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

NANOG 80

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Originally presented at the ACM Internet Measurement Conference 2019

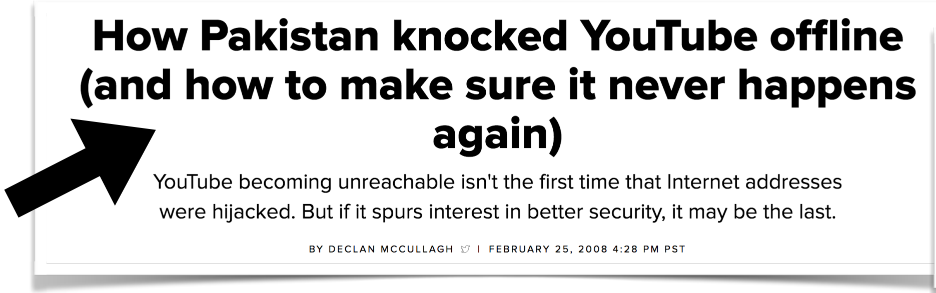
Internet Policy Research Initiative
Massachusetts Institute of Technology

CSAIL

caida

UC San Diego

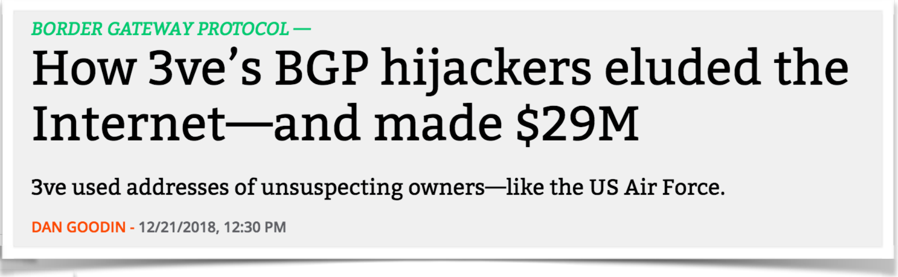
BGP hijacking is pervasive in the Internet



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

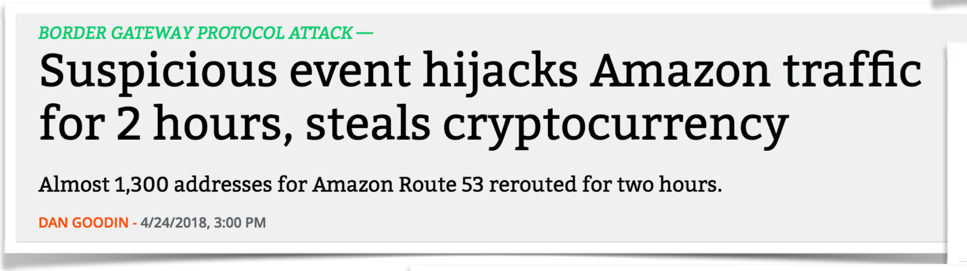


BORDER GATEWAY PROTOCOL —

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



BORDER GATEWAY PROTOCOL ATTACK —

Suspicious event hijacks Amazon traffic for 2 hours, steals cryptocurrency

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

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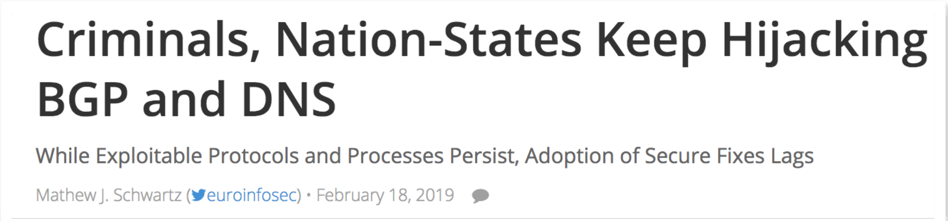
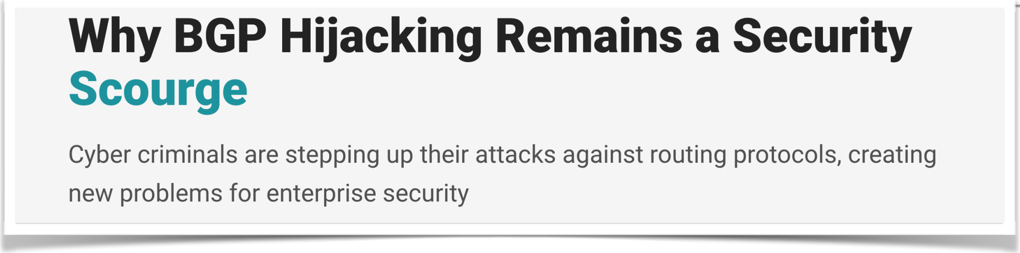


Criminals, Nation-States Keep Hijacking BGP and DNS

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

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



Why BGP Hijacking Remains a Security Scourge

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

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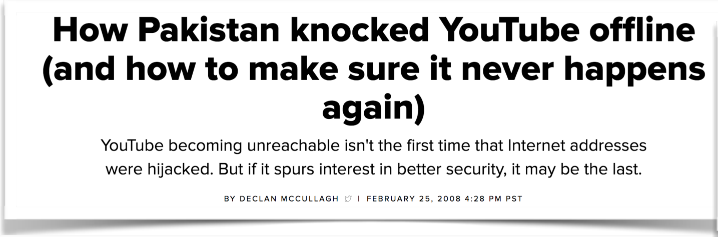

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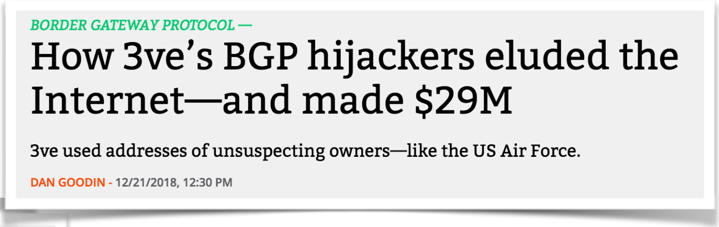

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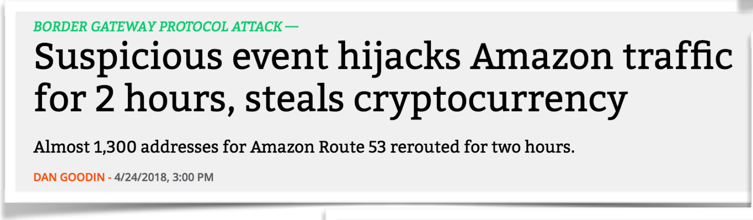

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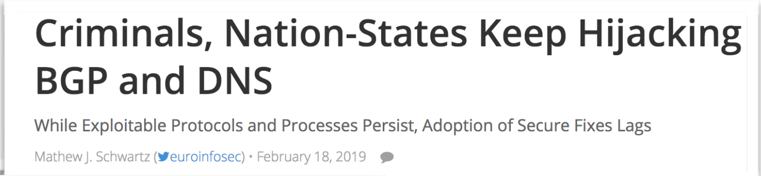

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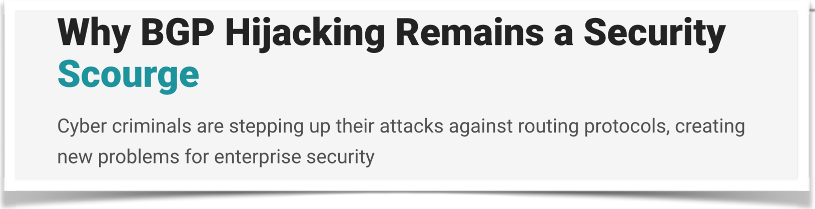
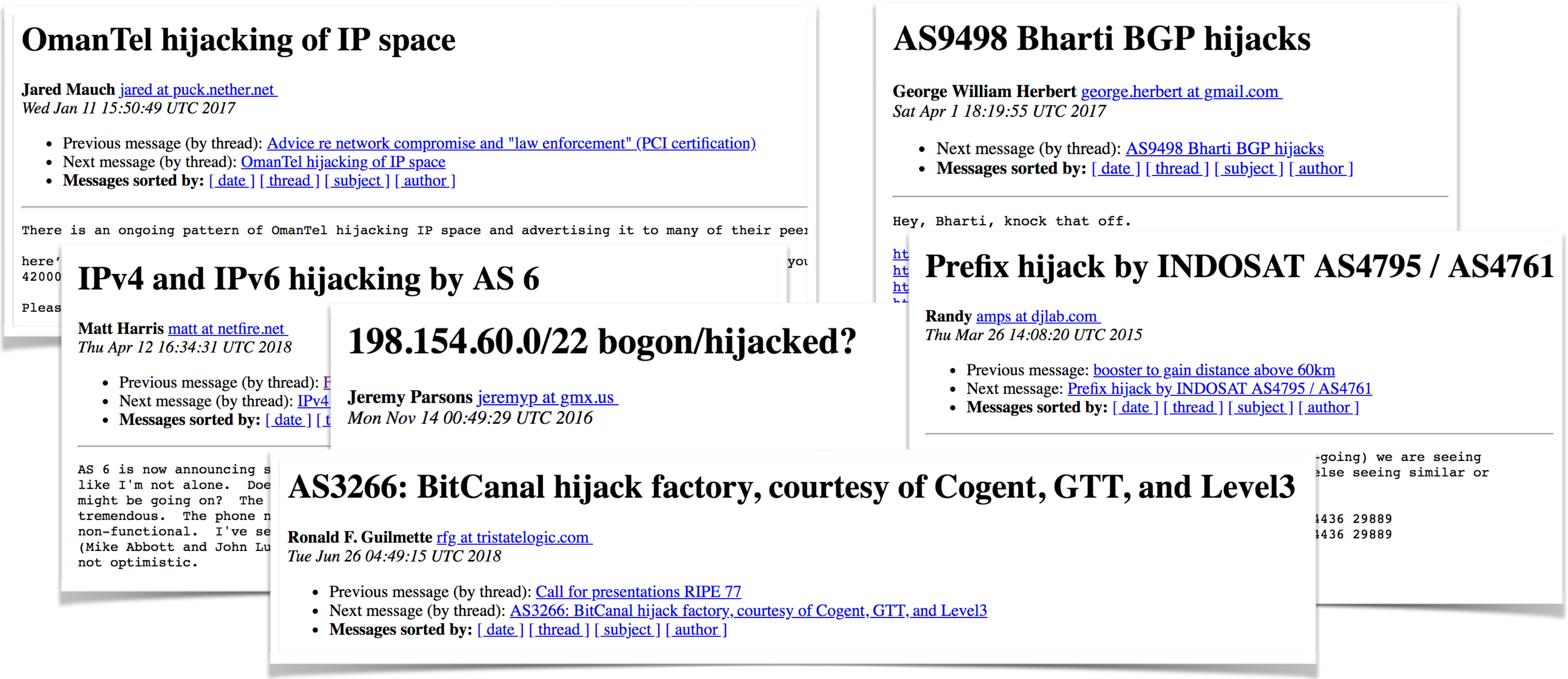


