123 responses were received from 34 countries. The survey revealed that Internet measurements are not widely conducted in the region largely due to the inadequacy of deployed measurement platforms, the lack of awareness in the subject, and the lack of relevant skills to carry out the measurement tasks. We outlined some recommendations to remedy these issues.

Keywords: Measurement · Network monitoring · Platforms · Mobile · Metrics · Fixed-line · Measurement-tools

1 Introduction

Internet measurement platforms are infrastructures that are dedicated to periodically running Internet performance and topology measurements. The platforms are broadly categorised as either passive (network traffic monitoring) or active (network probing). Over the years, several such platforms and tools [1–10] have been deployed at strategic locations in access, backbone, behind residential Internet gateways, as well as on user devices. These platforms provide network telemetry, for e.g. to monitor the quality of fixed-line or mobile access networks.

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The platforms implement a range of measurement techniques to infer network performance, including through client-side probing and passive monitoring, as well as through remote probing architectures. Remote probing of fixed-line access networks, for instance, is done by injecting packets and using responses received from residential gateways to infer broadband link characteristics [11].

A number of these platforms provide software-based solutions and include Netalyzr [6], SpeedChecker[1], Ookla SpeedTest[2], Glasnost [9], and Shaper-Probe [10], all of which provide a software interface for end users to measure broadband performance. The Netalyzr tool, communicates with a collection of servers to measure key network performance and diagnostic parameters from the perspective of the broadband user.

The hardware-based platforms, on the other hand, use dedicated devices – often termed probes – to run both user-defined measurements or pre-defined measurements with minimal end-user participation. Internet users tend to voluntarily host these probes for the benefit of being able to monitor, among other things, whether their network providers indeed adhere to the advertised service offerings. Internet Service Providers (ISPs), on the other hand, tend to use the data from such platforms to identify and address problems in its eyeball network, as well as to evaluate the Quality of Service (QoS) experienced from their customers' perspective. Popular among these hardware-based platforms are RIPE Atlas [1] and PerfSONAR [3]. RIPE Atlas is a distributed measurement infrastructure deployed by the RIPE NCC and consists of small hardware probes and larger server-like anchors. The hardware probes run active measurements to determine network connectivity and global reachability, whereas the anchors serve as dedicated servers that can act as sources and sinks for the network measurement traffic. Similarly, PerfSONAR is a network monitoring framework focused on measuring end-to-end performance for paths crossing multi-domain networks.

Other systems have been developed mostly for local wireless and mobile networks. Some of the popular mobile platforms include Netradar [5], Portolan [8], MySpeedtest [12], and more recent platforms include Nornet [13], MONROE [7] and LiveLab [14]. Netradar, for instance, is a crowd-based mobile measurement platform that measures link capacity of cellular networks from smartphones and tablets.

While many of these measurement platforms and tools produce the expected results and have gained substantial deployments in many parts of the globe, their availability in Africa and other parts of the developing world still lags. For example, M-Lab has only seven live servers in Africa. Given the limited number of measurement vantage points and limited network resources in Africa, data regarding the Africa's Internet operations remains limited. Generating this high fidelity data could be achieved with the deployment of these measurement probes and conducting short and long term measurement campaigns. These activities will give the Internet community a good understanding of the peculiarities of

[1] https://www.speedchecker.com/speed-test-tools/.
[2] www.speedtest.net.

Africa's Internet, which is a key towards building technologies and solutions that will spread the use of Internet in the region by making it cheaper, easily accessible to all, and fast enough.

This paper seeks to establish the awareness and extent to which the various measurement tools and platforms are being adopted and used by various players in Africa's Internet ecosystem. Hence an online survey was instituted and responses collected from different categories of users in the region. The authors found a lack of interest in carrying out measurement by Africa's Internet community as well as a lack of awareness and skills necessary to run a successful measurement campaign. A number of suggestions to remedy the issues discovered were outlined in the conclusion section including the need for Internet bodies and groups to intensify awareness campaigns and increase the number of Internet skills acquisition workshops on Internet measurement as well as the need for the Internet community to host more probes and keep the devices running at all times.

2 Related Work

Recently, there has been a growing interest in measuring different aspects of Internet connectivity and performance in Africa. Gilmore et al. [15] conducted one of the first studies to characterise African Internet connectivity. Using traceroutes, they mapped Internet connectivity from South Africa to all IP blocks that are allocated by AFRINIC[3]. Later, Chavula *et al.* [16] used active network measurements to quantify the level of local peering and inter-continental traffic exchange among Africa's Research and Education Networks. The study showed that, as of 2013, up to 75% of Africa's inter-university traffic followed circuitous inter-continental routes, and that such traffic was characterised by latencies that were more than double those of traffic exchanged within the continent. More recently, measurement studies by Fanou *et al.* [17,18] offered a wider view of the AS level topology interconnecting African ISPs using data collected in 2014 from RIPE Atlas probes located in African countries. They highlighted an extreme lack of peering between African ISPs, which results in circuitous routing and consequently very high delays. Gupta *et al.* [19] collected traceroutes between South Africa, Kenya, and Tunisia to investigate the interconnectivity between African ISPs. The study underscored the poor connectivity between African ISPs and that most of them were more likely to be present at European IXPs than regional IXPs. This resulted in circuitous routing paths and consequently higher round trip delays. Livadariu et al. [20] leveraged RIPE RIS and Routeviews data to examine IPv6 adoption in Africa.

