



The Quest for a Resilient Internet Access in a Constrained Geopolitical Environment

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Internet resilience in question : the case of Pakistan



- In 2022 two kinds of external shock have affected Pakistan's Internet access :
- Six major submarine cables disturbances have impacted business operations & public services in Pakistan.
- During the summer, large scale floods have led to network failures at several critical places.



Resilient Network Access



What drives resilience ? For a country like Pakistan where :

- (1) Physical connectivity concentrates at a singleton feed point (stub network)
- (2) Content of interest generally lies outside national boundaries

We consider a restrictive definition of resilience :

Uninterrupted access to the content of broad interest in a region.

Research questions

- **R1:** Why does Pakistan's Internet offer limited resilience to physical network failures both at the internal and external connectivity end ?
- **R2:** How does the geography of Pakistan's Internet topology impact its overall network resilience?
- **R3 :** What types of constraints Pakistanis ISPs face when building their networks?
- **R4:** How does the interaction of risks bring significant challenges to the quest for Internet resilience?

An exploration of Pakistan's connectivity and its exposure to risks



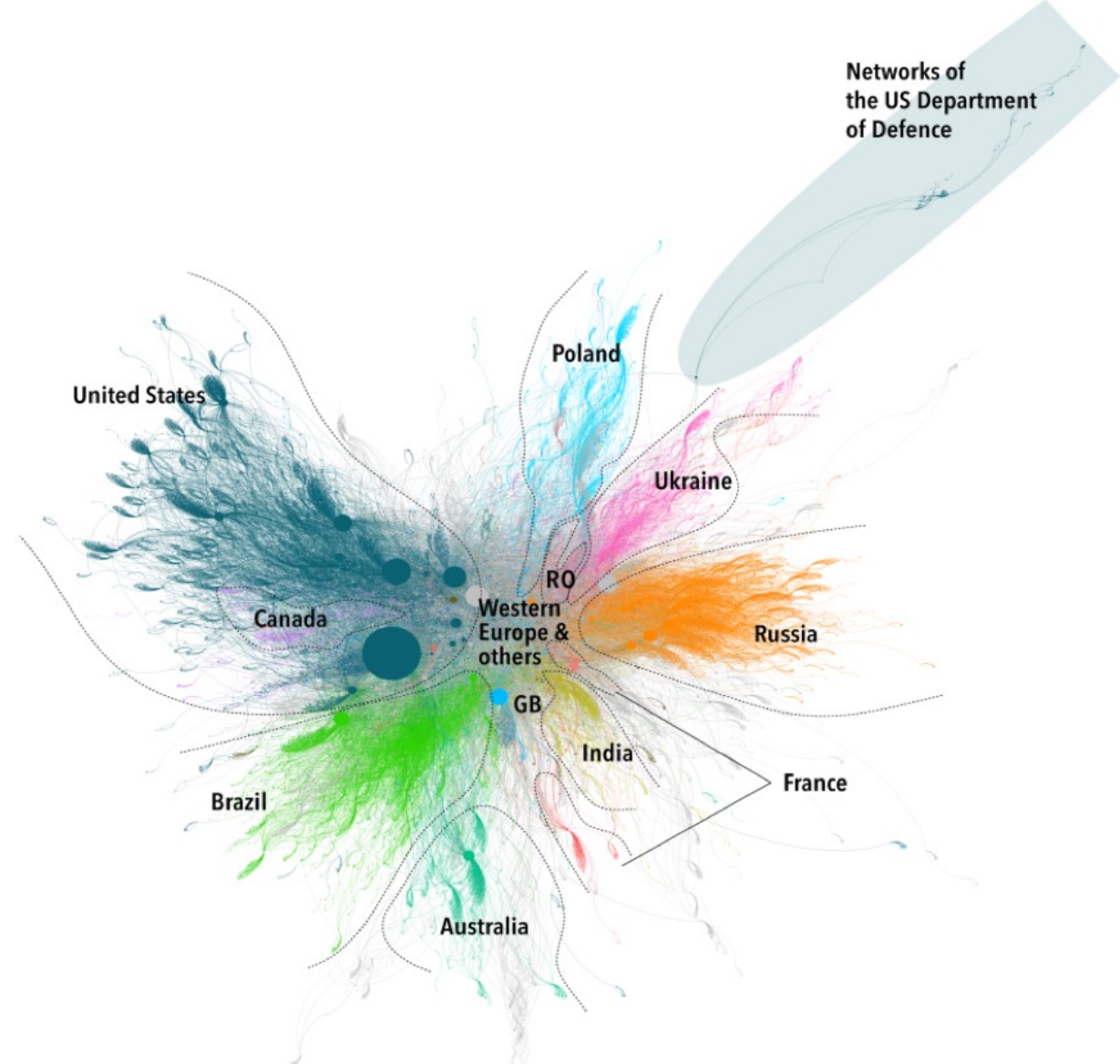
- 1) Internal connectivity : An over-concentrated network structure
- 2) External connectivity : Scarcity of regional links and dependency over foreign-hosted contents
- 3) Understanding risks interactions and its effect on Internet access : the case of summer 2022 floods

Methodology : Spatial Analysis

- To assess the resilience of Pakistan's network we mapped **both the layers of connectivity : physical and logical.**
- A cartography of :
- the mesh of cables connecting Pakistan to the Internet
- the routing policies using BGP data

Logical layer mapping

- GEODE's BGP platform : capturing BGP updates crossing different ASes.
- Generating a full graph of AS relationship every minute by processing up to 30 BGP flow from publicly available BGP routing data, RouteViews, RIPE RIS etc.
- +89 000 nodes and 200 000 links are included, a snapshot of all visible Internet routes.
- Each node is an AS and each link is a BGP agreement.
- We used the Force Atlas 2 visualization algorithm + a betweenness centrality metric.



A snapshot of the global Internet in May 2018.

Pétiniaud, L. (2018) "Geopolitics of Routing", RIPE Labs, 17/07/2019,

https://labs.ripe.net/author/louis_petiniaud/geopolitics-of-routing/.