Why BGP Hijacking Remains a Security Scourge

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
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
- **Messages sorted by:** [date] [thread] [subject] [author]

```
There is an ongoing pattern of OmanTel hijacking IP space and advertising it to many of their peer

here'                                                                                          you
42000

Pleas
```

AS9498 Bharti BGP hijacks

George William Herbert george.herbert at gmail.com
Sat Apr 1 18:19:55 UTC 2017

- Next message (by thread): AS9498 Bharti BGP hijacks
- **Messages sorted by:** [date] [thread] [subject] [author]

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Hey, Bharti, knock that off.

ht
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IPv4 and IPv6 hijacking by AS 6

Matt Harris matt at netfire.net
Thu Apr 12 16:34:31 UTC 2018

- Previous message (by thread): F
- Next message (by thread): IPv4
- **Messages sorted by:** [date] [t

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198.154.60.0/22 bogon/hijacked?

Jeremy Parsons jeremyp at gmx.us
Mon Nov 14 00:49:29 UTC 2016

Prefix hijack by INDOSAT AS4795 / AS4761

Randy amps at djlab.com
Thu Mar 26 14:08:20 UTC 2015

- Previous message: booster to gain distance above 60km
- Next message: Prefix hijack by INDOSAT AS4795 / AS4761
- **Messages sorted by:** [date] [thread] [subject] [author]

```
-going) we are seeing
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4436 29889
4436 29889
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AS3266: BitCanal hijack factory, courtesy of Cogent, GTT, and Level3

Ronald F. Guilmette rfg at tristatelogic.com
Tue Jun 26 04:49:15 UTC 2018

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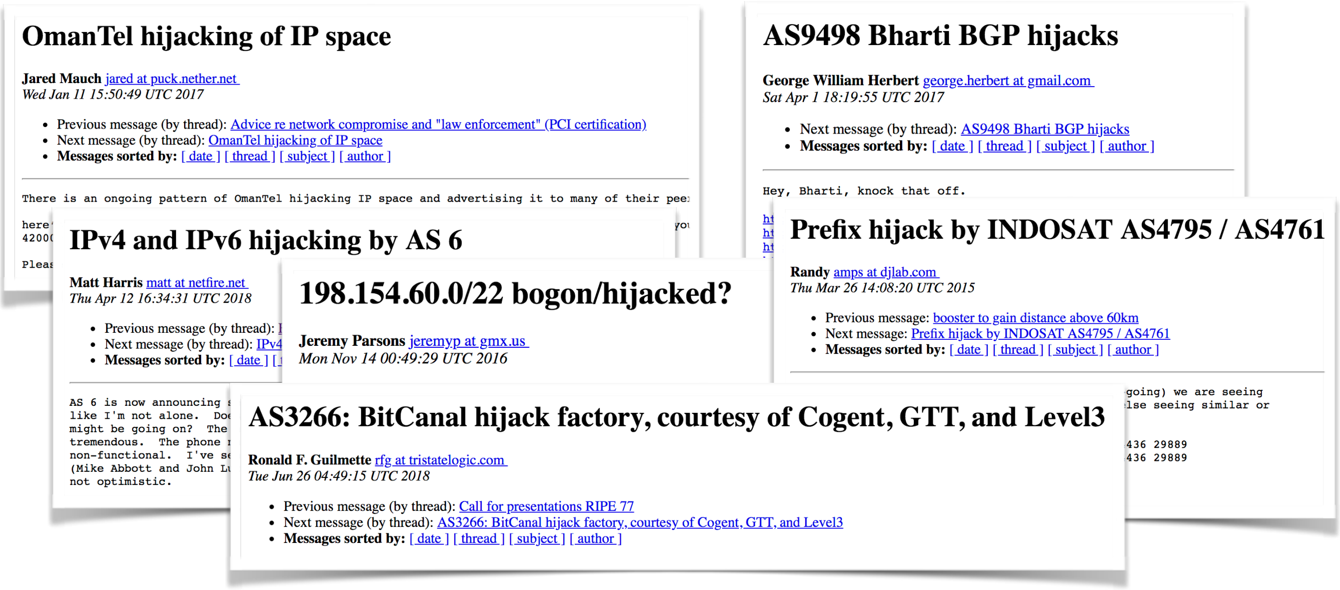

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436 29889
436 29889
```
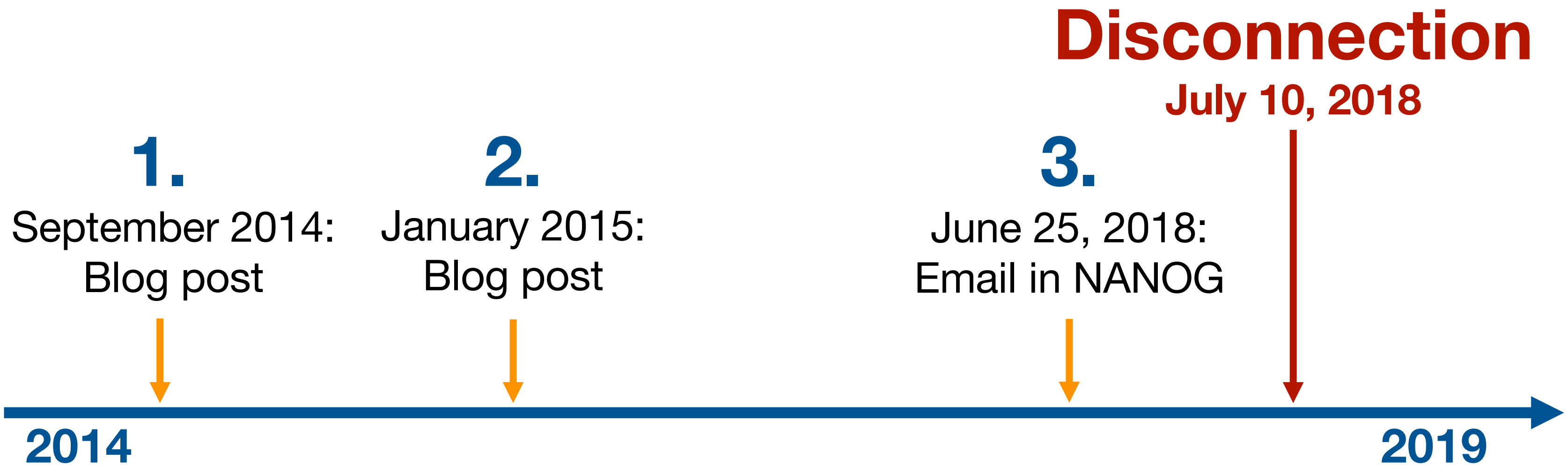

- ***Serial hijackers***: ASes that **repeatedly hijack** over **long periods** of time.

