An Empirical Evaluation of Longitudinal Anycast Catchment Stability

PAM 2025, Universidad de San Andrés, Online

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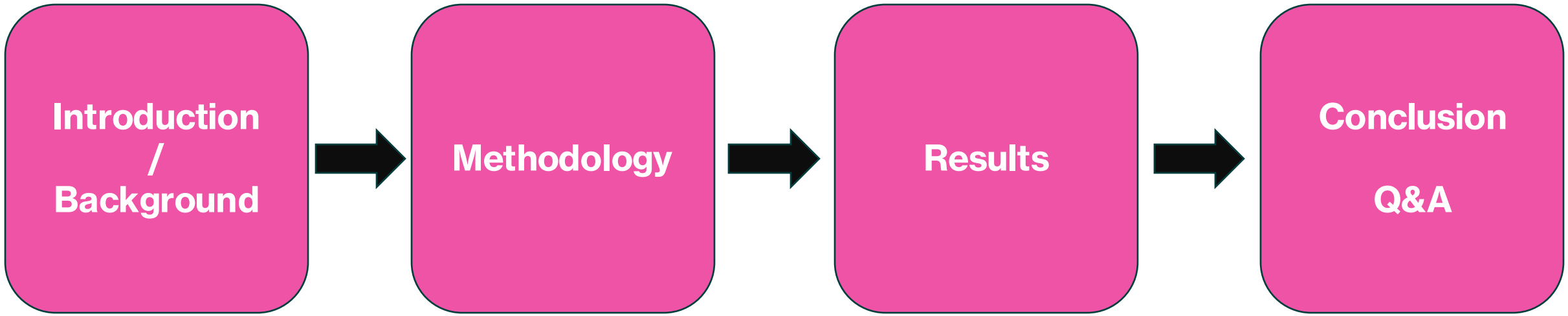
Remi Hendriks, Bernhard Degen, Bas Palinckx,

Raffaele Sommese, Roland van Rijswijk-Deij

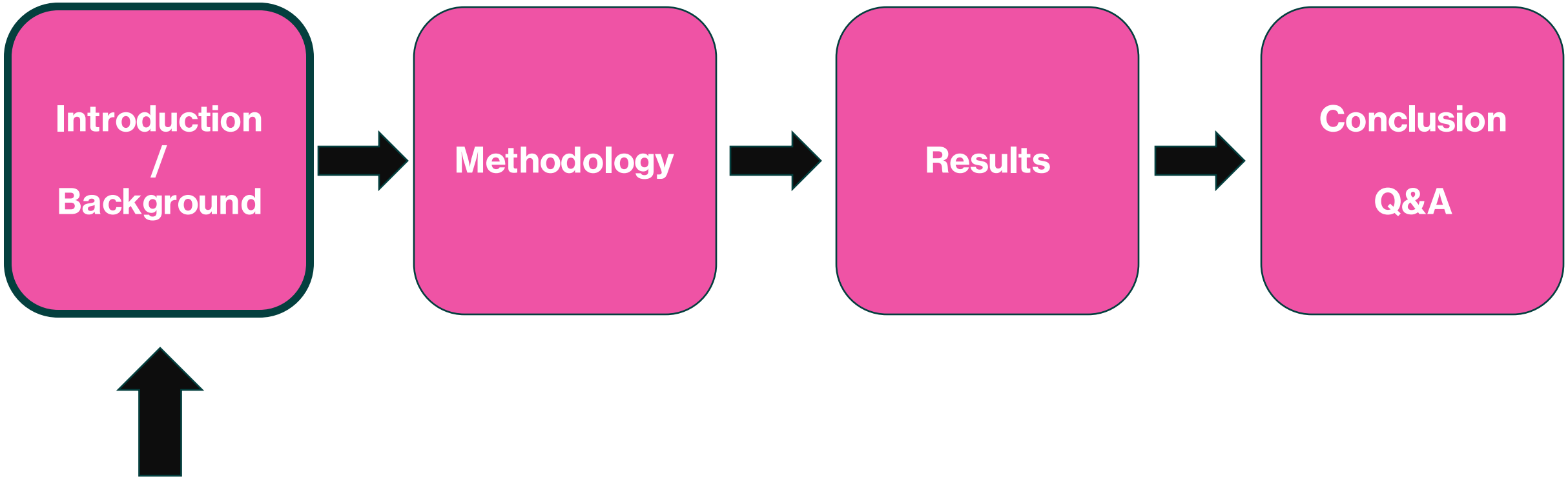
UNIVERSITY OF TWENTE.

DACS
Design and Analysis of Communication Systems

Structure


Introduction / Background
Methodology
Results
Conclusion
Q&A

Structure


Introduction / Background
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Q&A

Introduction / Background
Catchment mapping

- Anycast: announcing an IP prefix at multiple Points of Presence (PoPs)
  - BGP directs clients to different PoPs
  - Example: DNS root-servers
- To assess client distribution, catchment mappings are used
- Catchment: the set of addresses that route to a particular anycast PoP
- Verfploeter [1] allows for actively measuring catchment mappings

[1] Broad and load-aware anycast mapping with Verfploeter, de Vries et al. IMC'17

Introduction / Background
Catchment mapping

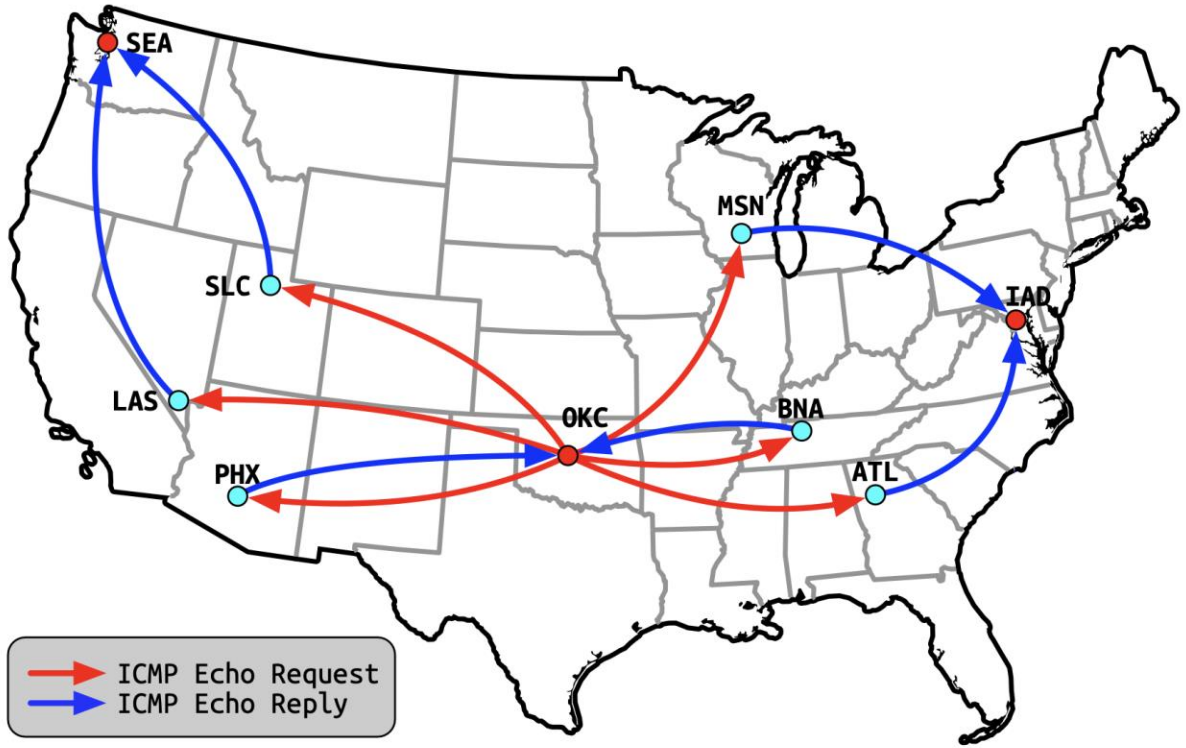


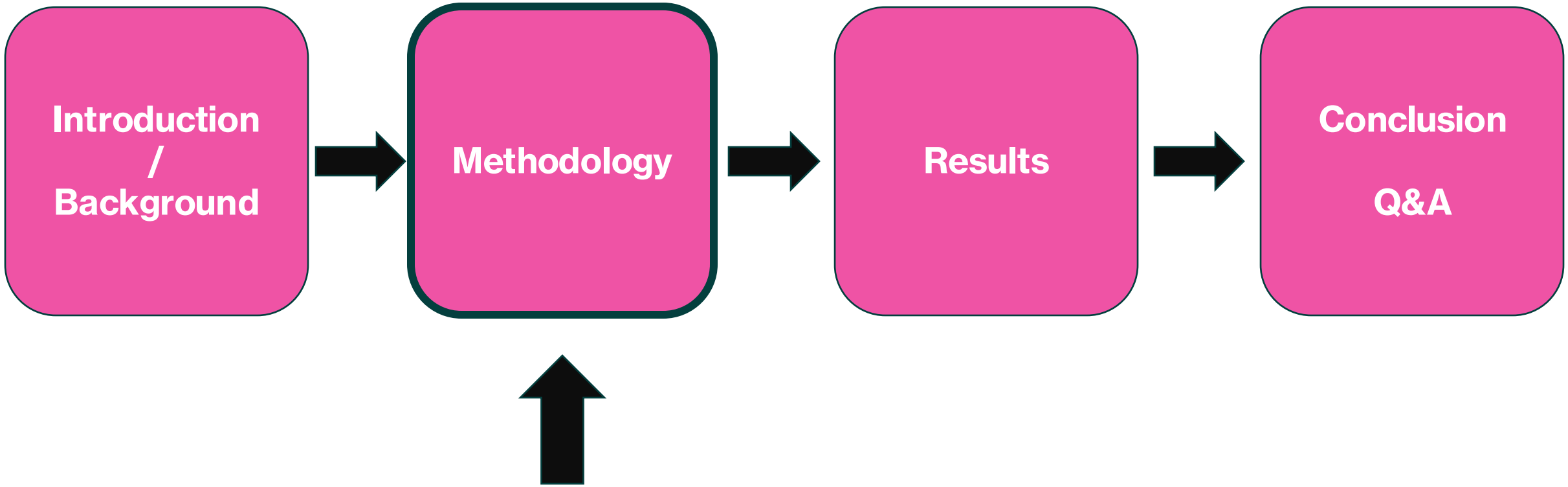
Fig. 1: The Verfploeter [18] method; an anycast site (red) sends ICMP probes to a hitlist, responses from clients (blue) end up at the "closest" anycast site.

Introduction / Background
Problem statement

- Catchment mappings are useful
  - Gives insights in the performance of anycast networks
  - Allows for troubleshooting sub-optimal routing
    - *E.g.,* network region routing to distant PoP when a nearby PoP is available
- Problem statement:

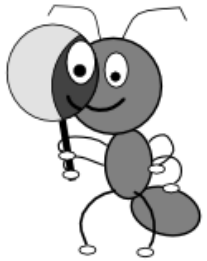
  Stability of catchment mappings (and anycast routing) largely unknown
  - How often should operators measure catchment mappings?
  - *E.g.,* is my catchment mapping from today valid for tomorrow?
    - What about next week? Next month? ...

