

Profiling BGP Serial Hijackers: Capturing Persistent Misbehavior in the Global Routing Table

ACM Internet Measurement Conference 2019

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MIT

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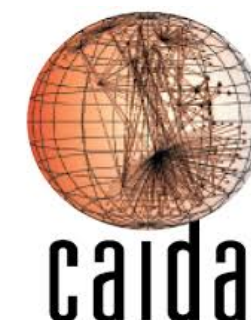
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UC San Diego

BGP hijacking is pervasive in the Internet

How Pakistan knocked YouTube offline (and how to make sure it never happens again)

YouTube becoming unreachable isn't the first time that Internet addresses were hijacked. But if it spurs interest in better security, it may be the last.

BY DECLAN MCCULLAGH | FEBRUARY 25, 2008 4:28 PM PST

BORDER GATEWAY PROTOCOL —

How 3ve's BGP hijackers eluded the Internet—and made \$29M

3ve used addresses of unsuspecting owners—like the US Air Force.

DAN GOODIN - 12/21/2018, 12:30 PM

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Suspicious event hijacks Amazon traffic for 2 hours, steals cryptocurrency

Almost 1,300 addresses for Amazon Route 53 rerouted for two hours.

DAN GOODIN - 4/24/2018, 3:00 PM

Criminals, Nation-States Keep Hijacking BGP and DNS

While Exploitable Protocols and Processes Persist, Adoption of Secure Fixes Lags

Mathew J. Schwartz (@euroinfosec) • February 18, 2019

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Cyber criminals are stepping up their attacks against routing protocols, creating new problems for enterprise security

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Cyber criminals are stepping up their attacks against routing protocols, creating new problems for enterprise security

▶ The problem of BGP hijacking is **still** far from solved.

Hijack disclosure in mailing lists

OmanTel hijacking of IP space

Jared Mauch [jared at puck.nether.net](mailto:jared@puck.nether.net)
Wed Jan 11 15:50:49 UTC 2017

- Previous message (by thread): [Advice re network compromise and "law enforcement" \(PCI certification\)](#)
- Next message (by thread): [OmanTel hijacking of IP space](#)
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There is an ongoing pattern of OmanTel hijacking IP space and advertising it to many of their peers

here'
42000
Pleas

IPv4 and IPv6 hijacking by AS 6

Matt Harris [matt at netfire.net](mailto:matt@netfire.net)
Thu Apr 12 16:34:31 UTC 2018

- Previous message (by thread): [F](#)
- Next message (by thread): [IPv4](#)
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AS 6 is now announcing s
like I'm not alone. Doe
might be going on? The
tremendous. The phone n
non-functional. I've se
(Mike Abbott and John Lu
not optimistic.

198.154.60.0/22 bogon/hijacked?

Jeremy Parsons [jeremyp at gmx.us](mailto:jeremyp@gmx.us)
Mon Nov 14 00:49:29 UTC 2016

AS3266: BitCanal hijack factory, courtesy of Cogent, GTT, and Level3

Ronald F. Guilmette [rfg at tristatelogic.com](mailto:rfg@tristatelogic.com)
Tue Jun 26 04:49:15 UTC 2018

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AS9498 Bharti BGP hijacks

George William Herbert [george.herbert at gmail.com](mailto:george.herbert@gmail.com)
Sat Apr 1 18:19:55 UTC 2017

- Next message (by thread): [AS9498 Bharti BGP hijacks](#)
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Hey, Bharti, knock that off.

[ht](#)
[ht](#)
[ht](#)
[tt](#)

Prefix hijack by INDOSAT AS4795 / AS4761

Randy [amps at djlab.com](mailto:amps@djlab.com)
Thu Mar 26 14:08:20 UTC 2015

- Previous message: [booster to gain distance above 60km](#)
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-going) we are seeing
else seeing similar or

436 29889
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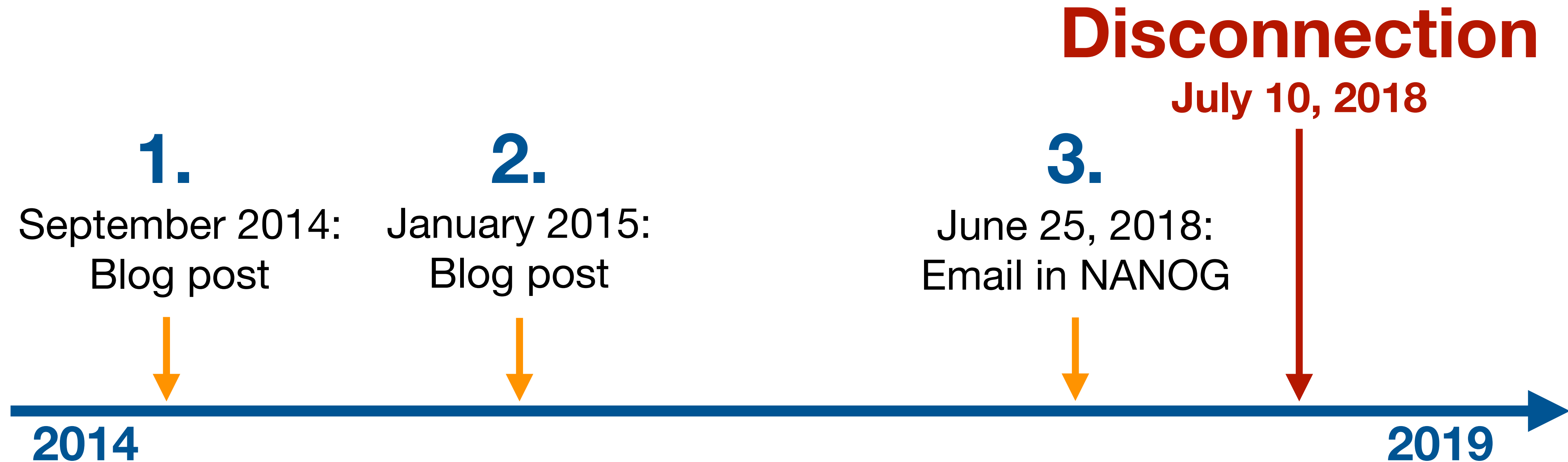
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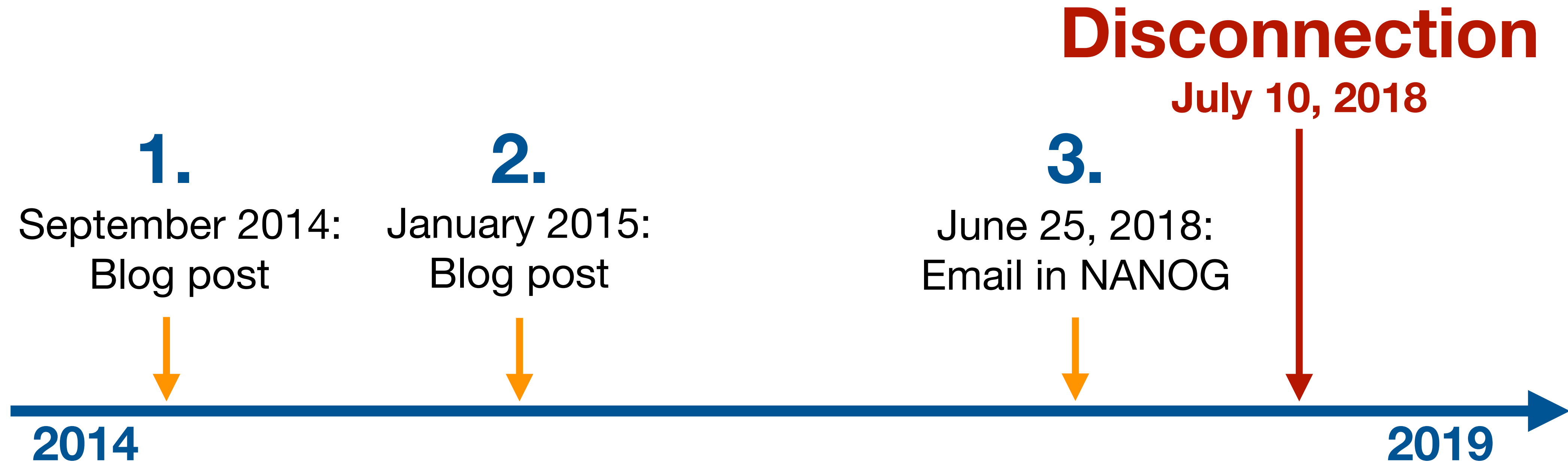
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► **Serial hijackers:** ASes that repeatedly hijack over long periods of time.

Bitcanal: an infamous serial hijacker



Bitcanal: an infamous serial hijacker



► It took **4 years** to disconnect this serial hijacker.

Research goals

Find serial hijackers in the Internet

- (i) Identify hijackers distinctive routing characteristics
- (ii) Build a machine learning system to flag suspicious ASes
- (iii) Evaluate our results

What can we learn about serial hijackers?

Ground truth: serial hijackers

23 serial hijackers:

- 10+ hijacks
- Most have been active over a year
- Up to 30,000 originated prefixes

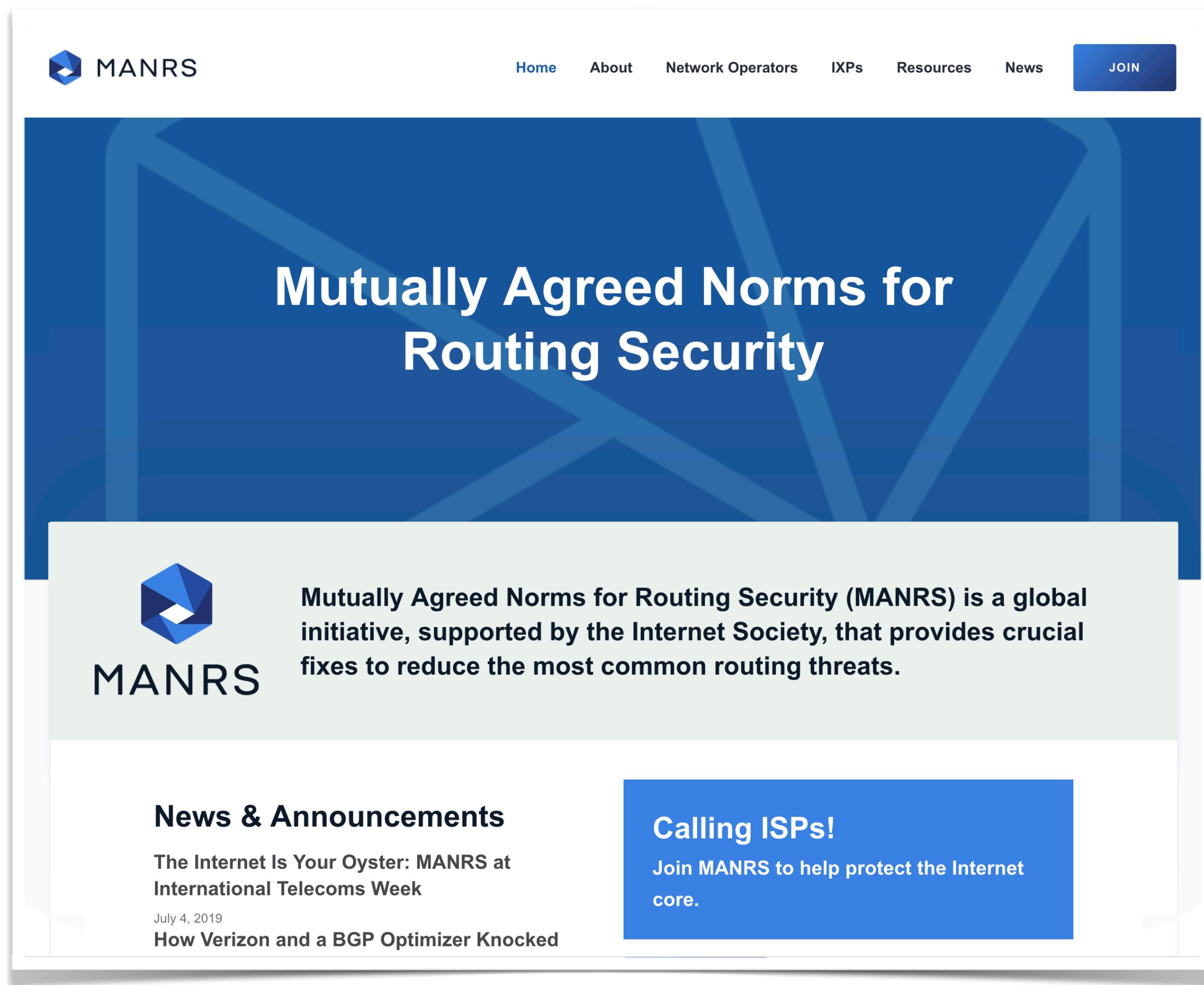


ASN country and RIR registration

Ground truth: legitimate ASes

230 Legitimate ASes:

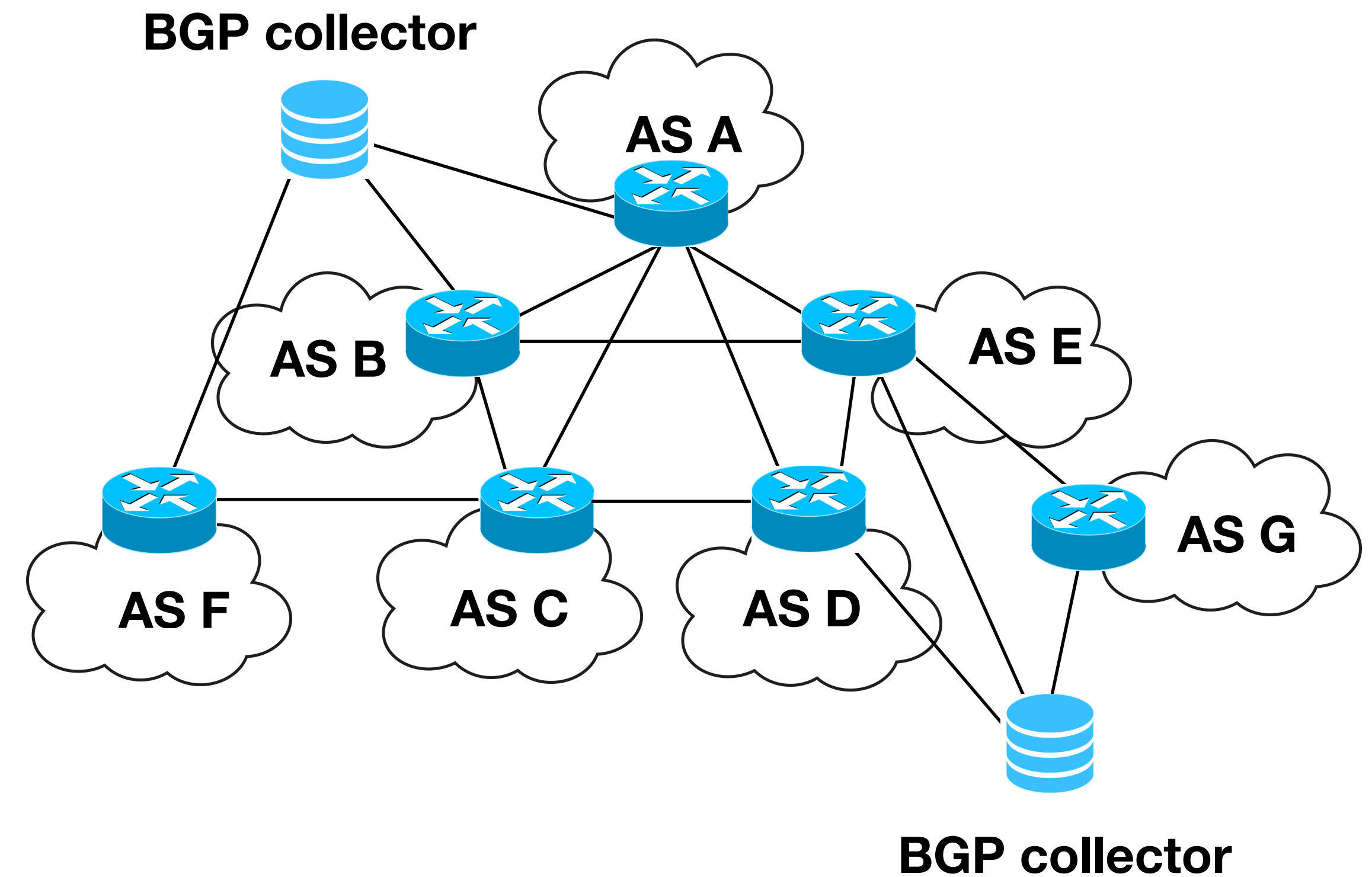
- 191 MANRS ASes
- 26 ASes manually selected



The screenshot shows the homepage of the MANRS website. At the top left is the MANRS logo, a blue cube with a white 'M' shape inside. To its right is the text 'MANRS'. Further right is a navigation menu with links for 'Home', 'About', 'Network Operators', 'IXPs', 'Resources', and 'News'. A blue 'JOIN' button is located at the top right. The main content area features a large blue banner with the text 'Mutually Agreed Norms for Routing Security' in white. Below the banner is a light green box containing the MANRS logo and a paragraph: 'Mutually Agreed Norms for Routing Security (MANRS) is a global initiative, supported by the Internet Society, that provides crucial fixes to reduce the most common routing threats.' Below this is a 'News & Announcements' section with a sub-heading 'The Internet Is Your Oyster: MANRS at International Telecoms Week' and a date 'July 4, 2019'. A blue box on the right contains the text 'Calling ISPs! Join MANRS to help protect the Internet core.' At the bottom of the news section is the text 'How Verizon and a BGP Optimizer Knocked'.

BGP dataset and processing

- RIPE RIS and RouteViews collectors (~40 col., ~1400+ col. peers)
- We process all **BGP updates** to reconstruct peer routing tables
- We extract **(prefix, origin AS)** pairs and the number of peers with each pair in their routing table (**visibility**)
- Data from Jan. 2014 to Dec. 2018



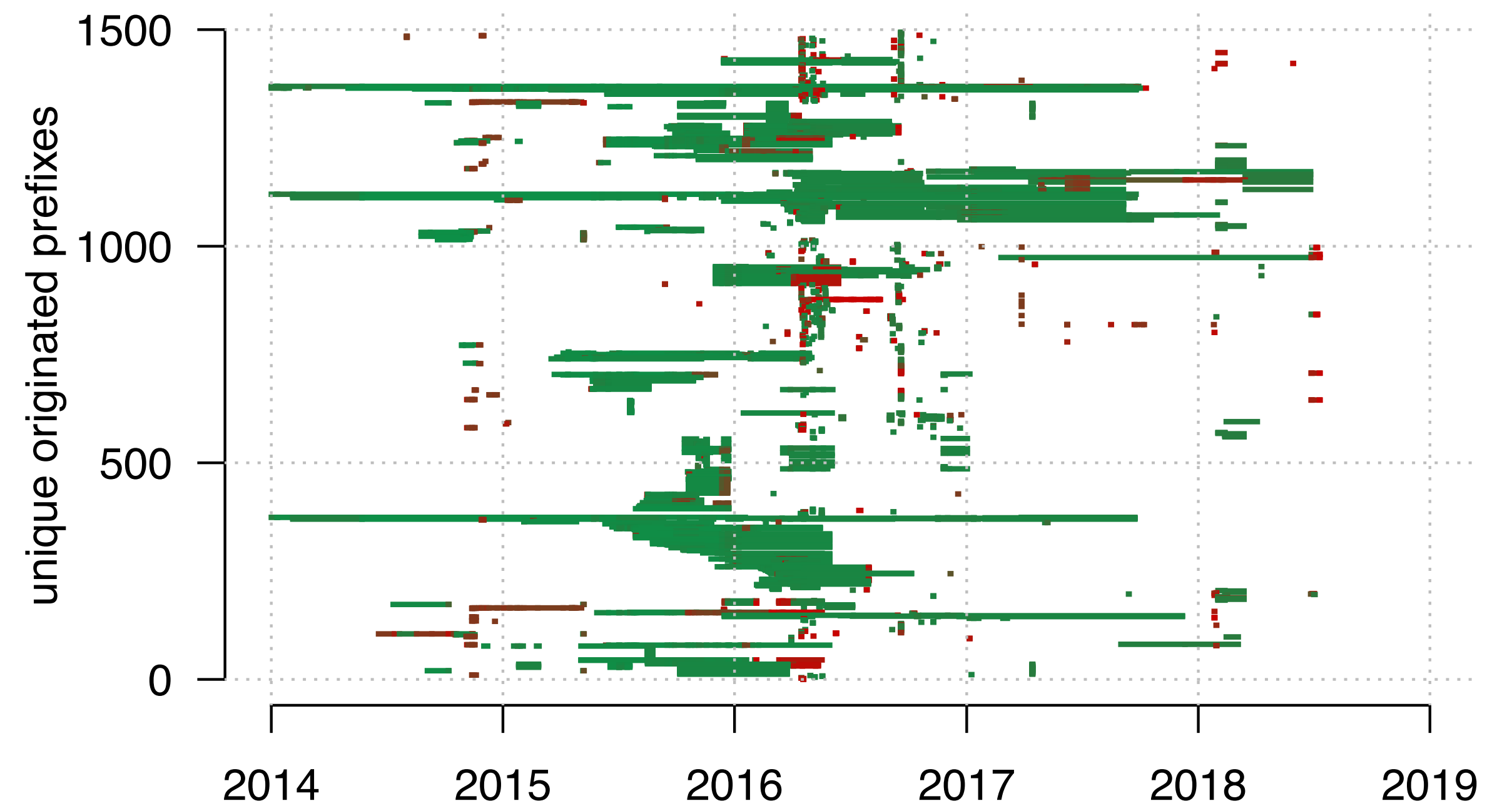
► **(prefix, origin AS, visibility, timestamp)** every 5 min.

