A First Look at Deployment Strategies of Services Provisioned using Anycast

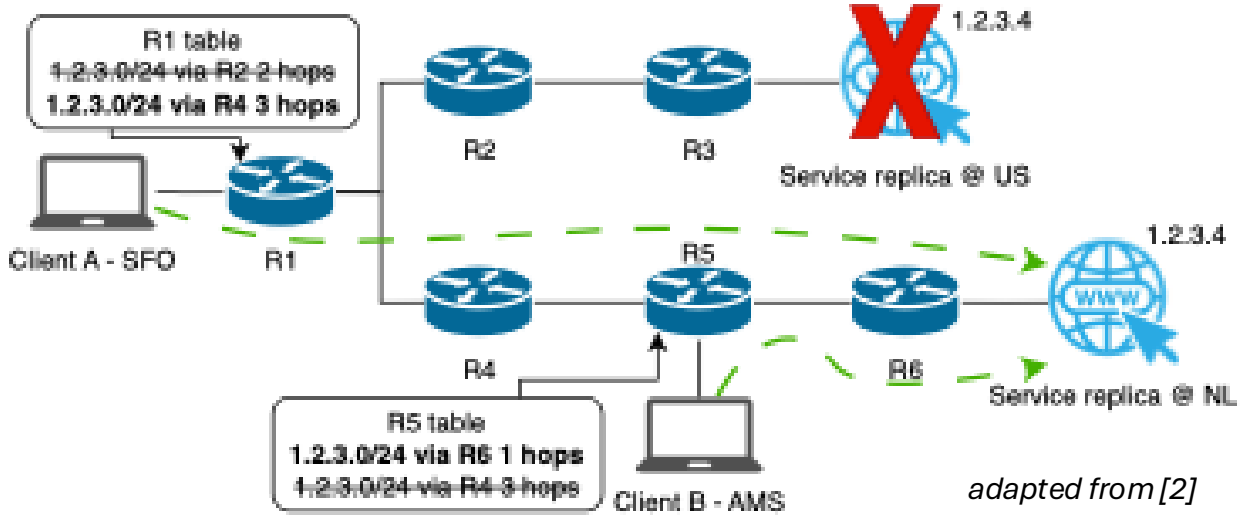
Remi Hendriks

WIDE Camp, Sep’26, Kyoto

UNIVERSITY
OF TWENTE.

What is Anycast?

- Making a service address available in multiple locations (Points of Presence – PoPs) *[1]*
- Using BGP to 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

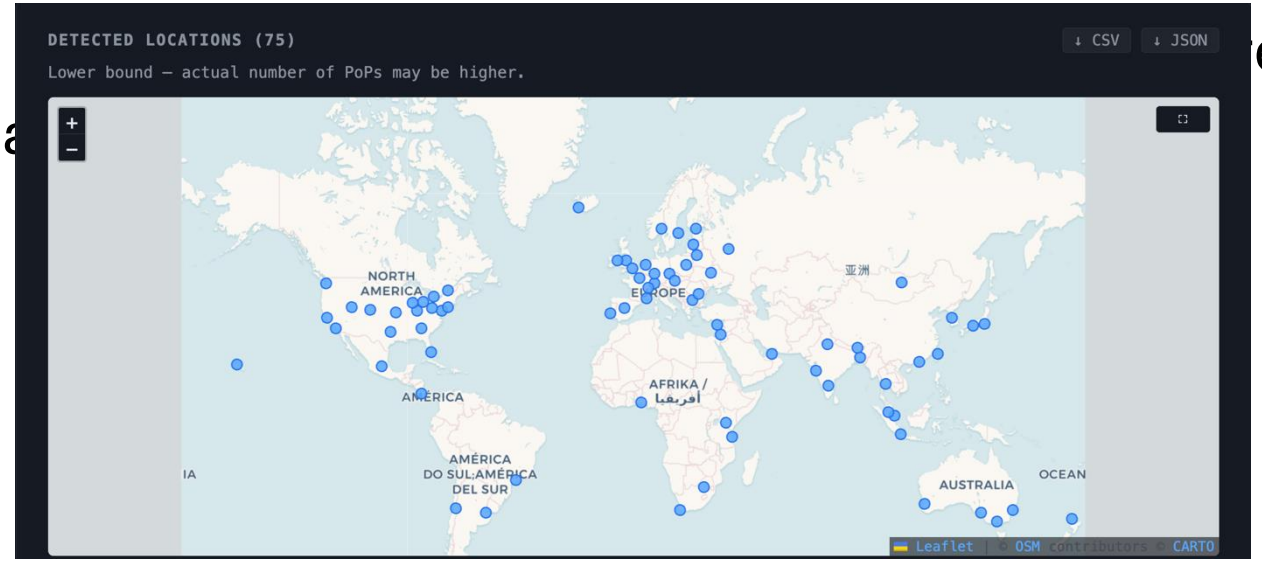
- How do operators deploy their anycast infrastructure?
  - AS topology
  - Geographic distribution
  - IP address utilization
- What services do operators replicate using anycast?
  - Transport layer
  - Application layer

Research questions

- **How do operators deploy their anycast infrastructure?**
  - AS topology
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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

