A First Look at the Prevalence and Persistence of Middleboxes in the Wild

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mami
measurement and architecture for a middleboxed internet

LIÈGE université

measurement | architecture | experimentation

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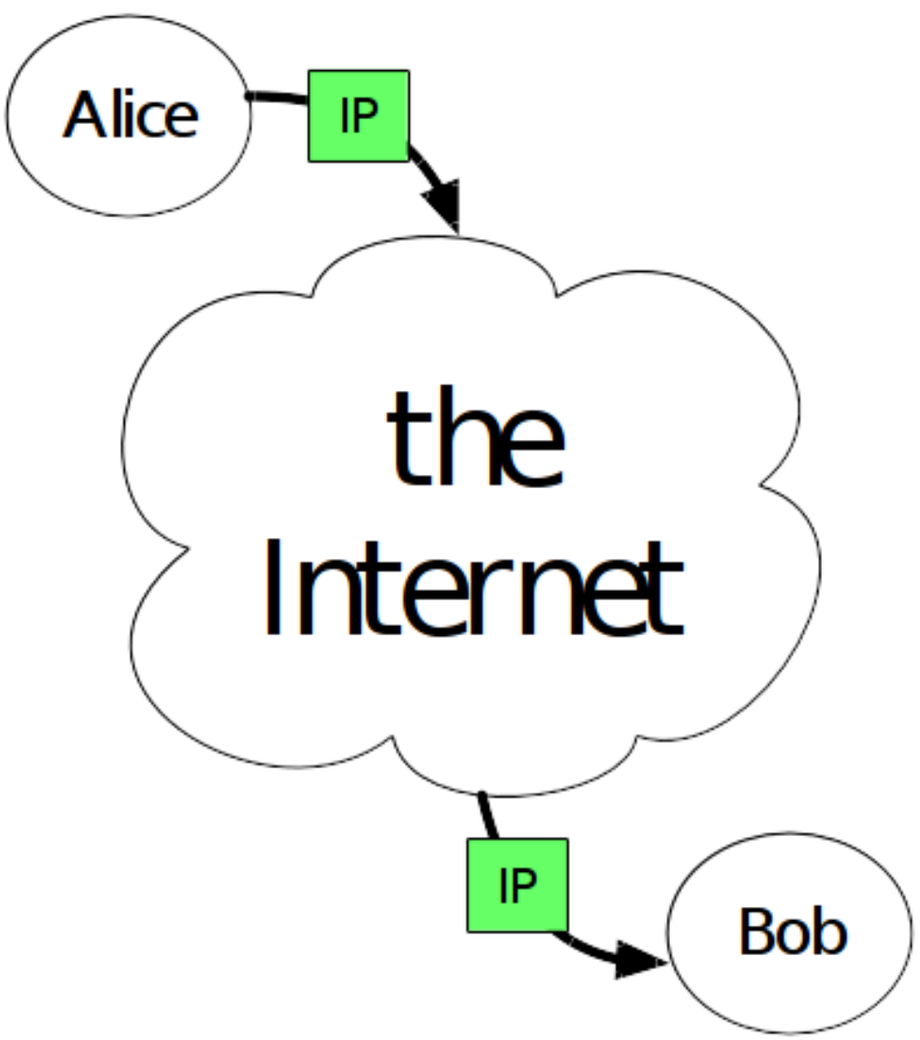
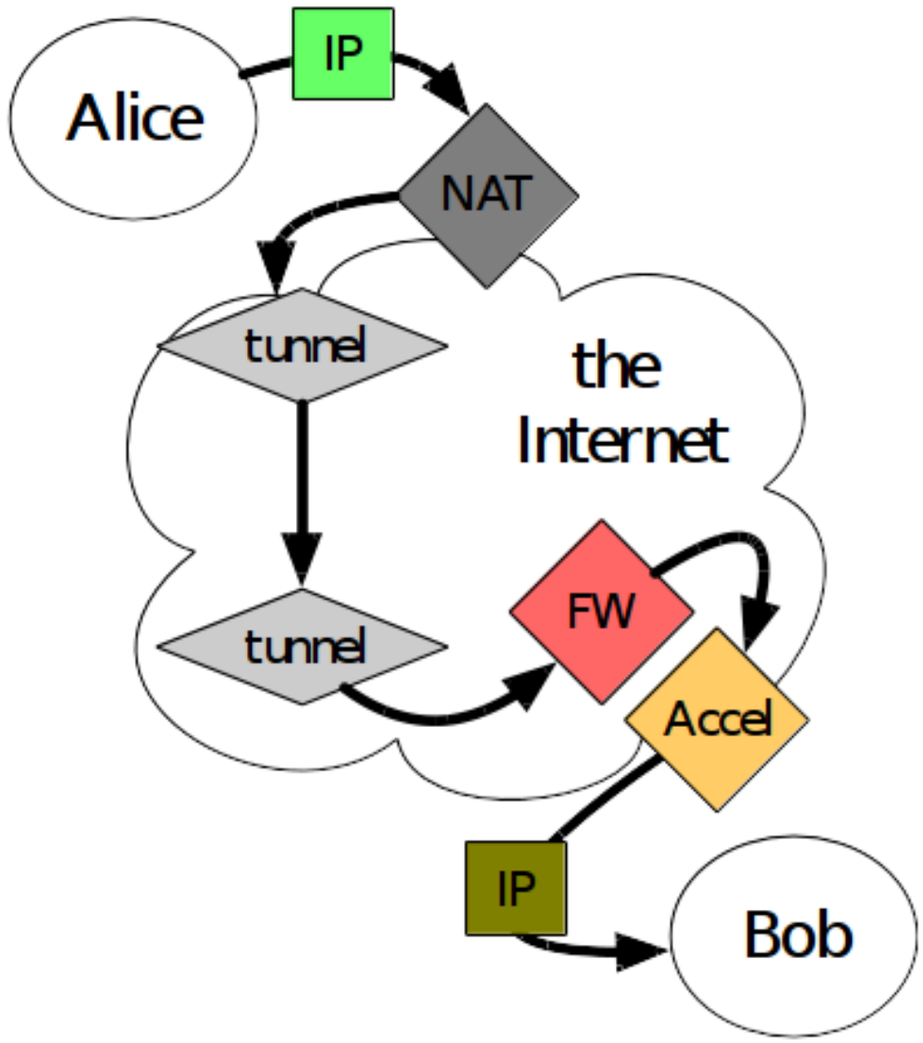
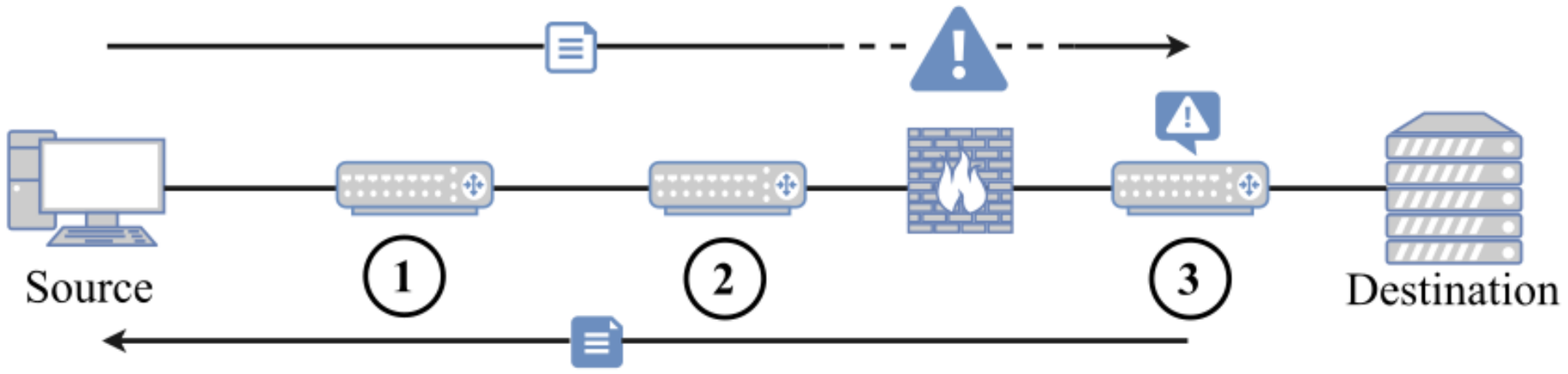
A middleboxed internet



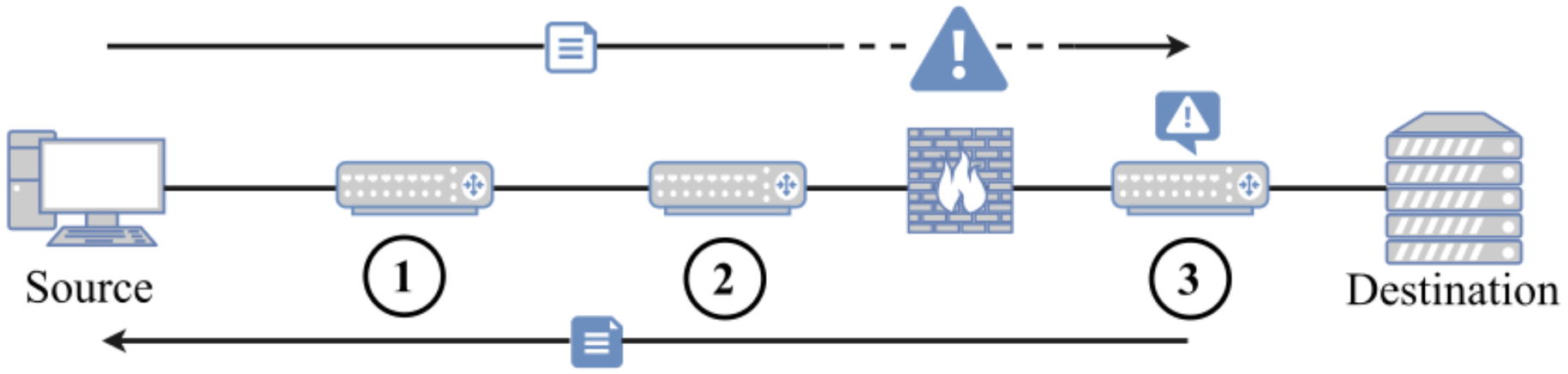


tracebox


Source
1
2
3
Destination


Router
Middlebox
TCP Probe
ICMP Message
Informant router
x
ICMP-triggering TTL

tracebox

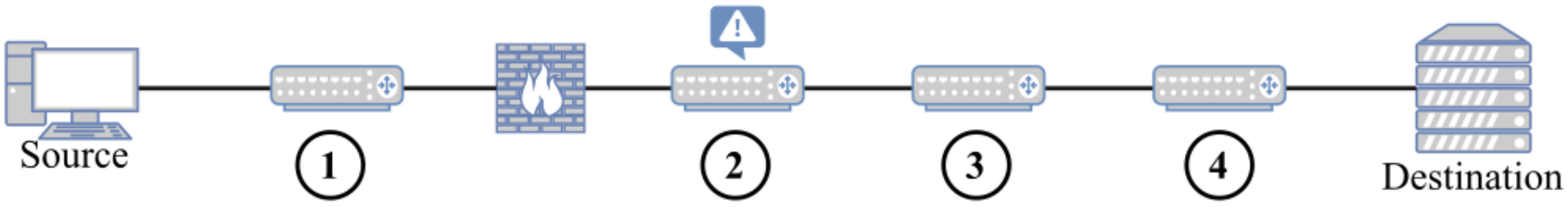


- **RFC 792** : “The internet header plus the first 64 bits”
- **RFC 1812** : “as much [...] as possible” (< 576 B)

Dataset

- 14 Campaigns, one every ~5 day over 70 days.
- From 89 nodes to 594,241 destinations, 9 ports.
- 948,457 responsive intermediate hops overall (59,861 HTTP-only).
- 2,978 ASs crossed.
- **0.5B probes**

tracebox



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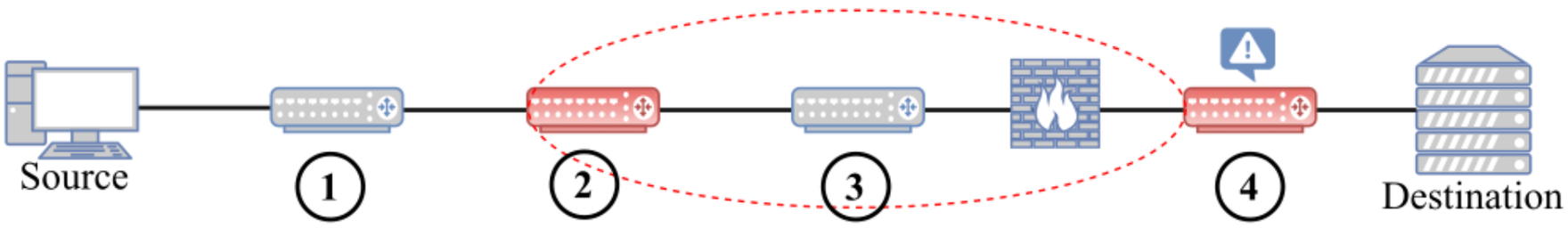

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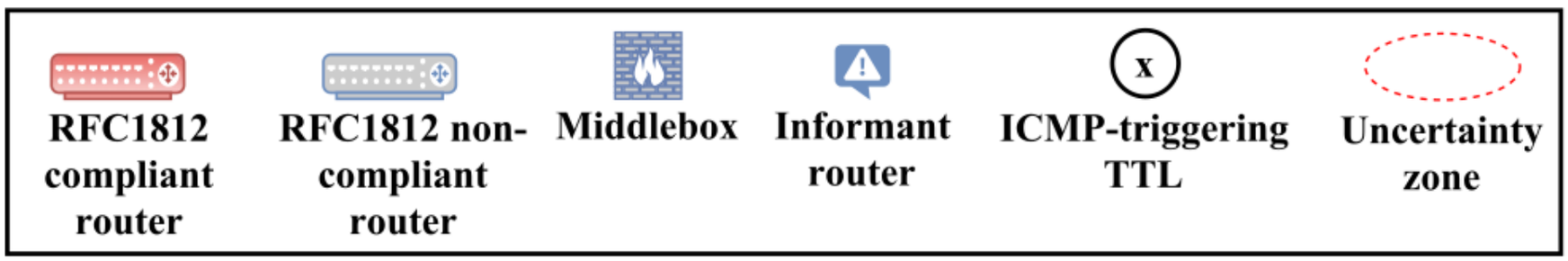
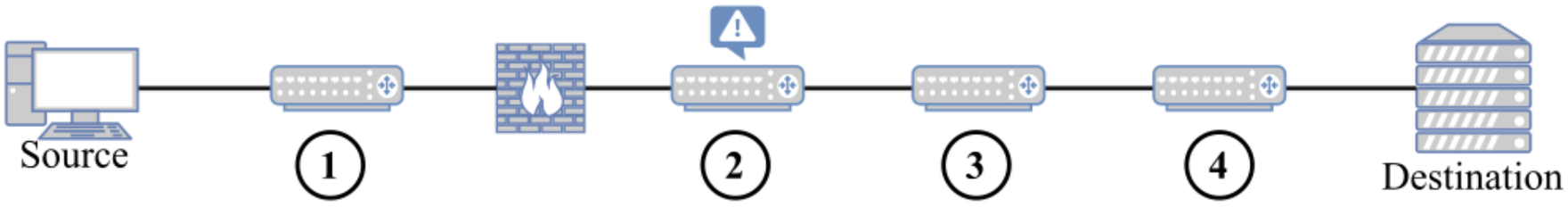


tracebox



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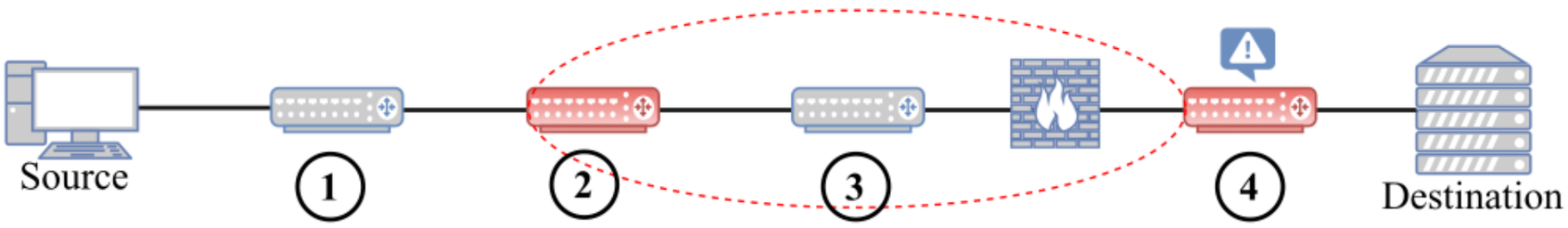