BGP origination behavior: legitimate vs. serial hijacker

British Telecom (AS 5400)



Bitcanal (AS 197426)

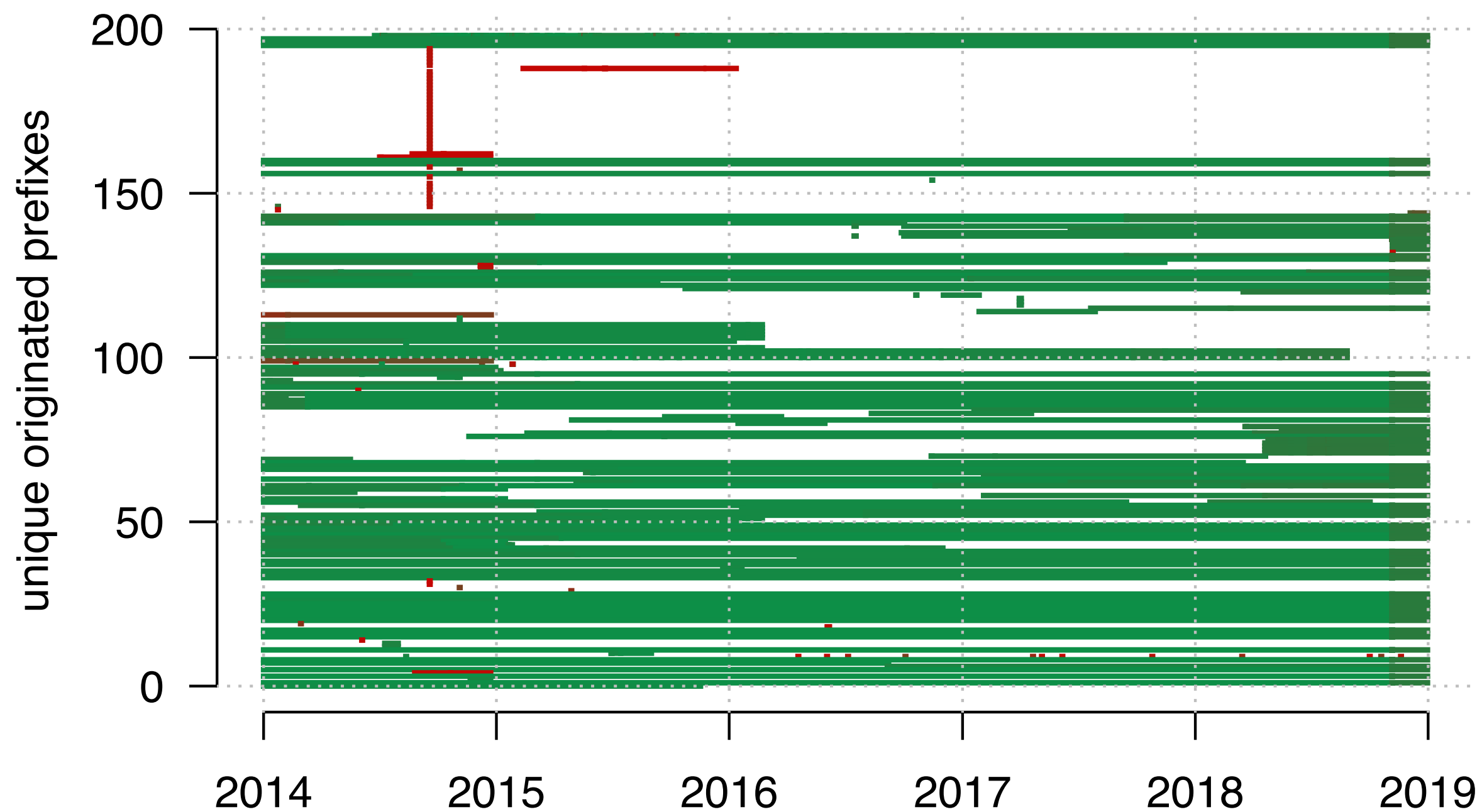


► Legitimate ASes mostly show **stable** BGP behavior.

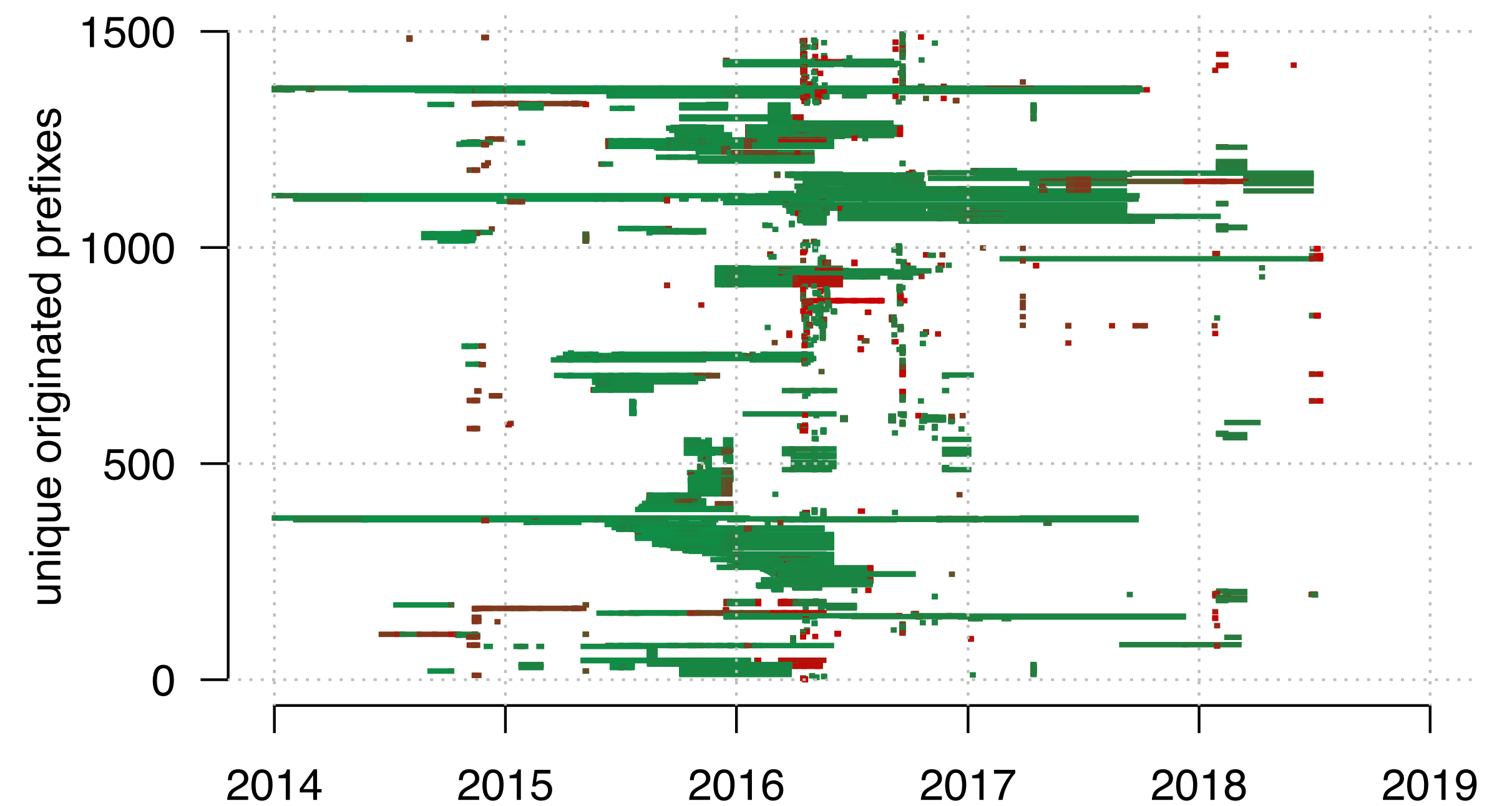
► Serial hijackers BGP activity is **visually different**.