Another wave of studies focused on performance. Chetty *et al.* [21] studied the performance of mobile and fixed broadband connectivity in South Africa and underscored the importance of peering decisions. Zaki *et al.* [22] measured

[3] AFRINIC is the Regional Internet Registry for Africa and the Indian Ocean.

webpage loading performance for users in Ghana and found that DNS resolution delay is the largest contributor. Recently, Formoso *et al.* [23] used measurements collected by SpeedChecker to quantify inter-country latency in Africa while Fanou *et al.* [24] employed RIPE Atlas to dissect the web ecosystem in Africa revealing that most of the content accessed by users in Africa is still served from outside the continent. With regards to application-level measurements, Phokeer *et al.* [25] ran a quality of experience (QoE) measurement study on local news website in Africa and found that most of Africa's local content is actually hosted in remote locations.

In terms of studying measurement infrastructure and tools, Bajpai *et al.* [26] and Goel *et al.* [27] have provided notable surveys. Bajpai *et al.* [26] detailed a taxonomy of measurement platforms on the basis of deployment use cases, and analysed the coverage and scale of measurement tools. Goel *et al.* [27] focused on mobile measurement tools and examined approaches to end-to-end mobile network performance measurement. They compared the available tools, highlighting their weaknesses and limitations in meeting the needs of developers, researchers, network operators, and regulators.

While the previous surveys [26,27] largely focused on the technology, our study sheds new light by focusing on the users' understanding and awareness of the measurement infrastructure, as well as highlighting measurement infrastructure that is potentially deployed within corporate networks and largely hidden from the research community. In addition, while it is clear that the previous measurements in Africa have largely drawn upon existing platforms like RIPE Atlas, SpeedChecker and Routeviews or small scale local setups, Africa-grown platforms are notably absent. Furthermore, there is a clear gap when it comes to measuring the performance of mobile broadband both in terms of studies and measurements infrastructures. This is unfortunate, given that most Internet access in Africa is mobile.

As the efforts to understand Africa's Internet intensifies, there is a need to find out more information about the platforms that enable the assessment of the Internet in the region and how these tools are utilised. Hence, the survey was conducted with a number of objectives in mind. Firstly, to improve the current understanding of Internet performance measurement in Africa. Secondly, to establish the state of Internet measurement platforms availability, capabilities, and challenges in the continent. And finally, to establish a good understanding of the needs of the African Internet community in terms of Internet measurement.

3 Survey Description

The online survey was run for the period of eight weeks between 2019-02-28 and 2019-04-14. It was made up of 31 questions and a total of 234 responses were received from 34 African countries.

3.1 Survey Sections

The survey opening section was made up of questions related to the respondents' country and their business/network category. This was followed by the "General section" – the first of five major sections – where we collected data about whether a business runs any measurement campaign or not and the related detail if campaign is currently running/was run in the past. The next four sections included "Metrics section", where we established the relevant metrics important to the different businesses; "Data Handling section", which established the type of data collected, the duration of the data collection, methods used to process, store, and report the data, etc.

The "Measurement Infrastructure" section asked questions about Internet measurement tools hosted/used by the networks and the respondents' level of satisfaction with the available tools. The last section is termed "Conclusion", where open-ended questions were asked including any remarks the respondents have as related to Internet measurement in the African region.

3.2 Collected Data and Cleanup

The countries where these responses came from included South Africa with 20 respondents as the first, Nigeria came second with 16, Sudan third with 8, Ethiopia and Uganda fourth with 7, while Kenya, Morocco, and Ghana came fifth with 4 responses each. These 9 countries constitute almost half the population of Africa and together with the responses from the other 24 countries, the composition gives us some confidence that our data has a continent-wide spread. The list of countries also shows that there are responses from all the 6 sub-regions of the continent[4].

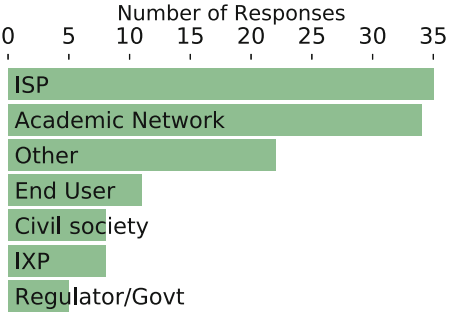

Fig. 1. Business categories that responded

[4] AFRINIC divides its Africa service region into 6 sub-regions, namely, Northern, Western, Central, Eastern, Southern and the Indian Ocean, https://AFRINIC.net/service-region.