Bitcanal: an infamous serial hijacker



Disconnection

July 10, 2018

1. September 2014: Blog post

2. January 2015: Blog post

3. June 25, 2018: Email in NANOG

2014

2019

▶ 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

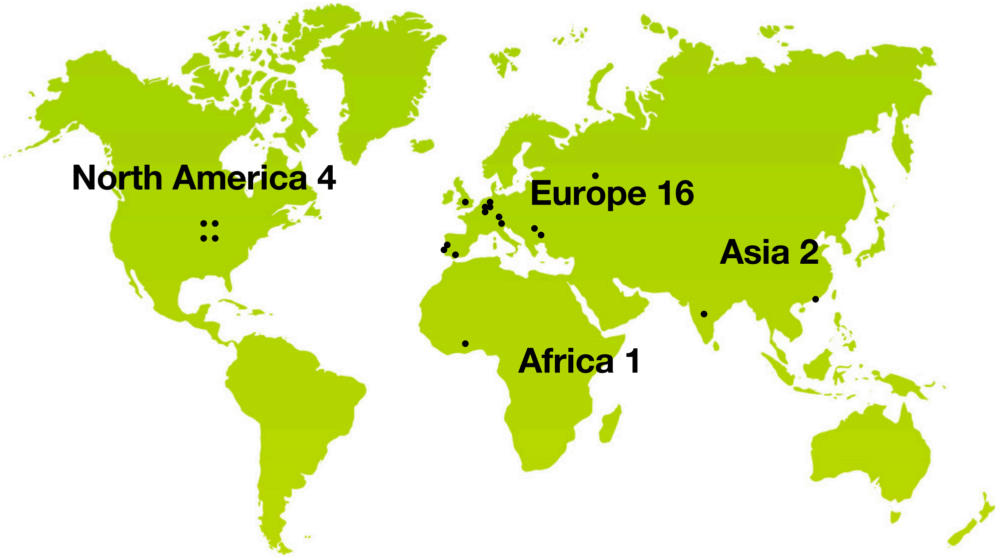
(iii) Evaluate our results

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

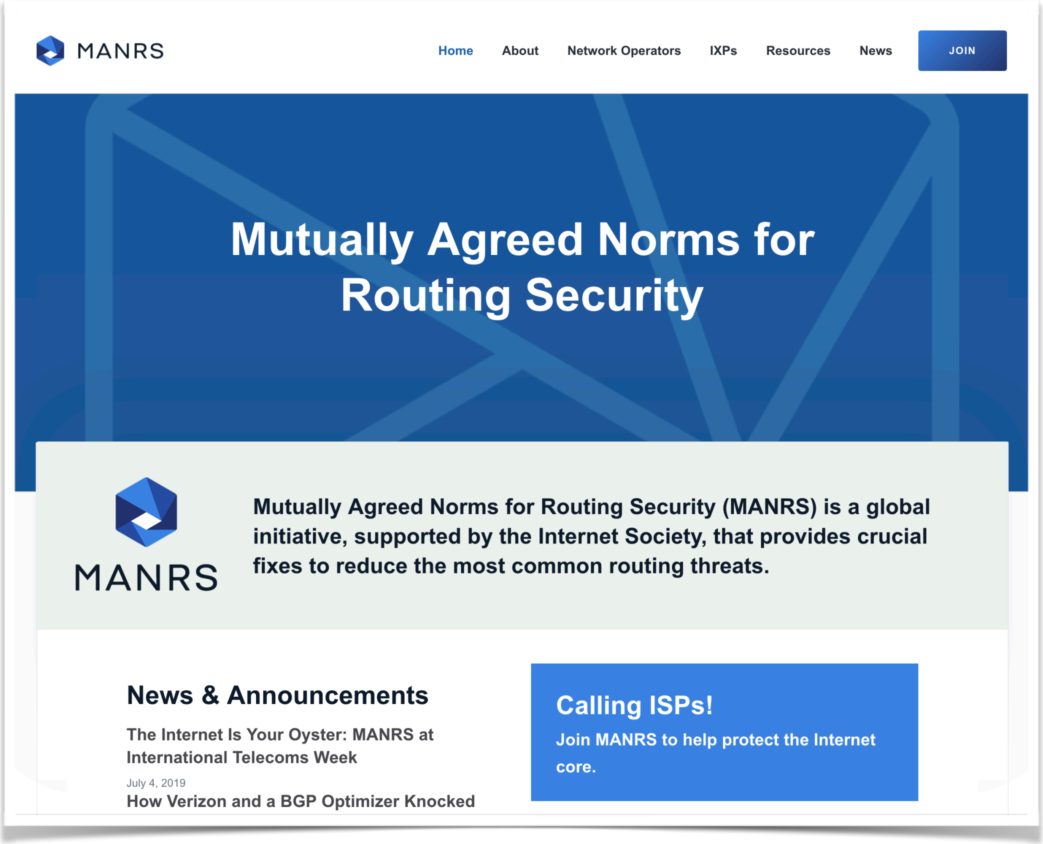


ASN country and RIR registration

Ground truth: legitimate ASes

230 Legitimate ASes:

- 191 MANRS ASes
- 26 ASes manually selected



Mutually Agreed Norms for Routing Security

MANRS

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.

News & Announcements

The Internet Is Your Oyster: MANRS at International Telecoms Week

July 4, 2019

How Verizon and a BGP Optimizer Knocked

Calling ISPs!

Join MANRS to help protect the Internet core.

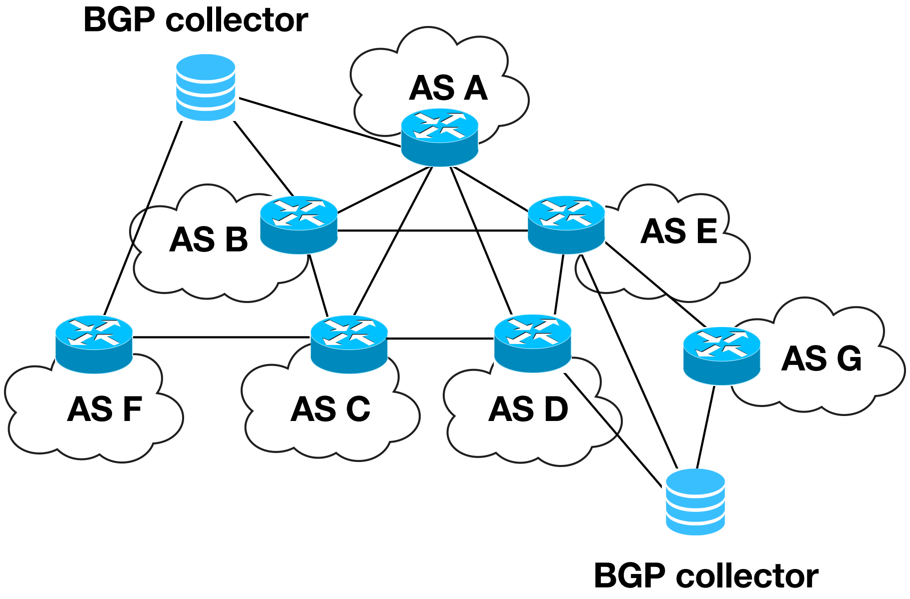
BGP dataset and processing

- 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)**

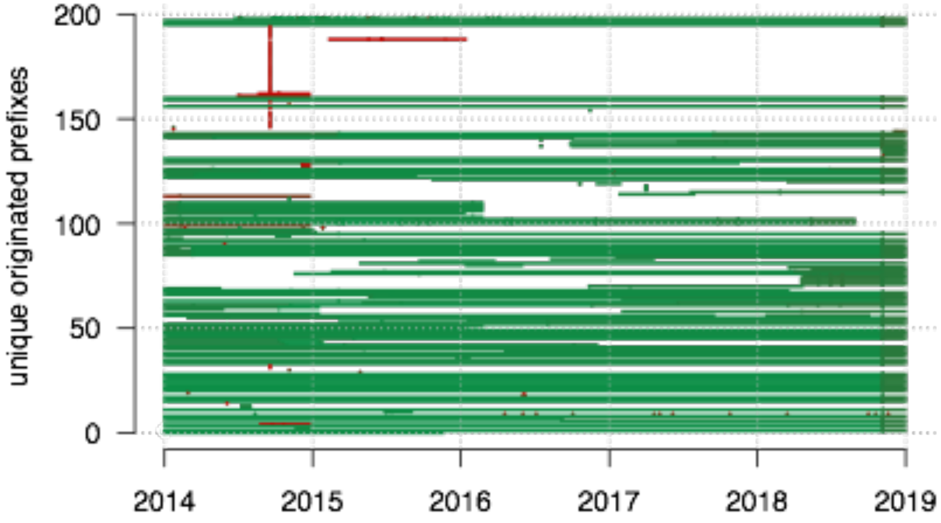
- Data from Jan. 2014 to Dec. 2018



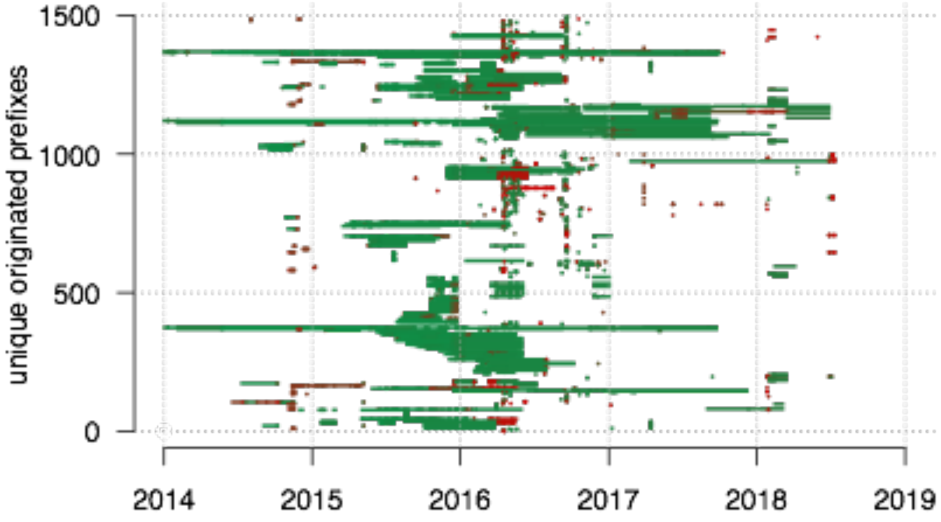
▶ **(prefix, origin AS, visibility, timestamp)** every 5 min.

