Detecting Prefix Hijackings in the Internet with Argus

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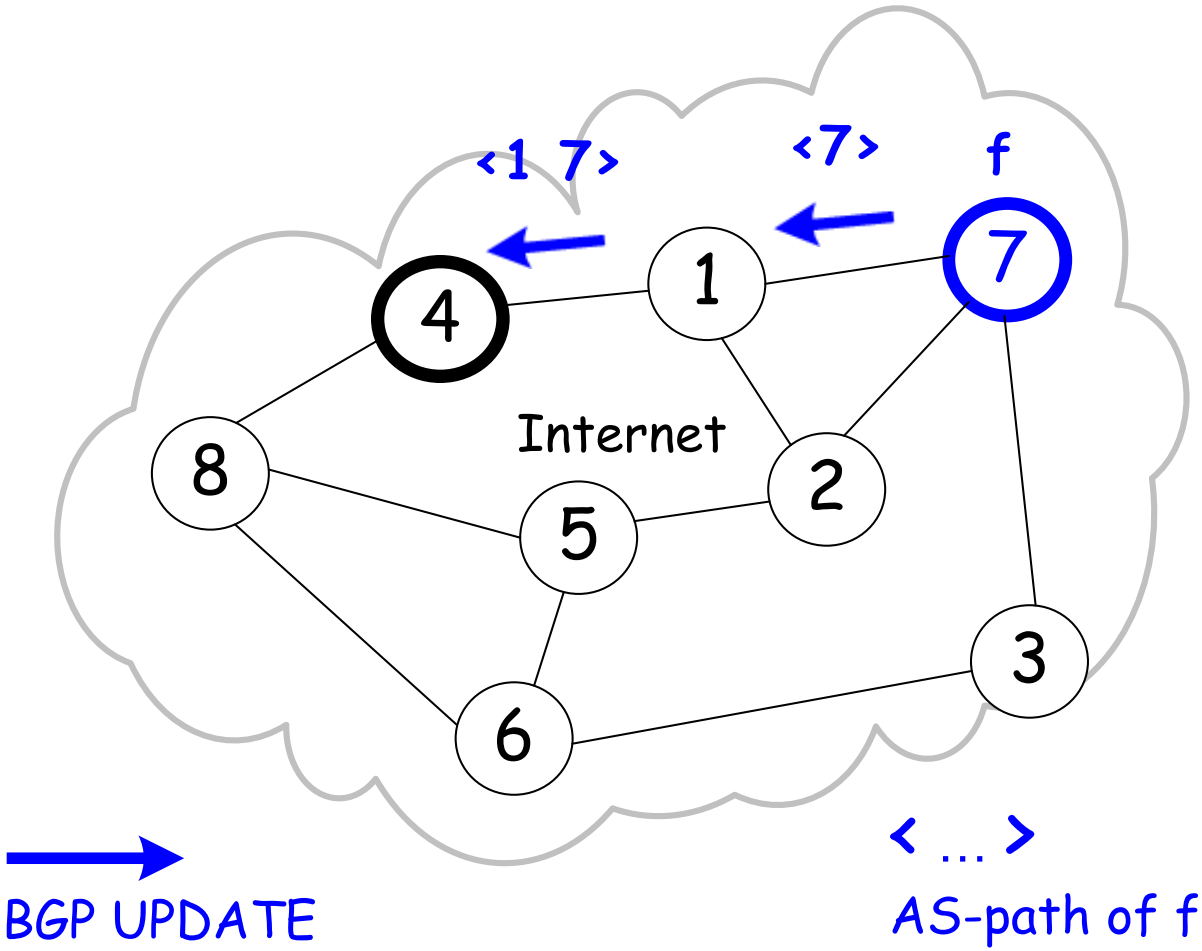
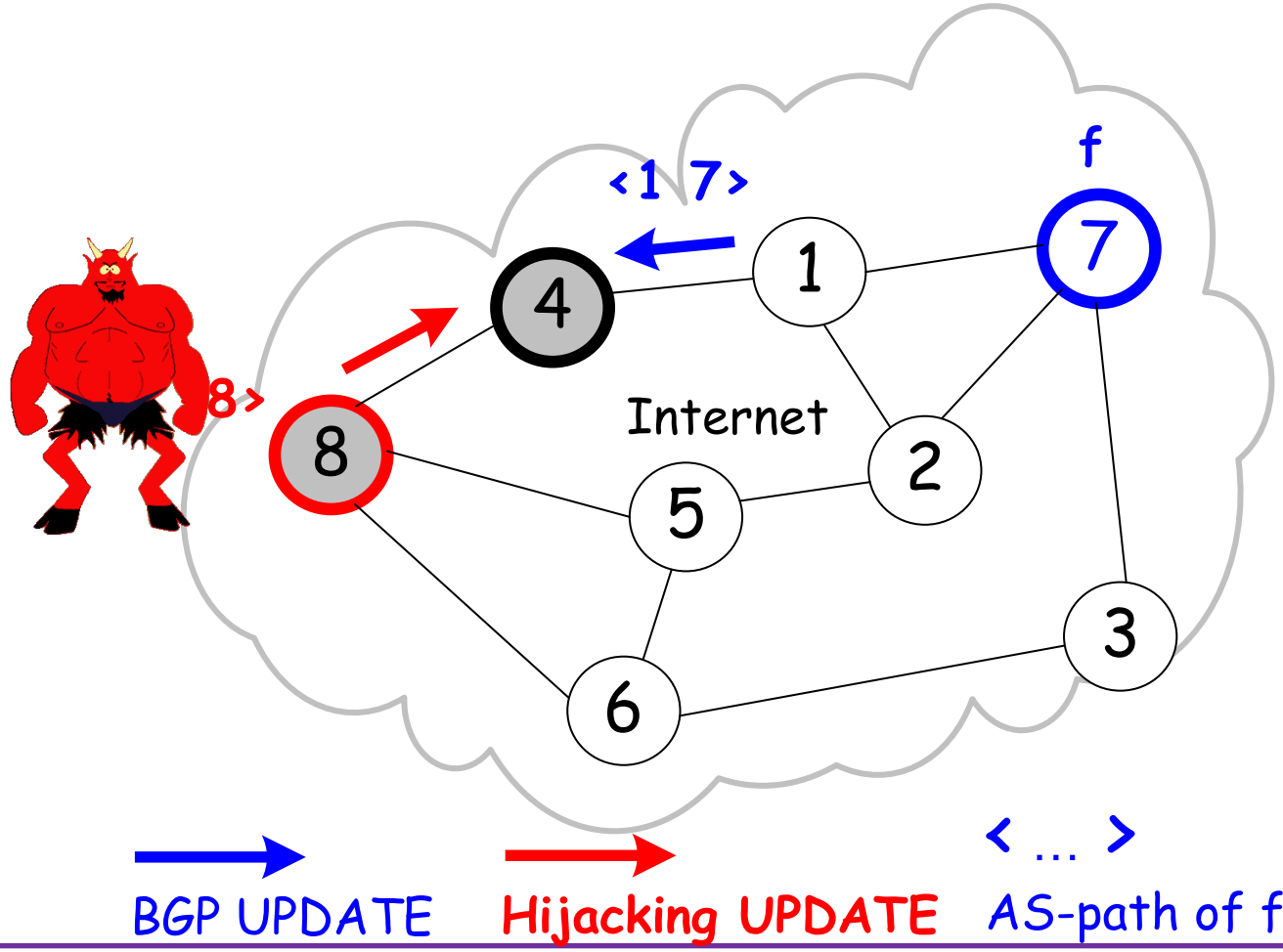
Outline

