Demo: Visualising Mobile Operator Connectivity

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Abstract

Telecommunications operators route much of their traffic across IP backbones, exchanging both mobile traffic (for routing or roaming) and Internet-bound traffic, at Internet Exchange Points (some of which also offer GRX/IPX services) strategically located across the globe. Operating largely independently, both for regulatory compliance and security, inter-operator peering within the telecoms field remains mostly invisible to external parties, compromising both strategic peering decisions with other mobile operators and minimising resilience risk analysis for governments or regulators. This demonstration focuses on resolving this specific issue, providing an interactive graph-based tool through which to understand and analyse the resilience of telecommunications networks within a global context, and highlighting challenges of resilience posed both by the structure of IP backbones and underlying geopolitical risks.

CCS Concepts

• **Networks** → **Intermediate nodes**; *Logical nodes*; *Mobile networks*.

Keywords

Internet, routers, traceroute, BGP, graph, telecommunication

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1 Introduction

Whilst telecommunications providers have been recognised as critical infrastructure for many years, conflicts like the war in Ukraine have highlighted the need for resilience and robustness in their connectivity. We have also seen new geopolitical dynamics and initiatives shape how we view this resiliency: European dependency on US-based technology companies is considered a potential vulnerability; and differing approaches to critical infrastructure regulation highlight a growing global trend towards network sovereignty. Operation of telecommunications networks, particularly in those supporting standards from 5G and beyond, relies deeply on the successful routing of traffic across IP backbones that sit beneath the mobile-specific protocols and routing, both when carrying mobile-specific traffic such as voice or text, or Internet-bound traffic such as accessing streaming services using a mobile device.

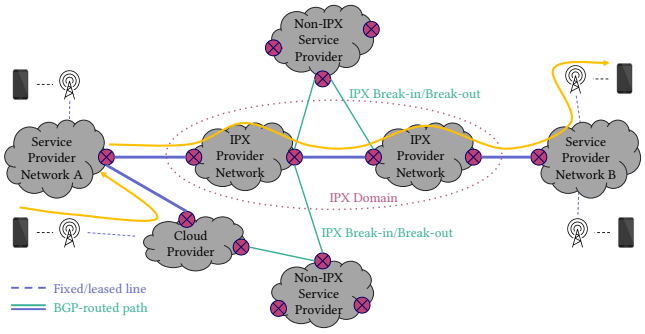

Figure 1: Routing mobile traffic across underlying telecoms provider IP backbones.

Peering between telecoms networks takes place at a relatively small number of physical locations – in the UK, primarily in three physical locations. This means telecom backbones are exposed to a substantive level of concentration risk, with a consequent impact on resiliency. The extent of this threat is not readily visible, but the exposure to simple configuration changes is significant - as demonstrated by Vodafone's IP network disconnecting up to 18 million people late last year [5].

In Figure 1, we present an example underlying IP backbone of two telecoms service provider networks (`A` and `B`), of which `A` implements a third-party cloud provider to connect a base station to its network core. The end-to-end routing utilises an IP topology to carry traffic through each stage of fronthaul, midhaul and backhaul (the latter of which is sometimes undistinguished), each network of which peers over the Border Gateway Protocol (BGP). In an Internet context, inter-network peering has long been exposed using the collection of BGP peering information and traceroutes [4].

This demonstration similarly uses Internet routing information collected through BGP and traceroutes, but applied to the telecommunications context. As such, we present an interactive interface through which to examine the inter-network topology of telecoms operators, using information provided from IXPs to identify GRX/IPX peering.

2 Overview

We collect routing data from BGP paths and communities, which are used to infer inter-AS connectivity, supplemented by hundreds of thousands of traceroutes from globally distributed probes mapped to their AS-level routing equivalents. These are later combined with information provided by IXPs and network operators to form a graph-based network topology representation. We present this

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graph-based topology using Gephi Lite [1], a publicly available online tool for the visual analysis of network graphs.