I- Internal connectivity

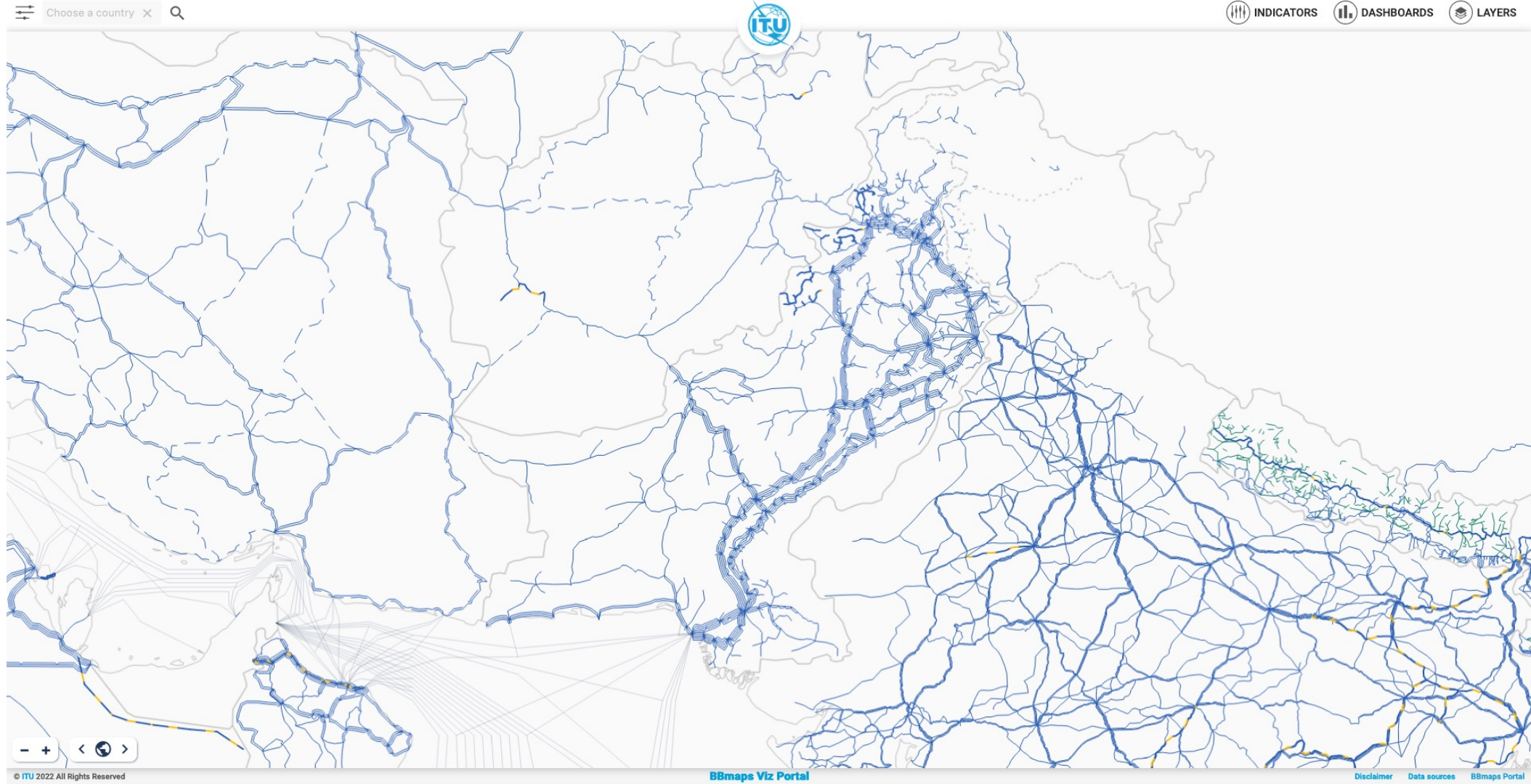
An over-concentrated
network structure

A physical network layer concentrated along the Indus axis

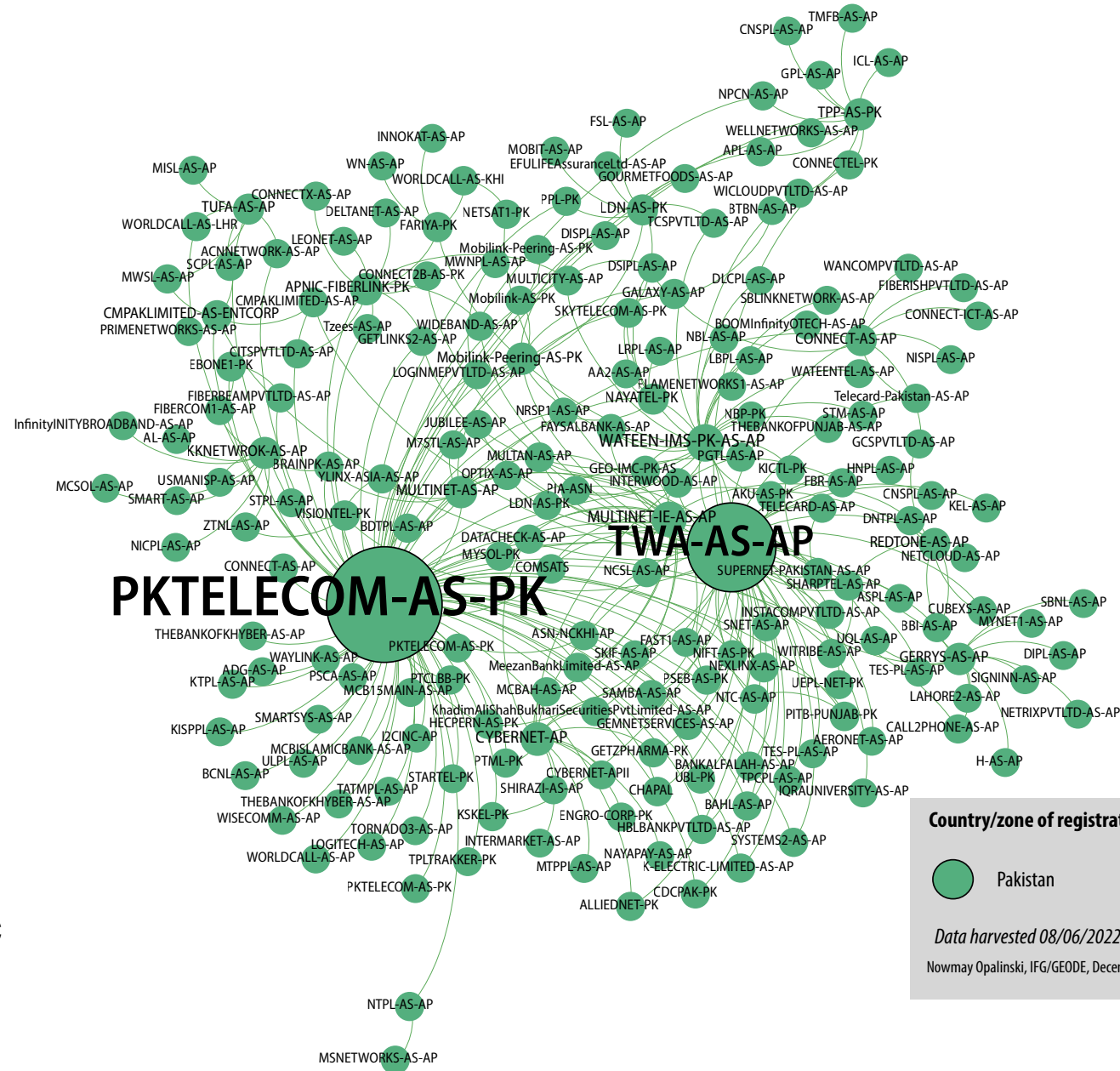
The most exhaustive map of Pakistan's fixed-line connectivity compiling data from 8 sources : :Ministry of IT, USF, PTCL, Wateen, Multinet, NTC, SCO, LINKdotNET.



ITU's Broadband map : <https://bbmaps.itu.int/bbmaps>



At the BGP level : a concentrated network topology



Pakistan-registered ASes' domestic peering Agreements

PTCL (AS 17557) and Transworld Associates (AS 89193) concentrate domestic data routes.

Country/zone of registration

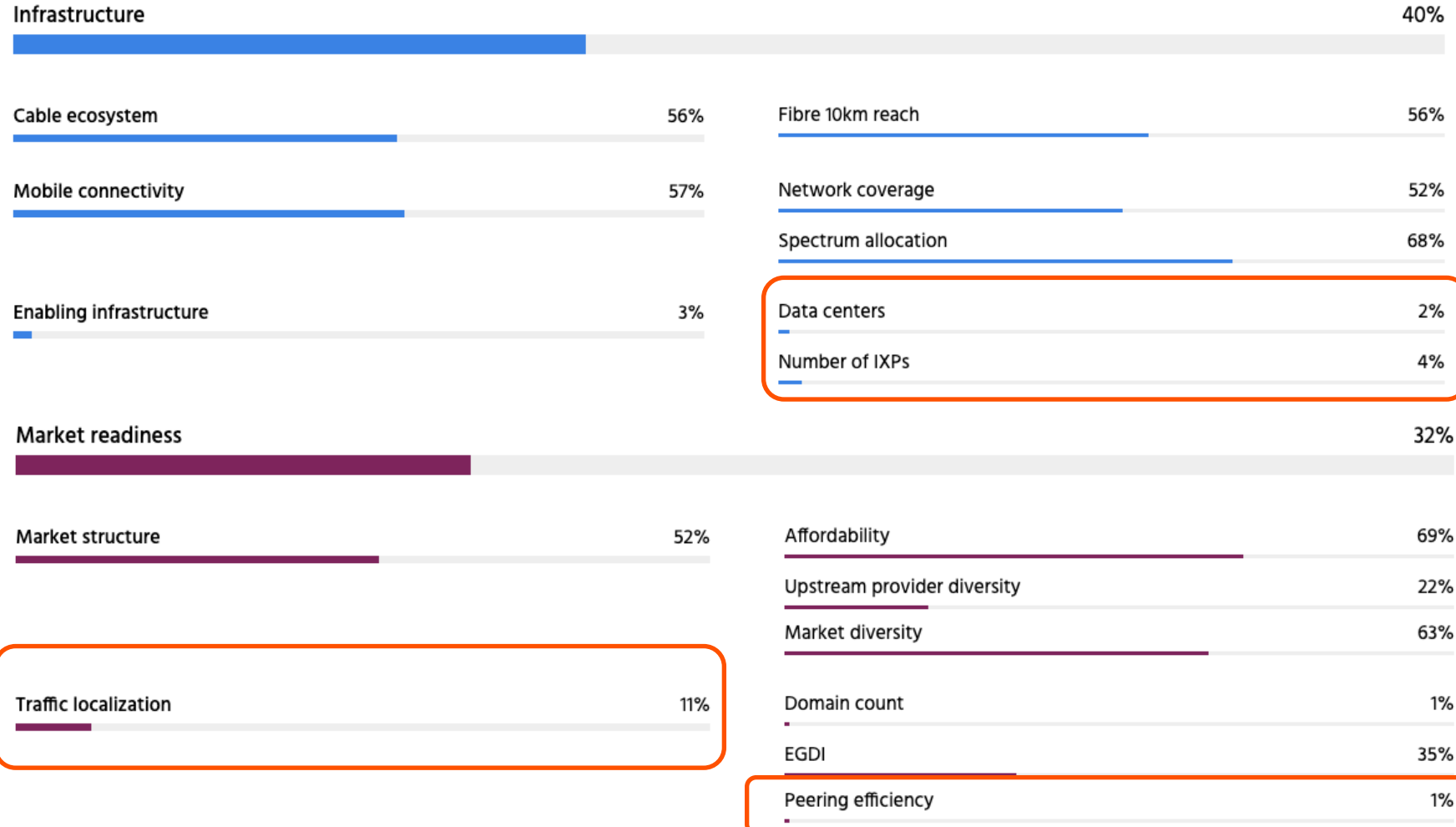
- Pakistan

Data harvested 08/06/2022
Nowmay Opalinski, IFG/GEODE, December 2022.

