

RIPE 88, Kraków
20-24 May 2024



Architecture and Routing in a Geopolitical World

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SYSTRON_{Lab}

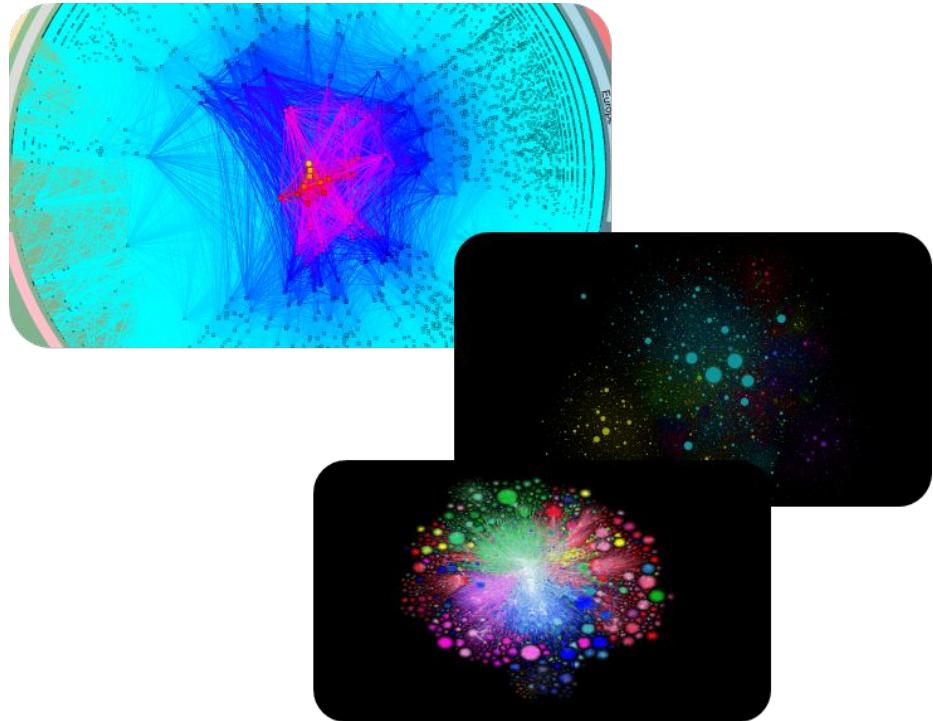


Engineering and
Physical Sciences
Research Council

What does the Internet look like?

Approaches to visualisation

- AS core [1]
- Hosted content [2]
- Connectivity map [3]



But why should we care?

[1] CAIDA, 2020, CAIDA's IPv4 and IPv6 AS Core.

[2] Ruslan Enikeev, Internet Map.

[3] Barrett Lyon, The Opte Project.

Objective: Utopian Internet

Predictable traffic
movement

Settlement-free
peering

Operational
resiliency

Low latency

Carrier
transparency

...a border-free, settlement-free, transparent, uncensored Internet?

Context: Local & Global Internet Governance

Internet Sovereignty

“the right of a state to govern its networks to serve national interests” [\[1\]](#)

NETmundial+10

“[Working] to create the networked global governance architecture that is human-centric, inclusive, environmentally friendly, and development-oriented, as the networked society demands.” [\[2\]](#)

[1] James Lewis, Sovereignty and the Evolution of Internet Ideology.

[1] Preliminary NETmundial+10 Outcome Document, 2024.

Context: Regulatory Intervention

- Content
- Platform
- Network



What is the Impact?

Does the topology differ between countries?

How does the topology differ between countries?

Why does the topology differ between countries?

InternetMapping Private

main 2 Branches 0 Tags Go to file Add file Code About

JerichoFalls: Update primary cli for refactored approach 7a6832a · 2 months ago 39 Commits

InternetMapping Update primary cli for refactored approach 2 months ago

viking RIPE Stat metadata collector 7 months ago

.gitignore Update .gitignore for VSCode last year

README.md Update readme with new prerequisites 2 months ago

poetry.lock Add numpy as dependency 2 months ago

pyproject.toml Add numpy as dependency 2 months ago

README

Our Work

The Internet Mapping Project

The Internet Mapping Project

Part of the [Secure Network Communication Across the Internet](#) Research Project by the [Cyber Security and Privacy](#) and [Real-Time and Distributed Systems](#) Research Groups from the [Department of Computer Science](#) at the University of York

Table of Contents

About The Project

We think that political constraints have prevented improvement in Internet routing protocols. Alternatives to BGP routing exist, but have not been widely adopted, potentially because of political considerations, government policies or limited industrial motivation. We're currently investigating Internet governance, the emergence of state sovereignty within the Internet, and understanding key Internet stakeholders and holders of power.

Acquire and process raw BGP data and combine with metadata from Internet registries and geolocation services. Provides static files for Internet mapping in Gephi, or analysis in Jupyter Notebooks, Observable notebooks, and bit.ly/sncat!

Readme Activity 0 stars 1 watching 0 forks

Languages

Python 69.7%	Jupyter Notebook 20.3%
Shell 14.4%	

A new tool to create metadata-rich Internet topology graphs at higher completeness

systronlab.github.io/projects/internet-mapping

Releasing source code next week.

1.

Our Approach

Observing the Internet

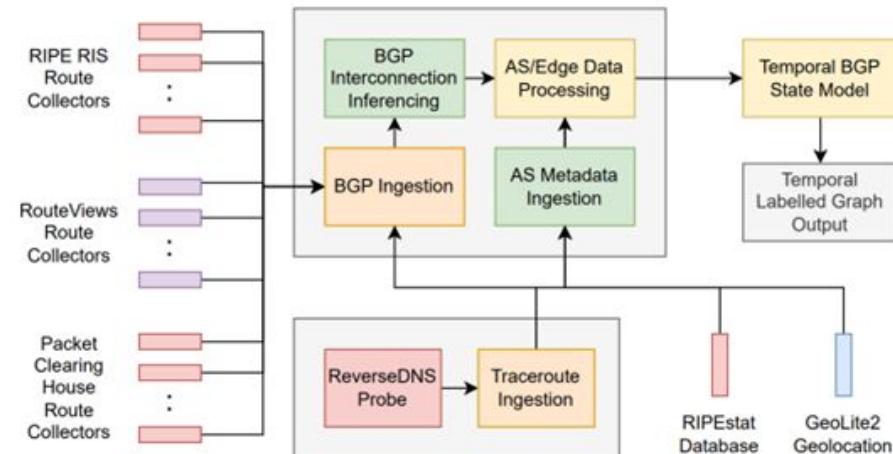


RIPE NCC



System Architecture

- **Route Collectors**
RIPE RIS, RouteViews, PCH
- **Metadata and Probes**
RIPEstat, RIPE Atlas, GeoLite2
- **Data Processing**
- **Graph output**