BGP origination behavior: legitimate vs. serial hijacker

British Telecom (AS 5400)



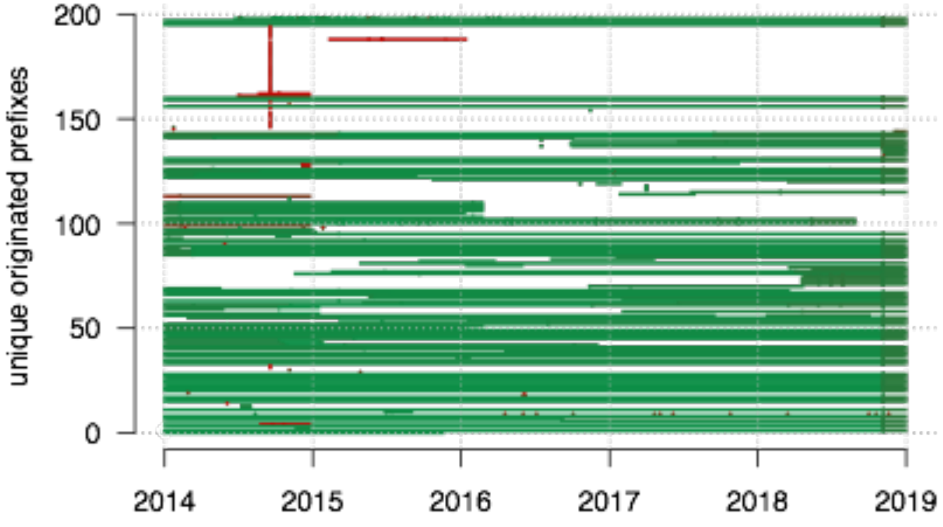
Bitcanal (AS 197426)



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

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

BGP origination behavior: legitimate vs. serial hijacker



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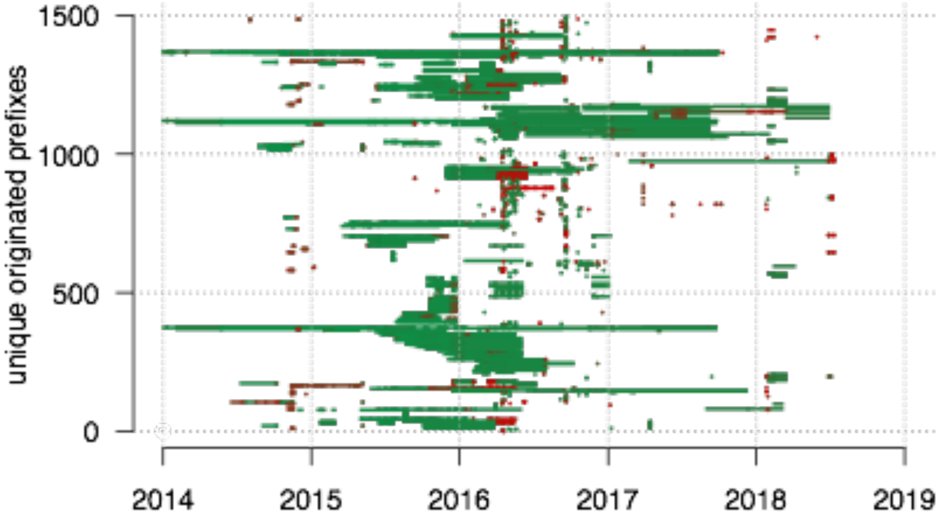
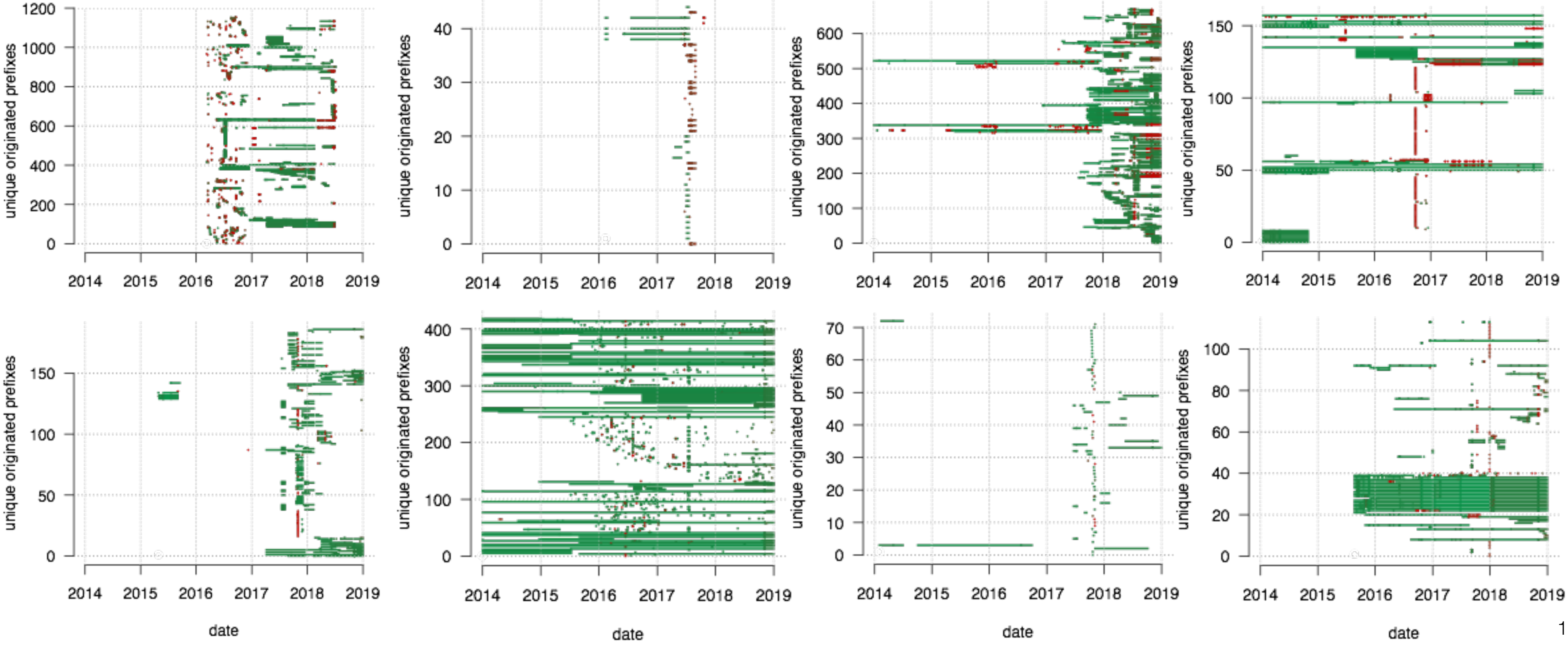


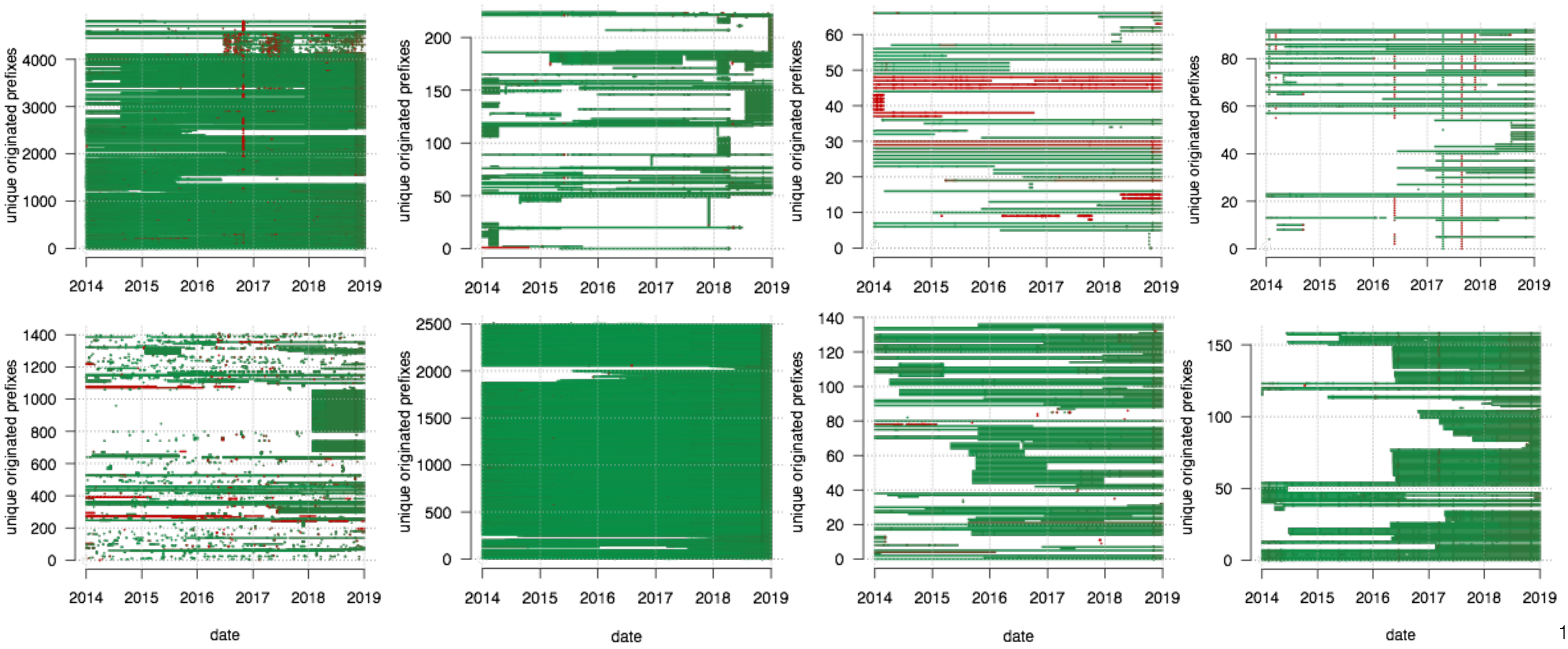
Bitcanal (AS 197426)