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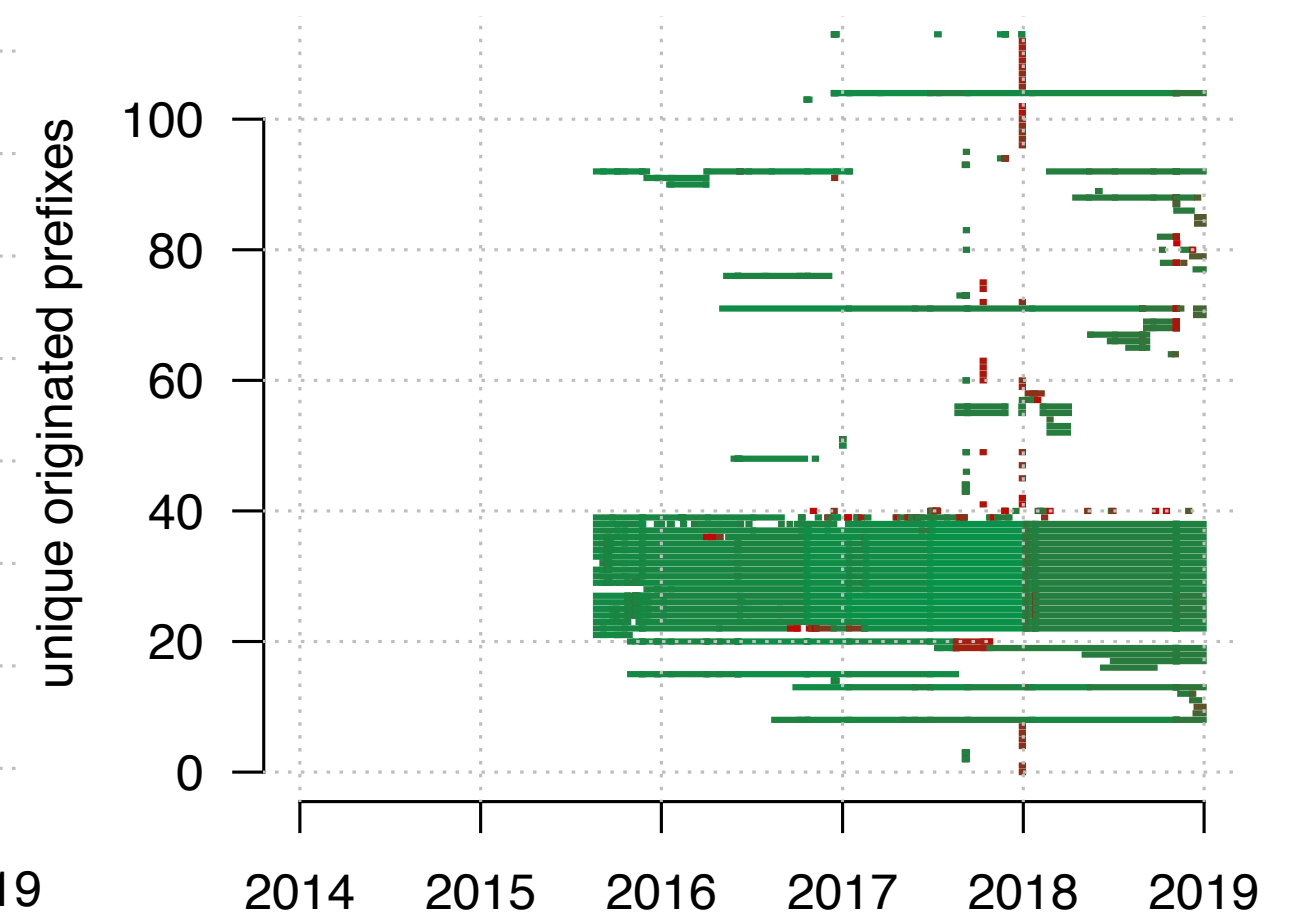
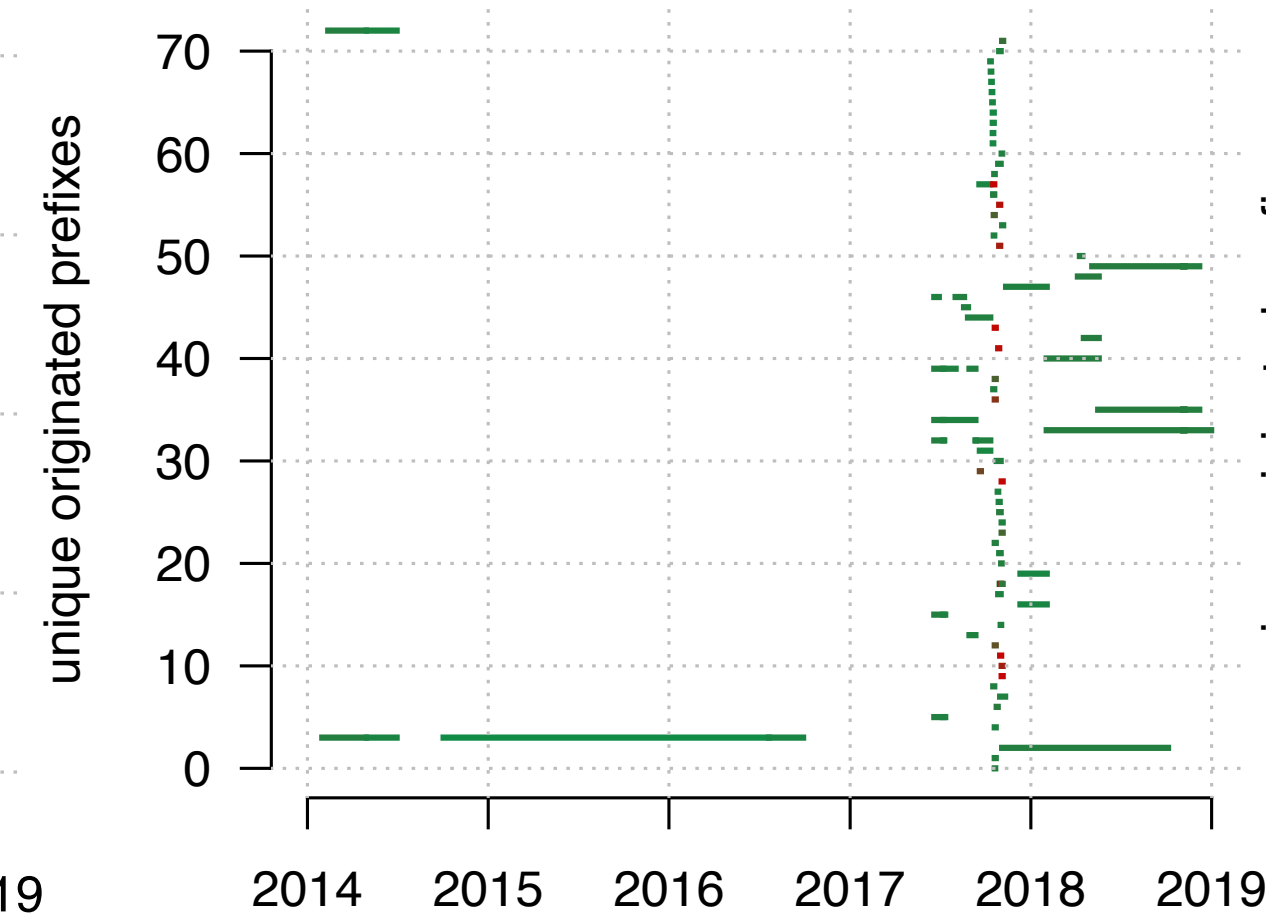
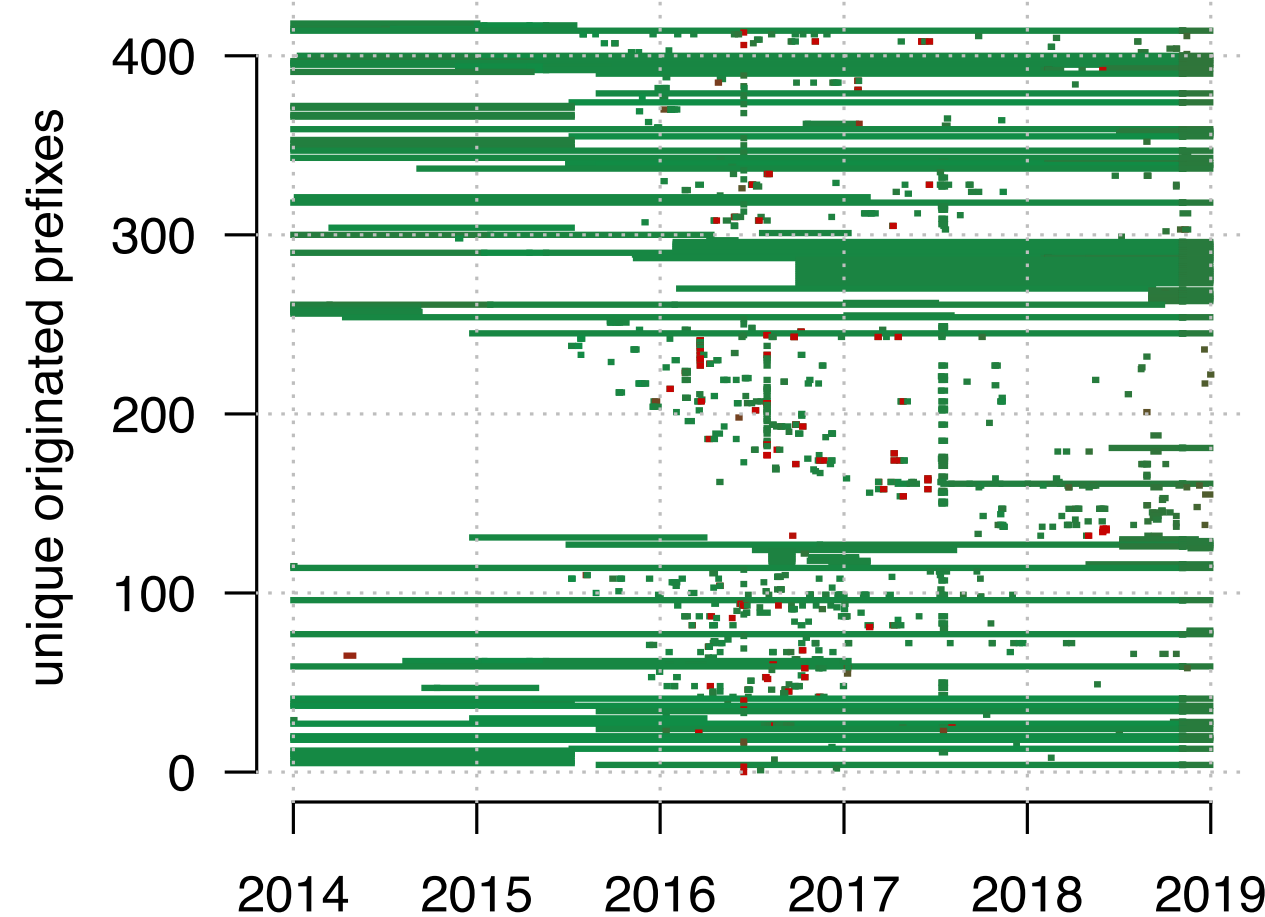
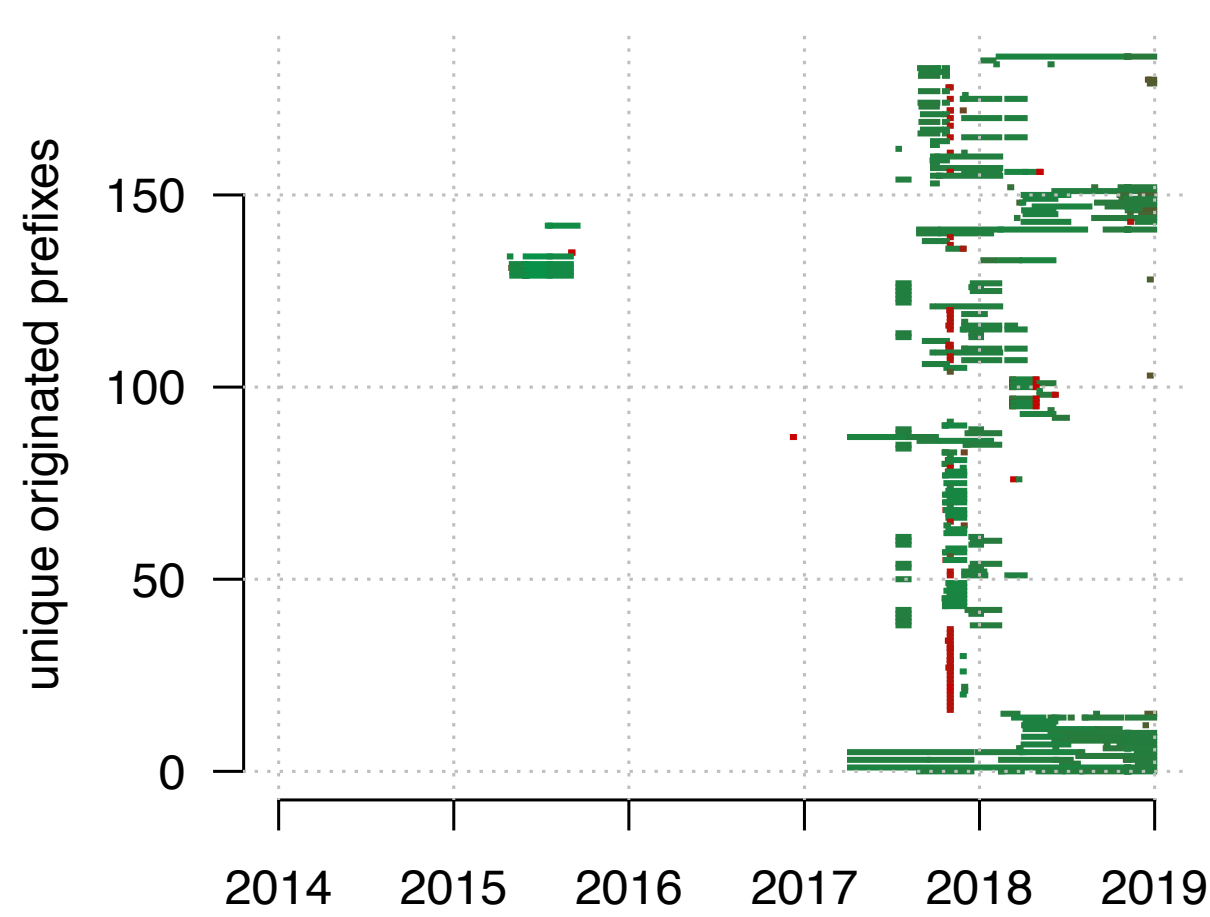
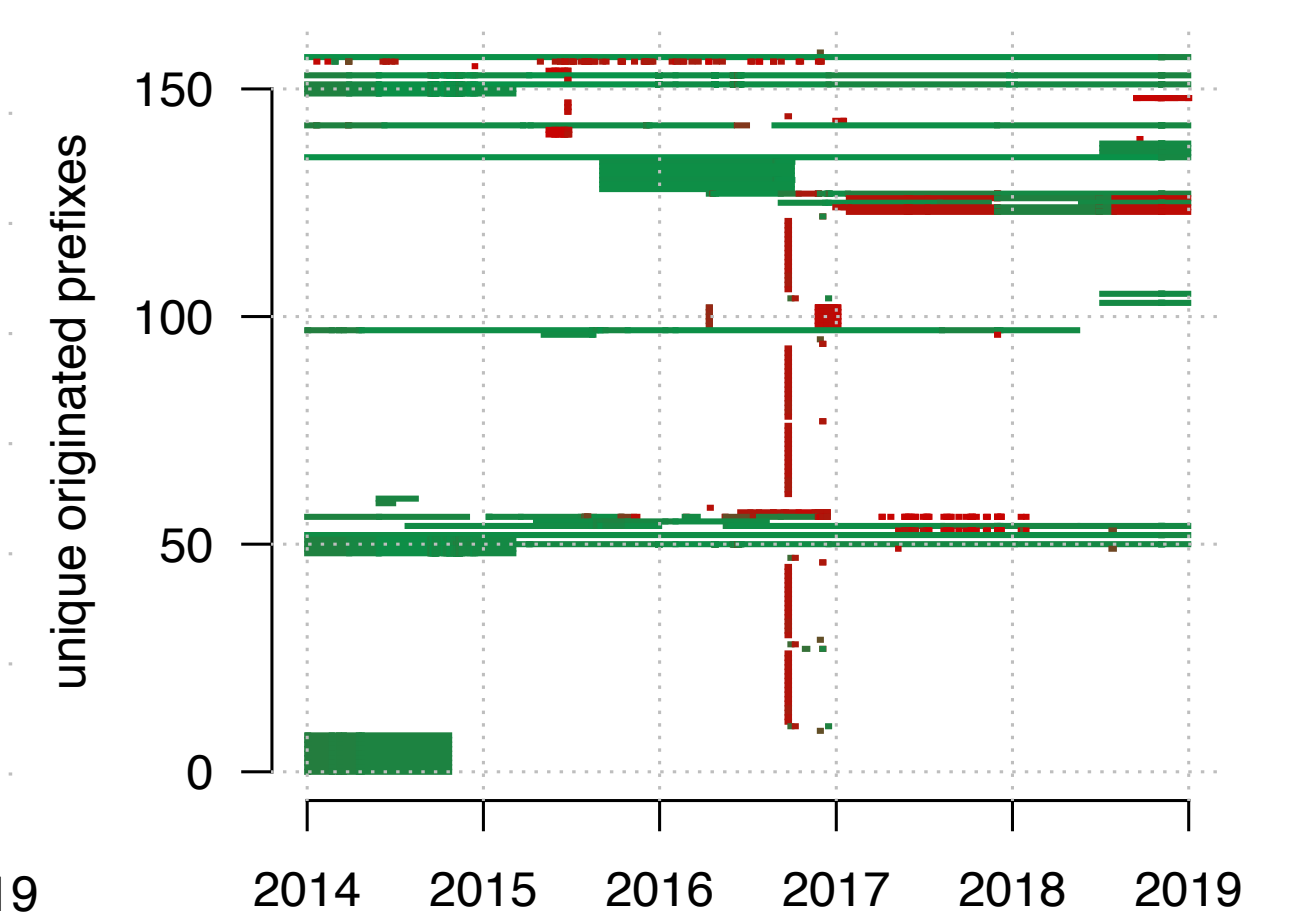
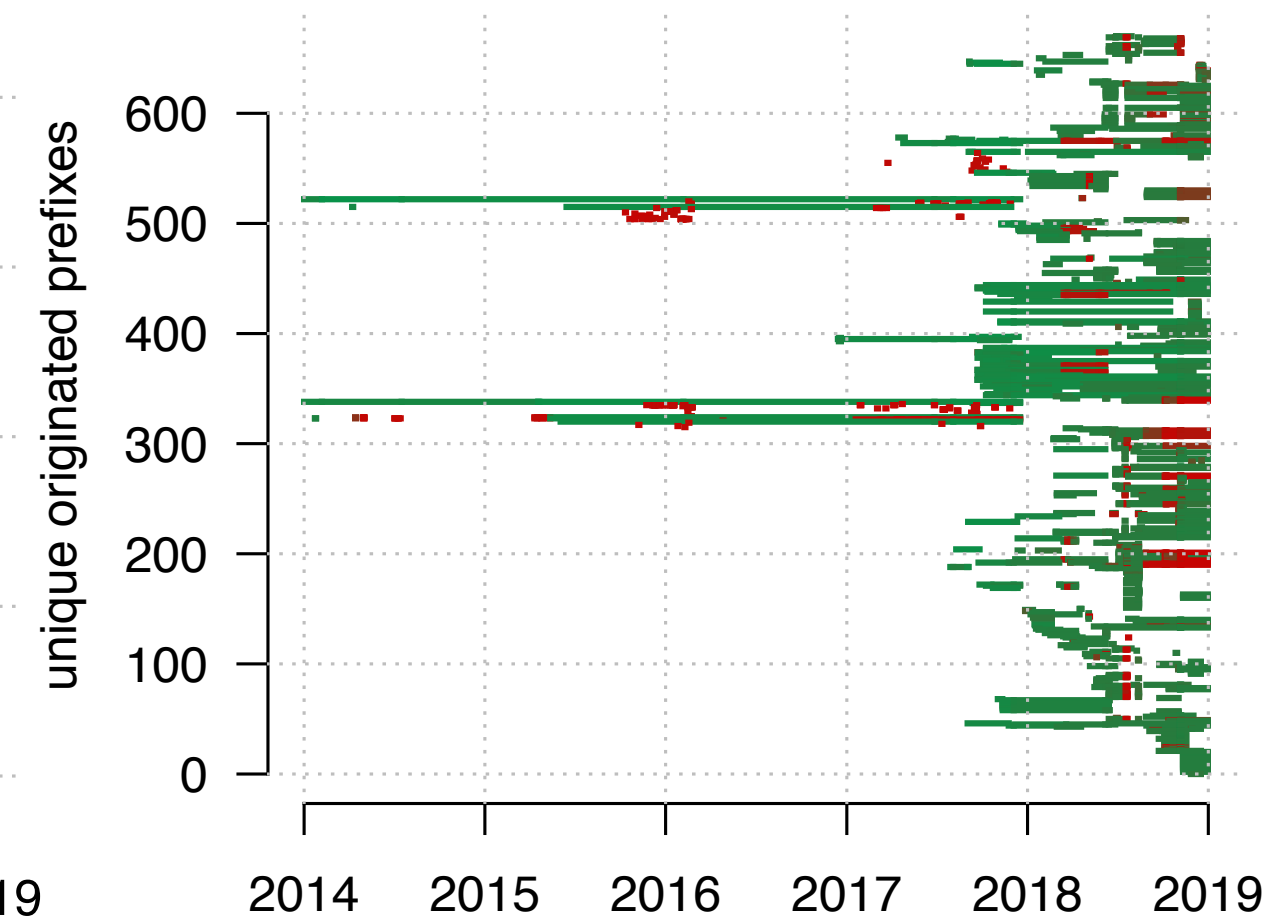
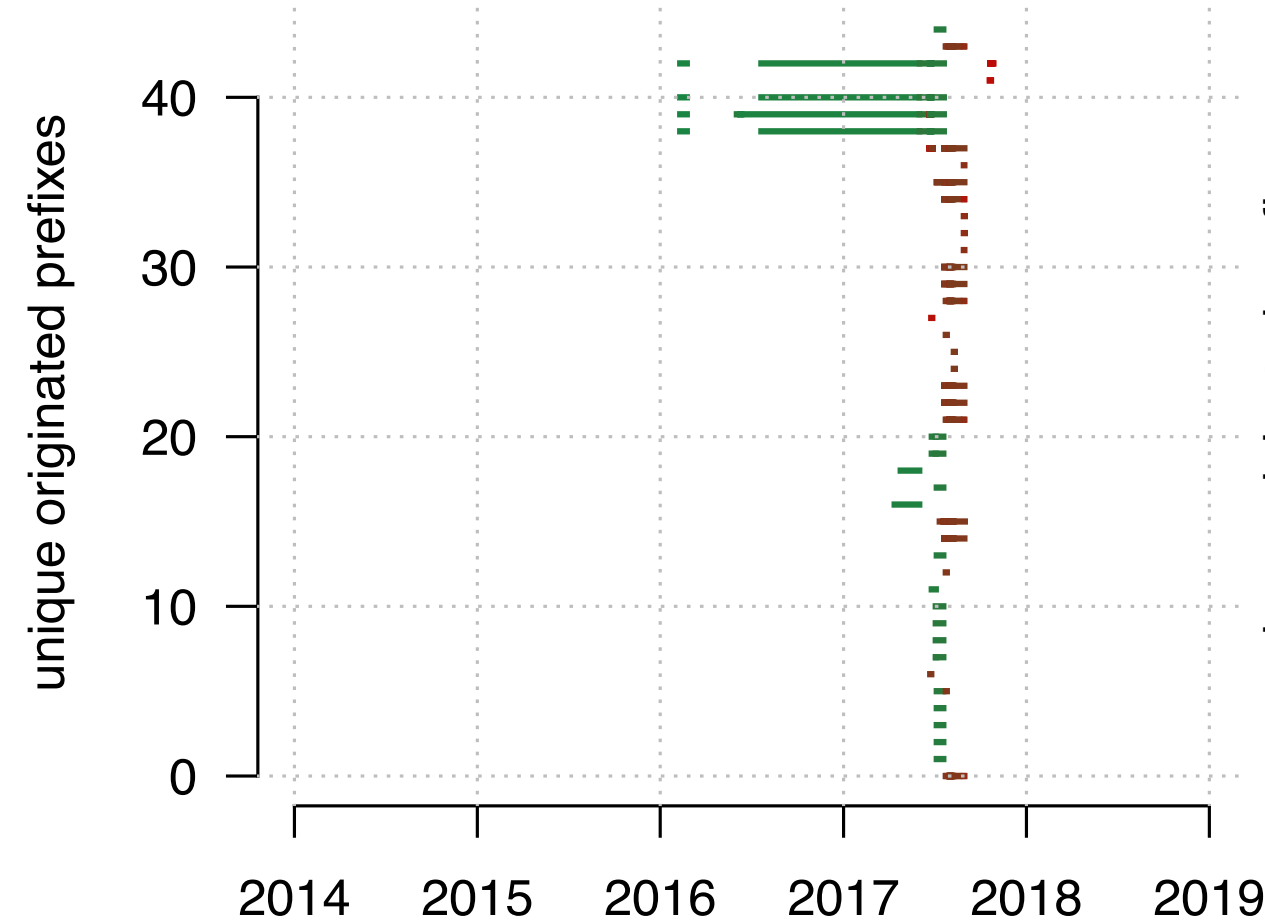
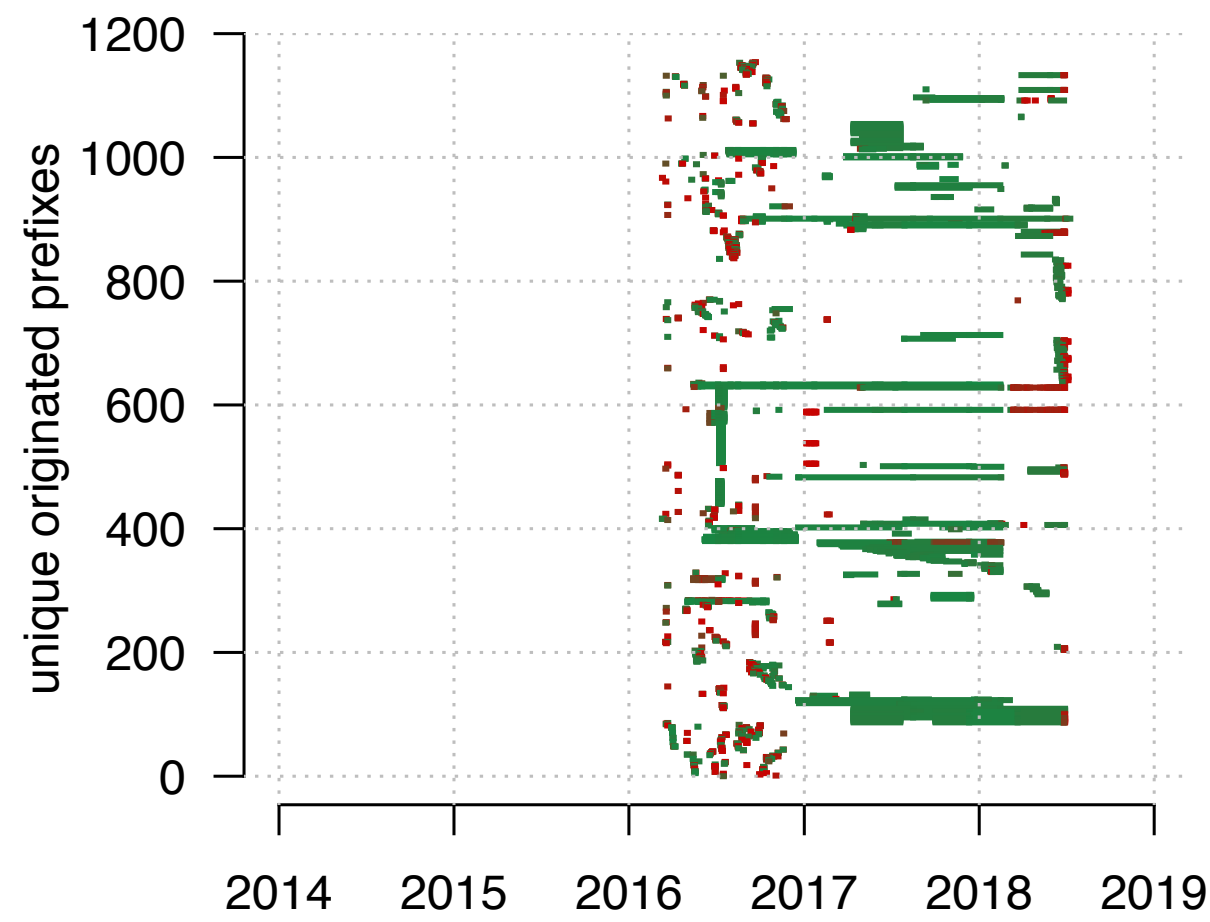


Bitcanal (AS 197426)



