Mapping the Anycast landscape

CENTR Meeting - Frankfurt, Germany

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caida

RIPE NCC

SIDN

Providing a daily anycast census

- Funded by **RIPE NCC Community Project Fund**
- Establishing measurement pipeline
- **A reliable daily census of anycast**
  - **Publicly available** for operators and researchers



Anycast census; why?

- Anycast is one of the most effective distribution and **resilience** techniques
  - Used for critical Internet services (e.g., DNS)
  - Deployed by CDNs for low-latency, reliability, ..
  - DDoS mitigation (used to provide DDoS protection services)

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- Anycast is **opaque**
  - Unknown if an address is anycast
  - Unknown if a service is provided using anycast
  - Unknown where anycast sites are located

Why does an operator care?

- Knowing what is, and what is not, Anycast helps with:
  - Network troubleshooting
  - Resilience assessment of third parties
  - Better traffic engineering choices

15:40

Realizing the census

- Daily measurement pipeline utilizes **two methodologies**
  - **Anycast-based**
  - **Latency-based**

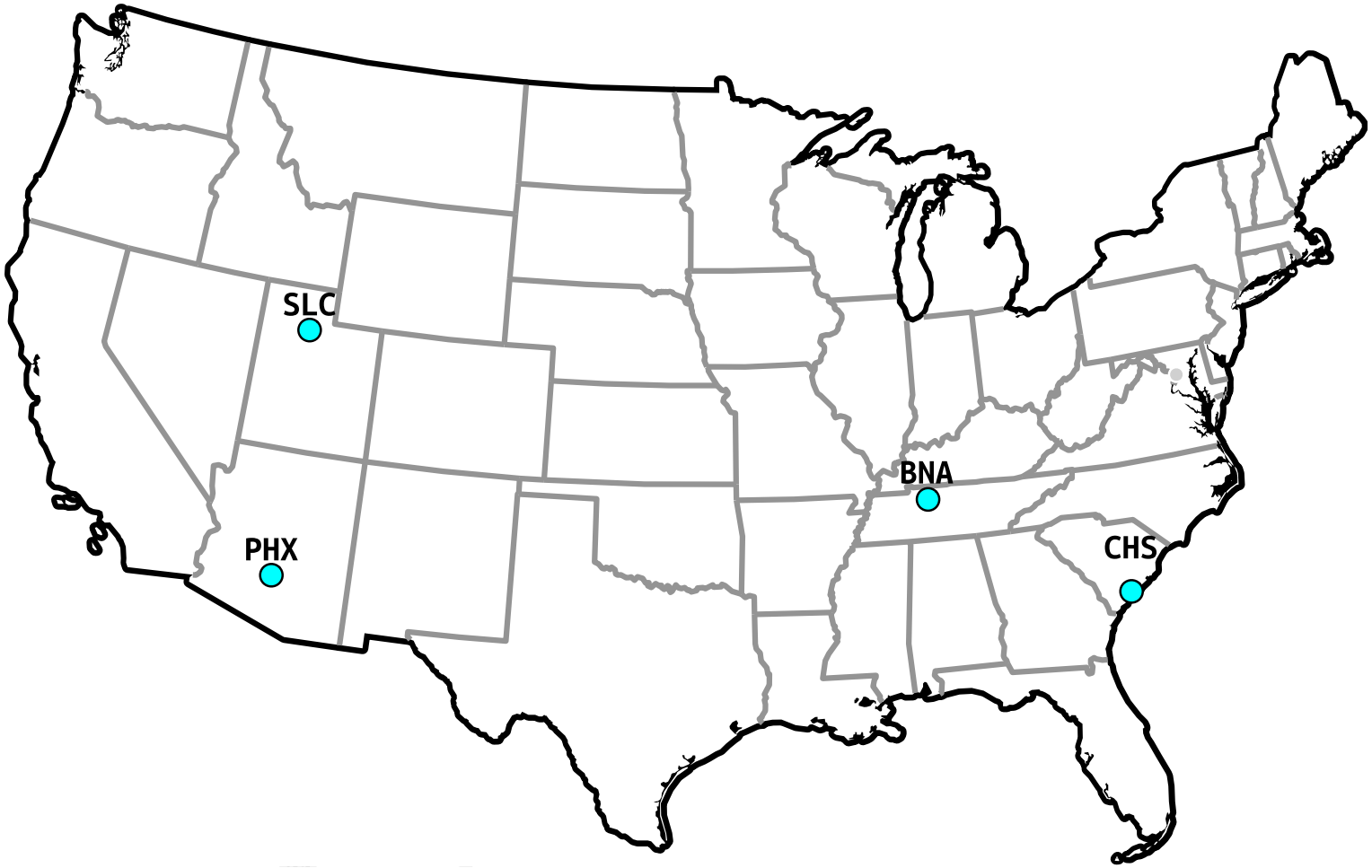
- Anycast-based measurement uses **MAnycast²** approach
  - Developed in an IMC2020 submission [1]
  - Leverages the concept of using anycast to measure anycast

- Latency-based measurement based on iGreedy [2]

