Poster: A decade of evolution in telecommunications infrastructure

Azan Khanyari, Ioana Livadariu, Haakon Bryhni, Ahmed Elmokashfi
Simula Metropolitan
{azan,ioana,haakonbryhni,ahmed}@simula.no

Abstract

Characterizing countries' standing in terms of the maturity of their telecommunications infrastructure is paramount to inform policy and investments. Here, we use a broad set of features to group countries according to the state of their infrastructures and track how this has changed between 2010 and 2020. While a few nations continue to dominate, the membership of this club has changed with several European countries leaving.

1 Introduction

Countries at varying stages of telecommunications infrastructure development face different challenges. Hence the knowledge of relative standing of a nation and how it has evolved over time can help inform telecommunication policy while also learning from successful strategies of developed countries with similar network profiles [3]. This study aims to capture the ground reality of a country's network/digital infrastructure development, its network interconnectivity preferences as well as intricate Internet traffic transit dependencies between the world countries by building two datasets, 10 years apart from 2010 to 2020. Each dataset comprises 13 diverse metrics, for a set of about 200 countries, sourced through publicly available network topology/interconnection databases sources. We apply unsupervised learning i.e. Agglomerative clustering which identifies 6 clusters of countries. We further analyze these clusters to shed light on improvements and major changes.

2 Dataset and Methodology

We devise a set of 13 features that aim to capture country-level network characteristics in terms of *infrastructure*, *interconnectivity*, *digital/IT services* and *global transit influence*. We compute the number of large and small internet service providers, as well as the number of connected undersea cables to describe the country network infrastructure. We further describe inter-connectivity by computing the number of IXP's and the percentage of domestic networks peering inside and outside of the country. To describe the country's digital/IT services we use data related to the mobile cellular and broadband subscriptions, as well as the Internet penetration rate. Finally, we characterise the country's global transit influence through the use of a metric called hegemony score [2], which quantifies centrality of a country in terms of global transit/access networks peering with the local networks as well as the number of countries the local networks provide transit to.

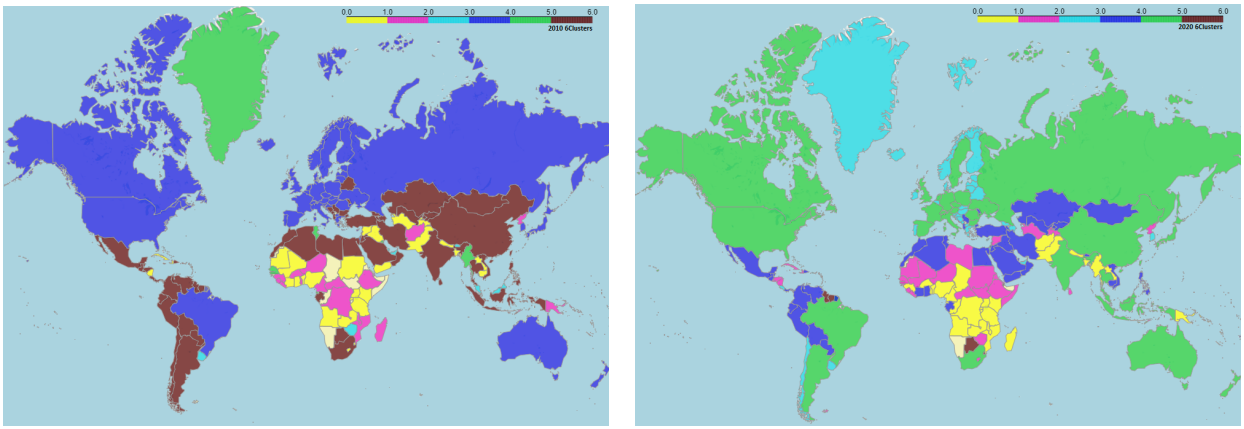
We further seek to group countries into similar clusters based on the similarities across the considered features. To this end, we feed the feature values into an unsupervised clustering model. After experimenting with a wide range of distance metrics and number of clusters, we set Soergel [1] as the distance metric and the number of clusters to six. We run clustering for data collected in 2010 and 2020, and further present the results and our insights.

3 Country-level clustering evolution

Figure 1 shows the how the countries cluster based on the selected features in 2010 (fig. 1(a)) and 2020 (fig. 1(b)). For both years, our clusters can be described as follows.