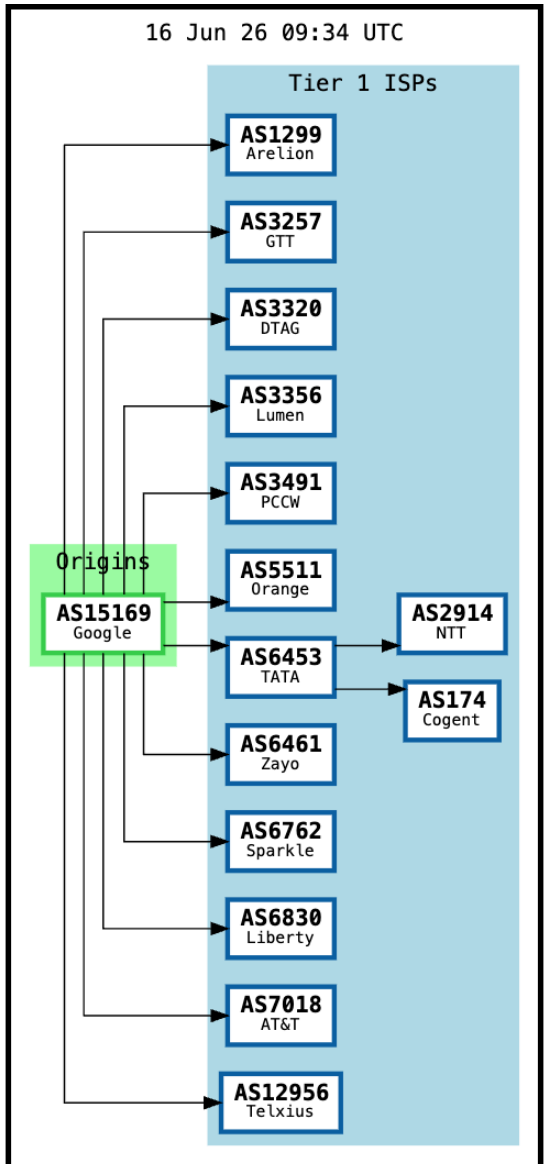
- Inferring upstream AS
  - Using data shared by E
- Expected: Large variet
- Reality:

ixes

refix-level granularity)

