

RIPE 88, Kraków  
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# Architecture and Routing in a Geopolitical World

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**SYSTRON**Lab

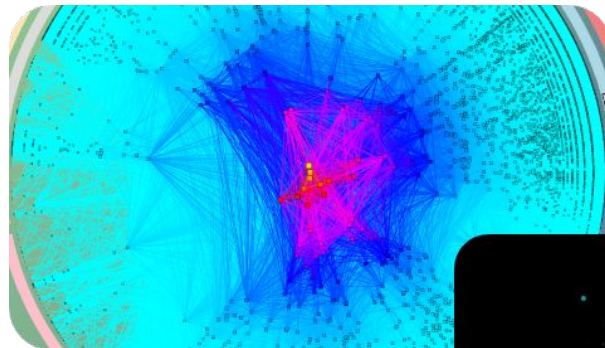


Engineering and  
Physical Sciences  
Research Council

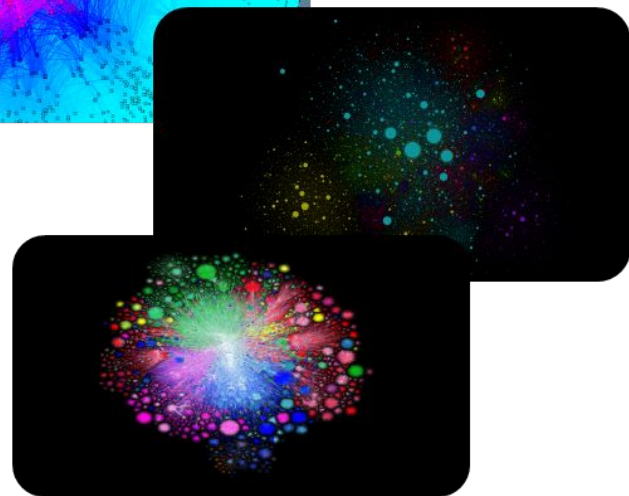
# What does the Internet look like?

## 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

Low latency

Operational  
resiliency

Settlement-free  
peering

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]

## NETmundail+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 NETmundail+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

Unwatch 1 Fork 0

main 2 Branches 0 Tags

Go to file Add file Codes 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	RIFE 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

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### 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 use in Gephi, or analysis in Jupyter or Observable notebooks.

[bit.ly/sncati](#)

- Readme
- Activity
- 0 stars
- 1 watching
- 0 forks

Languages

- Python 69.7%
- Jupyter Notebook 14.4%
- Shell 14.4%

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

[systronlab.github.io/projects/internet-mapping](https://systronlab.github.io/projects/internet-mapping)

Releasing source code next week.

# 1. Our Approach



# Observing the Internet



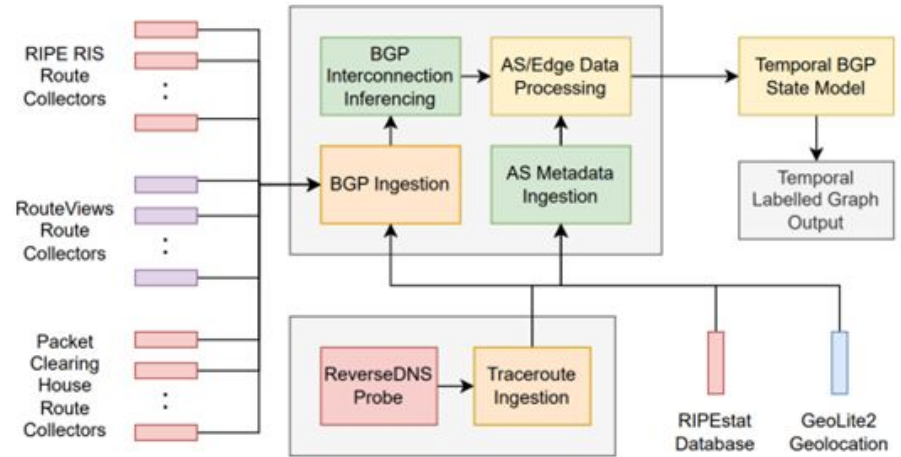
**RIPE NCC**



**PCH**  
Packet Clearing House

# 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**

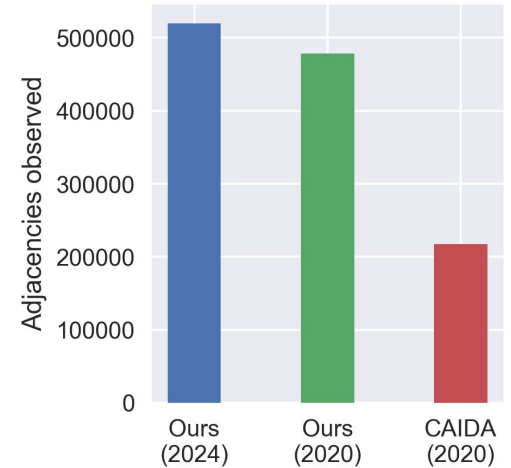
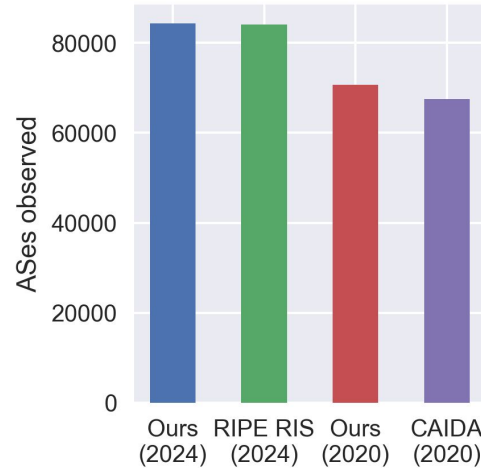
# Our Snapshot: 1 May 2024