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

Variability of BGP behavior: serial hijackers



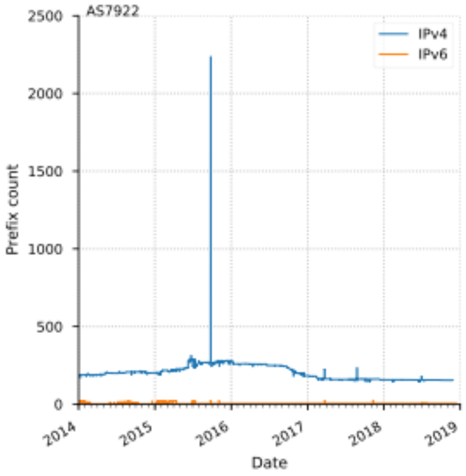
Variability of BGP behavior: legitimate ASes



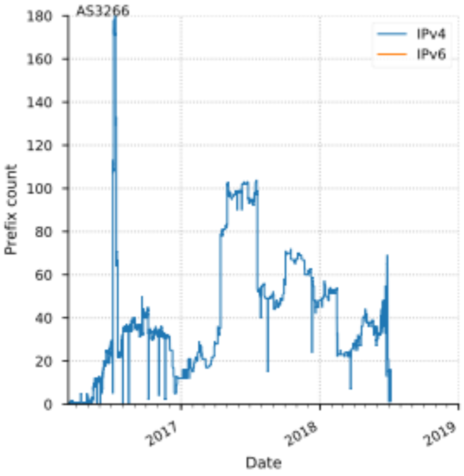
Expected serial hijacker behavior

- Repeated AS absence from the global routing table.
- Short prefix origination times.
- More multi-origin conflicts (MOAS).
- Volatile count of concurrently advertised prefixes.
- Broad geographical distribution of address space originated.

Comcast AS



Serial Hijacker AS



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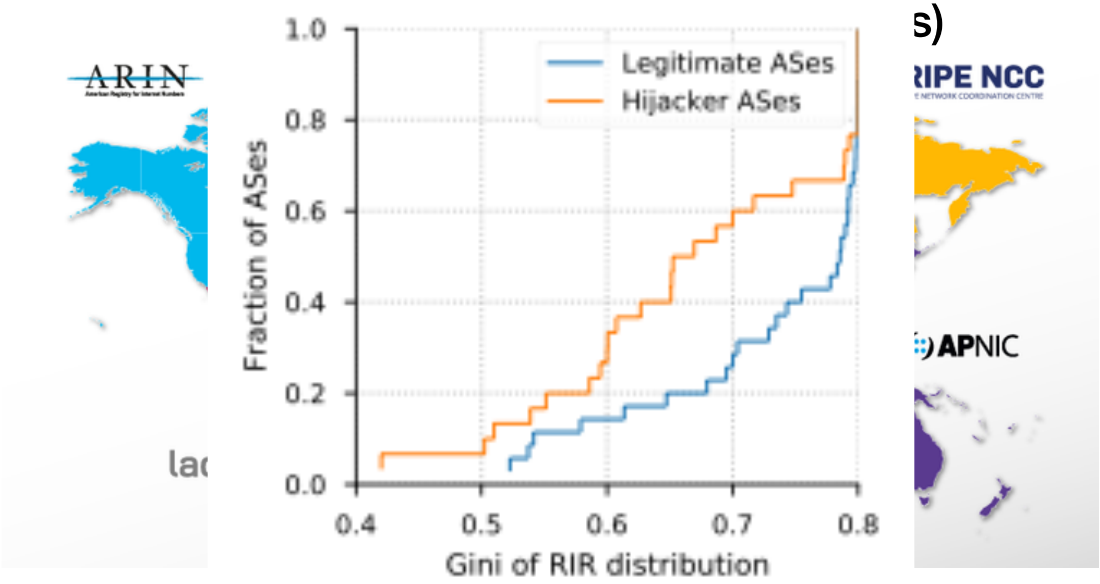

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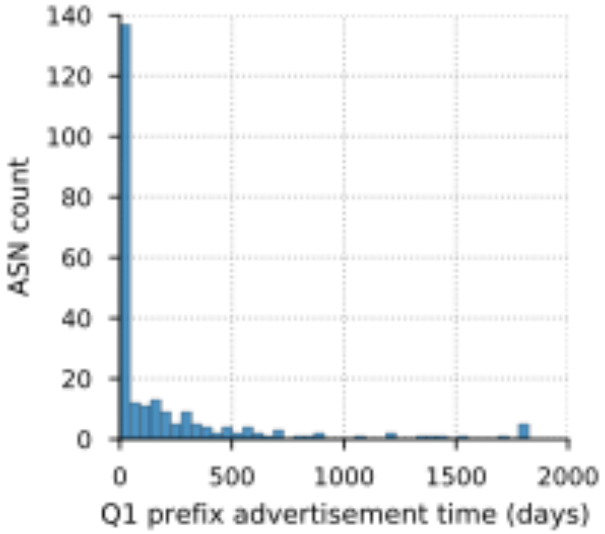
▶ We derived **52 features** to capture differences.

Challenges of applying ML to find more potential serial hijackers

- Heavy-tailed and skewed data:
  Monthly prefix changes [0,2600], Gini in [0,0.8]
- Very small ground truth:
  240 AS for 19,000 ASes
- Class Imbalance:
  23 serial hijacker vs. 217 legitimate networks



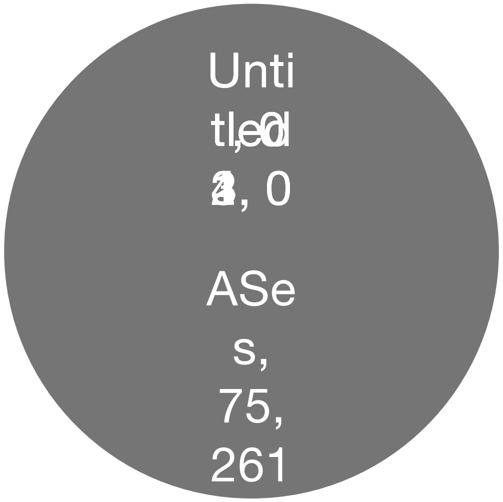
Our ML approach

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

▶ **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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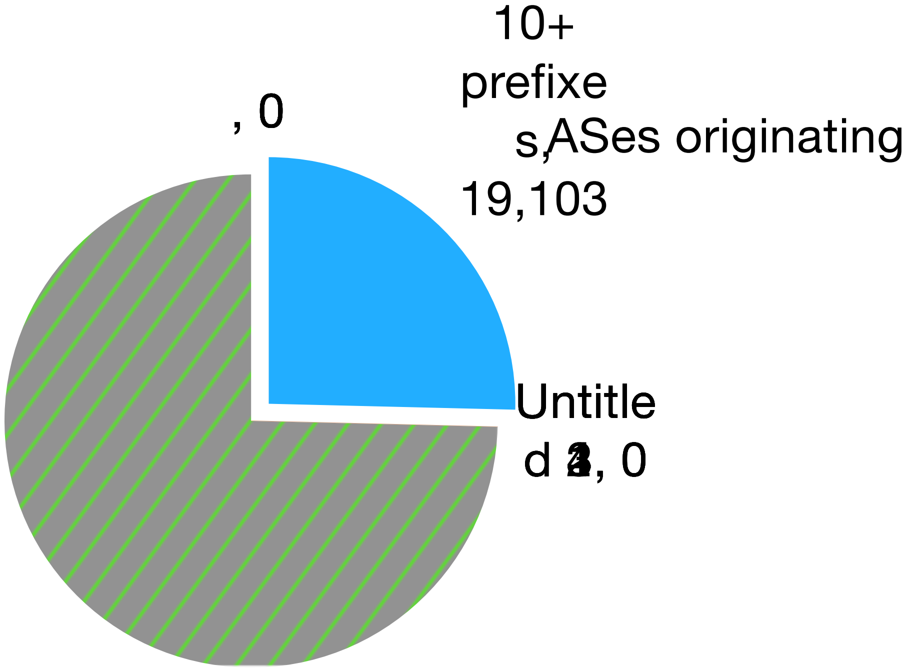