Capturing Location

- **Internet Registry**
RIPEstat, pulling data from ARIN, LACNIC, RIPE NCC, AFRINIC, APNIC
- **Prefix Geolocation**
MaxMind GeoLite2 City

MaxMind also uses
some WHOIS data

Adding Metadata

- **Registered Owner**

Processed into a usable format and sibling ASes (same owner) detected
(using orgName, orgId, opaqueId, PeeringDB)

- **Registered Location (country)**

- **State Ownership Data**

Using state_owned_as dataset to identify majority state-owned ASes

Output

- **Node**
AS with metadata (owner, registered location, geolocation, etc)
- **Edge**
Adjacency between ASes



2. **The Internet in 2024**

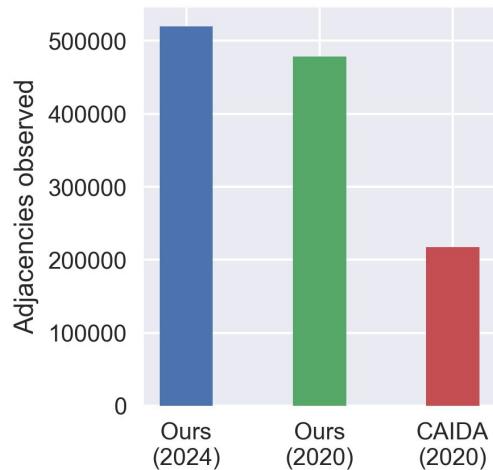
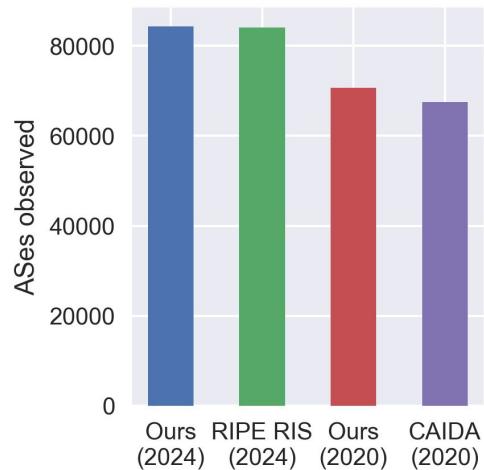
Our Snapshot: 1 May 2024

Our Topology

- 84,266 ASes
(72% of NRO assignments)