## Our Topology

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

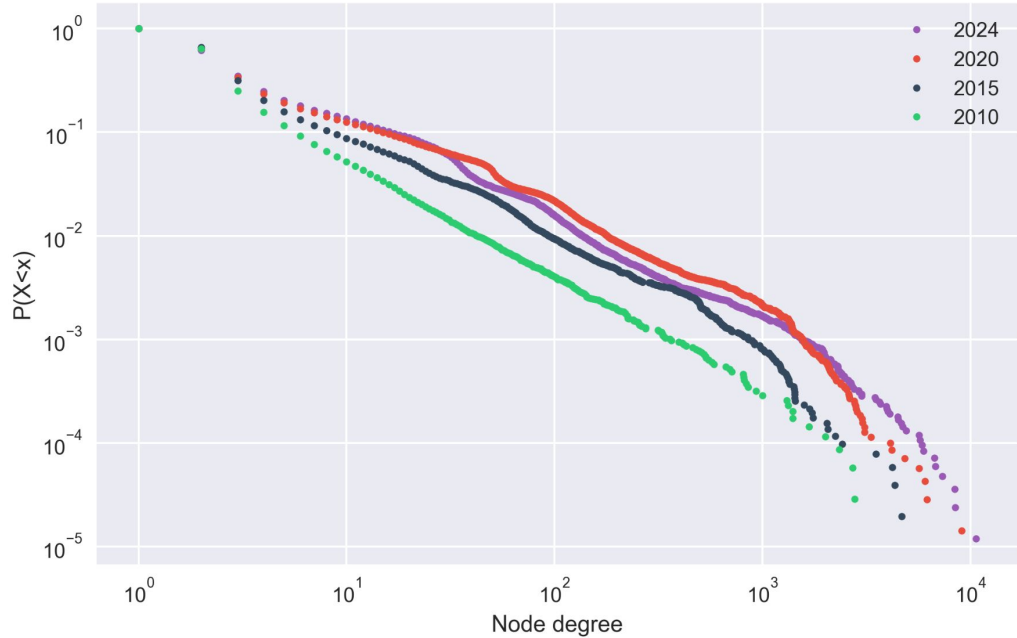
## Comparisons

- 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)