- Introduction
  - Prefix Hijacking
  - Existing Detection Methods
- Argus
  - Key Observation & Algorithm
  - System Architecture & Implementation
- Internet Monitoring Practice
  - Evaluation
  - Statistics
  - Case Studies
- Conclusion

Inter-domain Routing



Prefix Hijacking



Black-holing Hijackings

- Packets dropped by the attacker

- Also caused by unintentional mis-configurations
  - 2010, China Tele. hijacked **15%** of Internet(prefixes)
  - 2008, Pakistan Tele. hijacked Youtube for **2 hours**

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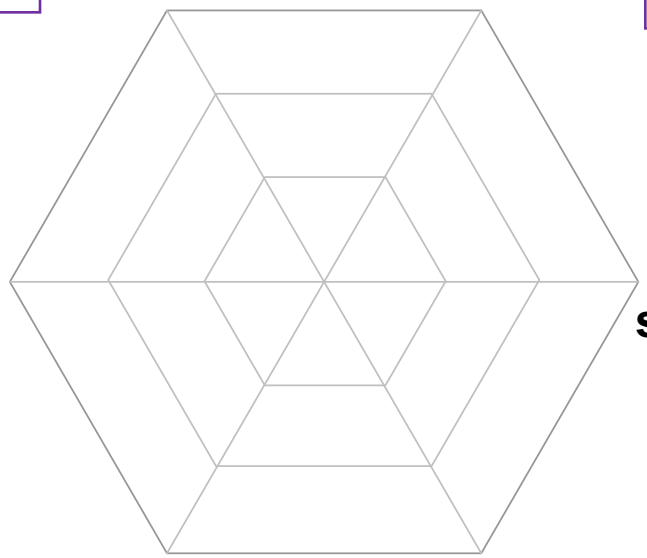
Challenges of Hijacking Detection

Hijacking can pollute a large number of ASes in several seconds!