The respondents also represented different business categories as shown in Fig. 1. ISPs group, which forms the bulk of the responses also comprised of Telecom Operators and Wireless Network providers. There were also responses from Academic Networks (included in this group were Academic Institutions network and National Research and Education Networks) with the second largest number of responses. Responses were also received from Internet eXchange Points (IXP), Civil Society, Regulator/Government Agency, End-user (Home/Mobile Broadband), and the 'Other' category, which comprised of Enterprise Network, Community Network, ccTLD/DNS Operator, Data Centre, and Cable Operator.

For the purpose of cleaning, all incomplete responses from the 234 attempts were removed and 123 entries were left.

4 Status of Internet Measurement

In this section, the paper examines some of the responses received in relation to prevalence of Internet measurements, the purpose of running measurements, and the metrics that are important to the different businesses in the region.

Table 1. Internet measurement by business category

Business category	Total responses	Number running	
		Campaign [%]	Measurement [%]
ISP	35	7 [20]	24 [69]
Academic Network	34	7 [21]	14 [41]
IXP	8	1 [13]	4 [50]
Civil society	8	5 [63]	6 [75]
Regulator/Govt	5	0	2 [40]
End User	11	4 [36]	3 [27]
Other	22	7 [32]	15 [68]

4.1 Prevalence of Measurement

As the first question related to measurement in the survey, we asked "Have you ever run any internet measurement campaign - either as a business owner or a home broadband/mobile device user?" in order to get the percentage of business running measurements in the region. Only 31 (25.20% of the) respondents answered with a YES. This small number was quite a surprise considering that the bulk of the responses, as highlighted in Sect. 3.2, came from networks that serve a lot of users and should, in theory, want to know how their networks perform. Although not intended, the question was understood by our respondents

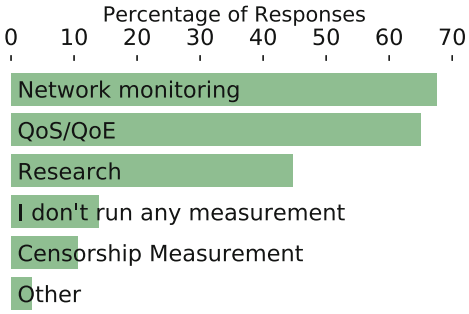

Fig. 2. The main purpose of running measurement

to mean measurement campaigns of some significance likely involving some specialised devices and one that ran for a good number of weeks/months.

This became apparent from two other aspects of the survey as follows. When the 31 respondents with 'YES' in the question above were later asked to provide more detail, we received responses such as "Regular user satisfaction measurement campaign,"I have been the lead collaborator with the Open Observatory of Network Inference (OONI) on Internet censorship research in Nigeria.", "we host perfSONAR measurement nodes which are part of the Academic Network measurement probes for multidomain measurements.", and other similar responses. Secondly, when we later asked a question about performance metrics of interest and followed up with the question, "Do you collect data for the metrics selected in the previous question?" 55.28% of the 123 respondents answered positively – that they have collected some measurement data.

We could understand from the 55.28% figure that while measurement campaigns are not popular with the different business categories, a good number of the networks have conducted some Internet measurement in the past – see Table 1 for more detail.

4.2 Purpose of Running Measurement

Here, we try to understand what is the main purpose that the different businesses are carrying out measurements on their networks for. As highlighted in Fig. 2, about 67% of respondents said that they run measurement for network monitoring, 65% for QoS/QoE, about 45% for research, and a small percentage going for censorship and other reasons. Network monitoring and QoS being the most prevalent reason why measurements are carried out is in line with the dominant source of the survey responses, the ISPs.

Looking at the data, of the 83 respondents that selected network monitoring from the options, 29 of them are ISPs followed by Academic Networks with 21. It is also quite impressive that research comes third among the reasons why businesses conduct measurement on their network. The research option indicates

that apart from the business side of measurement, there is some level of interest in Internet measurement research in the African region.

4.3 Metrics of Relevance

While understanding the general purpose of running measurement gives us some clue about 'why measurement' in general, we also asked a question about metrics of interest to have a better understanding of the performance parameters that are of relevance to the different business categories. It turned out that bandwidth/throughput is the most popular metric in general, chosen by 111 of the total respondents. This is followed by latency chosen by 99 respondents, route reachability, 78, and network utilisation came fifth with 75, among others. With ISPs – especially – and Academic Networks leading the survey responses, it is understandable that bandwidth and latency are the prevalent answers.

