A First Look at Deployment Strategies of Services Provisioned using Anycast

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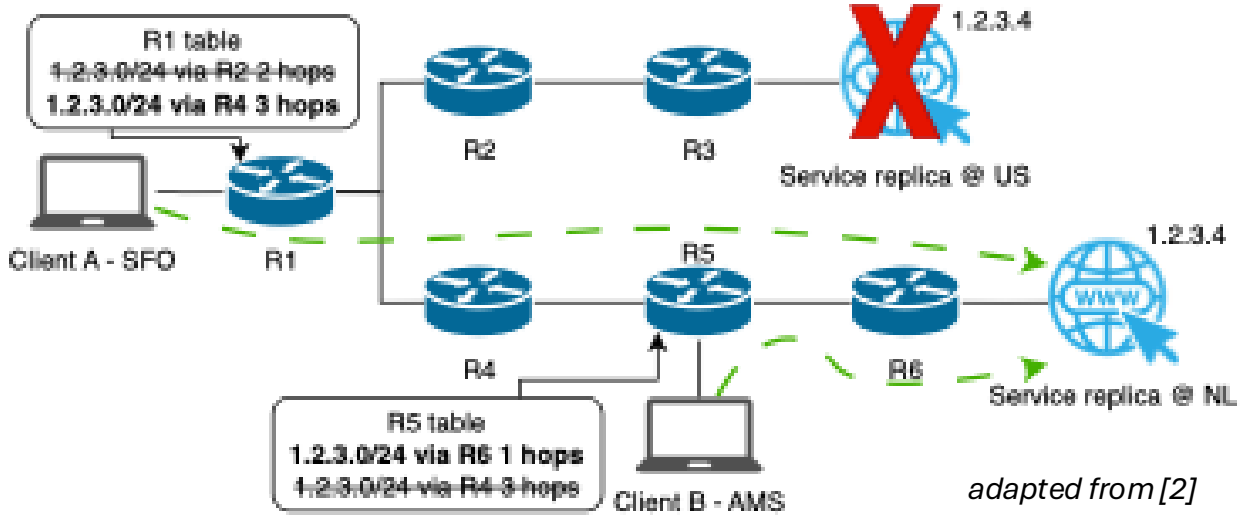


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What is anycast?

- Making a service address available in multiple locations (Points of Presence – PoPs) *[1]*
- Using BGP announce the IP prefix at multiple locations
- Key benefits:
  - Resilienc
  - Latency r
  - Load distr



adapted from [2]

[1] Abbley, et al. RFC 4786, 2006. https://www.rfc-editor.org/info/rfc4786/

[2] Bertholdo, "Anycast in the age of hypergiants: Towards tools and techniques for the other 99% of ASes," PhD Thesis. University of Twente, Netherlands, Sep. 2023

Anycast is Significant and needs Attention

1,000+
ASes deploy anycast
(LACeS 2026 *[2]*)

14,346
IPv4 /24 prefixes
detected

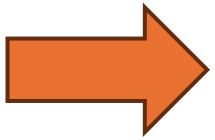
13,007
IPv6 /48 prefixes
detected

10+ years
Since last study on
service deployment
(Cicalese et al. *[1]*)

- Widely used by CDNs *[1, 2]*
- Best practice for critical Internet infrastructure (*e.g.*, DNS *[3]*)
- “approximately 50% of users encounter an A-CDN cache during normal browsing activity” [4]

[1] Cicalese, et al. “Characterizing IPv4 anycast adoption and deployment,” CoNEXT 2015. https://doi.org/10.1145/2716281.2836101
[2] Hendriks, et al. “LACeS: An Open, Fast, Responsible and Efficient Longitudinal Anycast Census System” IMC 2025. https://doi.org/10.1145/3730567.3764484
[3] Moura, et al. RFC 9199, 2022. https://www.rfc-editor.org/info/rfc9199/
[4] Giordano, et al. " A First Characterization of Anycast Traffic from Passive Traces." TMA 2016. https://dl.ifip.org/db/conf/tma/tma2016/tma2016-final30.pdf