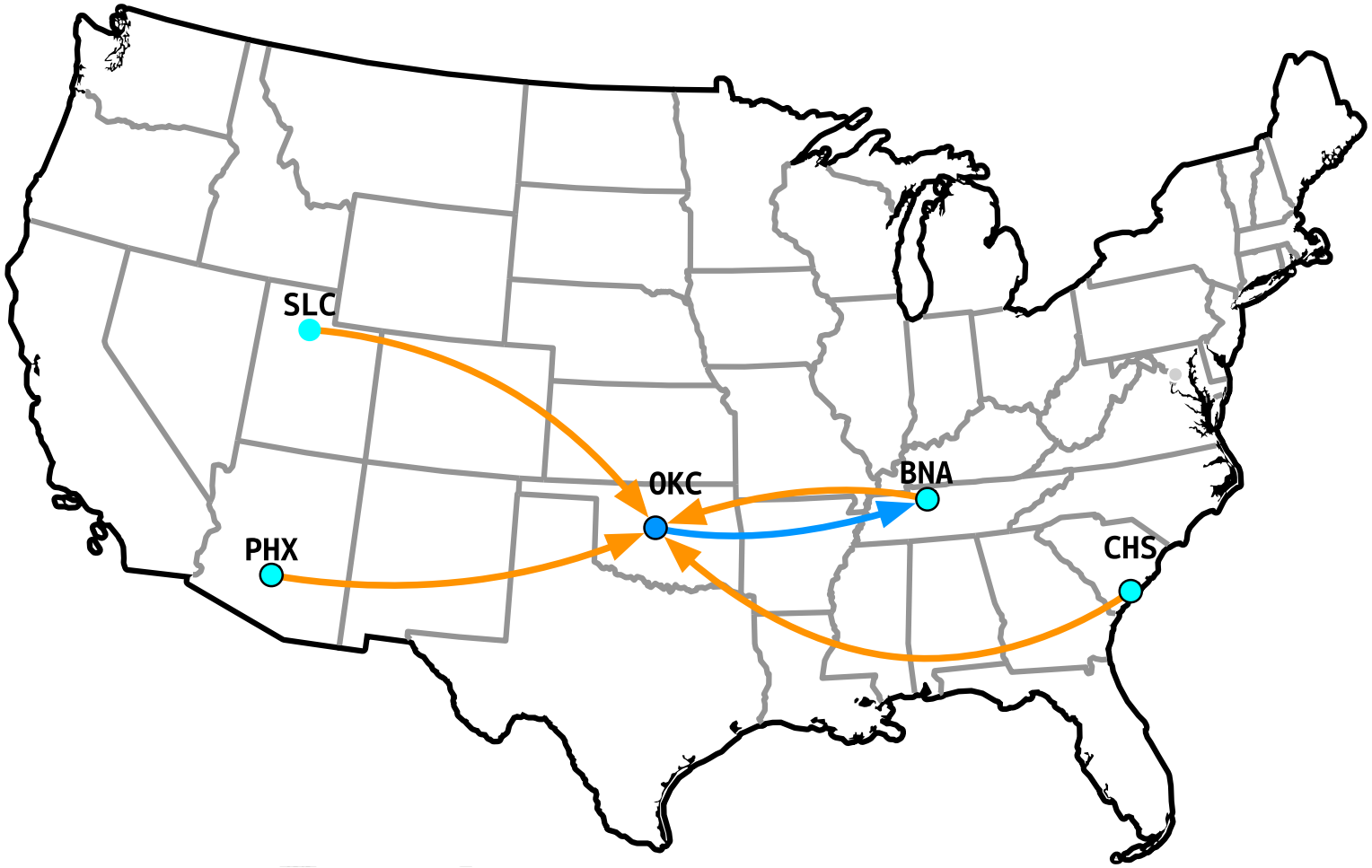
[1] Sommese et al. "MAnycast²: Using Anycast to Measure Anycast" ACM IMC '20

[2] Cicalese et al. "Latency-Based Anycast Geolocation: Algorithms, Software, and Data Sets," in IEEE Journal on Selected Areas in Communications '16