The different responses by category are shown in Fig. 3 and we could see that for some networks such as that of Civil Society, 'performance of certain applications' is more important than the second overall popular metric, latency. We could also see for 'Other' networks (such as enterprise, cable operator, community network, etc.) network utilisation is of more importance than latency. It is also instructive that most of the respondents are sure of the metrics that are vital to their businesses as there were only two selections for the option 'Not sure!'.

We have also learned from the survey that data aggregation during measurement is mostly done at the country level, followed by autonomous system (AS) level, and then the point of presence level. AS level, as could be expected, is the popular level for ISPs.

5 Measurement Tools and Infrastructure

5.1 Popular Measurement Platforms

Systems: We asked the respondents about the measurement tools they use to collect data and their answers included the use of popular platforms such as RIPE Atlas and Speedchecker, the use of tools developed in-house, the use of interviews, etc. The survey question outlined six platforms, which included the two mentioned above, as well as M-Lab/NDT, CAIDA Ark[5], PerfSONAR, and Bismark Nodes[6], as well as an option to choose personal computer (PC) where measurement platforms were not involved. We also provided an option, 'Other,' where respondents could type the name of a measurement tool(s) they used on their network.

We counted more than 30 different measurement systems mentioned in the 'Other' section. The measurement systems were mostly PC software/web-based including, Uptime Robot, Netflow, View response PRTG, MRTG, Cacti,

[5] http://www.caida.org/projects/ark/.
[6] http://projectbismark.net/.

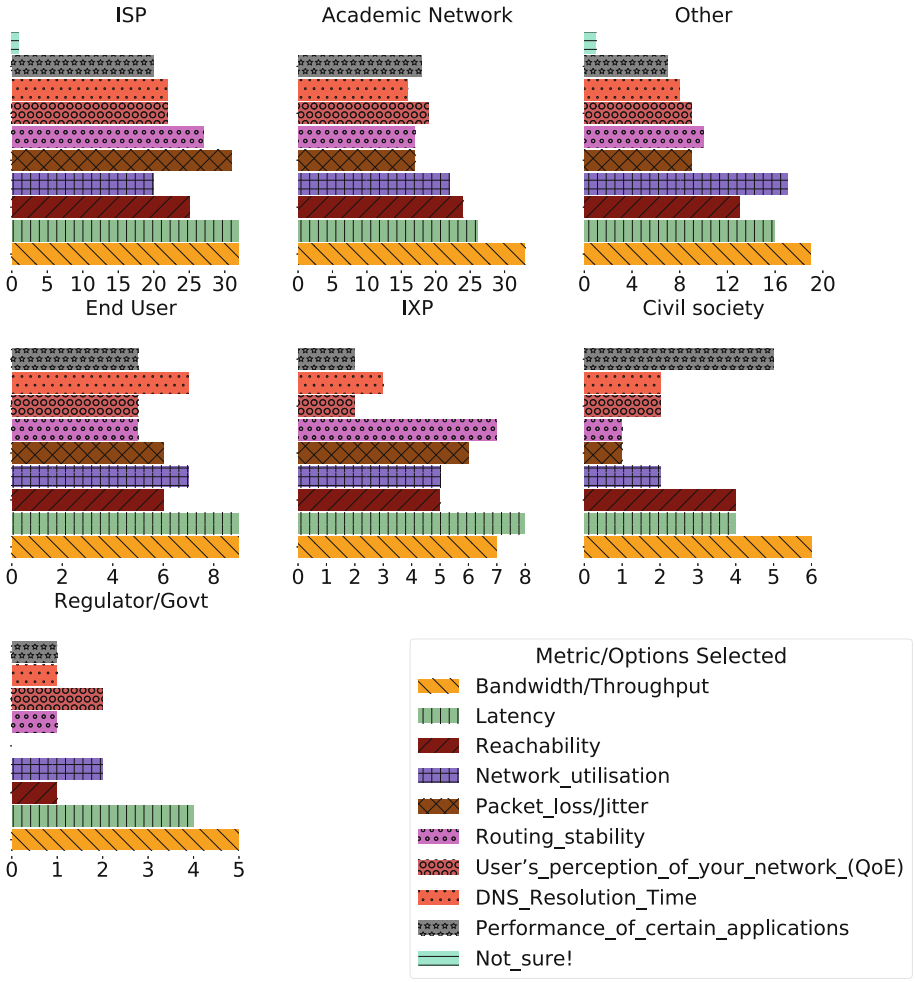

Fig. 3. Metrics of interest

WANkiller, etc. This explains why the option PC was the most popular choice from the list as shown in Table 2. The different platforms/systems chosen as the responses indicate the diverse nature of the tools deployed for Internet measurement in the region.