► We need features that **capture this behavioral difference.**

Variability of BGP behavior: serial hijackers



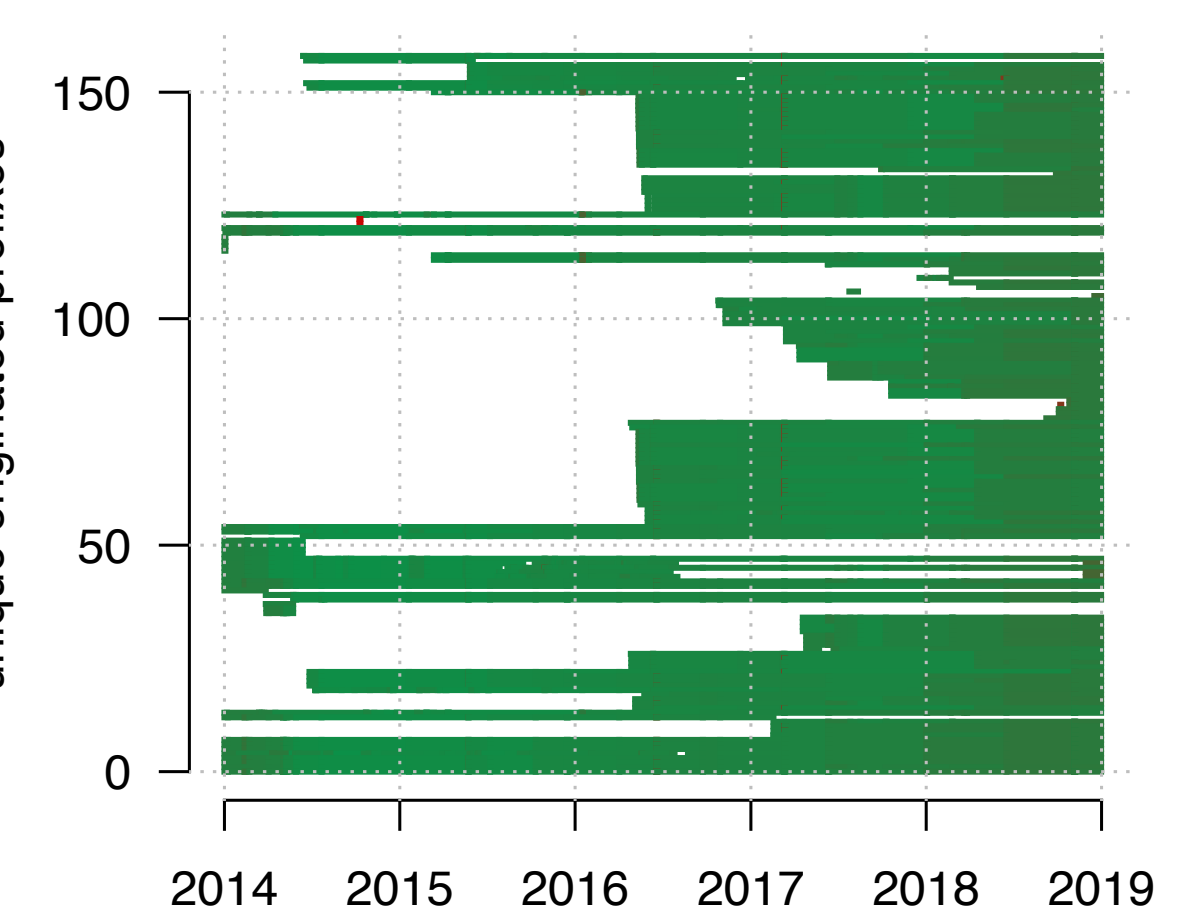
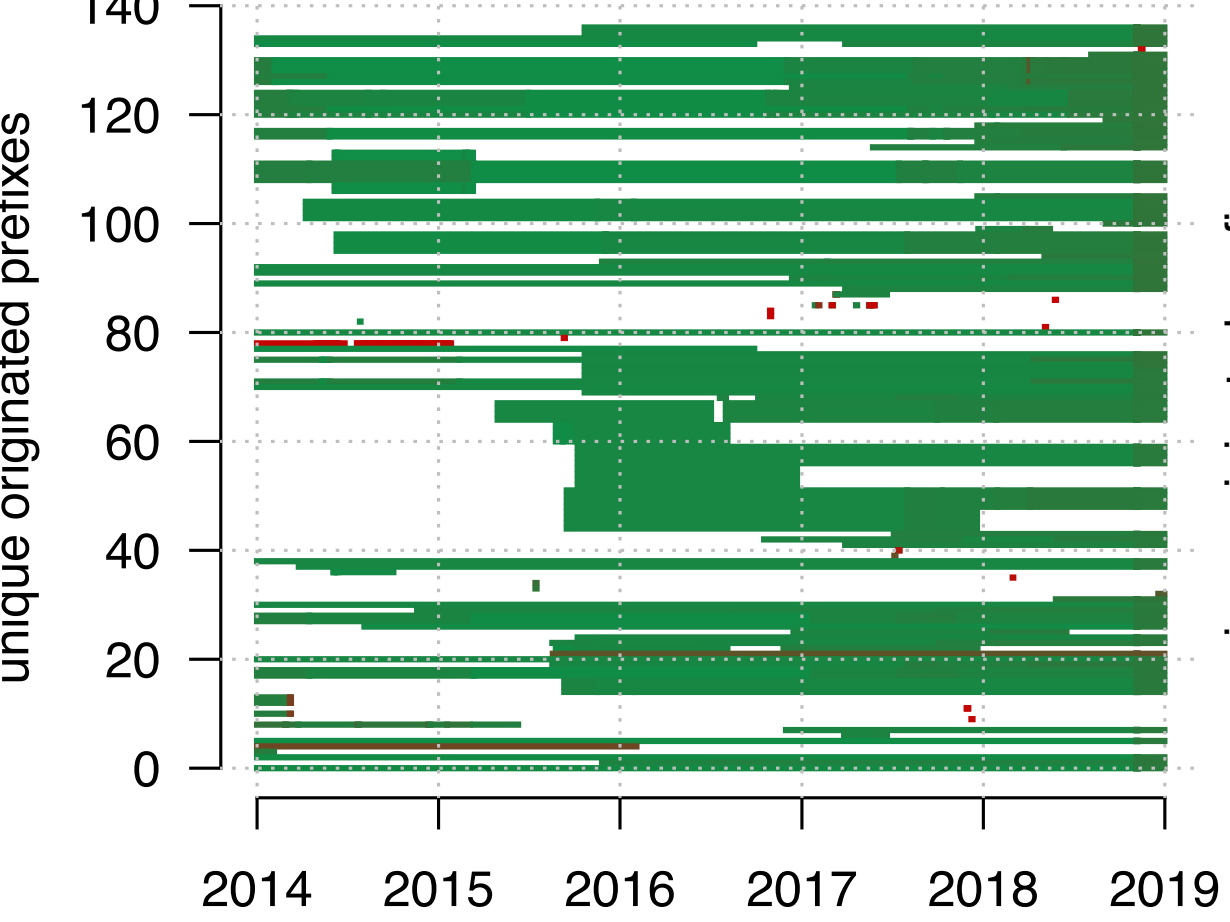
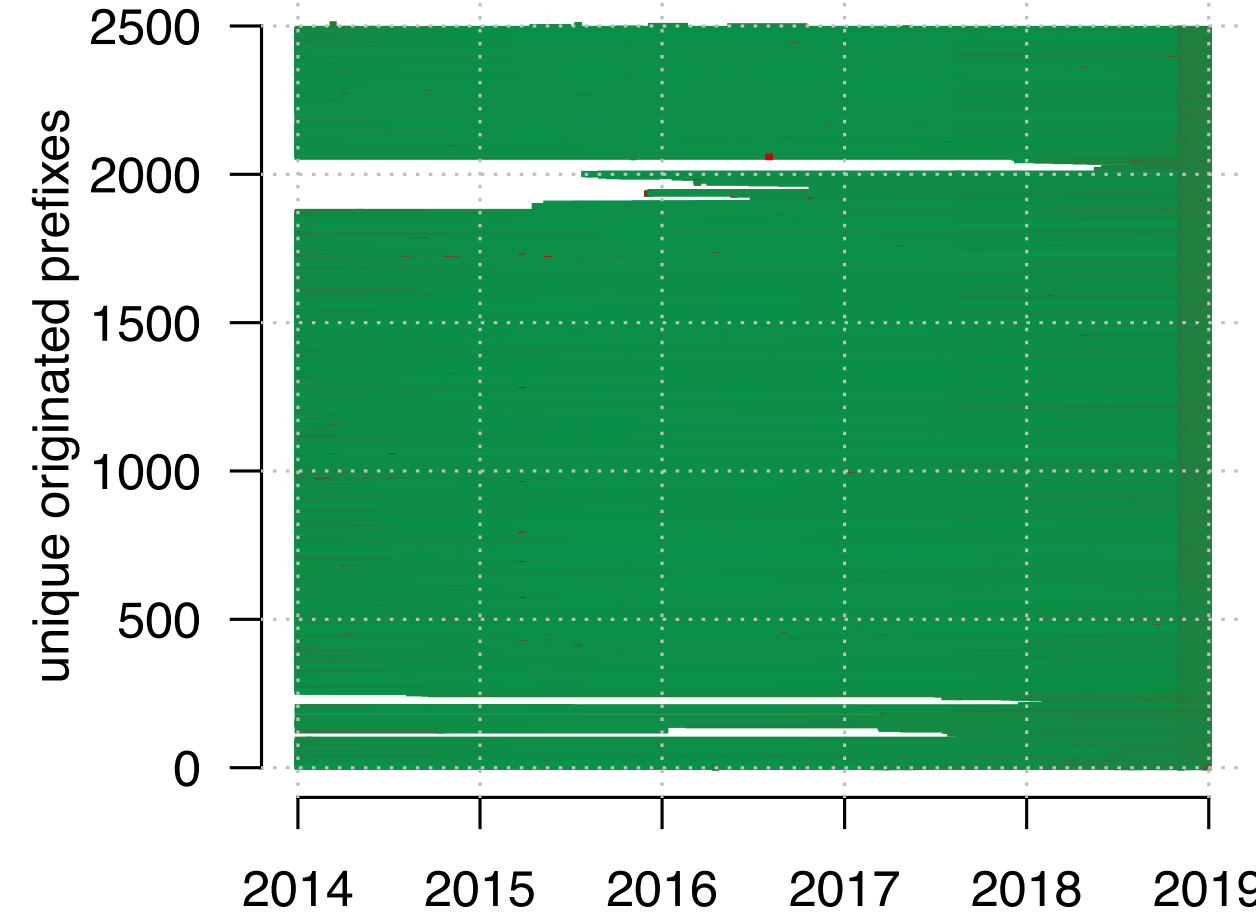
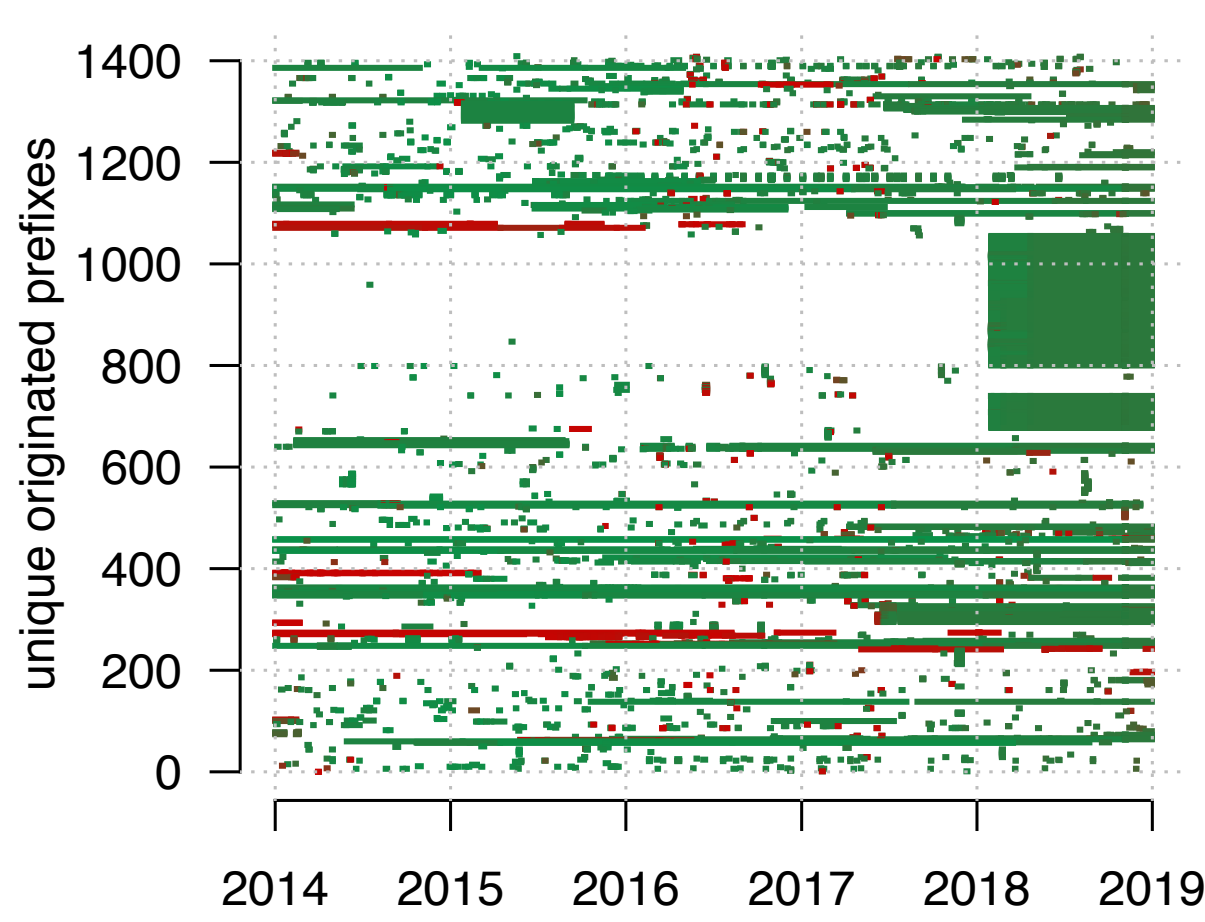
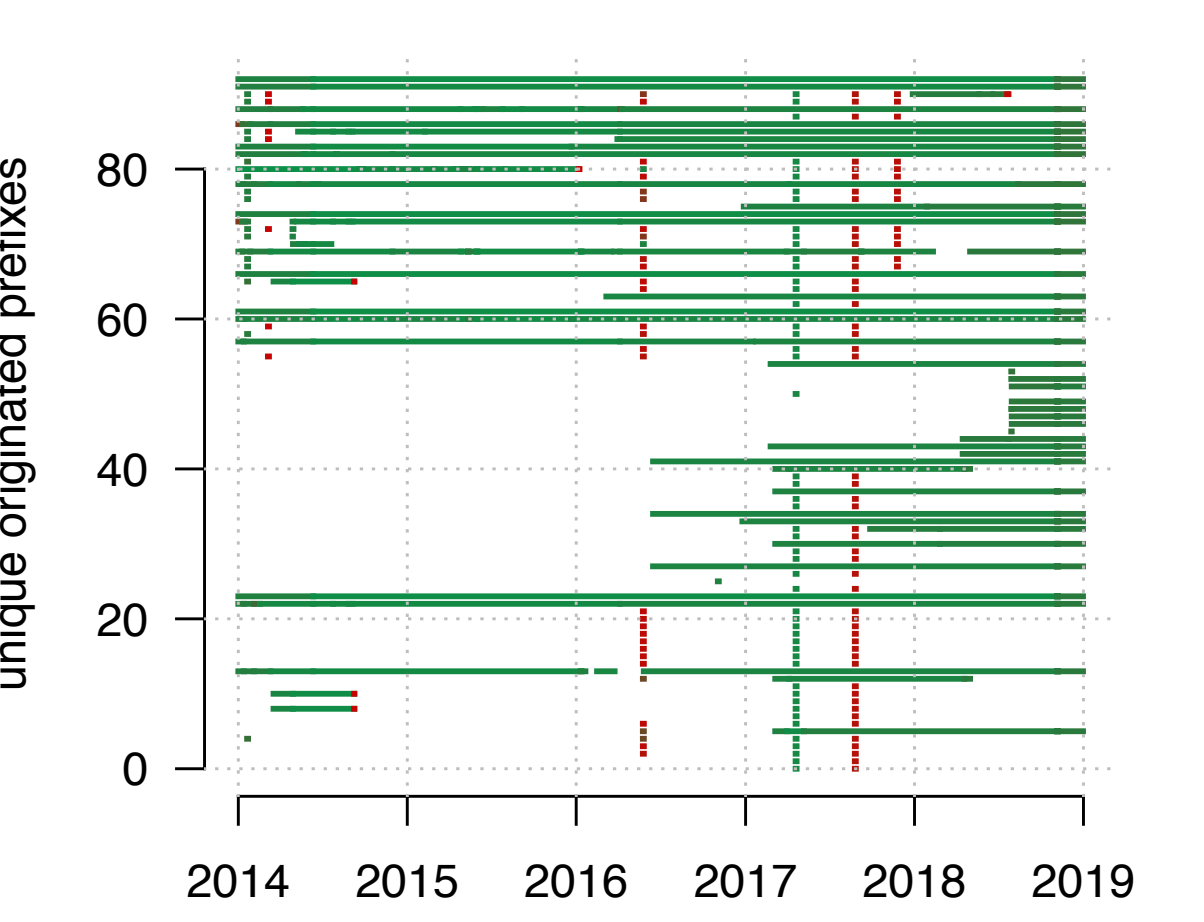
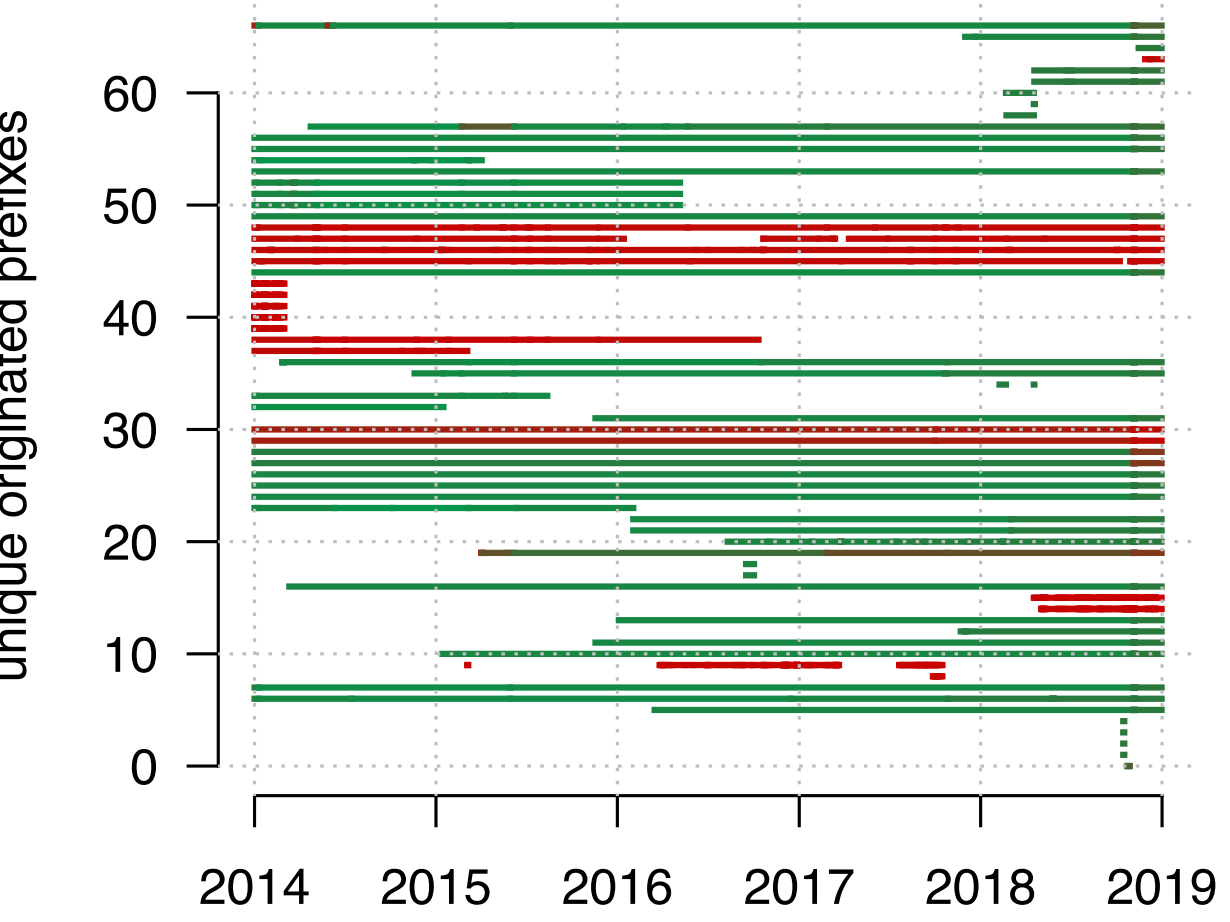
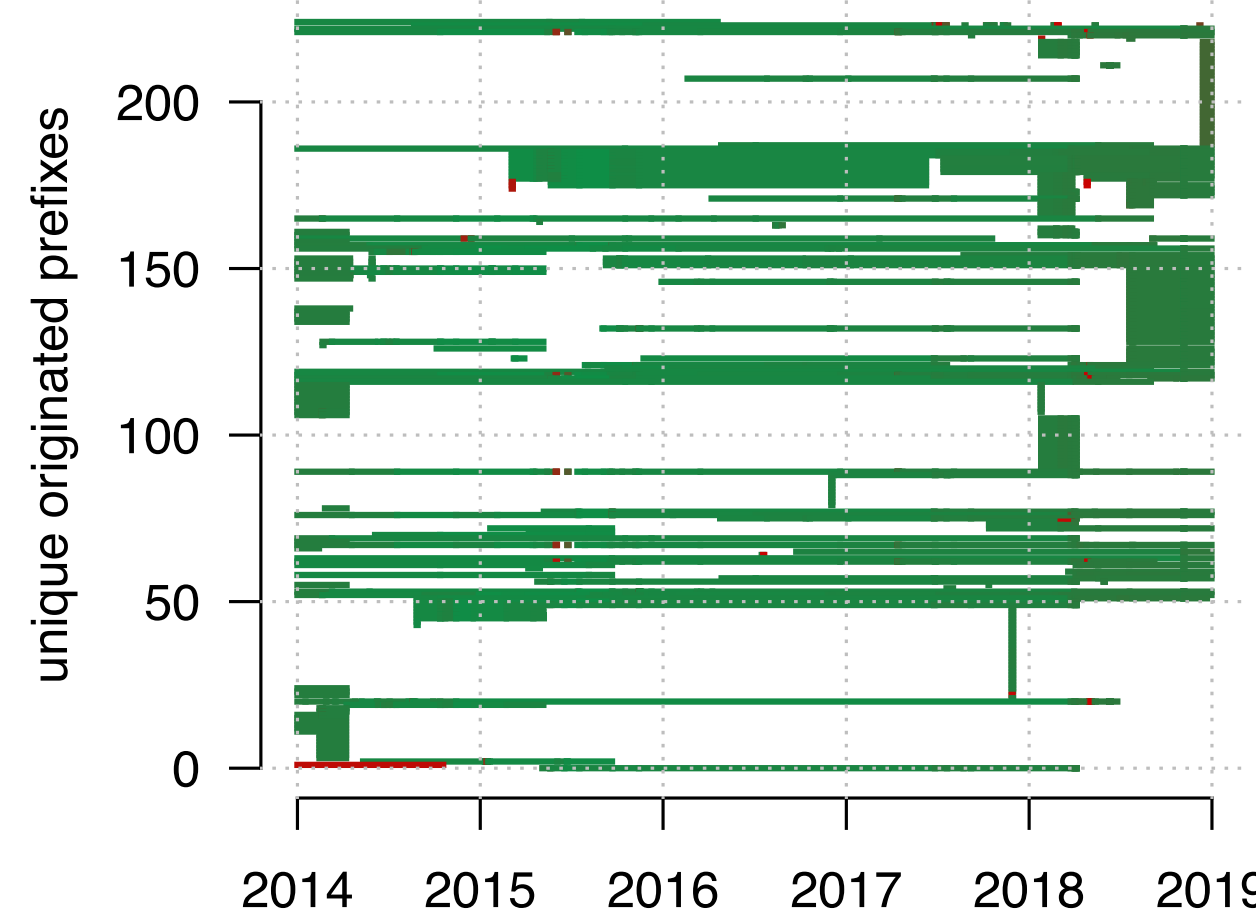
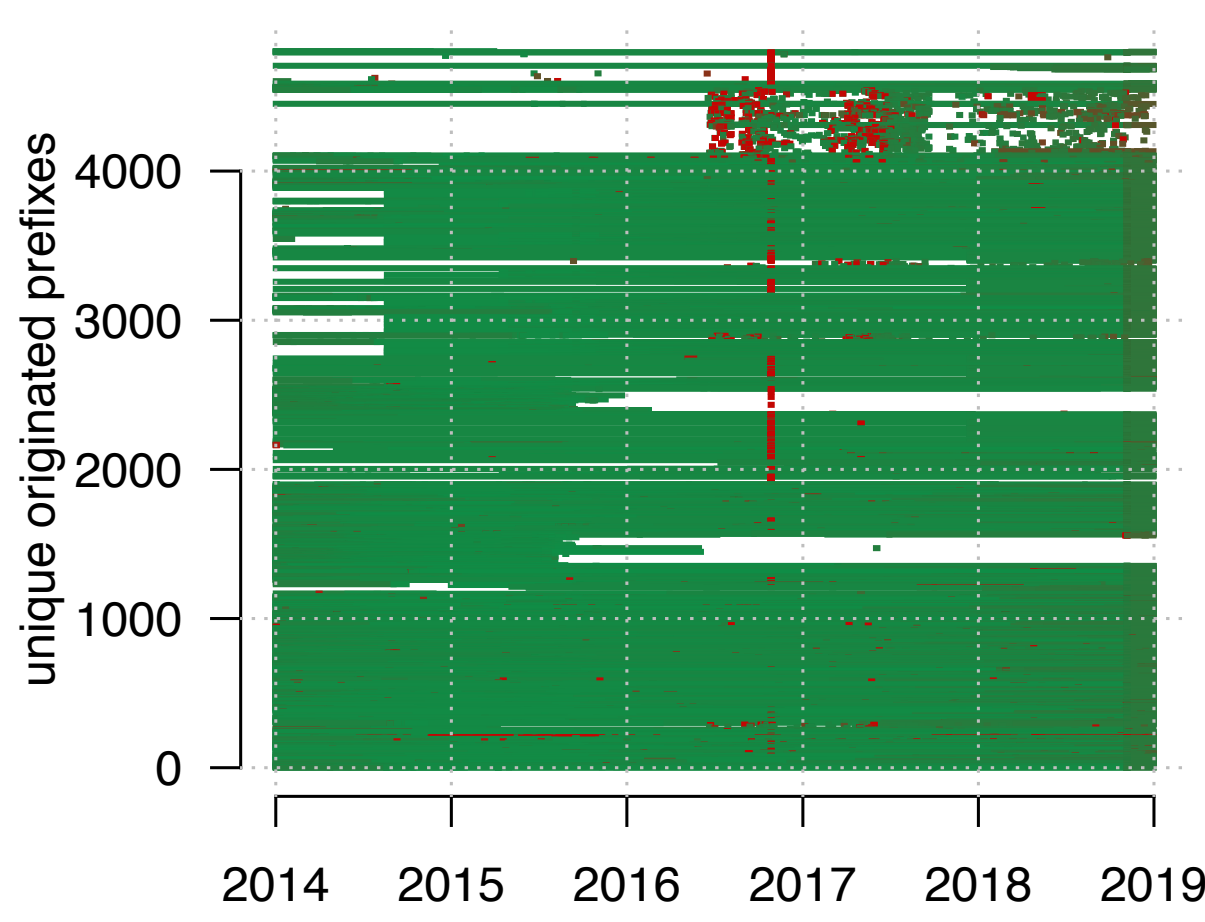
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Variability of BGP behavior: legitimate ASes