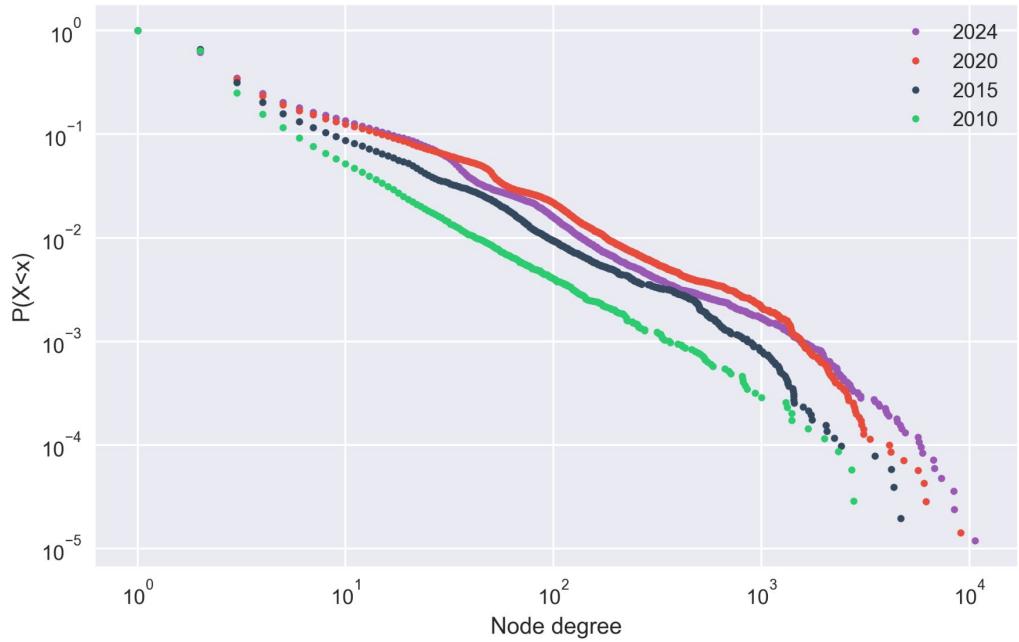
Comparisons

- 116,977 NRO assignments
- 84,042 ASes seen in RIS



Maximum Degree

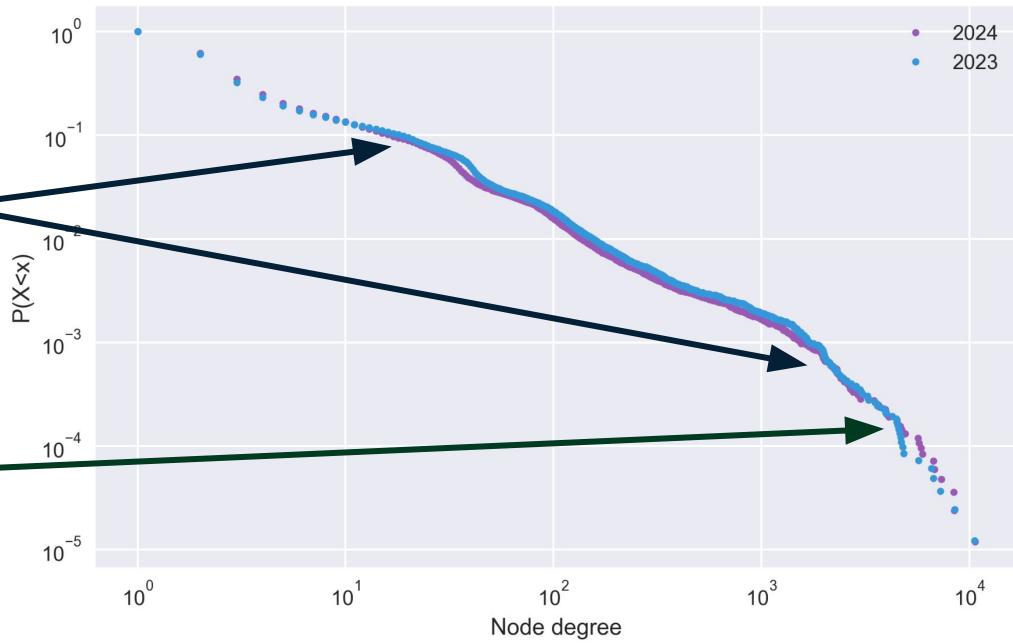
CCDF plot of the maximum degree of an AS combined with its probability (log-log scale)



Maximum Degree

Decrease in Medium-Degree
Between 2023 and 2024, the volume of nodes in the mid-degree range reduces.

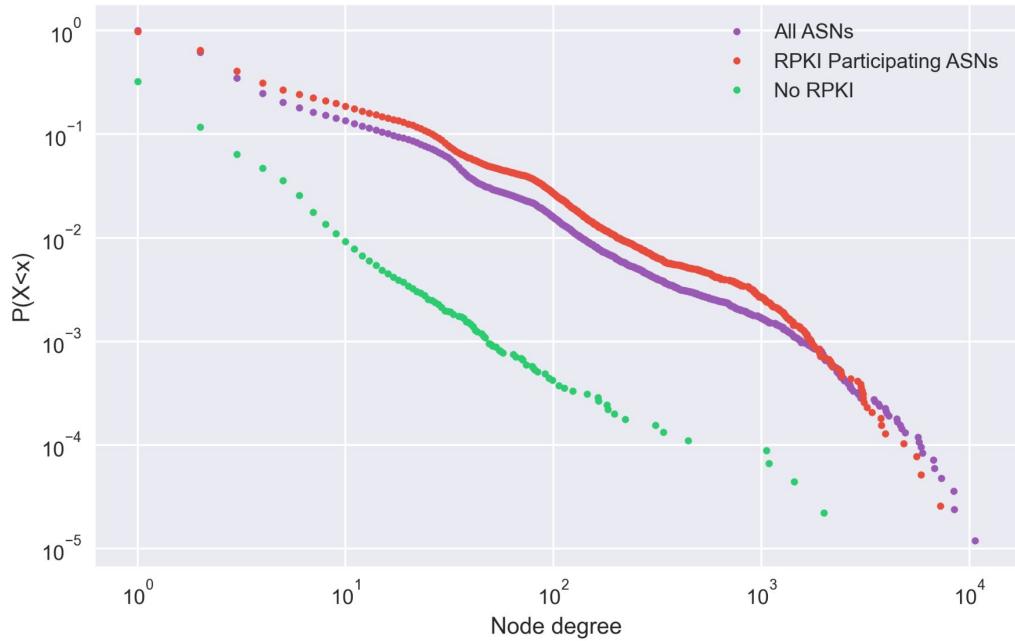
Increase in High-Degree
The number of the highest degree nodes grows.



Maximum Degree & RPKI

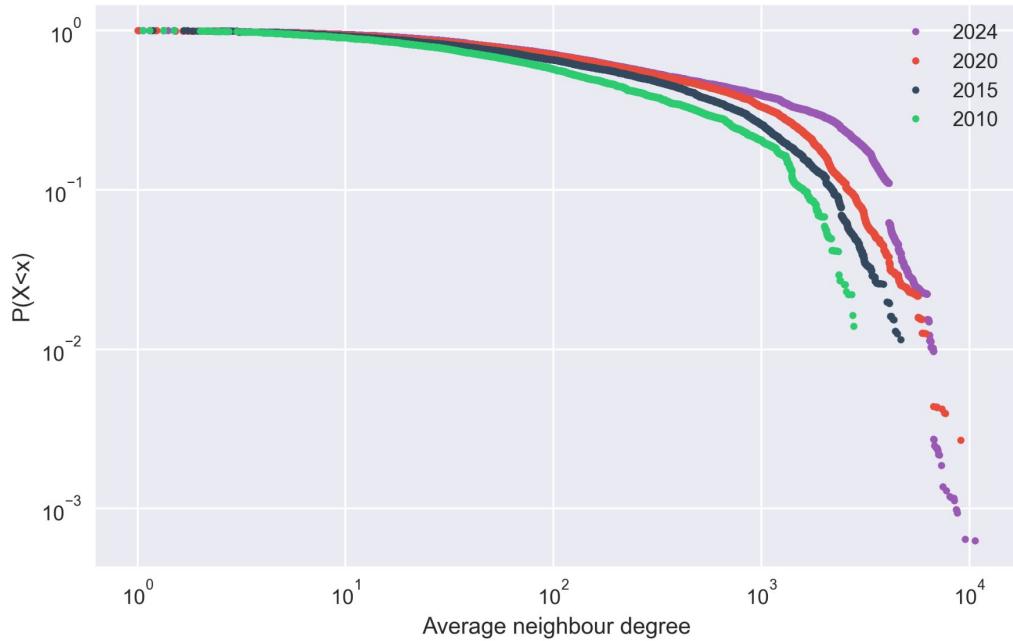
CCDF plot of ASes:

- with an RPKI deployment (at least one ROA object)
- without an RPKI deployment



Average Neighbour Degree

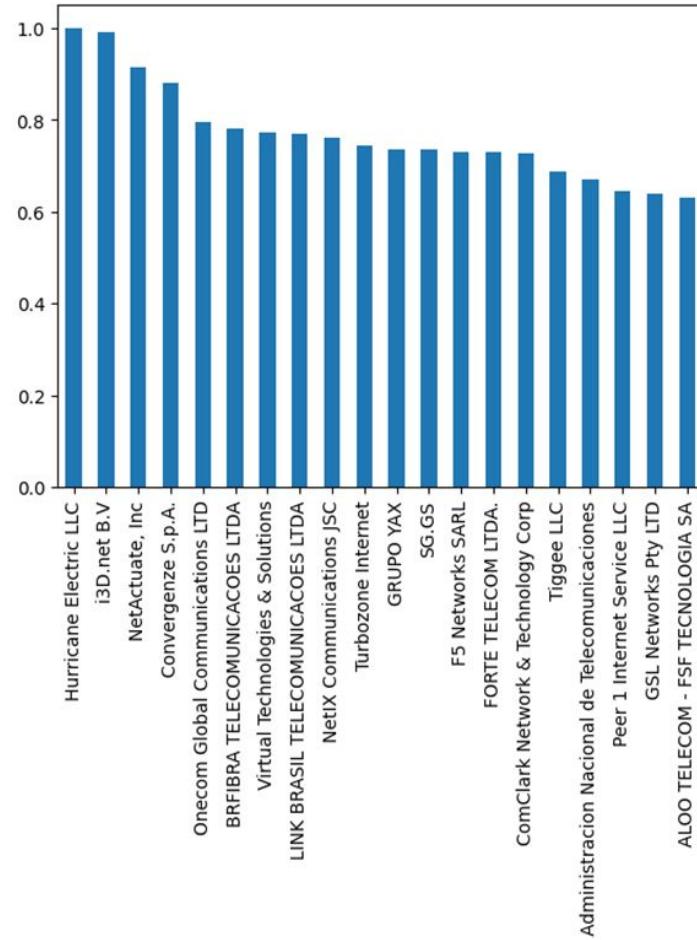
CCDF plot of the average degree in a node's neighbourhood (e.g. the average degree of all nodes directly connected to a node)



Most Influential*

Ranking the most eigencentral ASes within the topology.

- How well-connected is a node, also considering its field of neighbours?



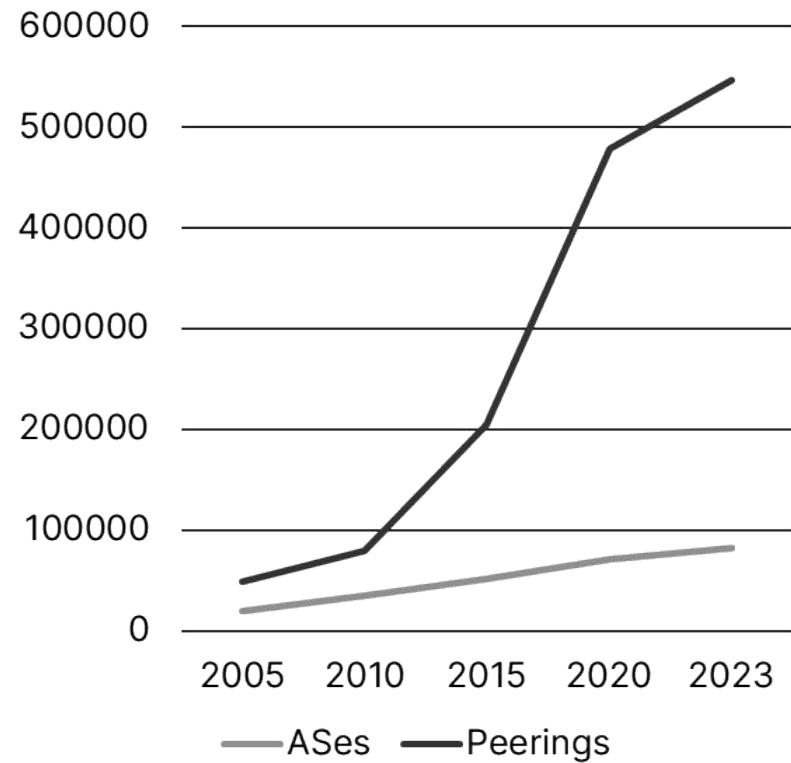
*Some vantage-point based bias exists, so results are only indicative rather than conclusive.