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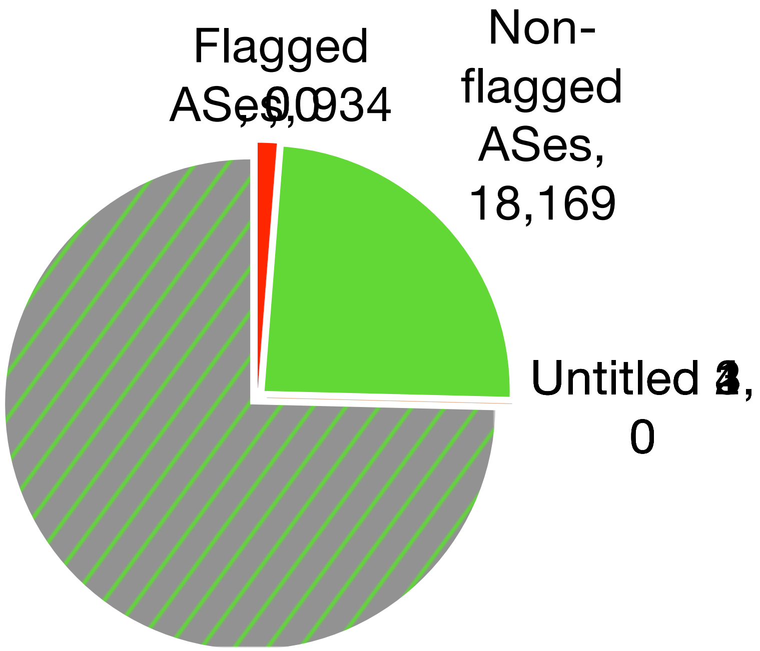

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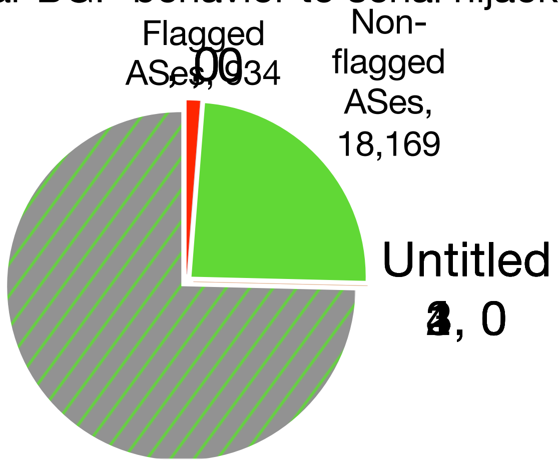
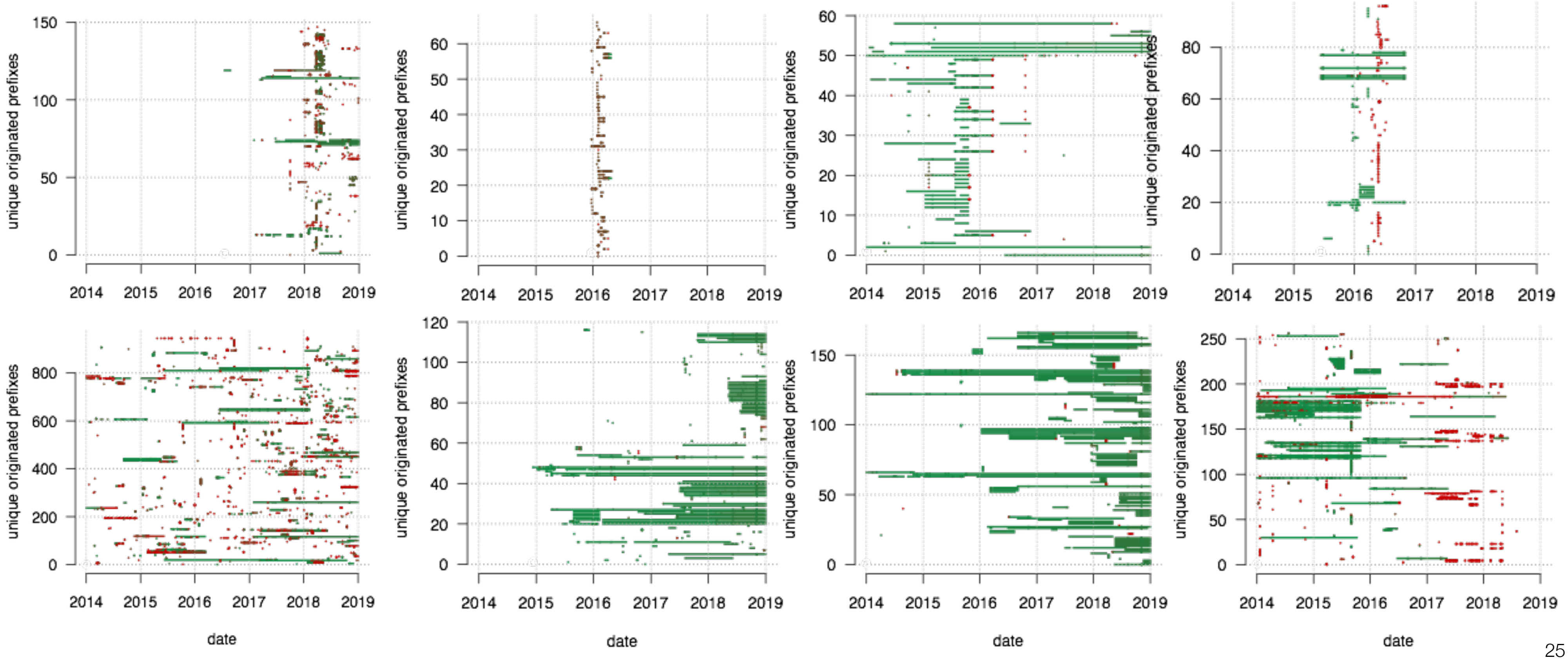


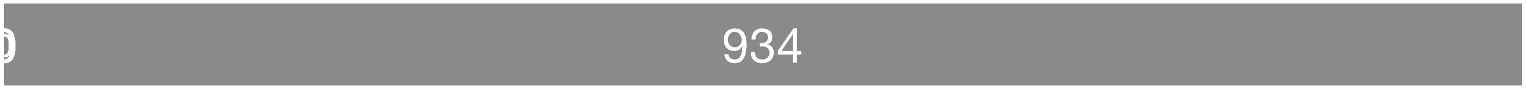
- Flagged ASes are:
  - **4.9%** of ASes originating 10+ prefixes
  - **1.2%** of all ASes.

BGP behavior of flagged ASes



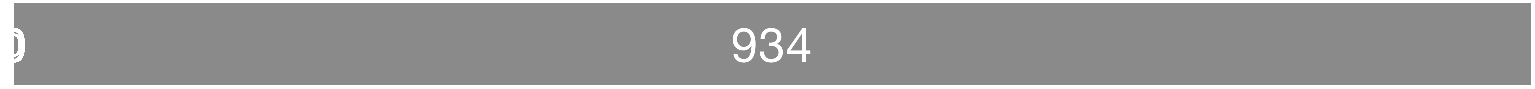
What are ASes flagged by our classifier?

- **Indication of malicious behavior**



What are ASes flagged by our classifier?

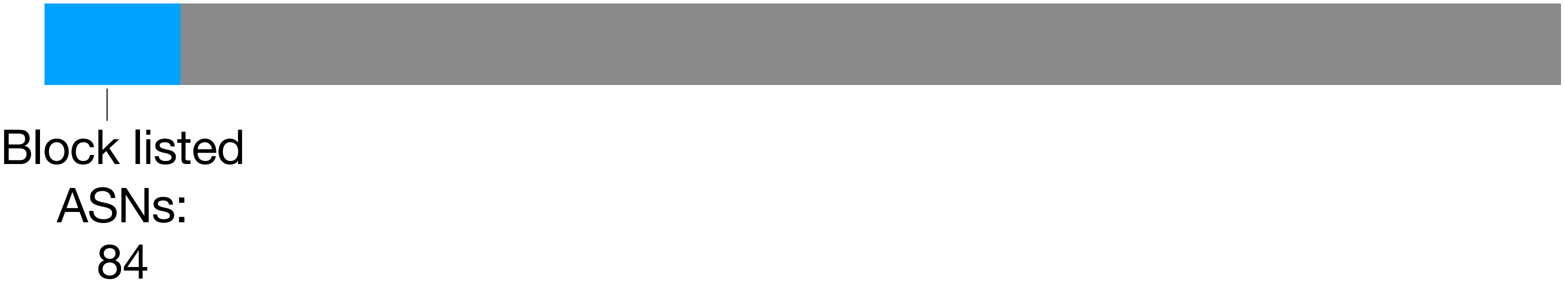
- **Indication of malicious behavior**
  - Block listed ASNs:



What are ASes flagged by our classifier?