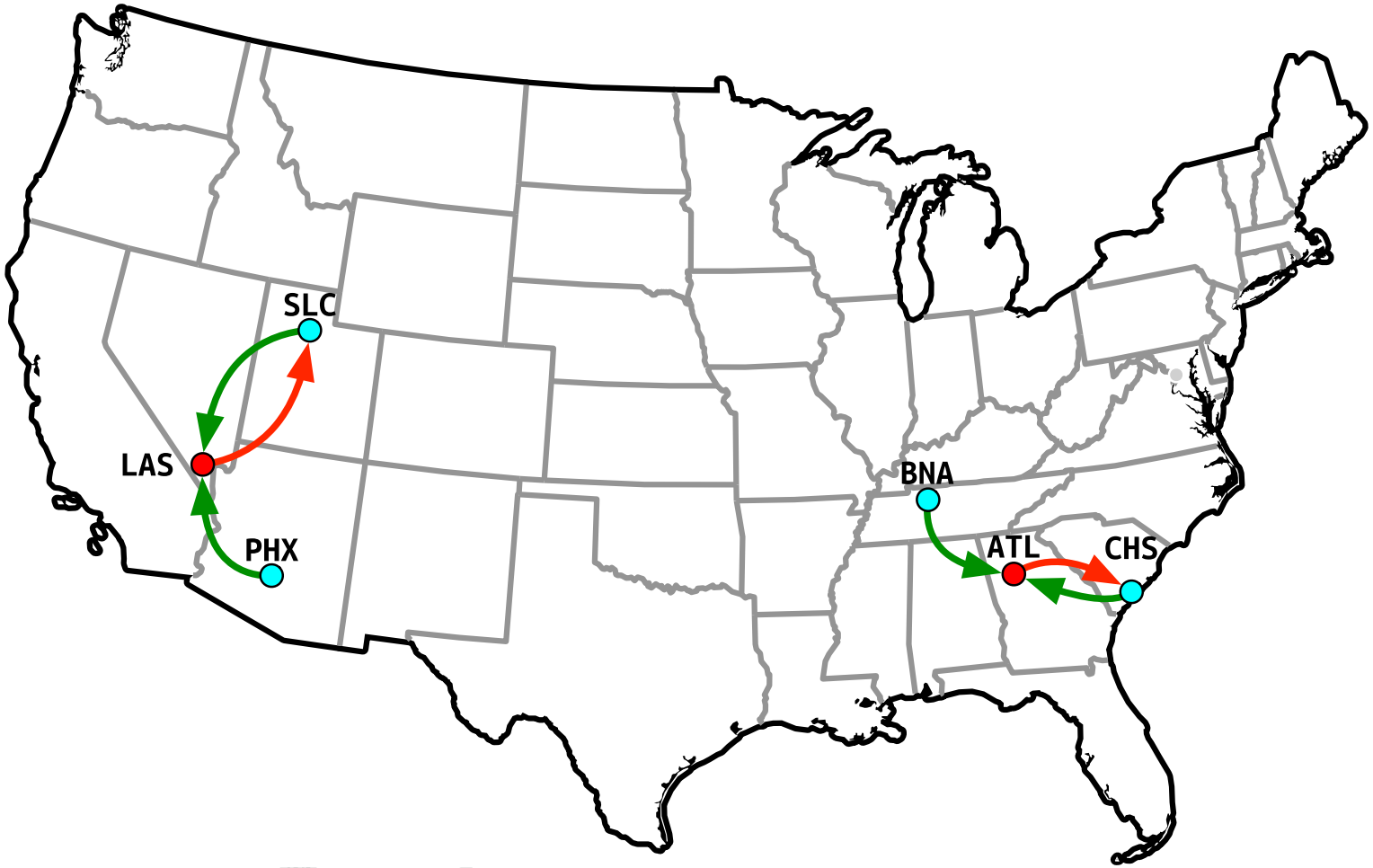
Anycast-based measurement Set-up



Anycast-based measurement
Unicast



Anycast-based measurement
Anycast



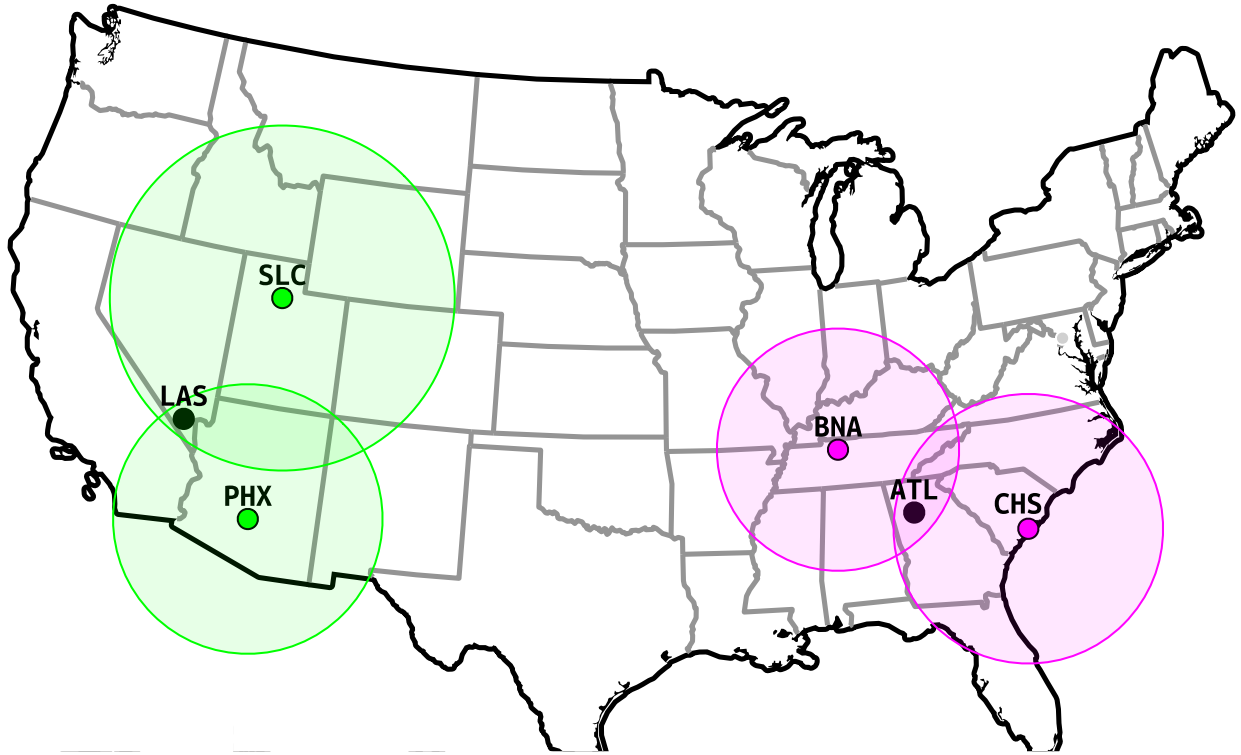
Anycast-based measurement
Pros and cons

- Pros:
  - **Low probing-cost** (suitable for Internet scale measurement)
  - **Low FP rate** (rarely misclassifies anycast as unicast)
- Cons:
  - **Considerable FP rate** (falsely classifying unicast as anycast)
    - Caused by *e.g.,* route flips
  - **No geolocation** of sites (only detection & enumeration)

GCD measurement

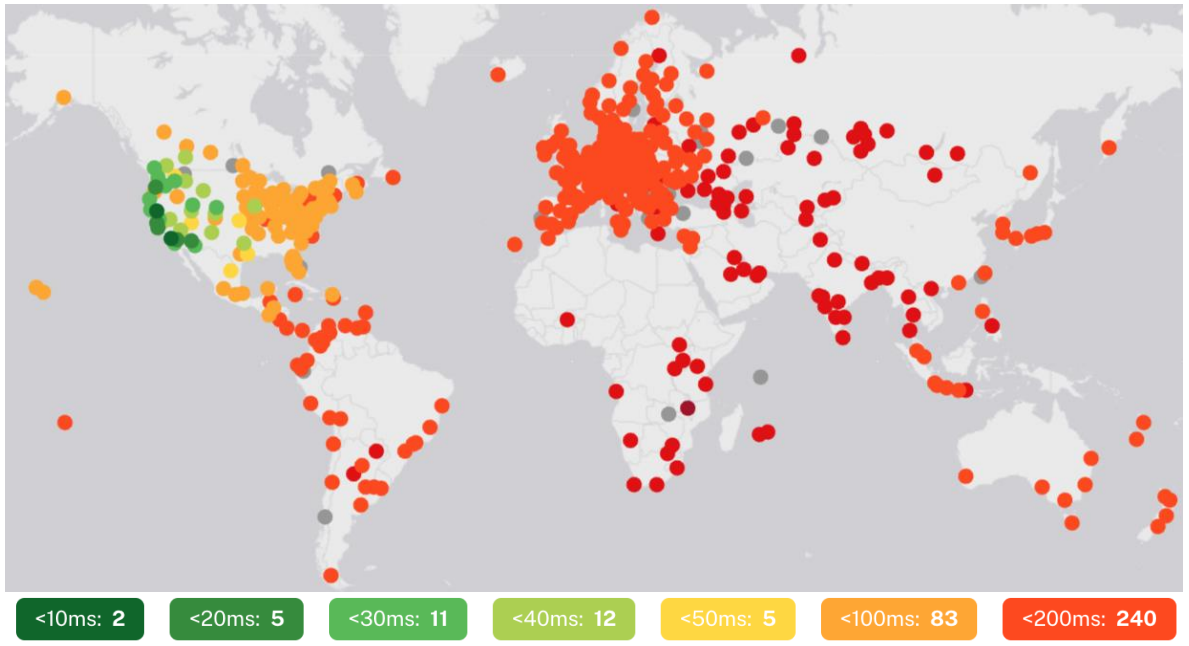
- GCD (**Great Circle Distance**)
- Latency-based measurement using **speed-of-light violations**
- Current state-of-the-art
- Pros:
  - Low FP/FN rate (**highly accurate**)
  - **Geolocation possible**
- Cons:
  - Requires large measurement platform (e.g., RIPE Atlas, CAIDA Ark)
  - High probing cost