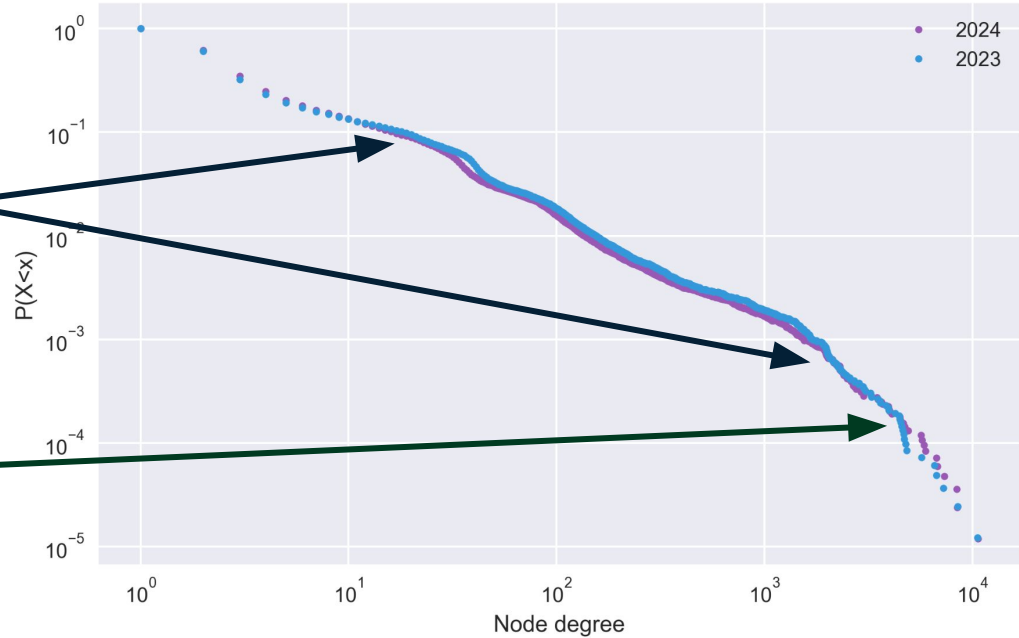




# Maximum Degree

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

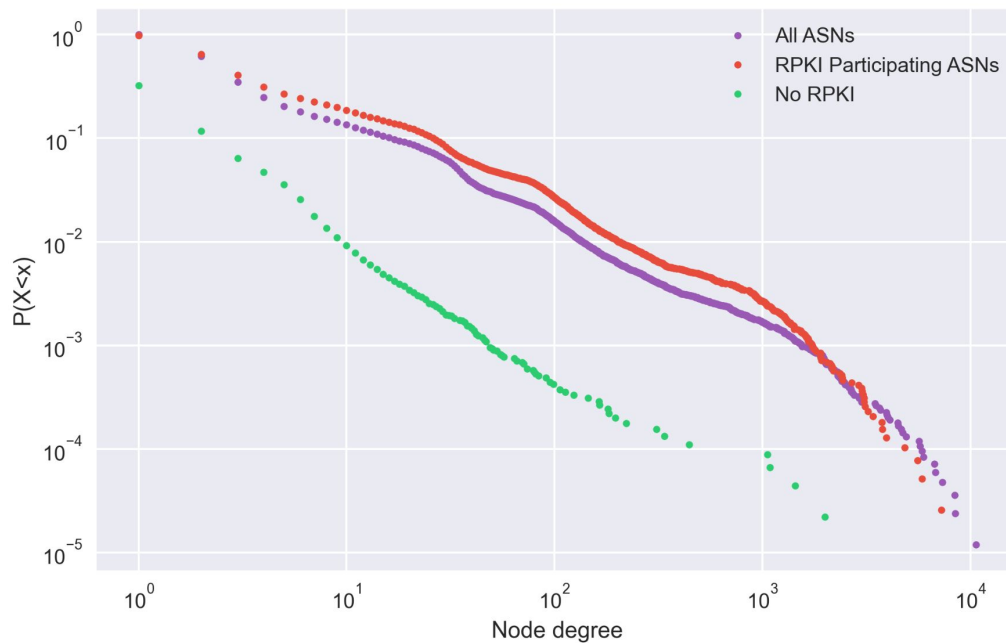
**Increase in High-Degree**  
The number of the highest degree nodes grows.



# Maximum Degree & RPKI

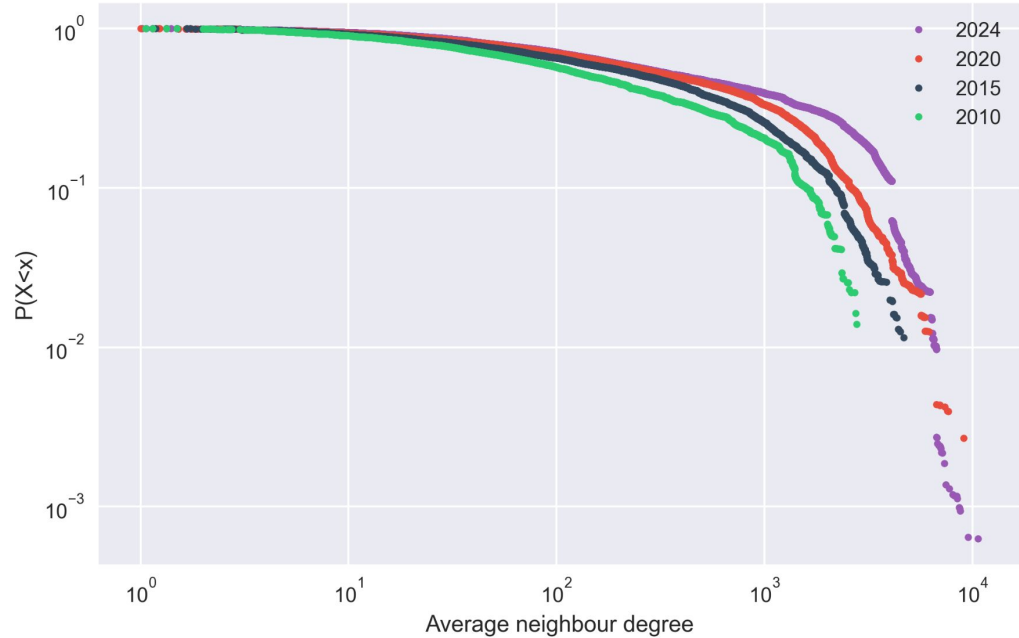
CCDF plot of ASes:

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



# Average Neighbour Degree

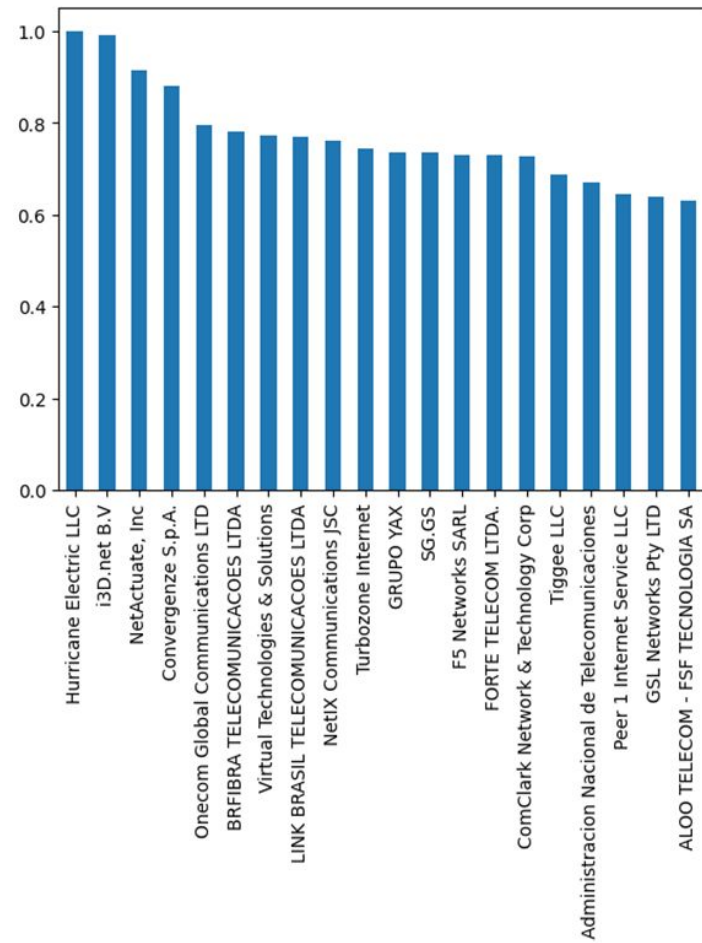
CCDF plot of the average degree in a node's neighbourhood (e.g. the average degree of all nodes directly connected to a node)



# Most Influential\*

Ranking the most eigencentral ASes within the topology.