Research questions

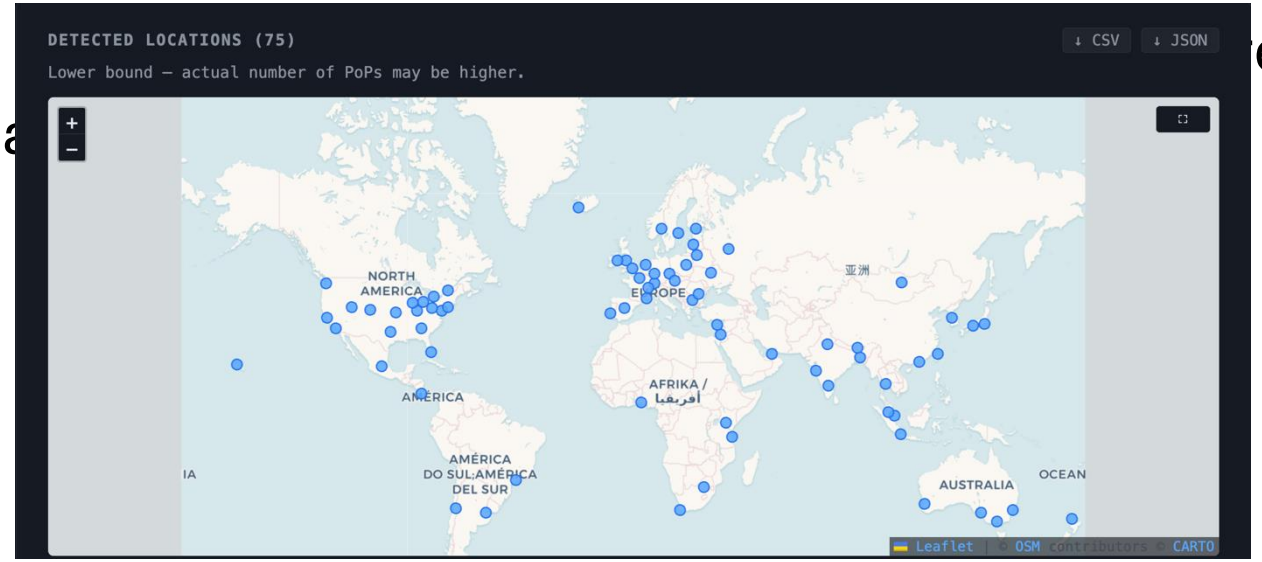


What deployment strategies characterize modern anycast deployment?

What services are offered on anycast networks?

Input Data Set

- We use LACeS *[3]*. A daily anycast census at University of Twente
- LACeS detects, enumerates, and geolocates anycast
  - Detection of IPv4 and IPv6 anycast
  - Enumeration
  - Geolocation a



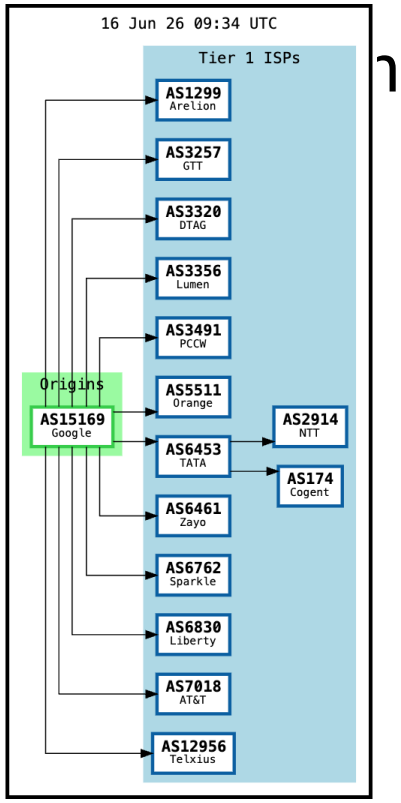
Example: Enumeration count (75) and geolocation of Cloudflare's public DNS resolver - https://manycast.net/?q=1.1.1.1 (16-06-2026)

[3] R. Hendriks, et al. "LACeS: An Open, Fast, Responsible and Efficient Longitudinal Anycast Census System" IMC 2025. https://doi.org/10.1145/3730567.3764484

Anycast Topology: Upstream Providers

- Inferring upstream ASes of anycast prefixes
  - Using data shared by Ben Cox, bgp.tools (prefix-level granularity)
- Expected: Large variety ns due to distributed nature
- Reality:

37%
of IPv4 routed prefixes
have a single upstream

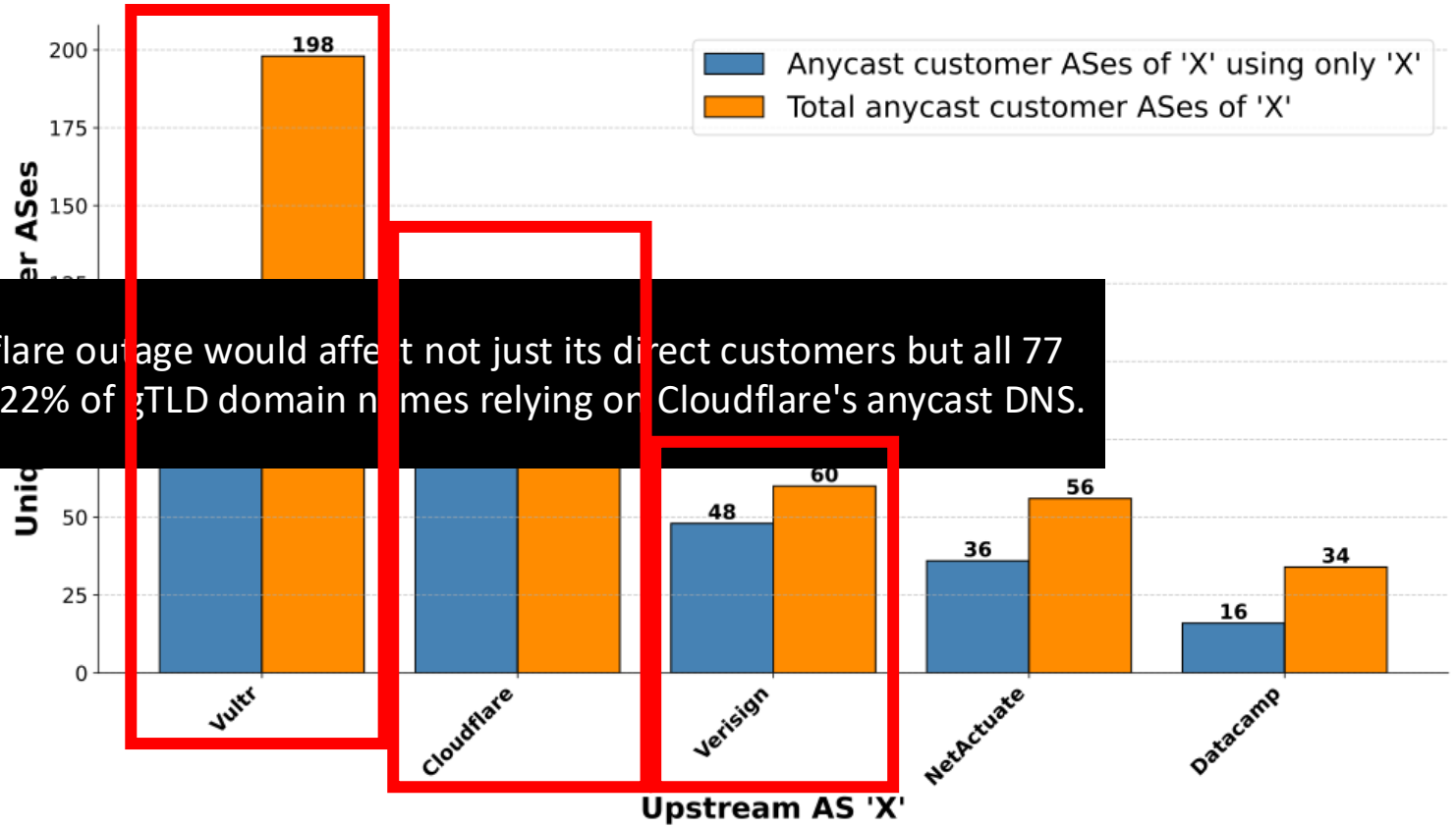


29%
of IPv6 routed prefixes
have a single upstream

Example: Upstream connectivity for 8.8.8.8 (Google)

Anycast Topology: Upstream Providers

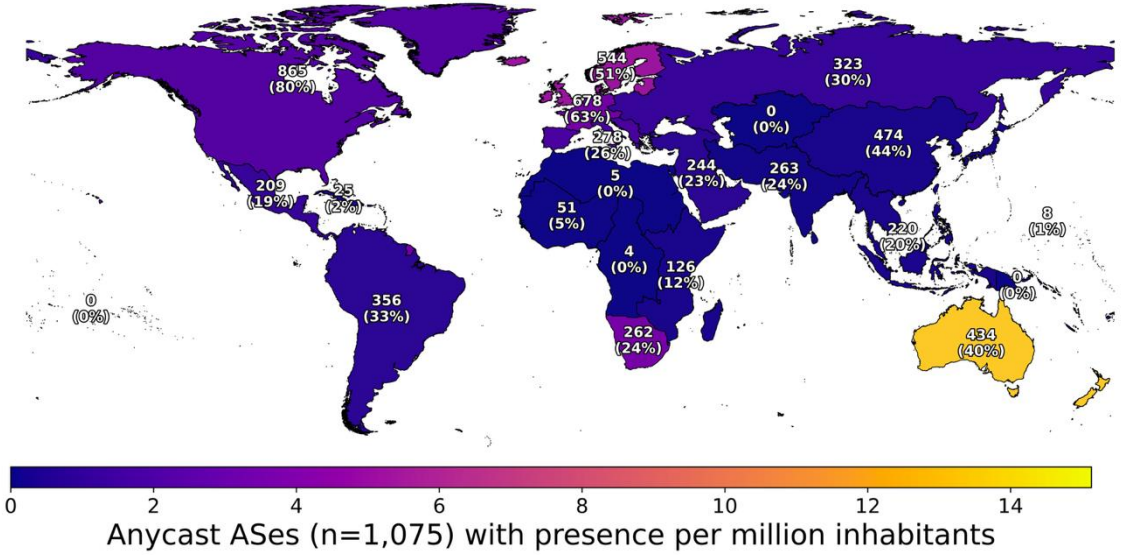
- Single upstream ASes
- Mostly BYOAS Providers
  - Bring-Your-Own-AS
- 198 (1/5) ASes use Vultr
  - 84
  - Aff
- Cloud
  - *E.g.*, F-root (AS 3557)
  - Replicated at 300+ PoPs
- Verisign
  - Same Org links (MOAS)



Hidden dependency risk: A Cloudflare outage would affect not just its direct customers but all 77 downstream anycast ASes — and 22% of gTLD domain names relying on Cloudflare's anycast DNS.