  (unsuitable for Internet scale)



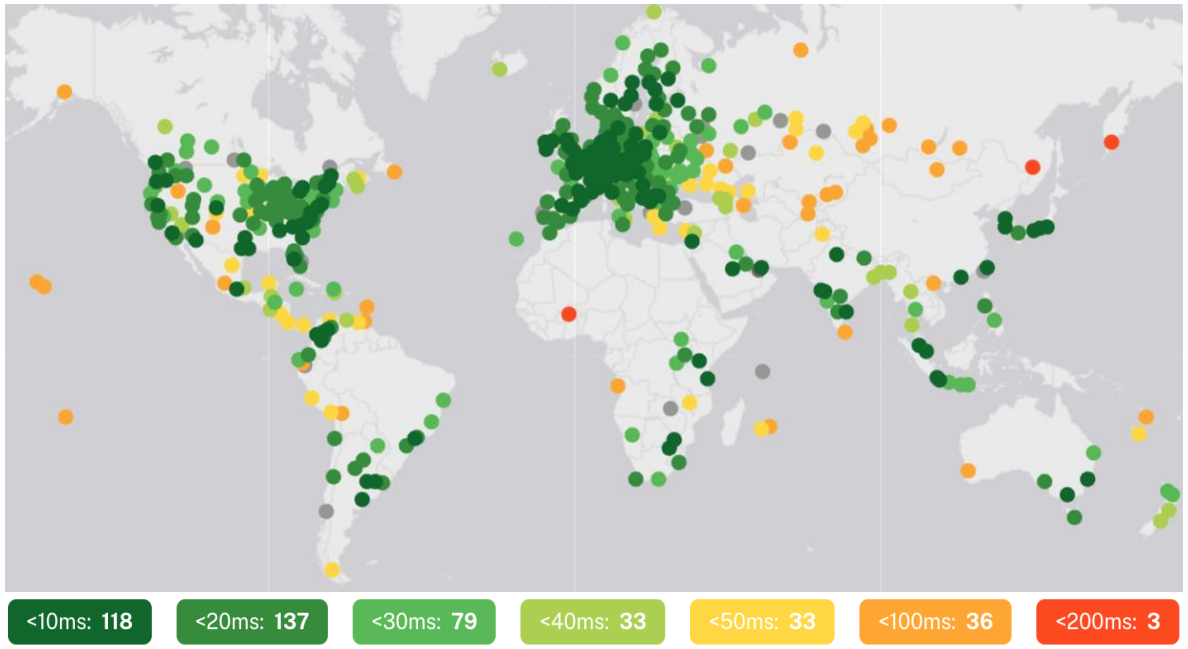
GCD measurement
RIPE Atlas example

Unicast



https://atlas.ripe.net/measurements/79147535/

Anycast



https://atlas.ripe.net/measurements/79137270/

RIPE NCC
RIPE Atlas

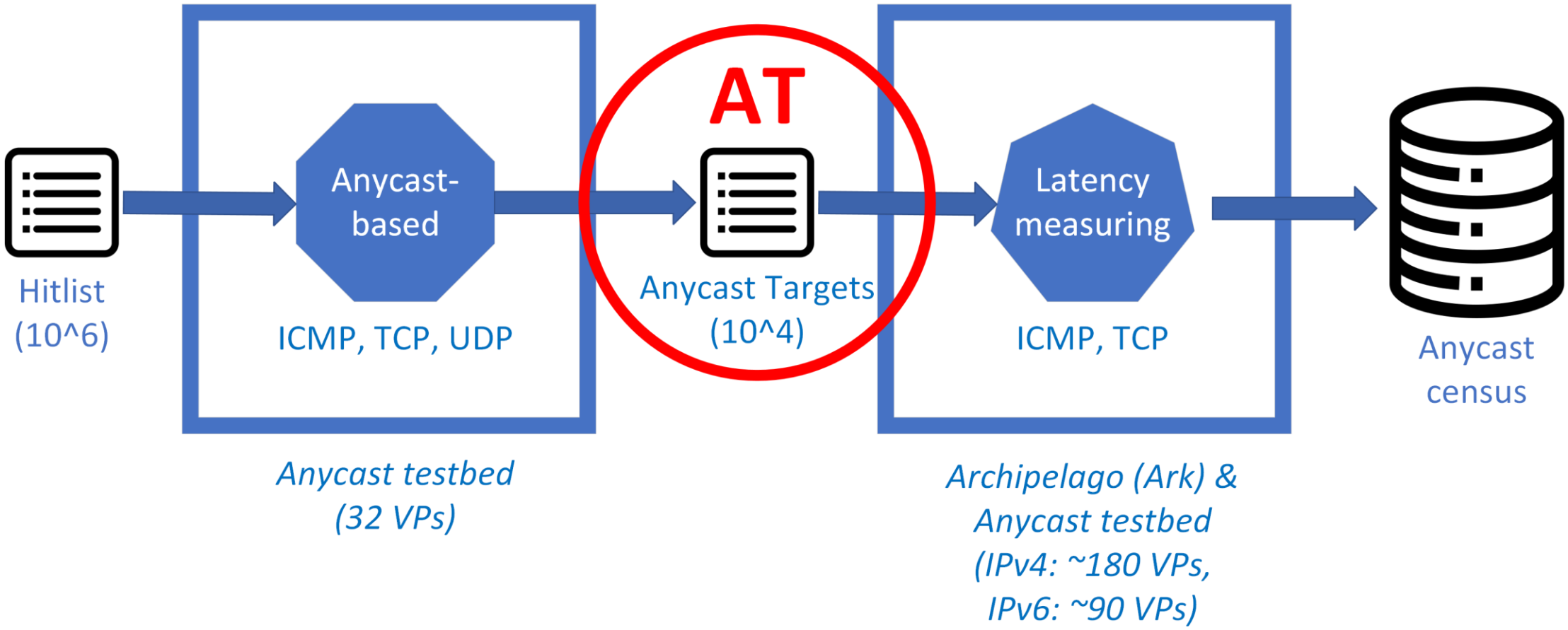
We combine the two

- Perform anycast-based census
  - Input: Internet wide hitlist (USC/ISI IPv4, TUM + OpenINTEL IPv6)