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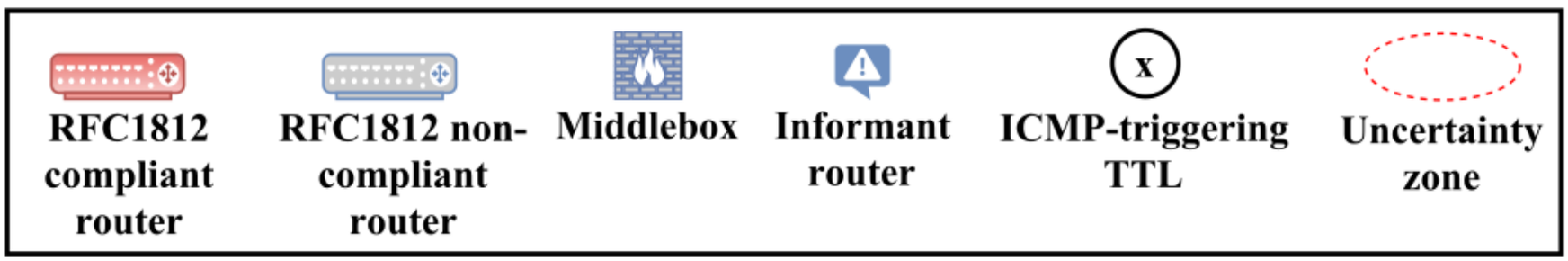
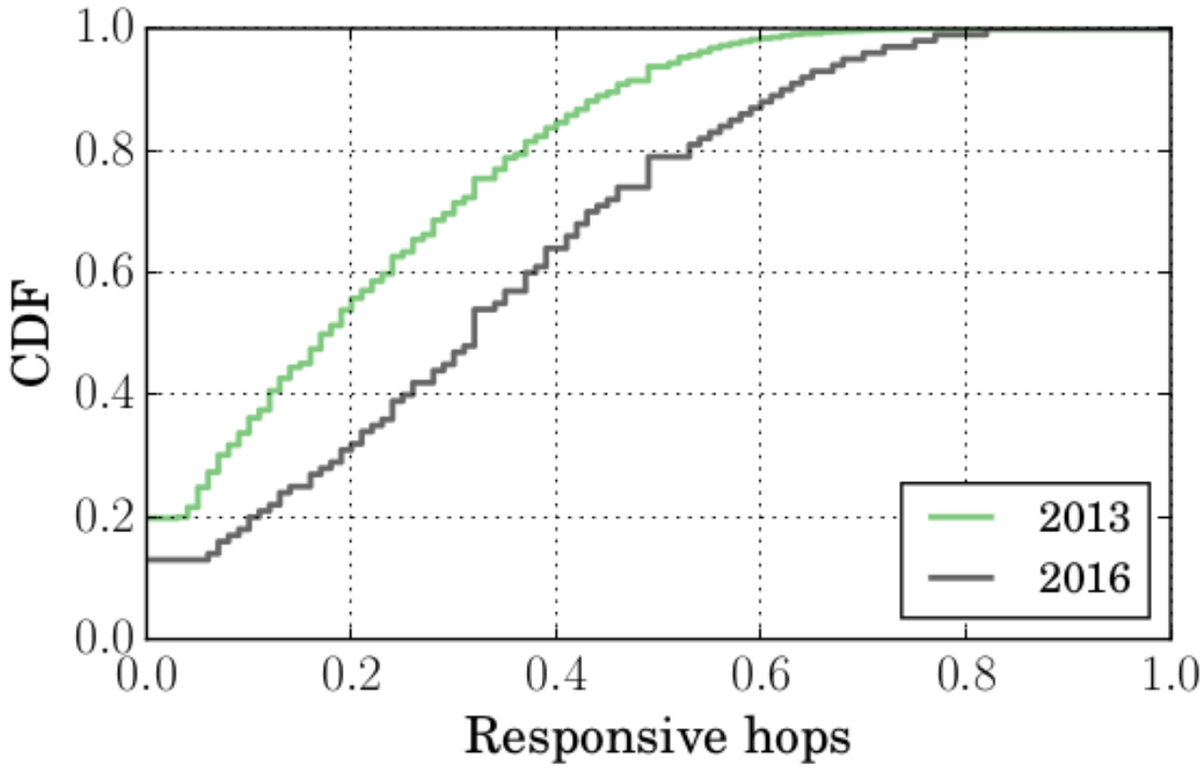
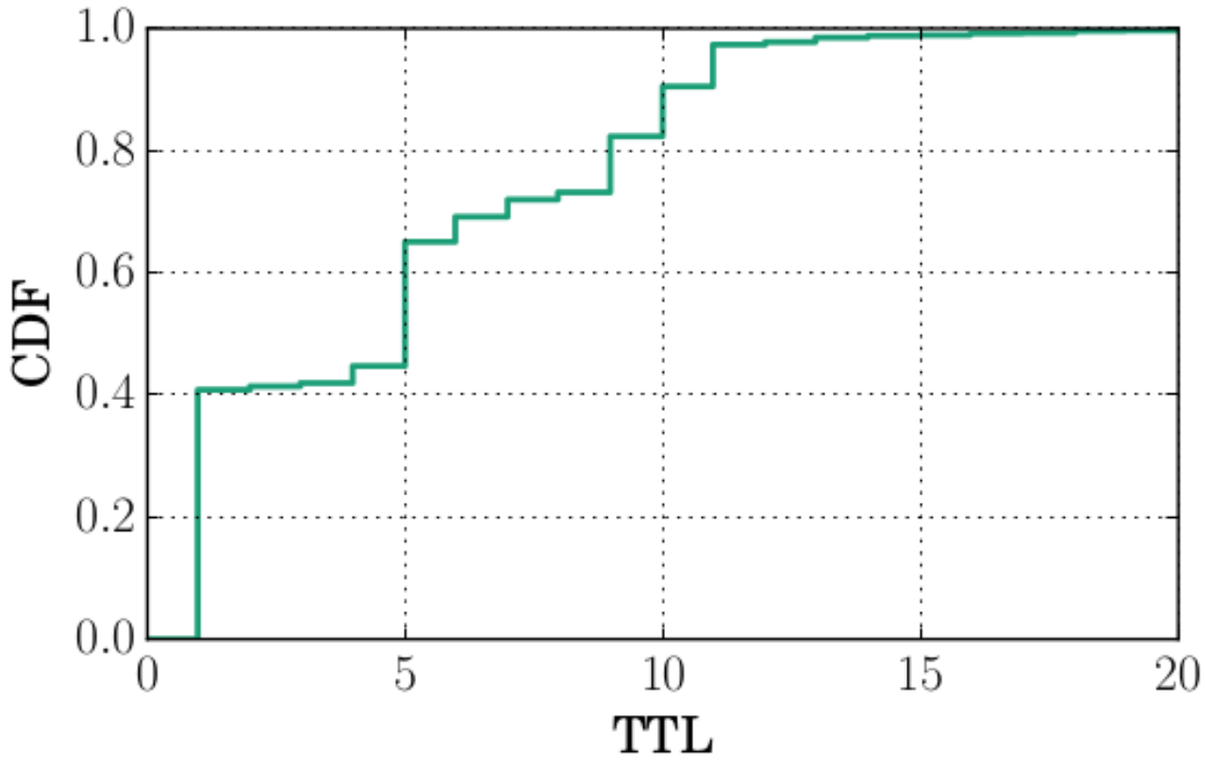


- **U Zone** : Observed sizes ? Workaround ?

Uncertainty Zone

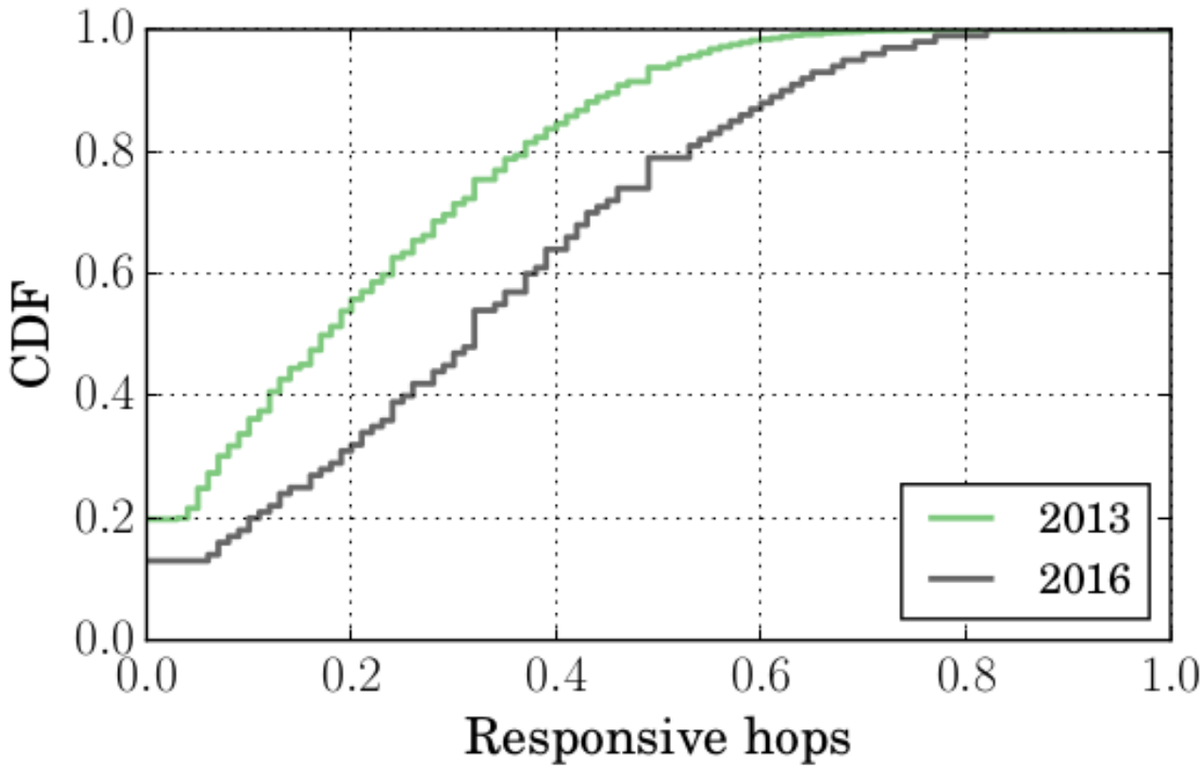


Proportion of RFC 1812 routers on observed paths



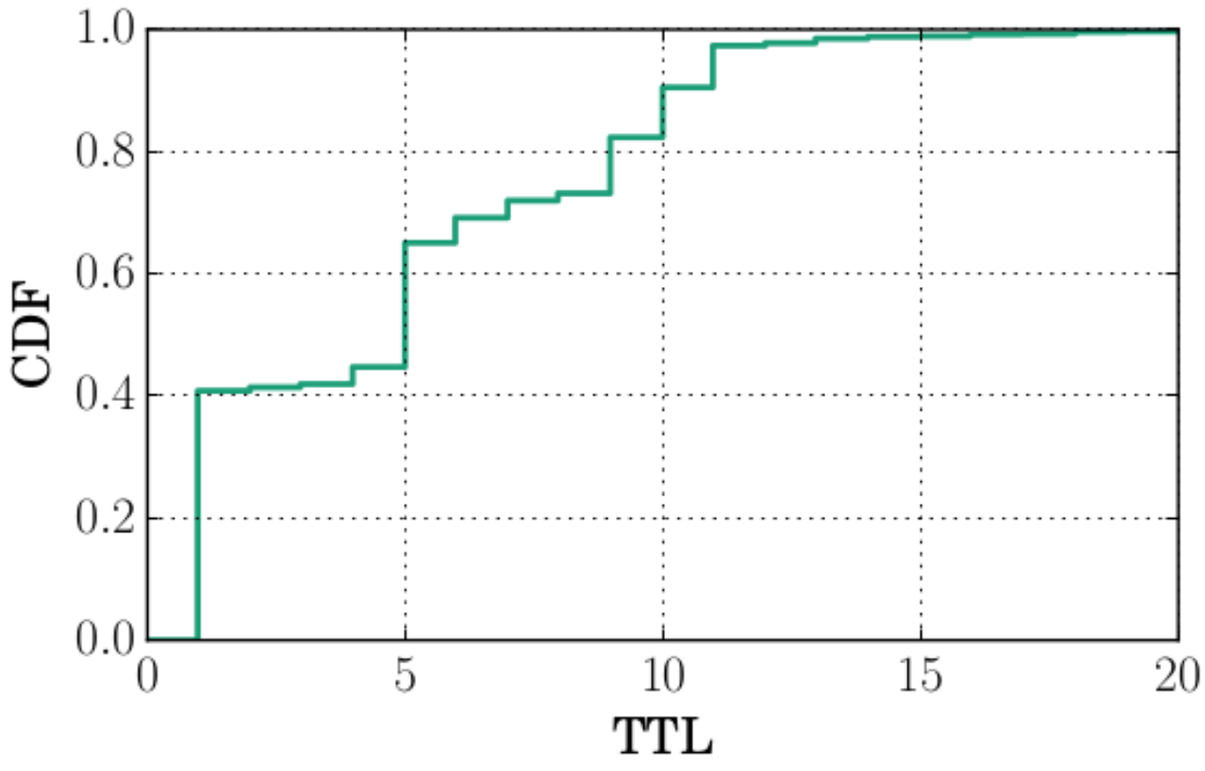
Sizes of U Zones

Uncertainty Zone



Proportion of RFC 1812 routers on observed paths

- *Increases over time*

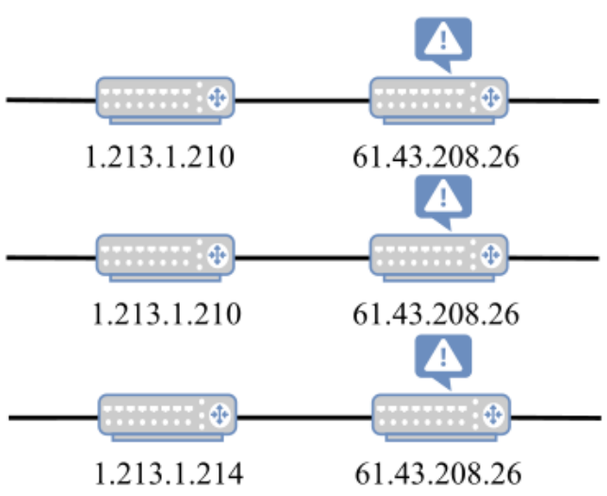


Sizes of U Zones

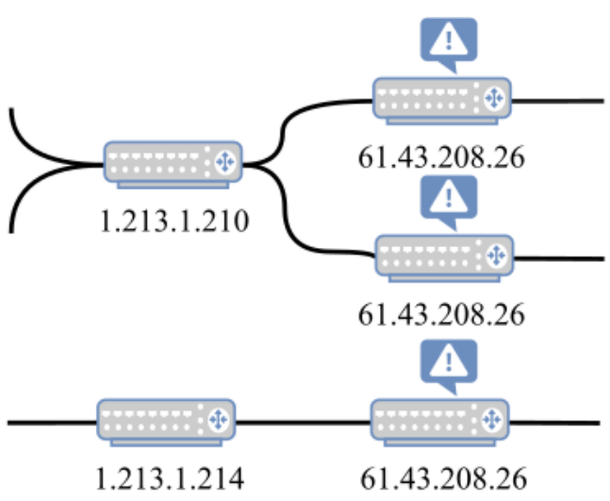
- None for 15.5M obs. (41%)
- ≤ 5 for 23M obs. (66%)