Geographic Placement of Anycast PoPs

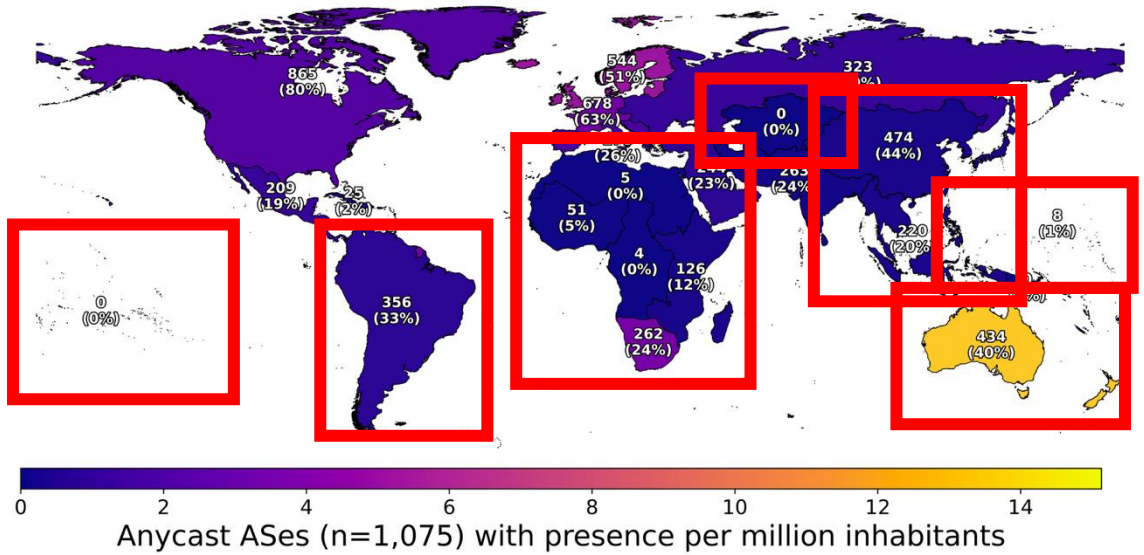
- Where do anycast operators replicate anycast services?
- Geolocation data from LACeS
  - Limitation: lower-bound of real deployment
- Normalized by inhabitant count



**Dynamic (daily updated) version available at manycast.net*

Geographic Placement of Anycast PoPs

- AU/NZ most represented per capita
- South America, Eastern Asia
  - Considerable presence
  - Yet underserved per capita
- Africa, Central Asia, Pacific Islands
  - Very sparse presence



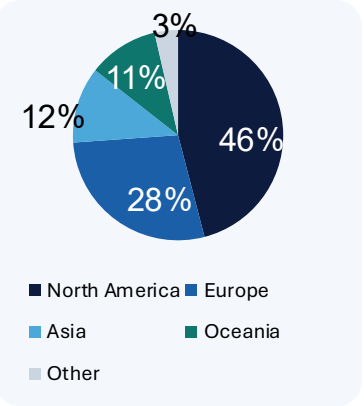
**Dynamic (daily updated) version available at manycast.net*

Regional Anycast

74%
ASes with ≥1 global (multi-continent) prefix

35%
ASes with ≥1 prefix confined to 1 continent

23
ASes with regional prefixes in multiple continents



- Anycast is used regionally
  - *E.g.*, ccTLDs (.nz nameservers anycasted within New Zealand)
  - DNS4EU: European DNS resolver (anycasted within the EU jurisdiction)
  - CDNs use it for traffic steering (latency)

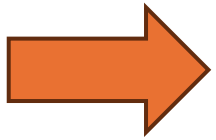
IP Utilization

- IPv4 an
  - Why
  - How
  - Do c
- IP utili
- Main fi
  - 77%
  - *E.g.,*
  - CDNs have high IP utilization
  - The top 5 ASes originate 88% of active anycast IPs

Org (ASN)	Active IPs	/24s	Active IP ratio
Cloudflare (13335)	658×10^3	2 866	0.896
Google (396982)	492×10^3	4 298	0.447
Fastly (54113)	209×10^3	827	0.989
AWS (16509)	133×10^3	1 603	0.325
Cloudflare (209242)	60×10^3	270	0.862