    (10^6 prefixes)
  - Output: set of "*anycast targets" (**AT**)* (includes TPs and FPs)
- Perform GCD-based measurement
  - Input: ***AT***

    (10^4 prefixes)
  - *Output: Anycast prefixes + enumeration + locations individual sites*

Pipeline


Hitlist
(10^6)
Anycast-based
ICMP, TCP, UDP
AT
Anycast Targets
(10^4)
Latency measuring
ICMP, TCP
Anycast census
Anycast testbed
(32 VPs)
Archipelago (Ark) &
Anycast testbed
(IPv4: ~180 VPs,
IPv6: ~90 VPs)

Anycast-based measurement tool

- Developed anycast measurement tool
  - Scalable
  - Efficient
  - Robust
  - Responsible
  - Coverage: IPv4, IPv6, TCP, DNS, ICMP, ..
- Deployed using Vultr
  - 32 locations
  - 19 countries, 6 continents

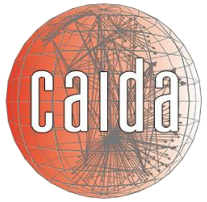
Anycast-based measurement tool

- Anycast operator use-cases:
  - Catchment analysis at Internet scale in minutes
  - Measure multiple prefixes simultaneously -> side-by-side comparison
  - Measure Internet regions experiencing undesired load-balancing

Latency-based measurement system

- GCD measurements with CAIDA's Ark [1] and Vultr VPs
  - ~ 180 vantage points
- Implemented using Scamper [2] tool

- Accurate geolocation and enumeration of 'small' anycast deployments
- Geolocation and enumeration up to 60 distinguishable sites for 'large' deployments



[1] https://www.caida.org/projects/ark

[2] https://www.caida.org/catalog/software/scamper/

Results
GCD-confirmed prefixes

- ~12.3k anycasted /24s (783 ASes)
- ~5.9k anycasted /48s (364 ASes)
- 249 ASes found to anycast both IPv4 and IPv6

Results
GCD-confirmed prefixes

AS	Organization	IPv4	IPv6	
396982	Google Cloud	3,345	3	
13335	Cloudflare	3,131	162	
16509	Amazon	1,235	86	✓
54113	Fastly	438	56	✓
15169	Google	282	6	
209242	Cloudflare Spectrum	234	2,836	
19551	Incapsula	2	292	
12041	Afilias	222	207	
44273	GoDaddy	31	122	

Table 6: Largest ASes originating anycast prefixes for IPv4 and IPv6.

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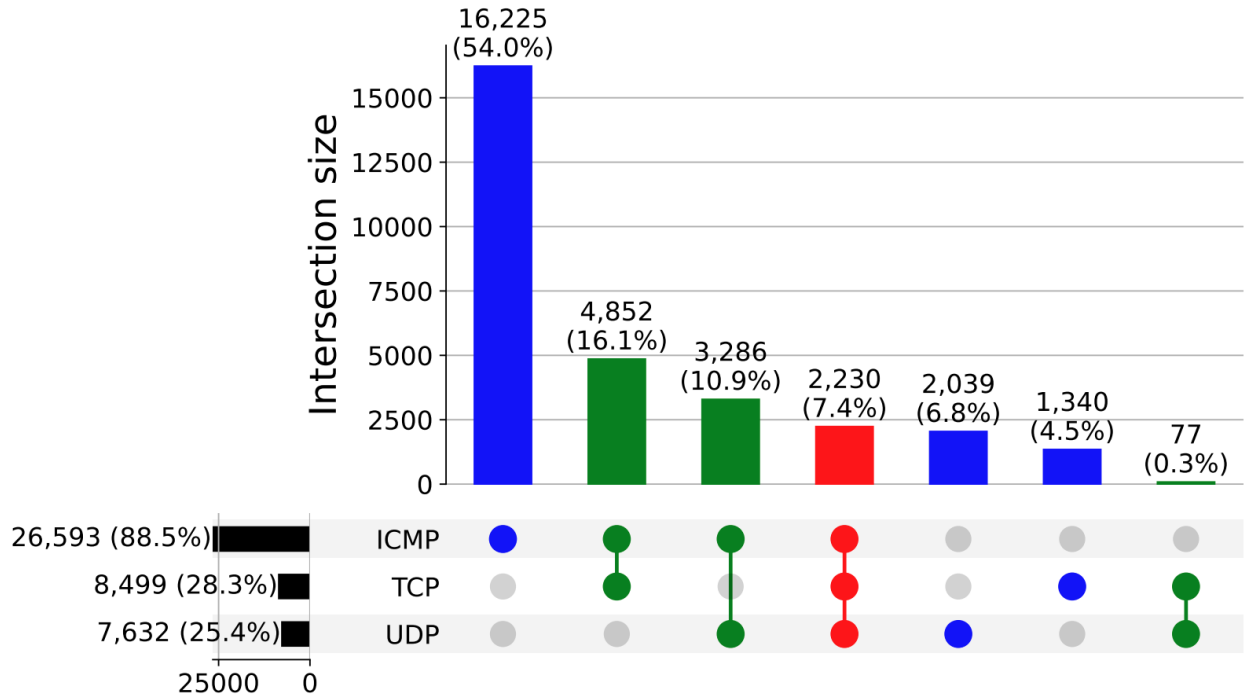


Figure 6: MAnycastR detection of anycast candidates for ICMPv4, TCPv4, and UDPv4.