ASes and Peerings

The number of ASes
(registered or observed) has
increased by 411%

The number of (public)
interconnections has
increased 1,119%

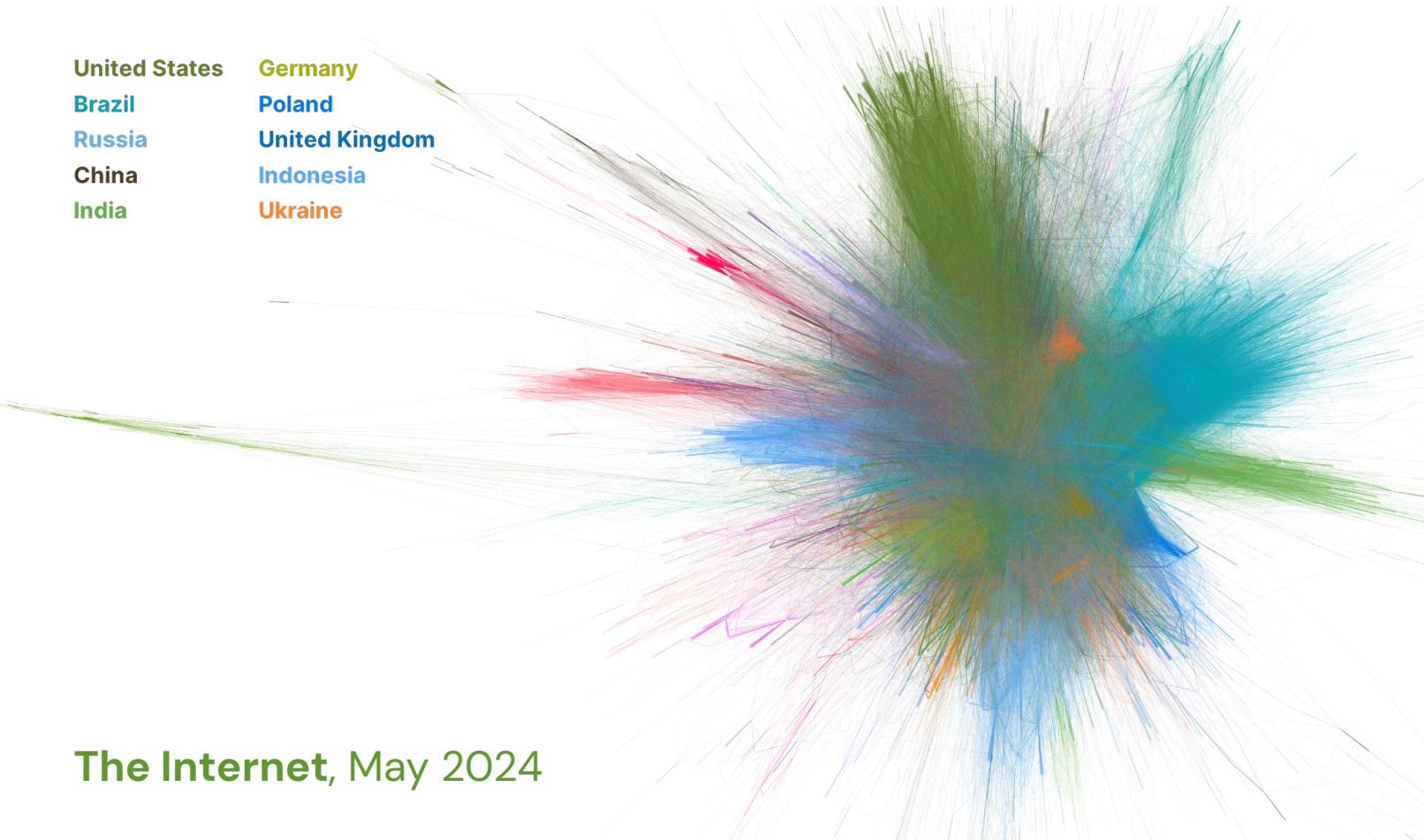
Average path length has
increased from 3.7 to 12.



3.

The Does

United States Germany
Brazil Poland
Russia United Kingdom
China Indonesia
India Ukraine



The Internet, May 2024

4.

The How

Foreign Neighbours



Unique Upstream Neighbours

Where X is a country of interest, N the Internet's ASes, and K the ASes within X :

$$K = \{k \in N \mid \text{country}(k) = X\}$$

Where I is the neighbours:

$$I = \{i \in N \mid \exists k \in K : i \in \text{neighbours}(k)\}$$

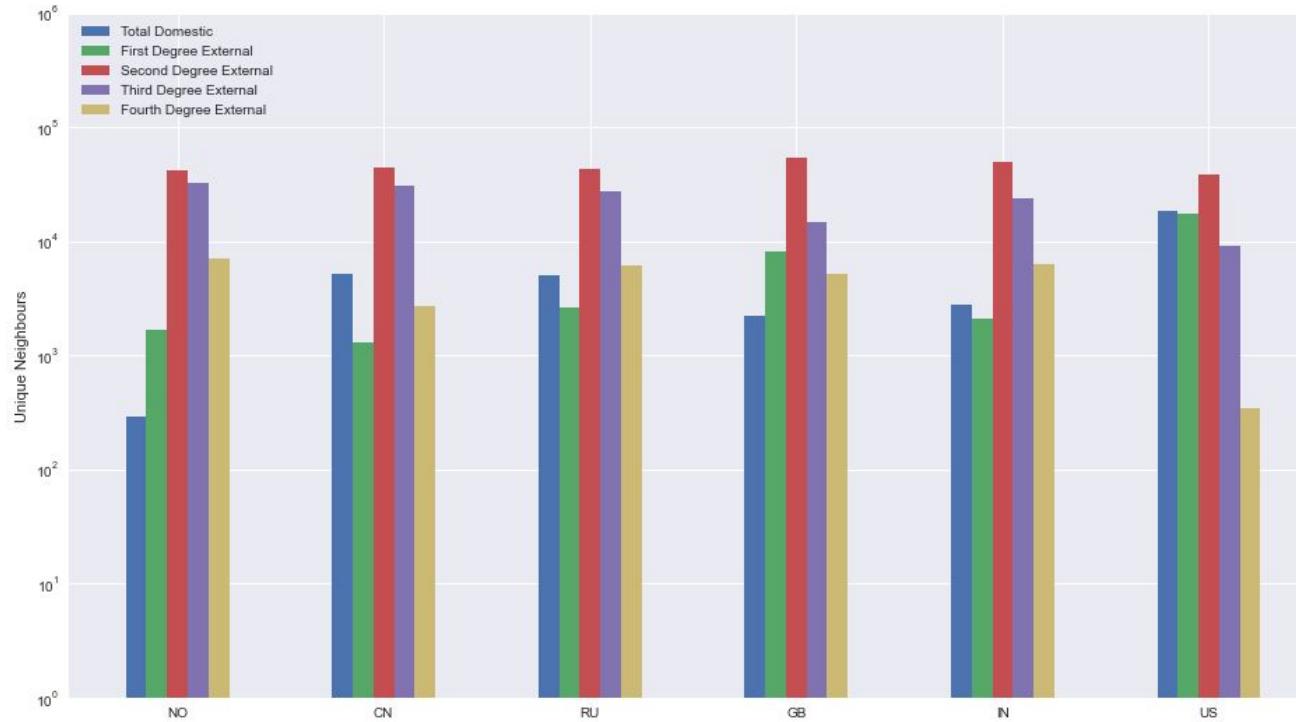
Where I_0 is the set of first-degree neighbours of country X , the sets $I_1 \rightarrow I_d$ where $d \in \mathbb{N}$:

$$I_1 = \{f \in N \mid \exists i \in I_0 : f \in \text{neighbours}(i)\} \setminus I_0$$

Or more generally:

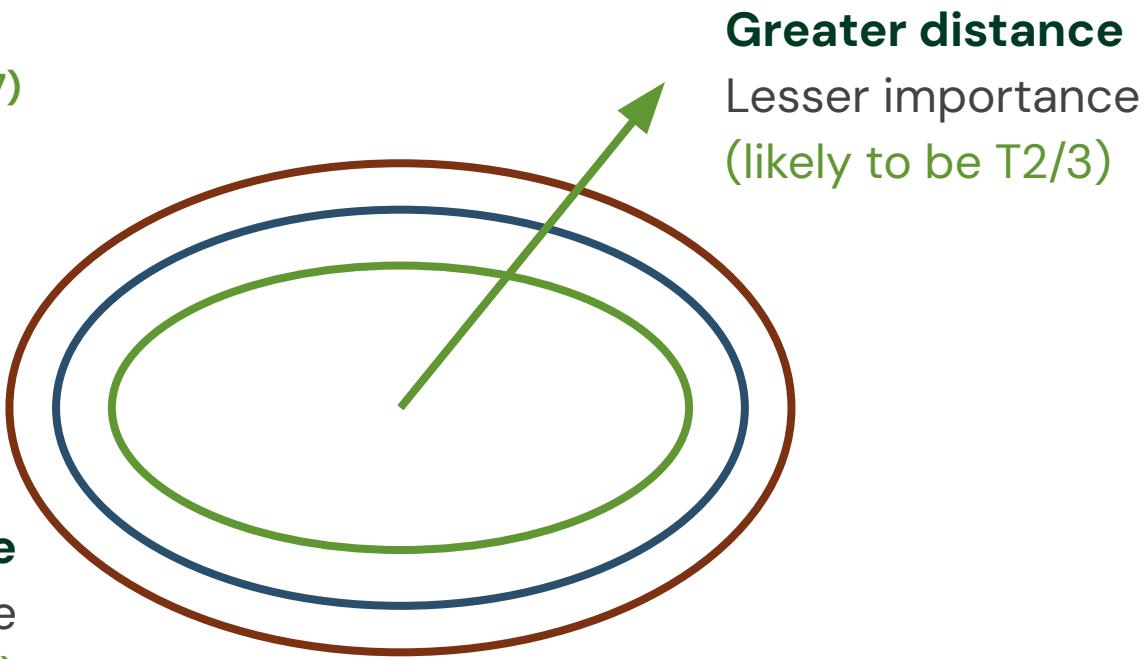
$$I_d = \{f \in N \mid \exists i \in I_{d-1} : f \in \text{neighbours}(i)\} \setminus (I_{d-1} \cup \dots \cup I_{d-q}) : q \in \mathbb{N} \wedge d > 0 \wedge d - q \geq 0$$

Unique Upstream Neighbours



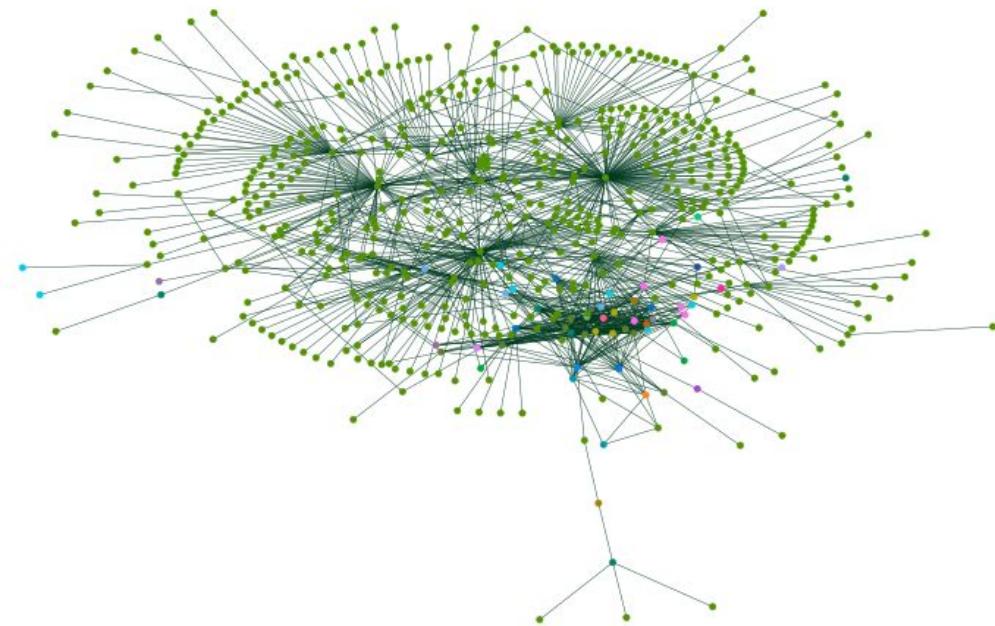
Visualising Connectivity

Using Kamada & Kawai (1987)