Pre-processing: Summary

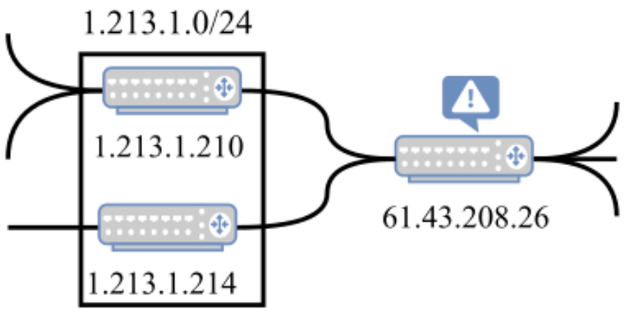
- Observation : *A single modification observed on a path during a campaign.*



a. Offenders derivation



b. Offenders grouping



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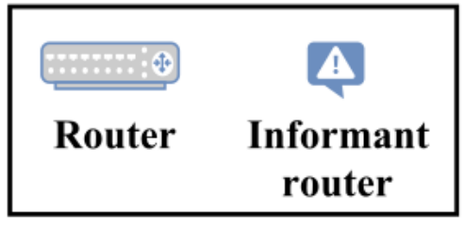


Input: 38M obs.

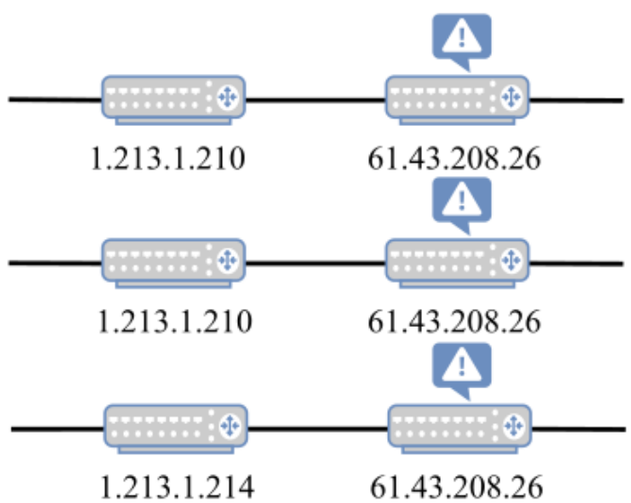
a. Label observations

b. Aggregate observations

c. Merge offenders into middleboxes

Output: 8K MBs

Pre-processing: derivation (Step 1)



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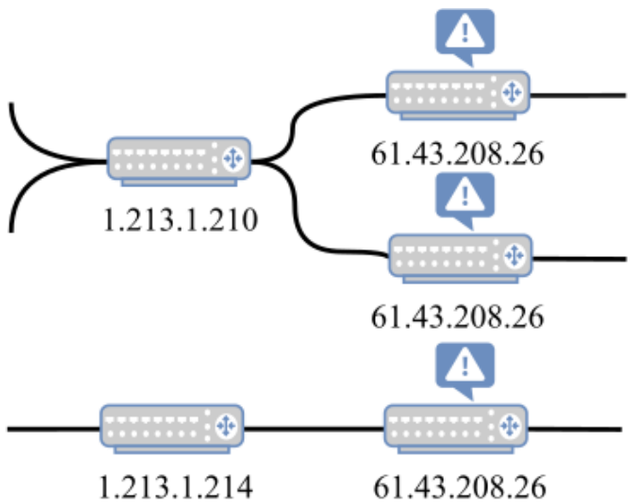

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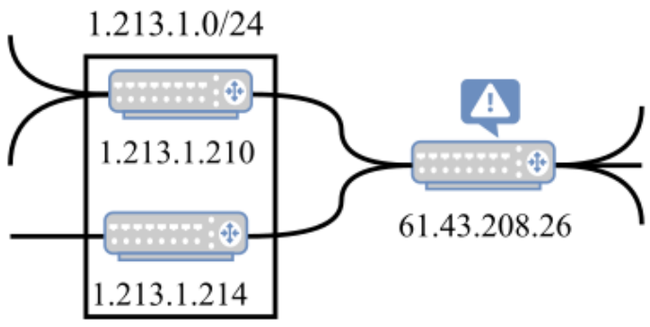

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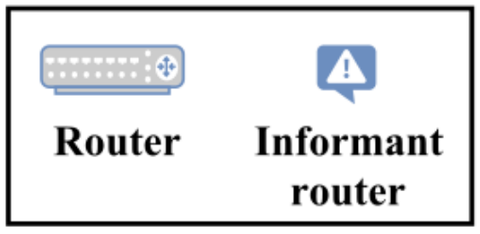

Pre-processing: derivation (Step 1)

- Offender : *The router preceding the middlebox on a given path*

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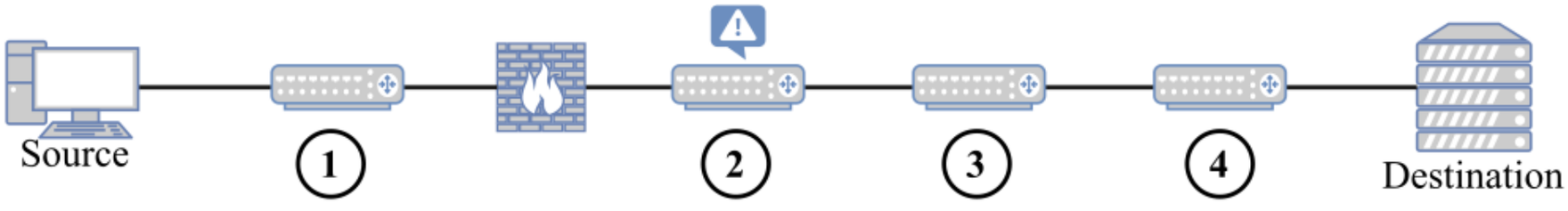

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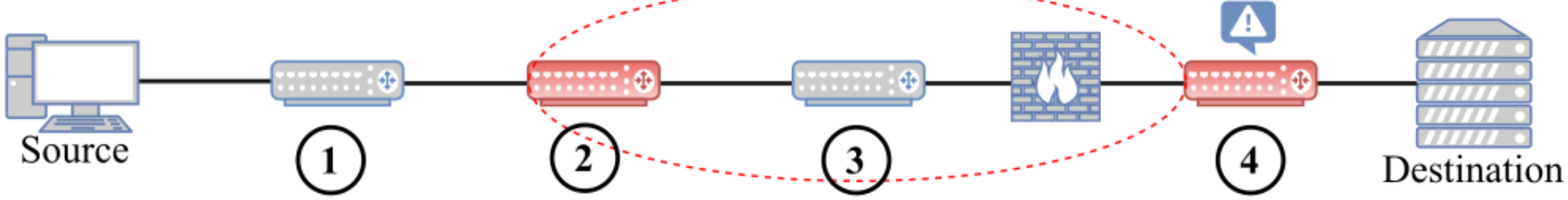

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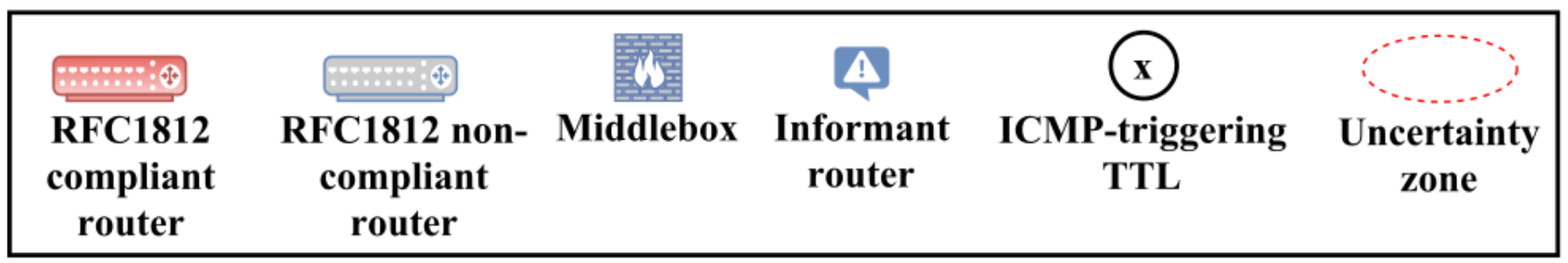

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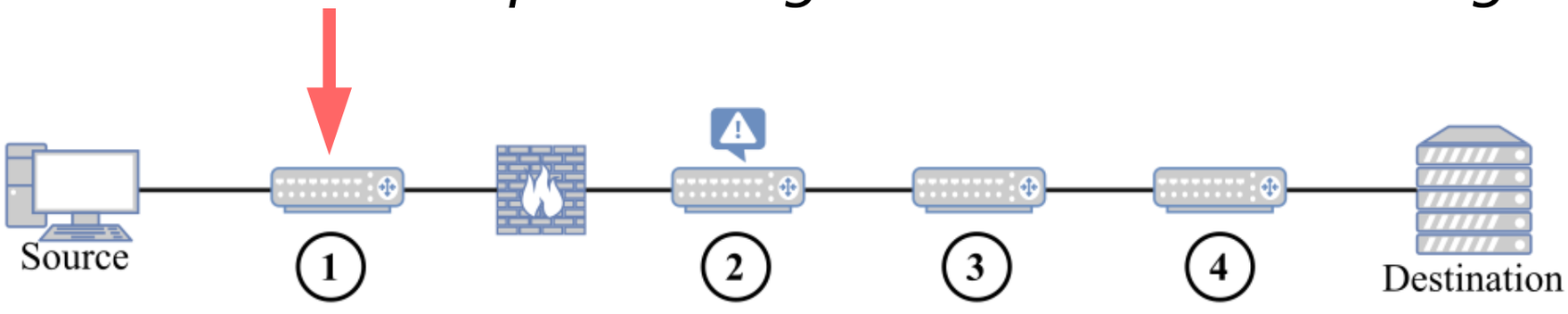

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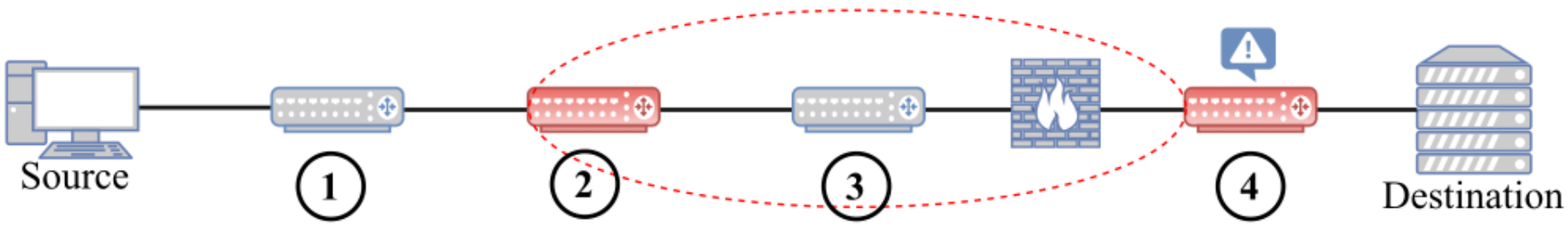

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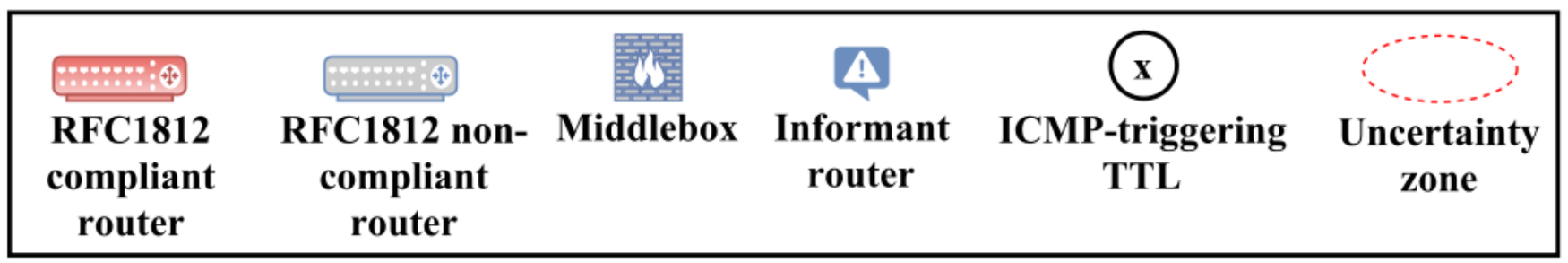

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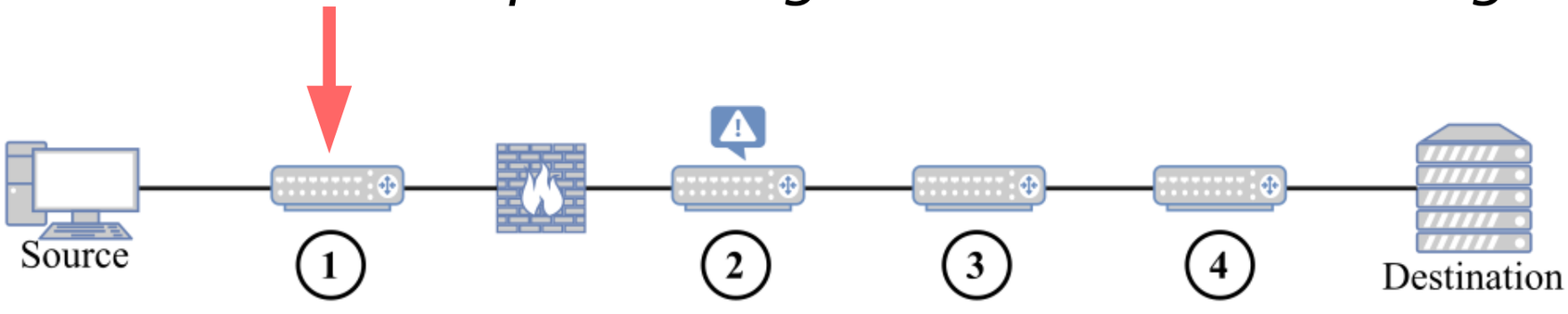

