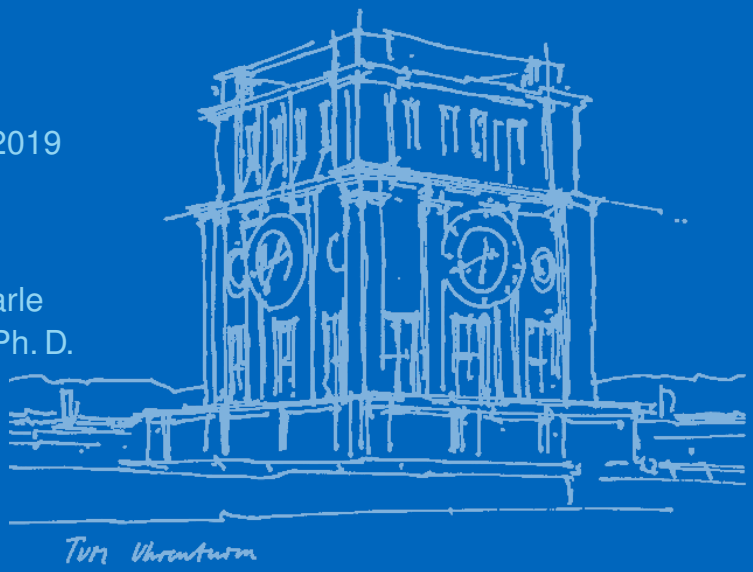
Chair of Network Architectures and Services
Department of Informatics
Technical University of Munich

Evaluating Network Security Using Internet-wide Measurements

Oliver Gasser

Ph. D. Defense, Friday 24th May, 2019

Chairman: Prof. Dr. Jörg Ott
Examiners: Prof. Dr.-Ing. Georg Carle
Prof. Anja Feldmann, Ph. D.



Motivation

SYDNEY, Australia, August 15, 2018

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Detection, Response and Privacy Driving Demand for Security Products and Services

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TLS Certs Outliving Domain Ownership Open Door to MitM and DoS

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Memcached DDoS: The biggest, baddest denial of service attacker yet

Distributed denial of service attacks just got turned up to 11 with Memcrashed, an internet assault that can slam a website with over a terabyte of bad traffic.

By Steven J. Vaughan-Nichols for Networking | March 1, 2018 -- 23:38 GMT (23:38 GMT) | Topic: Security

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The Internet

- Internet measurements can be leveraged to empirically assess security of
  - protocols,
  - devices,
  - implementations, and
  - configurations
- Vast IPv6 address space poses big challenge for Internet measurements

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Goals

- Improve measurement methodology for Internet-wide security measurements
  - IPv4 and IPv6
- Empirically assess security of three different protocols
  - HTTPS
  - BACnet
  - IPMI

Research questions

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RQ I

RQ II

RQ III

RQ IV

RQ V

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RQ I: How can we perform Internet-scale IPv6 measurements?

ZMapv6 goscanner

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- IPv6 address space too large to perform brute-force measurements
- Assemble lists of IPv6 target addresses: IPv6 hitlists

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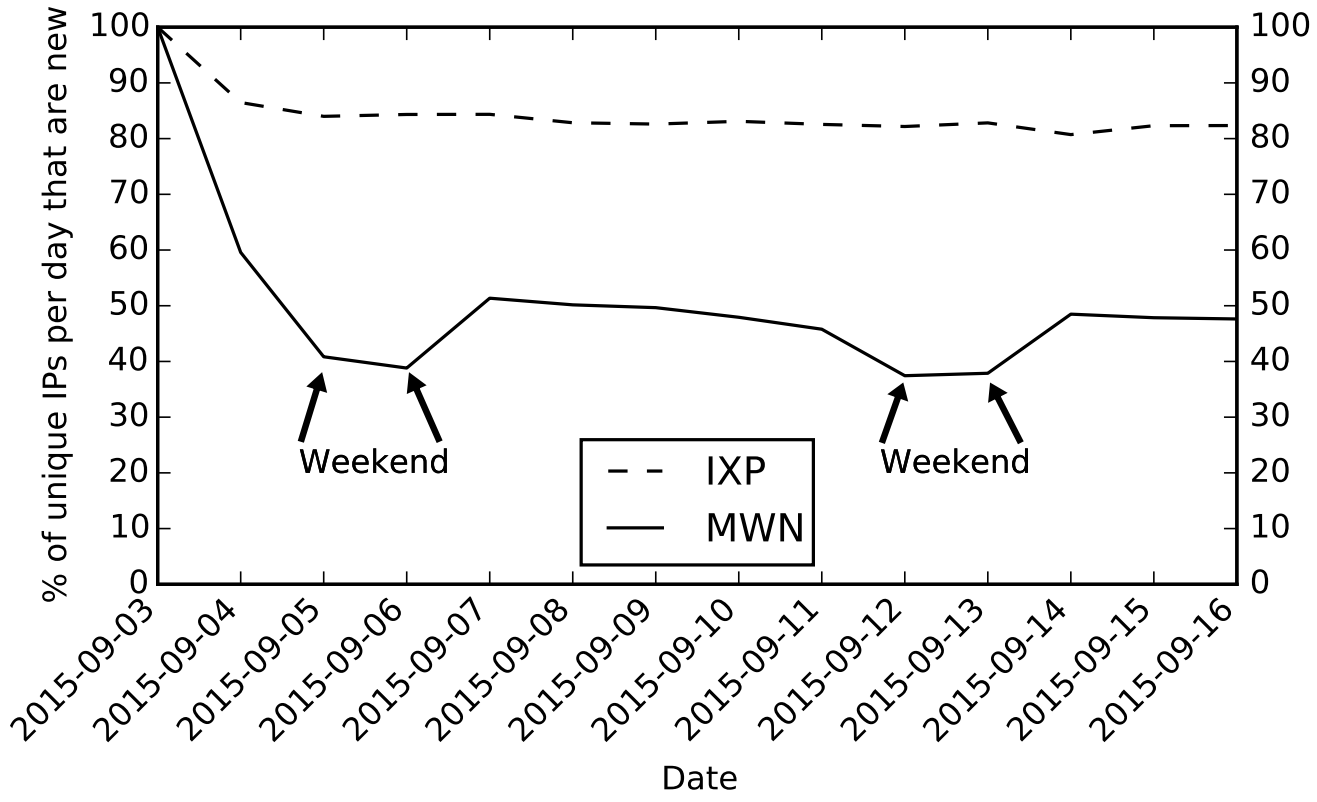
Measurements & analyses

- Passive and active measurements
- Empirical analysis of different types of biases
  - Weekly patterns
  - Different host populations
  - Different number of addresses
  - Over-representation of certain prefixes

RQ II: How biased are address sources for IPv6 hitlists?