RIPE Atlas, selected by 29% of respondents, is the most frequently used platform in the region. This is likely because RIPE probes are the most-widely deployed of hardware measurement platforms in Africa with 231 active probes and anchors, as of 10 May 2019, distributed in 126 Autonomous Systems (ASes) (39 of which have both IPv4 and IPv6 connectivity). This represents quite a little coverage of 7.3% of the 1,728 ASNs issued by AFRINIC. What is surprising, however, is that the other measurement platforms were not as patronised

Table 2. Measurement platforms usage by percentage

Business category	Academic Network	ISP	Other	End user	Civil society	IXP	Regulator/ Govt agency	Total responses [%]
PC	25.49	23.53	27.45	11.76	3.92	3.92	3.92	51 [41.50%]
RIPE Atlas	28.57	30.95	14.29	11.90	4.76	9.52	0	42 [34.10%]
Speed checker	26.92	26.92	15.38	15.38	7.69	3.85	3.85	26 [21.10%]
Perf SONAR	70	20	0	10	0	0	0	10 [8.1%]
CAIDA Ark	37.5	25	0	12.5	0	25	0	8 [6.5%]
M-Lab/ NDT	33.33	0	33.33	0	33.33	0	0	3 [2.40%]
Bismark	0	0	0	0	0	0	0	0

by networks across the continent despite the fact they allow for some vital measurement projects not available with RIPE.

For instance, bandwidth/throughput is the most popular metric as discussed in Sect. 4.3 and PerfSONAR is a software-based tool that allows for TCP/UDP throughput measurement, unlike the RIPE platform that does not have such a measurement feature, nevertheless, PerfSONAR was chosen by only 10 respondents. Speedchecker and M-Lab/NDT are two platforms that also provide throughput measurement feature and while the former is the second most-voted platform, M-Lab had only 3 votes. Speedchecker's ease of use could be the reason for its popularity as the software could be installed on hand-held devices or be directly integrated into websites for seamless measurement. On the other hand, the size and the requirements of the server infrastructure necessary to deploy M-Lab/NDT is likely one of the reasons for its minimum spread in the region.

What made RIPE Atlas more popular and added to its widespread adoption, apart from the fact that the project has been around for a number of years, could be the organisation's strategic partnerships with many entities in the African region, such as AFRINIC. We could also attribute the poor utilisation of the useful features provided by the other measurement platforms to lack of awareness from the side of the businesses under review.

Mobile Apps: With Africa's Internet mostly accessed through mobile devices, we investigated the use of mobile apps to measure Internet. While businesses could utilise these apps to understand what customers receive, the customers, on the other hand, could use the apps to know if their networks is at the level expected. As could be seen from Fig. 4, mobile measurement apps are not as popular as the measurement platforms discussed, with more than half of our respondents not using any of the apps. This could be understood considering the fact that apps are mostly popular with end users and they form a small number of our respondents. However, the End User category with a total of only

11 respondents had the highest selection of apps per group in comparison to other categories[7].

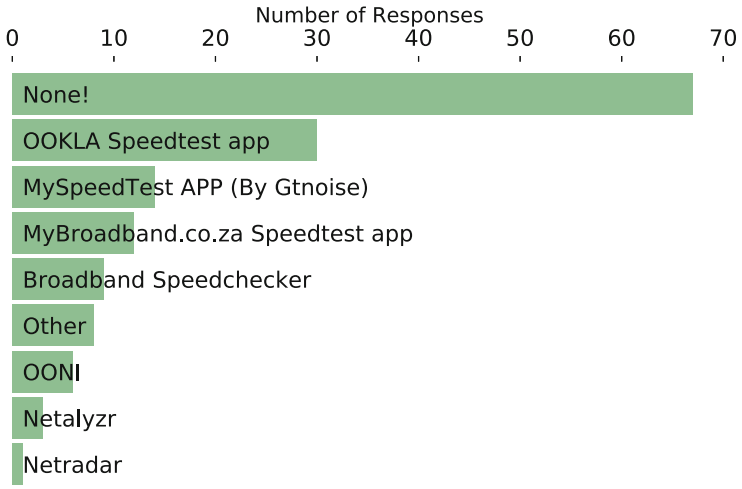

Fig. 4. Measurement apps for mobile devices

5.2 Hosting Measurement Platforms

Having established the popular measurement platforms, we attempted to understand the number of businesses which are currently hosting a measurement probe. 65 of the 123 respondents answered that they host no measurement platform, which indicates some level of disinterest in participation in Internet measurement activity by networks in the African region. The most noticeable of this disinterest is in the case of Regulators/Government Agency group with no probe hosted.

Furthermore, ISPs and Academic Networks accounted for 62% of the total number of the platforms hosted, which means that only a few businesses, outside these 2 categories, are supporting Internet measurement projects. In line with the responses in Sect. 5.1, RIPE Atlas probes are the most popular with 41 devices hosted followed by Ookla Speedtest Server as a distant second with 13. SamKnows, OONI Probe, Bismark Node, and M-Lab pod are the least patronised platforms in the region as detailed in Table 3.