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

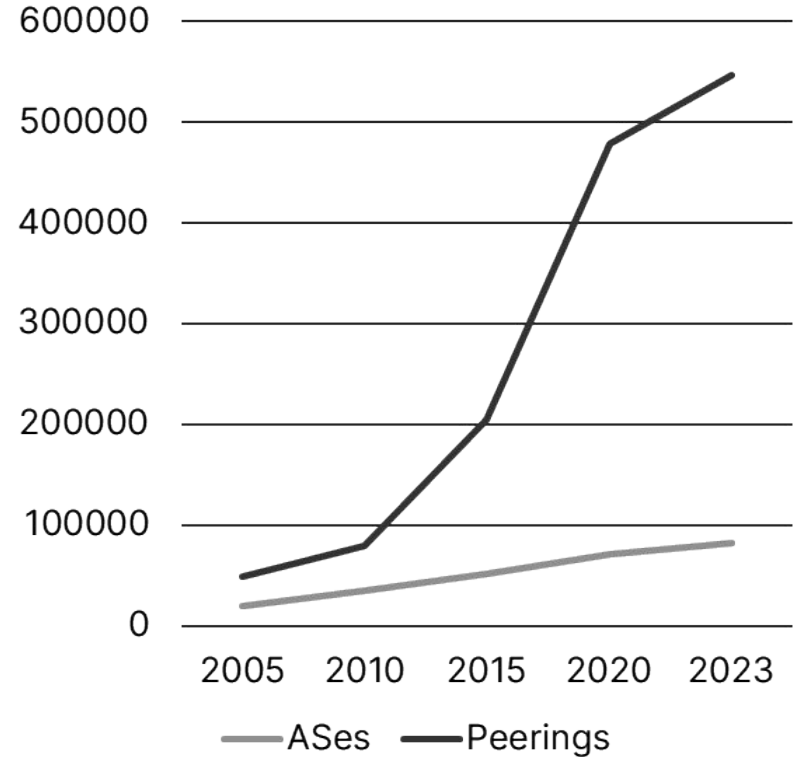


# ASes and Peerings

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

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

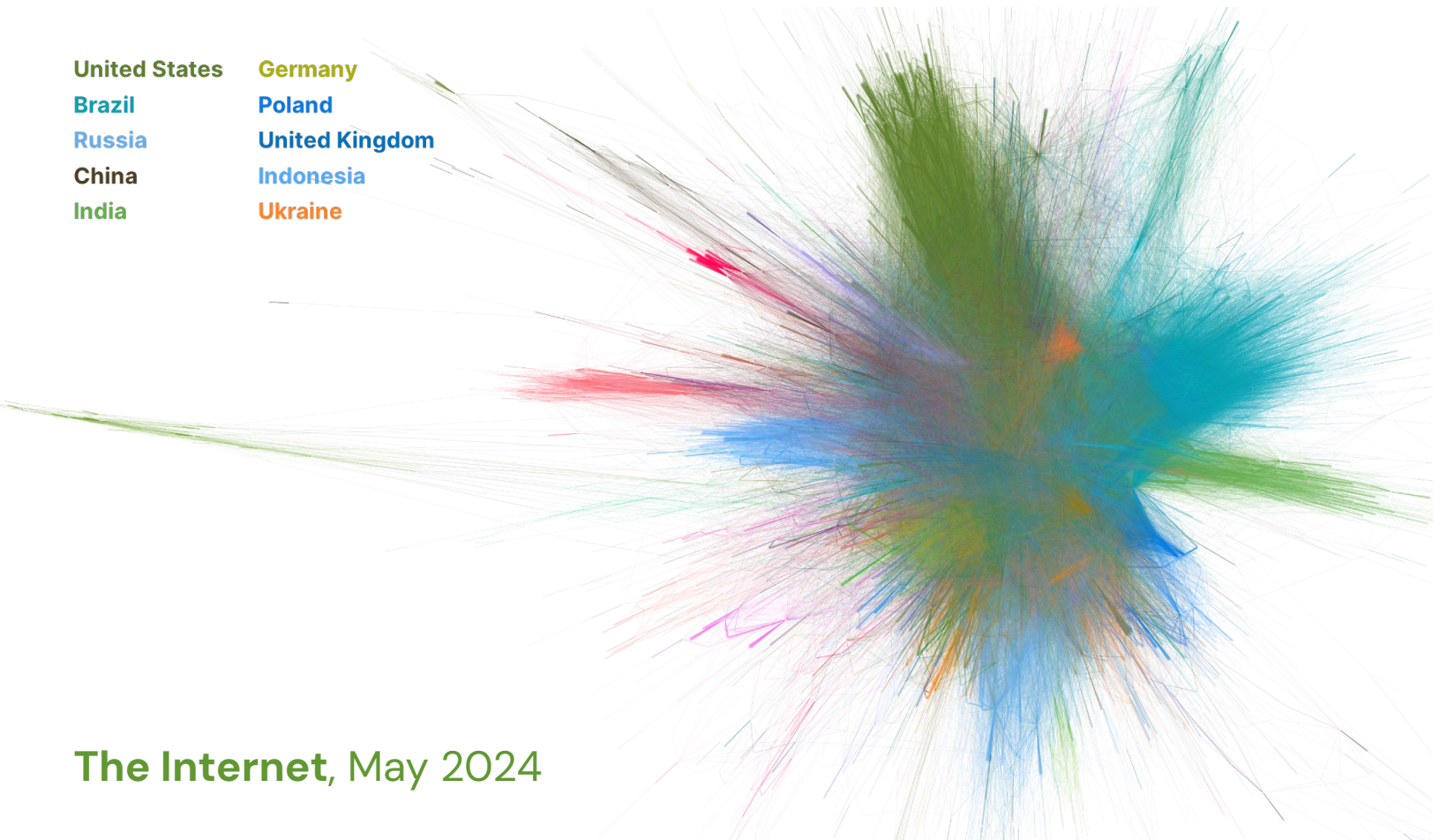
Average path length has **increased from 3.7 to 12.**