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Expected serial hijacker behavior

- Repeated AS absence from the global routing table.

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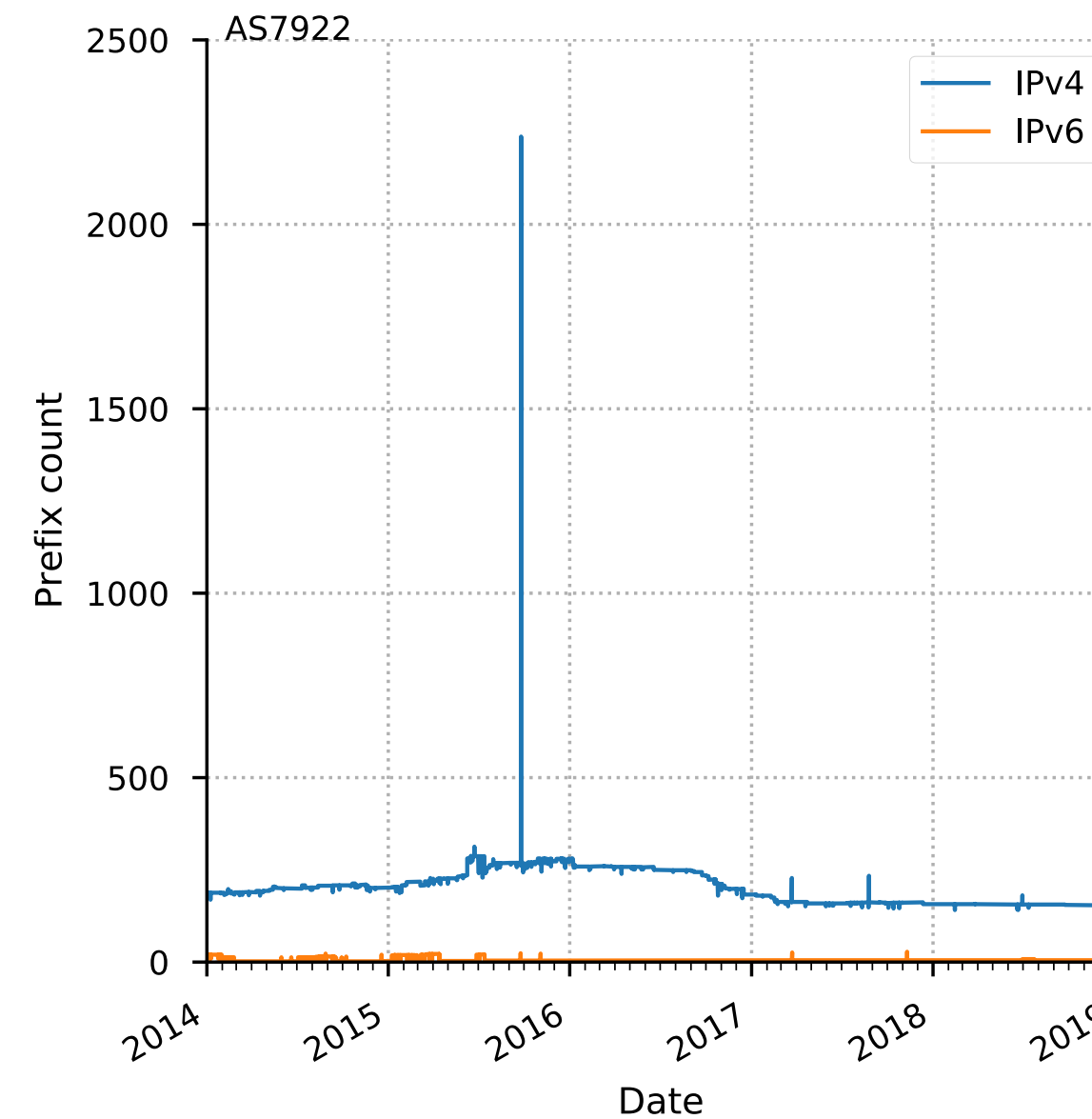
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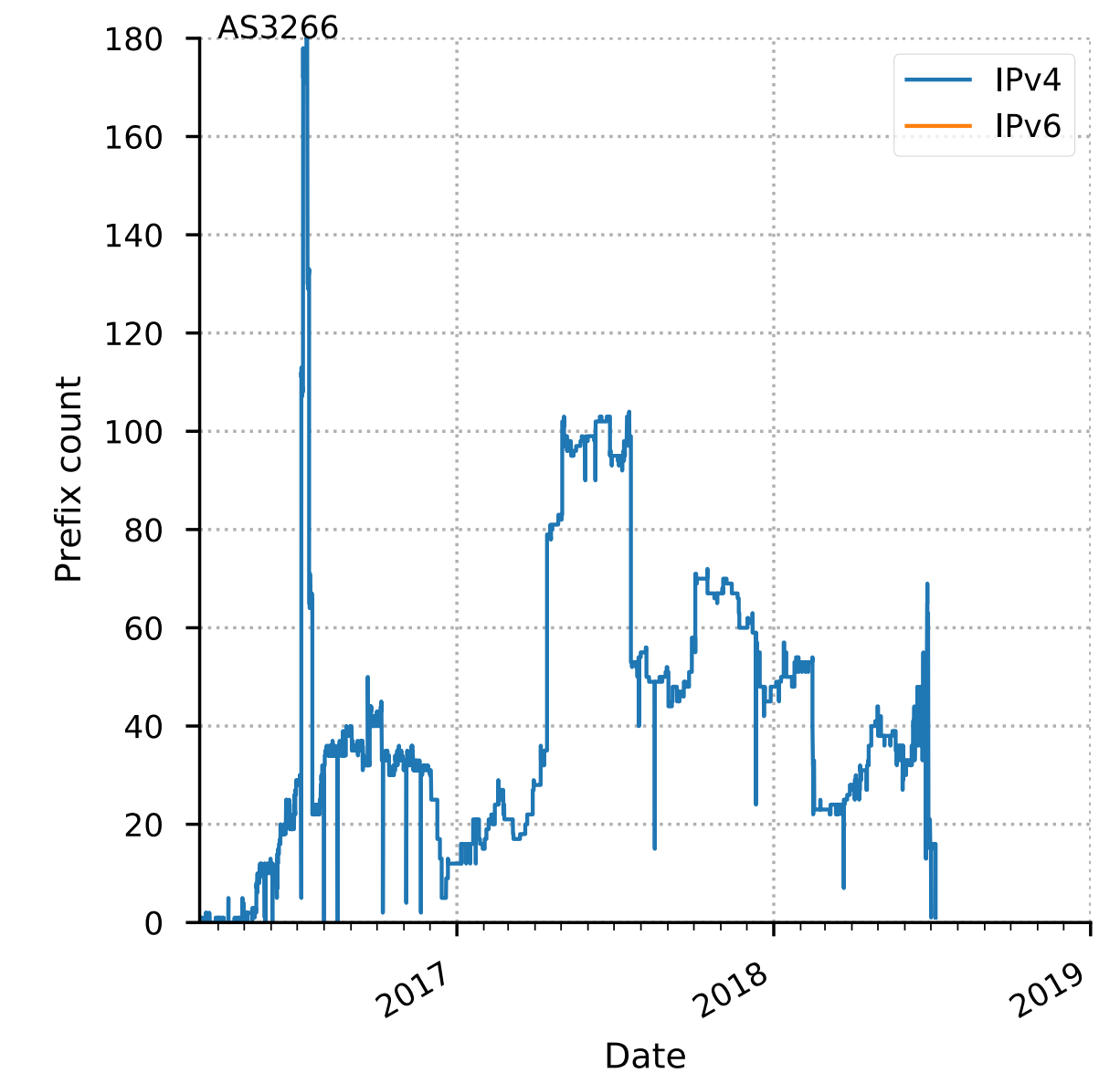
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Comcast AS



Serial Hijacker AS

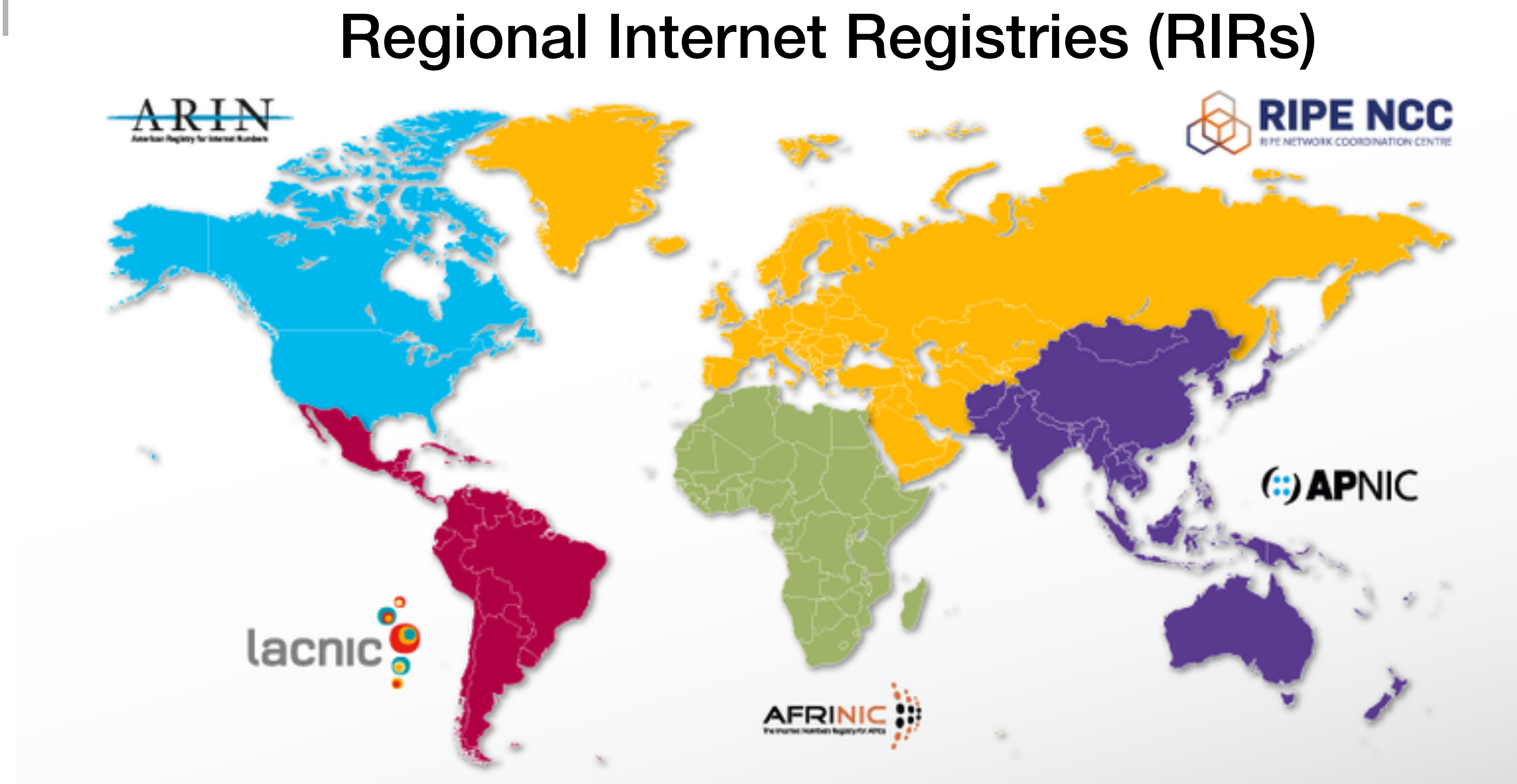


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- **Broad geographical distribution of address space originated.**