IPv6 hitlist passive sources: new IPv6 addresses per day



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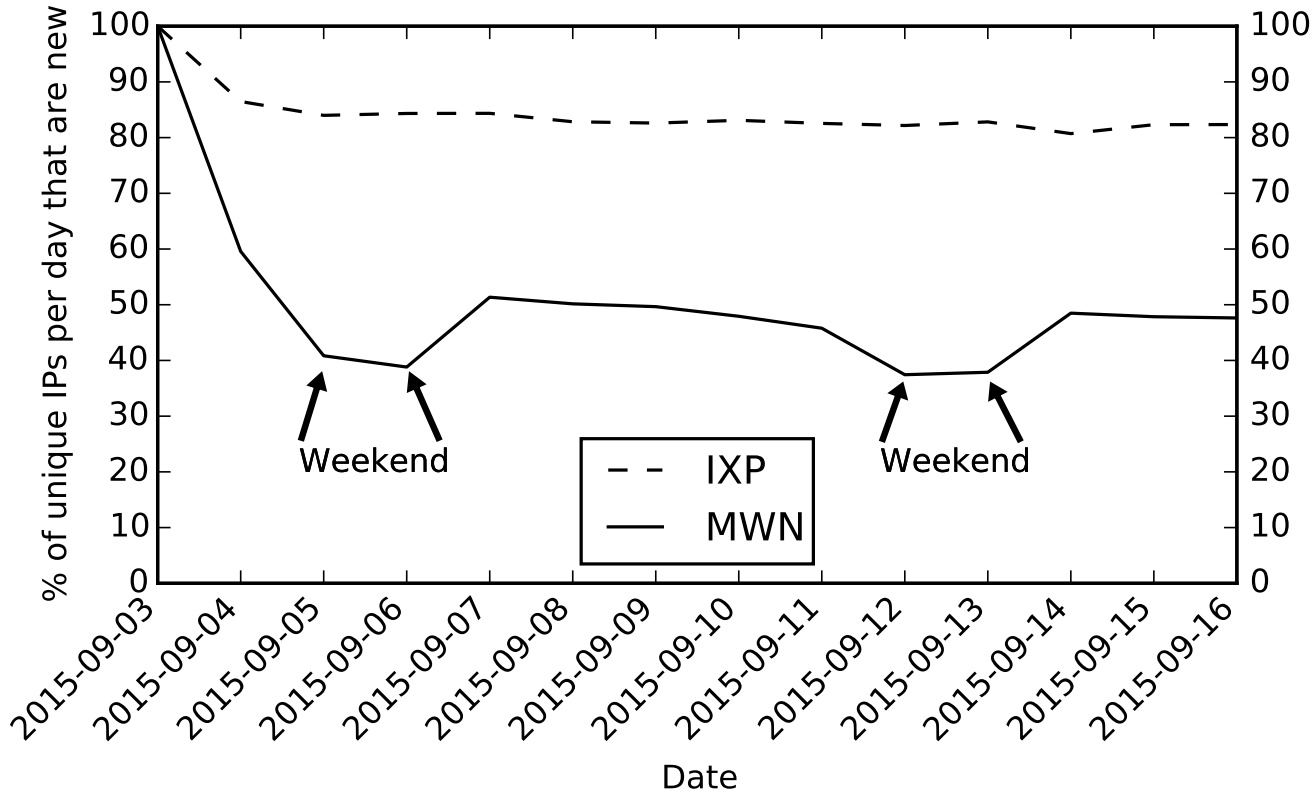
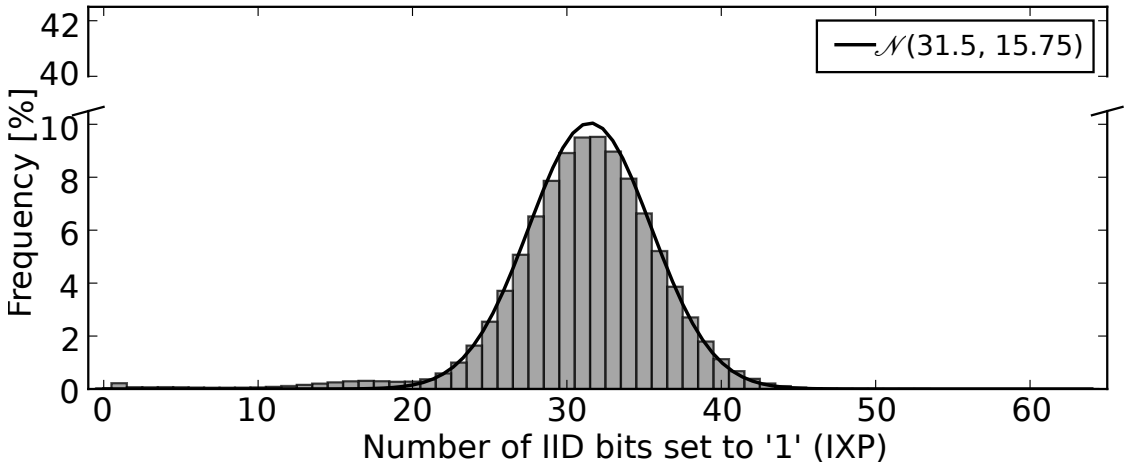


- Large share of new addresses each day hints at privacy extensions

RQ II: How biased are address sources for IPv6 hitlists?

IPv6 hitlist passive vs. active sources: Hamming weight distribution



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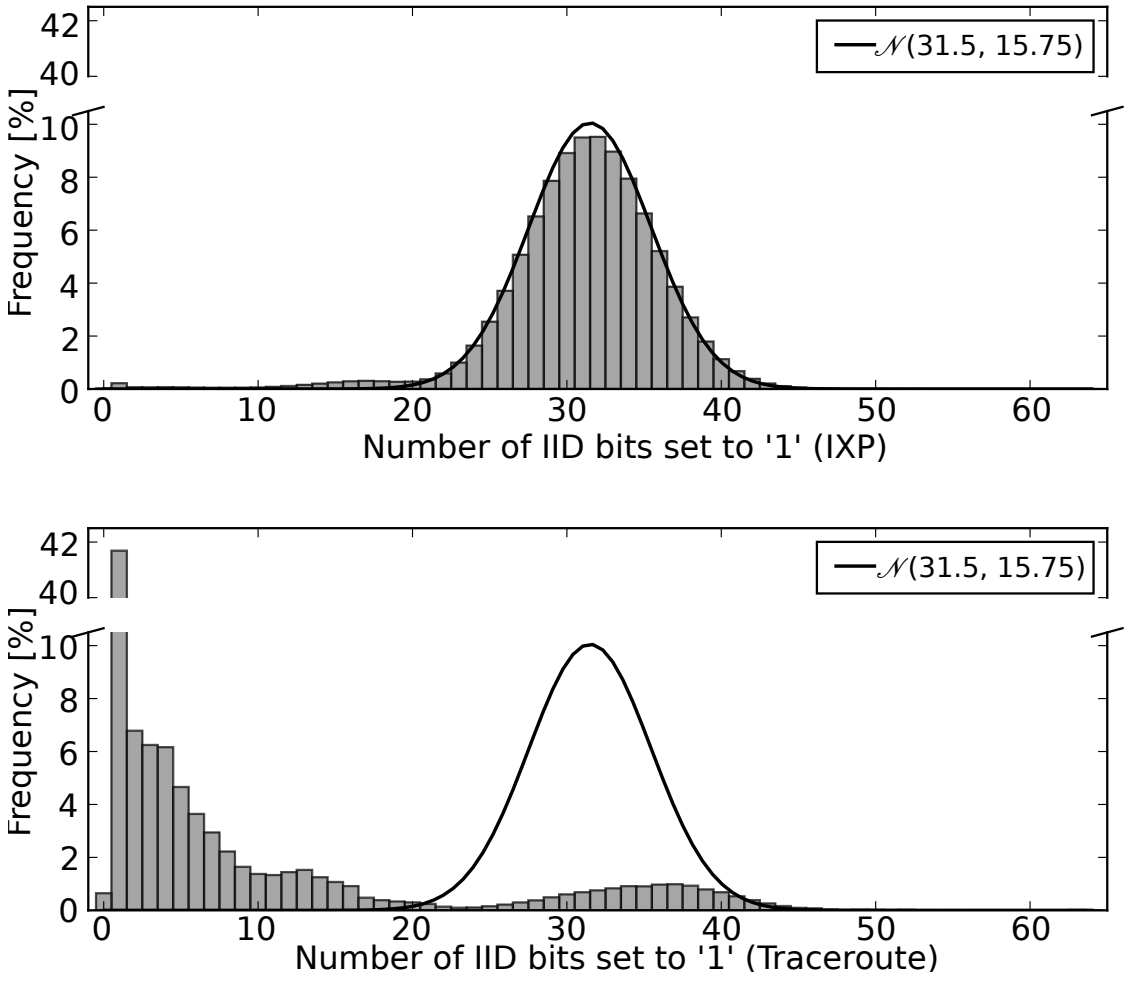