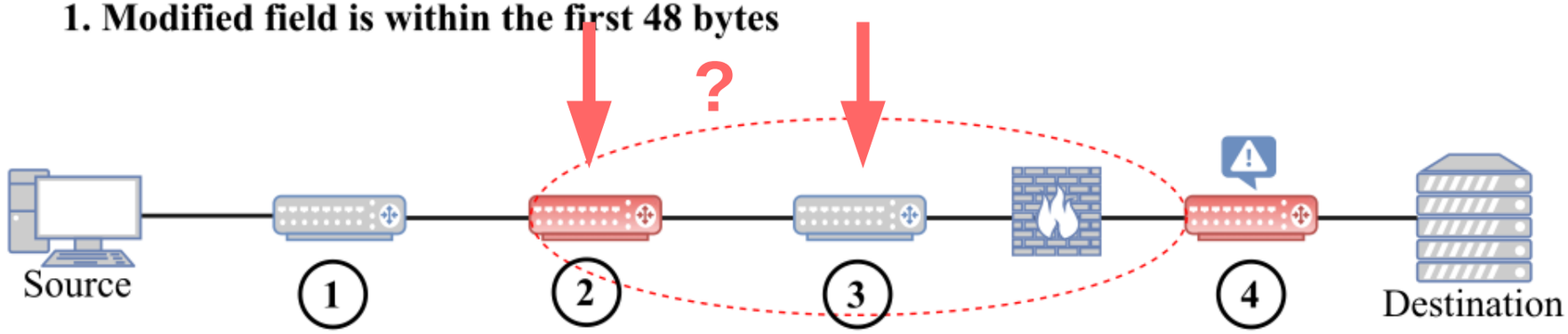

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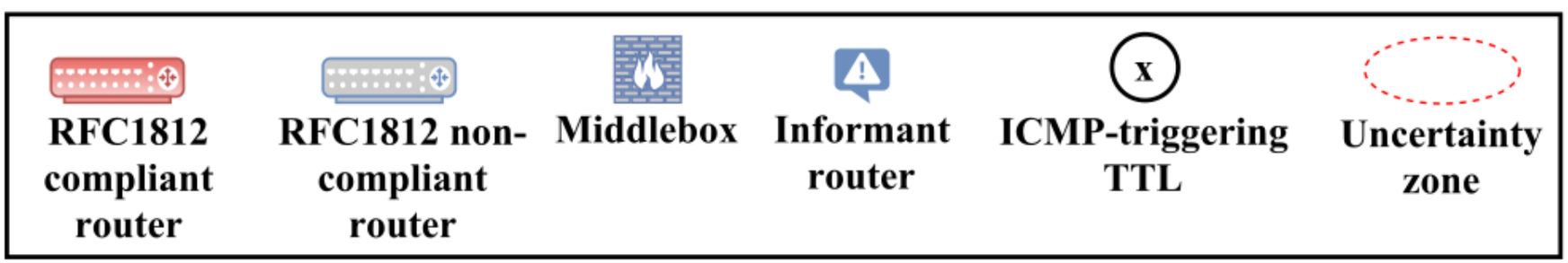