Lastly, we used a Likert scale to get respondents to state their satisfaction level with the current measurement platforms in Africa from 'Highly Satisfied' to 'Highly Disappointed'. As shown in Fig. 5, about 70% are either OK, Satisfied, or highly satisfied with what is available and the other 30% are disappointed with the current measurement platforms.

[7] End User: 11 respondents, 18 selections; ISP: 35 respondents, 34 selections; etc.

Table 3. Measurement platforms hosting responses

Business category	RIPE Atlas	Ookla	Perf-SONAR	CAIDA ark monitor	M-Lab pod	Bismark Node	OONI Probe	Sam-Knows
ISP	18	9	1	1	0	0	0	0
Acad. Network	13	1	9	2	2	0	0	0
IXP	6	1	0	2	0	0	0	0
End user	4	0	1	0	0	1	0	0
Civil society	1	0	0	0	0	0	1	0
Regulator/Govt	0	0	0	0	0	0	0	0
Other	6	2	0	0	0	0	0	0
Total	49	13	11	5	2	1	1	0

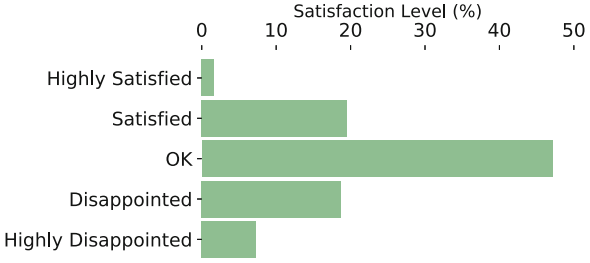

Fig. 5. Level of satisfaction with the existing measurement platforms

5.3 Data Handling

We mentioned in Sect. 4.3 that data aggregation during measurement as reported by respondents is mostly done at the country level, followed by AS level, and then the point of presence level. We asked further questions regarding the measurement data that the respondents collect. These questions bothered on the duration of collected data necessary for analysis, the tools used for the analysis, and the sort of reporting the respondents produced from the data. As for the duration of collected data, 43 of the respondents chose 'Less than a year' option from the question – which is in line with the preference of short term measurements over long term campaigns discussed in Sect. 4.1 – 38 chose '1–2 years', 13 went for '2–3 years' and 11 chose the 'More than 3 years' options. There are up to 18 respondents who chose the 'Not sure!' option.

Our question related to the tools used for data analysis/visualisation provided three different tools as options, MS Excel, Python tools, and R tools. There is also an option to select whether a respondent was not conducting any analysis as well as the 'Other' option to name the tool that was used if different, or in addition, to the provided options. More than 20 different tools were highlighted by respondents who chose the 'Other' options and their responses included Netflow, Tcpdump, ELK, "Custom dev," "provided by nagios," "utils developed by the University of Reunion", etc. MS Excel was the popular tool used and was

voted by 43 respondents, 15 for python and 12 for R. Note that this is a multiple choice question and some respondents chose more than one tool for their answer. Hence, users may be utilising one tool for an aspect of their data analysis and another for a different aspect. Lastly, 52 of the respondents reported not to be carrying out any analysis/visualisation and this figure is closed to the number of respondents who are not running any measurement as reported earlier.

For the question related to reporting the measurement data, respondents included termly reports (daily, weekly, monthly, and yearly), real-time monitoring, research analysis, and reporting a one-off performance analysis on a need-basis, as the different ways that the data measured was reported.

6 Discussion

6.1 Conducting Measurement

Our survey results show that Internet measurement campaigns are not a commonplace in the African region. Measurement campaigns that could run for a considerable amount of time were not very popular with the different business categories, as discussed in Sect. 4.1, despite the benefits that could be derived therefrom. Only 25.20% acknowledged to have run some measurement campaign in the past. Most networks prefer short-term measurement exercises, apparently to understand what was happening at that moment, which could be adequate in some instances. There seemed to be no interest in carrying out a continuous measurement, which could give the businesses a bigger picture of their networks and/or that of their customers.

Furthermore, with only 55.28% of respondents carrying out some measurement, it means that almost half of the members of the networks surveyed are not carrying measurements on their networks. We have also mentioned in the previous section that 52 of the respondents indicated that they do not carry out analysis/visualisation of any measurement data. As will be elaborated in the following subsection, there is a lack of awareness on what Internet measurement entails, what available tools are out there, what benefits it brings to a business, etc.