Pakistan's Network Resilience Metrics from Internet Society Pulse



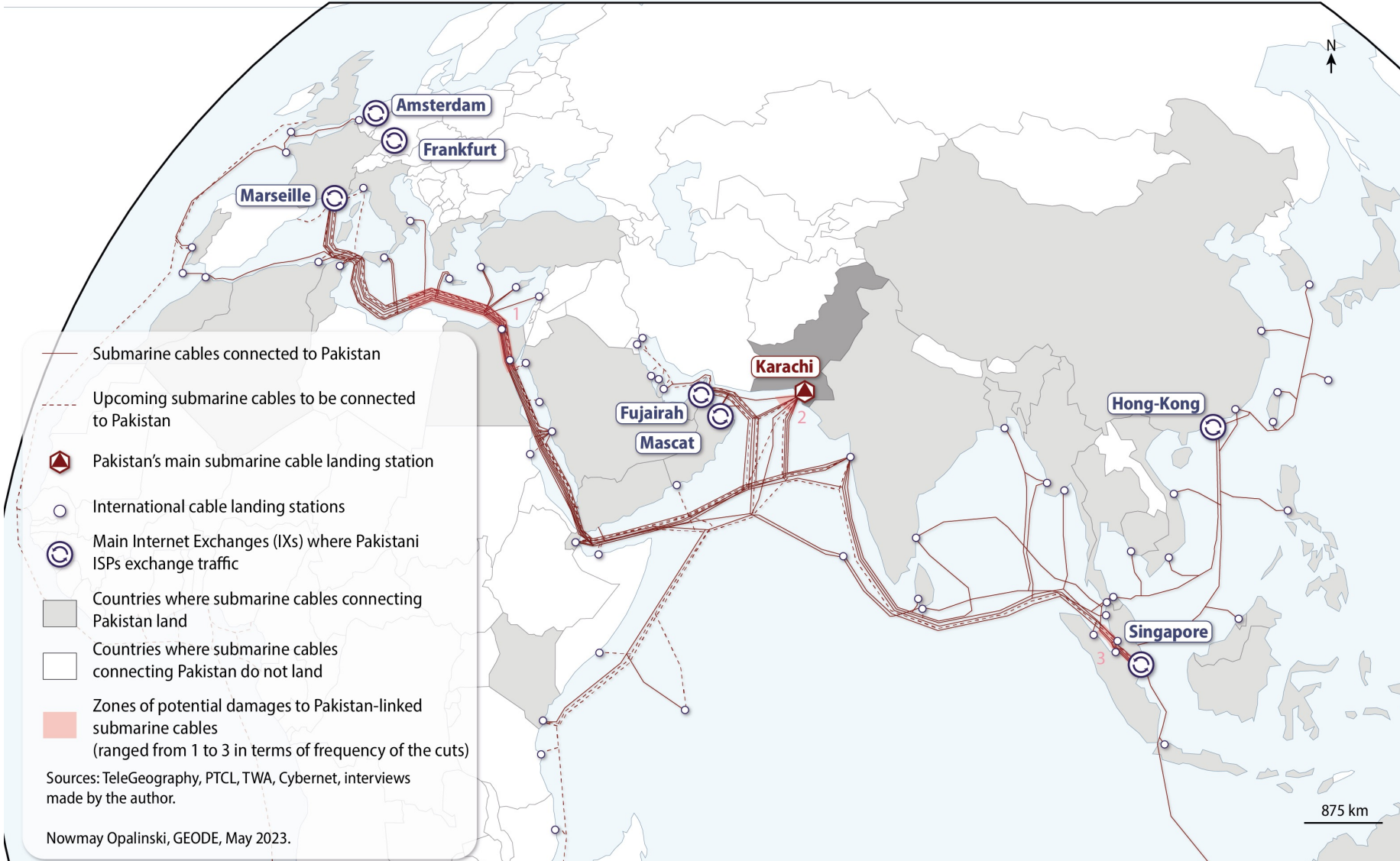
Pakistan



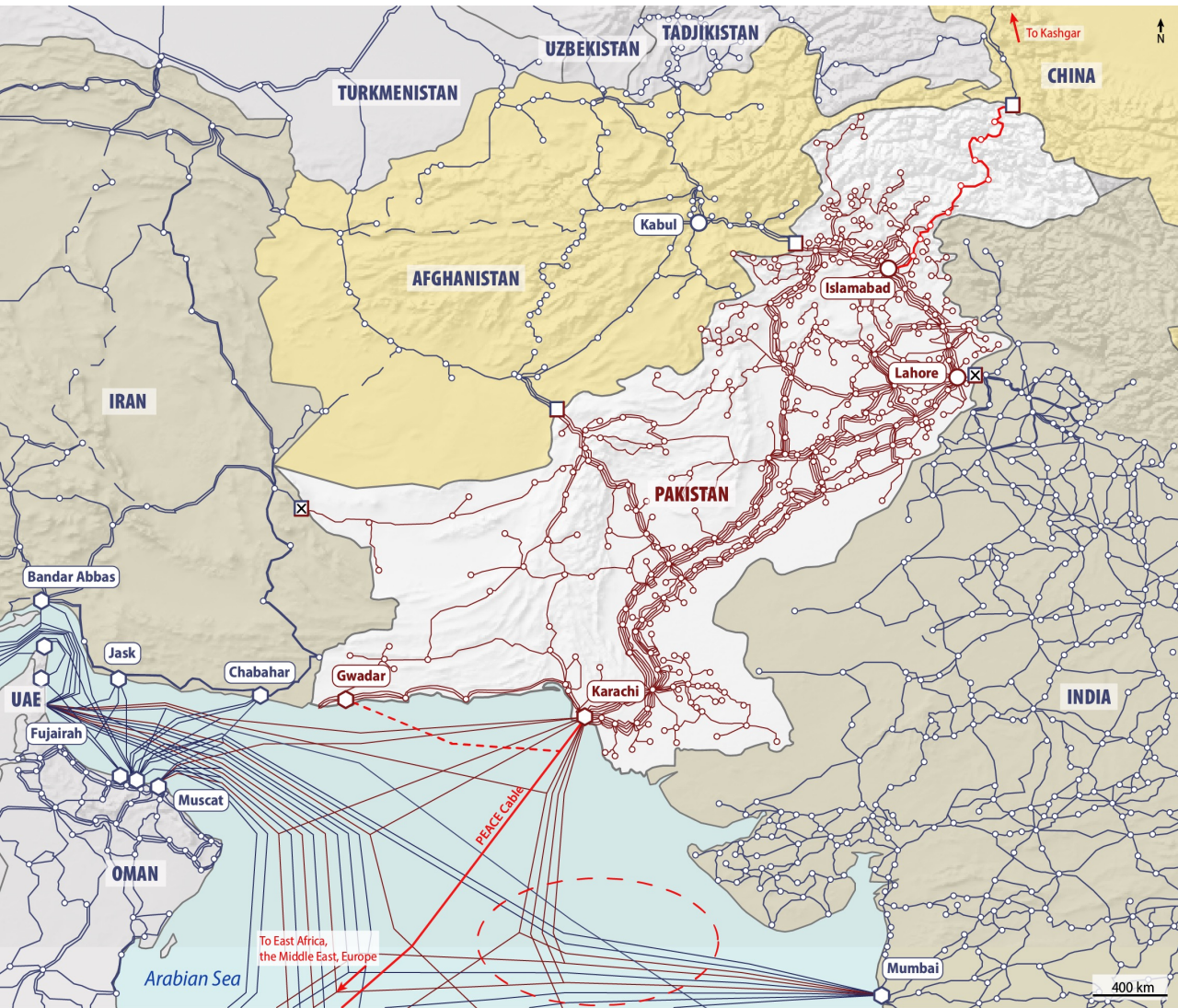
II- External connectivity

Scarcity of regional links
and dependency over
foreign-hosted contents

Submarine connectivity : Karachi as the neuralgic point for global Internet access



Terrestrial connectivity is limited by security considerations



Pakistan's Internet network interconnections with its neighborhood: a low degree of integration and emerging links with China along CPEC

Pakistan's few active connections with its direct neighbors result in a high dependency on international submarine cables ...

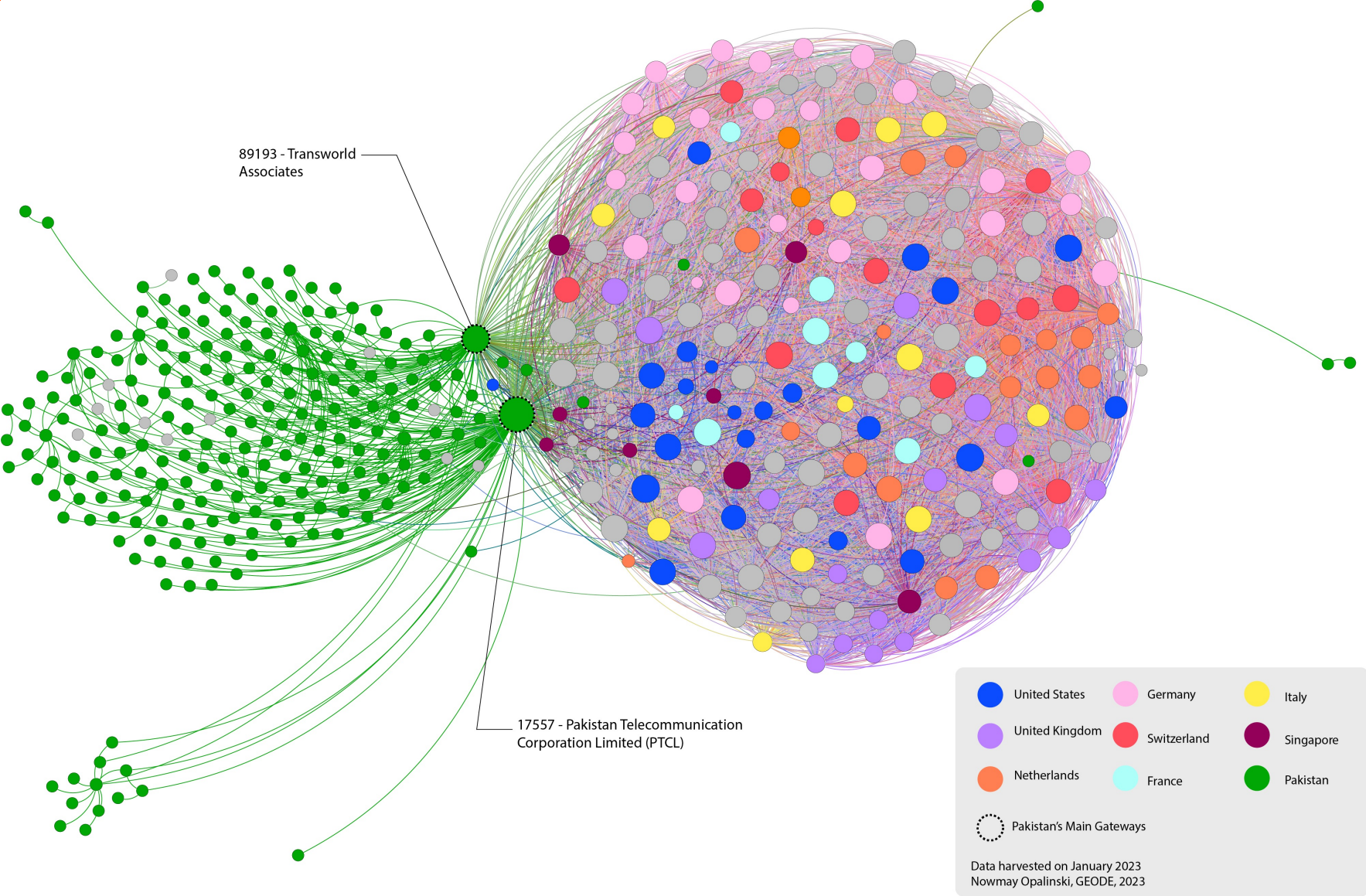
- | | | | | | |
|--|--|--|--|--|---|
| | Fiber Optic backbone / nodes | | Submarine cable landing stations | | Country with a direct terrestrial connection with Pakistan |
| | International submarine cables | | Active cross-border terrestrial link | | Country with a direct non-active terrestrial with Pakistan |
| | Pakistan's network / Neighboring countries' networks | | Inactive cross-border terrestrial link | | Country with no-direct terrestrial connection with Pakistan |

... new alternative China-sponsored paths should help bringing more resiliency and securing sensitive communications.