# 3. The Does

United States  
Brazil  
Russia  
China  
India

Germany  
Poland  
United Kingdom  
Indonesia  
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:

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

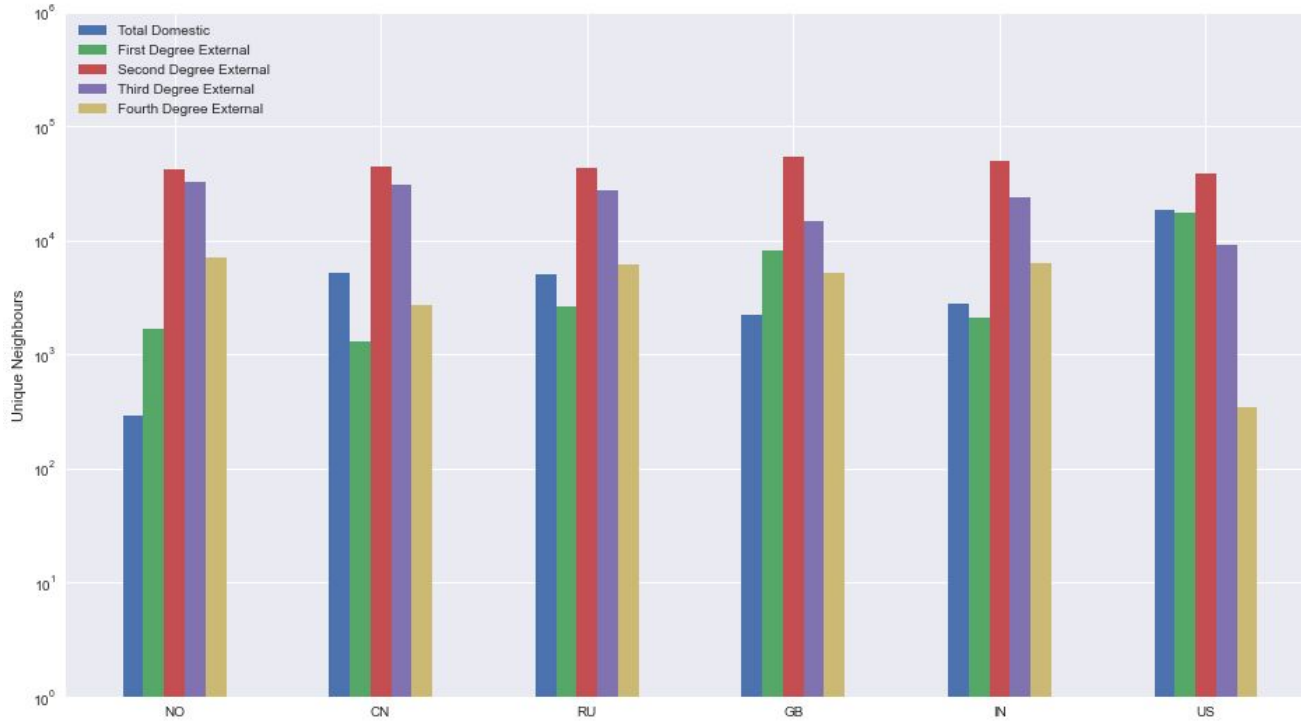
Where  $I_0$  is the set of first-degree neighbours of country  $X$ , the sets  $I_1 \rightarrow I_d$  where  $d \in \mathbb{N}$ :

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

Or more generally:

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

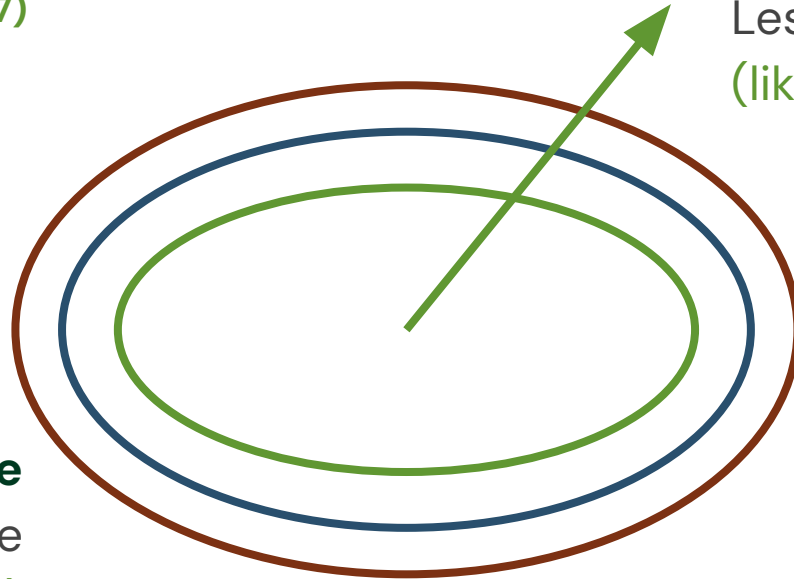
# Unique Upstream Neighbours



# Visualising Connectivity

Using **Kamada & Kawai (1987)**

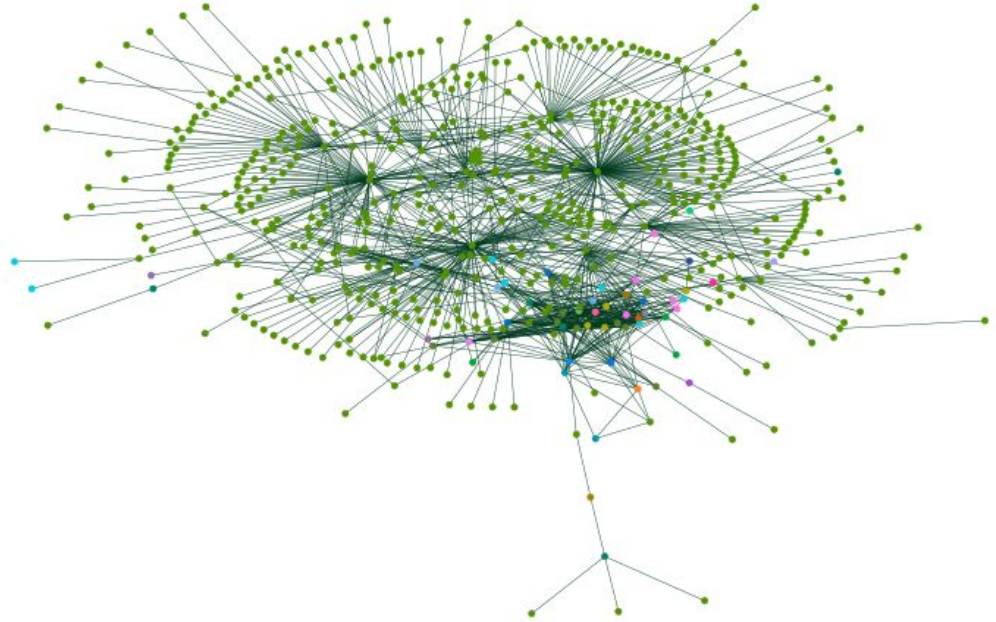
**Greater distance**  
Lesser importance  
(likely to be T2/3)