ue to distributed nature

37%
of IPv4 routed prefixes
have a single upstream

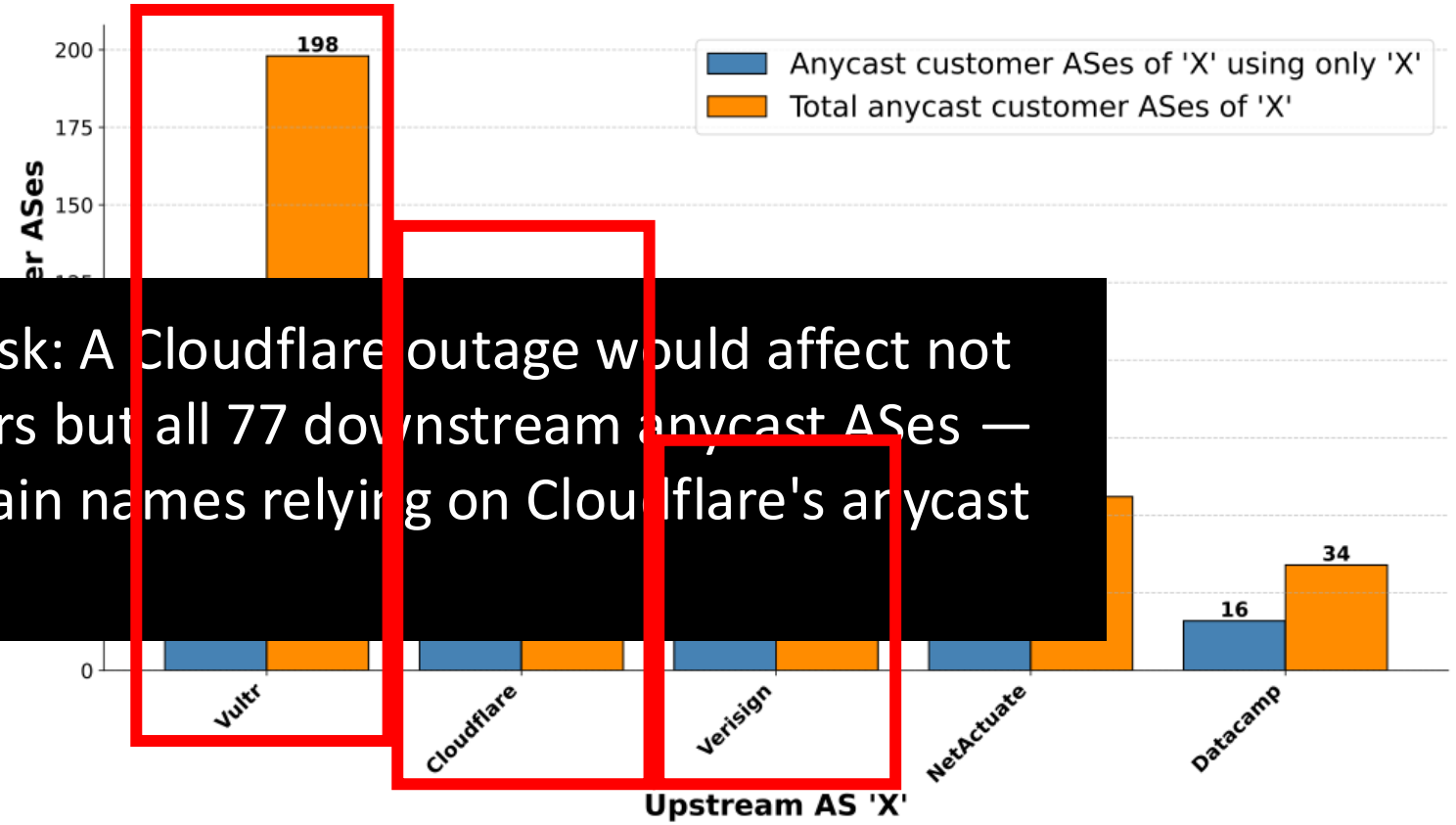


29%
of IPv6 routed prefixes
have a single upstream

Example: Upstream connectivity for 8.8.8.8 (Google)

Anycast Topology: Upstream Providers

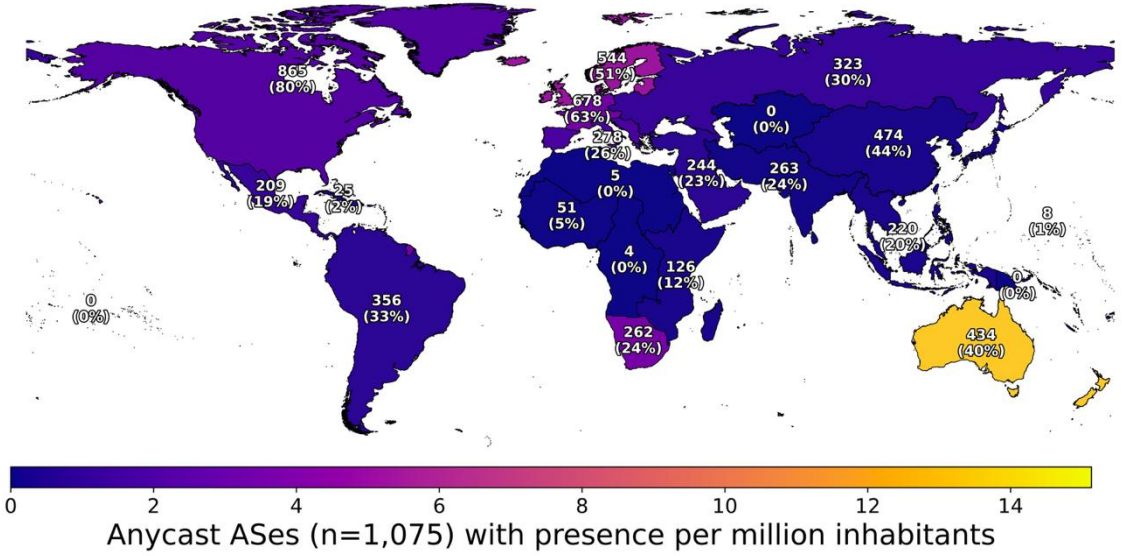
- Single upstream ASes
- Mostly BYOAS Providers
  - Bring-Your-Own-AS
- 198 (1/5) ASes use Vultr
  - 84
  - Aff
- Cloud
  - *E.g*
  - Rep
- Verisign
  - Same Org links (MOAS)



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.

Where do anycast operators deploy services?

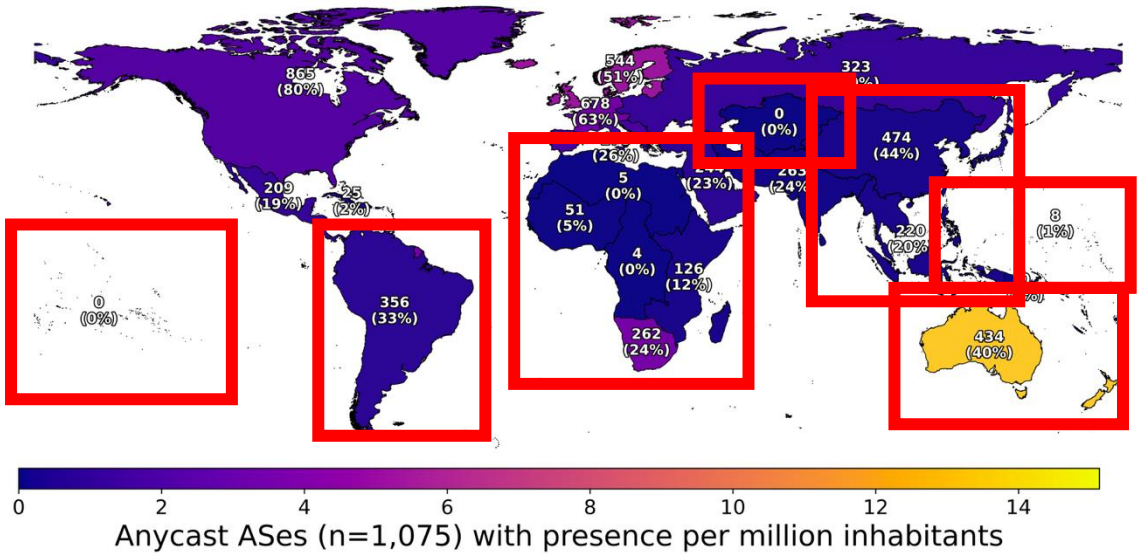
- Geolocation data from LACeS
  - Limitation: lower-bound of real deployment
- Normalized by inhabitant count