- | | | | |
|--|---|--|--|
| | Pak-China cross-border terrestrial cable (Huawei/SCO venture) | | Submarine cables vulnerable to Indian interception according to the Pakistani military |
| | PEACE submarine cable (Hengtong Marine Electric) | | |

Sources : ITU, Telegeography, Pakistan Telecommunication Authority, PTCL interviews with Telecom engineers in the field. Conception and realization: Nowmay Opalinski (GEODE/IFG), June 2023.

Pakistan's international connectivity : bottlenecks at the international gateways

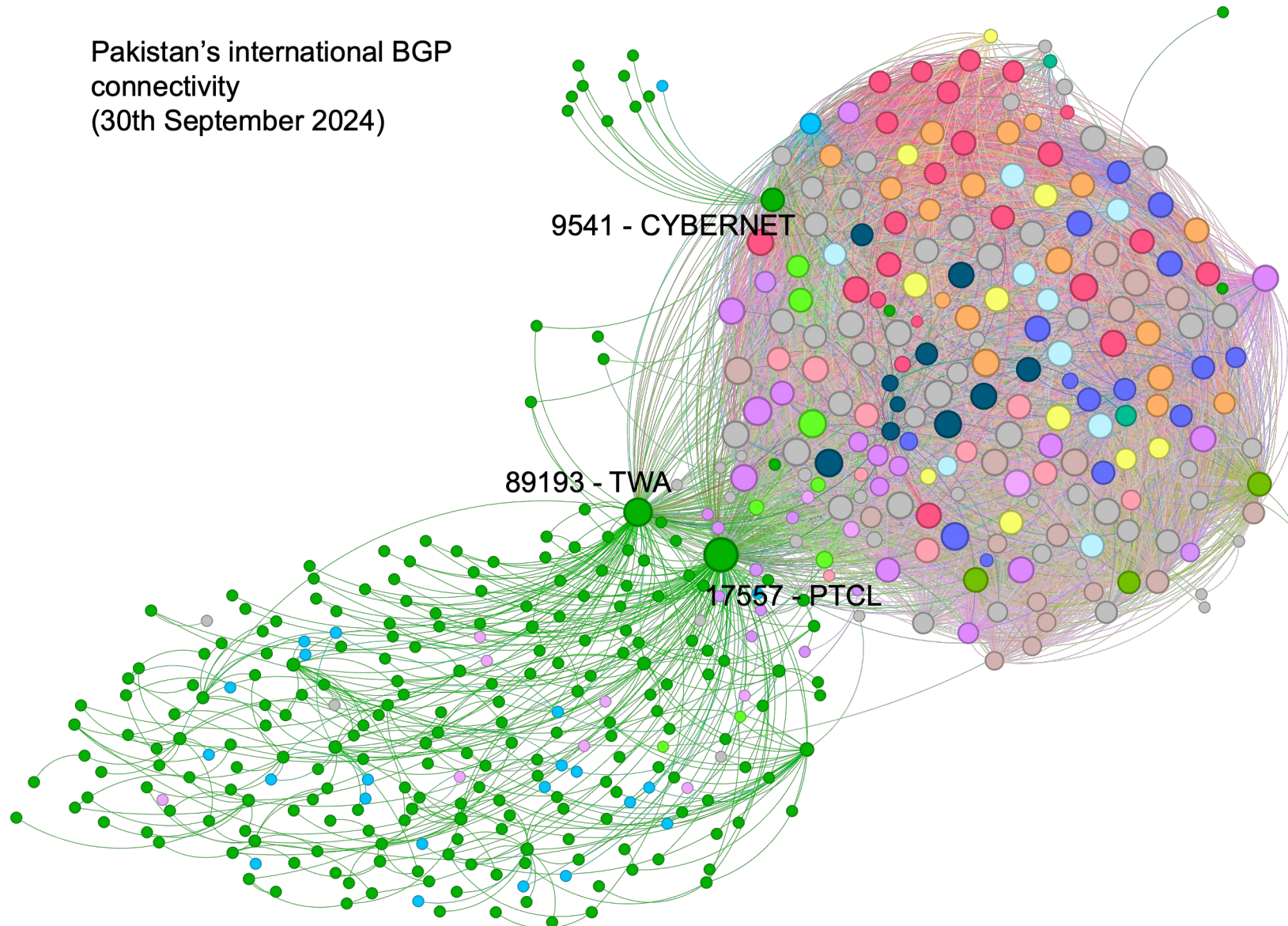


Pakistan's 2 core domestic nodes are also its two principal international gateways : jeopardizing overall resilience.

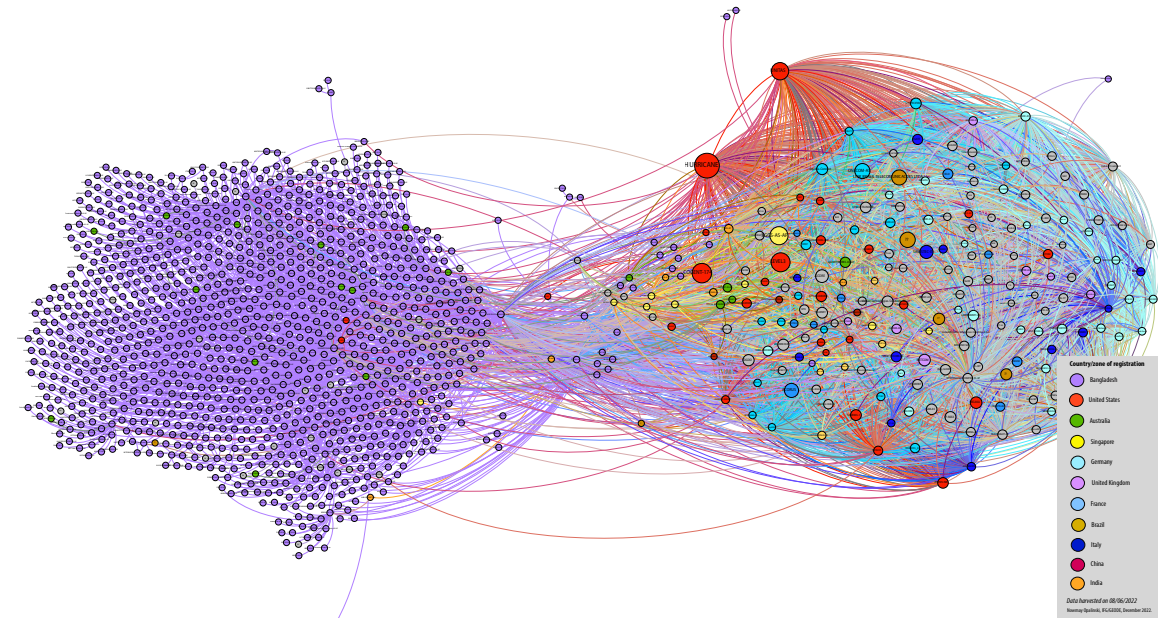
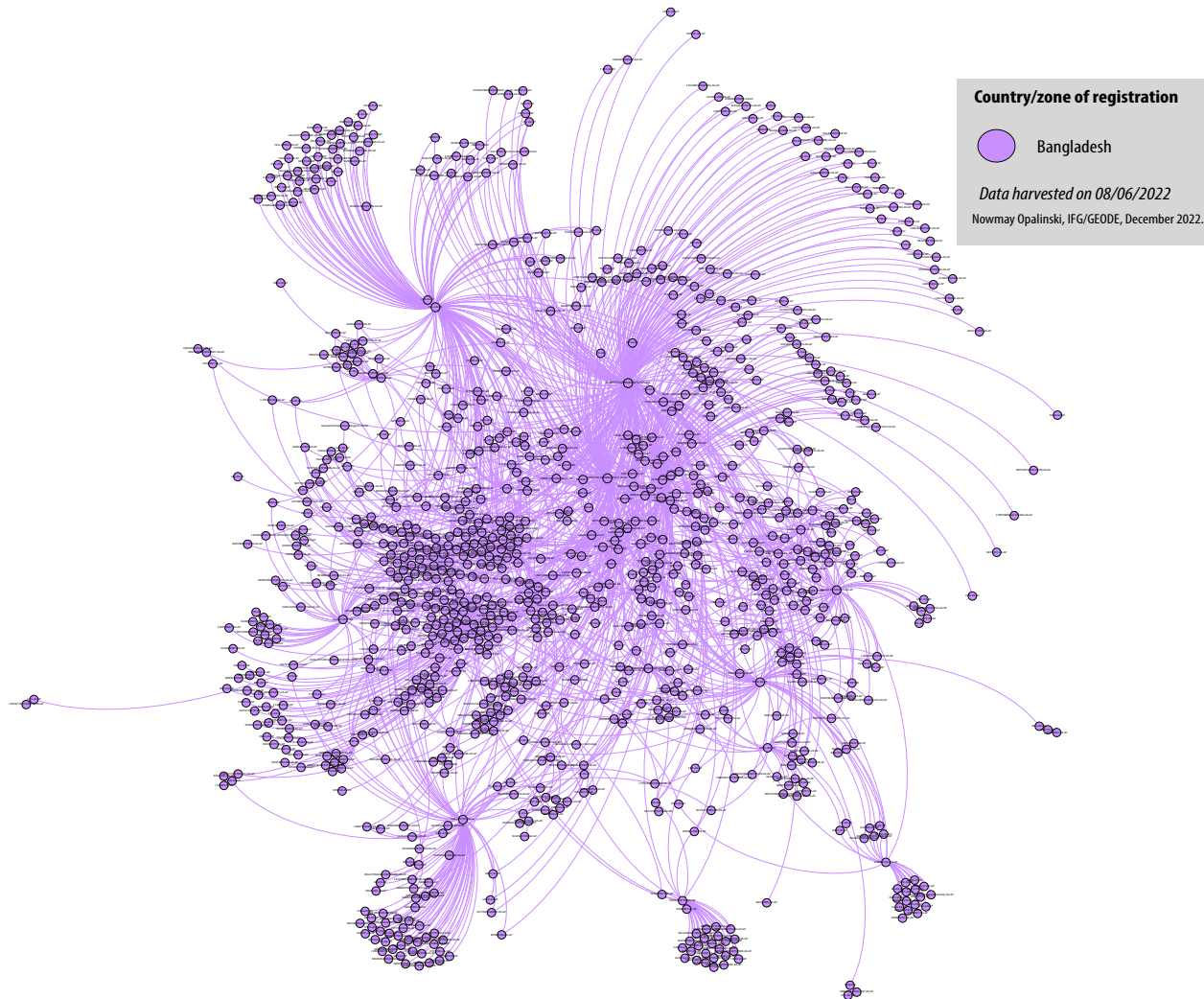
Evolving patterns : Cybernet rises as the third international gateway



