Ego-Centered View to Overcome the Internet Measurement Challenges in West Africa

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Abstract. Measuring the Internet topology in West Africa is a challenge that can be overcome. We propose in this paper to perform ego-centered view measurement of the topology. We show that the obtained graph is relevant qualitatively to represent the topology. The lack of Internet Exchange points between Internet service providers in West Africa leads to high diameter in the topology, which is the result of a poor collaboration among such providers in this geographical area of the Internet. The appearance of "bogon" IP addresses in our measurements reveals a weak administration policy in this part of the Internet.

Keywords: Internet · Measurement · West Africa · Topology

1 Introduction

Many studies have been done to provide better tools and methods to measure the Internet topology [9,11,12,15,17]. Most measurement methods consist to perform traceroute-like measurement from several machines during a period of time [1]. But studying the Internet topology in West Africa remains a challenge. The instability of connection and the selective power cuts due to the insufficiency of electrical power in West Africa countries make difficult such measurement of the Internet topology.

In this paper, we present an approach of measurement in the West Africa context that consists to perform ego-centered measurement of the topology. Instead of trying to measure the entire West Africa Internet, we focus on what a single machine can see of the topology. We obtain a tree structure that is relevant to analyze in networking. We perform two-day measurement with the TRACETREE tool [11], using many sets of destinations chosen randomly among more than three million of major IP addresses blocks allocated to West Africa countries.

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We obtain a graph representing the topology by the union of round measurements. We analyze this graph through some properties like the diameter, the distribution of degrees that are used to characterize complex networks. The first researchers in the field of complex networks have shown how these properties play a key role in the robustness of the Internet [4,5].

Despite the fact that our measurement is a small sample, we find a distribution of degree like that of the Internet. Among the IP addresses observed by our measurement, many of them are located outside the Africa continent. This means a weak collaboration between the Internet service providers (ISP) in West Africa. Internet exchange points (IXP) should be established between them.

The rest of the paper is organized as follows; Sect. 2 presents ego-centered view approach and the measurements; Sect. 3 gives main properties of the obtained graph. In Sect. 4, we present a discussion of our results.

2 Approach and Measurement

Most campaigns of Internet measurement are based on traceroute-like tools. It consists to perform paths measurement from computers called sources towards set of target IP addresses called destinations. The main challenges with this method are the choice of suitable sources and destinations allowing to see more the topology and the bias on the measurement due to the tool [1].

We do not aim to map the entire topology of West-Africa Internet but only on what a single machine can see of this topology [11,13]. The approach has been used to study the dynamics of the Internet in previous work and measurement tool TRACETREE has been designed for this purpose.

The TRACETREE output is a tree which is made by routes between the monitor(root) and the destinations(leaves). The obtained tree is an ego-centered view of the topology around the monitor. The recommended number of destinations must not exceed 3 000 to avoid overload the network traffic near the monitor. For more description of TRACETREE tool, see [11].

For this work, we have chosen randomly the destinations among 3 millions major IP addresses blocks allocated by AFRINIC [2] to 12 countries in West-Africa. These are Benin, Burkina Faso, Cote d'ivoire, Ghana, Guinée, Liberia, Mali, Niger, Nigeria, Sierra Leone, Sénégal and Togo.

We used three different sets of 500, 1 000 and 3 000 destinations. We make sure that the IP addresses reply to ping when chosen. For each set of destinations, we have performed 100 rounds of TRACETREE measurements with a monitor located in Ouagadougou. There is a delay of 10 min between consecutive rounds, representing two-day measurement. We finally merged the outputs of the TRACETREE measurements, which is a graph representing what the monitor may see of the topology.

3 Properties

In this section we present basic properties of ego-centered views. We analyze the Internet topology of West-Africa comparatively to the results observed with other measurements.