Pre-processing: derivation (Step 1)

```
def offender(probe):
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Pre-processing: derivation (Step 1)

def offender(probe):

- No U zone: the router that precedes the informant router
- U zone: Heuristics

Pre-processing: derivation (Step 1)

def offender(probe):

- No U zone: the router that precedes the informant router
- U zone: Heuristics

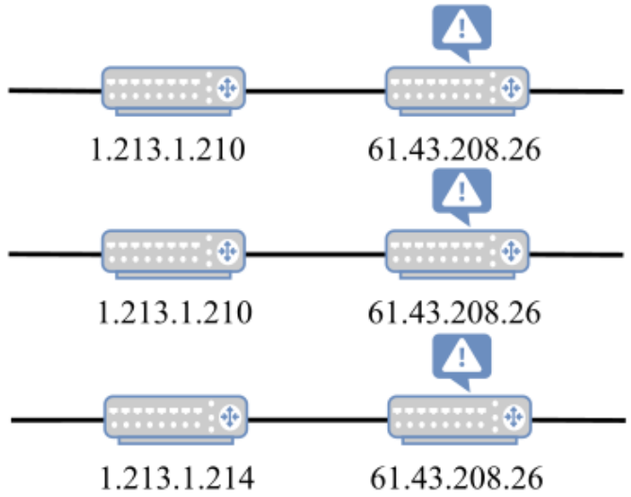
1. * at informant_TTL–1 : offender at informant_TTL-2
2. * at informant_TTL-2 : offender at informant_TTL-3
3. a)Major AS in U zone, b)If a router was used for labeling, pick it
4. First router of U zone (if used for labeling)

Pre-processing: derivation (Step 1)

Output:

- Offender AS for 99% obs.
- Offender IP for 52% obs. (20M)

Pre-processing: grouping (Step 2)



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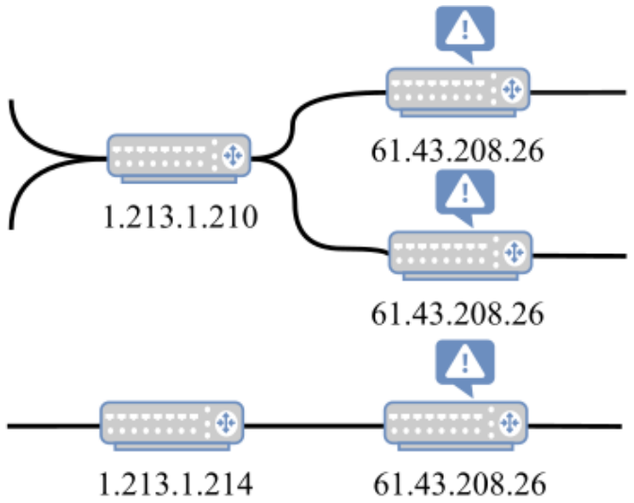

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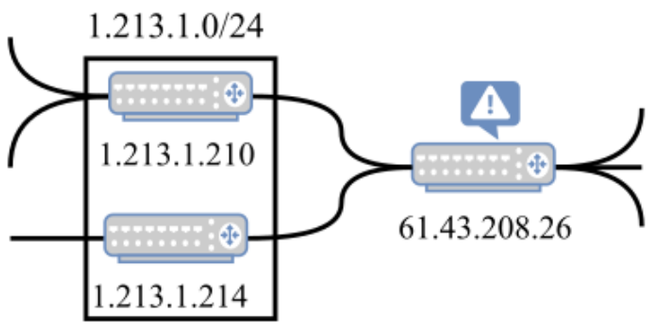

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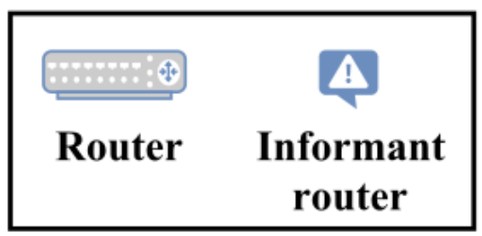


Pre-processing: grouping (Step 2)

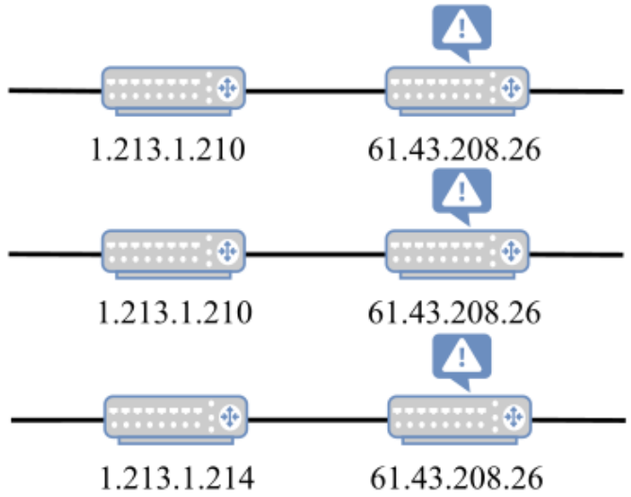
- MB profiles
- Cross-check heuristics: at least one trivial case or Heuristic#1 per offender
- 5% threshold:
  - inconsistent modifications: drop all obs.
  - inconsistent positions: mark as conflict

Pre-processing: grouping (Step 2)

Output:

- 8,322 offenders

Pre-processing: merging (Step 3)



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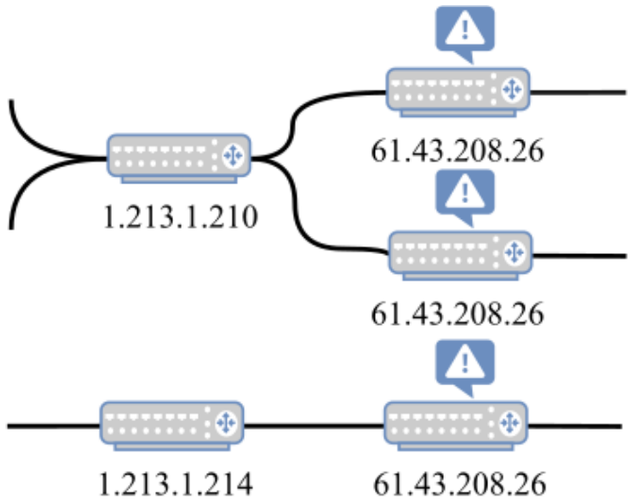

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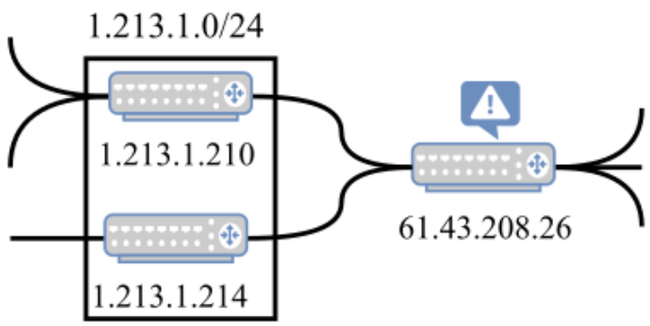

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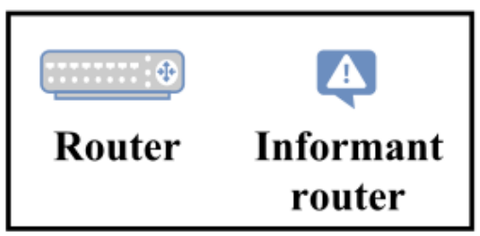

Pre-processing: merging (Step 3)

Merge offenders if:

1. Same subnet (/24)
2. Consistent modifications
3. Same set of next hops (offender_TTL+1)

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Merge offenders if:

1. Same subnet (/24)
2. Consistent modifications
3. Same set of next hops (offender_TTL+1)

- 505 merged into 198
- (7 cases of Multi-Origin AS Conflicts)

Pre-processing: merging (Step 3)

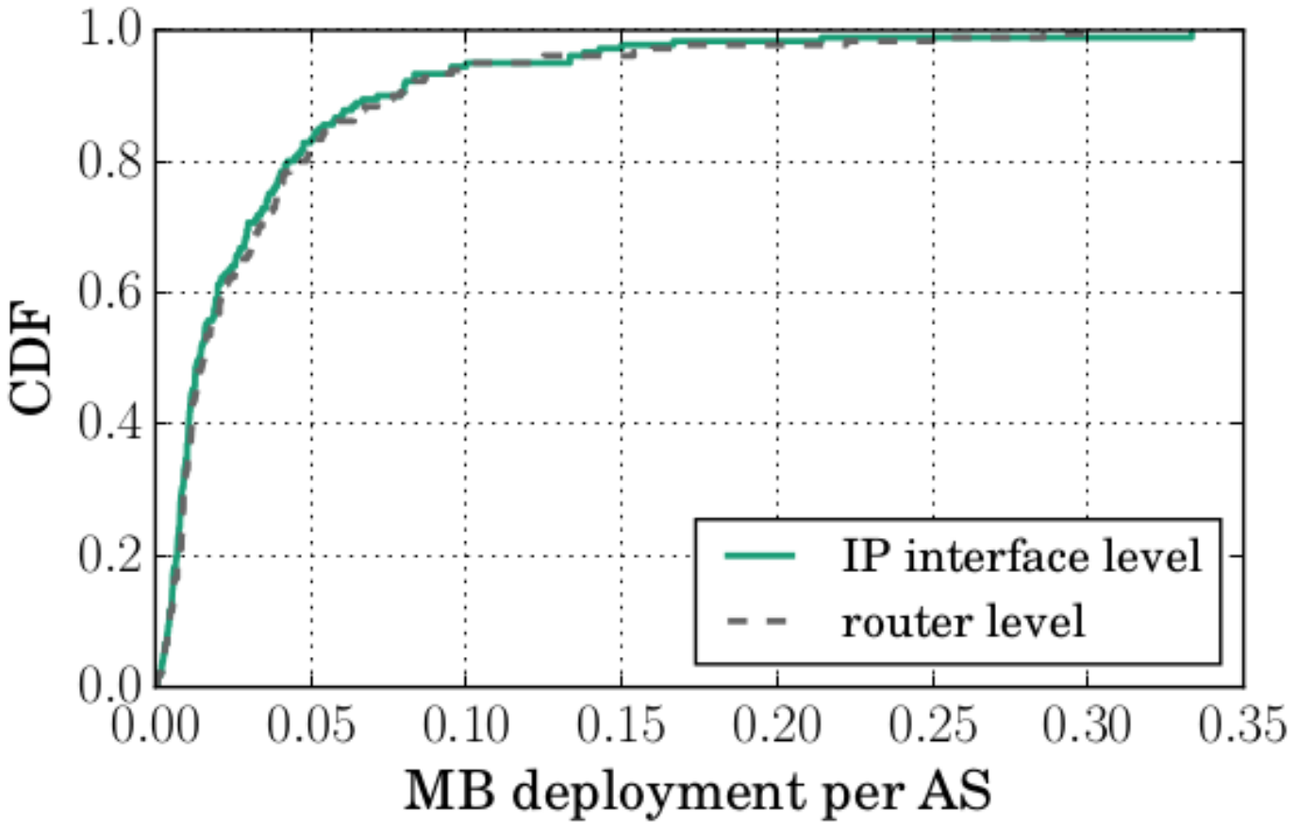
Output:

- 8,005 offenders

Results: prevalence

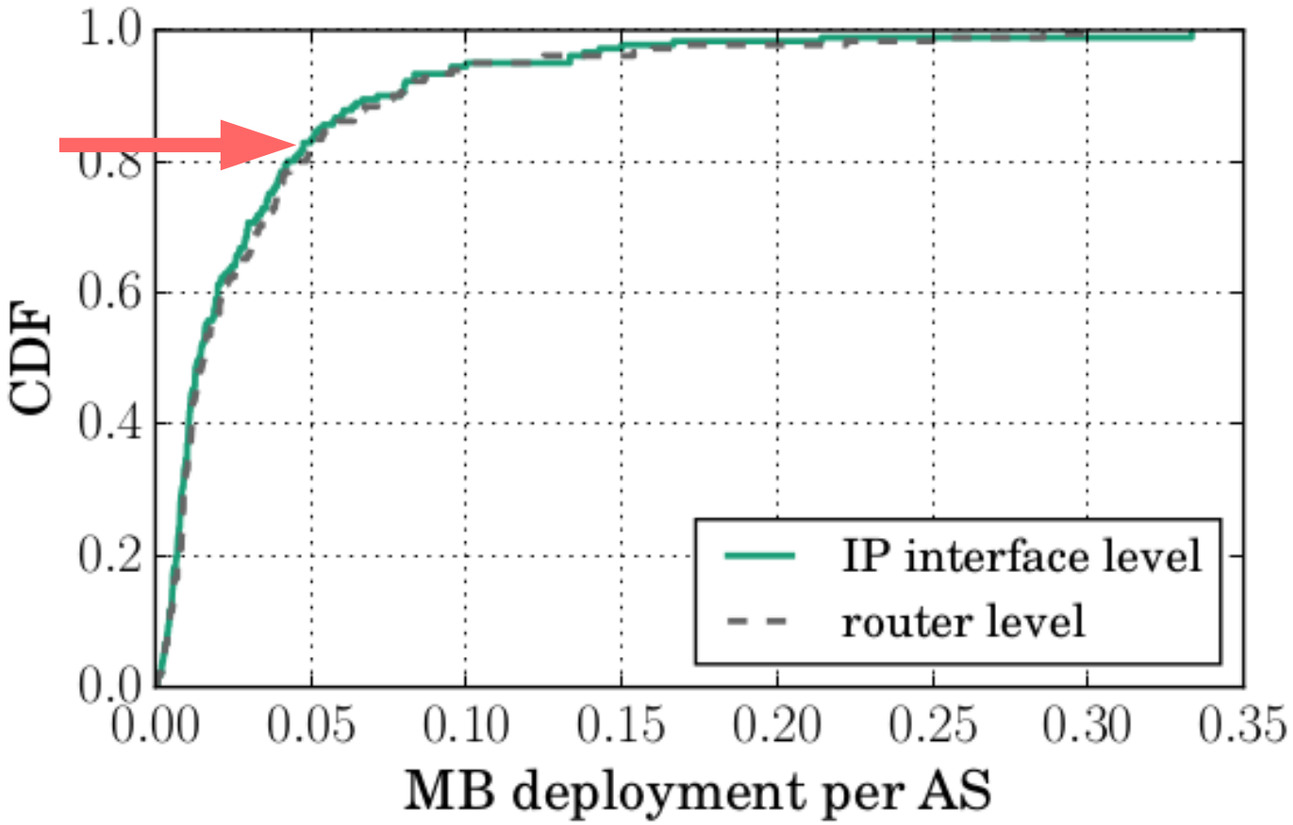
- *Deployment*: Proportion of MBs in AS
- *Popularity*: Paths affected by MB
- *Position*: Location of MB in AS topology

Prevalence: deployment



Deployed MB / IP interfaces, per AS. Alias resolution using CAIDA ITDK dataset.

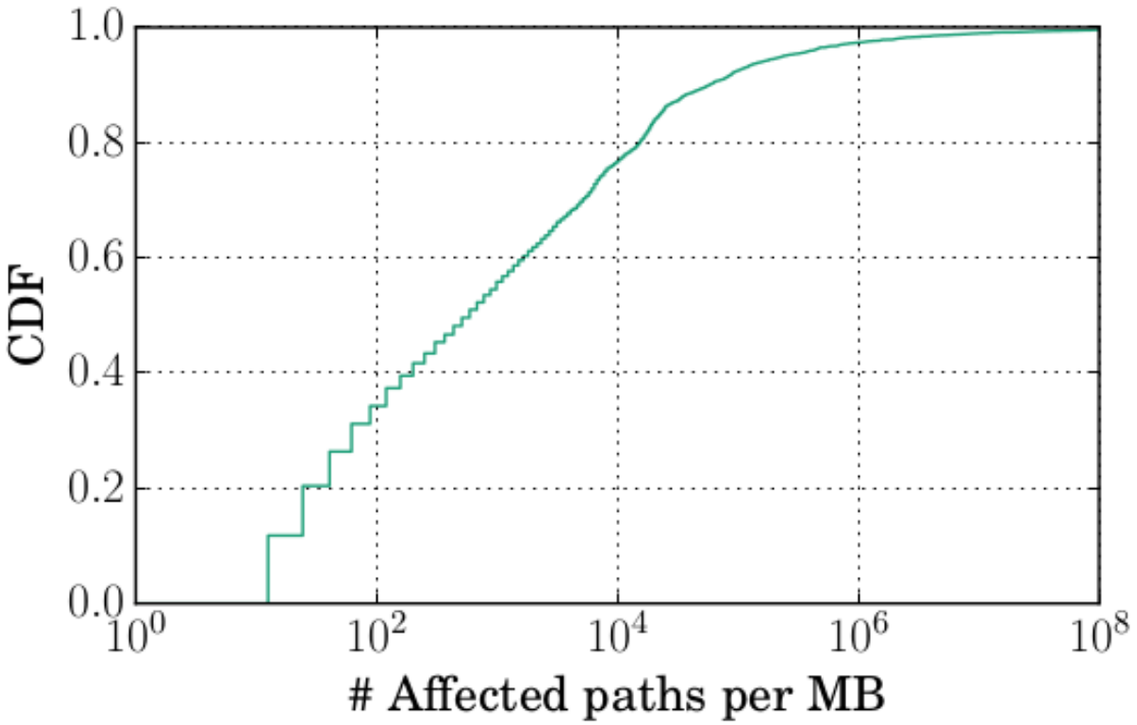
Prevalence: deployment



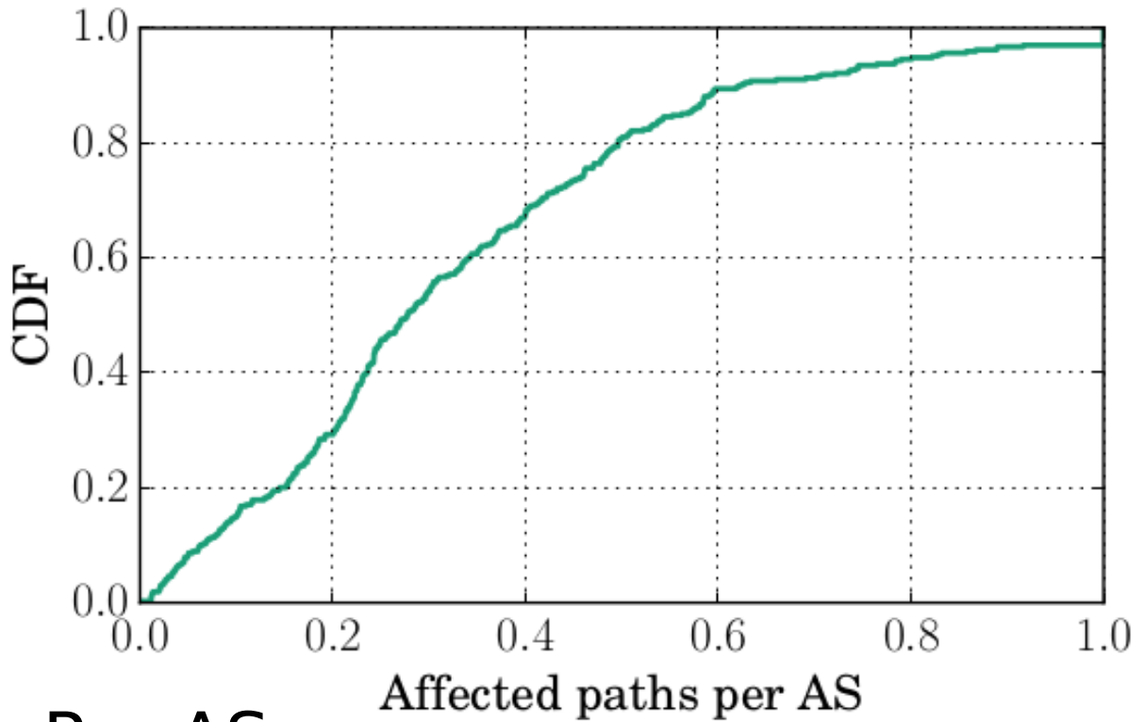
Deployed MB / IP interfaces, per AS. Alias resolution using CAIDA ITDK dataset.

- In general, less than 5%
- Cogent: 1.5%

Prevalence: popularity

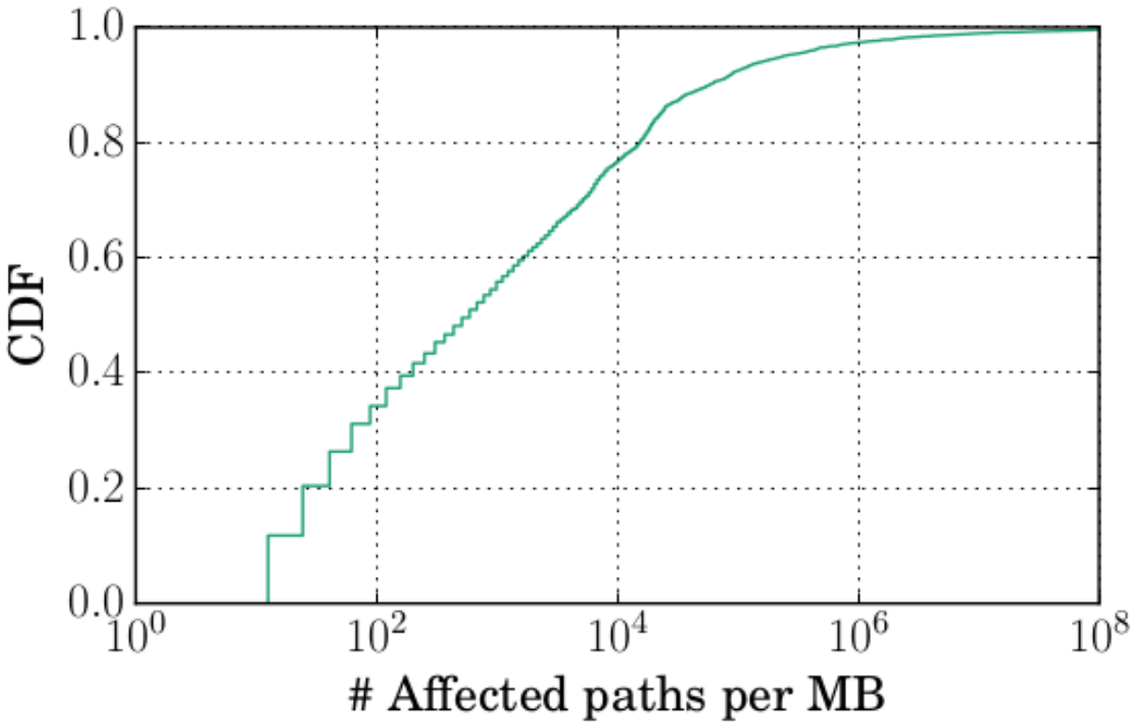


Per MB

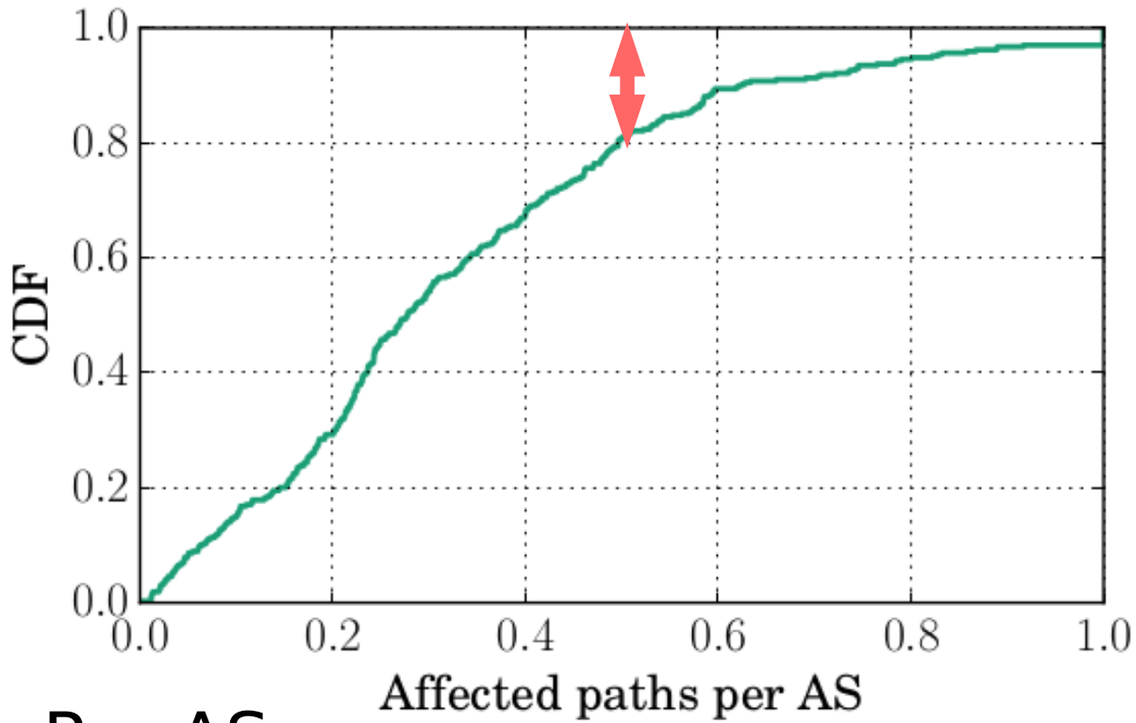


Per AS

Prevalence: popularity



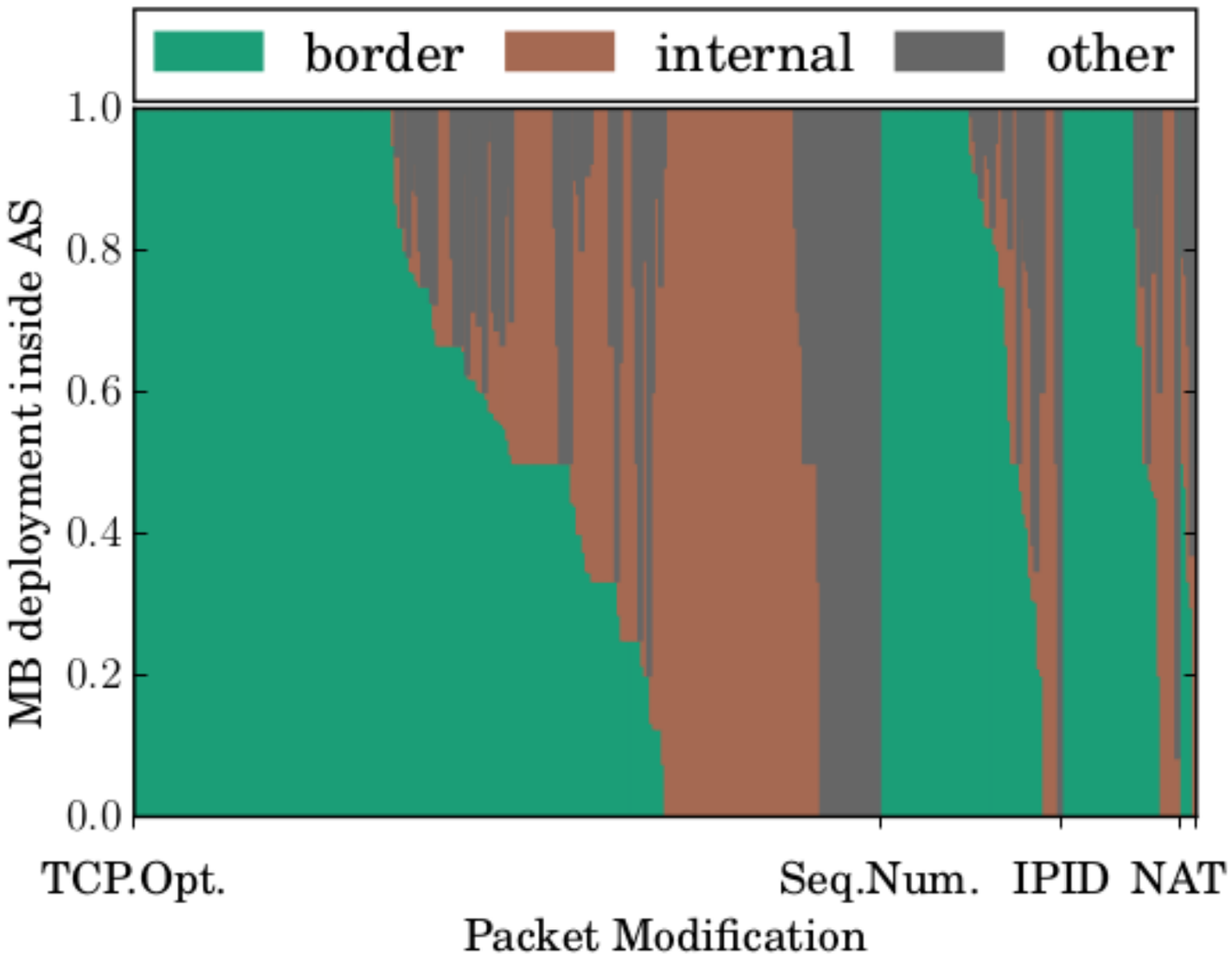
Per MB



Per AS

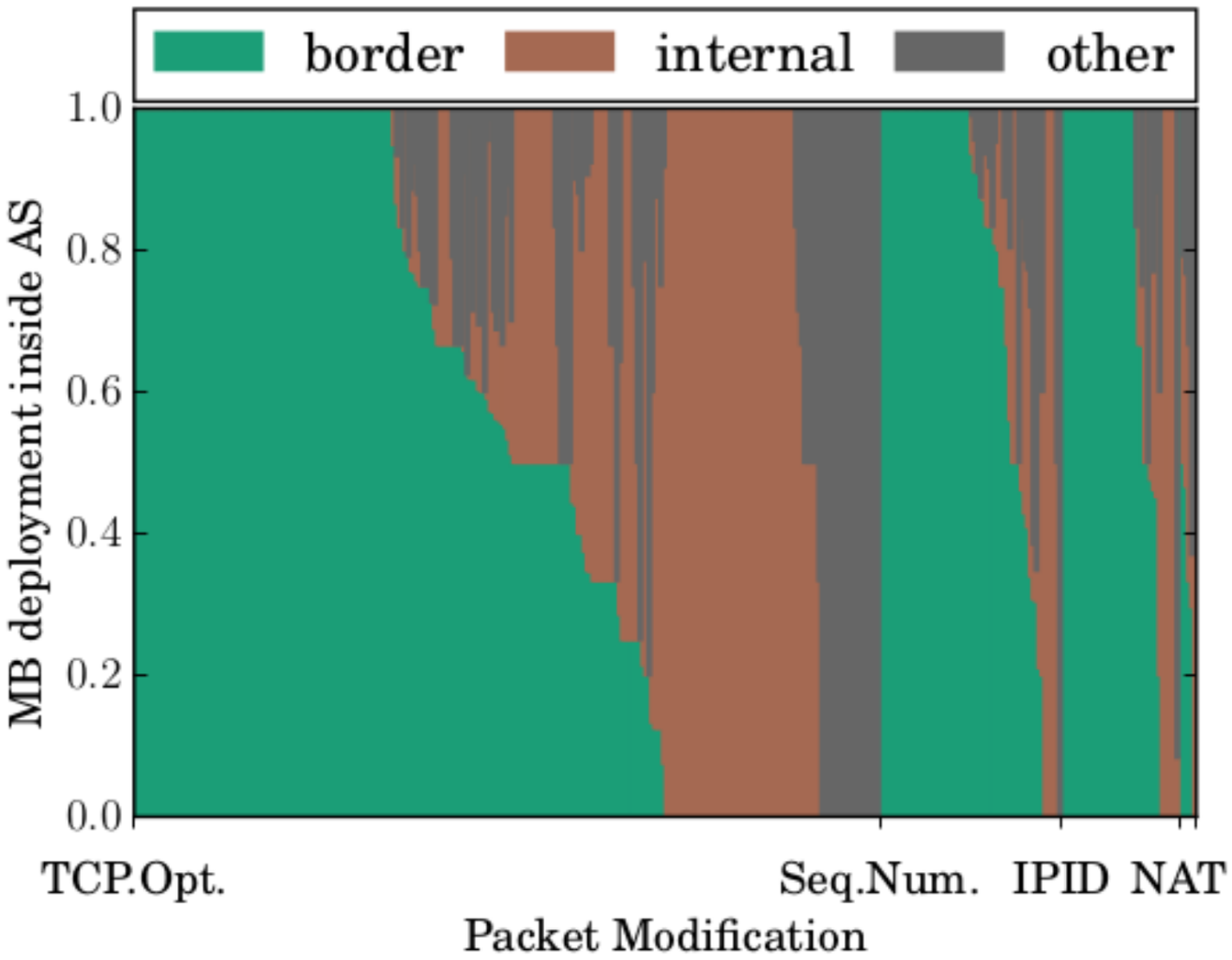
- For 20% of the ASes, more than 50% of paths crossing it are affected by 1+ MB(s)
- Cogent: 44M paths, 2.1M affected: 5%

Prevalence: position



MB Positions, per categories of modif., per AS

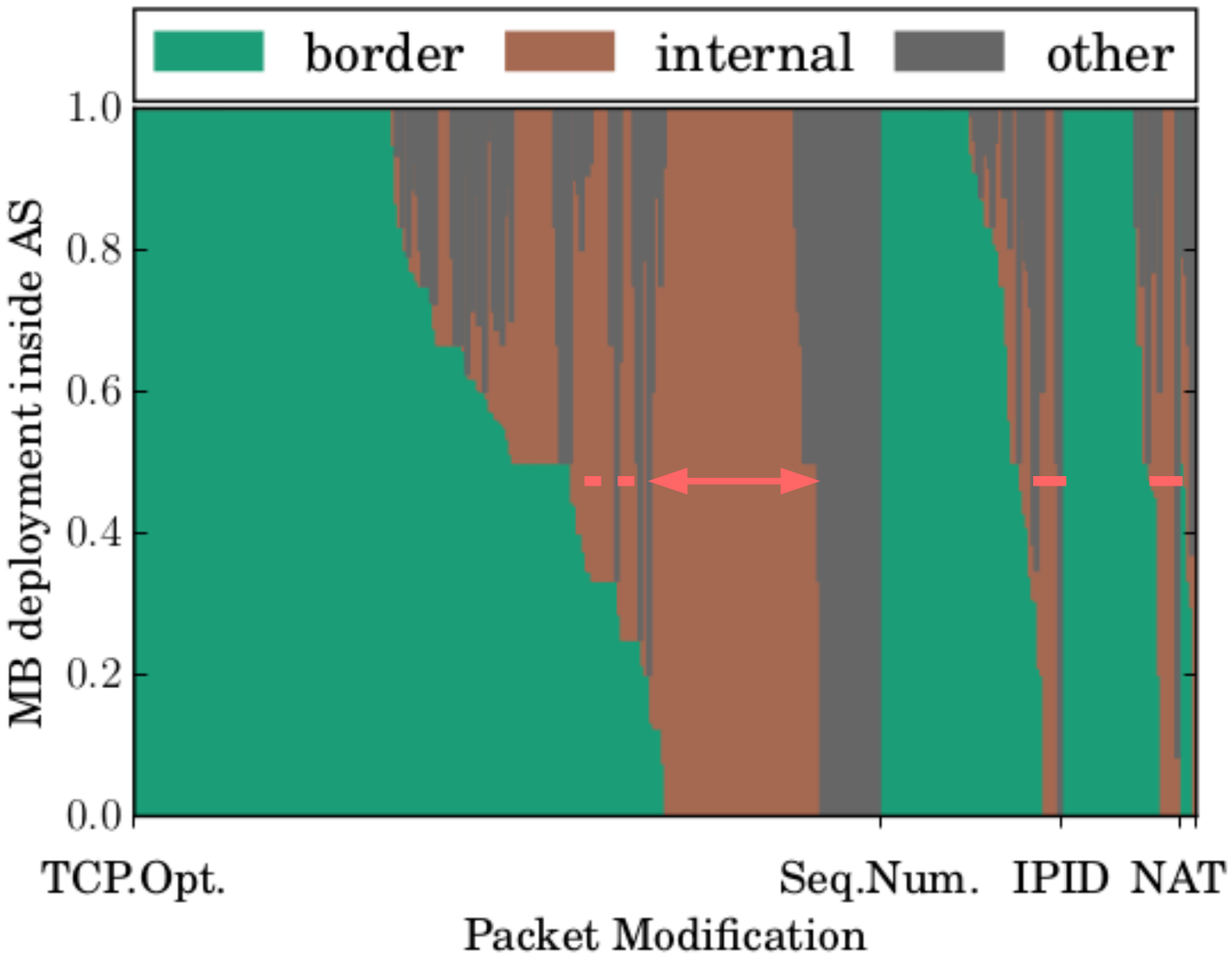
Prevalence: position