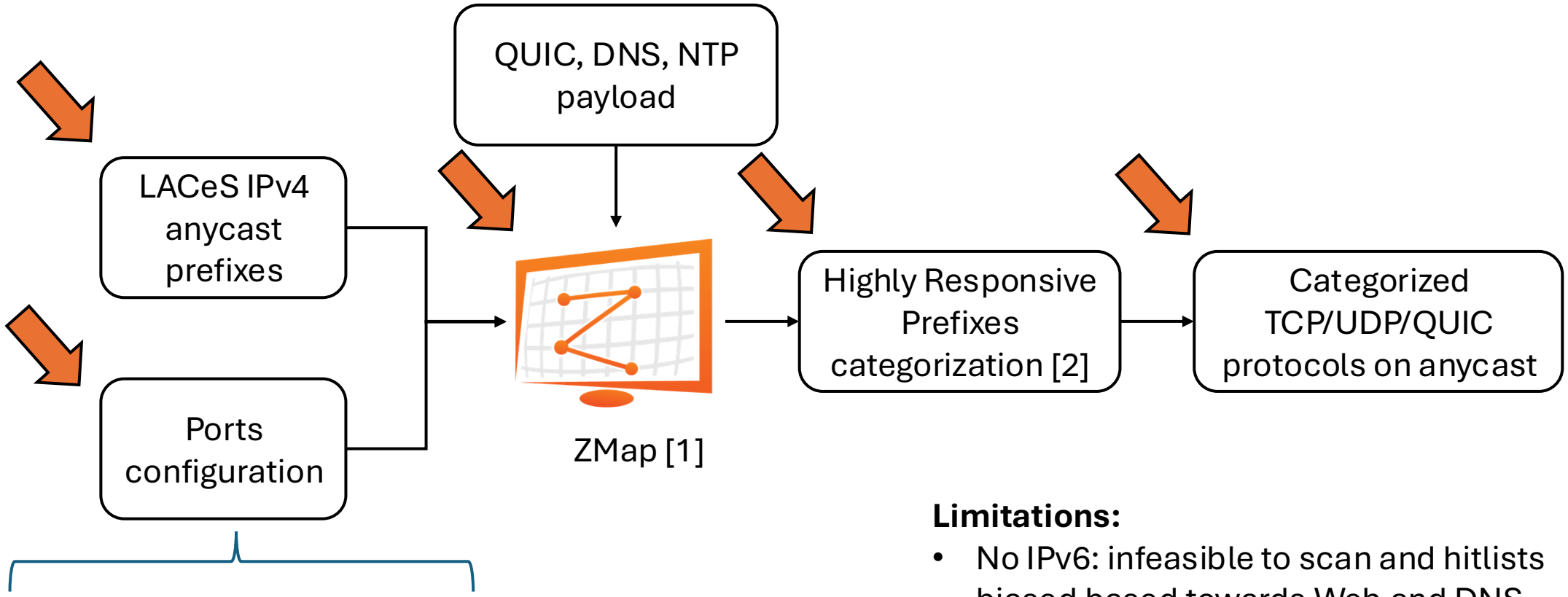
Research questions

What deployment strategies characterize modern anycast deployment?



What services are offered on anycast networks?

Measuring Transport Layer



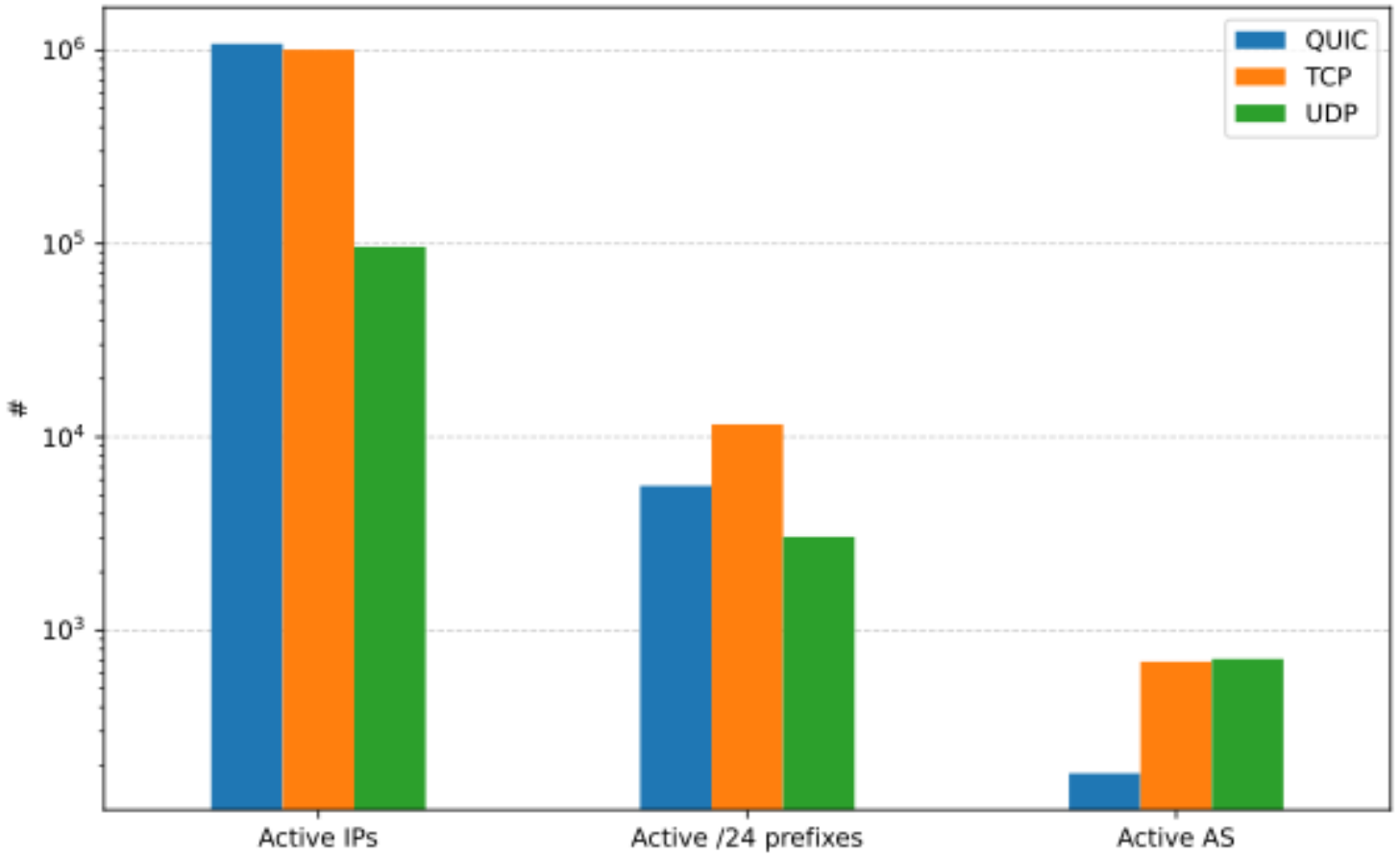
Limitations:

- No IPv6: infeasible to scan and hitlists biased based towards Web and DNS
- 3 VPs (results from NL VP): covering multiple VPs can burden network operators

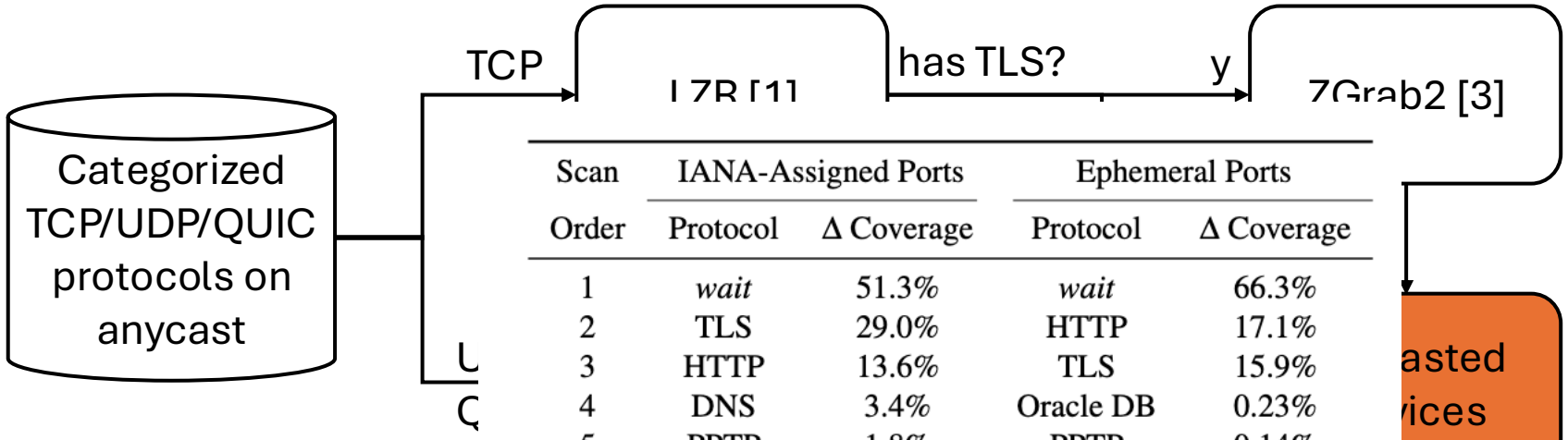
[1] Durumeric et. al, "ZMap: Fast internet-wide scanning and its security applications," USENIX Security, 2013.
[2] Sattler et. al, "Packed to the brim: Investigating the impact of highly responsive prefixes on internet-wide measurement campaigns," CoNEXT 2023. https://doi.org/10.1145/3629146

Transport Layer Anycast Utilization

- QUIC has substantial adoption with comparable numbers to TCP at the active IPs level
  - ~98% with official version 1
  - ~40% also accept a draft QUIC version
- Prefixes with QUIC are “dense”, with more responsive IPs
- A few ASes are pushing QUIC (CloudFlare, Google, Amazon, and Fastly)



Detecting Services on Anycast



Scan	IANA-Assigned Ports		Ephemeral Ports	
Order	Protocol	Δ Coverage	Protocol	Δ Coverage
1	*wait*	51.3%	*wait*	66.3%
2	TLS	29.0%	HTTP	17.1%
3	HTTP	13.6%	TLS	15.9%
4	DNS	3.4%	Oracle DB	0.23%
5	PPTP	1.8%	PPTP	0.14%

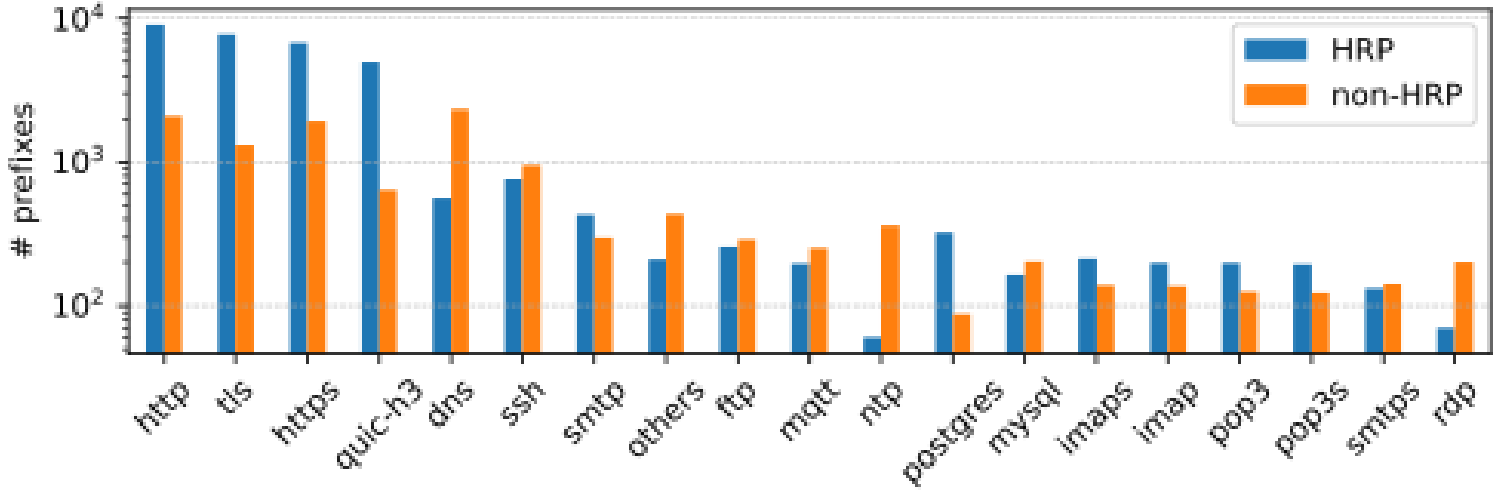
Table 2: **Optimal Handshake Order**—For IANA-assigned ports, waiting and then sending a TLS Client Hello discovers 80.3% of unexpected services. Five handshakes can identify over 99% of identifiable unexpected services.