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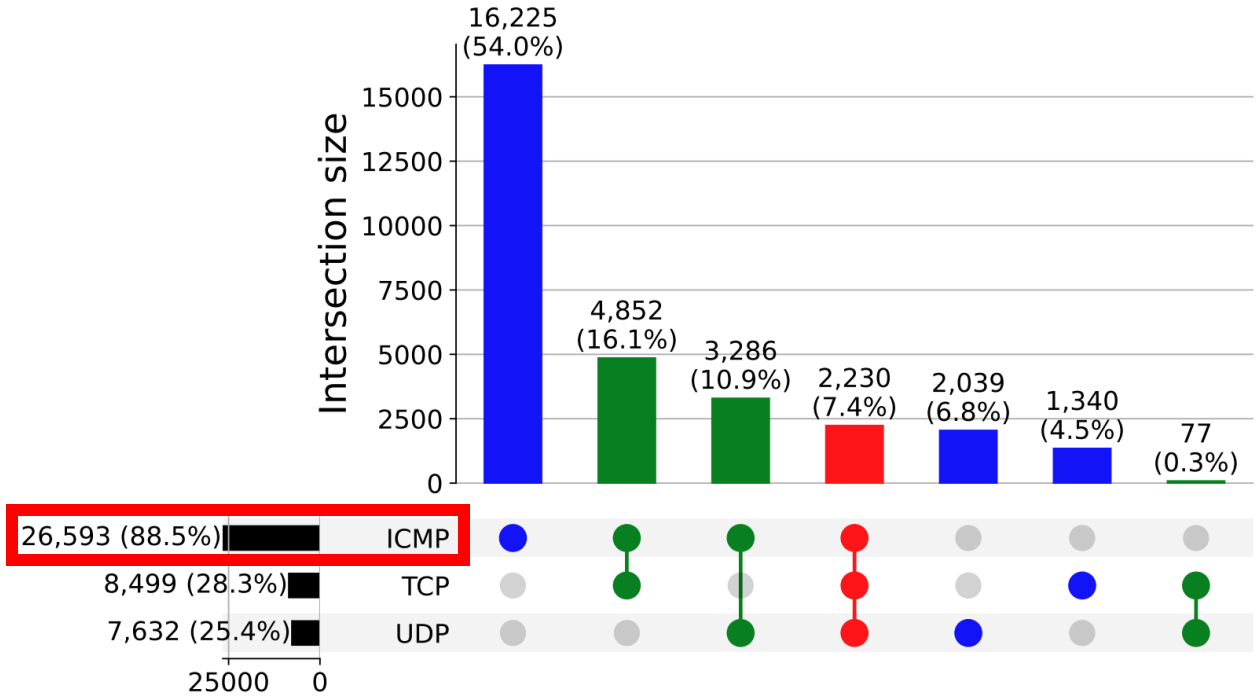


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Main takeaways:

- Majority detectable using ICMP (89%)

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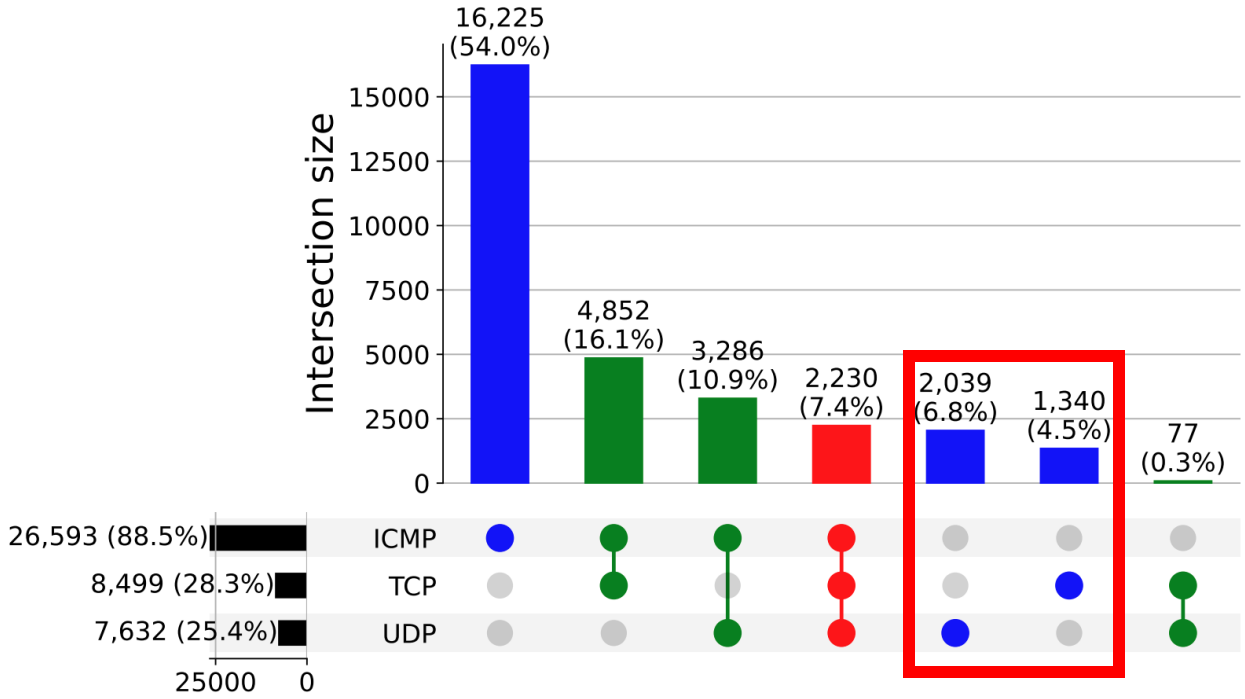
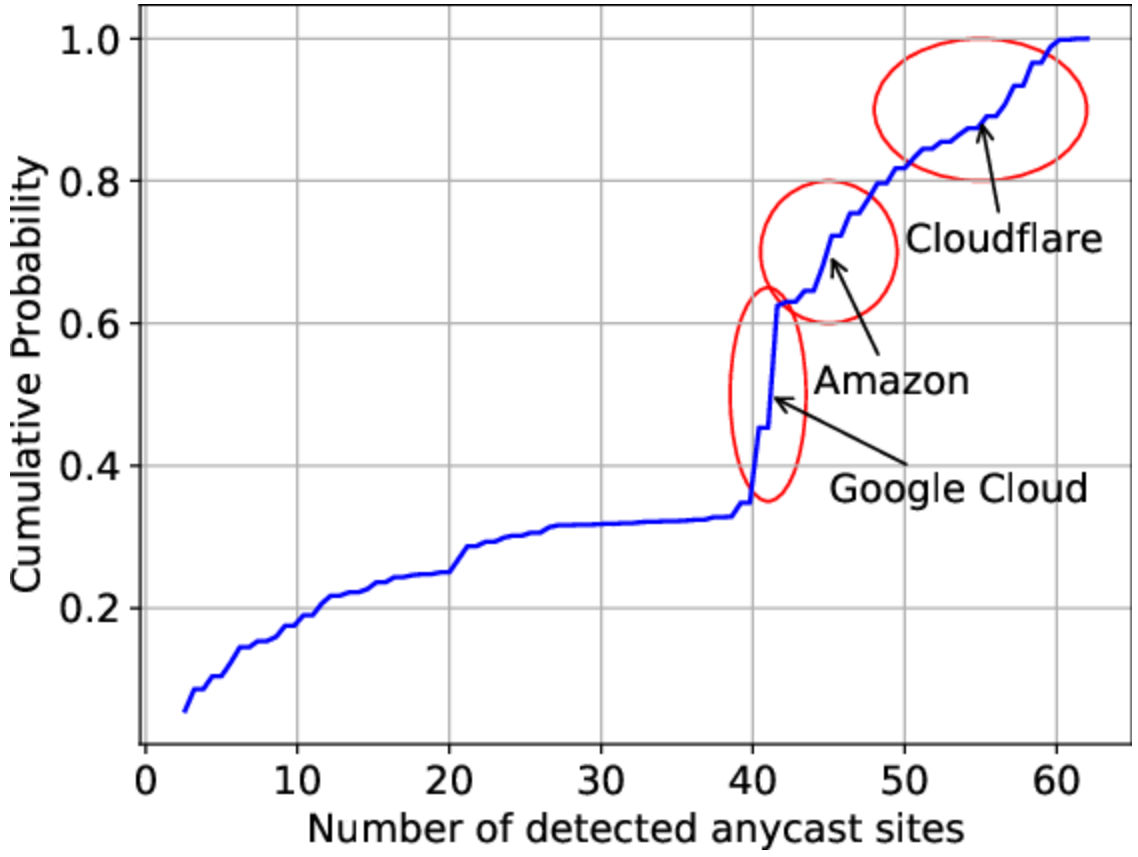