MB Positions, per categories of modif., per AS

- Border: 4,210 (52.6%)
- Internal: 2,931 (36.6%)
- Other: conflict or unable to derive position (9.1%), or moved ? (1.7%)

Prevalence: position



MB Positions, per categories of modif., per AS

- Border: 4,210 (52.6%)
- Internal: 2,931 (36.6%)
- Other: conflict or unable to derive position (9.1%), or moved ? (1.7%)

- At the exception of 65 ASes (19%) that deploys the majority of their MBs in their core, *ASes tend to deploy most of their MBs at their border*.

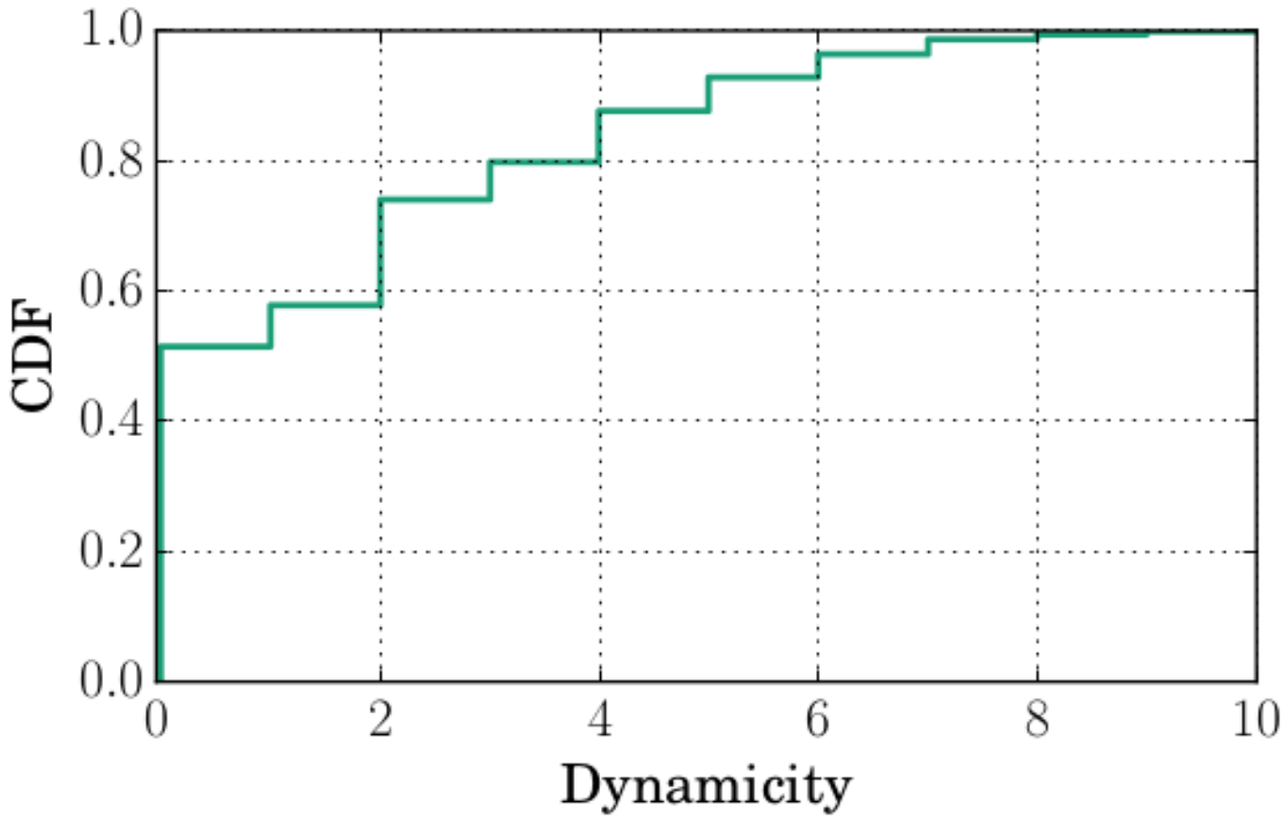
Results: persistence

Results: persistence

- Keep sub-paths visible with HTTP and non-HTTP probes
- 5,888 offenders

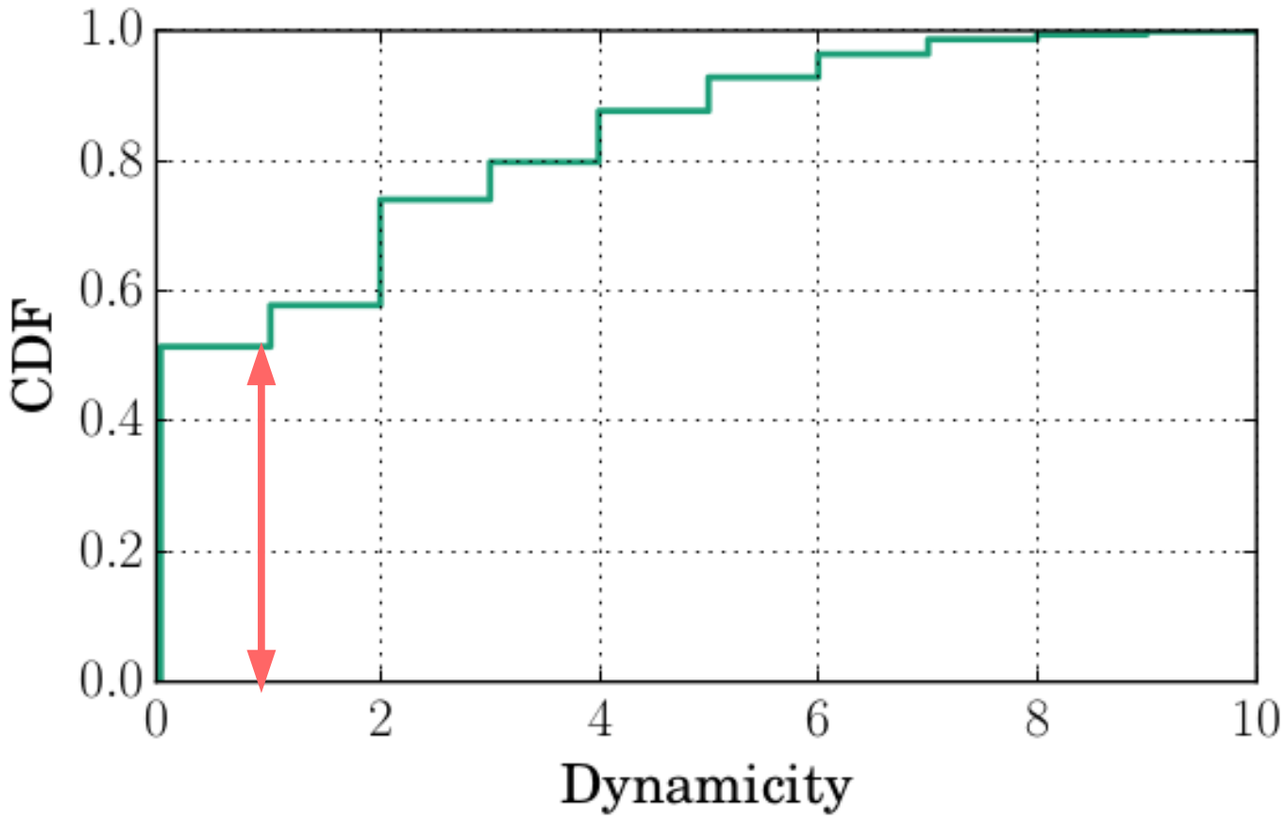
- Active: if it was used for labeling
- Inactive: if it was responsive, but not used for labeling
- Offline/invisible: it was not observed

Results: persistence



State changes per MB, Invisible == Active. 14 campaigns over 70 days.

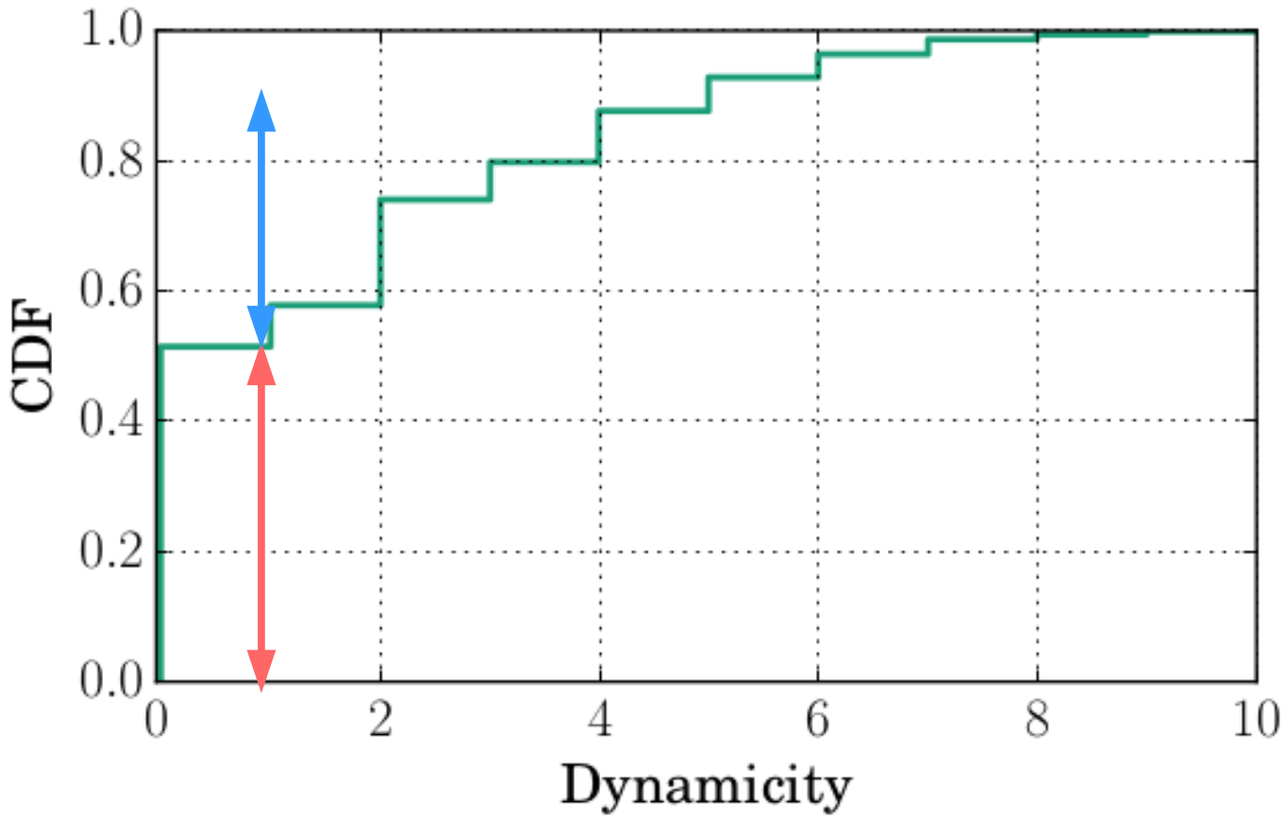
Results: persistence



State changes per MB, Invisible == Active. 14 campaigns over 70 days.

- 51% are stable

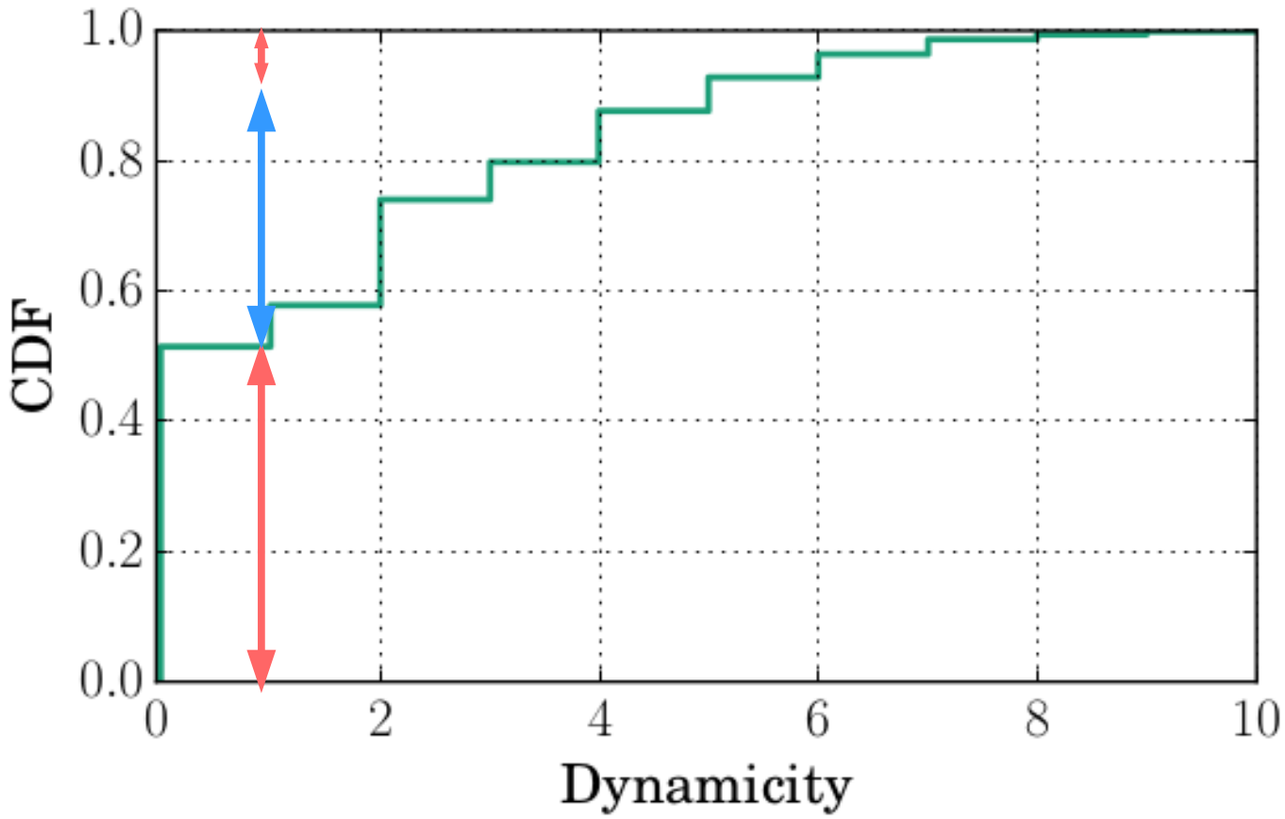
Results: persistence



State changes per MB, Invisible == Active. 14 campaigns over 70 days.

- 51% are stable
- 38% are slightly intermittent/dynamic ([1;4])

Results: persistence



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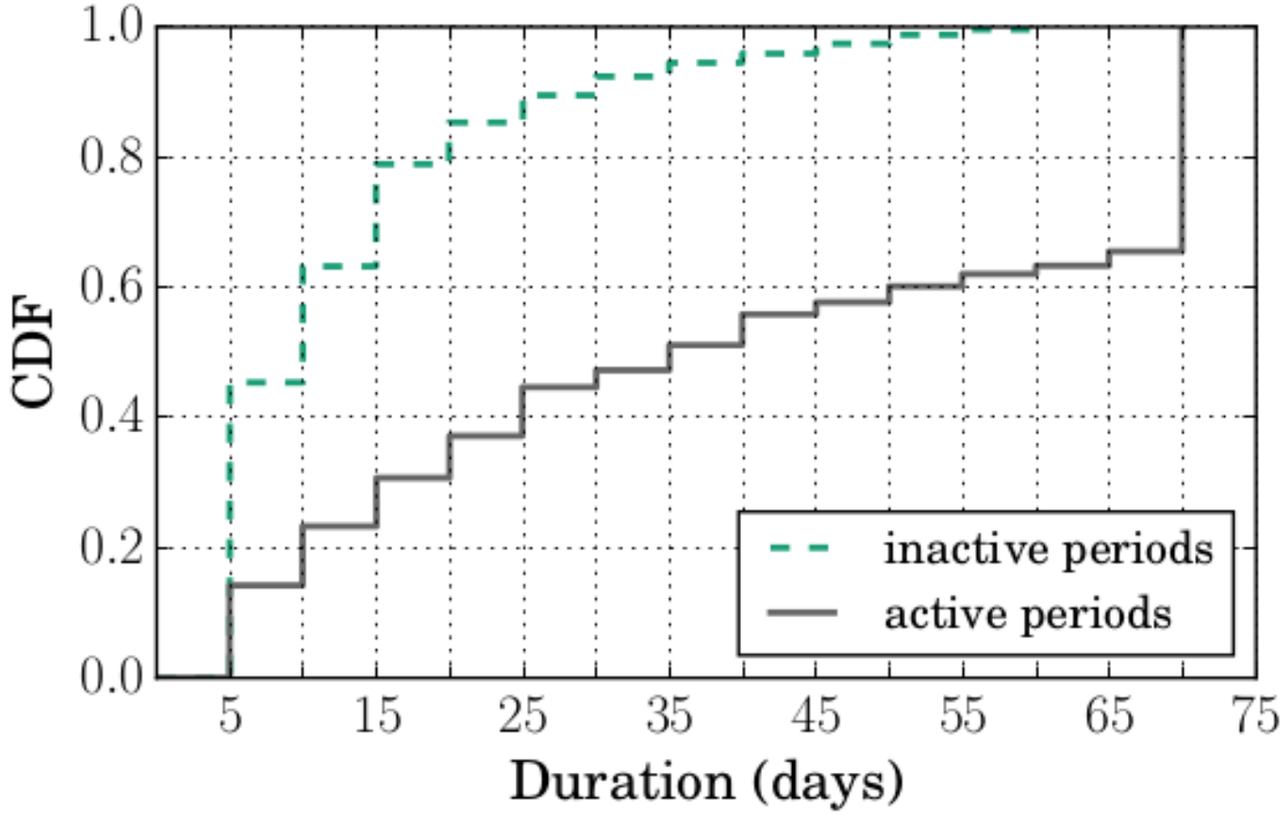
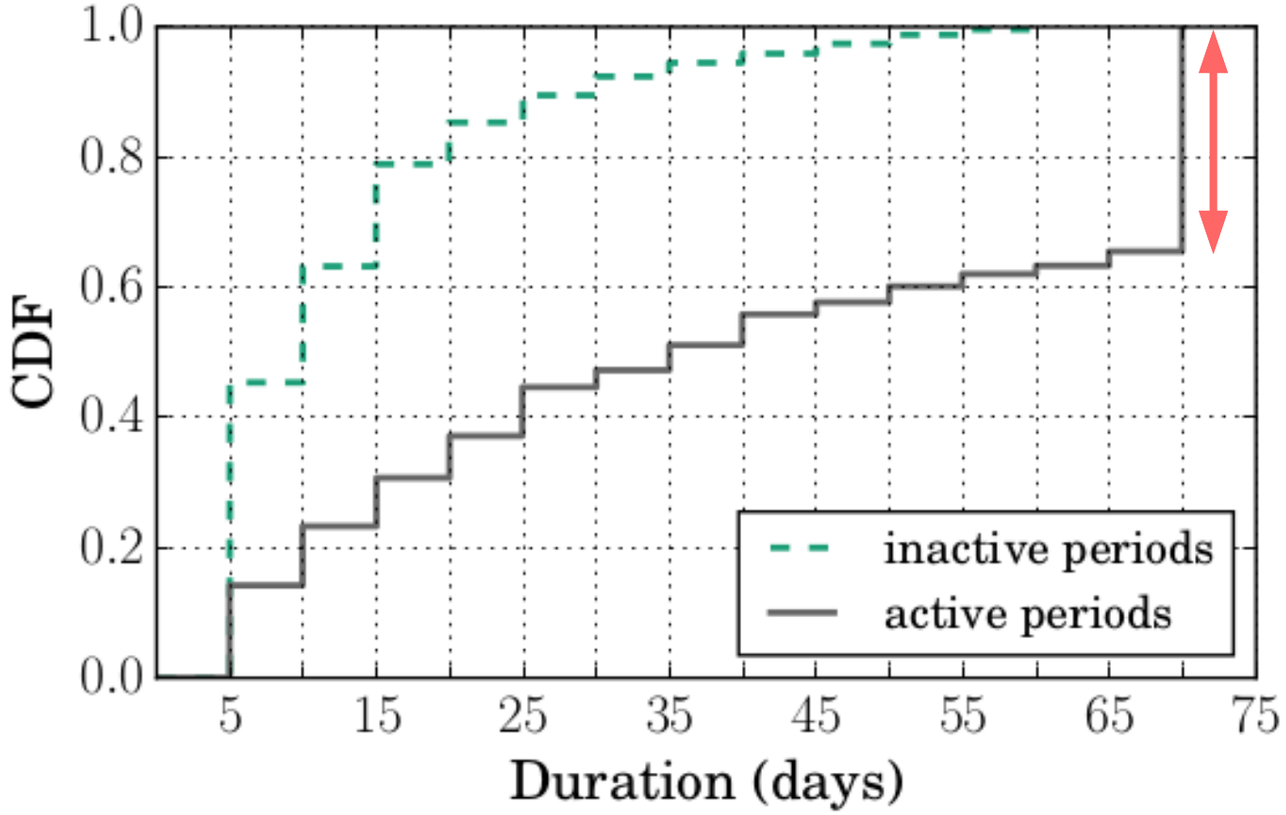
- 51% are stable
- 38% are slightly intermittent/dynamic ([1;4])
- 11% are highly intermittent ([5;10])

Results: persistence



State durations (max 70 days)

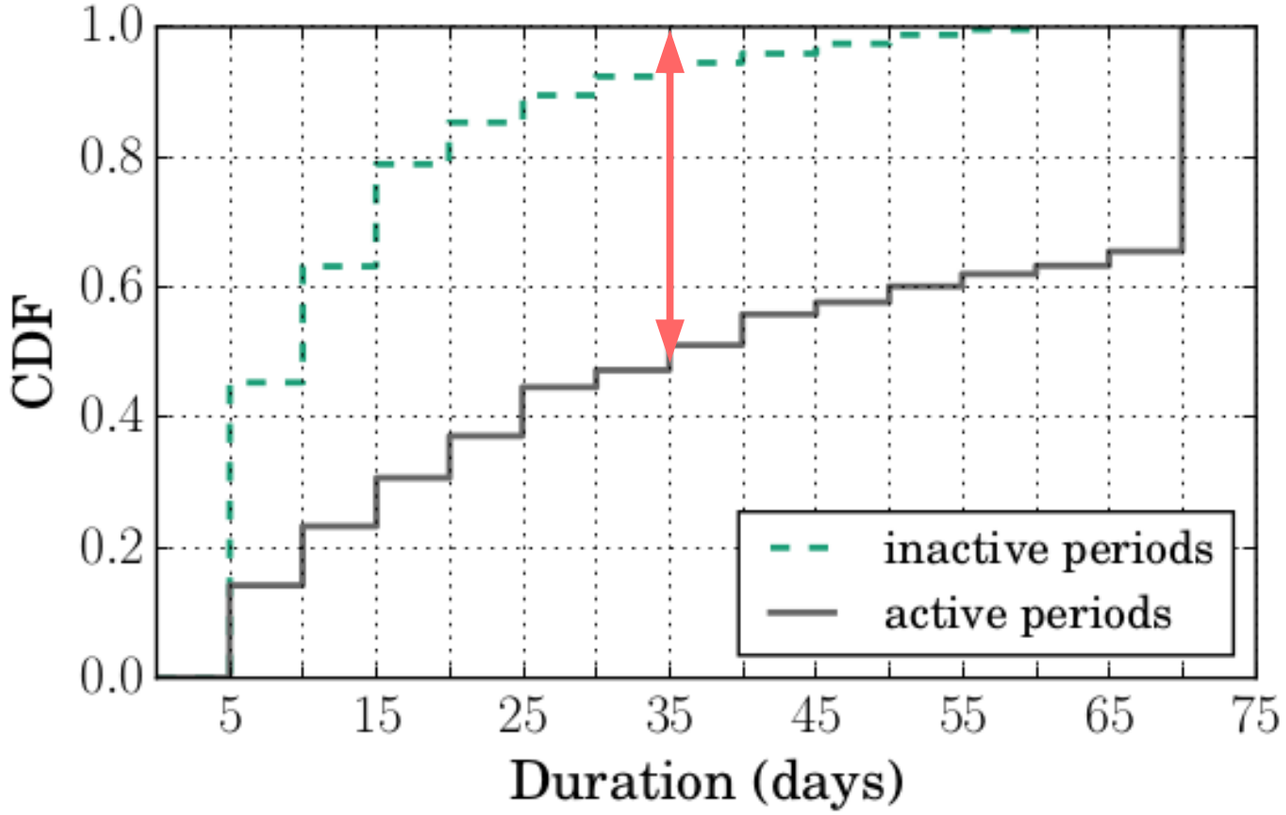
Results: persistence



State durations (max 70 days)

- 38% of periods are 70 days (the 51% stable MBs)

Results: persistence



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- 50% of active periods lasts more than 35 day

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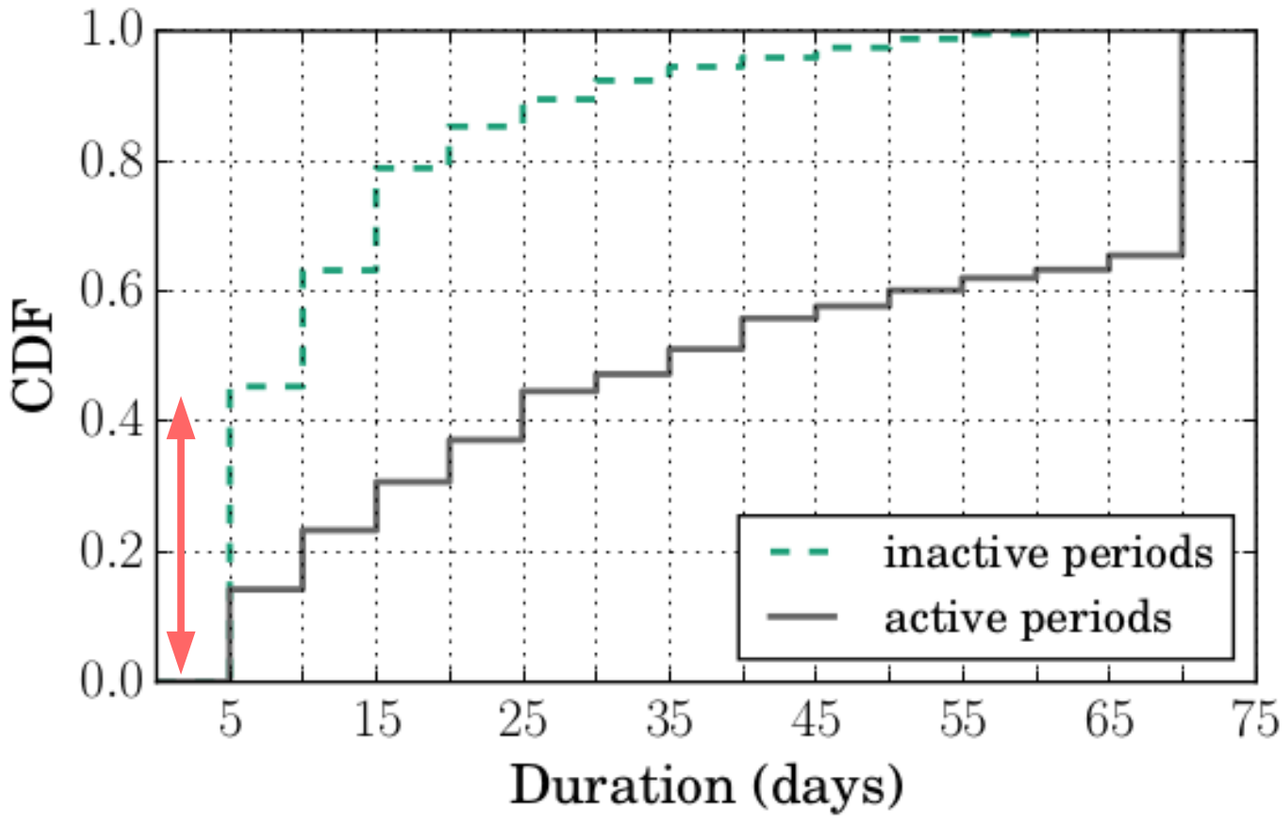

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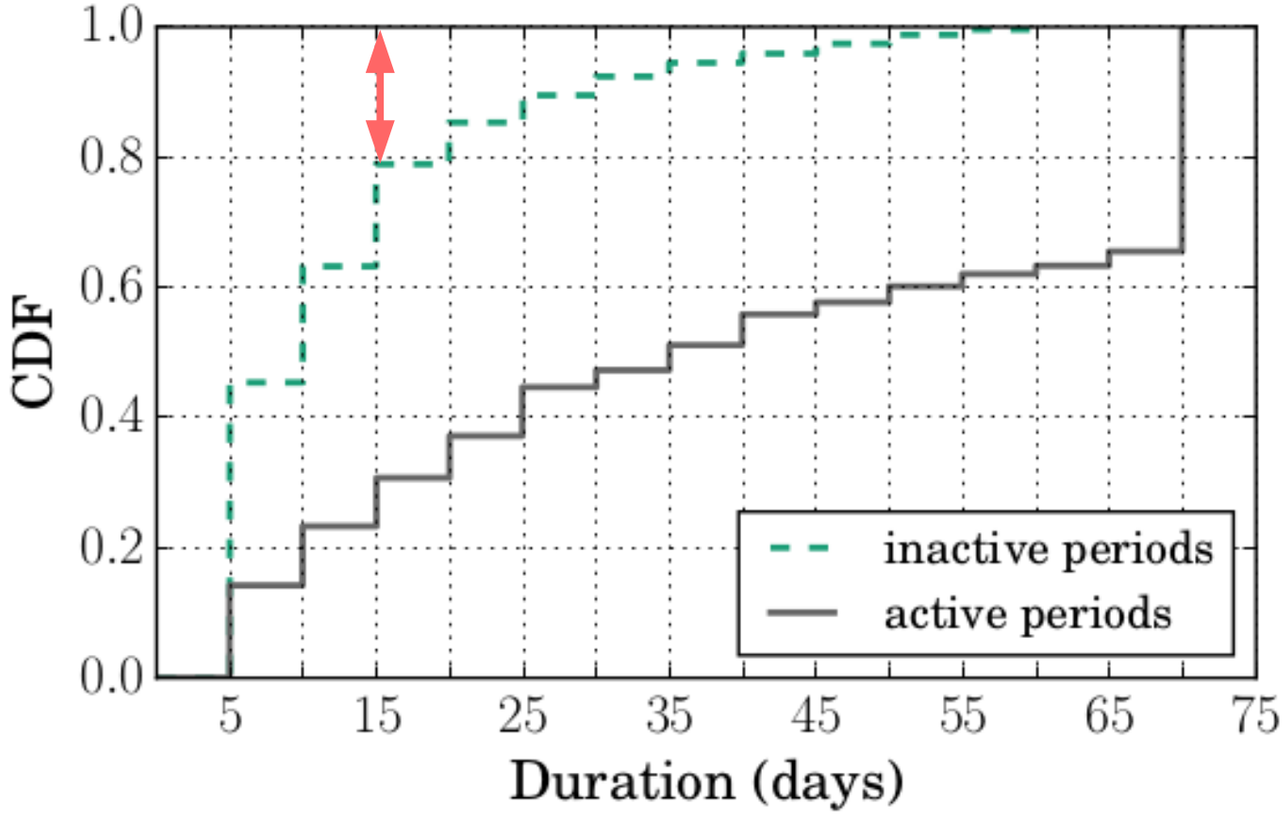
- 50% of active periods lasts more than 35 days
- 44% of inactive periods are short-lived (5 days)

Results: persistence



State durations (max 70 days)

- 38% of periods are 70 days (the 51% stable Mbs)
- 50% of active periods lasts more than 35 days
- 44% of inactive periods are short-lived (5 days)
- 20% are longer than 15 days

Summary

- MB deployment is marginal
- MBs don’t affect many paths crossing its AS
- A majority of MBs are deployed at AS borders
- MBs are relatively stable

Future works

- Investigate dynamicity
- NATs (Workshop on Mobile Network Measurement (MNM’17))

- IPv6

Questions ?

Future works: NAT trick (MNM)

- **RFC 792** : “The internet header plus the first 64 bits”
- **RFC 1812** : “as much [...] as possible” (< 576 B)

- **RFC 5508** : “Revert the IP and transport headers […] to their original form”
- **RFC 5508**: “SHOULD NOT validate the transport checksum”

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- **RFC 5508** : “Revert the IP and transport headers […] to their original form”
- **RFC 5508**: “SHOULD NOT validate the transport checksum”

- Correlation in transport checksums offsets == NATS ?

Example