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Methodology
Measurement set-up

- Daily Verfploeter catchment mappings spanning 6 months
- Targets
  - USC/ISI hitlist [2] (IPv4)
  - IPv6 public hitlist [3] + OpenINTEL [4] AAAA record addresses (IPv6)
- Probing strategy
  - One target per smallest propagated BGP prefix size (IPv4: /24, IPv6: /48) as representative
  - 3.5M responsive /24s and 0.5M IPv6 /48s responsive throughout the entire analysis period



Technical University of Munich

Open INTEL

[2] USC/LANDER project: Internet Addresses Survey Dataset. isi.edu/ant/lander

[3] Clusters in the Expanse: Understanding and Unbiasing IPv6 hitlists. Gasser et al. IMC '18

[4] A High-Performance, Scalable infrastructure for Large-Scale Active DNS Measurements. van Rijswijk-Deij et al. IEEE Journal '16

Methodology
Measurement set-up

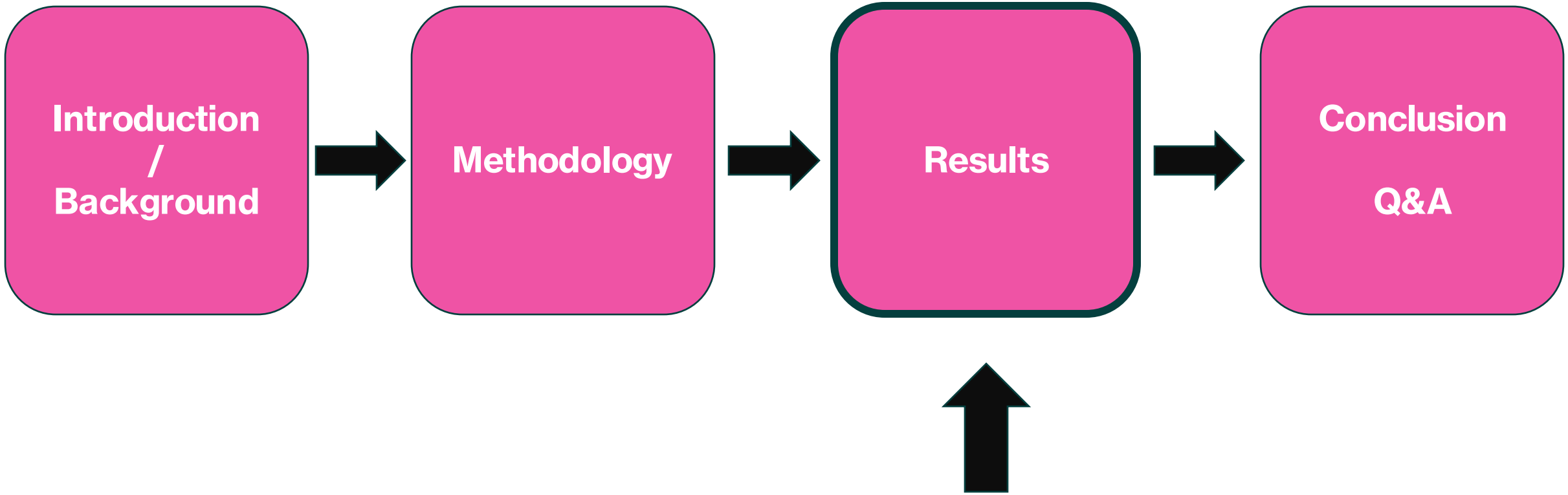
- Anycast testbed comprising 32 PoPs
  - 20 countries; 6 continents
  - Hosted by Vultr
  - Anycast a /24 and /40 prefix

    for IPv4 and IPv6 respectively

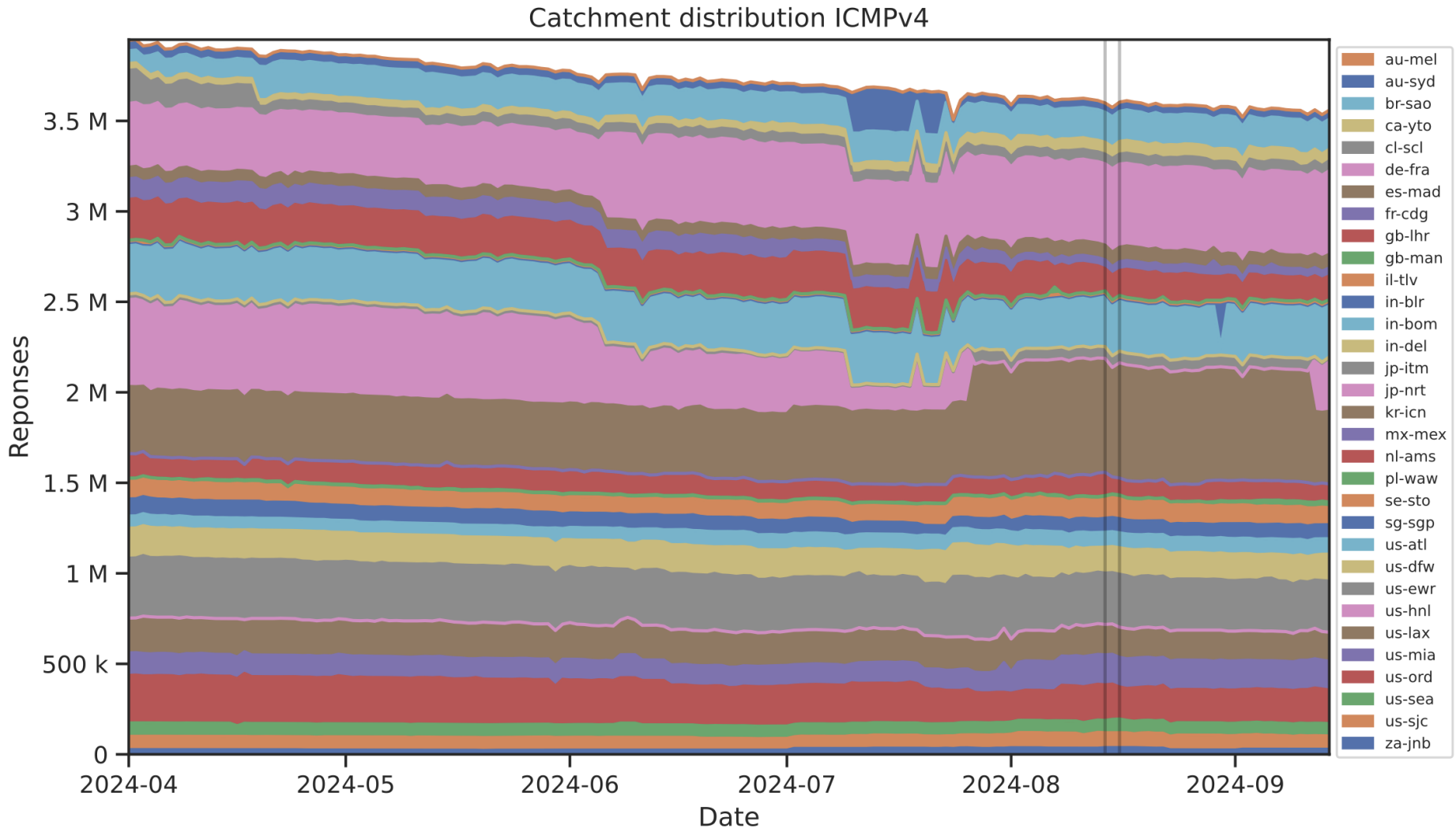


Vultr datacenter locations
https://www.vultr.com/features/datacenter-locations/

Structure

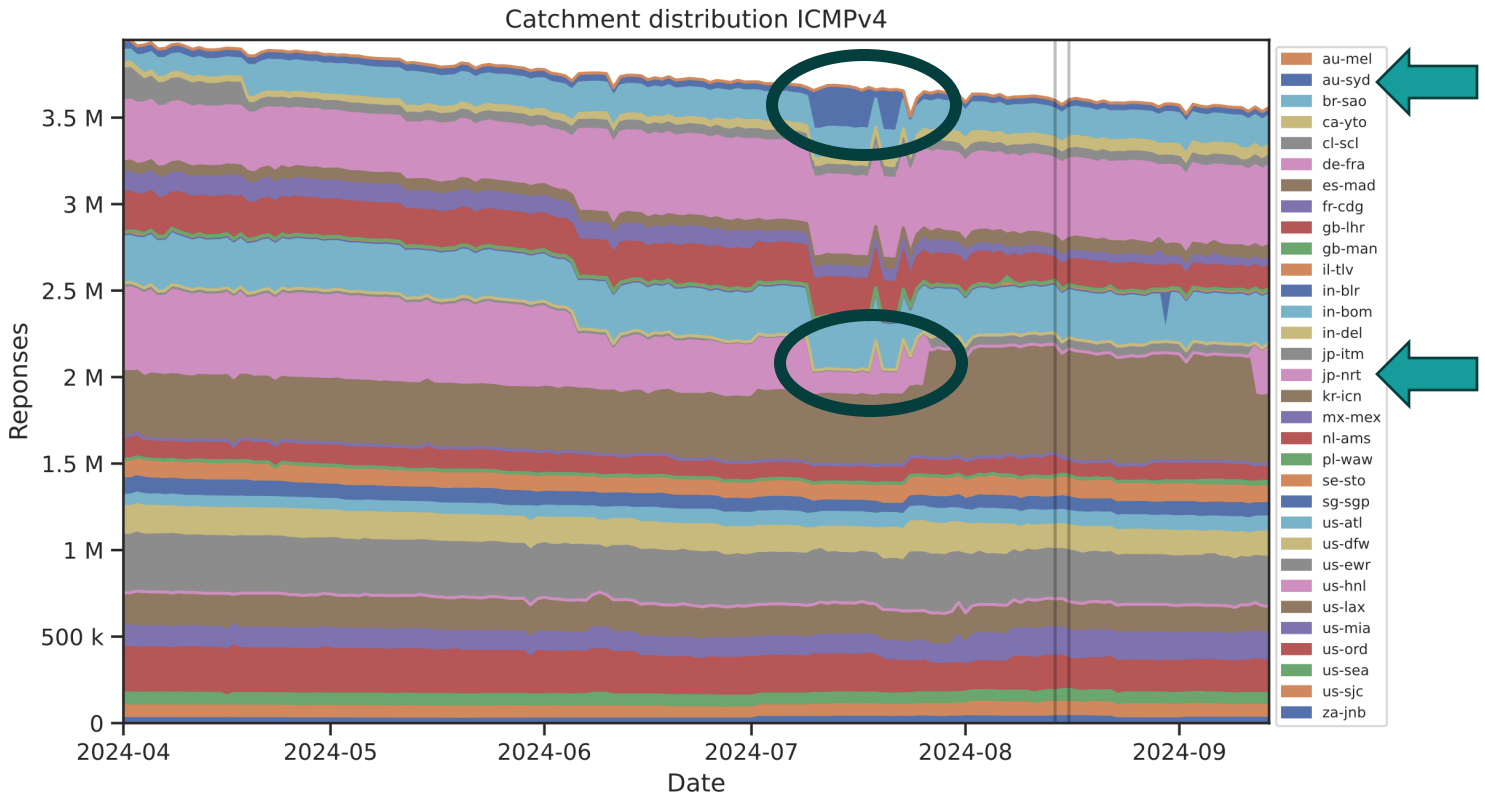

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Results
Longitudinal catchment distribution