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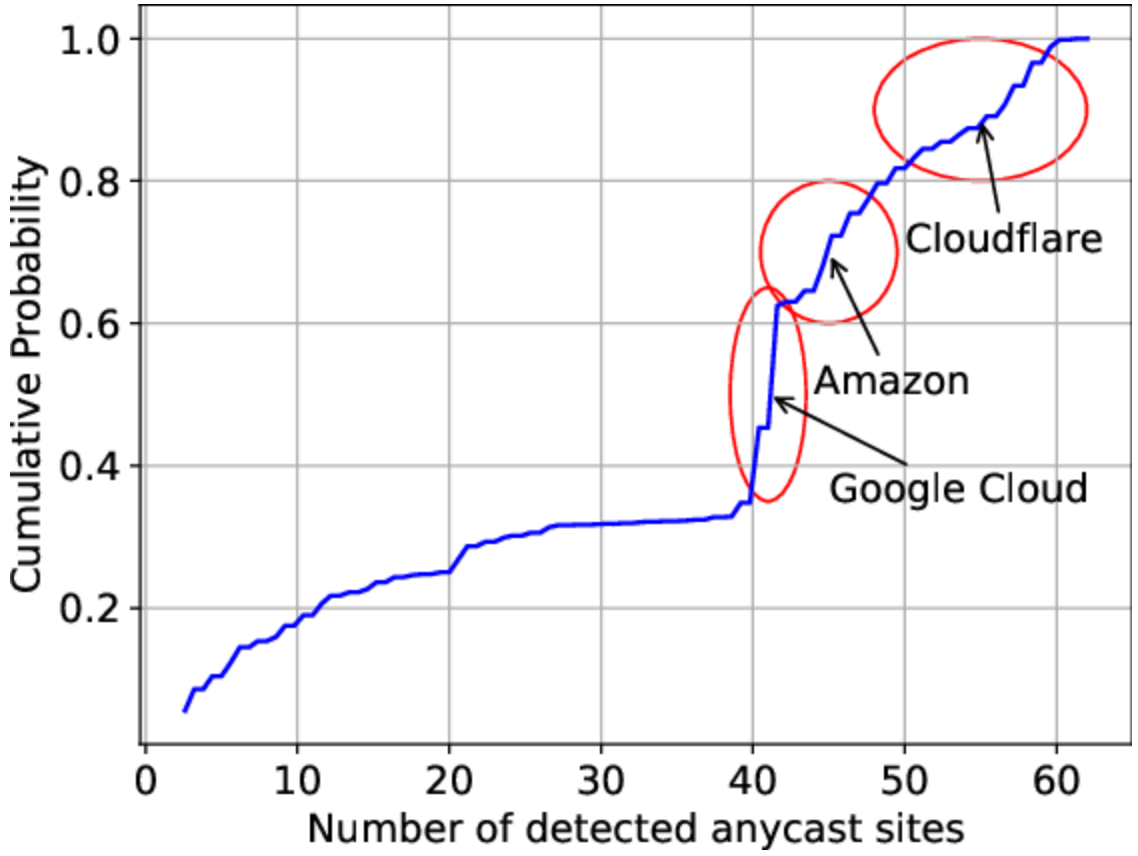
Main takeaways:

- Majority detectable using ICMP (89%)
- Additional prefixes found (not detected with traditional approaches)
  - 2.0k UDP
  - 1.3k TCP

Results
Enumerating deployments



Results
Enumerating deployments



Enumeration:

- Lower bound of real deployment
- Accurate for small deployments (few sites)
- Indication of size for large deployments (many sites)

Longitudinal observations (preliminary)

- Longitudinal measurement lets us map the development of Anycast

- Daily measurement allows us to observe:
  - Anycast deployments regularly changing in size
  - Prefixes switching between unicast and anycast (on-demand anycast)
  - Cases of BGP prefix hijacking
  - Cases of temporary anycast (anti-DDoS?)
  - Anycast outages (entirely or at particular sites)

Results
Zooming in on the DNS

- Nameserver record address from the OPEN Intel project
  - 'Measurement of A/AAAA for NS'

	/24, /48 prefixes	Responsive	Anycast
IPv4	243,884	157,362	2,528
IPv6	22,372	15,424	1,343

Open INTEL

Conclusion

- Created **responsible**, **scalable**, **accurate** anycast measurement pipeline