explain how we derive the LZR handshakes

[1] Izhikevich et. al, "LZR: Identifying unexpected internet services," in USENIX Security 2021.
[2] Zirngibl et. al, "QUIC Hunter: Finding QUIC Deployments and Identifying Server Libraries Across the Internet," PAM 2024.
[3] Durumeric et. al, "A search engine backed by internet-wide scanning," CCS 2015.

Services on Anycast prefixes

- Nearly all (96%) of anycast prefixes host at least one service
- 84% of identified services run the expected protocol
- SSH: default OpenSSH behaviour to listen on all local addresses may unintentionally expose to anycast
- We found instances ~1000 IP addresses hosting Gmail (SMTP on 465)
- Databases: exposure possibly due to misconfiguration, where online tutorials recommend binding to 0.0.0.0 and relying on firewall rules [1]



https://snapshooter.com/learn/mysql/allow-mysql-remote-access

DNS on anycast

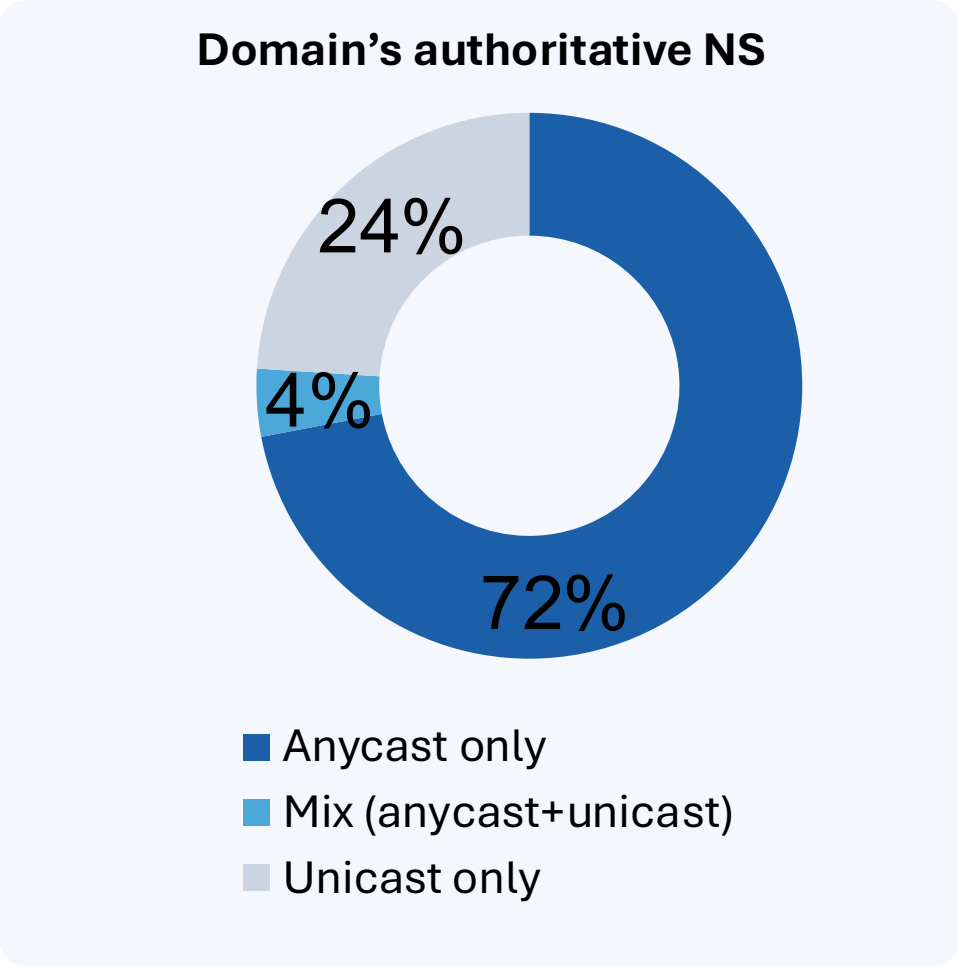
- We find 2.9k prefixes hosting DNS
- DNS-over-QUIC is a small population of 1.3k IPs; 95% from NextDNS