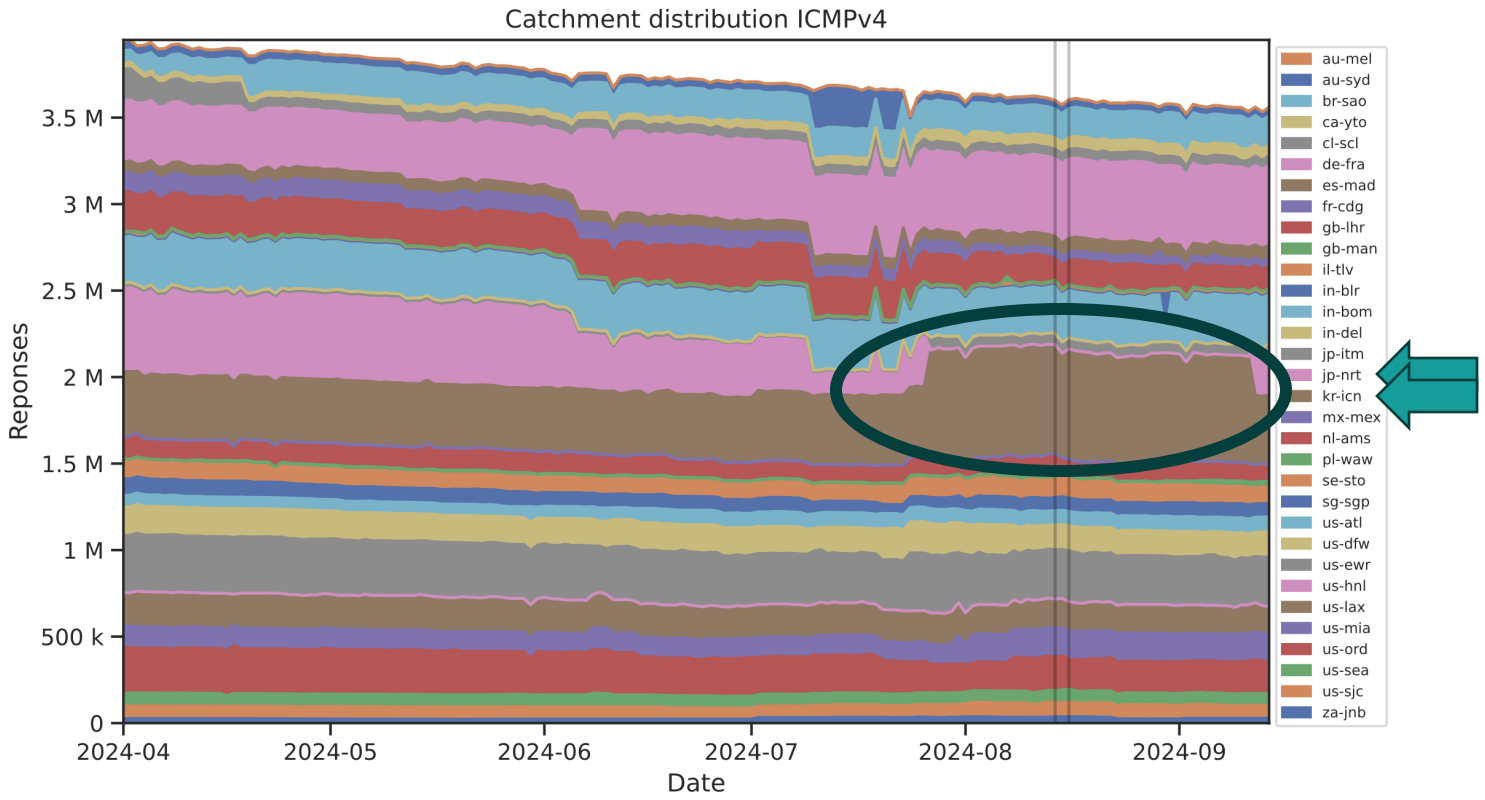
Results
Longitudinal catchment distribution

- July 10
  - jp-nrt (Tokyo) loses most traffic
  - au-syd (Sydney) expands five-fold



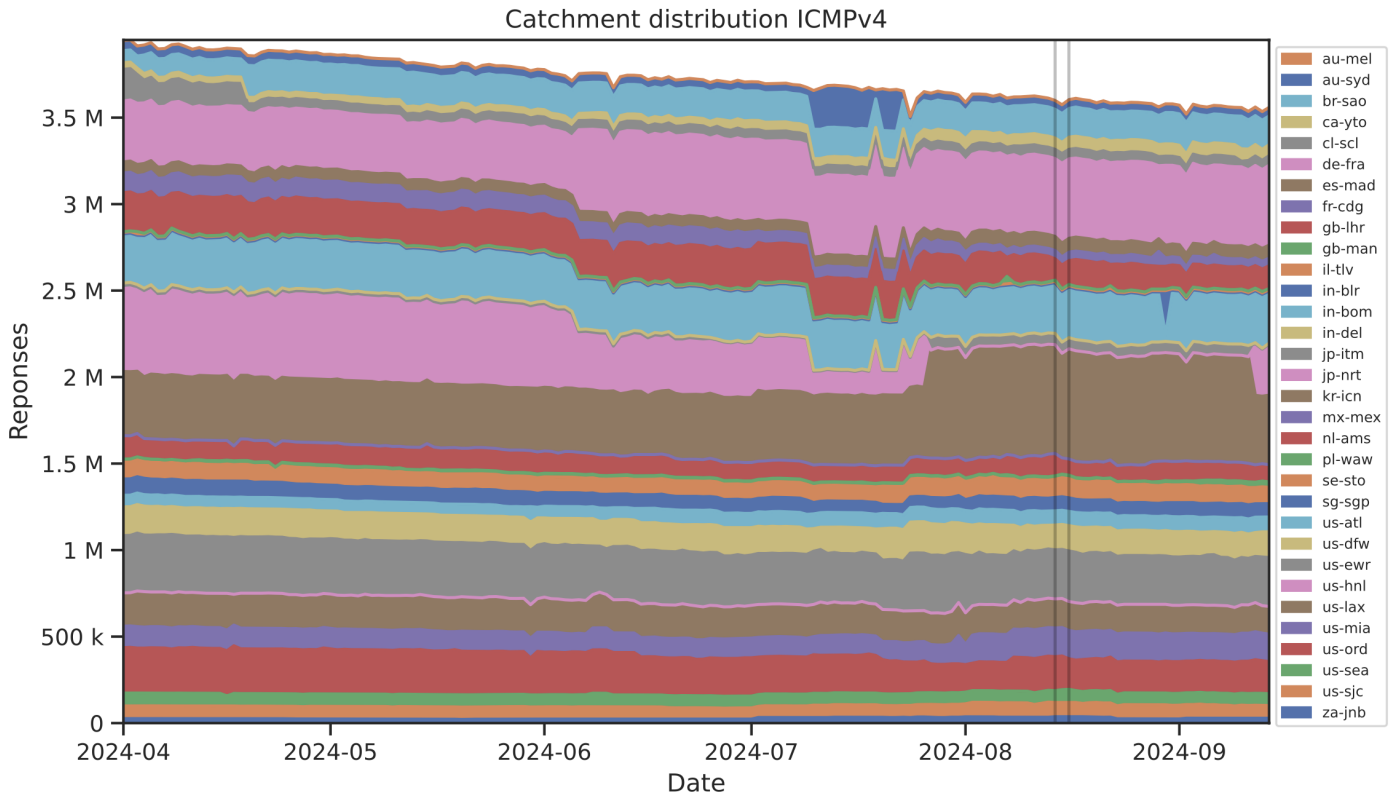
Results
Longitudinal catchment distribution

- July 10
  - jp-nrt (Tokyo) loses most traffic
  - au-syd (Sydney) expands five-fold
- July 27 – September 12
  - kr-icn (Seoul) increases by 200k
  - jp-nrt (Tokyo) shrinks further



Results
Longitudinal catchment distribution

- Takeaways:
  - Large difference in catchment sizes (caused by topological differences)
  - Large catchment shifts visible (suggesting large re-routing events)



Results
Zooming in on jp-nrt (Tokyo)

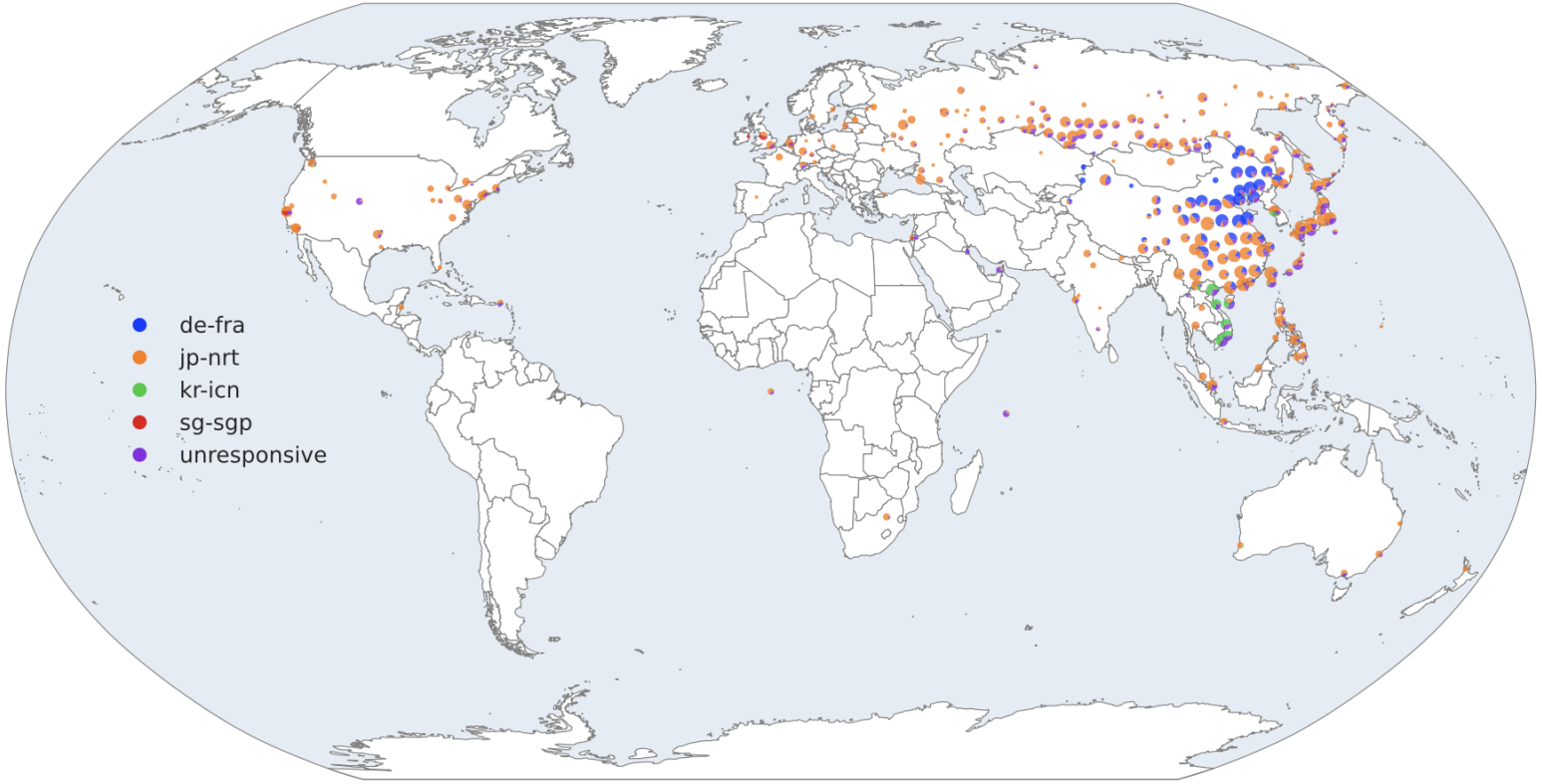


Fig. 7: Visualization of the geolocation of prefixes in the catchment of jp-nrt on April 1st, and where they re-routed to on July 1st indicated with pie charts.