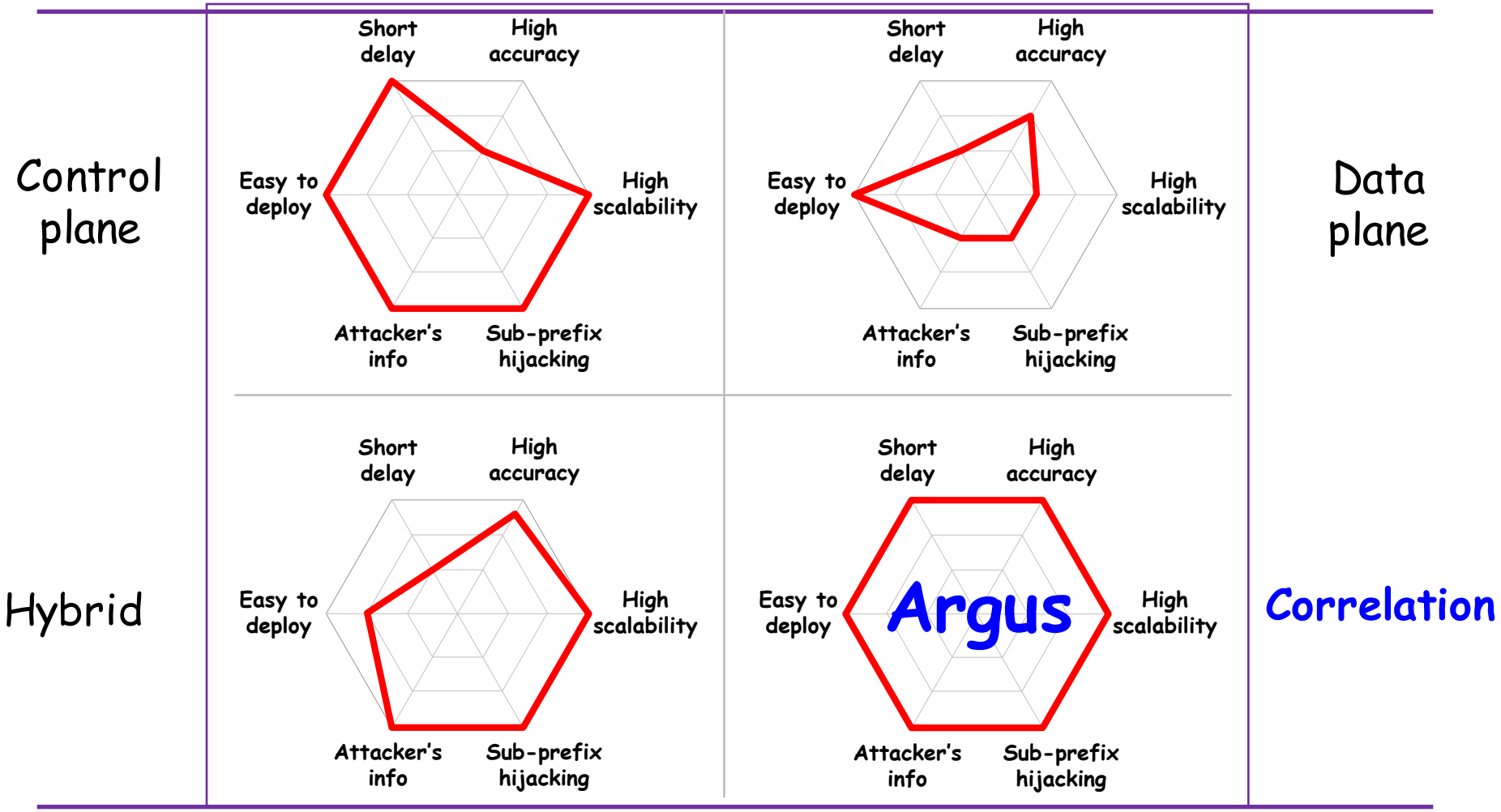


Multi-homing, TE, BGP anycast, Backup links, Route failure, Policy change

Real system or service

Monitoring the whole Internet

Our Approach



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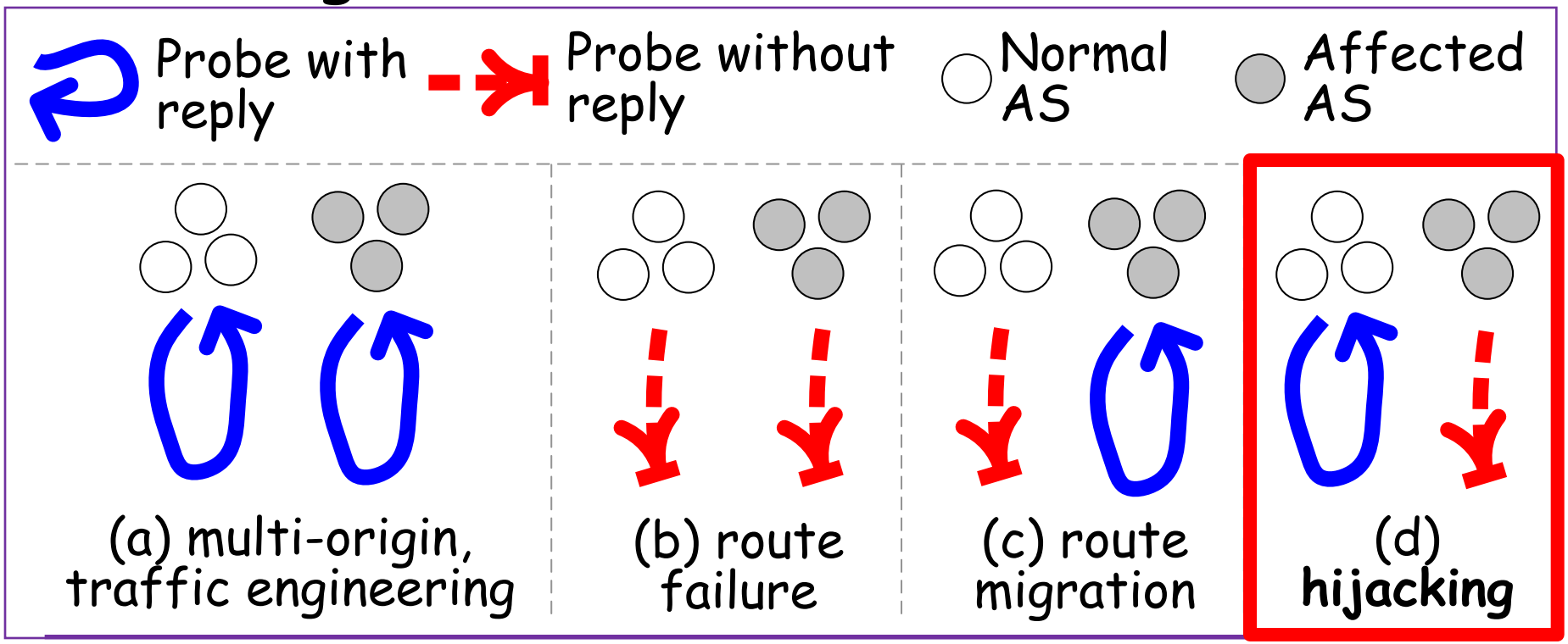
Key Observations: Relationship between Control and Data Plane