We could also see some poor handling of issues related to measurement when we look at statistics from an external body, such as RIPE NCC. RIPE Atlas records show that, of the 1026 probes delivered to users across the African region between 13 June 2014 and 10 May 2019, only 231 (22.5%) are currently connected as depicted in Fig. 6. Around 10% of the probes were never connected to the Internet and a whopping 60% of the nodes were abandoned (meaning they have not been connected for a long period of time). While we should take into account many possible reasons for disconnecting the probes – for instance, equipment damage, loss, and users who disconnected the probes because the devices were no more needed – when counting the number of abandoned probes, it is still a large number of devices that are left unconnected to the network for a very long time. While it is important that platform providers distribute more probes and for businesses and individuals to accept and deploy the devices, an important

factor in the success of Internet measurement is keeping the devices running all the time for as long as possible. The 7% disconnected nodes on the figure are devices that have been offline for a short period of time.

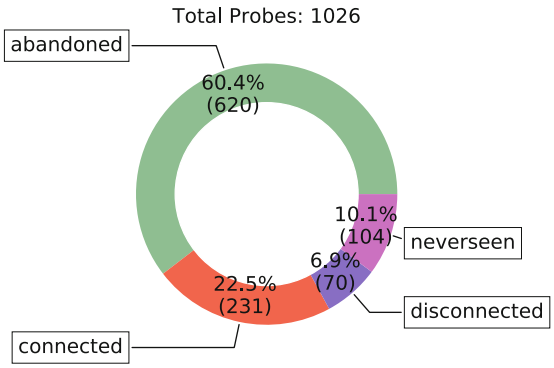

Fig. 6. Status of RIPE Atlas probes in Africa as of 10 May 2019

6.2 Awareness and Skills Development

We asked a question in the survey regarding the lack of use of Internet measurement platforms in order to understand the reasons for the apathy in conducting Internet measurement in the region. As it can be observed from Fig. 7, "Lack of technical know-how" was cited as the number one reason indicating the need for skills development. The second option, "Lack of data processing and visualisation tools," is also an indication that there is a need for awareness and skills development campaigns to introduce some of the users concerned to many open source platforms that they could use for analysis and data visualisation. There are some answers from the 12 respondents who chose the 'Other' option, which included "My laptop is sufficient because I share the same WI-FI connections with my phone", "Not sure", "do not have any", "not aware of their existence", etc. These responses all point to the fact that there is a need for some awareness campaign regarding Internet measurement.

The need for skills is a recurring decimal in other questions that were asked in the survey. To establish the factors hindering Internet measurement in Africa, a question about the factors provided a number of options for respondents to choose from as well as the 'Other' option for respondents who would add factors not captured in our list. Respondents chose different factors as shown in Fig. 8 and the two votes for 'Other' came with the following statements: "Lack of awareness of tools and the importance of the subject" and another response "I don't think enough people care enough to do it." In addition, we could see from the figure that "Lack of well-trained personnel" is the most voted factor with 73

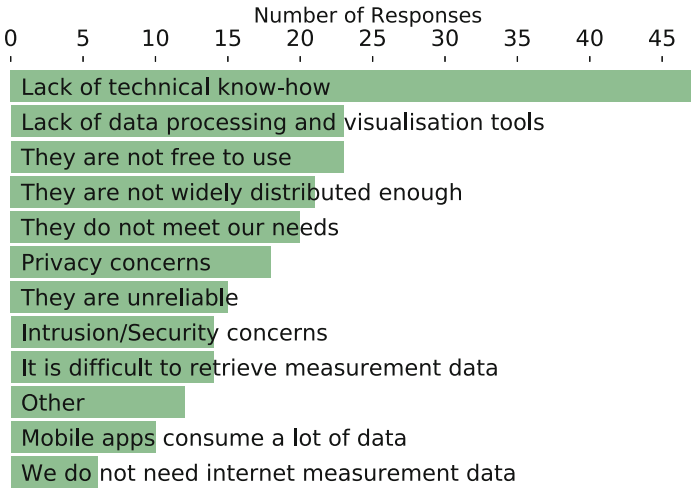

Fig. 7. Reasons respondents were not using the measurement platforms

followed by lack of interest with 57 all pointing to the need for training in order for Internet measurement to pick up pace in Africa.

Similarly, when we asked an open-ended question "What do you think is currently missing in the available measurement platforms/tools in Africa?" we got 47 answers mostly pointing on the need to develop skills. Following are some of the views of the respondents: "... Nous avons des ingénieurs sur place mais il faut de renforcement de capacité sur les outils/plateformes de métrologie de l'internet." which means "We have engineers on site but we need capacity building on the tools/platforms for measuring the Internet." "Some training and accessibility to the tools will help", "more training and know-how sessions across Africa", "Enough service to the rural communities," "Make internet scalable and available for every one," "Enabling law that protect privacy," "knowledge about the tools", etc.