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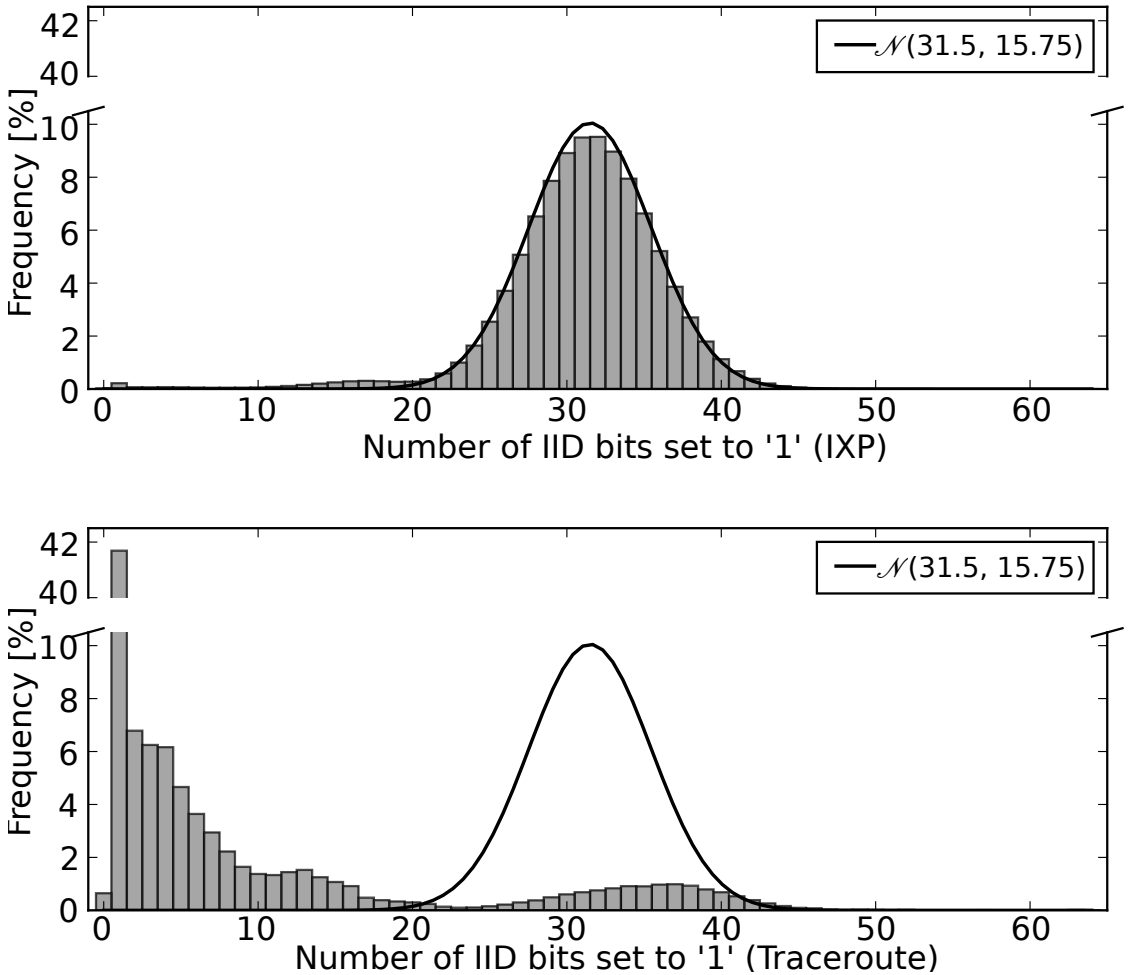

- Different host populations: clients at IXP (privacy extensions) vs. routers (manually assigned addresses)

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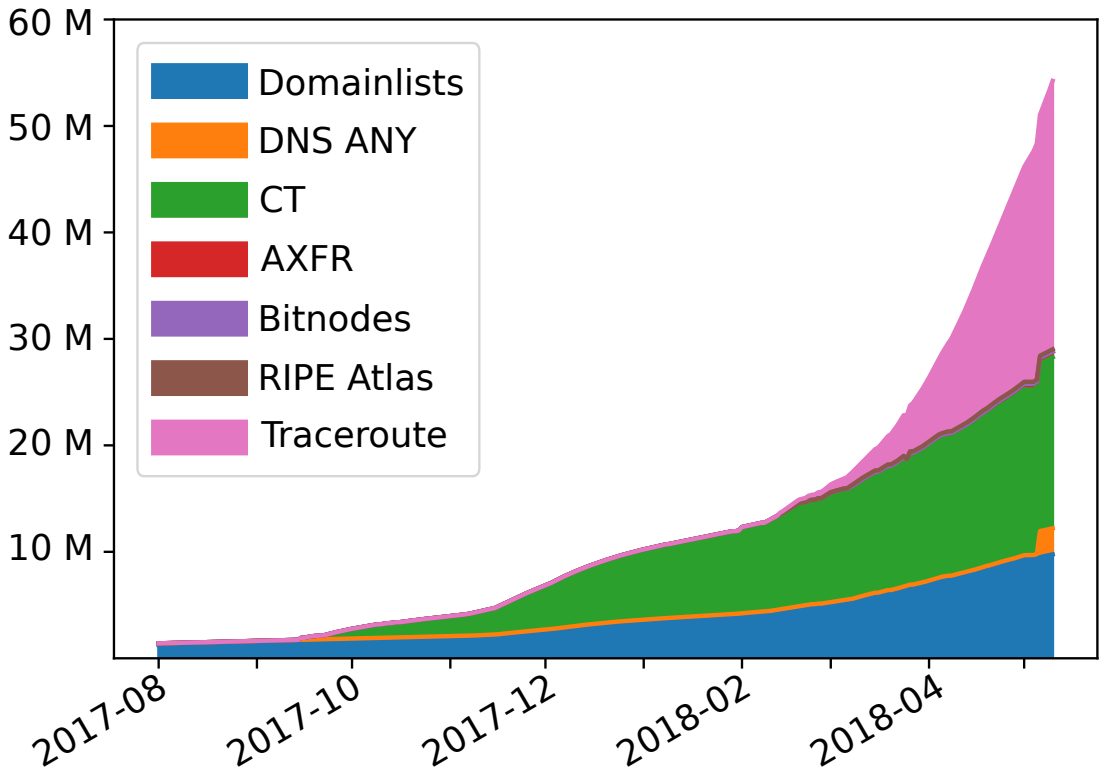
IPv6 hitlist active sources: Cumulative address runup



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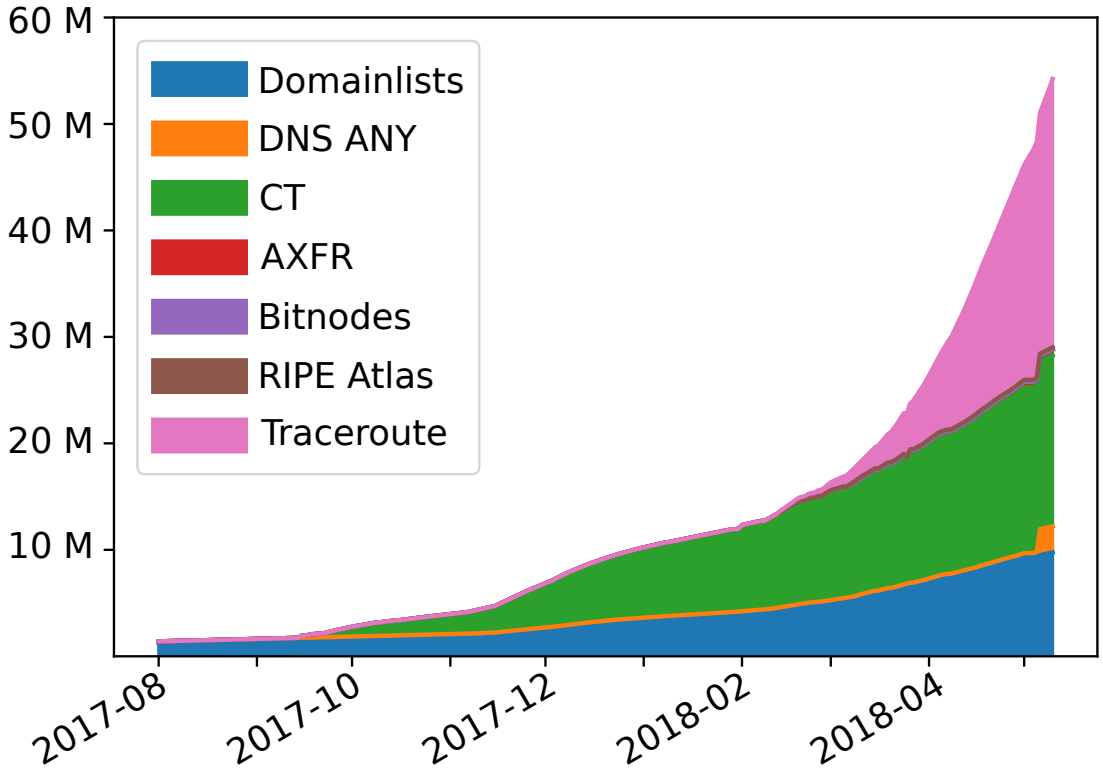

- Many addresses from domainlists, CT, and traceroutes
- Rapid increase of traceroute addresses due to CPE routers

RQ II: How biased are address sources for IPv6 hitlists?