Pakistan's international BGP connectivity
(30th September 2024)

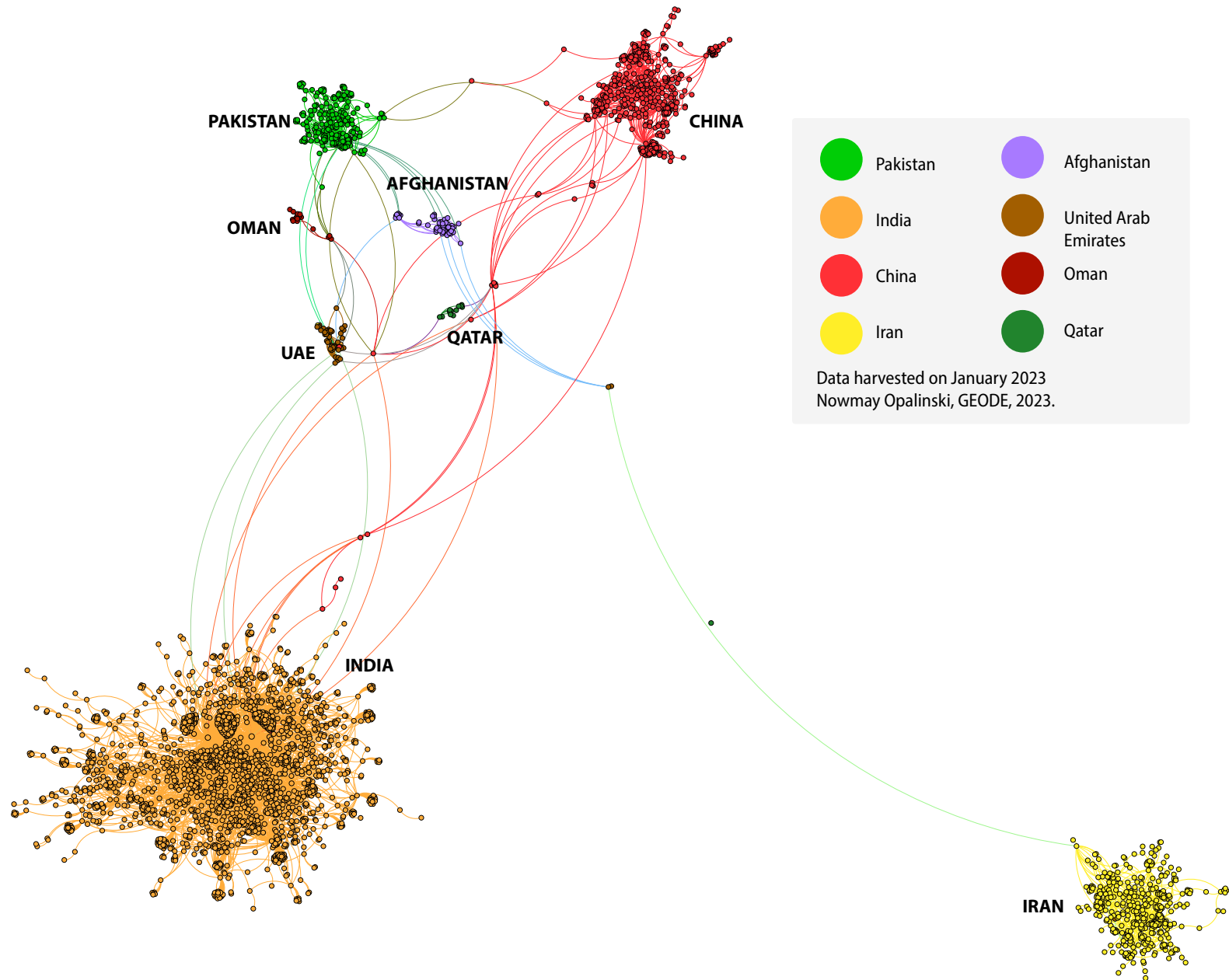


A comparison with Bangladesh's network : a much more dispersed logical architecture



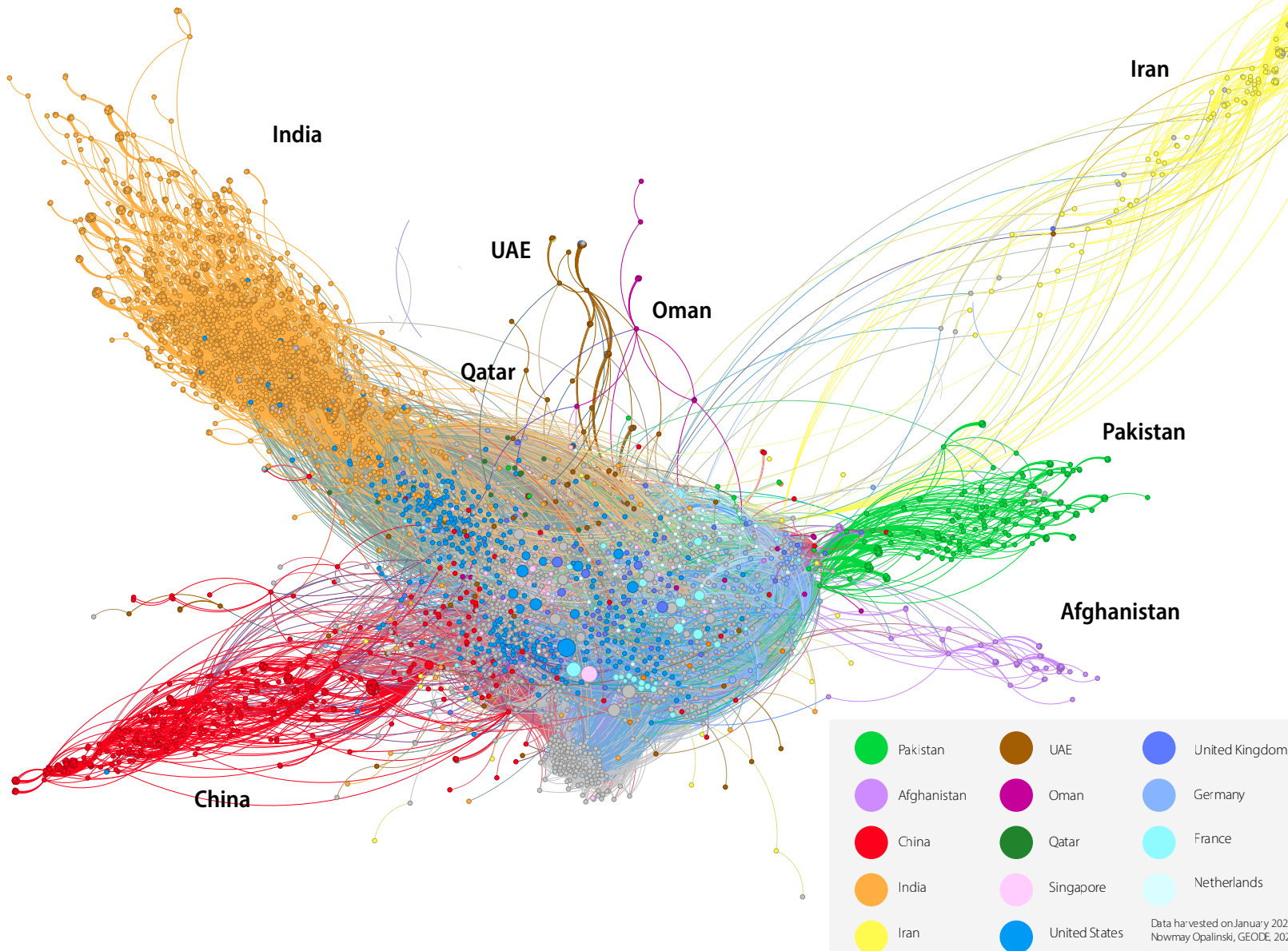
Bangladesh's domestic and international connectivity : a diversity of domestic core nodes and international gateways (34).

Scarce intra-regional routing agreements



- Pakistan has very few BGP agreements in its immediate neighbourhood.
- Graph spatialization emphasizes the absence of logical links with India and Iran.