6.3 Privacy and Security

Privacy and security concerns could have an impact on the adoption of Internet measurement in the region. To understand whether privacy and security rules and regulations have impacted on the prevalence of Internet measurement in Africa, we asked the respondents whether there are rules regulating passive Internet measurement in their countries and provided them with three options to choose from, 'YES', 'NO', and 'Not Sure!'. As can be seen from Fig. 9 most of the respondents (52.85%) are not aware if such laws exist in their country. Roughly a third of the respondents (30.08%) answered that such Internet privacy and security laws do not exist in their country. A small fraction of the respondents, 17%, answered positively on the availability of a privacy and security laws in their country. When we grouped the responses by country, we realised that, with the

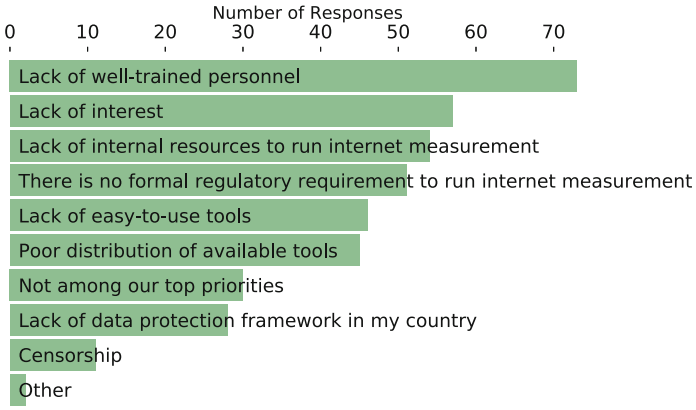

Fig. 8. Factors hindering internet measurement in Africa

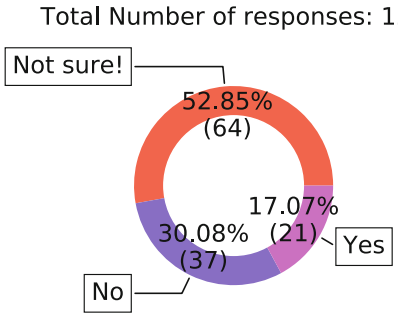

Fig. 9. Presence and level of awareness about privacy Laws

exception of Ghana where the four respondents answered 'YES', responses from same countries were alternating between 'YES', 'NO', and 'Not Sure!'. It is clear that even if such laws exist in countries where some respondents answered in the positive, the majority are not aware of the regulations.

There is no evidence from our data to show that privacy and security laws have any bearing on the prevalence of measurement in the region.

7 Conclusions and Recommendations

There has been a growing interest in measuring the different aspects of Internet connectivity and performance in Africa. This could be seen in the rise in measurement probes deployment across the continent and the number of research literature produced in recent years. The region, however, lags in terms of substantial deployment of probes in comparison with other regions across the world. This issue and the other areas of concerned discussed in the paper – including the poor rate at which Internet measurement is conducted and the lack of awareness and the necessary skills to handle measurement campaigns – need to be

addressed in order to generate high fidelity data regarding the continent's Internet operations. We believe the following points could help in this regard.

1. There is a need for Internet bodies and groups in Africa, such as AFRINIC, *NOGs, ISOC, IGF, etc., to actively sensitise the Internet community in the region of the benefits of participating in Internet measurement projects – with some focus given to the wireless networks as the number one source of connectivity in Africa. Local chapters of these bodies and groups should also create awareness about any existing laws regulating the use of traffic data.
2. The Internet bodies and groups should also increase the number of skills acquisition workshops where network administrators and users are taught the skills needed to conduct Internet measurement and data analysis. The local chapters should be encouraged to organise workshops of capacity building in the Internet measurement area. Internet measurement training programs and resources should be made available via online MOOCs or offline for the thousands who may not be able to attend training events.
3. There is a need for businesses, institutions, and individuals in Africa to host more probes/servers to increase the number of measurement vantage points in the region. It is also vital that these devices should be kept running at all time. Platform providers and their ambassadors should increase distribution and follow-up to ensure that probes stay connected to the Internet.
4. There is a need for collaborations between researchers in the academia and between them and the network engineers running the Internet. The researchers could use the practical knowledge of and insights from the engineers in building research questions that reflect reality. The Internet bodies should facilitate these collaborations.
5. While there is no evidence to show that privacy and security laws have any bearing on the prevalence of measurement in Africa, the governments in the region need to be proactive in coming up with laws that govern the usage of user traffic for the purpose of conducting Internet measurement. The governments should create awareness of the new or any existing law in this area and ensure compliance.
6. Our study also reveals that there is no silver bullet in terms of measurement platforms as a one-size-fits-all solution. Most if not all the existing platforms were built in the context of the developed world and did not take into account the particularities of African networks (or the developing world). In many African countries, there is a high prevalence of mobile phones/wireless networks and any new measurement initiative should take into account this reality. As such, incorporating spectrum sensing and QoE metrics could be an interesting improvement to existing solutions.
7. Moreover, the lack of interoperability between platforms and the lack of standardisation in the data models limit the sharing of information between platforms – feature that can be used to correlate different metrics for e.g. congestion and QoE. This could be another area of improvement.

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