- A **daily** census of anycast
  - Detection, enumeration, and geolocation

- We hope our census is useful to the community

  Publicly available at:

  https://github.com/anycast-census/anycast-census



Public census repo

Future

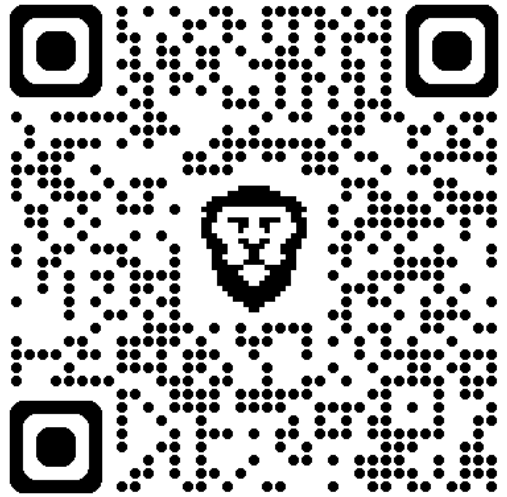
- Refining/improving pipeline
  - E.g., canary outage detection

- Public release of anycast-based measurement tool
- Web-interface/API for live measurements
- User-friendly dashboard to visualize data

- Signal-based measurement of short-lived anycast
  - Anti-DDoS ASes announcements
  - BGP route collector

- Longitudinal analysis of anycast

- We are open to suggestions and feedback



Public census repo

Call for action

We are looking for Ground-Truth operator validation

- If you operate an anycast deployment:
  - Please check if it is covered by our census
  - If not:
    - Reach out to us. Can we add your prefixes to our hitlist?
  - If yes:
    - Let us know. Can we cite you? By name or anonymously?

- Contact:
  - remi.hendriks@utwente.nl

Public census repo

Appendix slides

Appendix slides
Daily census output snippet classification + enumeration

File: YYYY/MM/DD/YYYY-MM-DD_v4.json


```
{"prefix": "1.0.0.0/24", "characterization":
    {"MAnycastICMPv4": {"anycast": true, "instances": 26},
    "MAnycastTCPv4": {"anycast": true, "instances": 26},
    "MAnycastUDPv4": {"anycast": null, "instances": 0},
    "iGreedyICMPv4": {"anycast": true, "instances": 60},
    "iGreedyTCPv4": {"anycast": true, "instances": 26}
    }
},
...
```

Appendix slides
Daily census output snippet locations

File: YYYY/MM/DD/YYYY-MM-DD_v4_locations.json


```
 {
   "prefix": "1.0.0.0/24",
   "count": 60,
   "instances": [
    {
      "marker": {
        "city": "Honolulu",
        "code_country": "US",
        "id": "HNL",
        "latitude": 21.3187007904,
        "longitude": -157.9219970703
      }
    },
...
```

Appendix slides
MAnycastR FNs breakdown

# of sites receiving	Candidate anycast	TPs	FPs	TP rate
2	14,966	620	14,346	4.14%
3	421	347	74	82.42%
4	307	284	23	92.51%
5	400	364	36	91.00%
5-10	918	901	17	98.15%
10-15	831	825	6	99.28%
15-20	3,890	3,886	4	99.90%
20-25	2,288	2,288	0	100.00%
25-32	2,572	2,572	0	100.00%
Total	26,593	12,087	14,506	45.45%

Table 3: Anycast-based ICMPv4 TP rate per number of sites receiving replies, taking GCD_{Ark} as ground-truth.

Appendix slides
MAnycastR IPv6 ATs by protocol

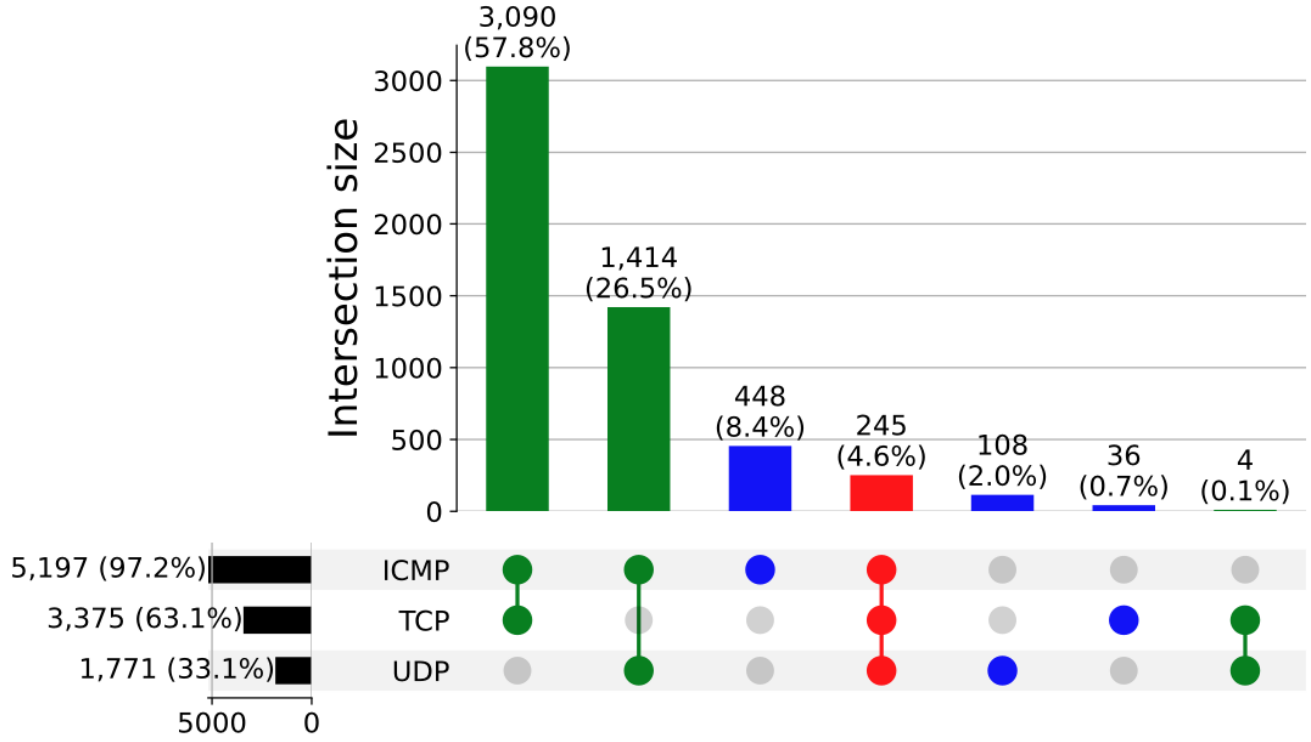


Figure 7: MAnycastR detection of anycast candidates for ICMPv6, TCPv6, and UDPv6.