Characterization of Anycast Adoption in the DNS Authoritative Infrastructure

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Introduction: DNS Evolution

- The Domain Name System (DNS) was originally designed to distribute both **load** and **responsibility**.
- Traditionally, Resilience relies on explicit nameserver replication and resolver failover (multiple NS records).
- Over time, another network-layer mechanism emerged:
  IP Anycast

How does Anycast work?

- In IP anycast, geographically diverse servers use **same** IP address.
- When a client sends a packet to this IP address, the packet will automatically be **routed** to the **(topologically) closest replica.**
- In case of failure, normal **Internet routing processes** will re-route packets to the next closest replica.
- Replica selection shifts from an explicit choice (**resolver**) to an implicit one (**BGP routing**).

History of Anycast Adoption in DNS Infrastructure

- Over the past decade, anycast was widely adopted by root name servers.
- In 2013, Xun et al. found **56% to 72% of TLD authoritative nameservers** had adopted anycast.
- Our work relied on publicly available anycast census data developed by Cicalese et al. and Sommese et al., and expands their original analysis.

Our Contribution

We investigated both TLD and SLD anycast adoption, shedding light on changes between **2017** and **2021**.

We analyzed reasons behind the increase in anycast adoption by comparing across TLDs and providers.

We assessed implications of anycast adoption for DNS resilience risk profiles.

Dataset

OpenINTEL Measurement Data: 187.5 million responsive domains across 1053 TLDs (2017-2021).

Historical Root Zone File from DNS-OARC archive (2017-2021).

Anycast census performed with iGreedy by Cicalese et al. in June 2017.

Anycast census we performed with MAnycast2 and iGreedy in January 2021.

Anycast Adoption by TLDs

- Top Level Domains have a critical role in the DNS hierarchy.
- Our results show increased deployment of anycast in TLD authoritative nameservers.
- In 2017, 93% of TLDs were using anycast (in whole or in part).
- In 2021, the percentage rose to 97%.
- Many ccTLDs moved from unicast to anycast.
- There was also clear expansion in number of replicas per IP.

Some BAD news

The .kr (Kirbati) TLD switched from fully anycast to mixed.

Three ccTLDs (.ve, .pa and .cd) switched from mixed anycast to unicast.

For .pa and .ve this is related to the sunset of the Internet System Consortium (ISC) secondary authoritative anycast service on January 31, 2020.

In 2021 half of the DNS relies on Anycast

- Using DNS data provided by the OpenINTEL project, we mapped the anycast adoption of ~65% of the global DNS SLDs infrastructure.
- In 2021, more than half of responsive SLDs use an anycast deployment for their nameservers.
- Compared to 2017, domains relying upon anycast increased by 11.7%.
- Domains relying on mixed infrastructure increased by 1.6%
- But only 2.3% of the nameservers are anycast!

	2017				2021			
Type	**Anycast**	**Unicast**	**Mixed**	**Total**	**Anycast**	**Unicast**	**Mixed**	**Total**
#SLD	74.2M (45.1%)	84M (51.1%)	6.2M (3.8%)	164.4M	106.4M (56.8%)	70.9M (37.8%)	10.2M (5.4%)	187.5M
#NS(IP)	10700	899028	N/A	909728	18179	756459	N/A	774638

Anycast implies concentration?

- Top 10 anycast organizations in 2017 and in 2021 are responsible for ~92% of domains adopting anycast.
- Top 10 unicast organizations count only for the 63%.
- GoDaddy alone accounted for half of domains adopting anycast.

Org	SLD	%	Org	SLD	%
GoDaddy	44145357	54.53%	Google.	3433523	4.24%
CloudFlare	6955596	8.59%	Uniregistry	2376567	2.94%
1&1 IONOS	4808600	5.94%	Akamai	1451470	1.79%
DynDNS	3883403	4.80%	Amazon	1068653	1.32%
VeriSign	3878585	4.79%	One.com	1016796	1.26%

TABLE V: Top 10 Anycast Organizations 2017, responsible for 90% of the anycast adoption. GoDaddy was market leader.

Org	SLD	%	Org	SLD	%
GoDaddy	52681291	44.11%	1&1 IONOS	6033089	5.05%
Cloudflare	15252317	12.77%	NSONE	3160888	2.65%
Google	11014408	9.22%	Amazon	2949373	2.47%
NeuStar	7968959	6.67%	NetActuate	1902258	1.59%
Zenlayer	6800764	5.69%	Tencent	1781520	1.49%

TABLE VI: Top 10 Anycast Organizations 2021, responsible for 92% of the anycast adoption. GoDaddy's market share slightly decrease, Cloudflare increased.