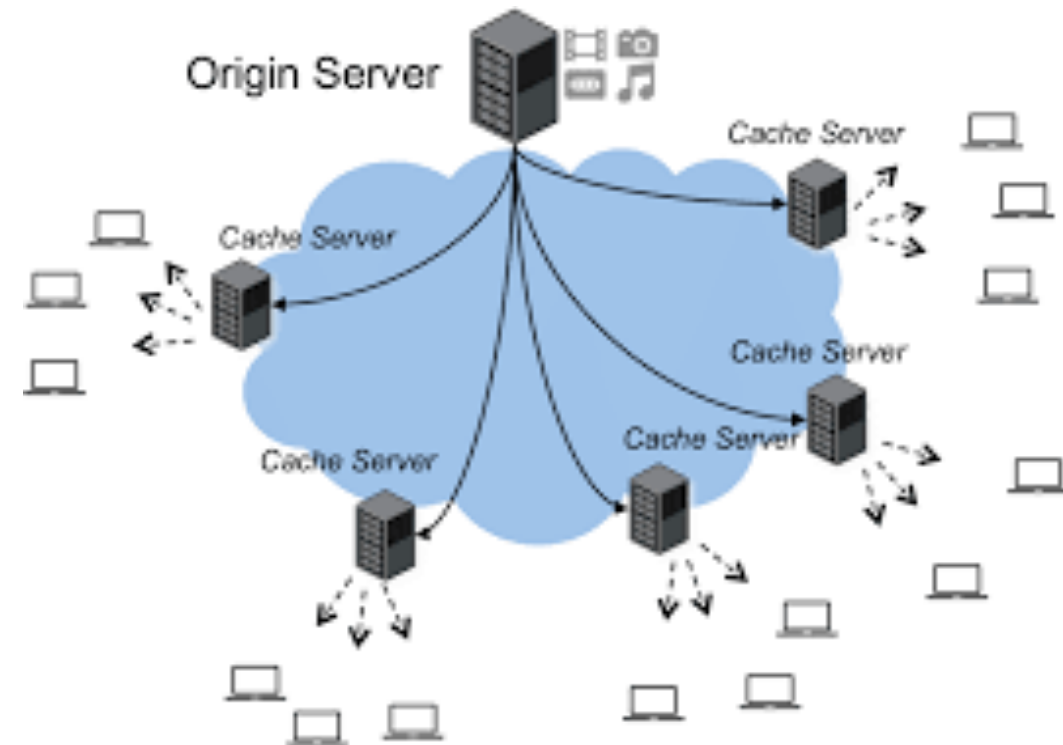
Most of the regional traffic transits through far-flung tiers



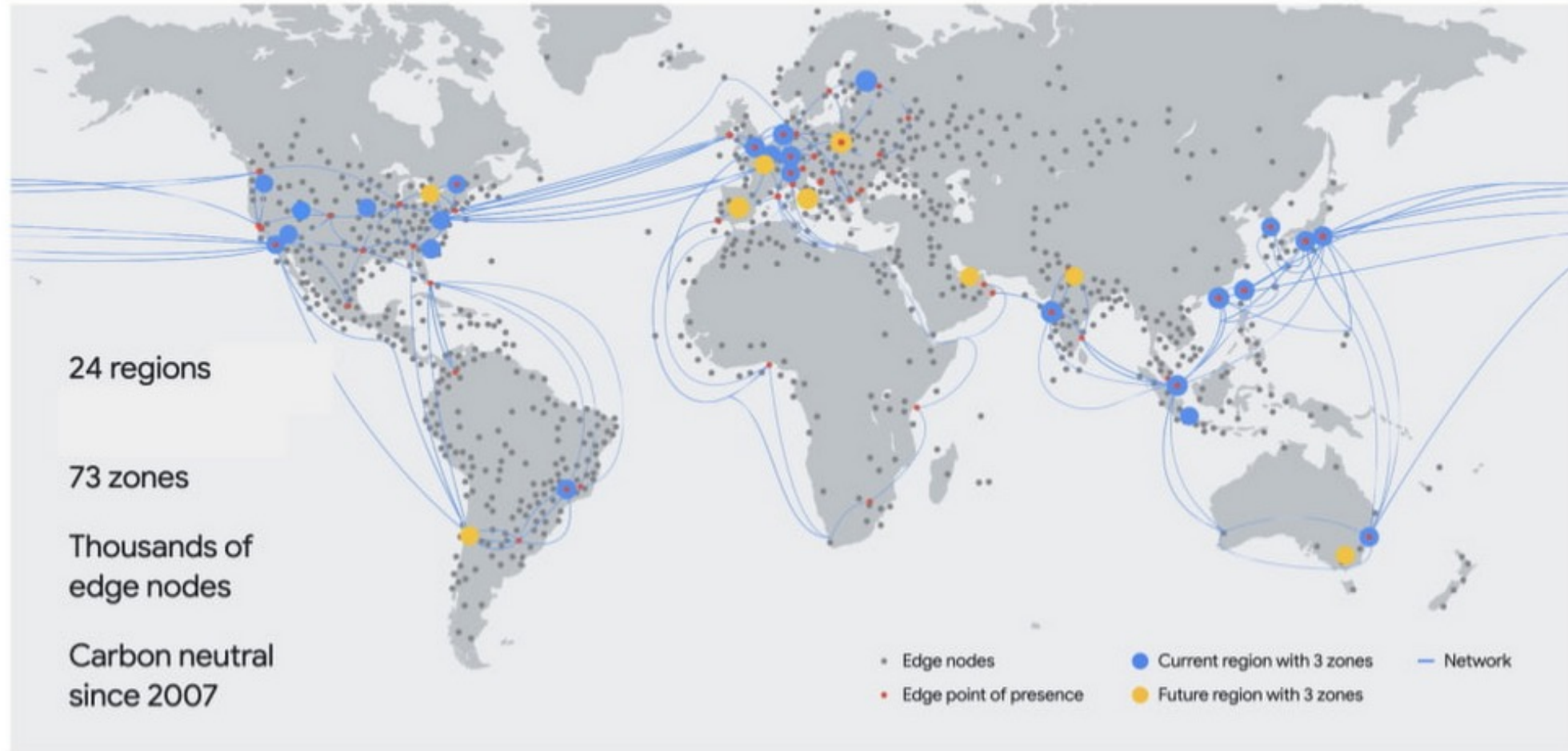
- Countries in the region mostly interconnect through Tier-1 ASes registered in the US, Europe or Singapore.

Content providers' global infrastructure: replicating content to get closer to the end-user

- Two types of infrastructure are key to the low latency and high availability of services of “hyperscalers” all around the globe.
- Content Delivery Networks (CDNs) can be stored digitally on client’s servers – through caches –, they replicate **passive contents**
- Points of Presence (PoPs) are physical infrastructures serving entire regions – specifically important for **dynamic contents** –

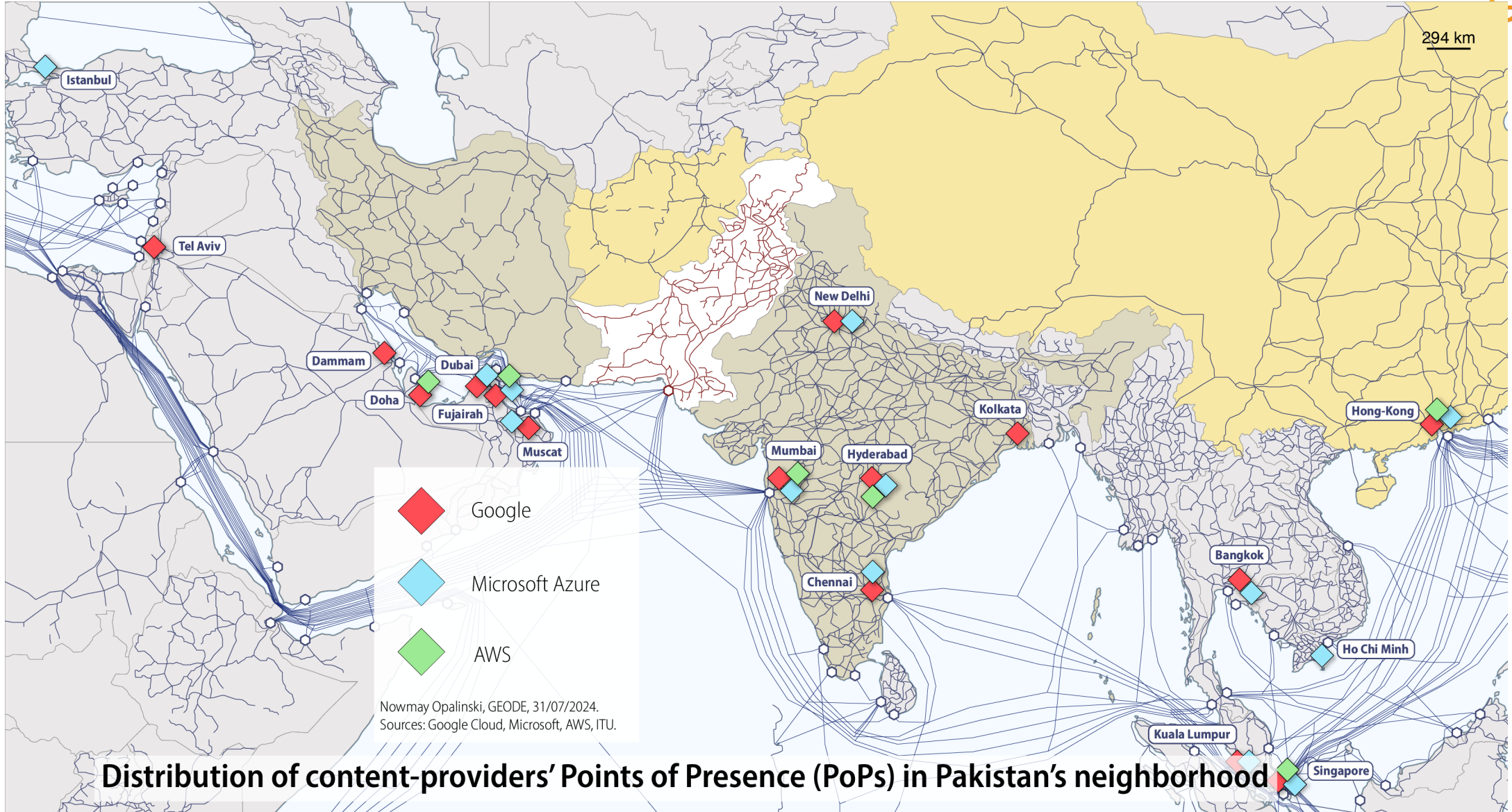


Google's distributed infrastructure : a case of selective global outreach



Source : Sweta Jain, "What's in a name? Understanding the Google Cloud network "edge", Google Cloud, 23/02/2021, <https://cloud.google.com/blog/products/networking/understanding-google-cloud-network-edge-points?hl=en>.