Taxonomy

- Alias: another address of the same host
- Aliased prefix: whole prefix bound to the same host
- Bias: some hosts overrepresented due to aliased prefixes

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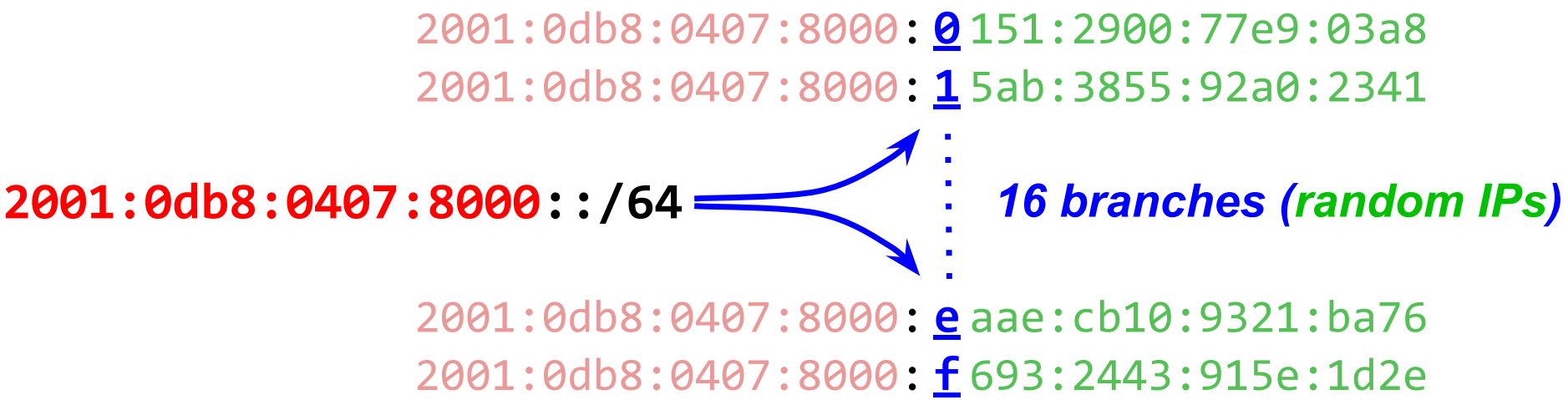
Aliased prefix detection



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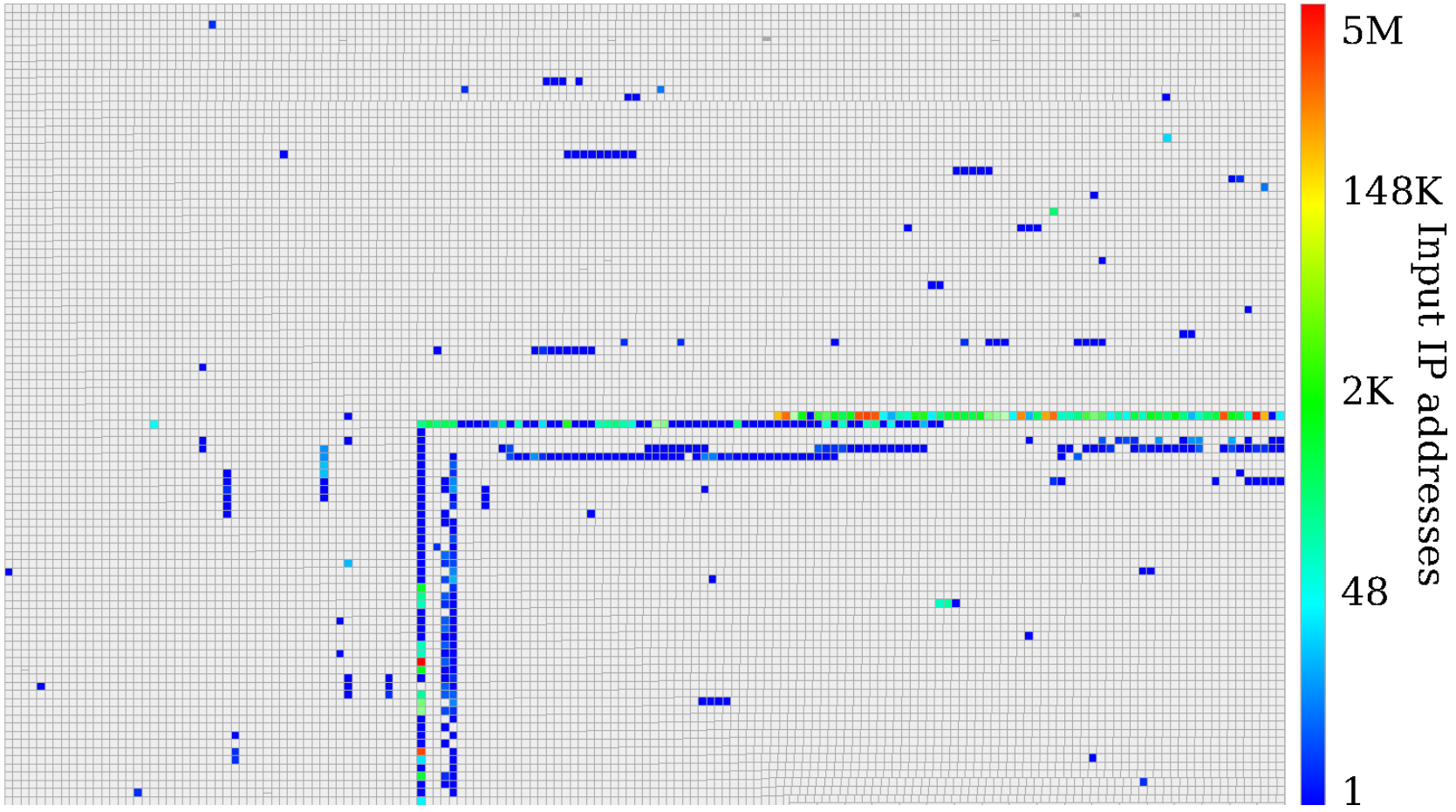
Detected aliased prefixes