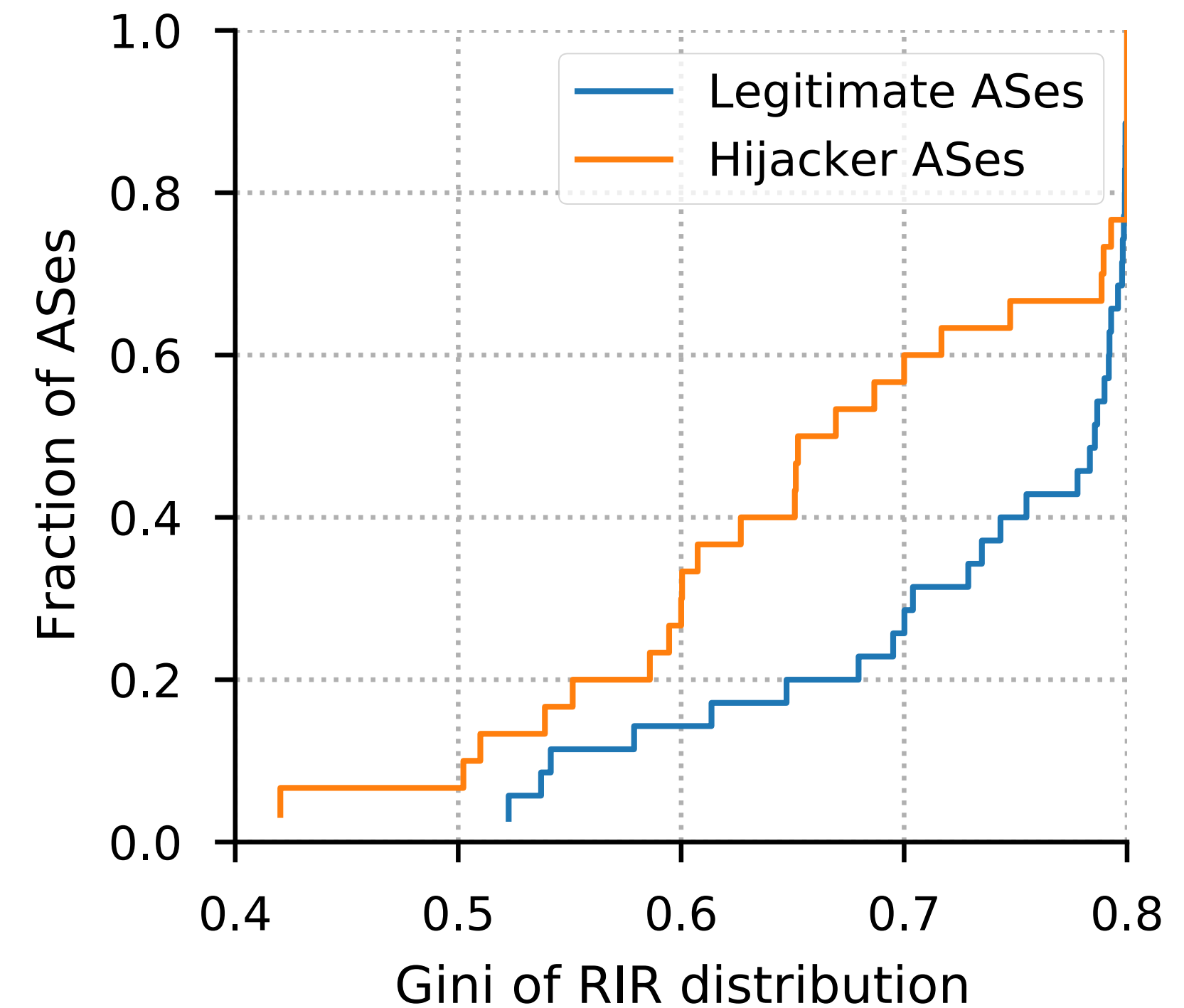
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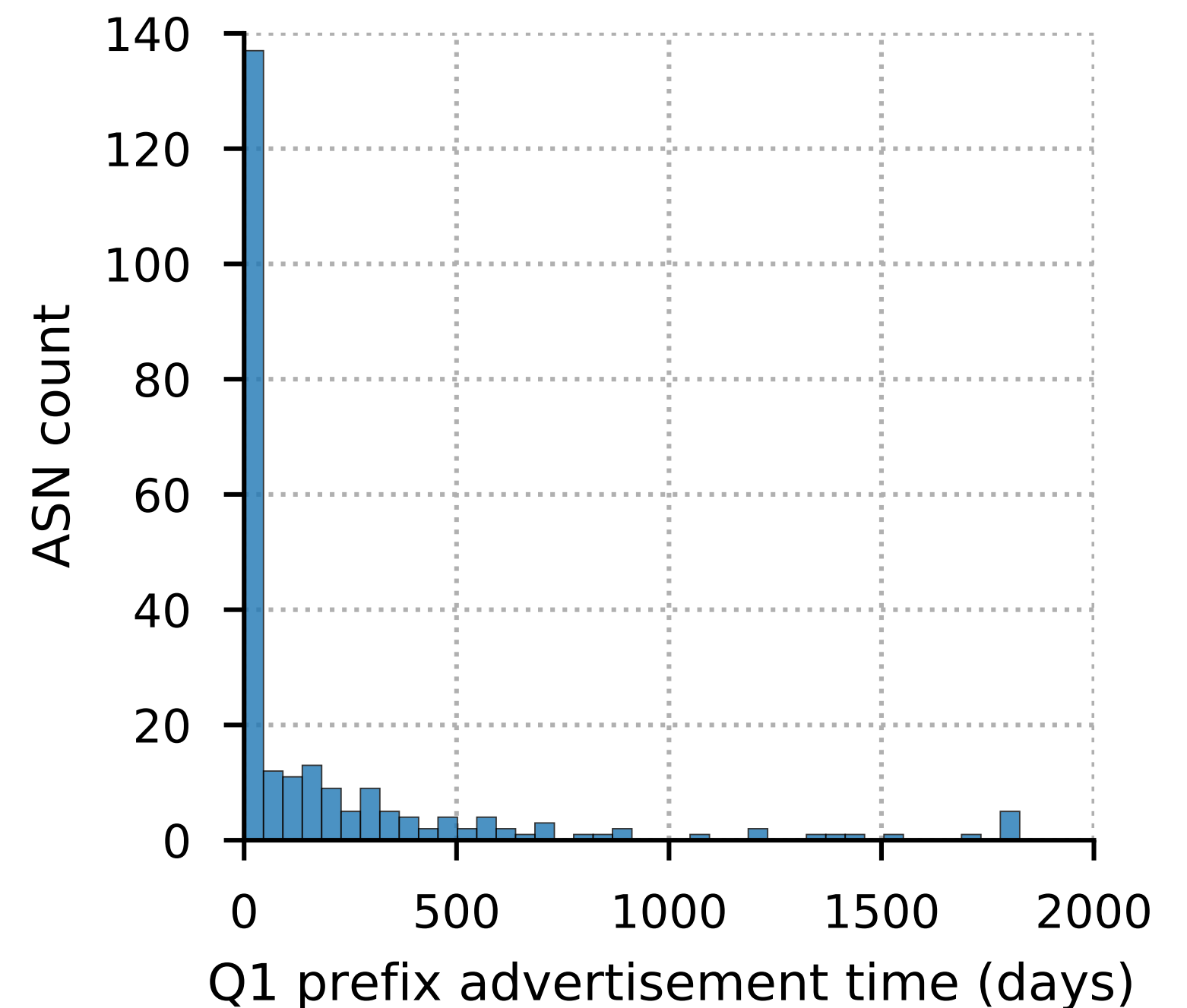
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▶ We derived **52 features** to capture differences.

Challenges of applying ML to find more potential serial hijackers

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- Heavy-tailed and skewed data:
Monthly prefix changes [0,2600], Gini in [0,0.8]



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240 AS for 19,000 ASes

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- Class Imbalance:
23 serial hijacker vs. 217 legitimate networks

Our ML approach

- Tree based classifier.
- Voting ensemble of extremely randomized forests.
- 3 over-sampling techniques.
- All 52 features with positive median drop column importance.

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 - Voting ensemble of extremely randomized forests.
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 - All 52 features with positive median drop column importance.
- ▶ **79% precision and 100% recall**
(in ground-truth using out-of-bag score)

Putting our classifier to work

- **Goal:** Find ASes exhibiting similar BGP behavior to serial hijackers in our ground truth.