The Gulf emerges as a regional connectivity hub, bringing more options to Pakistan

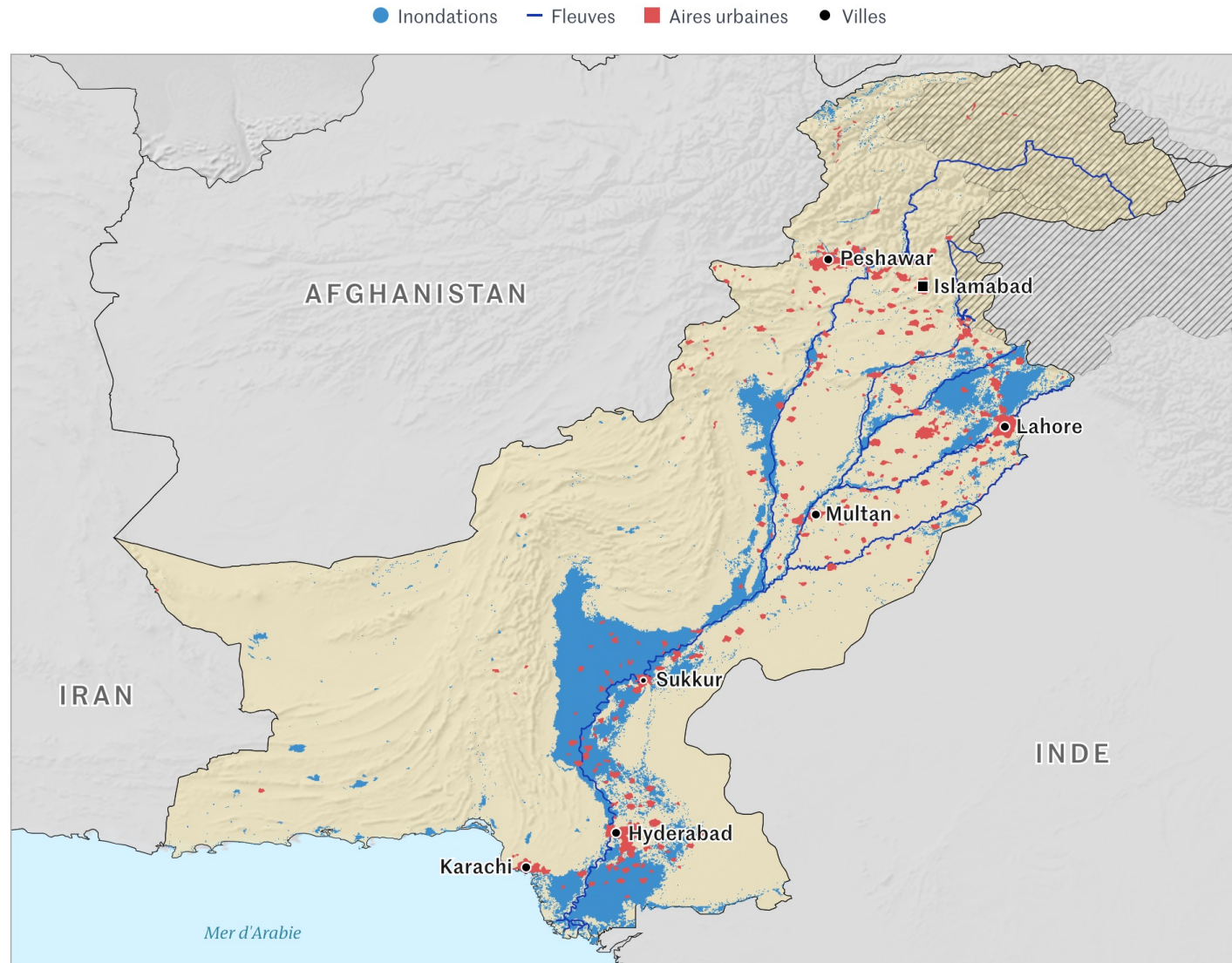


Distribution of content-providers' Points of Presence (PoPs) in Pakistan's neighborhood

What happened during the 2022
floods?





Unprecedented flood scale

Surfaces affected by floods between the 1st of July 2022 to 31st of August 2022. Data retrieved from UNOSAT.

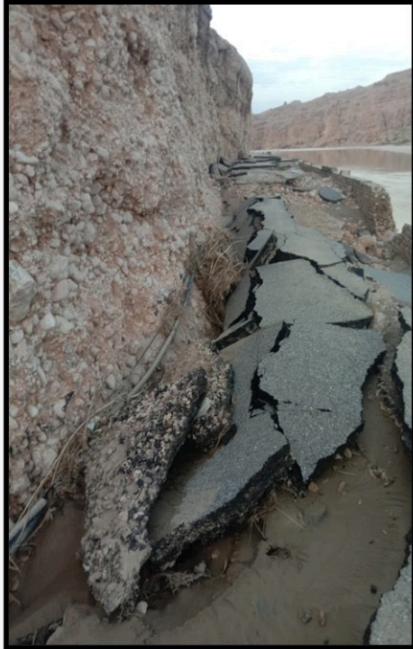
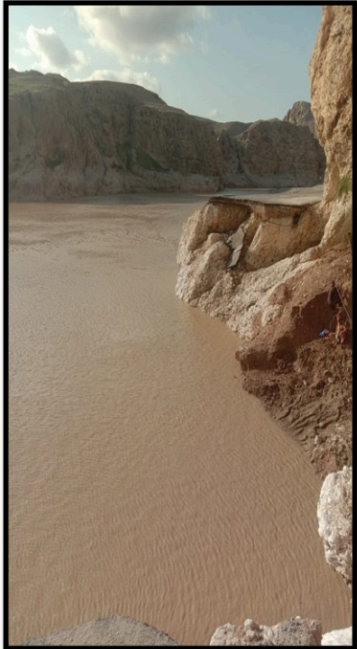


Source: Gary Dagorn, "Avant-après : les immenses inondations au Pakistan vues de l'espace", *Le Monde*, 07/09/2022.

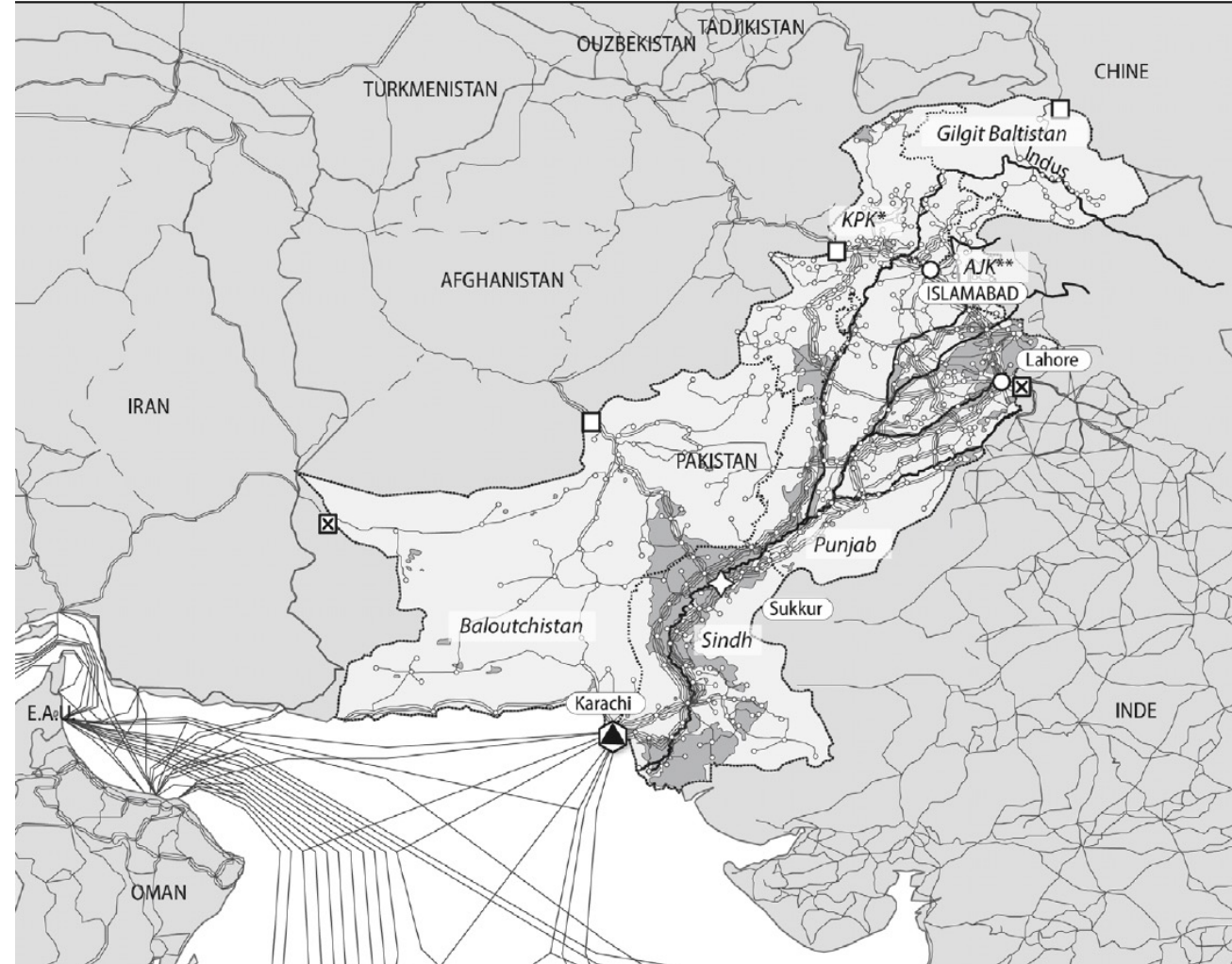
Impacts of the floods on mobile telecommunications (data from Pakistan's Ministry of IT and Telecommunications)