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

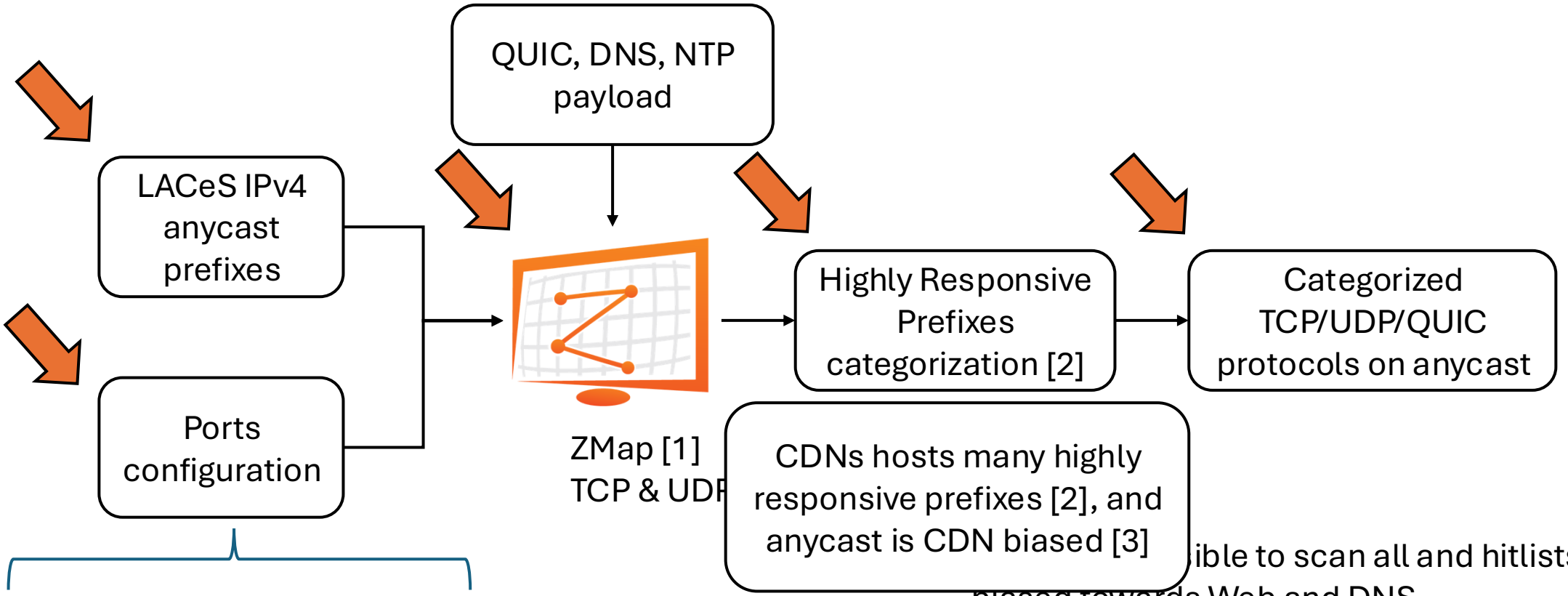
Where do anycast operators deploy services?

- 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*

Scanning methodology



[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

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

IP Utilization

- IPv4 anycast -> smallest prefix size /24 (255 addresses)
  - Why
  - How
  - Do c
- Main fi
  - 77%
  - *E.g.,*
  - CDN
  - The top 5 ASes originate 88 % of active anycast /24s