Results
Zooming in on jp-nrt (Tokyo)

- North-eastern China moved to Frankfurt
- Vietnam moved to Seoul

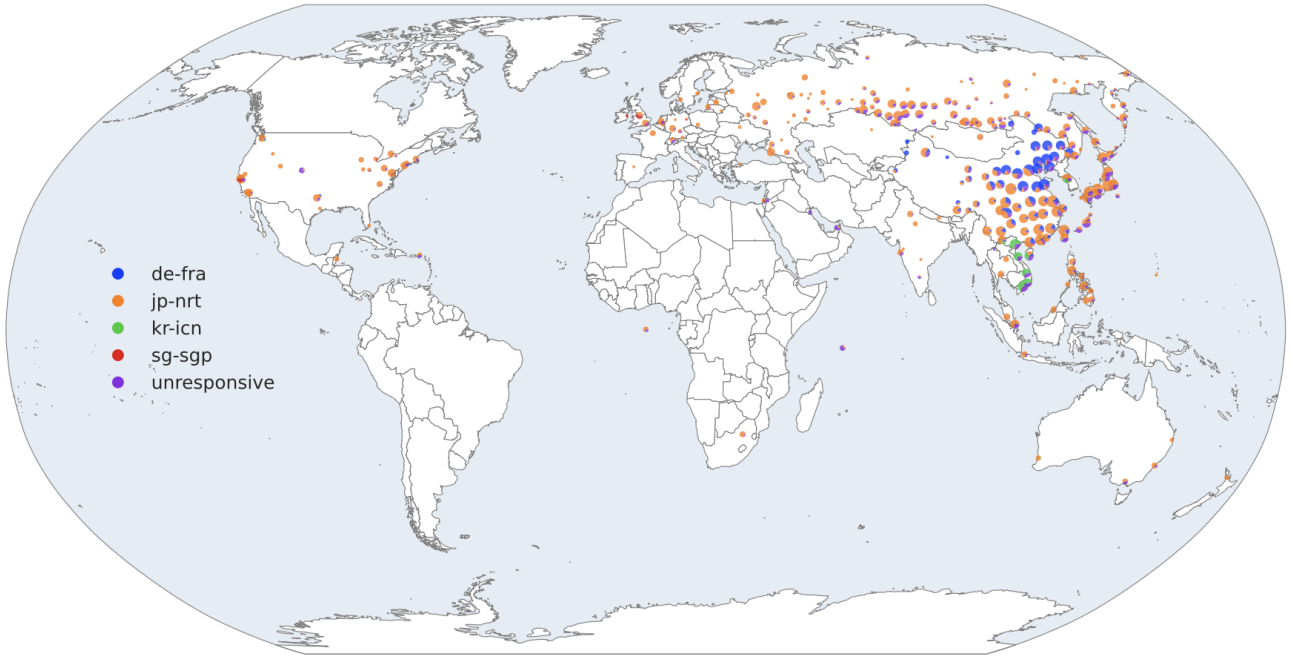


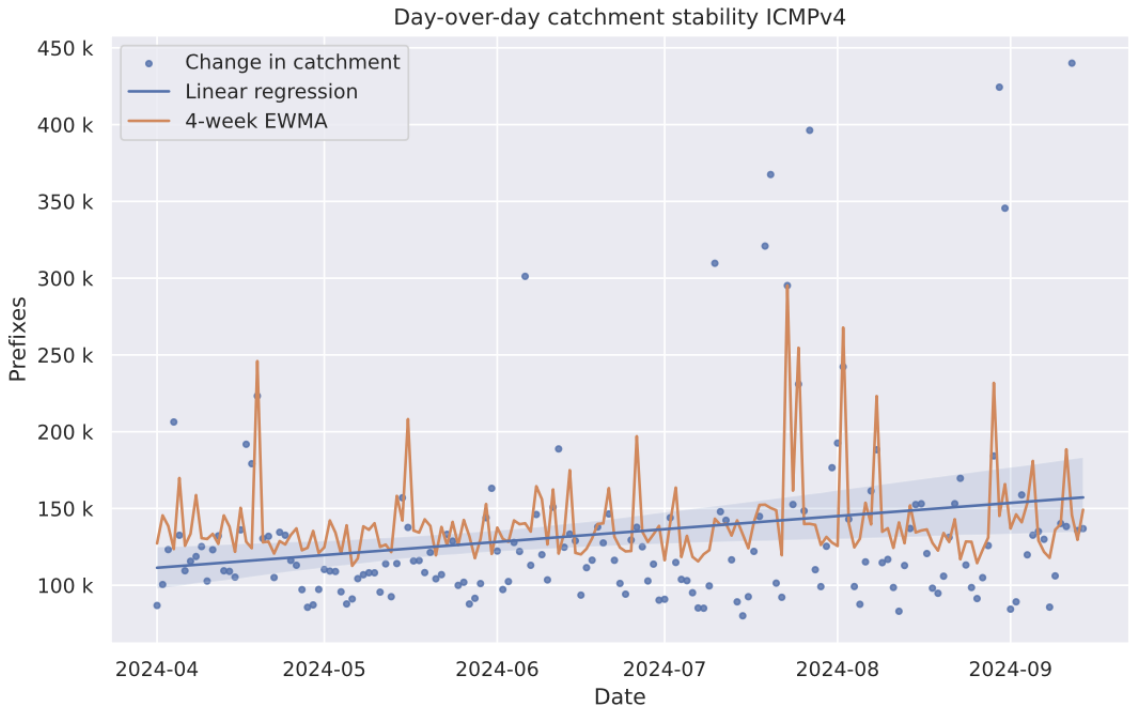
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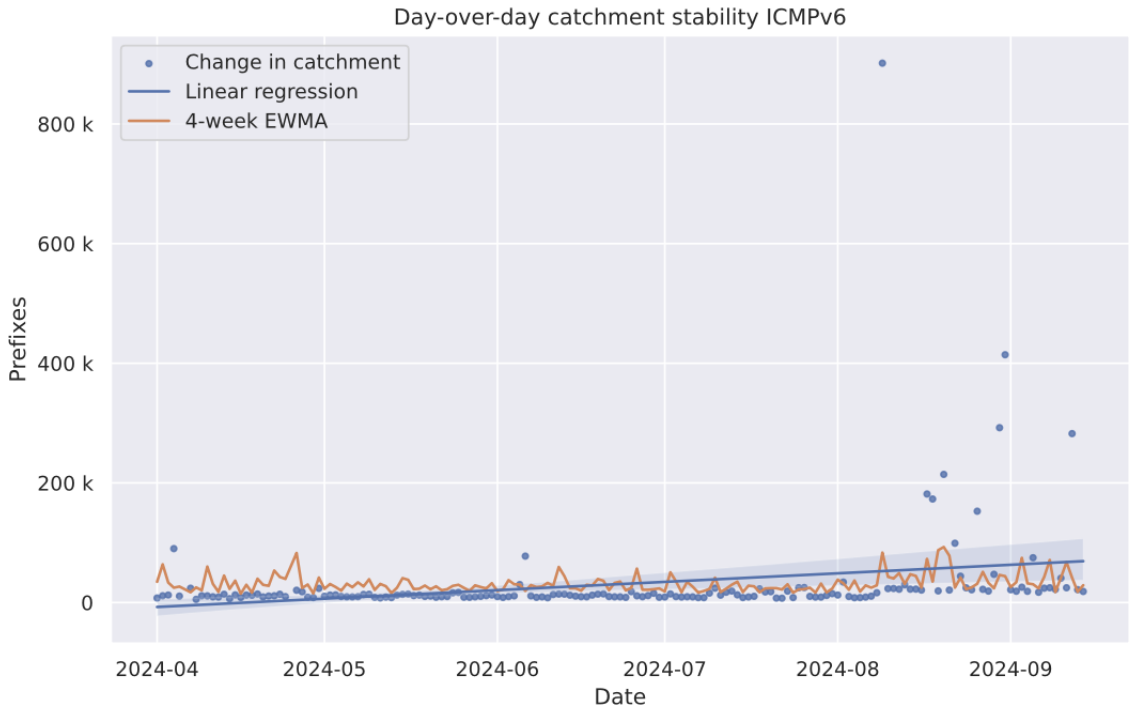
Table 1: Differences in RTT for the largest catchment changes observed at jp-nrt between April 1st and July 1st.

New site in July	Number of prefixes	Mean RTT to JP-NRT	Mean RTT to new site
de-fra	125,418	73.0 ms	255.3 ms (+250%)
jp-nrt*	296,304	89.5 ms	83.4 ms (-7%)
kr-icn	9,291	92.7 ms	99.4 ms (+7%)
sg-sgp	1,134	59.5 ms	43.5 ms (-27%)
Total	432,147	84.0 ms	141.1 ms (+68%)
unresponsive	78,153	81.7 ms	*n/a*