**Closer to the centre**  
Greater importance  
(more likely to be T1/2)

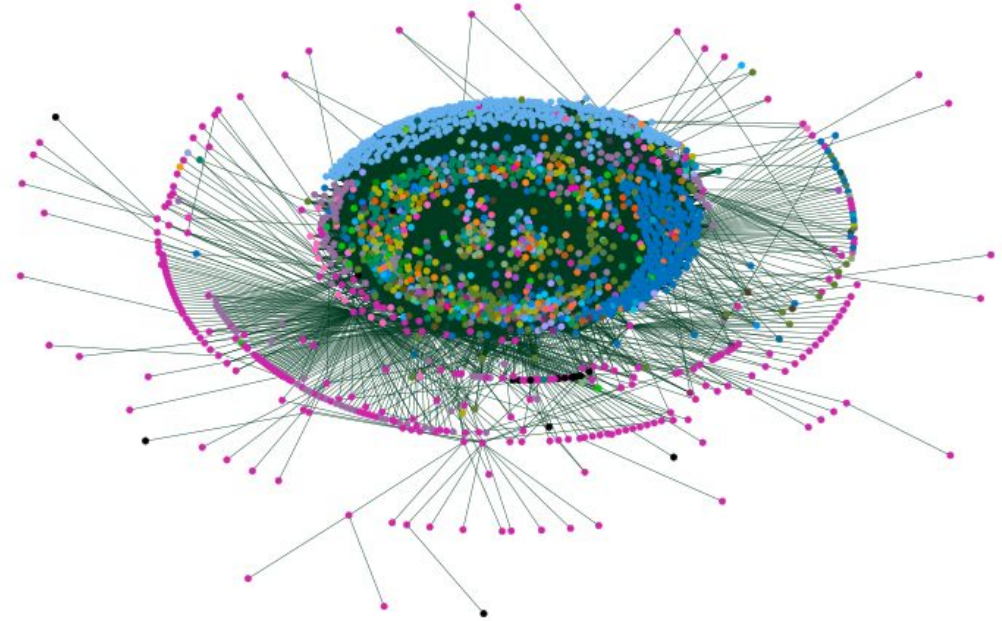
# Iran

- 527 domestic ASes
- 57 foreign neighbours



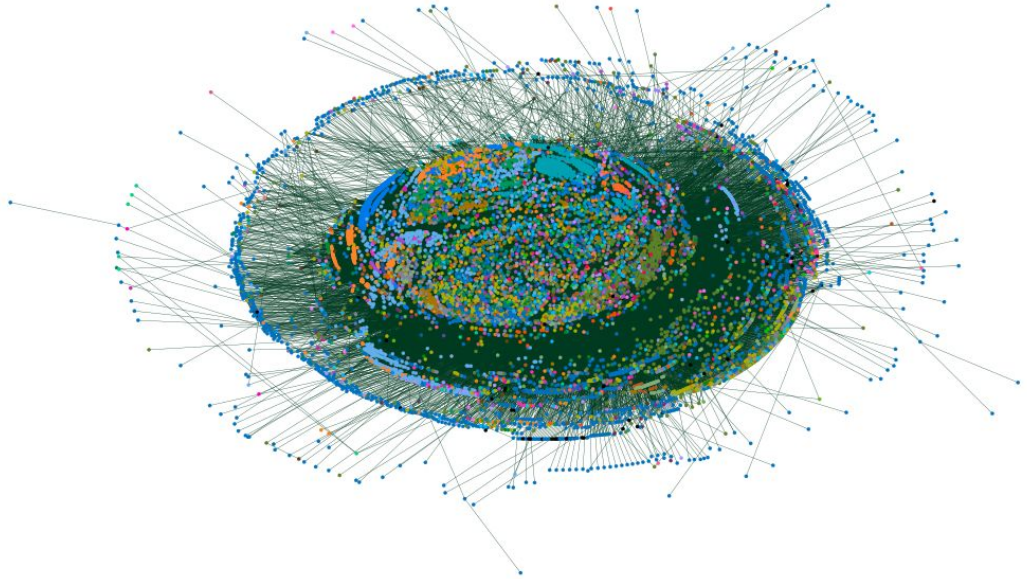
# Norway

- 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

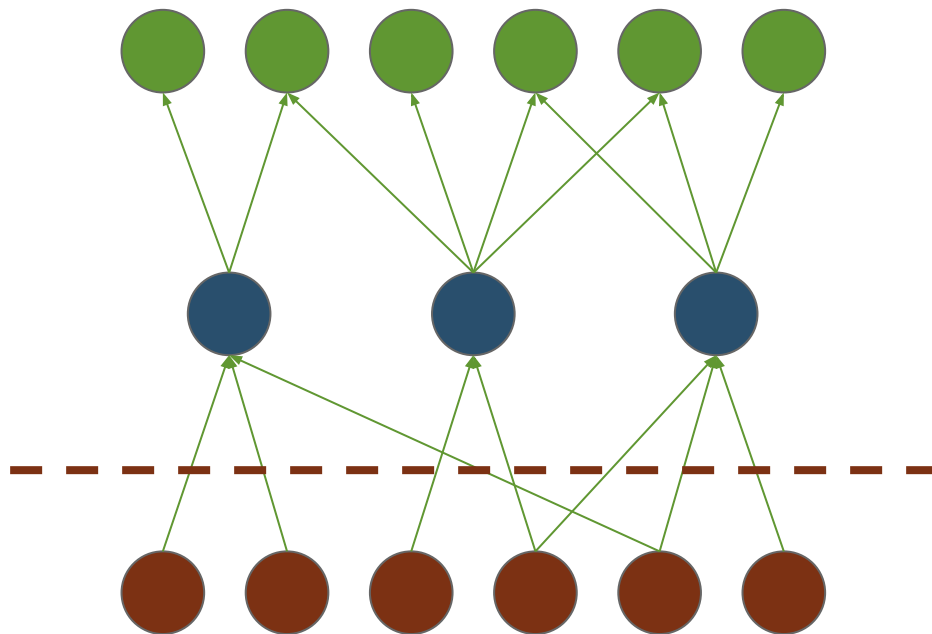
DNS, TCP, HTTP anomalies

## Mitigation

Also considering the ratio of 'normal' traffic.