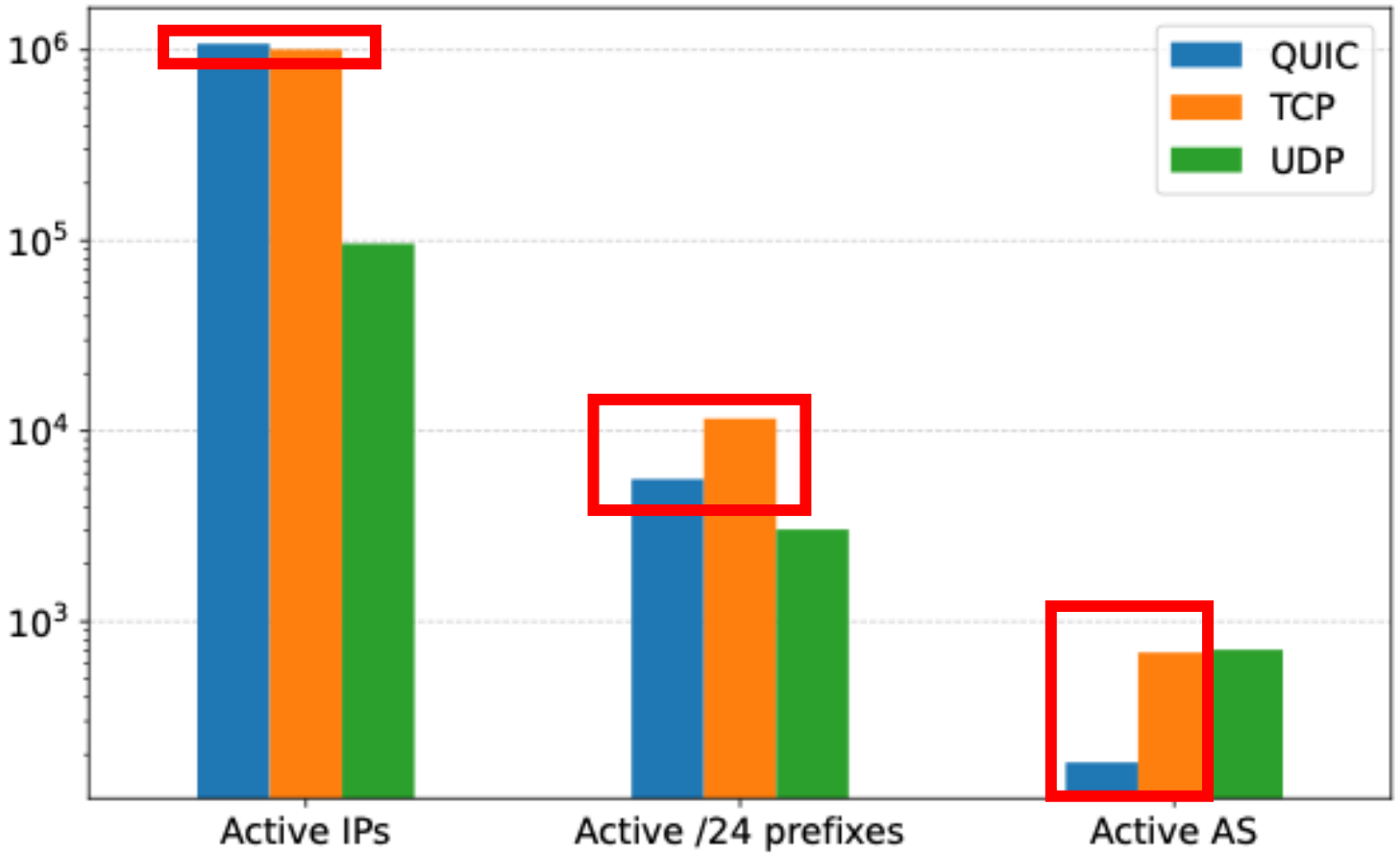
Org (ASN)	Active IPs	/24s	Active IP ratio
Cloudflare (13335)	658×10^3	2 866	0.896
Google (396982)	492×10^3	4 298	0.447
Fastly (54113)	209×10^3	827	0.989
AWS (16509)	133×10^3	1 603	0.325
Cloudflare (209242)	60×10^3	270	0.862

Research questions

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- **What services do operators replicate using anycast?**
  - Transport layer
  - Application layer

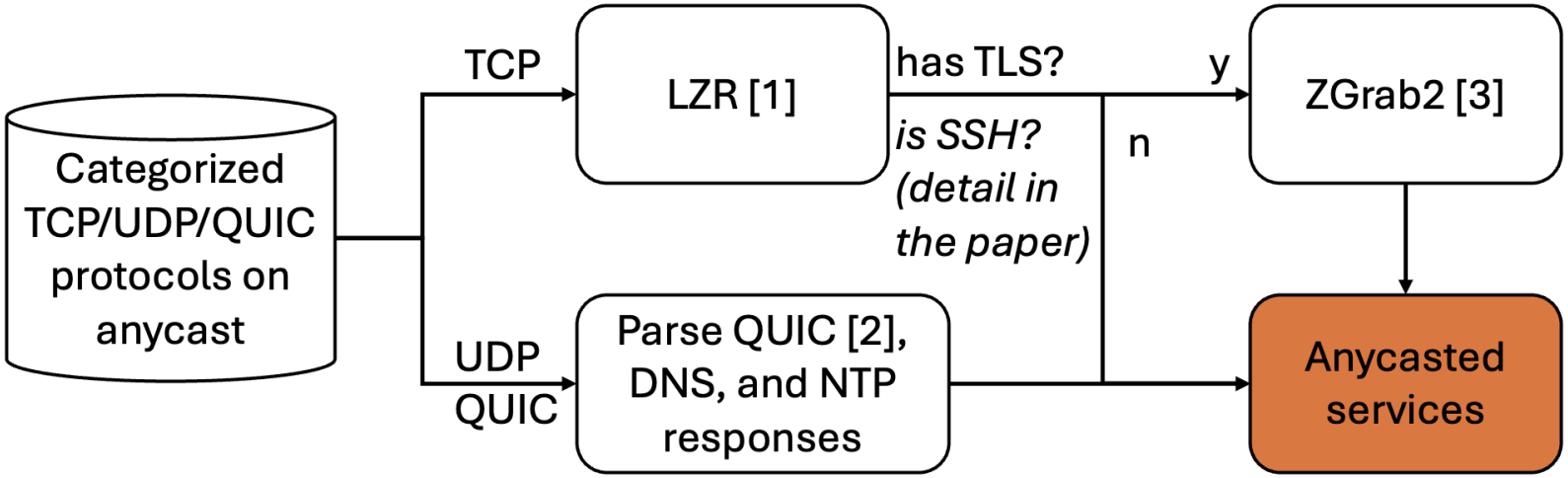
Anycast Utilization on Transport Layer

- Stateful services common
- **Infrastructure modernization:** QUIC has substantial adoption
  - ~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)