Most developed cluster: Countries comprised in this cluster have relatively high values across all features. Marked with dark blue in figure 1(a), the cluster includes 51 countries and covers most of Europe, North America and Asia-Pacific. The internet service providers (ISP) have a hierarchical structure with many large ISPs (LISP) having global presence and stubs which get transit from these networks. We find highest density of peering infrastructure coupled with extensive peering between domestic networks. Countries from other clusters are a direct/indirect customer of the countries within this cluster due to them being transit hubs. The United States, Sweden, United Kingdom, Canada and Germany are the top transit providers globally in 2010. The 2020 cluster comprises of both countries present in 2010 (22) and new entries (10). Note that the cluster is marked with green on figure 1(b). The peering infrastructure continues to be the best in this cluster with the greatest improvement for USA where number of IXPs in this country tripled. China, India, Malaysia and South Africa are new entries in the 2020 cluster. Most of the 2010 countries that left this cluster are located in Scandinavia and Eastern European. These countries do not register the same growth in infrastructure and inter-connectivity, and thus they are removed from this cluster.

Heterogeneous cluster: Countries grouped in this cluster exhibit high variability across most features. We mark this



(a) Year: 2010 (b) Year: 2020

Figure 1: Country clusters for 2010 (a) and 2020 (b).

cluster in figure 1 with brown and dark blue for 2010 and 2020, respectively. We find that the 2010 telecom market is competitive as these countries register the second highest number of stubs across all clusters. At the same time, only a third of these countries have any IXPs, which indicates weak intra-country connectivity. We find in the 2020 heterogeneous cluster 37 of these countries. Compared with the previous time period, we find improvements in both intra-connectivity and infrastructure. Specifically, a higher number of LISPs and higher peering preference both at domestic and foreign IXPs.

Weak clusters: Countries grouped in these clusters register low values for least one set of features. In 2010, countries in the weak clusters (marked with yellow, pink and green in figure 1(a)) are located in Africa and South Asia. Most of the countries in one of this weak clusters do not have LISPs and have no peering infrastructure. We note, however, that some of these countries like Tanzania, Kenya and Uganda established IXPs early on in part due to liberalisation in the telecom sector [4]. Countries grouped in other weak cluster have low values in terms of digital/IT services, i.e., low Internet penetration rate and mobile subscribers. A decade later, we find that the number of countries increased from 74 to 103. While we note an improvement in the interconnectivity and infrastructure, we find that the bulk of the weak countries in 2020 were also weak in 2010. We note that number of LISPs significantly increased for countries like Bangladesh, Mauritius, Pakistan, Nigeria and Angola. However, many countries do not show any improvement, Example of these include Cuba, Syria, Niger and Ethiopia. These results appear alarming since they suggest a widening digital divide. Going forward, we plan to investigate this thoroughly.

4 Conclusions

We have presented our initial work on analysing the country-level intra and inter connectivity evolution. Our results show an overall improvement in the network infrastructure and connectivity over the last decade. However, we find a significant number of countries grouped in the weak clusters both in 2010 and 2020, indicating that these countries need to double their efforts in improving their telecommunications infrastructure. We also find that a set of 22 countries continues to dominate in terms of infrastructure as well as being major transit providers for the rest of the world. These countries are mostly in the EU, USA, some Asian countries like Singapore, Japan, New Zealand. At the same time countries like India, China, Malaysia, South Africa have managed to enter the club of powerful nations, which is a cause for optimism. In terms of transit influence, USA, Sweden and the UK continue to remain the top 3 transit providers globally.

References

[1] Charu C Aggarwal, Alexander Hinneburg, and Daniel A Keim. 2001. On the surprising behavior of distance metrics in high dimensional space. In *International conference on database theory*. Springer, 420–434.

[2] Romain Fontugne, Anant Shah, and Emile Aben. 2018. The (thin) bridges of AS connectivity: Measuring dependency using AS hegemony. In *International Conference on Passive and Active Network Measurement*. Springer, 216–227.

[3] Christos Andreas Makridis and Max Smeets. 2019. Determinants of cyber readiness. *Journal of Cyber Policy* 4, 1 (2019), 72–89.

[4] Robert Schumann and Michael Kende. 2013. Lifting barriers to Internet development in Africa: suggestions for improving connectivity. *Analysys Mason Limited, London* 9 (2013).