Results
Day-to-day catchment churn



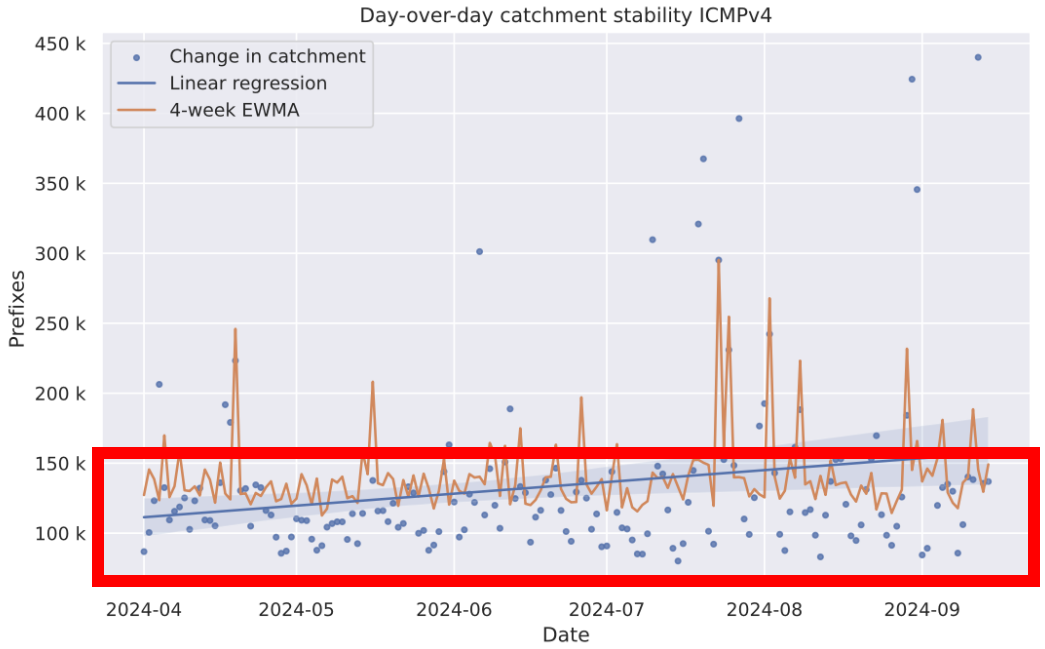
(a) ICMPv4



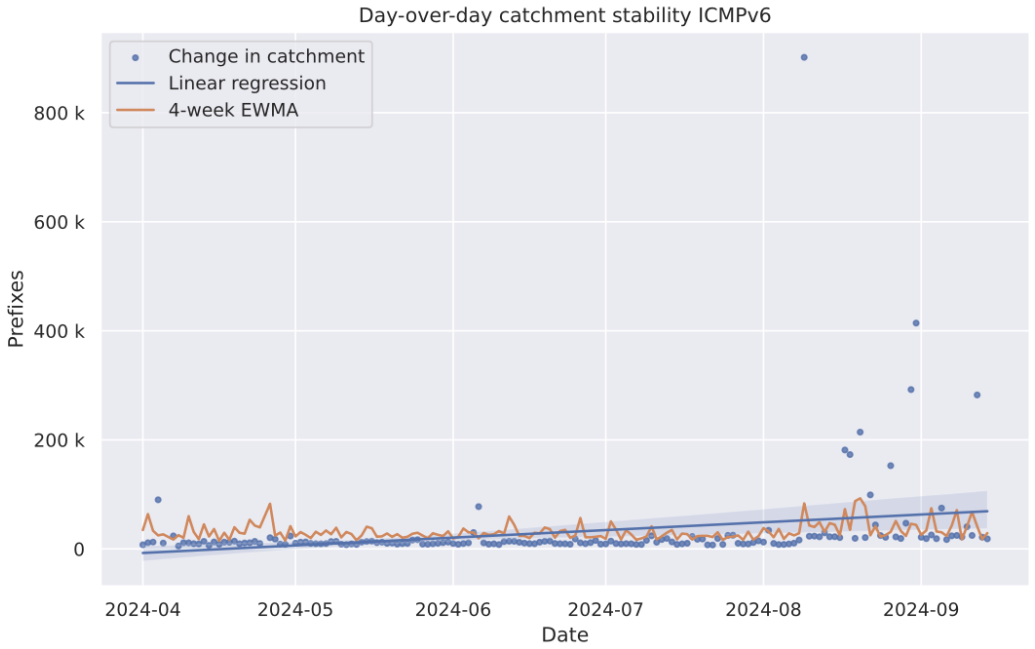
(b) ICMPv6

Results
Day-to-day catchment churn

- Takeaways:
  - Most catchment flips (IPv4) range from 100k to 150k prefixes



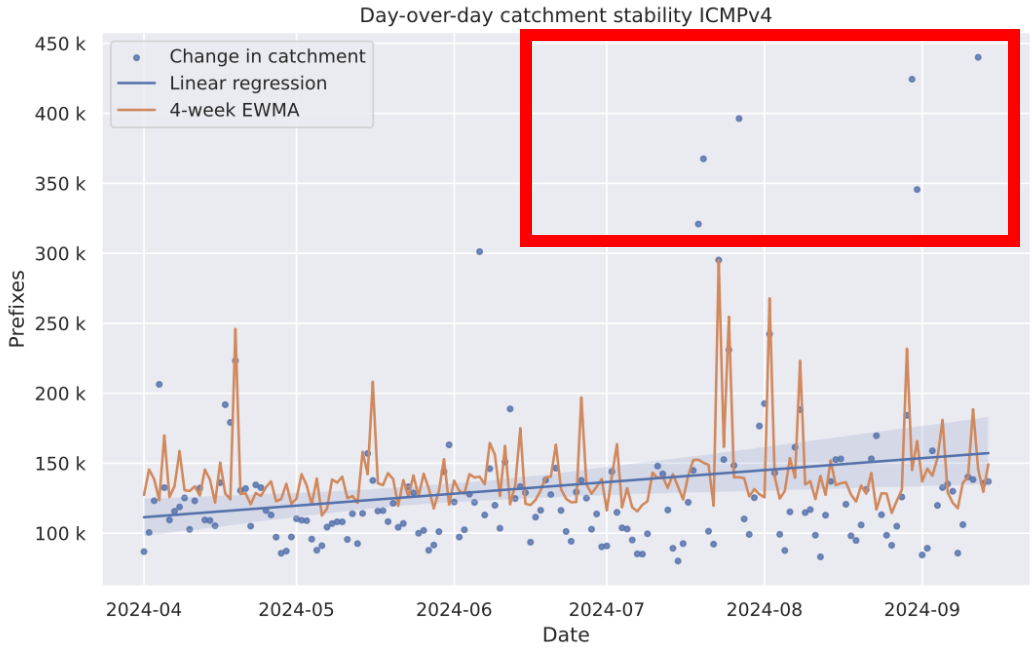
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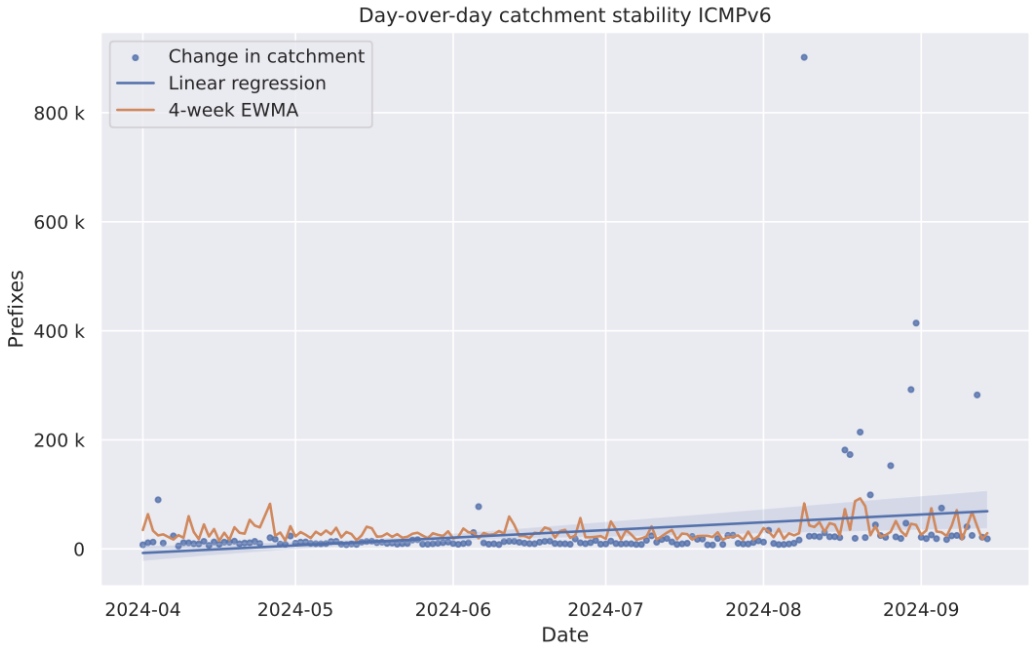
(b) ICMPv6

Results
Day-to-day catchment churn

- Takeaways:
  - Most catchment flips (IPv4) range from 100k to 150k prefixes
  - We observe occasional spikes, likely caused by re-routing events

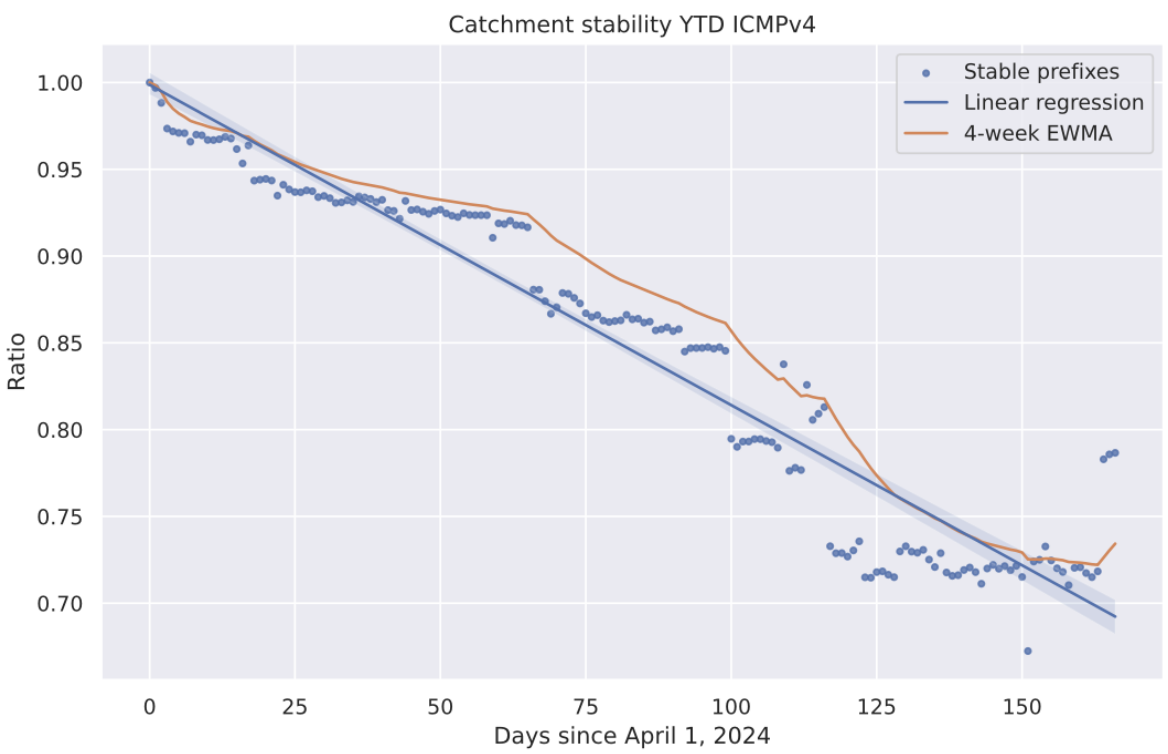


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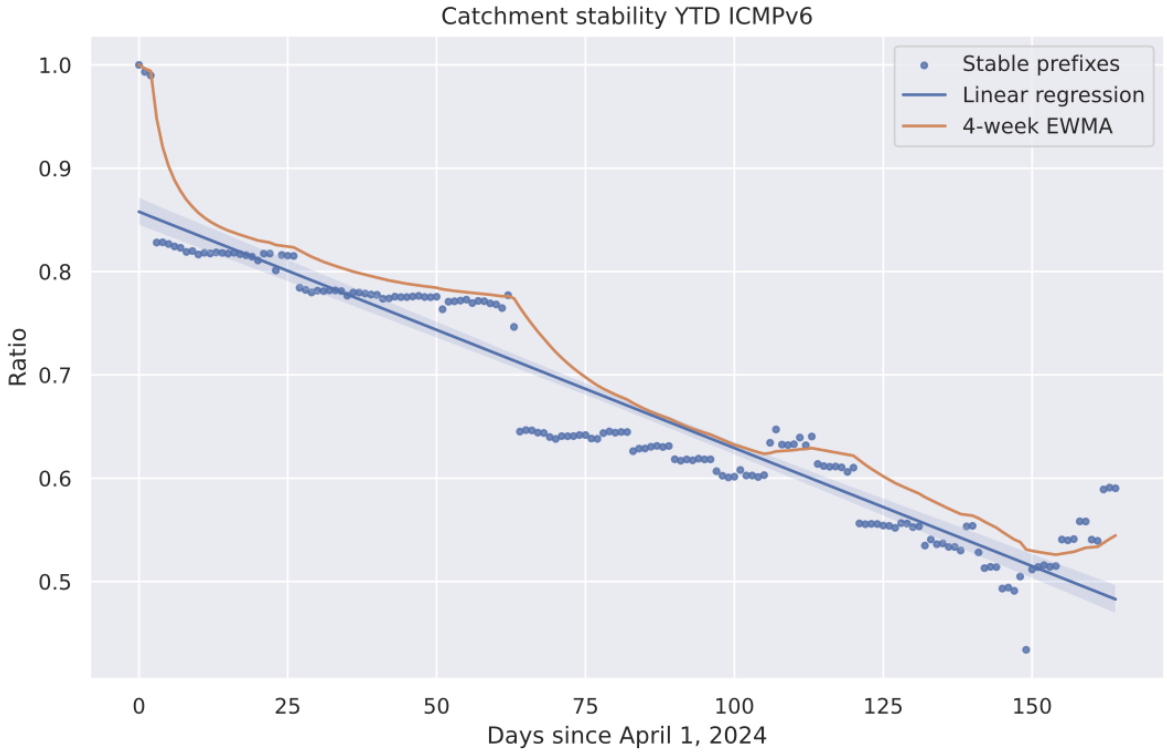