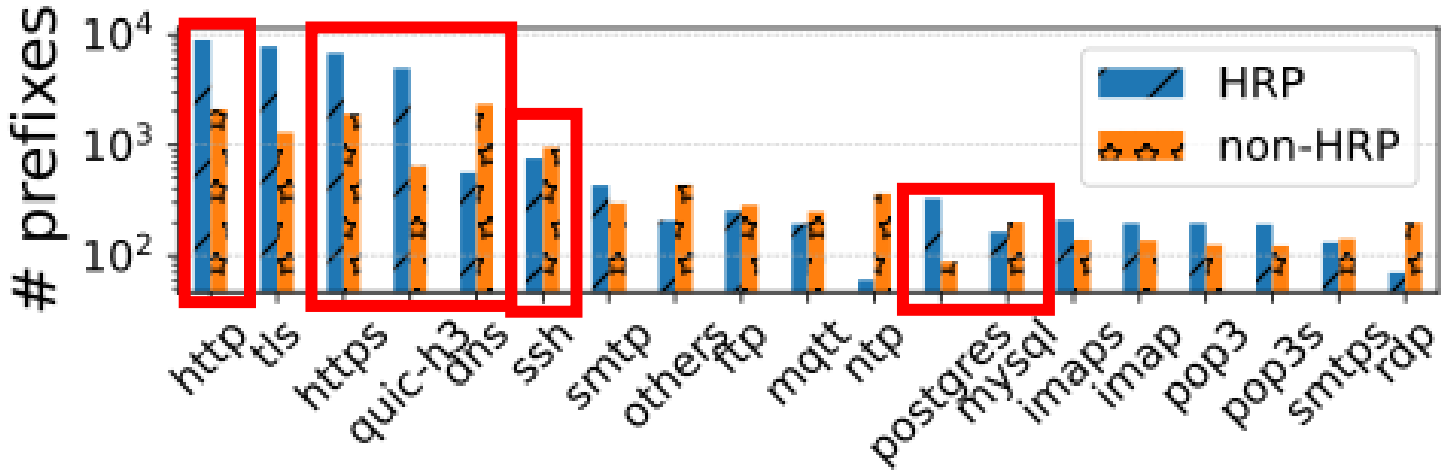
Detecting Services on Anycast

- Find services running on open ports found previously
- Using LZR[1], QUIC scanner [2] Zgrab2[3]



[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.