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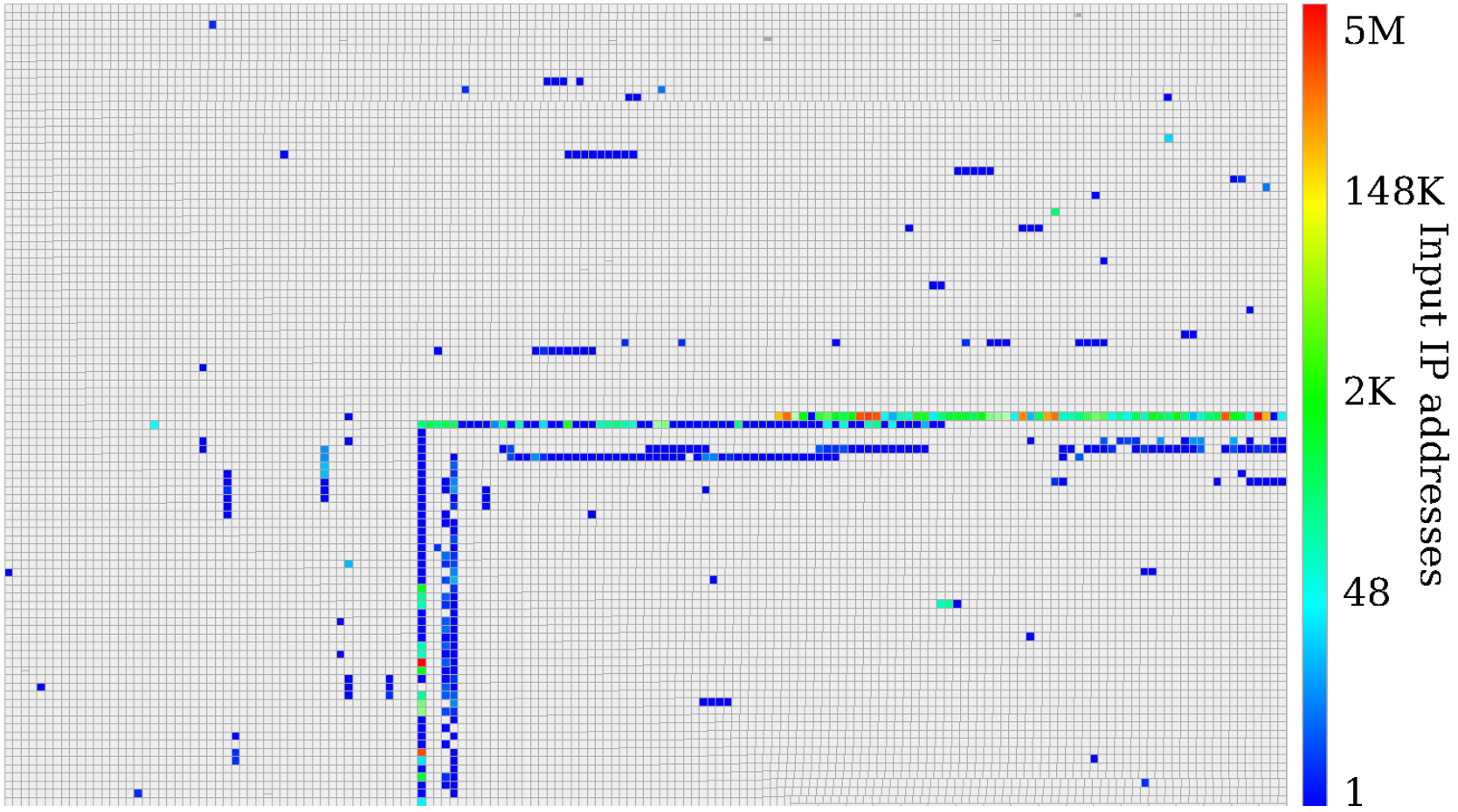
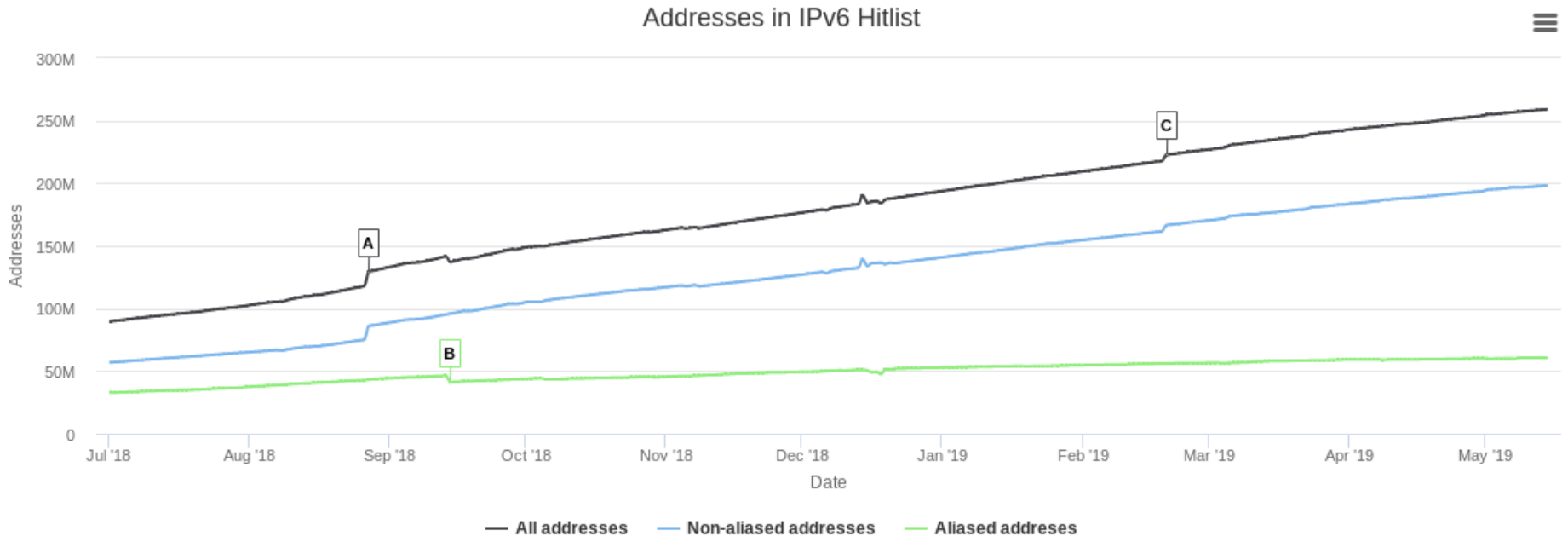


- Only 3.2 % of prefixes are aliased
- But 46.6 % of addresses are in aliased prefixes → bias

RQ II: How biased are address sources for IPv6 hitlists?

IPv6 Hitlist Service

We provide an IPv6 Hitlist Service where we publish **responsive IPv6 addresses, aliased prefixes, and non-aliased prefixes** to interested researchers. The IPv6 Hitlist Service consists of an openly accessible one and a registration-first service.



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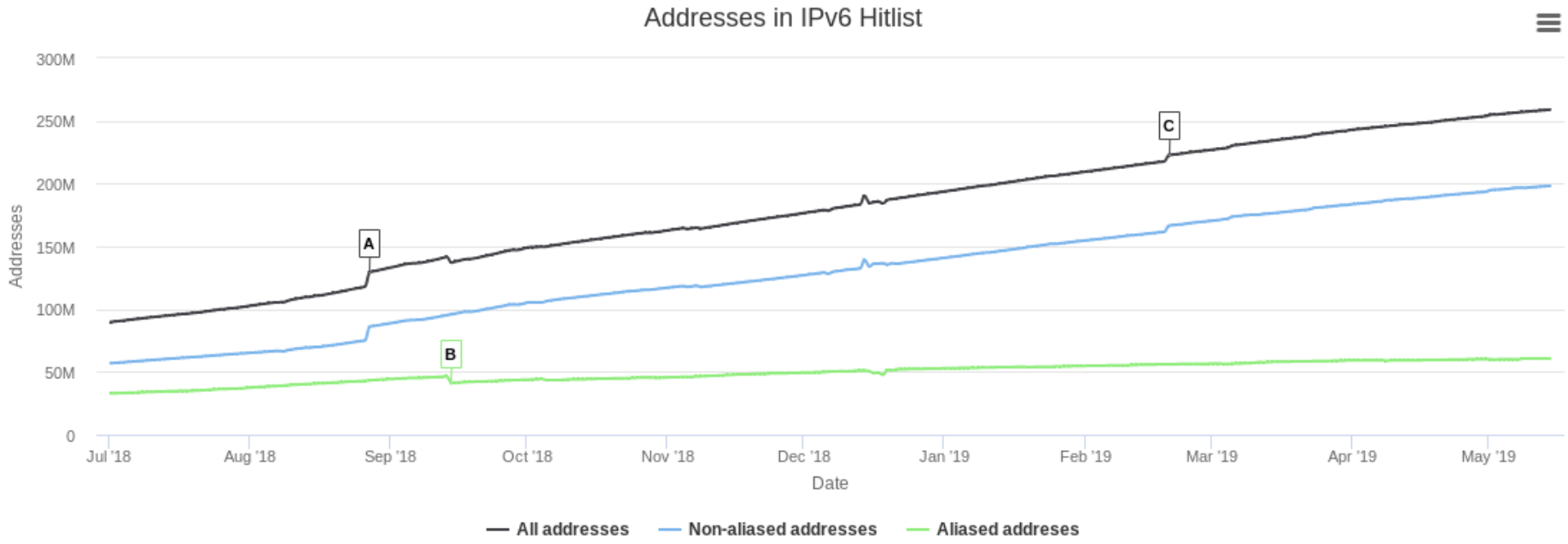

- Daily publication
  - Responsive IPv6 addresses for 5 protocol-port combinations
  - Aliased and non-aliased IPv6 prefixes
- Dozens of fellow researchers have access

RQ II: How biased are address sources for IPv6 hitlists?