The nature of ingesting from different types of data source naturally divides into four subsystems:

BGP data collection and processing. We process passively collected BGP data from globally distributed BGP listeners, capturing in particular the `AS_PATH` which is then filtered to remove poor quality data, and then used alongside multilateral peering inferences based on the `AS_COMMUNITIES` attribute, which is widely used at IXP route servers. In each case, it allows for the inference of adjacency between ASes based on sequential placement of ASNs in the `AS_PATH` or based on IXP presence and known structures of `AS_COMMUNITIES` and their intended route distributions.

Traceroute measurements. Sourced from RIPE Atlas, traceroutes provides a different but complementary view of AS connectivity. Use of these measurements requires mapping router IP addresses to parent ASes, which we complete using a subset of the metadata provided by the IXPDB and PeeringDB.

Metadata collection and processing. We collect from a variety of sources metadata about the most appropriate human-recognisable names for ASes [2], the most likely owner(s), network types (such as CDNs, transit networks, local ISPs and telecoms operators), where networks are physically present for peering, and in which countries they operate.

Graph-based representation. The processed data from each previous subsystem is collected over a 14-day period to capture less-visible aspects of the network topology, and merged to provide a richly-labelled abstract graph. Some attributes are reformatted into Gephi-optimised tags, including using comma-separation for lists of attibutes such as network type.

3 Demonstration

For demonstration, we make available the overall network connectivity graph showing the complete set of collected inter-network relations, in addition to the domestic graphs (based on company registration) for all ISO 3166 recognised countries, such as that shown in Figure 2.

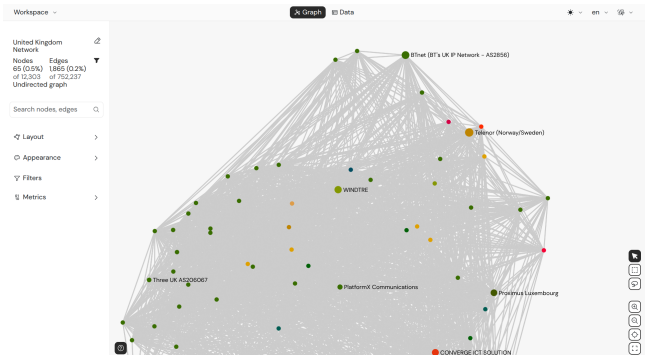

Figure 2: Connectivity of BT's IP backbone in the United Kingdom, collected using our tooling and demonstrated in the *Gephi Lite* graph viewer.

We also use operating locations of each network within the graph to identify the connectivity of specific countries and regions – such as the European Economic Area (EEA) – which share many common network operators. It is a natural extension of this to include the closest neighbours of these nodes, resulting in visualisations similar to that presented for the Islamic Republic of Iran (Figure 3).

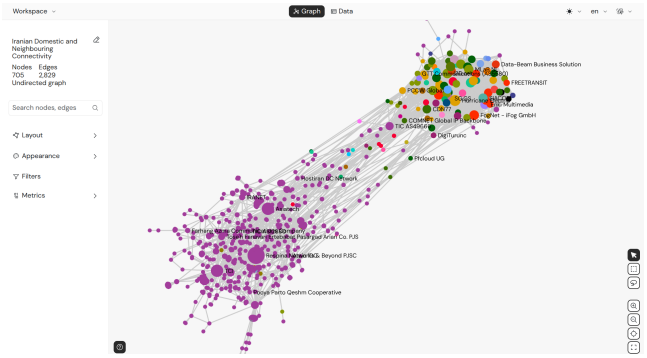

Figure 3: Connectivity of networks in, and connected to, those registered in the Islamic Republic of Iran.

Using Gephi Lite also enables the rearrangement of network nodes (operators) based on a variety of different positioning algorithms, and the filtering of both nodes and edges depending on a variety of characteristics, including: peering locations, ownership registration information; countries of operation; types of network services provided; and the estimated number of network users. Additionally, we also enrich the graph with information about the importance of each node within the presented context, helping to highlight the most critical service providers – and using metrics like Jaccard path similarity, we also identify and expose local provider 'bottlenecks'. Presentation of the network connectivity graphs enables insight into the geopolitical dynamics affecting network connectivity, in addition to key operators on which telecoms providers depend. We can also use this as the foundation of a graph to deploy with TERIS [3] to replicate specific routing scenarios and validate potential changes to improve resiliency.

Acknowledgments

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