(b) ICMPv6

Results
Catchment stability over time



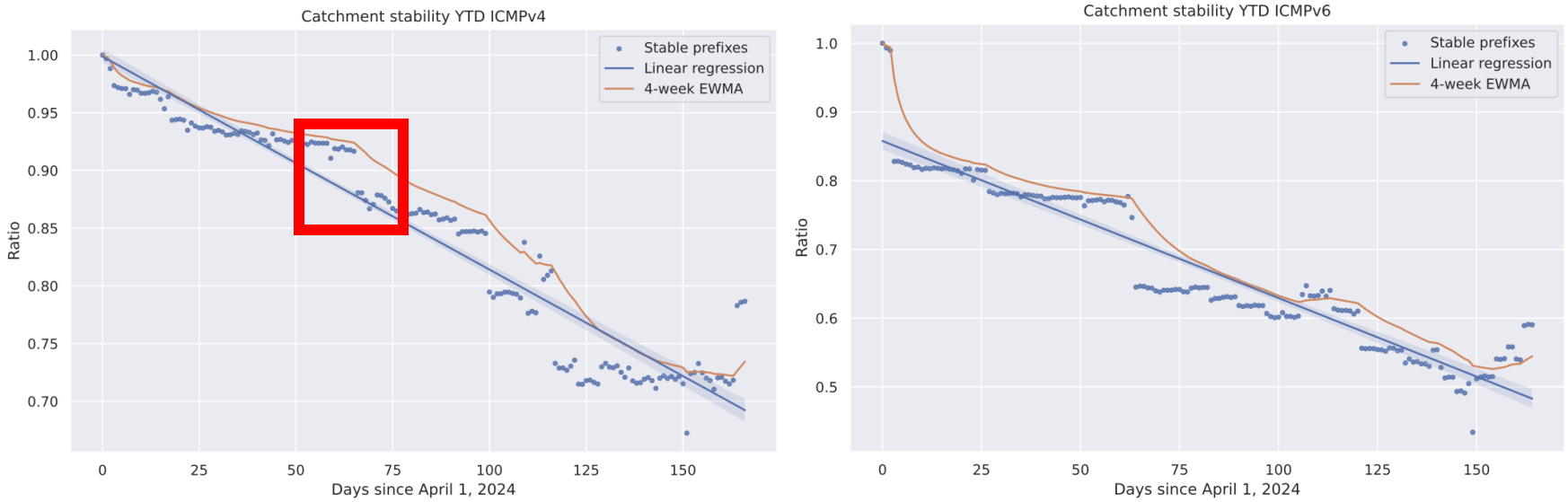
(a) ICMPv4



(b) ICMPv6

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Catchment stability over time

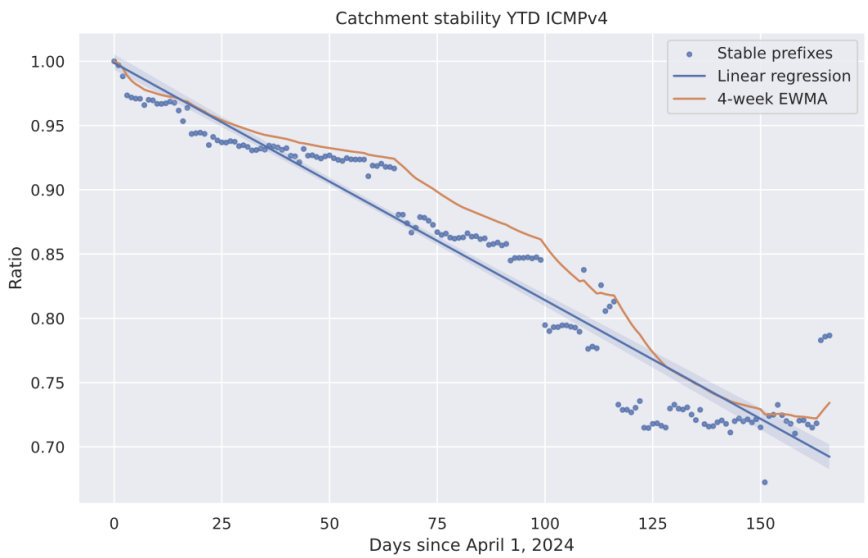
- Takeaways:
  - IPv4 mapping remains valid for 2 months (with an error rate of 10%)



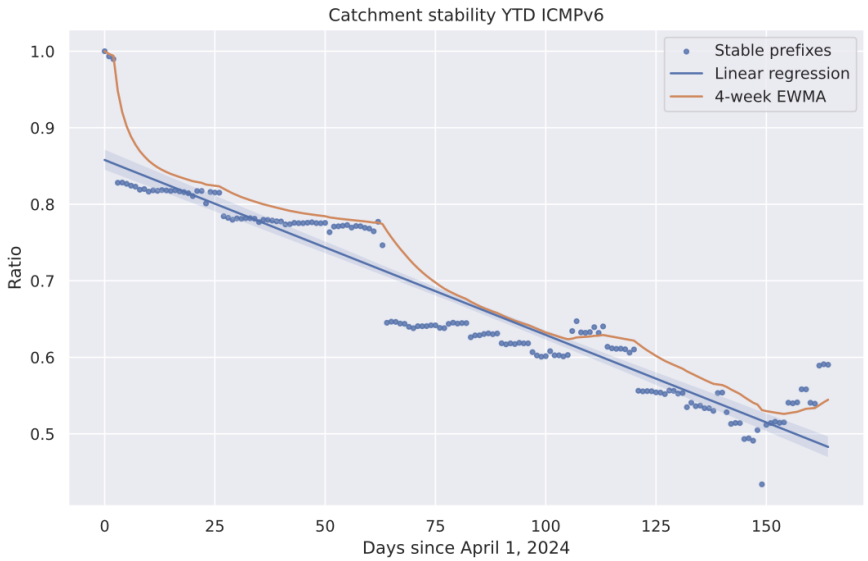
(a) ICMPv4 (b) ICMPv6

Results
Catchment stability over time

- Takeaways:
  - IPv4 mapping remains valid for 2 months (with an error rate of 10%)
  - Gradual decline with accelerations (likely due to re-routing events)



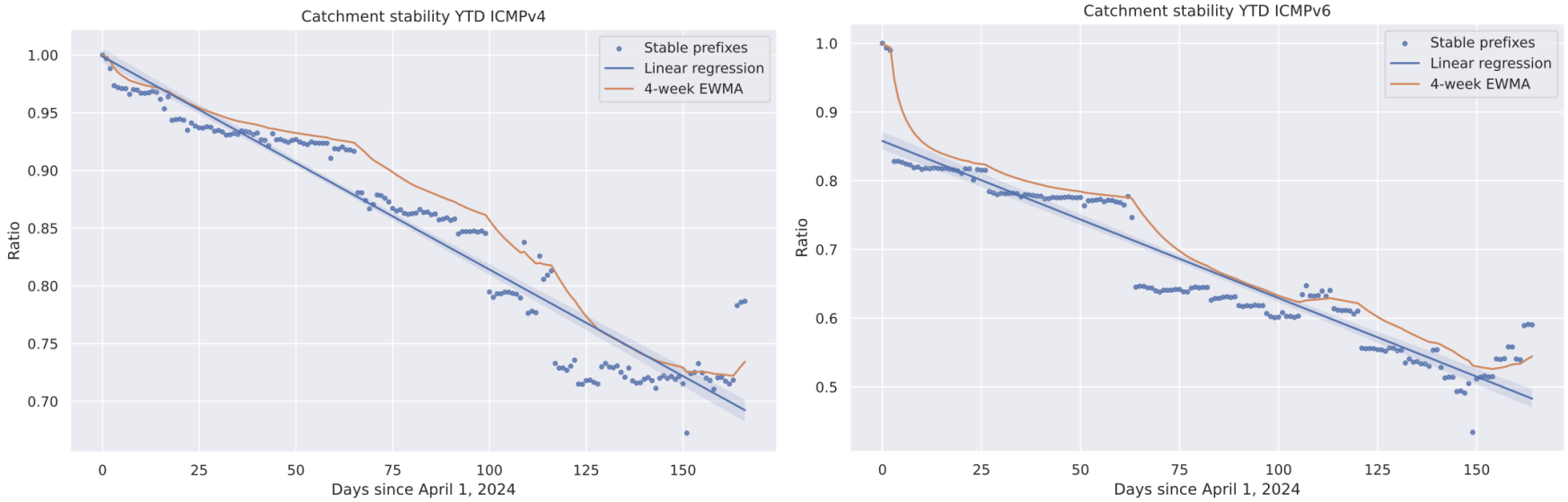
(a) ICMPv4



(b) ICMPv6

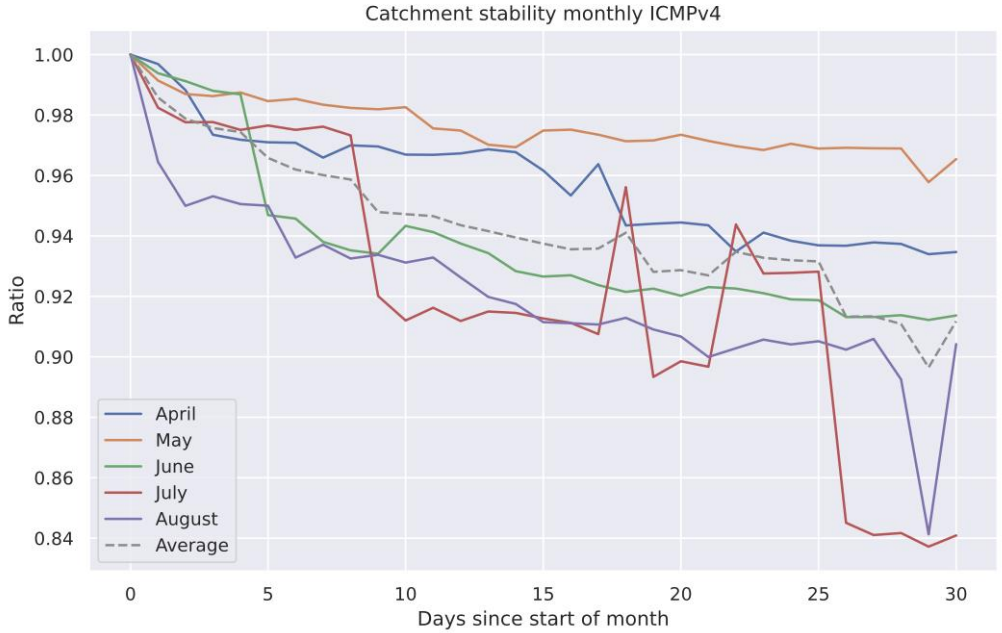
Results
Catchment stability over time

- Takeaways:
  - IPv4 mapping remains valid for 2 months (with an error rate of 10%)
  - Gradual decline with accelerations (likely due to re-routing events)
  - IPv6 more turbulent and less stable over time