Figure 1 shows that the number of IP addresses observed at each round increases when the number of destination grows. Each round measurement sees the number of IP addresses nearly equal to the number of destinations used. This lower number of observed IP addresses is due to the fact that some routers do not reply to the ICMP echo-reply probe. In addition, many destinations, randomly chosen may be unreachables or belong to the same network.

Moreover, with 3 000 destinations, the number of IP addresses seen is even lower and do not reach the number of destinations used. The number of IP addresses seen during the hundred rounds is not high comparatively to usual measurements, 452 for the set1 of 500 destinations, 482 for the set2 of 1 000 destinations and 1005 for the set3 of 3 000 destinations. This observation shows a weak density of the topology of West Africa Internet. With other measurements the number of IP addresses seen at each round is three time the number of destinations used [11,13].

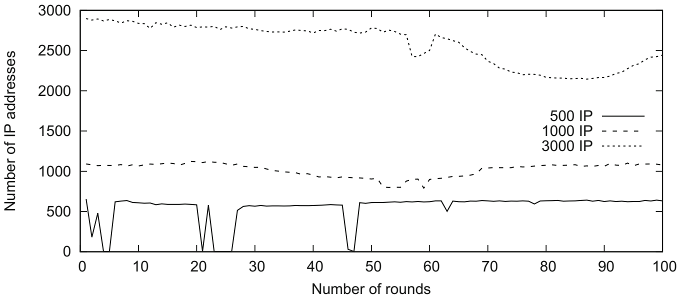

Fig. 1. Number of IP addresses observed at each round measurement for 500, 1 000 and 3 000 destinations.

We performed trial measurement with destinations without test them to ping. We observed at each round a number of IP addresses less than the half of the number of destinations. However, with the set of destinations were responding to ping before the measurement the 100 rounds of TRACETREE measurements did not allow to reach them all, see Table 1. The destinations unreached may be hidden by firewalls, the routing dynamics or they are simply out of the Internet during the measurement.

The diameter of a graph is defined as the highest distance that exists between any two vertices in the graph. The distance between two vertices is the smallest path between these vertices. The diameter is an important characteristic of the communication in a network. It characterizes the ability of two nodes to

Table 1. Basic properties of the graph of ego-centered views.

Destinations	IP addresses seen	Unreached destinations	Max degree	Diameter
set1: 500	891	61	150	28
set2: 1 000	1579	98	302	39
set3: 3 000	3341	204	837	30

communicate with each other. The smaller the diameter is, the better is the communication between them. The diameter does not grow linearly with the number of nodes. For instance the diameter of the graph of the Web with nearly one billion nodes is around 20 [3].

The diameter of the West Africa Internet topology is 30 for the measurement of the set of three thousand destinations that we consider more representative of the topology. We find this value of the diameter is relatively high comparatively to other measurements of the whole Internet at different levels of the topology [3,6].

The degree of a node in a graph is the number of links that connect it to its nearest neighbors. The degree of a node is an indicator of its importance for the communication in the network. Obviously, more the node has a high degree, more it is important for the communication between the nodes. The distribution of degrees is used to characterize the types of networks. There are two main types of distribution of degrees, homogeneous and heterogeneous. The heterogeneous distribution of degrees characterizes particularly complex networks. The distribution follows a power-law.

Figure 2 shows the cumulative distribution of degrees of the graph of 3341 nodes obtained with the union of 100 ego-centered views of the topology. We find an heterogeneous distribution of degrees of nodes. There is around 86% of nodes having the degree less or equal than 2 whereas 1.4% of them has a degree more than 10.