```
ko@node1:~/$ scamper -c "tracebox -v -t -p IP/TCP/SACKP/MSS(1460)" -i 208.97.177.124
tracebox standard mode from node1 to 208.97.177.124
 result: success
  1: 78.129.127.21     (28/40) IP::TTL(01) IP::Checksum(7746)
  2: 212.68.211.181    (28/40) IP::TTL(01) IP::Checksum(7746)
  3: 149.6.135.65      (40/40) TCP::Checksum(424f) IP::TTL(01) IP::Checksum(7746)
  4: 154.54.59.57      (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
  5: 154.54.74.94      (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
  6: 130.117.14.178    (28/40) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
  7: 64.125.21.77      (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
  8: 64.125.27.0       (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
  9: 64.125.29.17      (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
 10: 64.125.29.131     (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
 11: 64.125.29.229     (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
 12: 64.125.30.249     (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
 13: 64.125.31.42      (40/40) TCP::Checksum(424f) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
 14: 208.185.23.134    (40/40) TCP::Checksum(c5d9) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
TCP::Options::MSS(0204058c)
 15: 208.113.156.4     (28/40) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
 16: 208.113.156.14    (28/40) IP::DiffServicesCP(0a) IP::TTL(01) IP::Checksum(771e)
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8: 64.125.27.0
9: 64.125.29.17
10: 64.125.29.131
11: 64.125.29.229
12: 64.125.30.249
13: **64.125.31.**42 (40/40)
14: **208.185.23.134** (40/40)TCP:MSS(0204058c)
15: 208.113.156.4
16: 208.113.156.14
17: 208.97.177.124