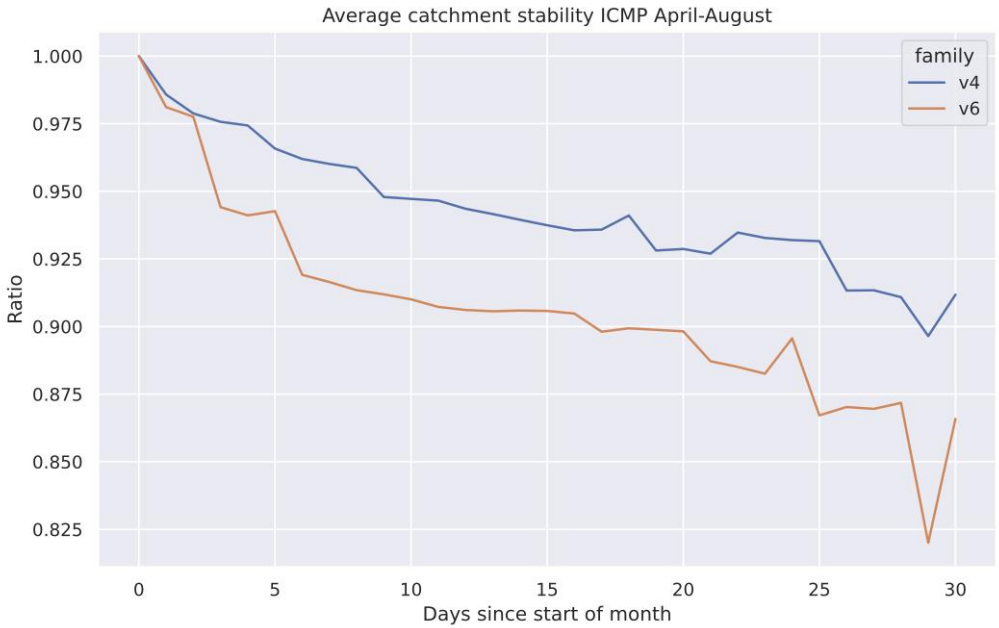


(a) ICMPv4 (b) ICMPv6

Results
Monthly catchment stability



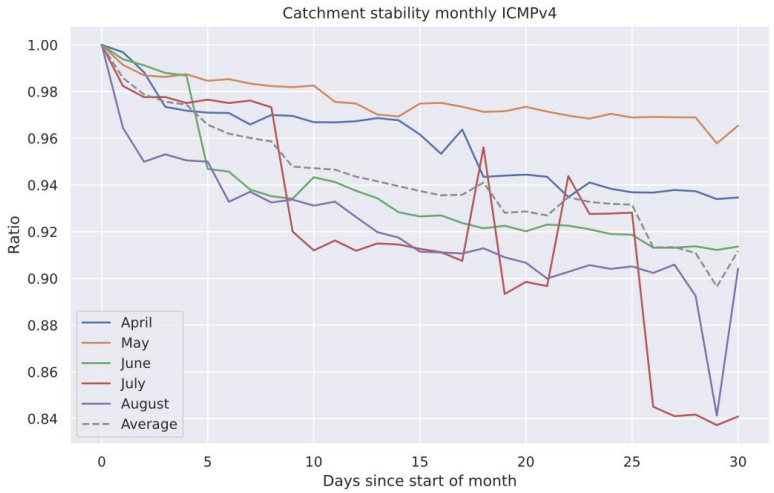
(a) Monthly stability with respect to the beginning of the month.



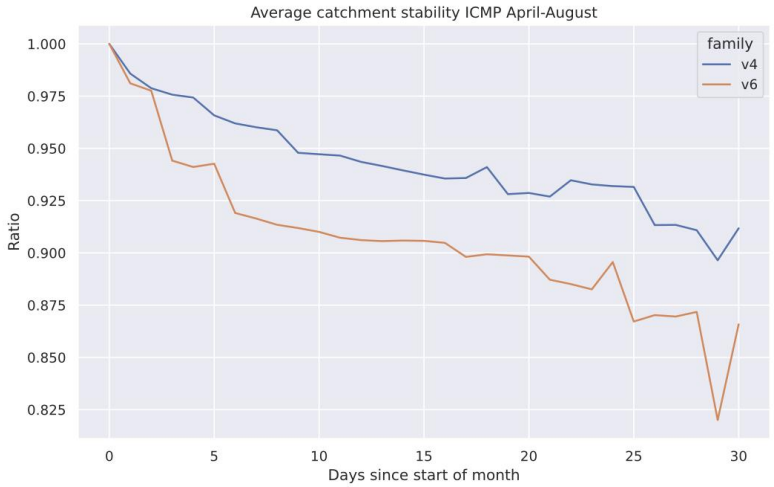
(b) Average monthly stability of ICMPv4 and ICMPv6 compared. We observe that IPv4 routing appears more stable on average and exhibits less variability.

Results
Monthly catchment stability

- Takeaways:
  - Catchments remain stable, on average, for an entire month



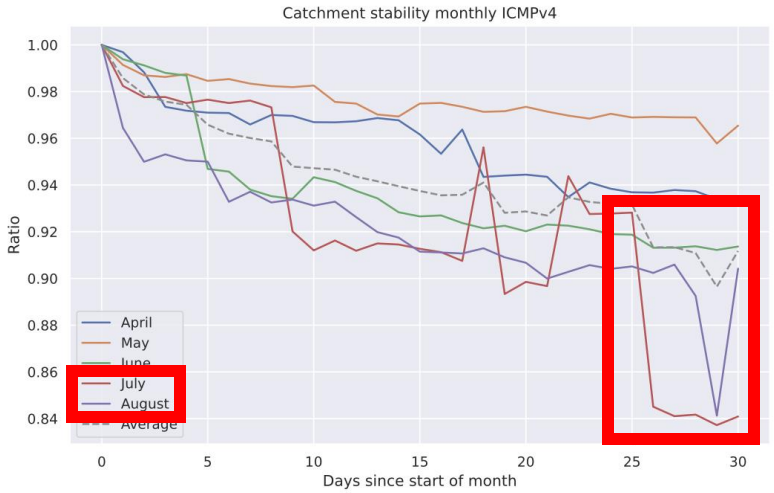
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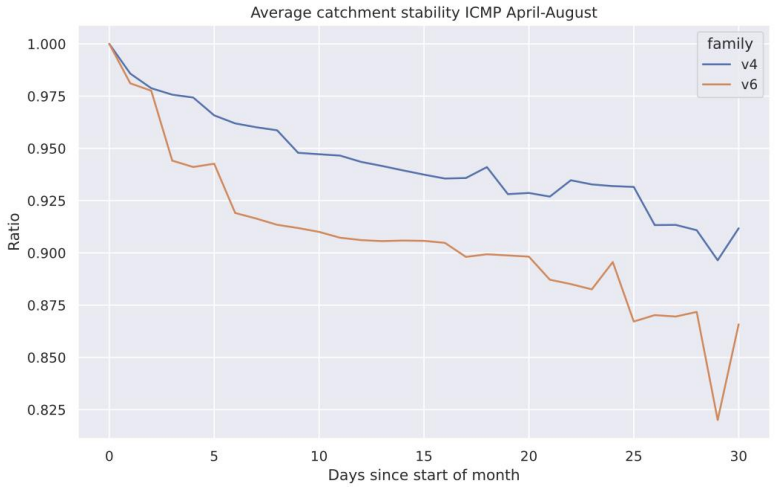
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Results
Monthly catchment stability

- Takeaways:
  - Catchments remain stable, on average, for an entire month
  - Two outliers: July, August deteriorate quickly after the third week



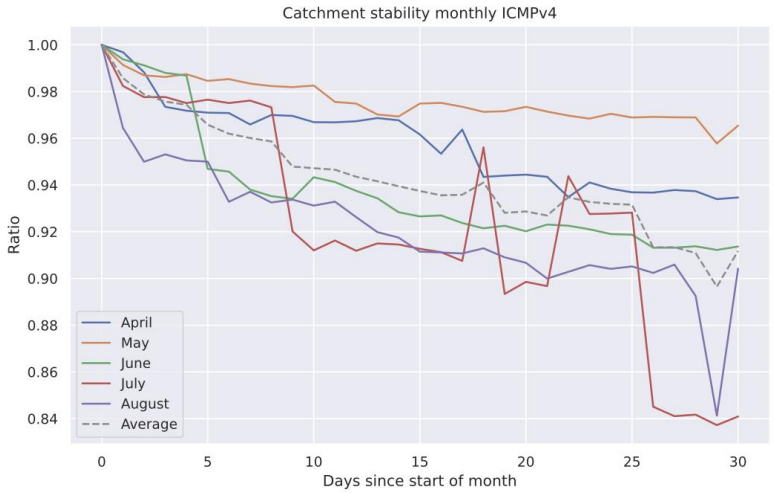
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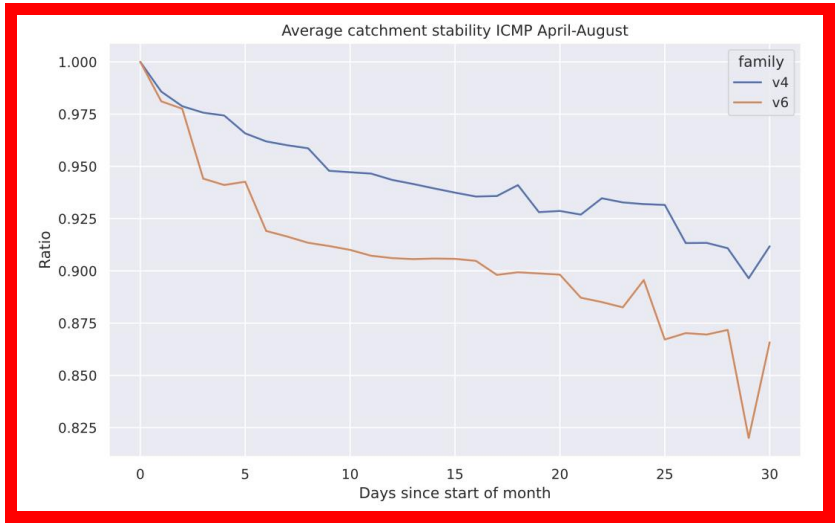
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Results
Monthly catchment stability

- Takeaways:
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  - Two outliers: July, August deteriorate quickly after the third week
  - Comparing IPv4 to IPv6; IPv4 routing appears more stable

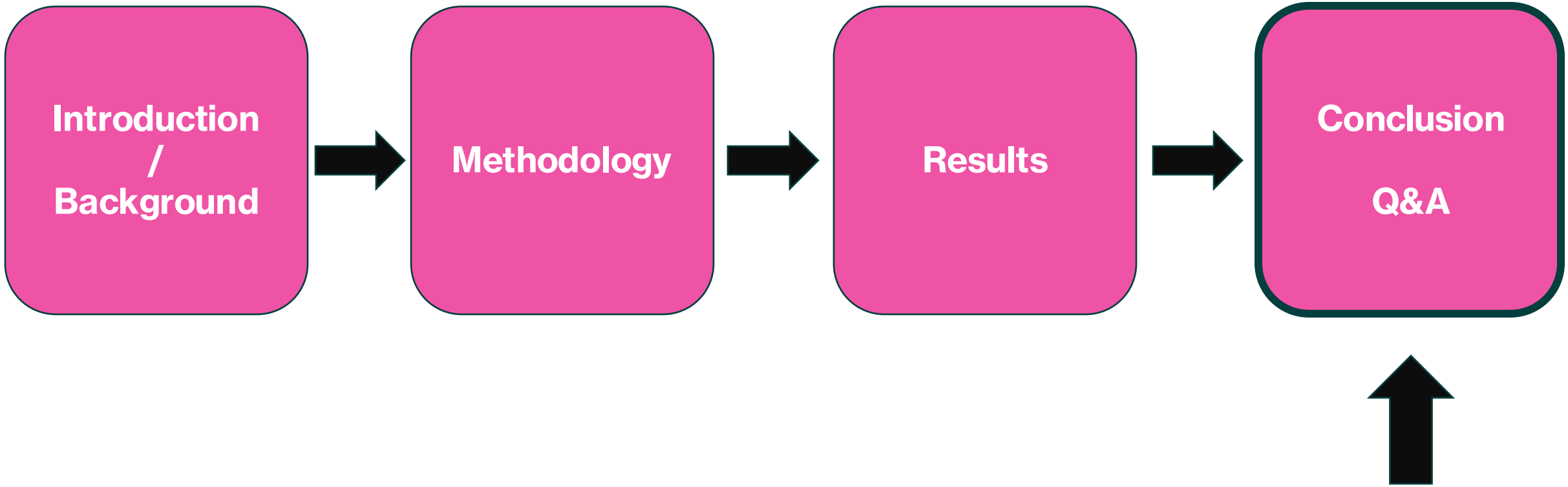


(a) Monthly stability with respect to the beginning of the month.