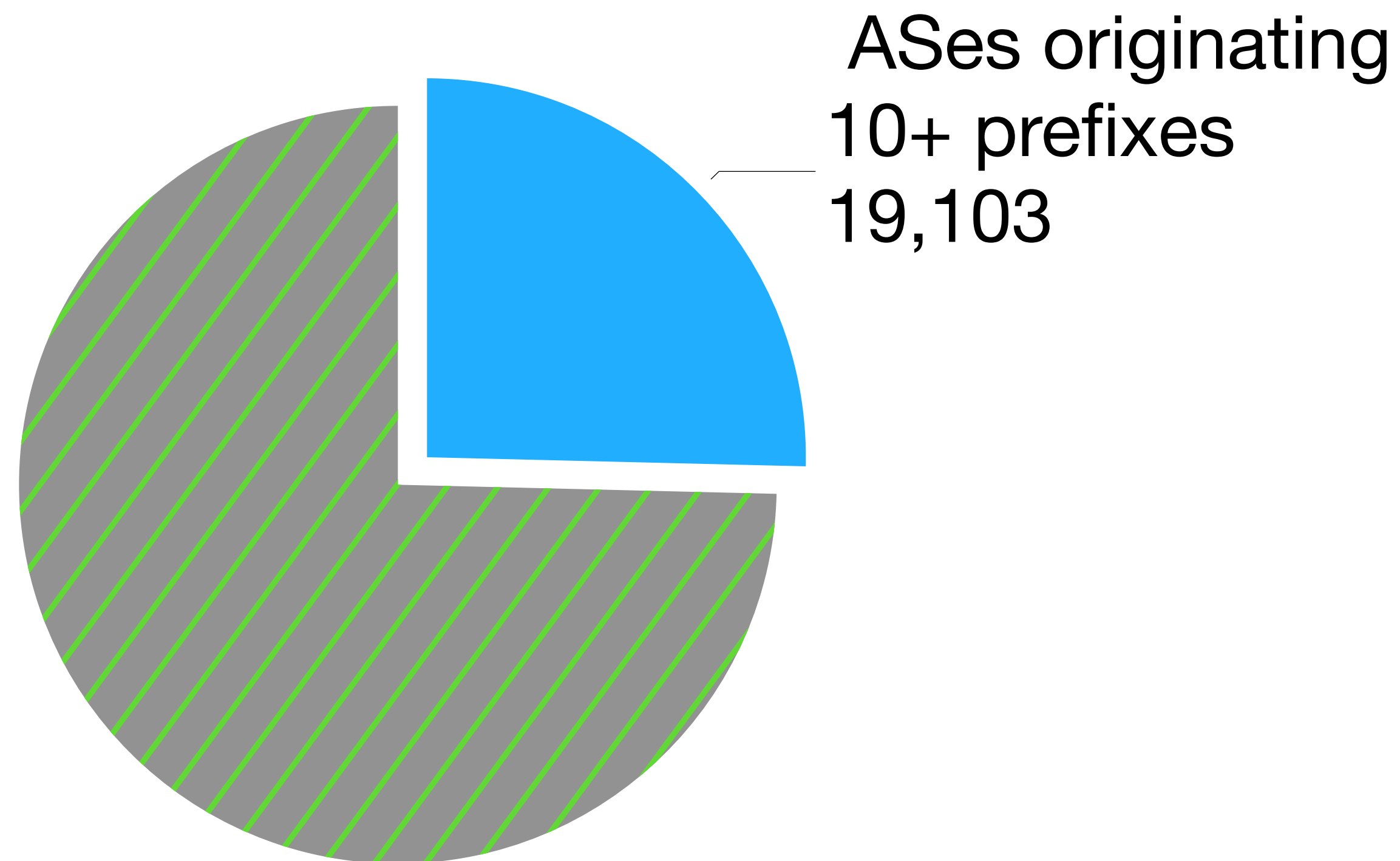
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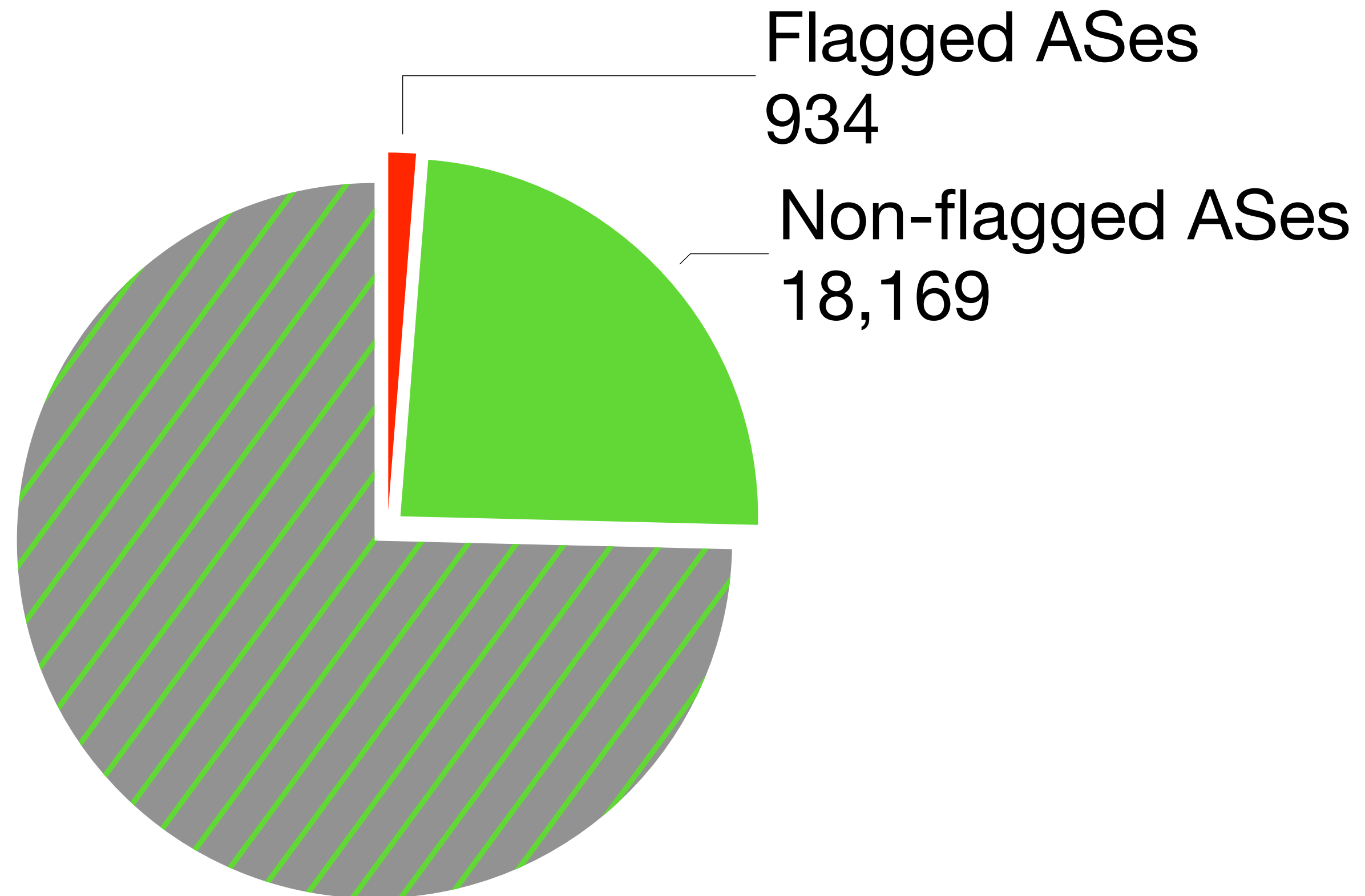
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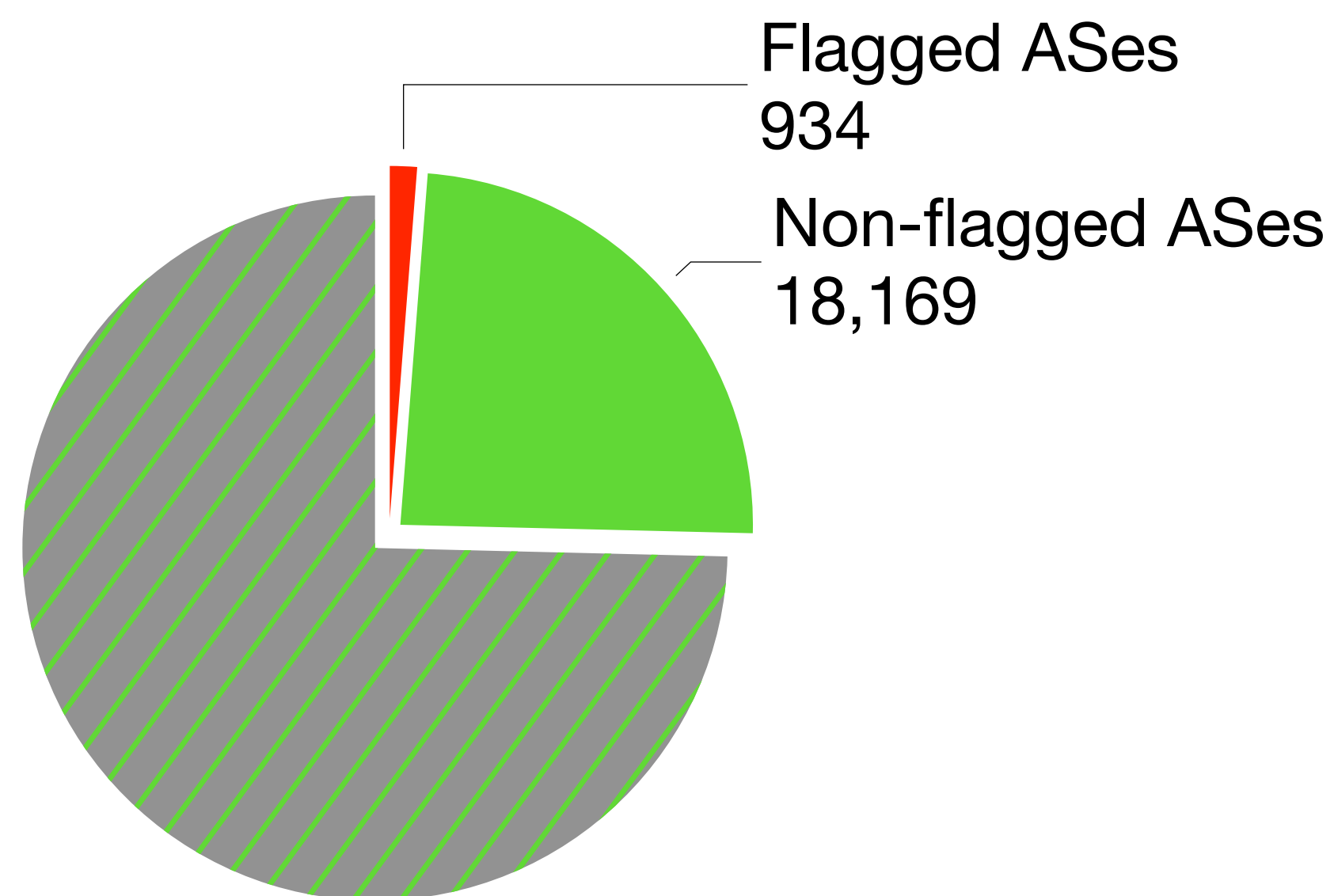
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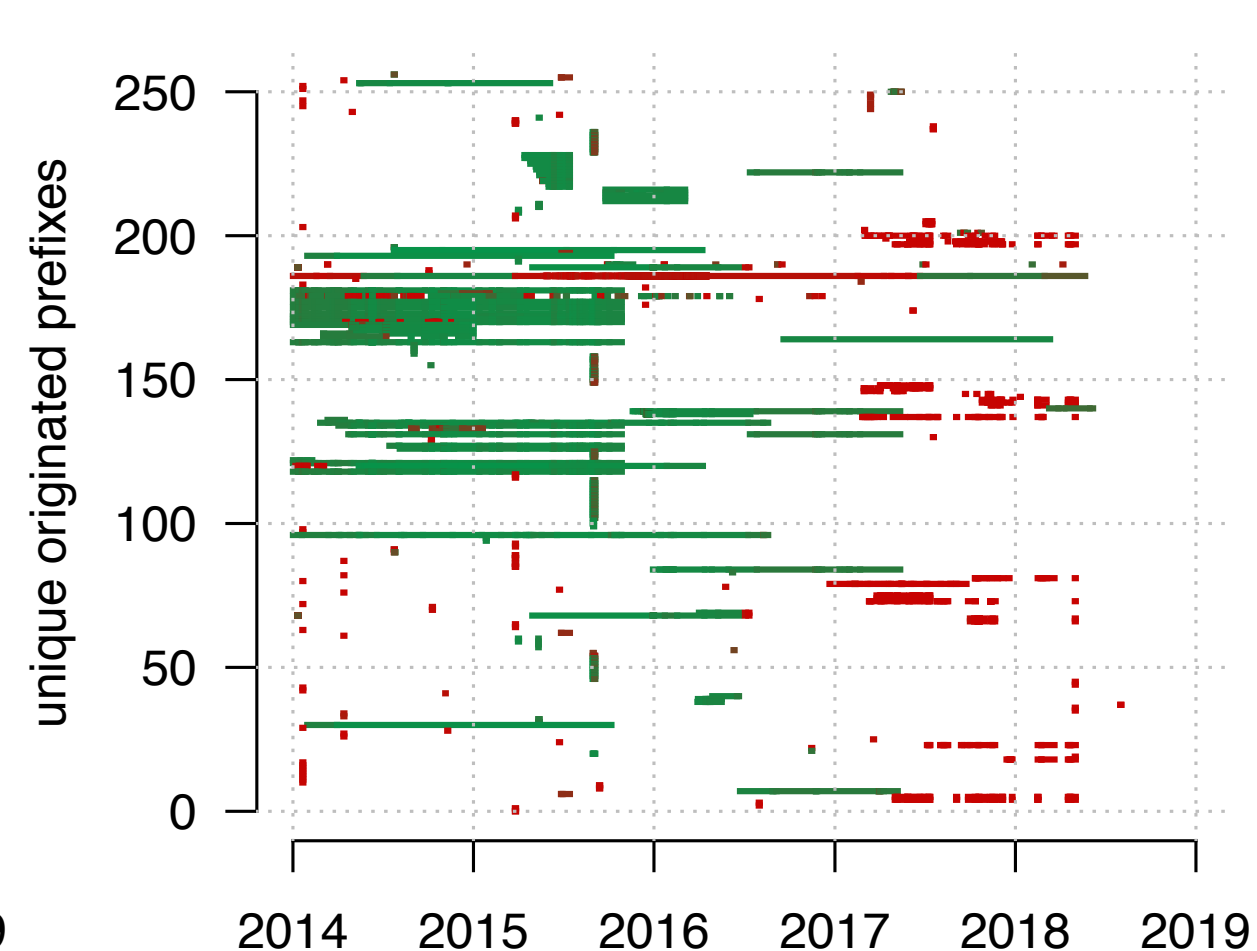
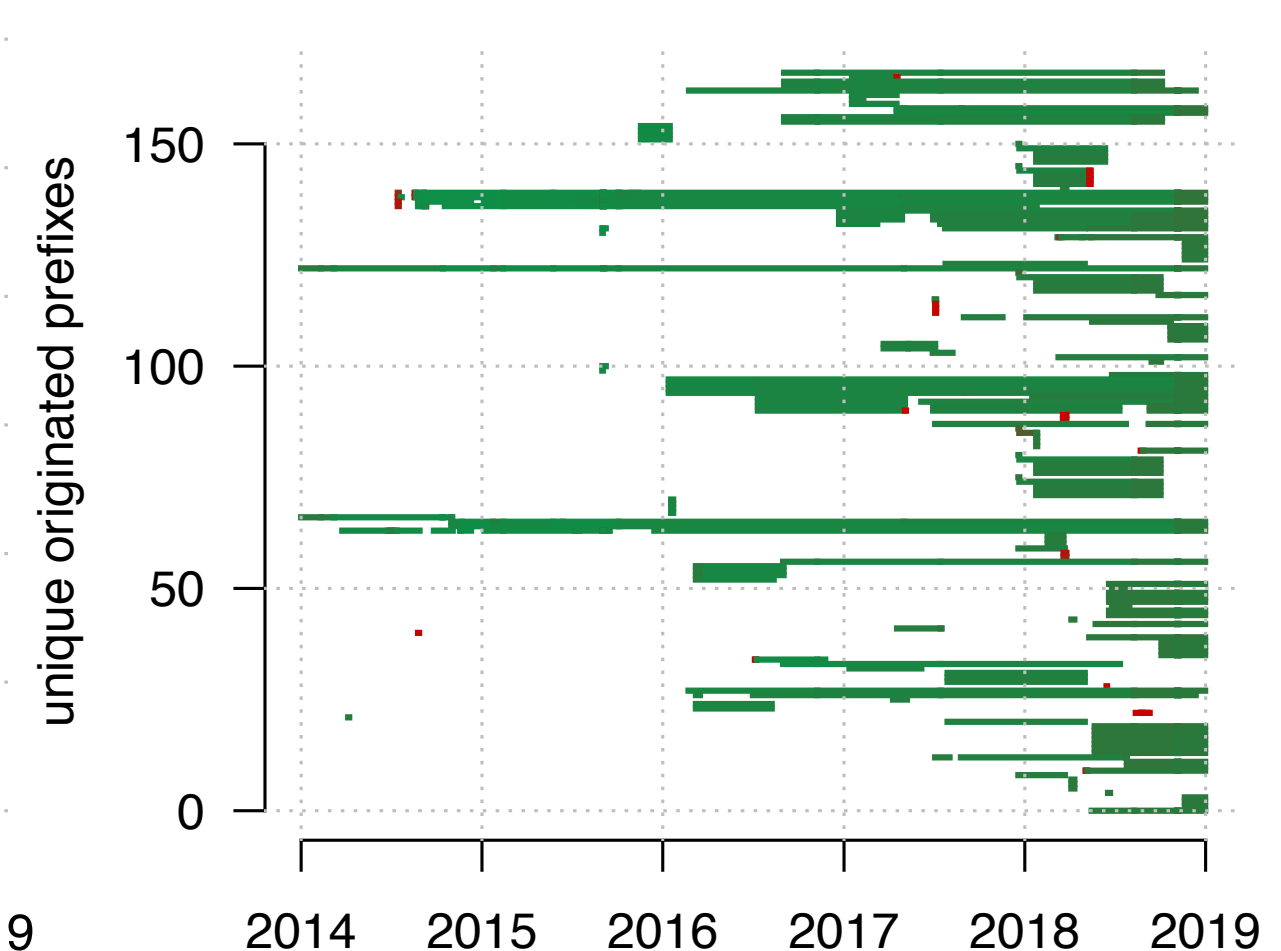
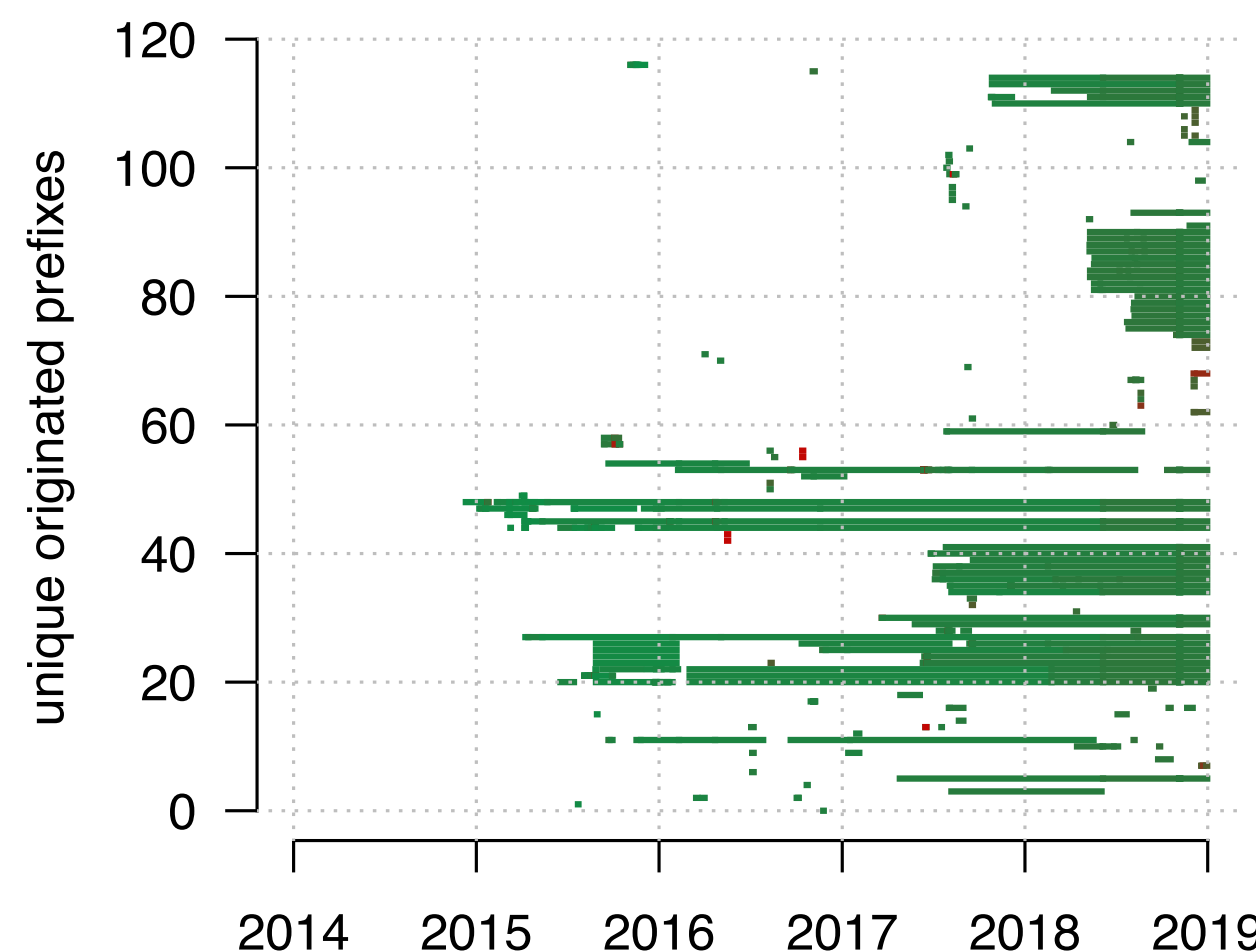
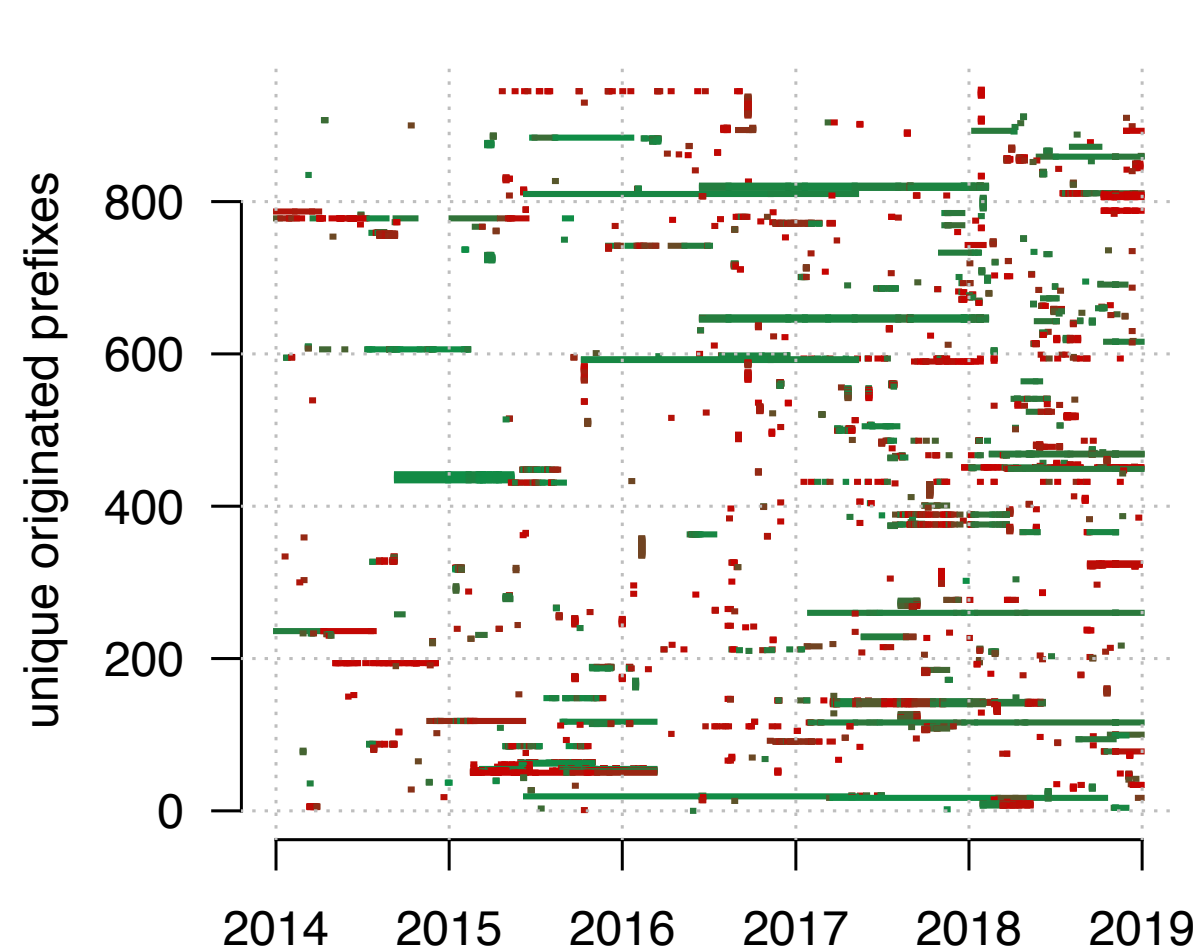
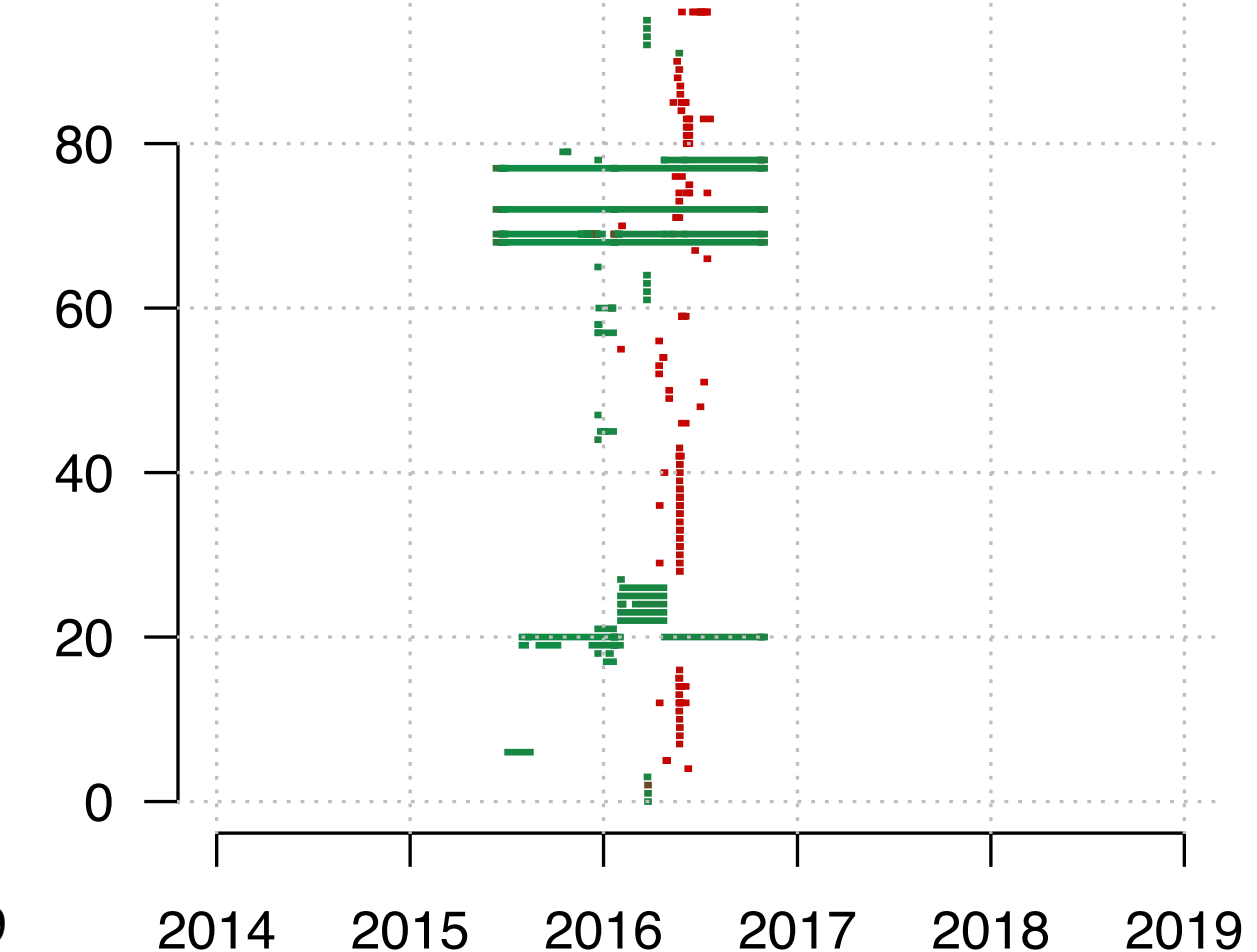
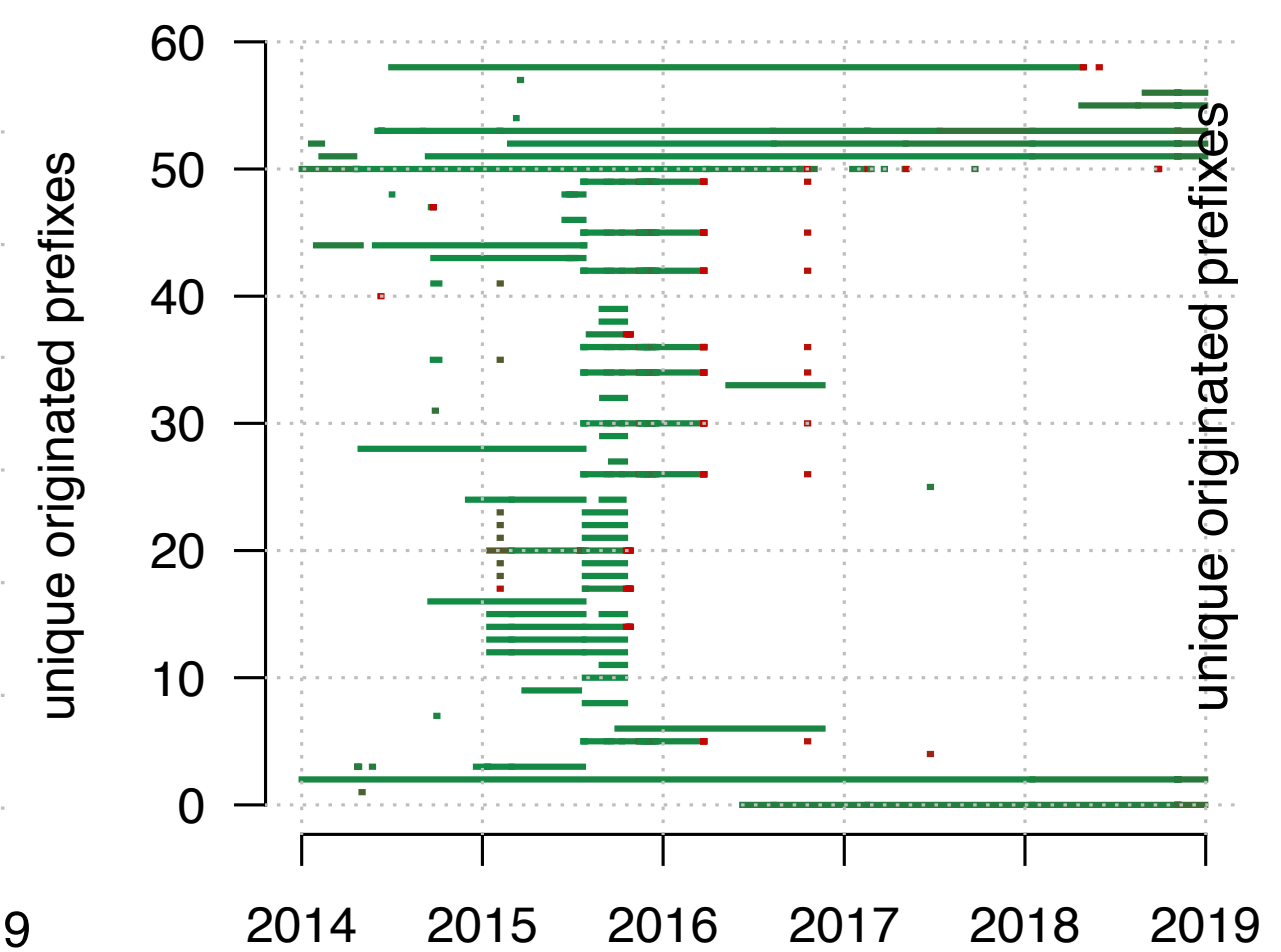
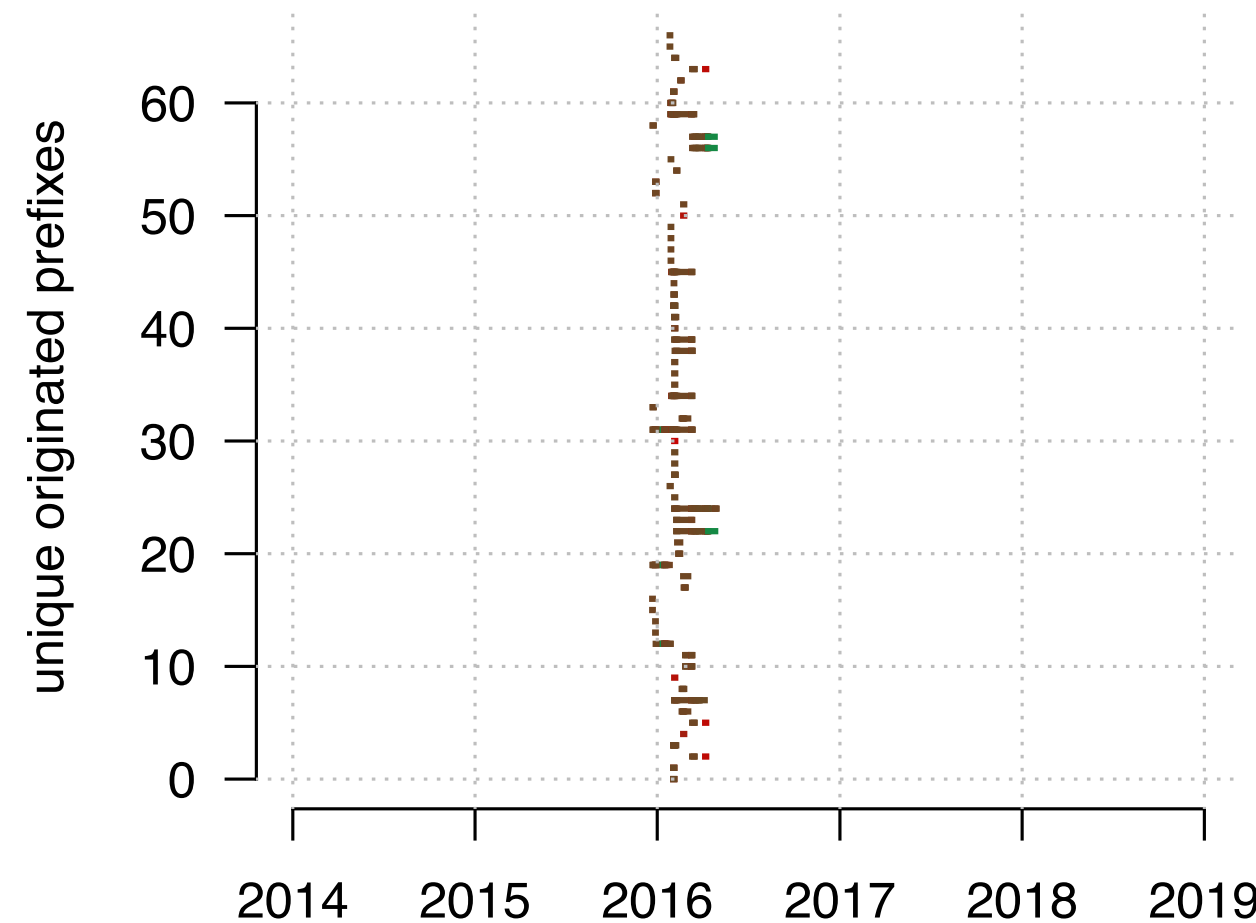
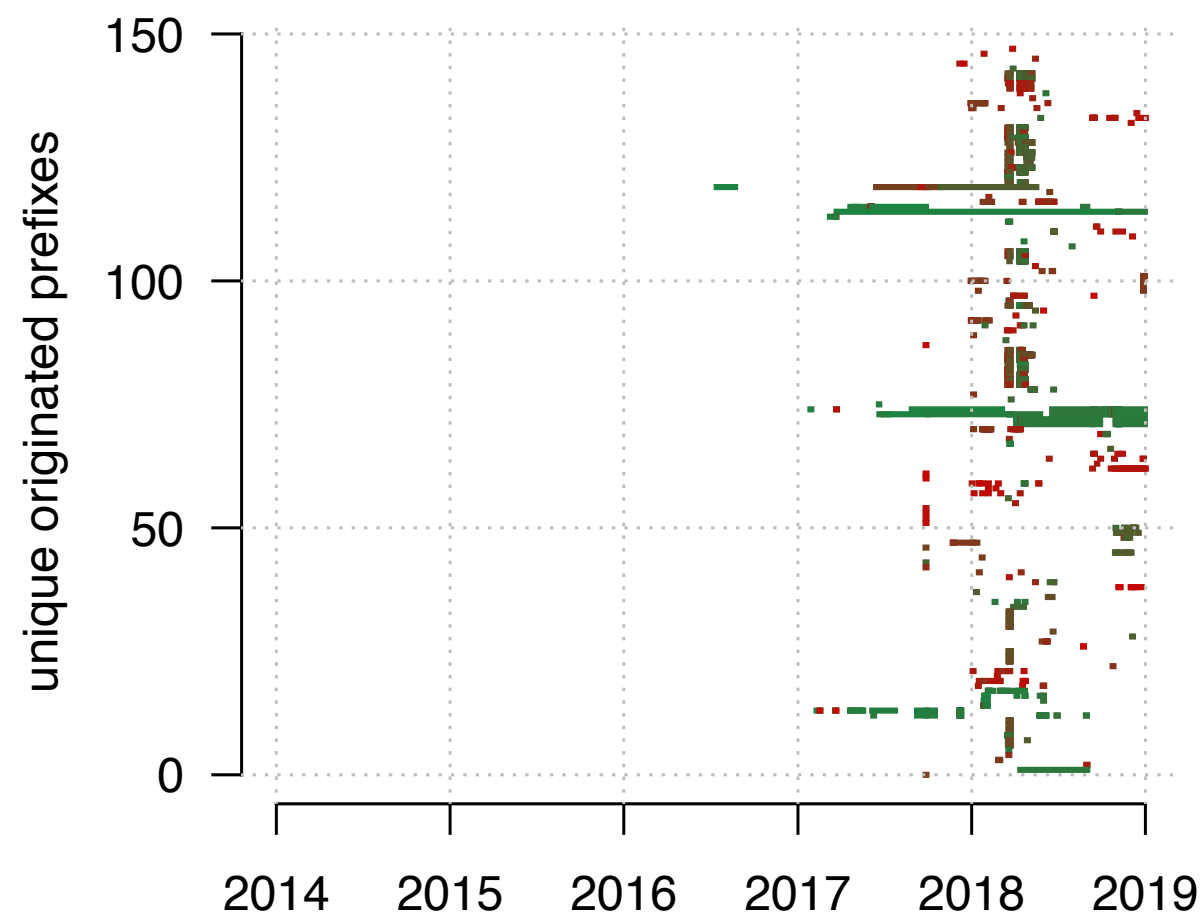
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- ▶ Flagged ASes are:
 - **4.9%** of ASes originating 10+ prefixes
 - **1.2%** of all ASes.