| CMO | Sindh | Balochistan | KPK | Punjab | AJK | GB | CMO Total |
|---|--|-------------|-------|--------|-------|-------|-----------|
|  | 454 | 339 | 68 | 0 | 0 | 0 | 861 |
|  | 434 | 549 | 183 | 149 | 0 | 0 | 1315 |
|  | 254 | 230 | 292 | 24 | 0 | 0 | 800 |
|  | 130 | 237 | 31 | 12 | 0 | 0 | 410 |
| Provincial Total of Down Sites | 1272 | 1355 | 574 | 185 | 0 | 0 | - |
| Total Sites in Province | 10599 | 3050 | 7664 | 28621 | 1334 | 465 | 51733 |
| Percentage of Down Sites in Province | 12.00% | 44.43% | 7.49% | 0.65% | 0.00% | 0.00% | - |
| NWD Total Down Sites | 3386 (6.48 % of entire Network) | | | | | | |

Huge damages on the fibre-optic network. (Pictures provided by Ministry of IT – August 2022)



A physical network exposed to climate induced-hazards



L'infrastructure de connectivité numérique pakistanaise : un réseau exposé aux aléas climatiques

Une infrastructure numérique fortement concentrée...

- Câbles terrestres de fibre optique et noeuds d'interconnexion
- Câbles sous-marins de fibre optique
- Station d'atterrage des câbles sous-marins

... avec un choix limité de connexions internationales...

- Point d'interconnexion transfrontalier actif
- Point d'interconnexion transfrontalier non-actif

... sévèrement affectée par les inondations de l'été 2022.

- Zones inondées
- Coupure ayant eu un impact majeur sur la connectivité nationale

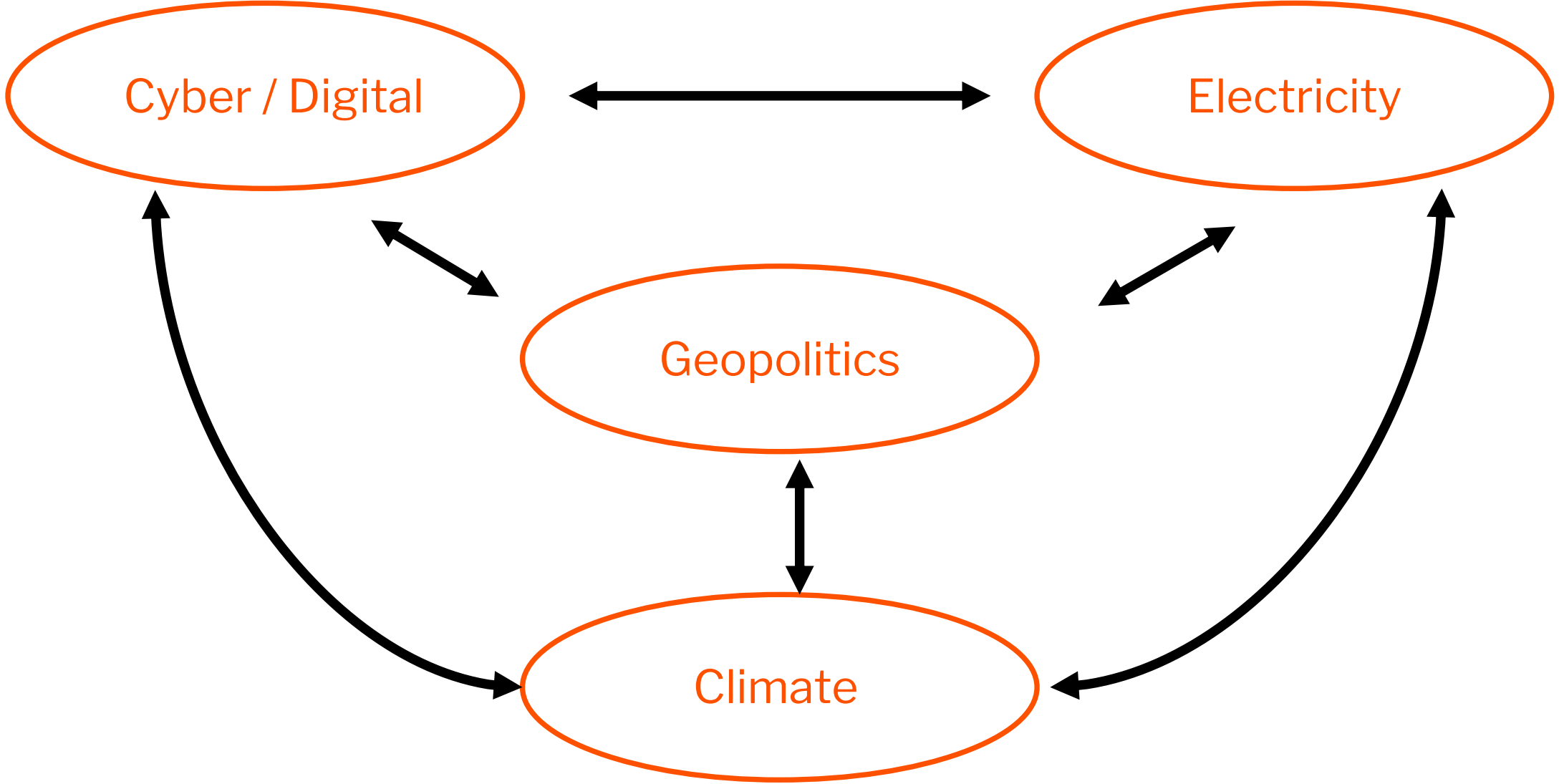
Sources : Le Monde, ITU, PTCL, Wateen, Multinet.

Nowmay Opalinski, IFG Lab, septembre 2024 .

*Khyber Pakhtunkhwa

** Azad-Jammu and Kashmir

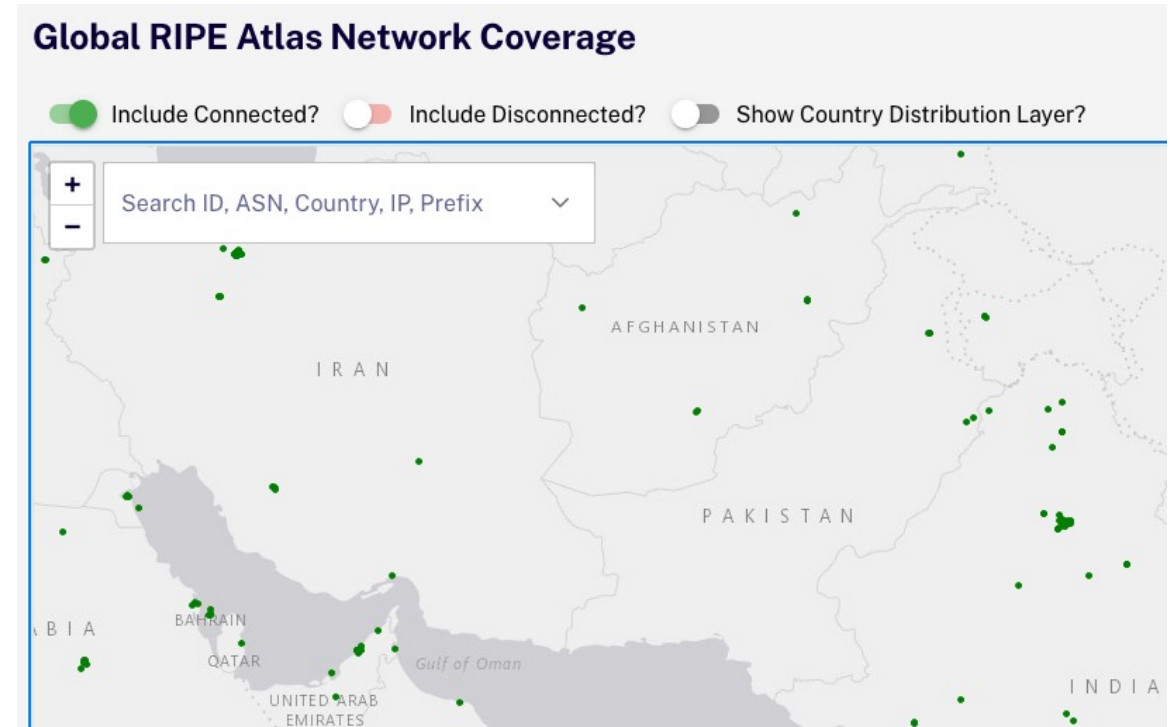
The interaction between risks shall be considered



What's next?

Active measurements are needed to better understand Pakistan's network lack of resilience

- Scarcity of measurement nodes throughout the region of study (CAIDA, RIPE Atlas etc.).
- We are currently expanding the nodes coverage through a collaboration with RIPE and CAIDA.
- Please help us increase the coverage of our probes within your networks !



RIPEAtlas Coverage in Pakistan on July 19th, 2024.

<https://atlas.ripe.net/coverage/>



Thank You !

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