Summary

- Identified different types of biases in IPv6 hitlist sources
  - Distort targets by almost 50 %
  - Biases can be detected
- IPv6 Hitlist Service provides fellow researchers with access to daily IPv6 address data

Publications (this research question)

- *Oliver Gasser, Quirin Scheitle, Pawel Foremski, Qasim Lone, Maciej Korczynski, Stephen D. Strowes, Luuk Hendriks, and Georg Carle*, “Clusters in the Expanse: Understanding and Unbiasing IPv6 Hitlists”, **IMC’18**.
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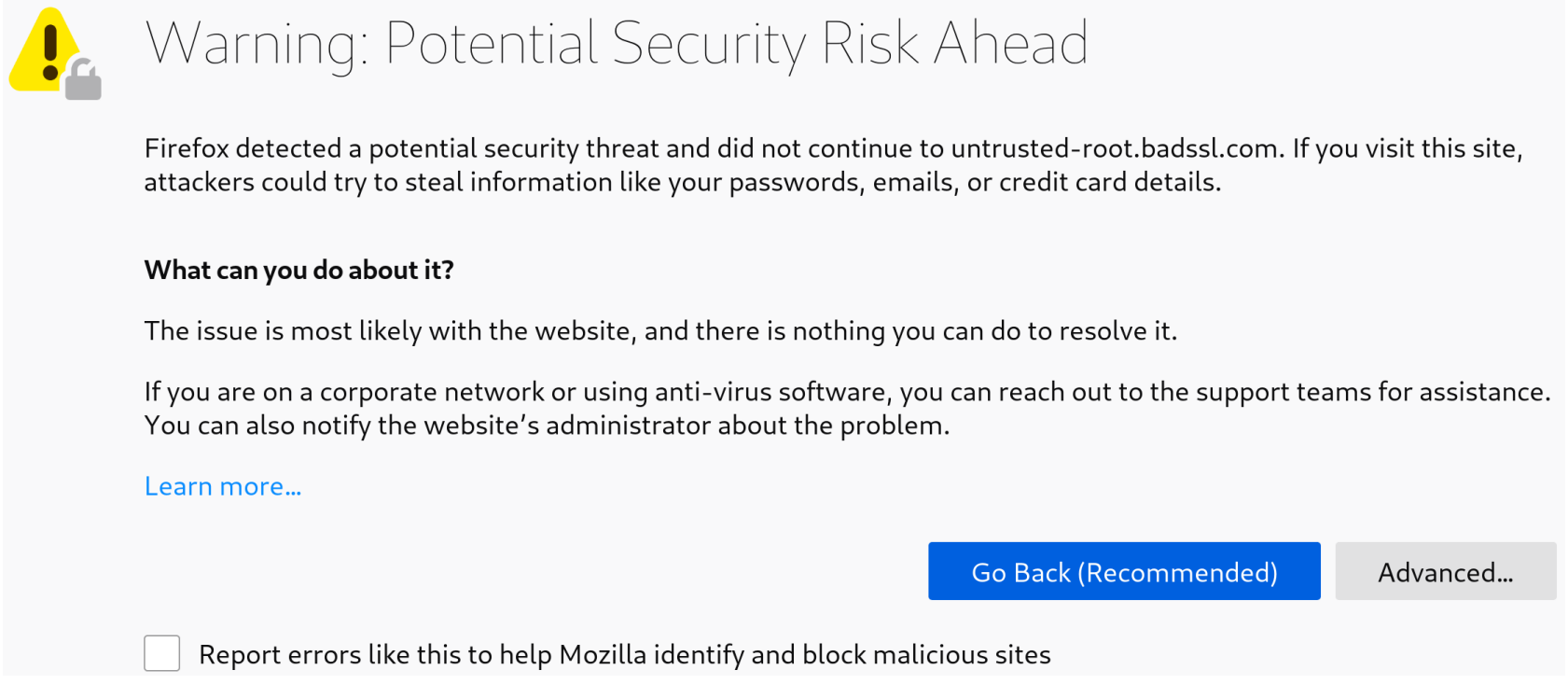

RQ III: Are HTTPS servers still vulnerable to MitM attacks?

Motivation

- HTTPS ecosystem experienced many security issues which allow for MitM attacks (e.g., misissued certificates, weak keys, CA breaches)
- A number of HTTPS security extensions have been proposed to make the HTTPS ecosystem more secure

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Measurements & analyses

- Active measurements
- Empirical analysis of different HTTPS ecosystem weaknesses
  - Insecure certificates
  - Downgrade from HTTPS to HTTP
  - Misissued certificates

RQ III: Are HTTPS servers still vulnerable to MitM attacks?

Baseline Requirements (BRs)

- Rules regarding certificates and issuing processes which CAs adhere to
- Devised within the CA/Browser Forum
- Each requirement has an enforcement date

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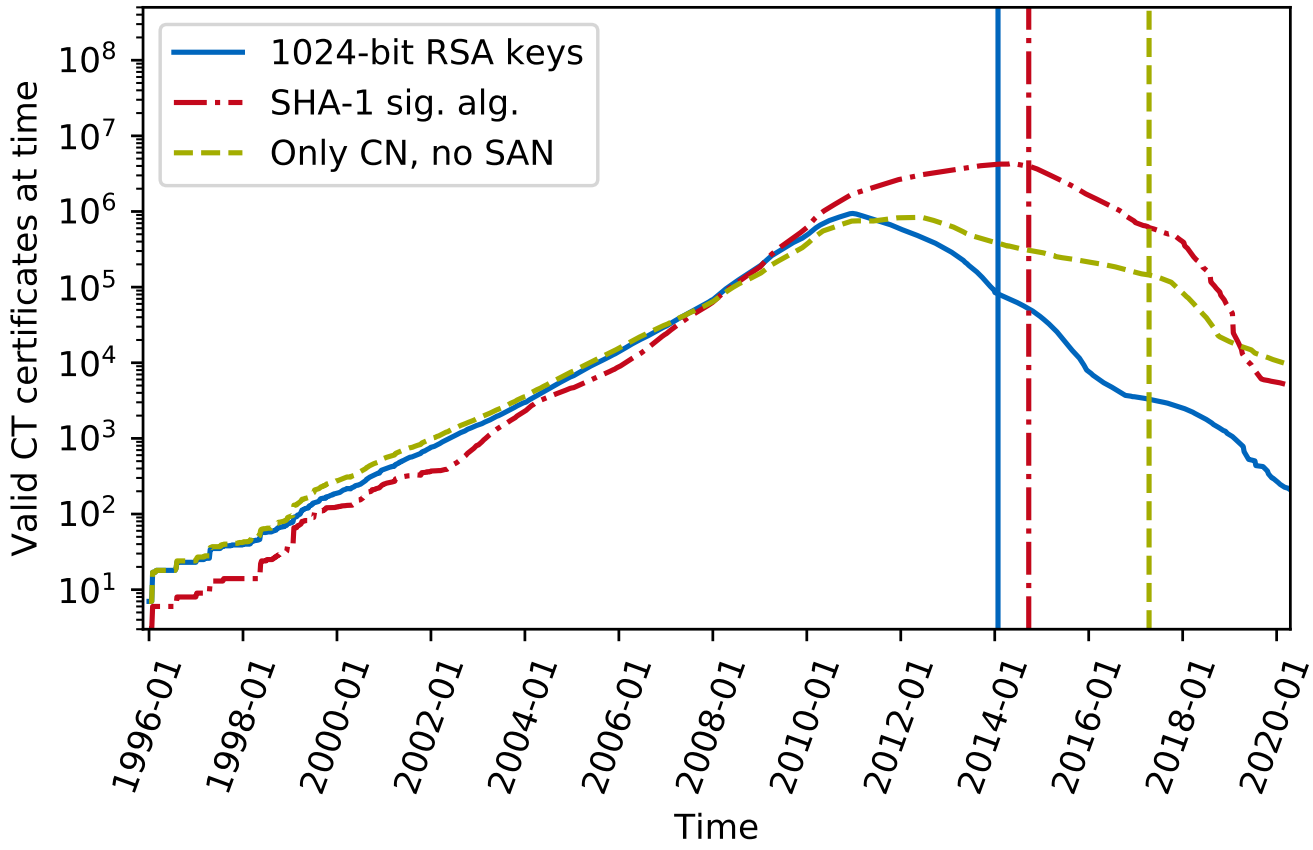
Analyze BR adherence of all certificates in Certificate Transparency (CT) logs

- Must not use 1024 bit keys
- Must not use SHA-1 signature algorithm
- Must contain SAN in addition to CN

RQ III: Are HTTPS servers still vulnerable to MitM attacks?