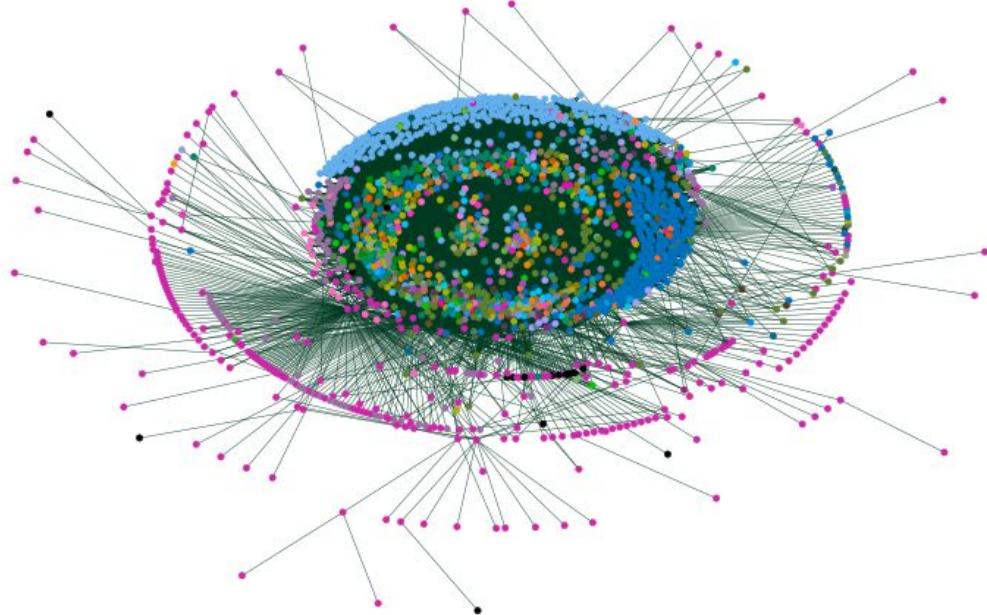
Iran

- 527 domestic ASes
- 57 foreign neighbours



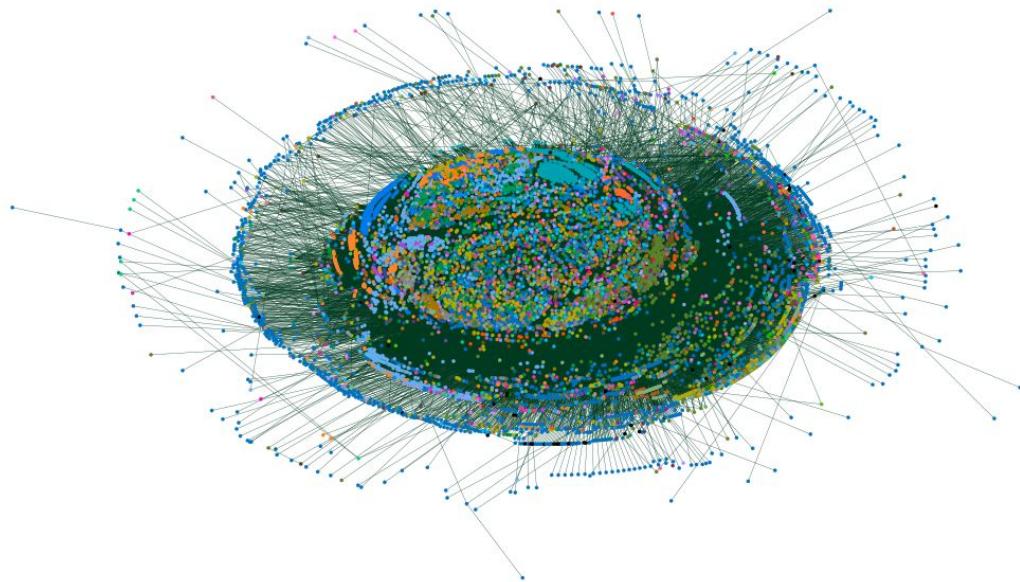
Norway

- 282 domestic ASes
- 489 foreign neighbours



United Kingdom

- 2,115 domestic ASes
- 3,572 foreign
neighbours



5. **Censorship: a Why?**

Detecting Censorship

Explicit

Users are aware of censorship taking place.

Blockpages

Incorrect DNS resolution



Non-Explicit

Users are possibly not aware of censorship taking place.

HTTP failures

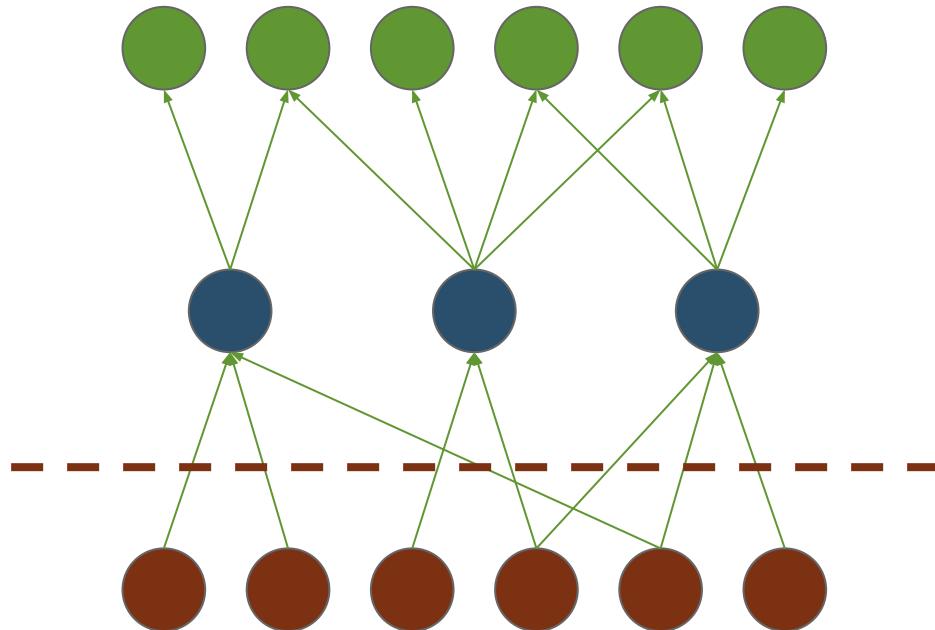
DNS, TCP, HTTP anomalies

Mitigation

Also considering the ratio of 'normal' traffic.