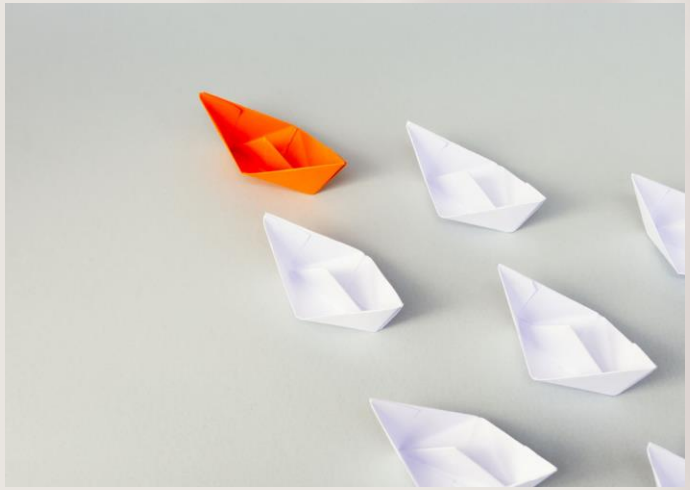
Domain owners choose anycast?

- OVH, a popular European hosting provider, offers optional* anycast service for DNS nameservers for €1.21/year.
- Nearly all SLDs using OVH's authoritative infrastructure use unicast.
- We measured 4,156,201 domains using OVH's unicast infrastructure.
- Only 130,951 domains were using anycast.

*The service is offered during the purchase of a new domain

Role of registrars in anycast adoption

- Popular registrars play a fundamental role in adoption
- In ccTLDs SLDs, our data shows lower adoption of 37.3%.
- Case Study: Sweden (.se) vs Netherlands (.nl)
  - .se has high anycast adoption, due to its larger registrar Loopia AB
  - .nl has a lower anycast adoption, due to the use of unicast by TransIP B.V.



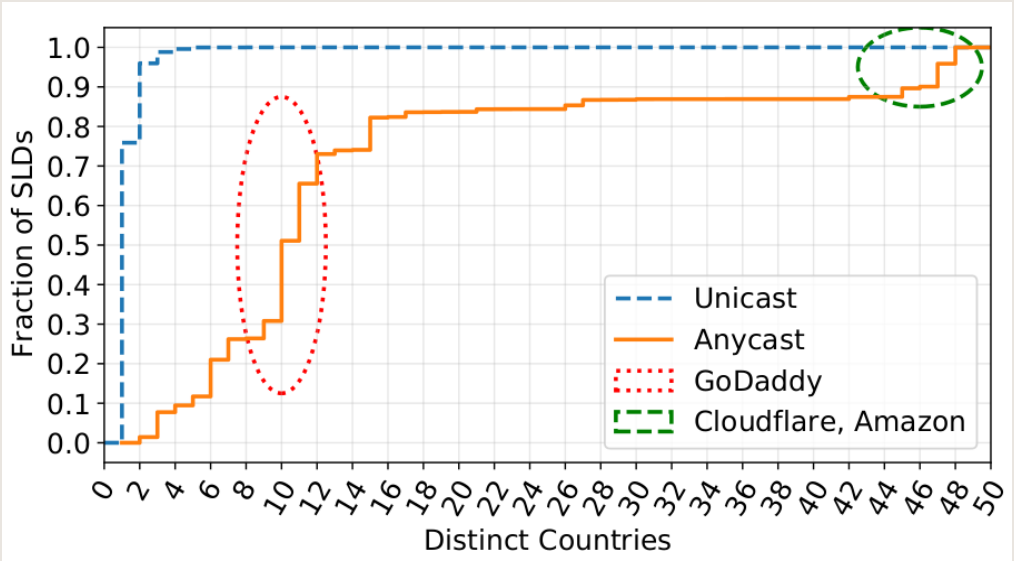
Implication of Anycast Adoption For DNS Resilience Risk Profiles

Anycast Failure Mode

- With anycast, resilience is not explicit in the DNS, but manifests in the routing system.
- Anycast hides (some of) the replica choice decision from the client.
- If all NS entries point to same IP, resolution relies entirely on anycast.
- If then a server or subnet fails silently, then everyone routed to that advertiser is effectively black-holed.

Anycast and Diversity

- Anycast authoritative nameserver deployments tend to use fewer IP addresses, since anycast provides diversity via the routing system.
- Anycast deployments are usually concentrated in a single ASN.
- Anycast deployments tent to be more globally distributed.



Do not use Anycast as Holy Grail of resilience!

- Loopia AB serves ~500K domains via anycast from a single /24 block.
- This means that Loopia relies as its only resilience mechanism uniquely on anycast, with all the consequences related to the possible silent failing of one instance.
- Same applies to 1&1 IONOS SE, responsible for ~6.8 million domains, announcing their anycast network from a single routed /22 block.

Conclusion

- We found high adoption of anycast as a resilience mechanism, reaching 97% for TLDs and 62% for SLDs in 2021.
- This adoption is driven mostly by engineering choices of few very large DNS infrastructure providers.
- Anycast adoption changes the DNS service availability risk profile but does not eliminate all risks.
- Future work will focus on characterizing the resilience of anycast, unicast, mixed deployments, including implications on performance metrics such as resolution latency.

Questions?