BR violations of certificates in CT logs



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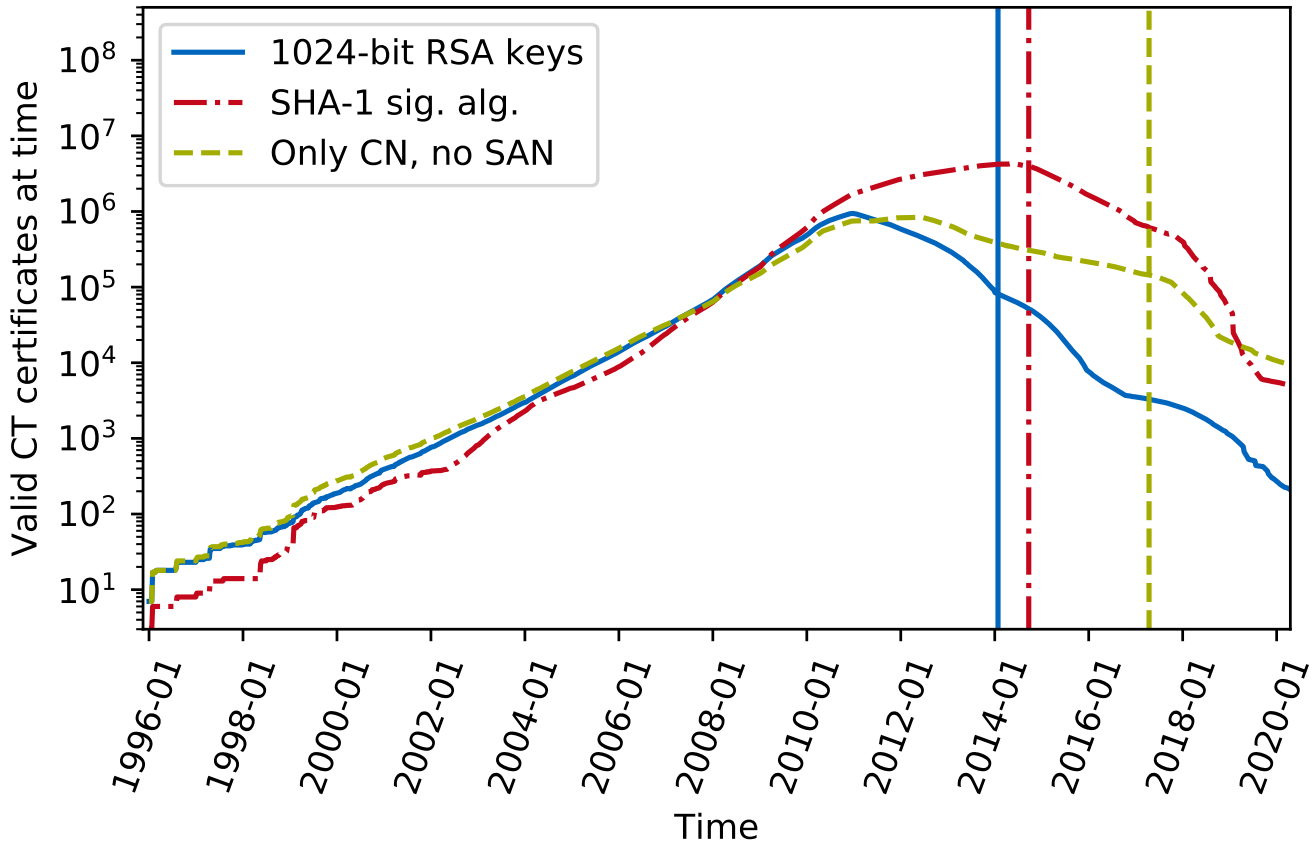
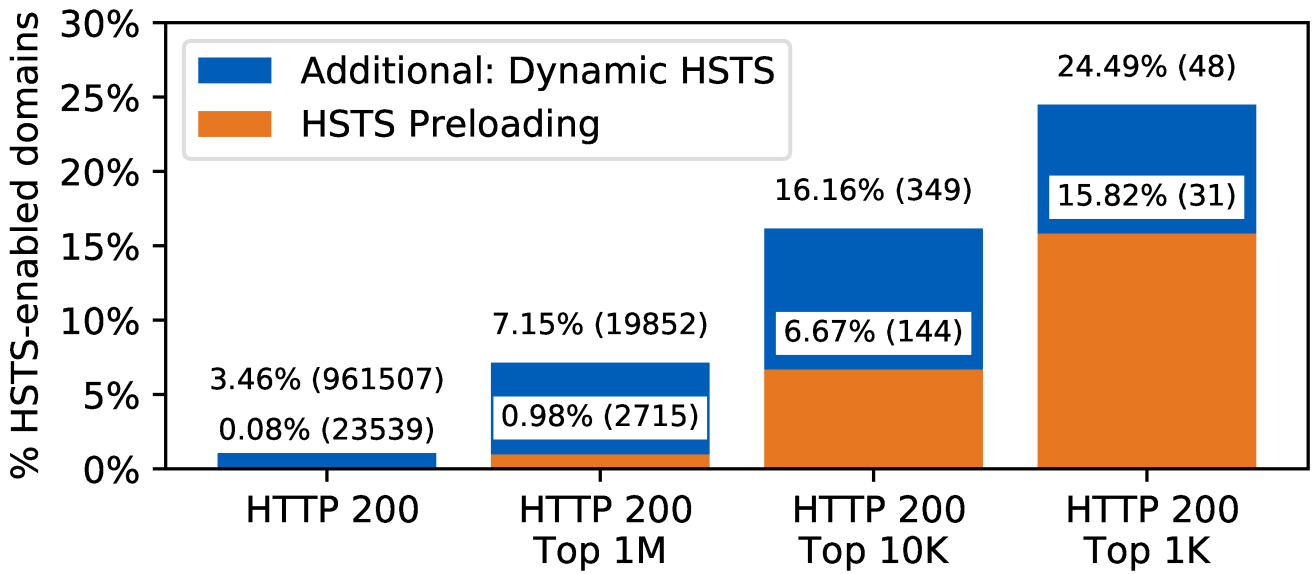


- Enforcement of stricter rules helps curb the number of insecure certificates
- But: Many valid insecure certificates are found in CT logs

RQ III: Are HTTPS servers still vulnerable to MitM attacks?