BGP behavior of flagged ASes



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What are ASes flagged by our classifier?

- **Indication of malicious behavior**
 - Blacklisted ASNs:

934

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What are ASes flagged by our classifier?

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 - Blacklisted ASNs: **84/290** ASes in *Spamhaus ASN DROP list*
 - ➔ Flagged ASes are **10x** more likely to be blacklisted



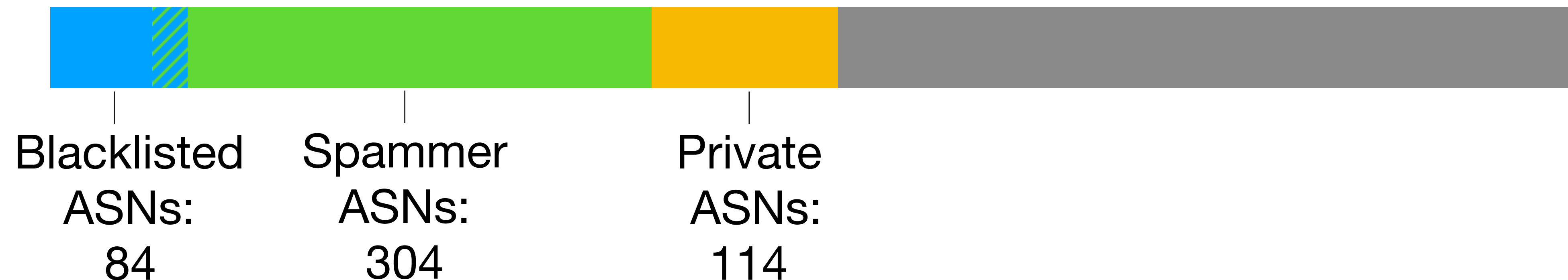
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- **Indication of malicious behavior**
 - Blacklisted ASNs: **84/290** ASes in *Spamhaus ASN DROP list*
 - Spammer ASNs: **33%** ASes have a prefix in UCE-PROTECT level 2 spam blacklist



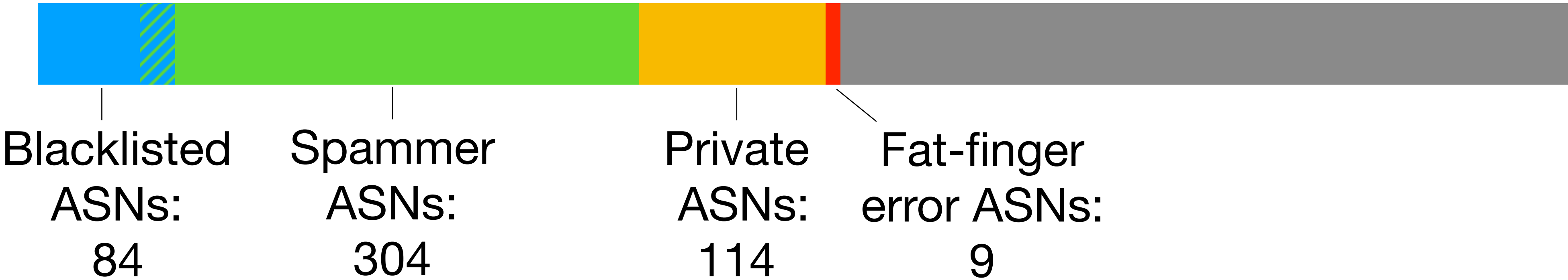
What are ASes flagged by our classifier?

- Indication of malicious behavior
- **Indication of misconfigurations**
- Private ASNs **12%**



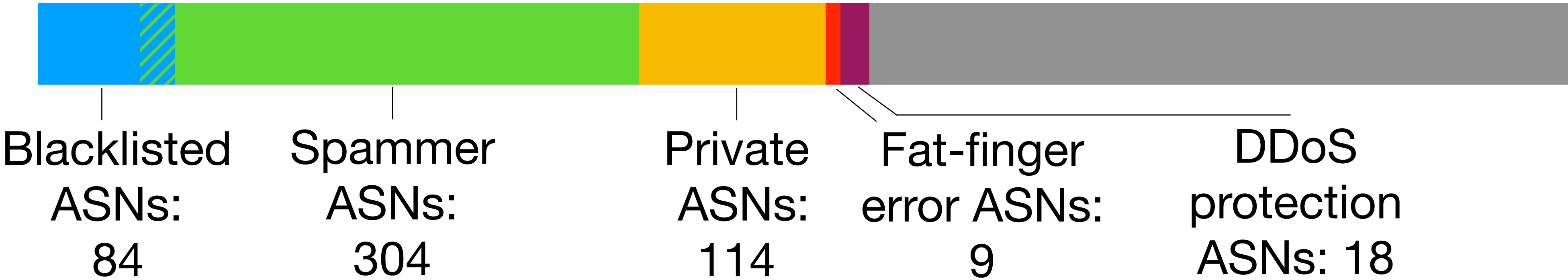
What are ASes flagged by our classifier?

- Indication of malicious behavior
- **Indication of misconfigurations**
 - Private ASNs **12%**
 - Fat-finger error ASNs **1%**



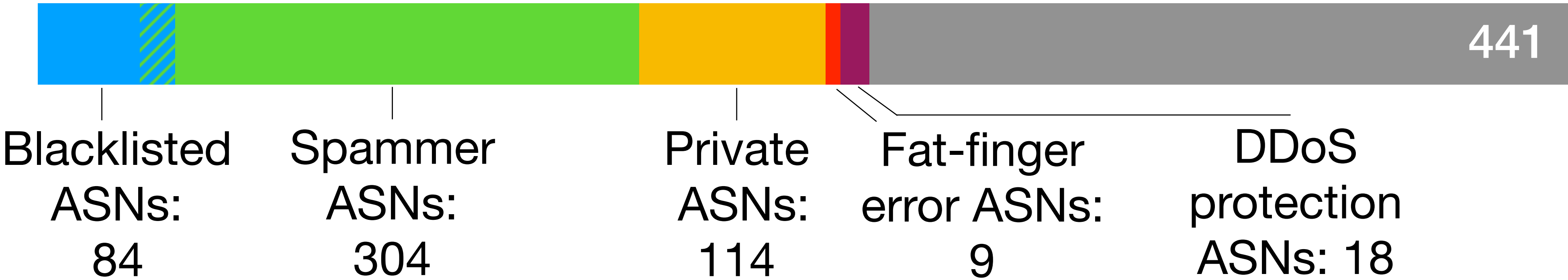
What are ASes flagged by our classifier?

- Indication of malicious behavior
- Indication of misconfigurations
- **Known false positives**
- DDoS protection ASNs **2%**



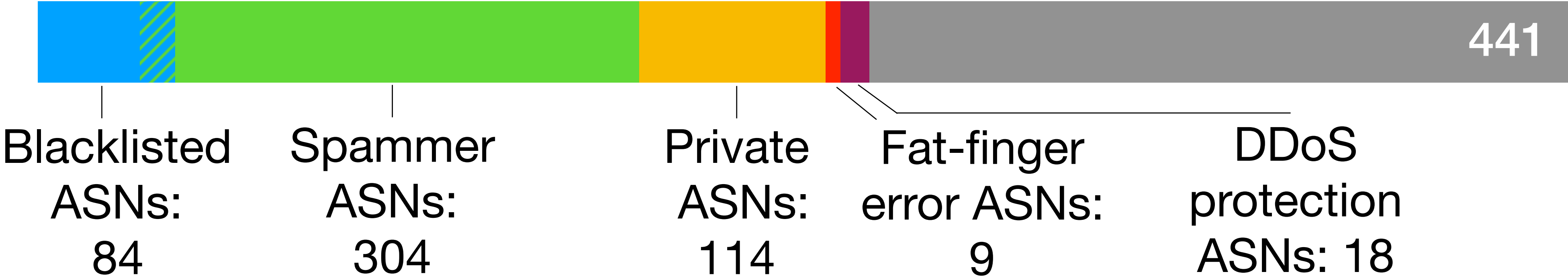
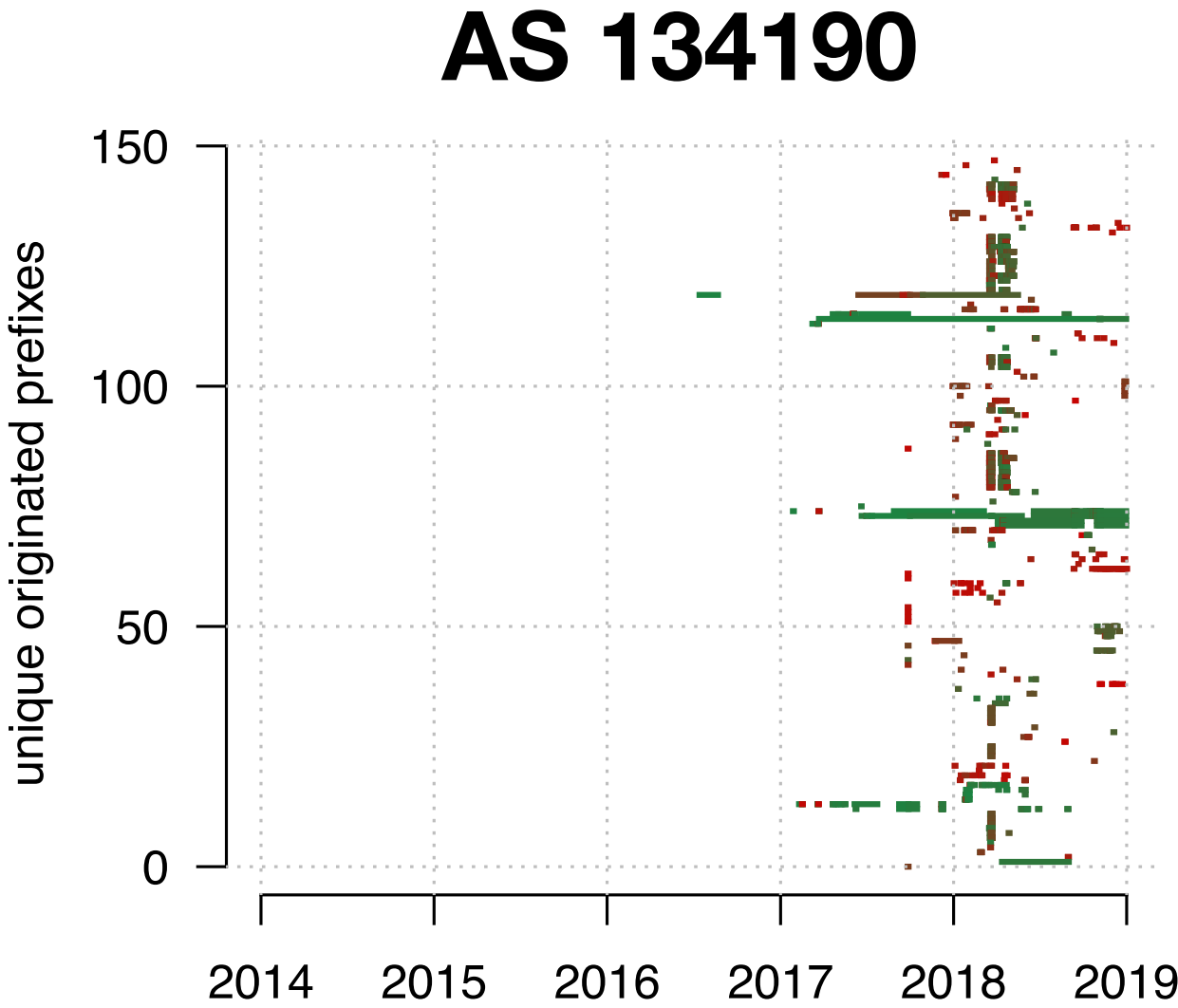
What are ASes flagged by our classifier?

- Indication of malicious behavior
- Indication of misconfigurations
- Known false positives



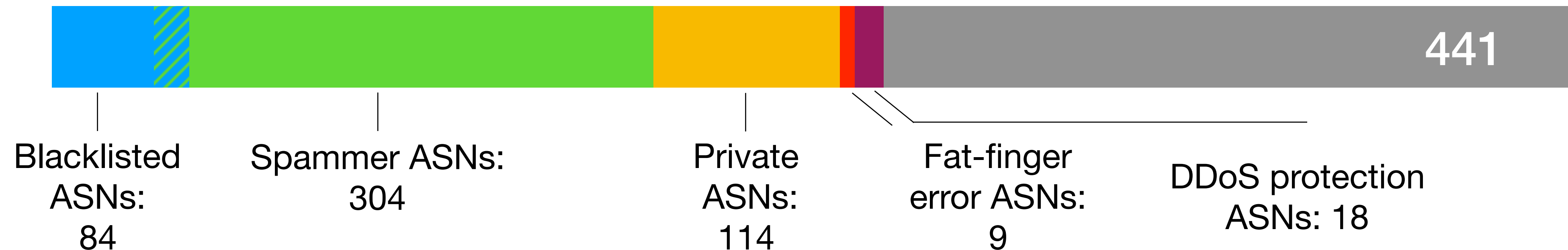
What are ASes flagged by our classifier?

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- Known false positives



What are ASes flagged by our classifier?

- Indication of malicious behavior
- Indication of misconfigurations
- Known false positives



- ▶ 53% of flagged ASes are in known categories.
- ▶ Many interesting ASes are in the other 47%.

What our classifier is not...

- A bulletproof identifier of malicious ASes.
- A system that exhaustively captures hijackers.

Key takeaways

- **First** longitudinal analysis of **serial hijacker** ASes.
- Features offer **state of affairs** of AS-wide **BGP behavior**.
- Classifier outcome provides **new data for network reputation** scoring systems.
- Effectively **narrows the focus on suspicious networks**, with much future work to be done.

Key takeaways

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