- **Indication of malicious behavior**
  - Block listed ASNs: **84/290** ASes in *Spamhaus ASN DROP list*

Flagged ASes are **10x** more likely to be block listed



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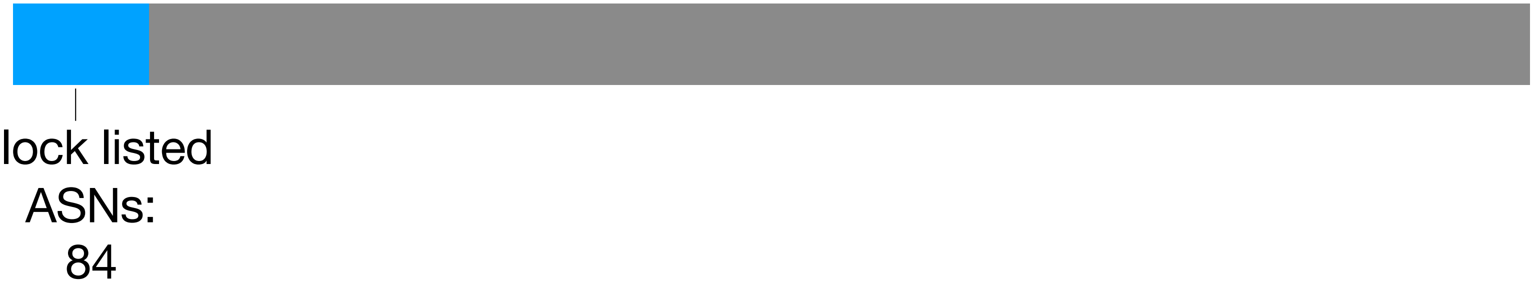
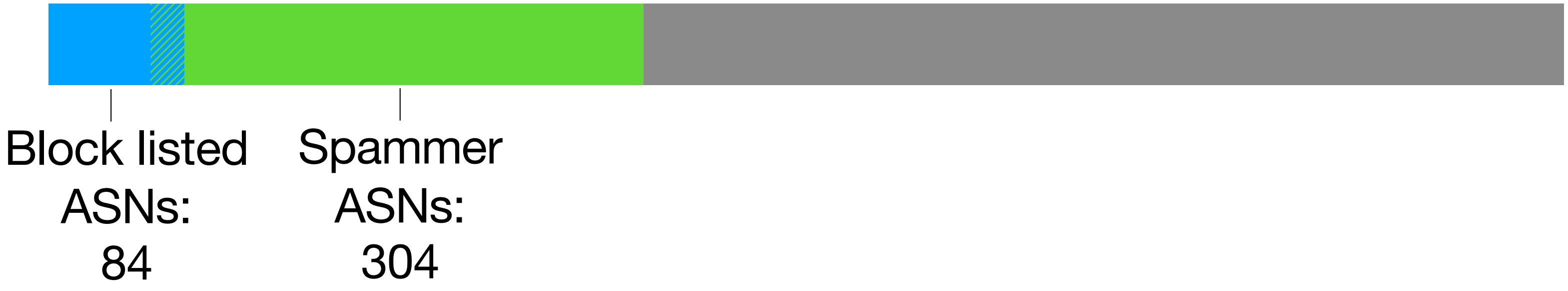
  - Spammer ASNs:



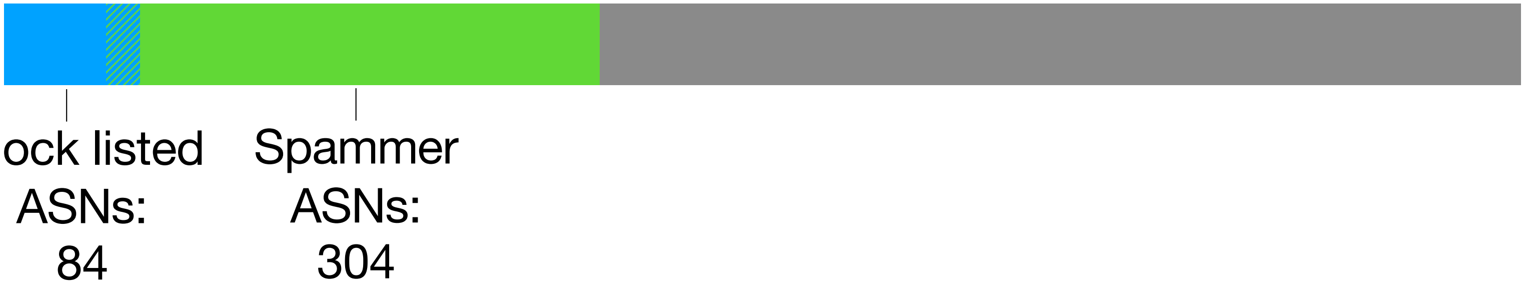
What are ASes flagged by our classifier?

- **Indication of malicious behavior**
  - Block listed 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**



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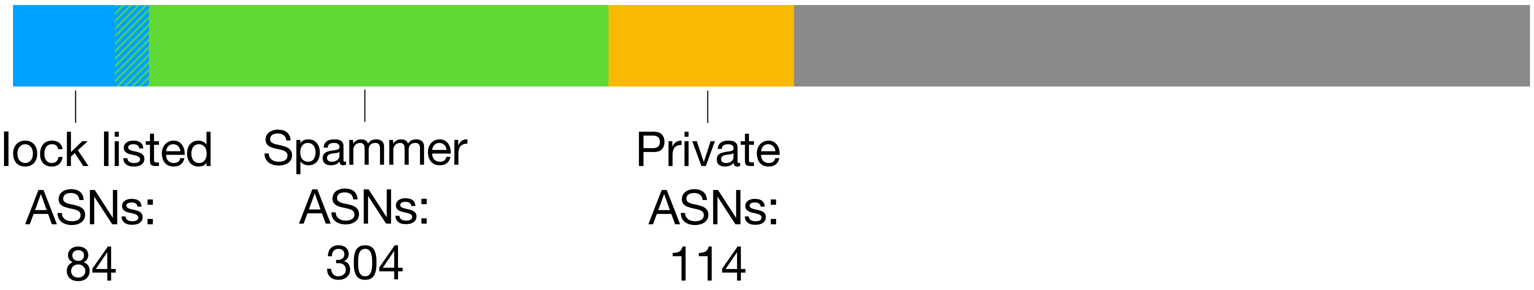
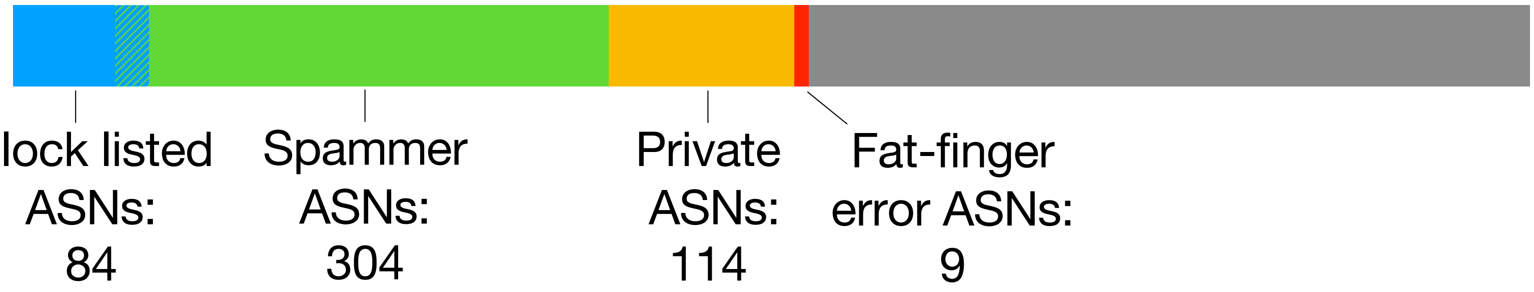
- Indication of malicious behavior
- **Indication of misconfigurations**
  - Private ASNs **12%**



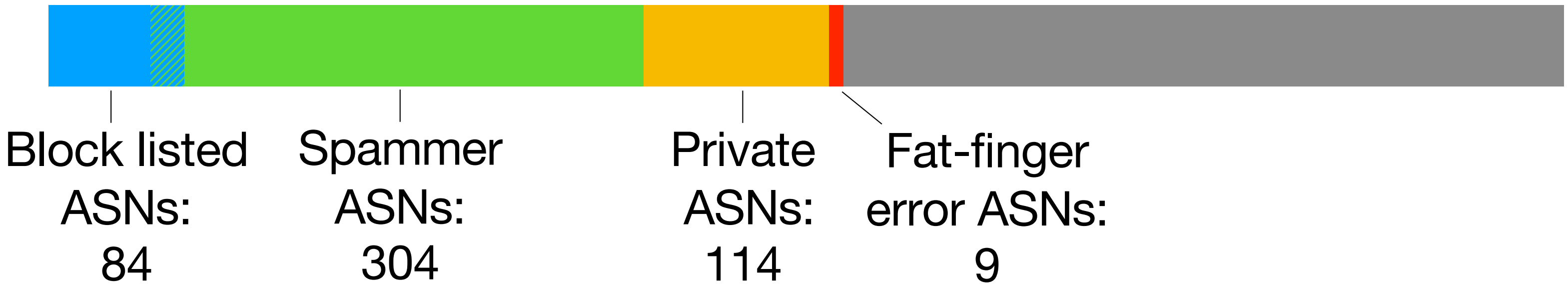
What are ASes flagged by our classifier?