ko@node2:~$
1: 139.165.222.1
2: 193.190.228.29
3: 193.190.228.141
4: 193.190.252.97
5: 193.190.252.43
6: 193.190.200.28
7: 193.190.200.34
8: 193.191.10.19
9: *
10: 80.249.208.122
11: 64.125.21.77
12: 64.125.27.0
13: 64.125.29.17
14: 64.125.29.131
15: 64.125.29.229
16: 64.125.30.249
17: **64.125.31.**42 (40/40)
18: **208.185.23.134** (40/40) TCP:MSS(0204058c)
19: 208.113.156.4
20: 208.113.156.14
21: 208.97.177.124

ko@node3:~/$
1: 129.22.150.2
2: 10.2.0.98
3: 10.2.0.241
4: 199.18.156.65
5: 64.57.29.173
6: 206.126.236.147
7: 138.187.159.14
8: *
9: 94.102.162.99
10: 64.125.21.77
11: 64.125.27.0
12: 64.125.29.19
13: 64.125.29.131
14: 64.125.29.229
15: 64.125.30.249
16: **64.125.31.**44 (40/40)
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18: 208.113.156.4
19: 208.113.156.14
20: 208.97.178.55

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9: *
10: 80.249.208.122
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12: 64.125.27.0
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12: 64.125.29.19
13: 64.125.29.131
14: 64.125.29.229
15: 64.125.30.249
16: **64.125.31.**44 (40/40)
17: **208.185.23.134** (40/40) TCP::MSS(0204058c)
18: 208.113.156.4
19: 208.113.156.14
20: 208.97.178.55

- 208.185.232.134 is the informant
- 64.125.31.42 and 64.125.31.44 are the offenders
- Merged into a single MB

Pre-processing: derivation (Step 1)

- *948,457 addresses observed*

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  Unresolved addresses:

- 21,330 (2.25%) from 10.0.0.0/8, 172.16.0.0/12 or 192.168.0.0/16
- 905 (0.1%) from 100.64.0.0/10
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- Keep if ends of unresolved zone are mapped to same AS.