Using OpenINTEL dataset, we see:

- Growth of DNS authoritative nameservers on anycast
  - 72% in 2026 vs. 57% in 2021
- Mix deployments can result in higher DNS name resolution latency.
- Few operators account for 66% of domains with authoritative NS on anycast
  - 28% Host Europe, 22% CloudFlare, 8% Google, 5% Vercara, and 3% IONOS

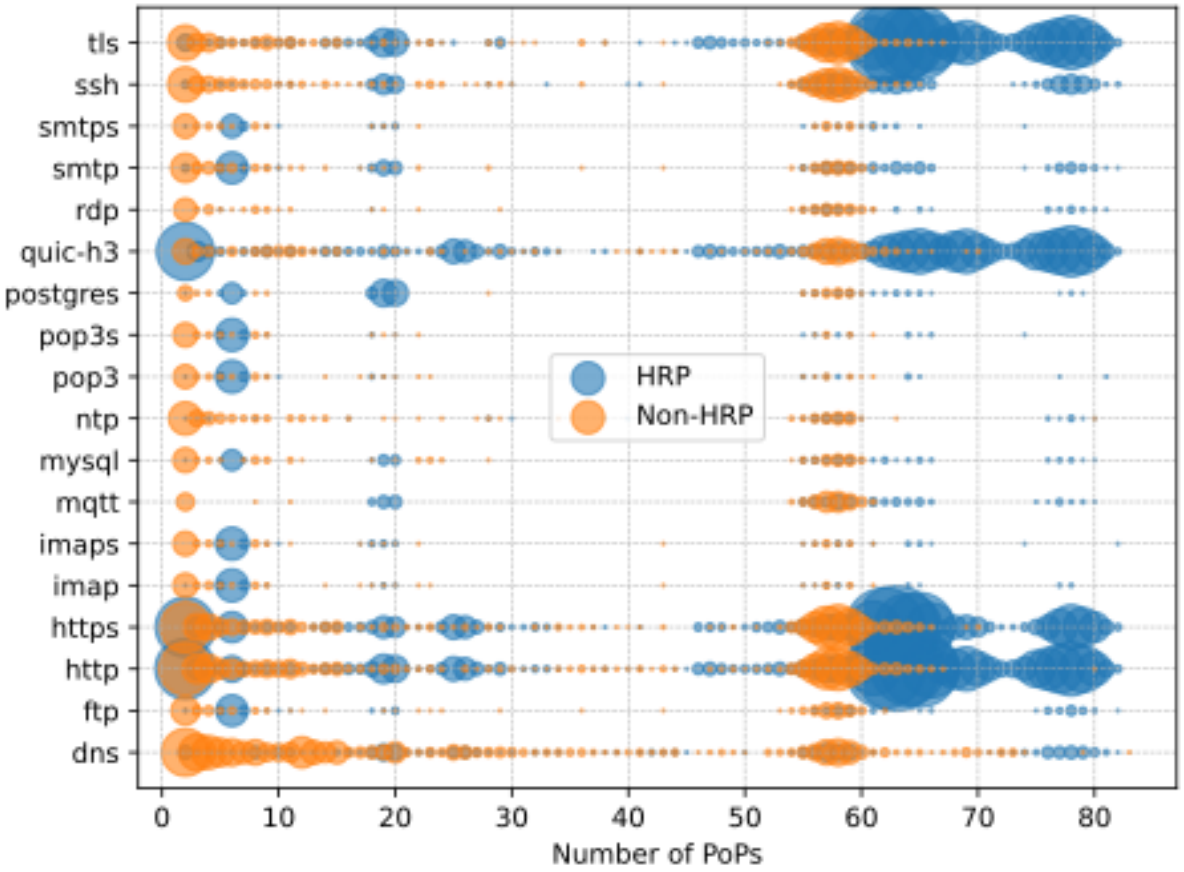
Open INTEL

>1k gTLDs, 204.1M domains (Feb. 18th 2026)



Services and PoPs

- Service-PoP distribution (when the same anycast prefix is measured in multiple locations):
  - services on small deployments (<15 PoPs)
  - medium (between 15 and 50 PoPs)
  - large (50+ PoPs)
- DNS is distributed across multiple PoPs
- Web has heavy presence on large deployments (50+ PoPs)
- Most of the services are deployed across multiple PoPs



Multi Vantage Point Scanning

0.8

Avg. Jaccard similarity (NL vs AU vantage pts)

0.9

Jaccard (DE vs AU) follow-up measurement

4%

Prefixes visible from AU are not TCP/UDP responsive from NL

Services are generally deployed consistently across locations, but discrepancies do exist

Conclusions

- In our research, we identified multiple services on anycast prefixes using the state-of-the-art data set and measurement tools
- Our contributions are:
  - We show evidences of consolidation where top 5 ASes originate 88% of active anycast IPs
  - We show BYOAS deployment pattern, revealing a hidden dependency in anycast
  - We find multiple services under anycast prefixes, with few operators driving the modernization of Web content delivery with QUIC
  - We show an increase in use of anycast in the authoritative name servers, with top 5 operators accounting for 66% of domains with authoritative NS on anycast

Thank you

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Github repo + dataset

Open to Work

Gustavo’s CV