HTTP Strict Transport Security (HSTS) deployment



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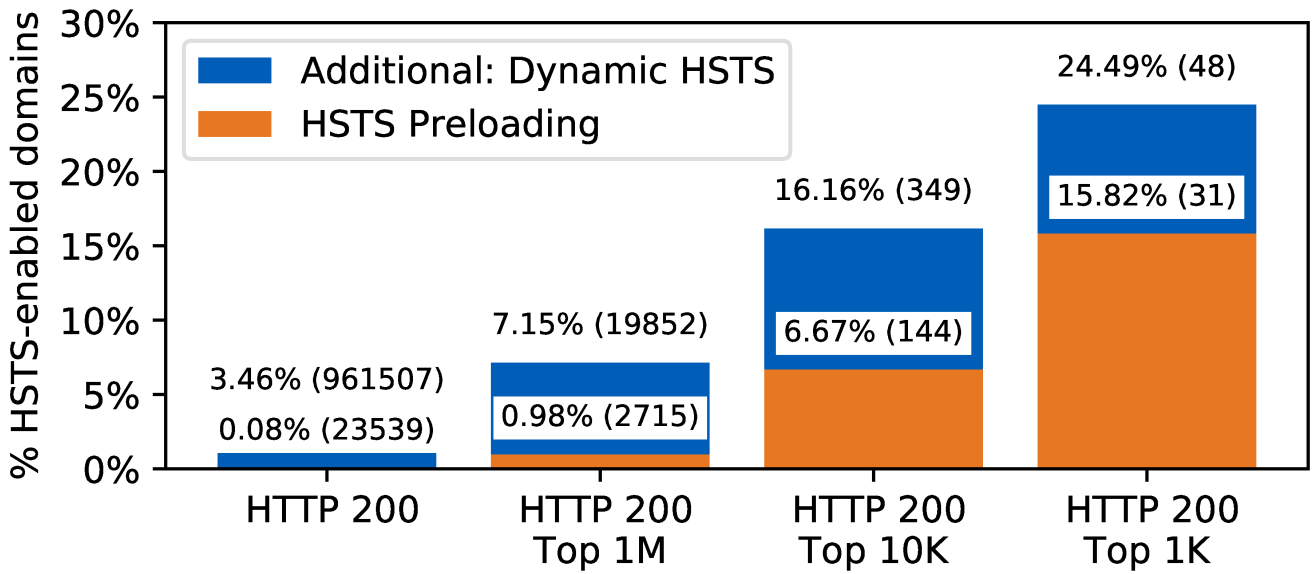

- Significant usage among top domains
- Preloading highly used among top domains, smaller usage among general population

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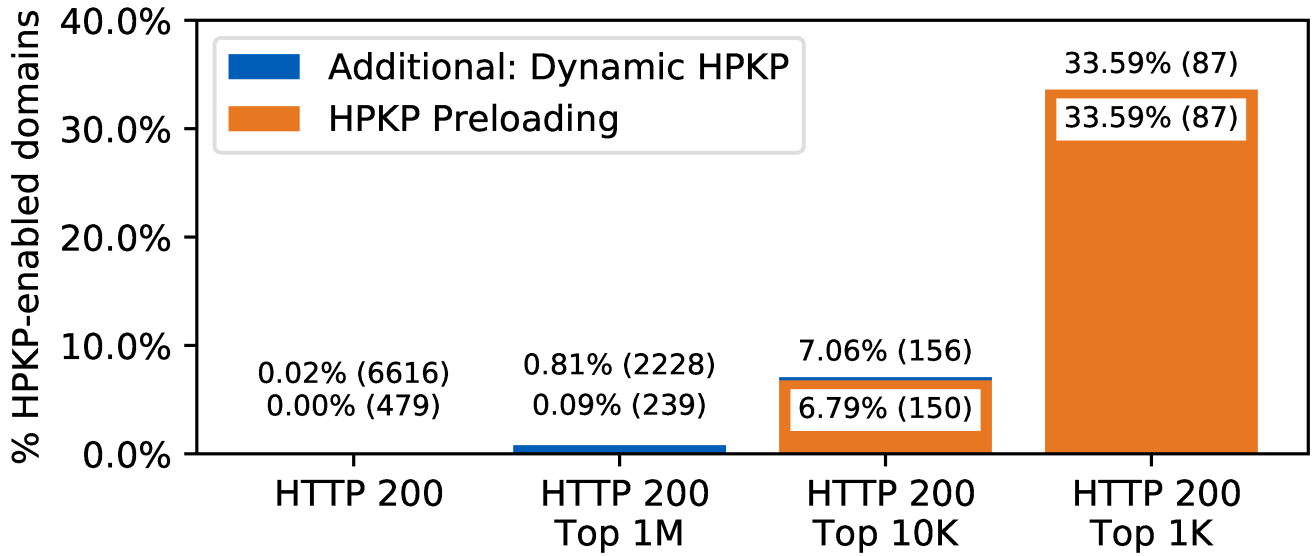
HTTP Public Key Pinning (HPKP) deployment



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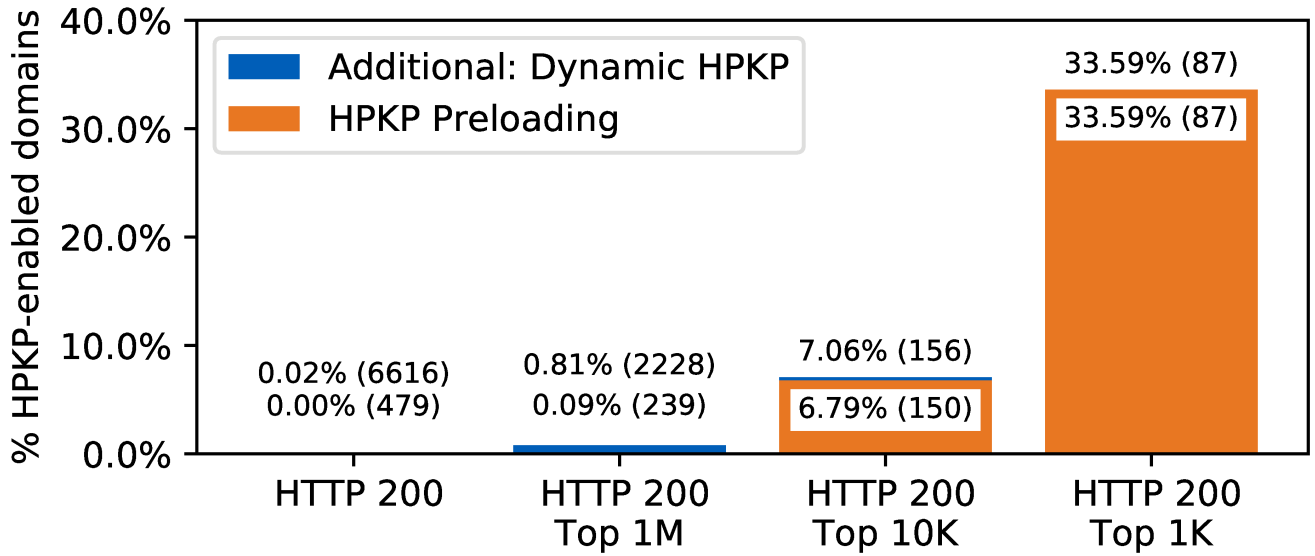

- Low usage among general population
- High usage through preloading among top domains

RQ III: Are HTTPS servers still vulnerable to MitM attacks?

Summary

- Thousands of insecure certificates are still valid
- High usage of HSTS and HPKP among top domains, mostly due to preloading
- Insecure certificates and lack of HTTPS security techniques make hosts vulnerable to Man-in-the-Middle attacks

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IPv6 measurements	✗	✗	✓	✓
Bias analyses	✗	✗	✓	✗
HTTPS security analyses	✓	✓	✗	✗
Reproducibility efforts	✗	✗	✓	✗
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- Internet measurement methodology
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  - Extensive bias analyses in hitlist sources
  - IPv6 Hitlist Service
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[2] Zakir Durumeric. “Fast Internet-Wide Scanning: A New Security Perspective”. PhD thesis. University of Michigan, 2017.

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[5] Oliver Gasser, Quirin Scheitle, Pawel Foremski, Qasim Lone, Maciej Korczynski, Stephen D. Strowes, Luuk Hendriks, and Georg Carle. “Clusters in the Expanse: Understanding and Unbiasing IPv6 Hitlists”. In: IMC’18. ACM. Boston, MA, USA, Nov. 2018. DOI: 10.1145/3278532.3278564.

[6] Oliver Gasser, Quirin Scheitle, Sebastian Gebhard, and Georg Carle. “Scanning the IPv6 Internet: Towards a Comprehensive Hitlist”. In: TMA’16. IFIP. Louvain-la-Neuve, Belgium, Apr. 2016.

[7] Luuk Hendriks. “Measuring IPv6 Resilience and Security”. PhD thesis. University of Twente, 2019.

[8] Ralph-Günther Holz. “Empirical Analysis of Public Key Infrastructures and Investigation of Improvements”. PhD thesis. Technical University of Munich, 2014.

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[9] IMC'18. ACM. Boston, MA, USA, Nov. 2018.

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