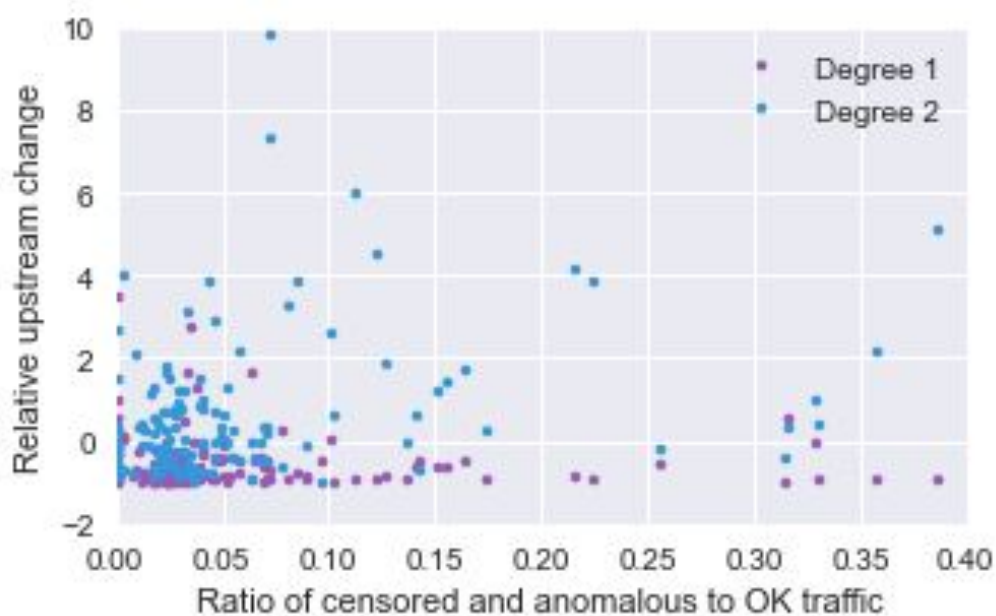
## Relative Upstream Change

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



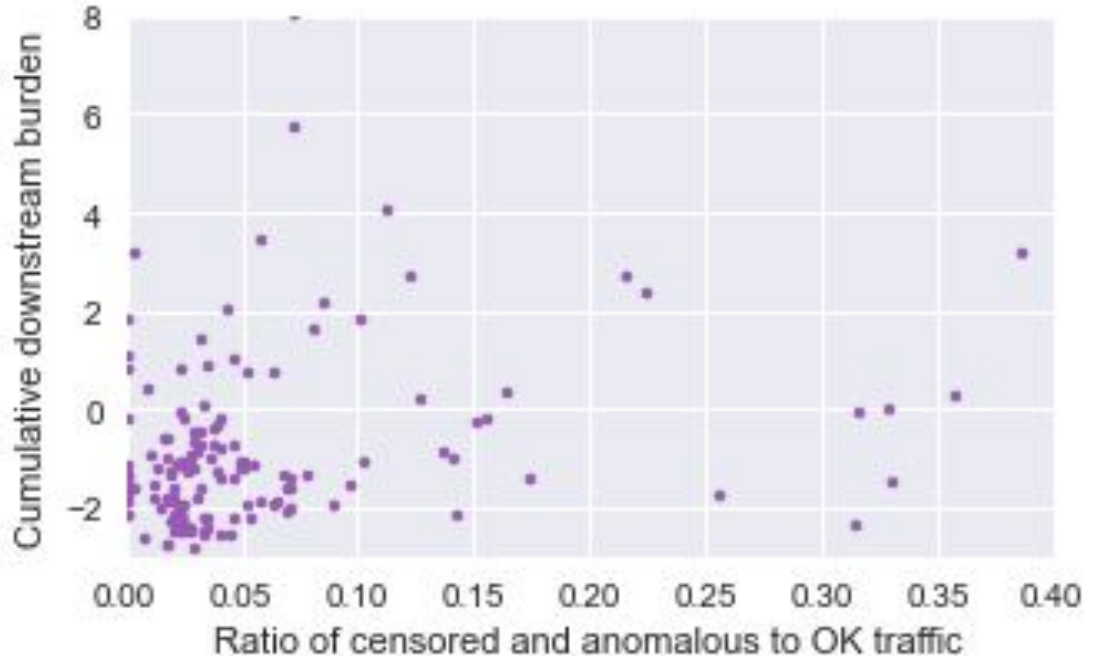
# Relative Upstream Change

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.

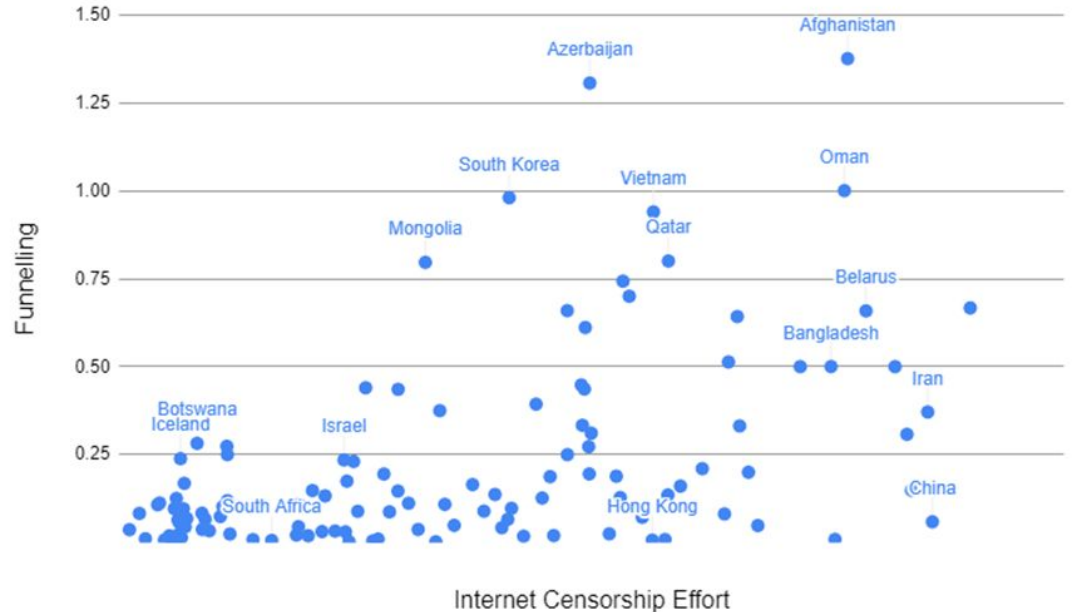


# Funnelling

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

**SYSTRON Lab**

[systronlab.github.io](https://systronlab.github.io)

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