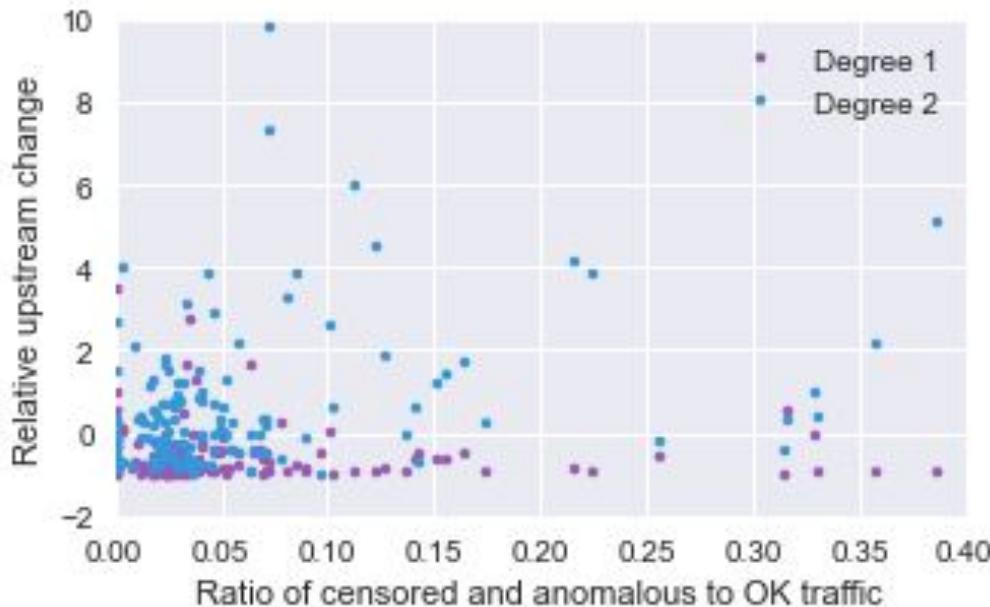
Relative Upstream Change

Capturing the change in the number of ASes at each step from the 'border'.



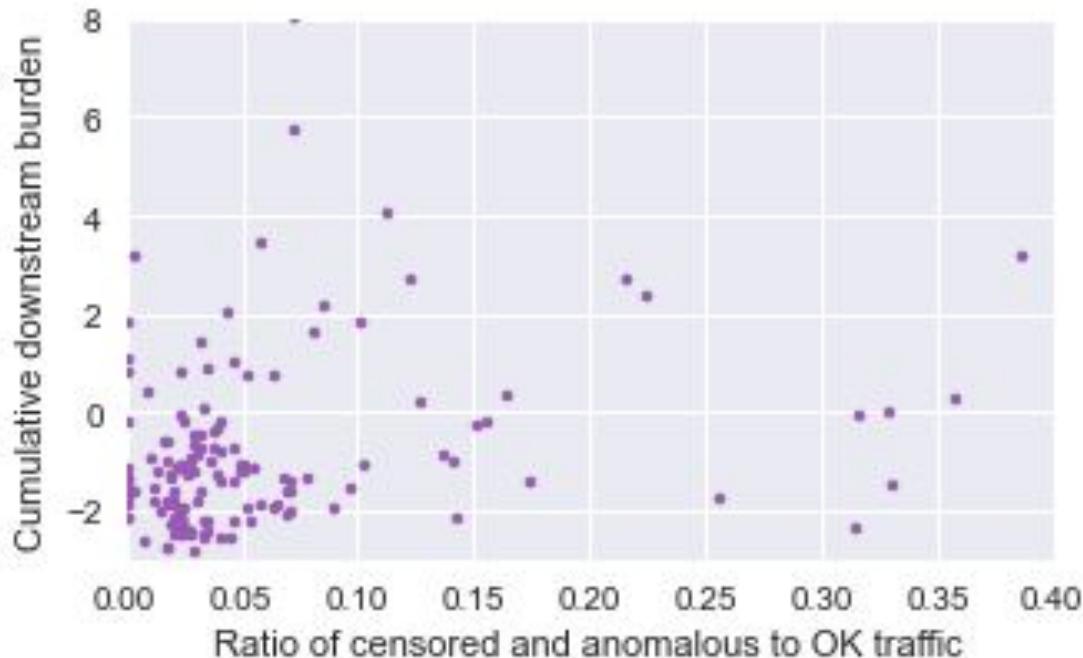
Relative Upstream Change

A relationship starts to become apparent as the degree increases...



Cumulative Downstream Burden

Starting to see some connection (~0.5 correlation coefficient) between the downstream burden and censored traffic.

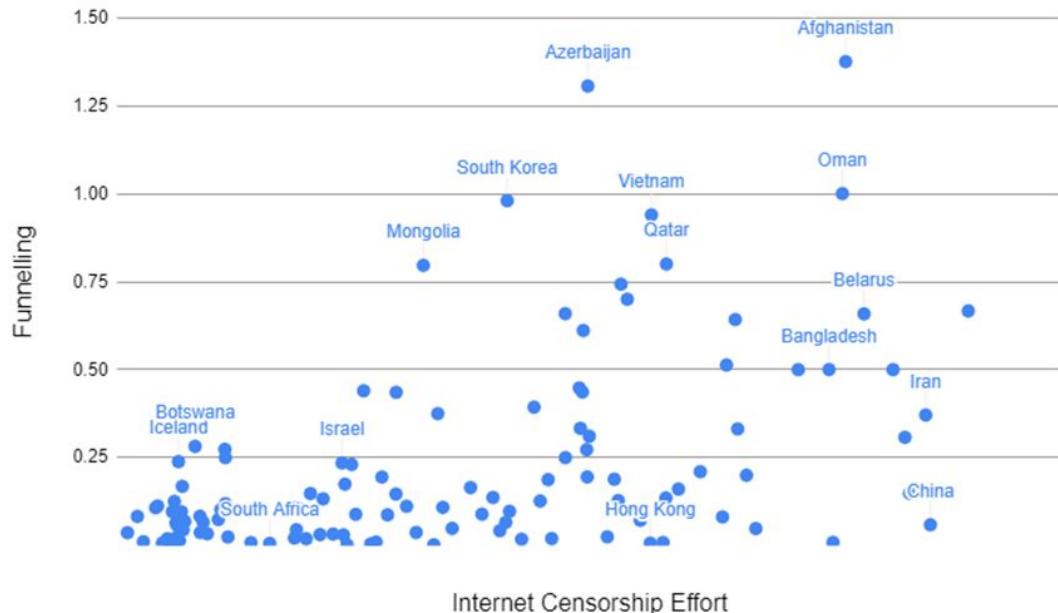


Funnelling

Based on the cumulative downstream burden, but weighted for network size.

Generally, higher censorship gives higher funnelling.

...with some exceptions (but remaining geopolitical)



Summary

Internet topology fusion tool

The volume of highest-degree
ASes is growing...

...and the volume of lowest-degree
is also growing

Geopolitics has a statistically
significant impact on topology
structure

Questions & Contact



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