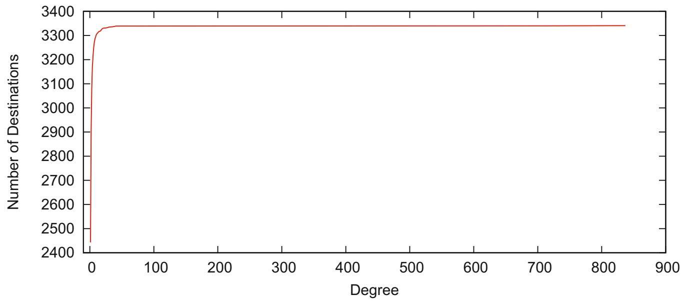

Fig. 2. Distribution of degrees of the graph obtained by the union of 100 ego-centered view measurements with 3 000 destinations.

Despite we focus on small part of the topology we find a distribution of degrees similar to those of complex networks. This result shows the relevance of our approach based on ego-centered view measurement of the topology.

4 Discussion

This work raises interesting questions on the evolution of the Internet topology in West Africa countries and the challenges to overcome regarding to topology measurement in this part of world. Many campaigns of Internet topology measurement have been made around the world but unfortunately the participation at these campaigns of Africa continent or West Africa region in particular is not enough [14–16,18]. Mostly, the campaign of Internet measurement is based on volunteers provides their computers connected to Internet to run measurement software during several weeks or months. This last condition make difficult to African volunteers to take part of these measurements. For instance, RIPE Atlas project provides measurement probes to anybody making request to participate [15]. The volunteers are free access to the measurement platform to perform their own measurement between the computers hosting the probes. Firstly, there are few volunteers in West Africa and secondly most of their computers are frequently offline, certainly due to problems of Internet connection or power cut.

We observed among the IP addresses seen by our measurement, 502 of them that are not in the major IP addresses blocks allocated by AFRINIC to twelve countries of West Africa. We made use of the Regional Internet Registry (RIR) service WHOIS to know what countries these IP addresses have been allocated. We found that most of these IP addresses belong to Countries out of Africa (Europe and USA). The presence of these IP addresses in our measurement demonstrates that some traffic have to pass by other continent before backing to the destinations located in West Africa. It appears clearly that there is not enough collaboration between the Internet service providers in West Africa countries. They have to put more Internet exchange points (IXP) in place.

Among the IP addresses that we observed in our measurement we found around ten *bogon*[1] IP addresses. Particularly, the IP addresses 10.93.187.25, 10.93.96.153 are important by their highest degrees.

A packet routed over the public Internet should never have a source address in a *bogon* list. The presence of these addresses in our measurement shows a problem of network administration that does not filter *bogon* addresses. *Team Cymru*[2] publishes a list of prefix *bogon* for this purposes.

5 Related Work

Internet measurement is among the research areas that needs more investigation in Africa. Nevertheless, there exists qualitative results showing how the state

[1] A *bogon* prefix is a route that should never appear in the Internet routing table.
[2] Team Cymru Research NFP is an Illinois non-profit and a US Federal organization.

and the challenges of the Internet in Africa [7,8,10]. The authors of this contribution [8] concerning the accessibility of the Web content in Africa point out clearly a poor inter-AS communication is Africa. The outcome of their work is similar to ours that shows the lack of Internet Exchange points between Internet Service Providers in West Africa.

Africa has known an emergence of IXP in the recent years but not enough solve the improve the communication between Internet Service Providers inside the continent. In previous work [7], the authors study the influence of the emergence of these IXP on AS path length. Their results show a major contribution of ISP located outside the Africa continent to the intra-continental paths.

Our work is related to this studies presented above but we emphasize however that our main track concerns the Internet mapping in Africa.

6 Conclusion and Perspectives

We presented the ego-centered view approach that we used to measure the Internet topology in West Africa. We showed that the obtained graph is relevant qualitatively to represent the topology. We analyzed the graph and found interesting results. The distribution of degrees is heterogeneous, similar to that of the Internet. But the diameter is high compared to other measures of the Internet. This high diameter is certainly due to presence of IP addresses located outside the African continent in the measurements.

This work could be considered as preliminary to an extended measure. For future work, it may be worthwhile to increase the number of sources of measure, in all the countries concerned.

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