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Conclusion

- Catchment analysis helps operators improve their anycast services
  - Since Internet routing is dynamic; catchment mappings should be repeated
- Findings
  - Catchments are stable in the short term (day-to-day operations)
  - IPv4 catchments are more stable than IPv6
  - Suggested frequencies
    - Weekly catchment measurements for IPv4
    - Daily for IPv6
- Future work
  - Spoofing and off-site traffic detection using catchment analysis

Appendix slides

Results
Visualizing catchment shifts

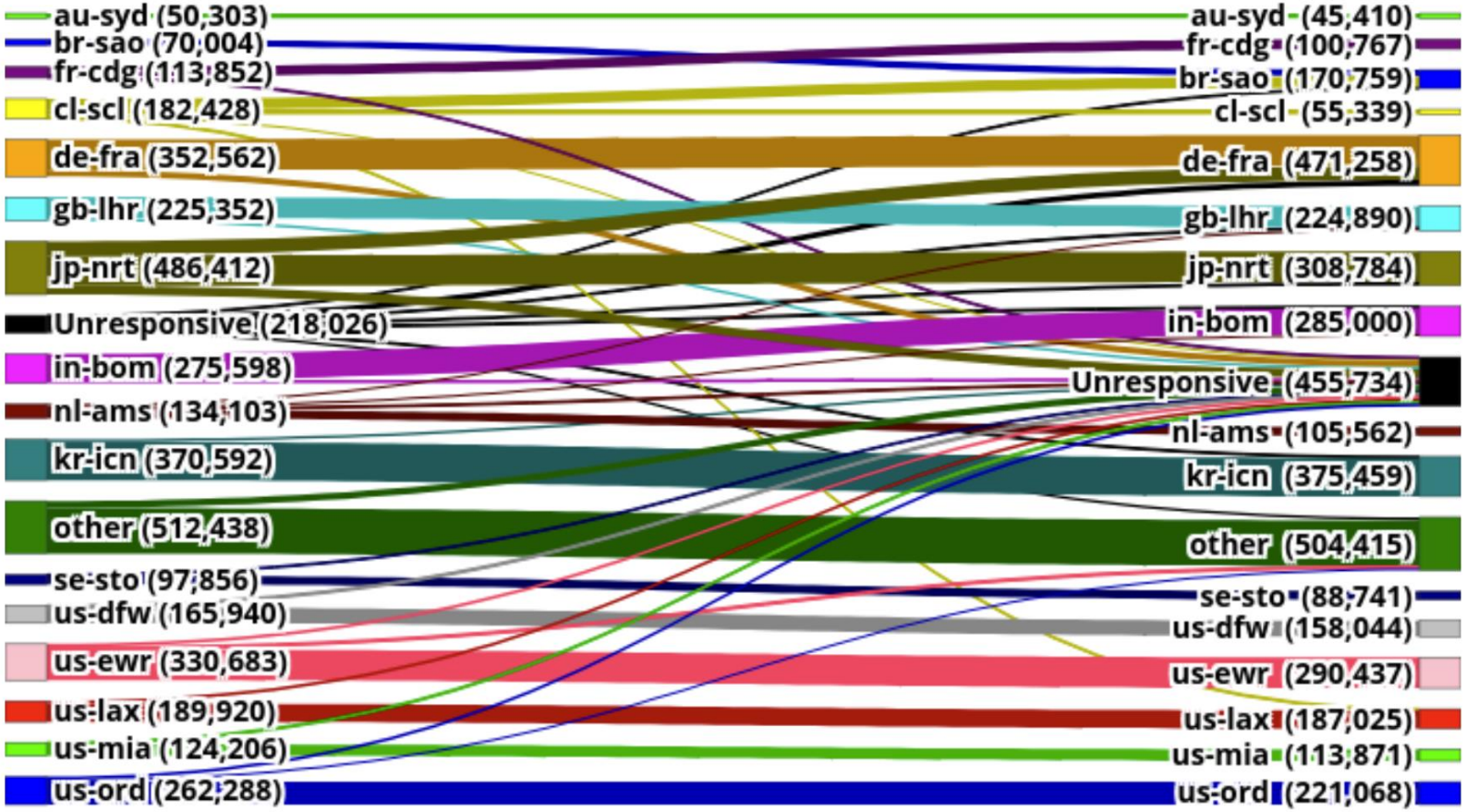


Fig. 6: Catchment shifts between April 1 (left) and July 1 (right), filtering on changes of $>$ 10,000 prefixes for the 16 largest sites.

Results
Visualizing catchment shifts

- 28% of prefixes changed catchment
  - 18% of which moved between continents

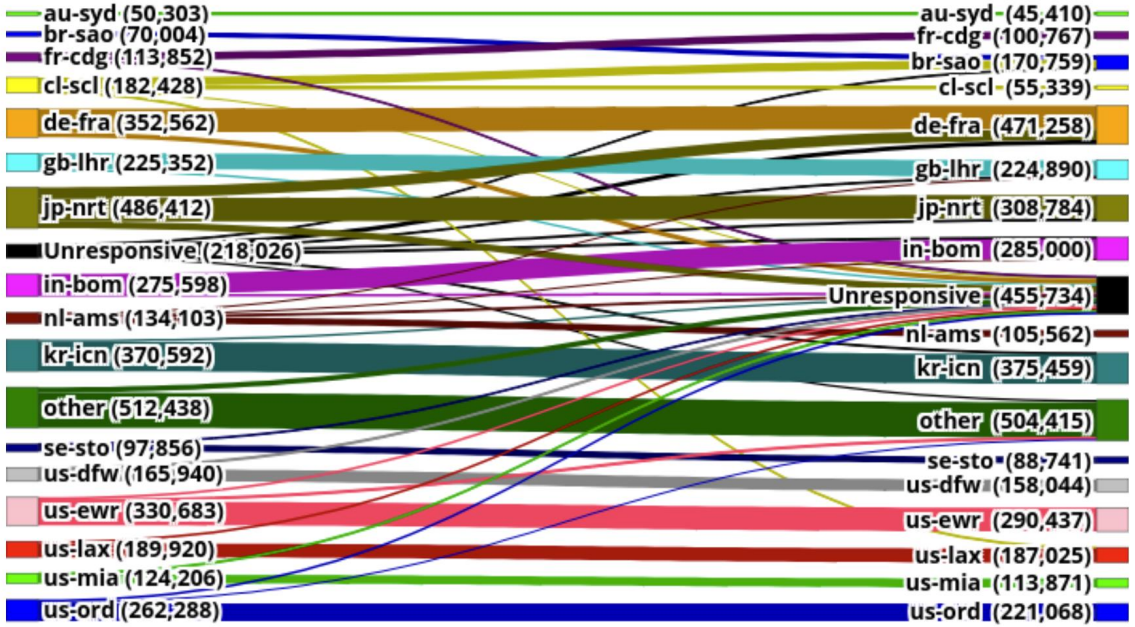


Fig. 6: Catchment shifts between April 1 (left) and July 1 (right), filtering on changes of $>$ 10,000 prefixes for the 16 largest sites.

Results
Visualizing catchment shifts

- 28% of prefixes changed catchment
  - 18% of which moved between continents
- Notable shifts include Santiago to Sao Paulo and Tokyo to Frankfurt

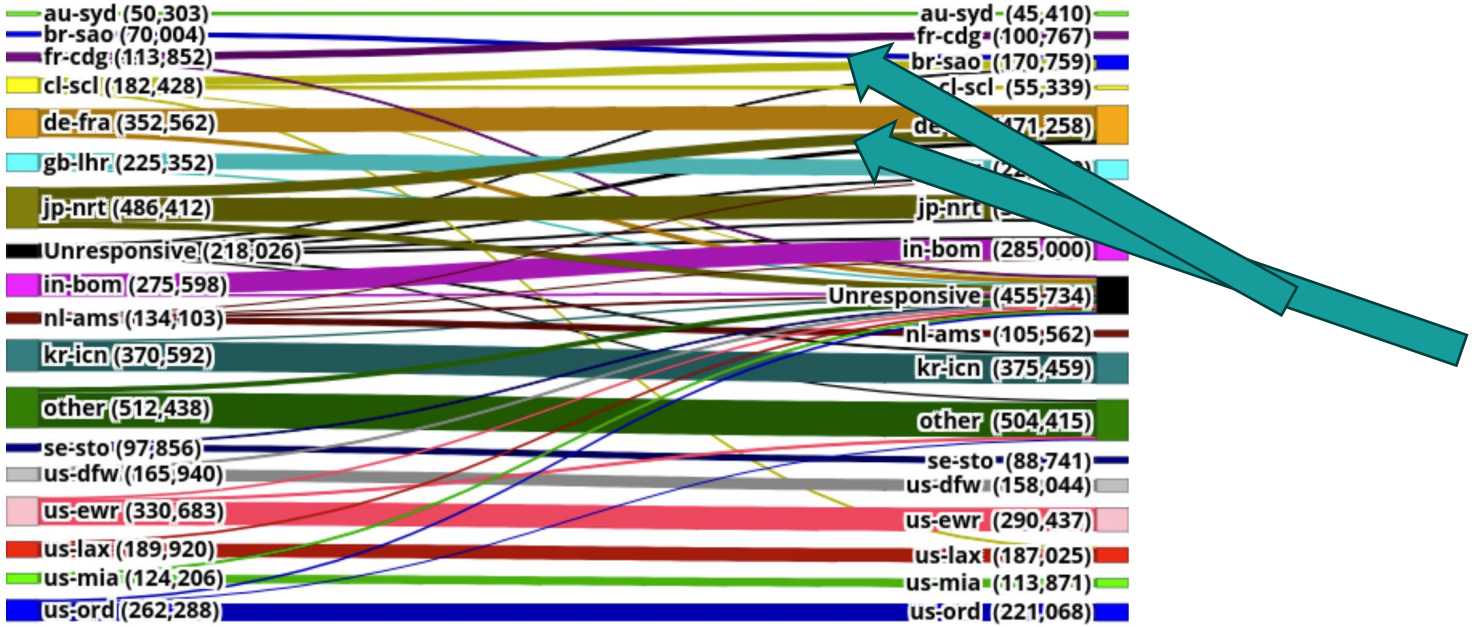


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