Anycast Utilization on Application Layer

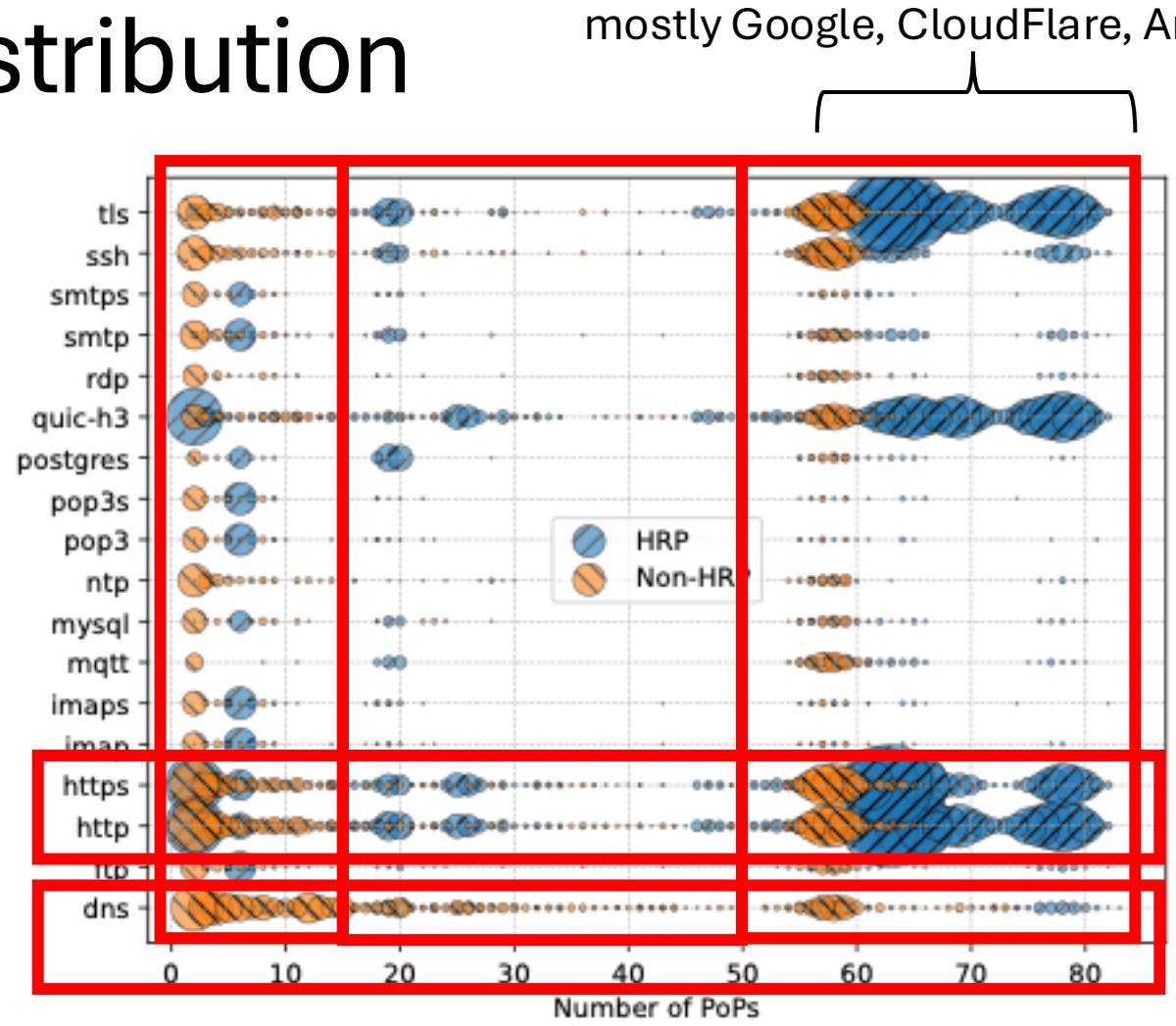


- **Service-oriented:** Nearly all (96%) of anycast prefixes host at least one service
  - Dominance of Web and DNS
- SSH instances could be a proxy, different machines, or a misconfiguration.
  - default OpenSSH behavior to listen on all local addresses, which may cause exposure of the unicast address unintentionally to anycast
- Databases: exposure possibly due to misconfiguration, where online tutorials recommend binding to 0.0.0.0 and relying on firewall rules [1]

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

Services and PoPs distribution

- **Deployment characteristics:**
  - services clustered 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)



Conclusions

- We characterized the deployment of anycast prefixes, showing:
  - How they deploy their infrastructure
  - Which services they replicate
- 5 ASes originate 88% of anycast IP addresses hosting services
- BYOAS is common, revealing a hidden dependency in anycast
- Geographical distribution is often not equitable
- IP/prefix level: Web most popular (TCP & QUIC)
  - Heavy preference for large deployments
- AS level: DNS most popular
  - Seen at both small and large deployments

Github repo + dataset

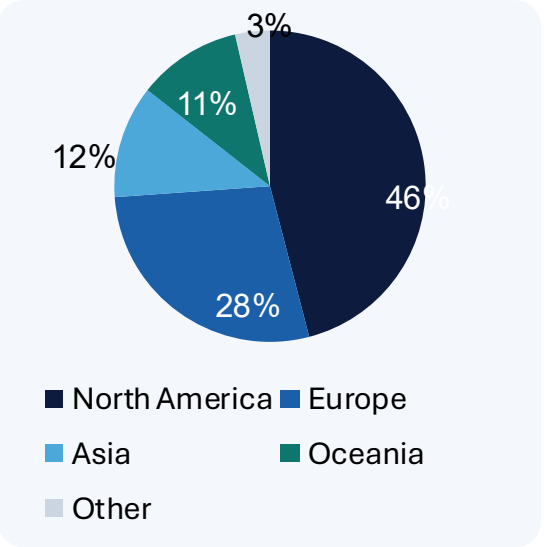
Appendix slides

Regional Anycast

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

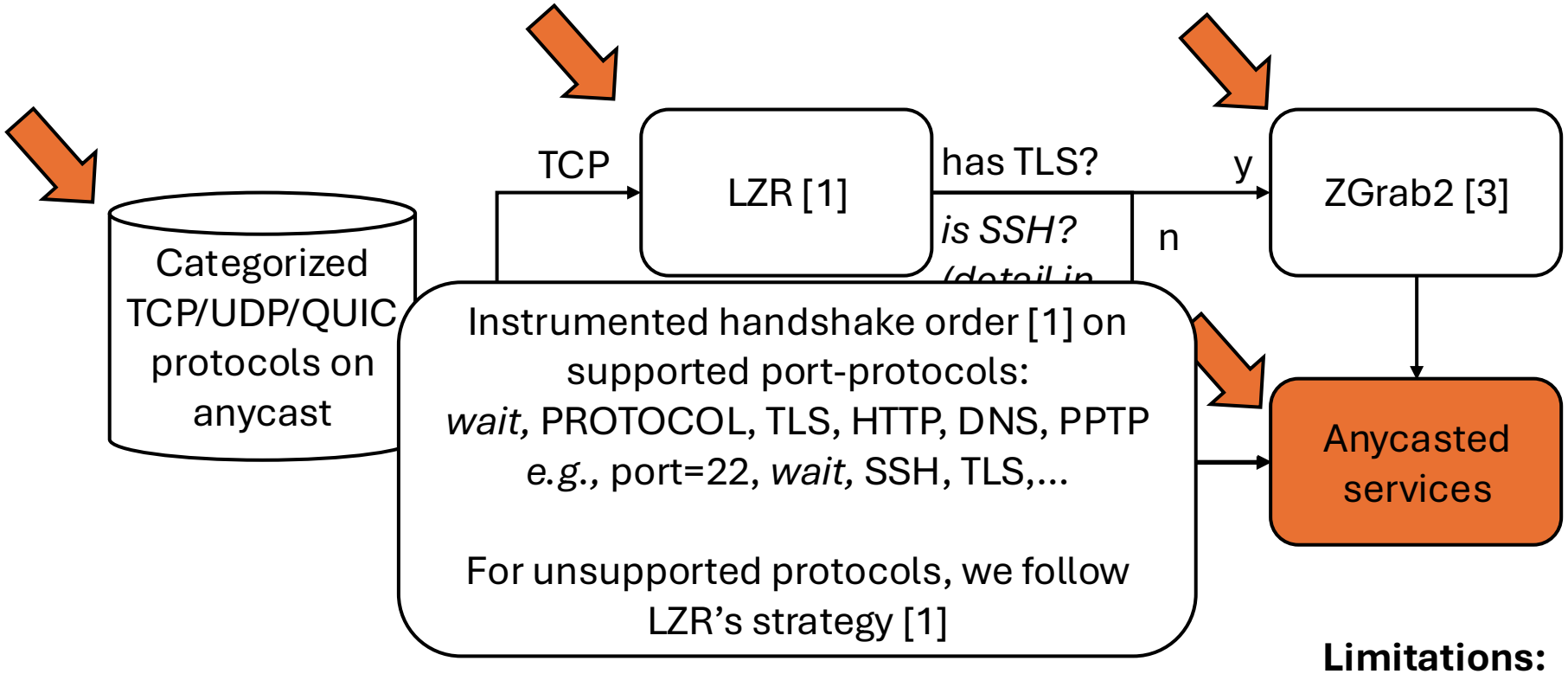
35%
ASes with ≥1 prefix confined to 1 continent