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



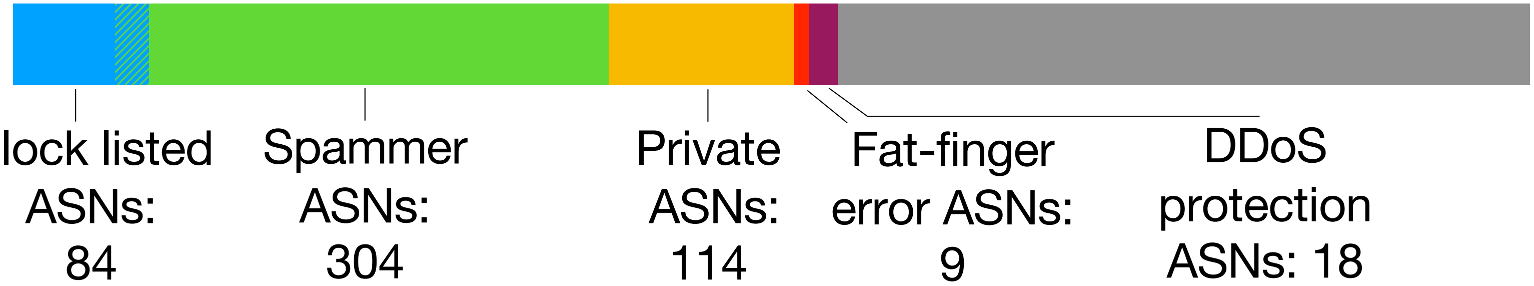
What are ASes flagged by our classifier?

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



What are ASes flagged by our classifier?

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



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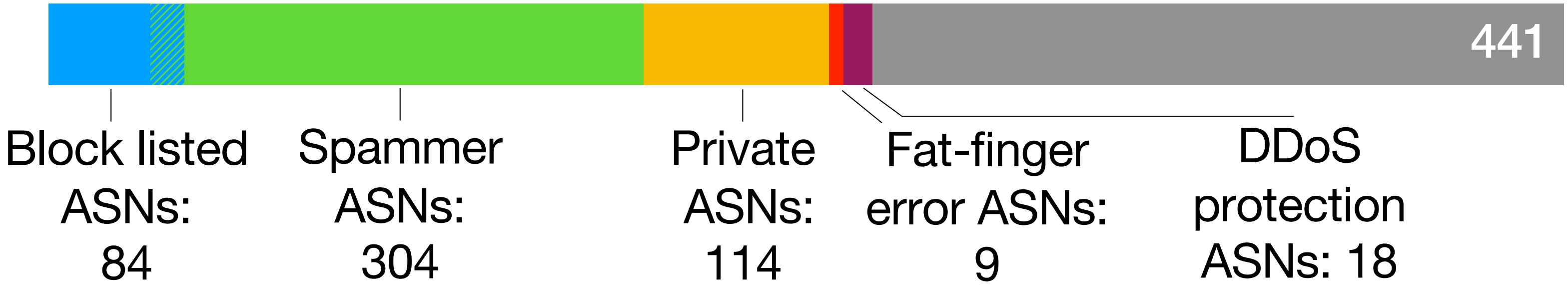
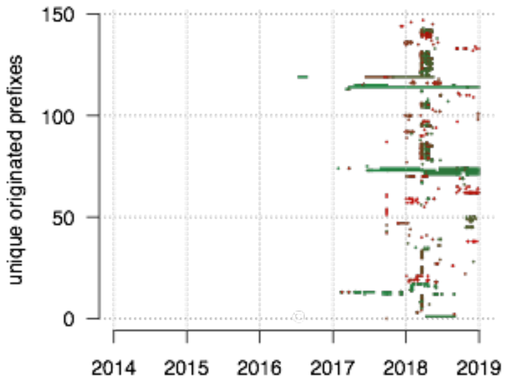
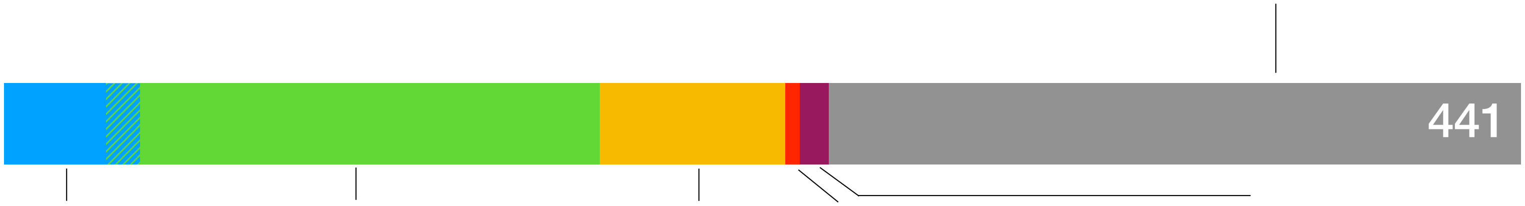


What are ASes flagged by our classifier?

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

AS 134190





Block listed ASNs: 84

Spammer ASNs: 304

Private ASNs: 114

Fat-finger error ASNs: 9

DDoS protection ASNs: 18

What are ASes flagged by our classifier?

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- Indication of misconfigurations
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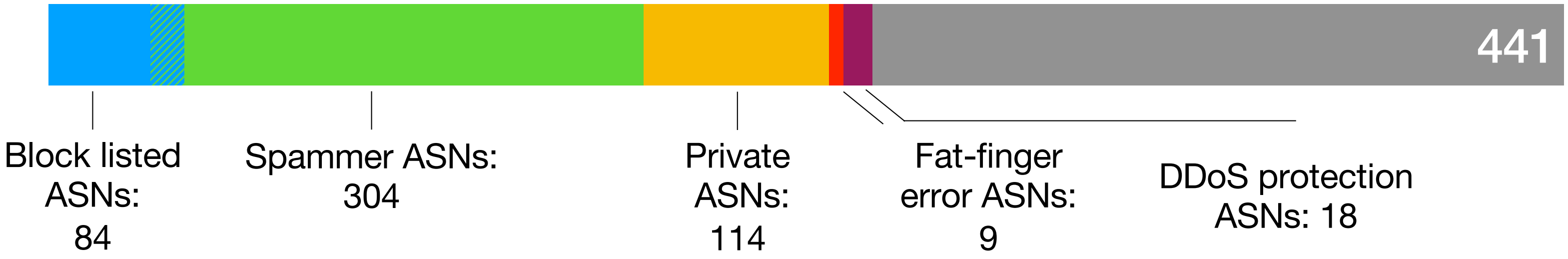

- 53% of flagged ASes are in known categories.

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- 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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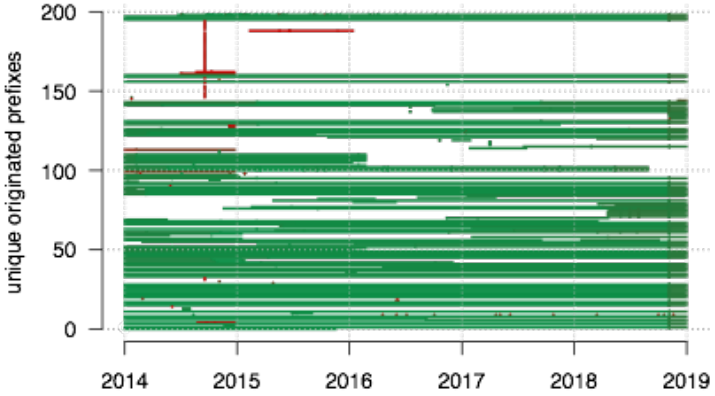
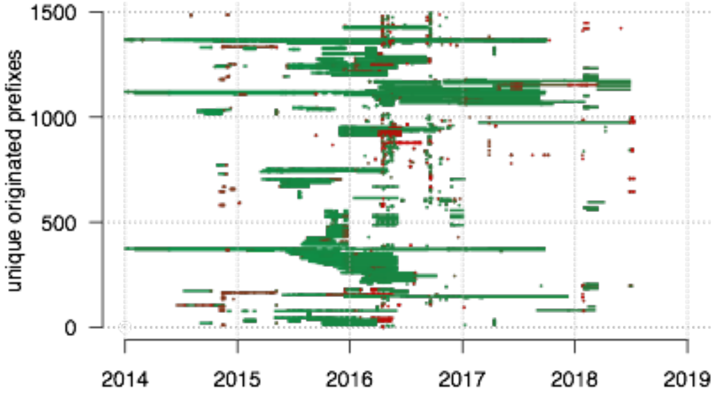
Legitimate AS



Serial hijacker AS


unique originated prefixes