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)

Detecting Services on Anycast



Limitations:

- LZR covers only 32 protocols

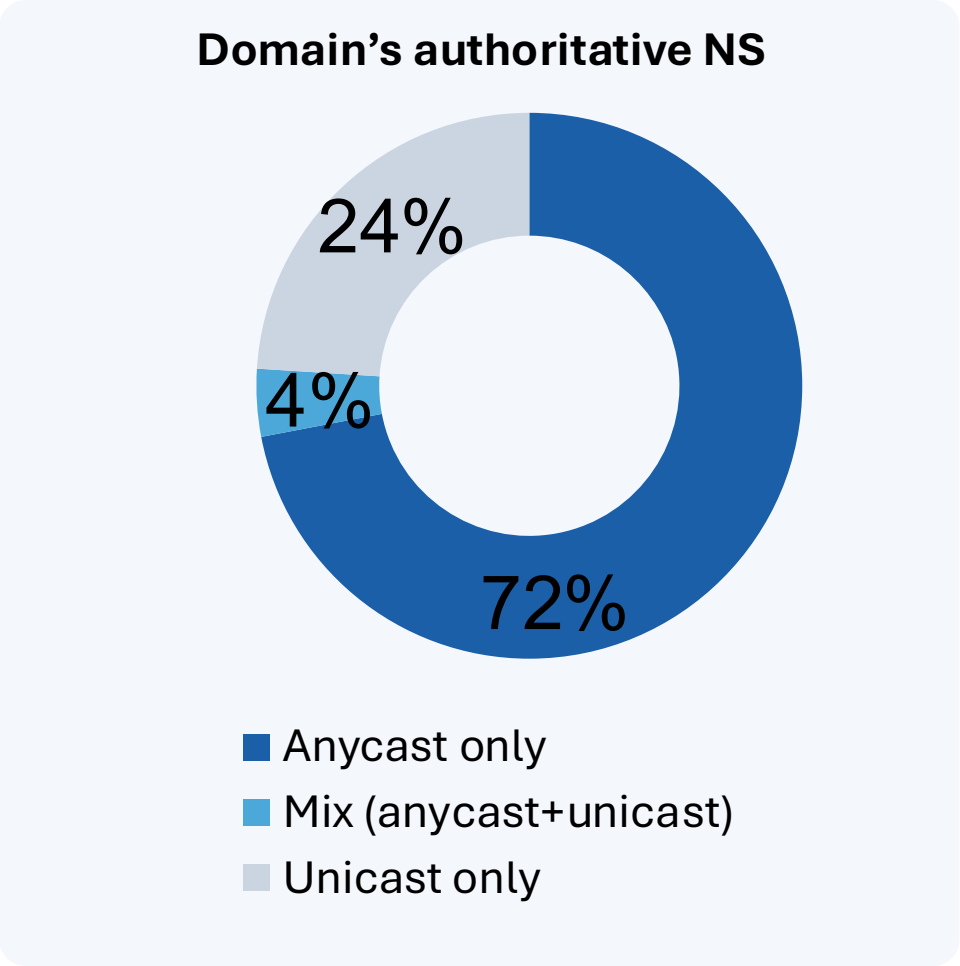
[1] Izhikevich et. al, "LZR: Identifying unexpected internet services," in USENIX Security 2021.
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[3] Durumeric et. al, "A search engine backed by internet-wide scanning," CCS 2015.

DNS on Anycast

- Growth of DNS authoritative nameservers on anycast
  - 72% in 2026 vs. 57% in 2021
- Mix deployments can result in higher DNS name resolution latency [1].
- 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)



[1] Muller et. al "Recursives in the wild: engineering authoritative DNS servers," IMC 2017.

Multi Vantage Point Service Scanning

$$J_{service} = \frac{|VP_1 \cap VP_2|_{prefixes}}{|VP_1 \cup VP_2|_{prefixes}}, \qquad J_{service} \in [0,1]$$

0.8

Avg. Jaccard similarity (NL vs AU VPs)

44 (<1%)

Anycast prefixes hosting a service are visible from AU are not visible from the NL

0.9

Avg. Jaccard similarity (DE vs AU VPs) follow-up measurement

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