- Only part of the Internet is polluted
- Distinguishable from other route events



Status Matching

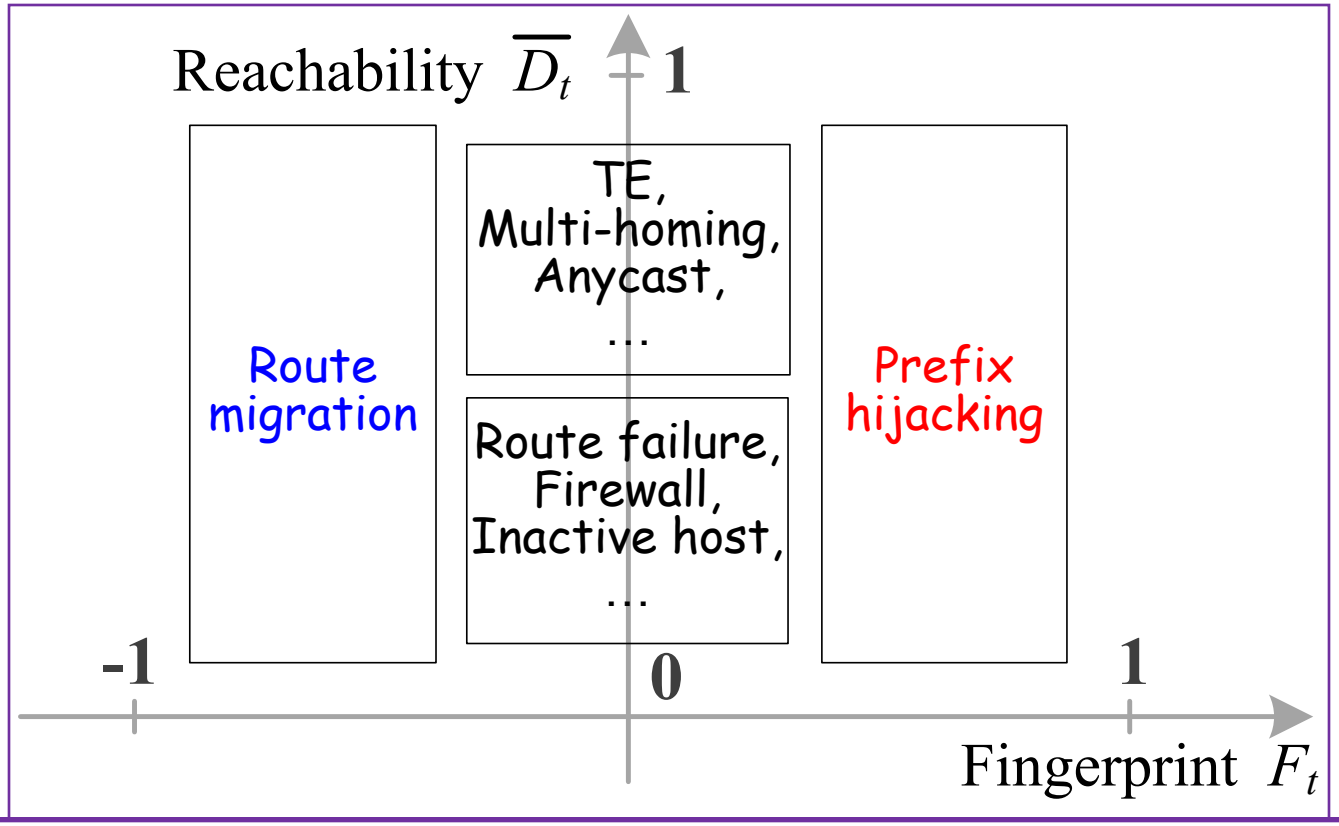
- Eyes of Argus: public route-servers, looking-glasses
  - Simple & fast commands: show ip bgp, ping
- Eye_j at time t
  - Control plane C_{tj} : not affected by the anomalous route?
  - Data plane D_{tj} : live IP in the corresponding prefix can be reached?
  - correlation coefficient of D and C – Raise an alarm if $F_t > \mu$

Fingerprint of a route event:

$$F_t = \frac{\sum_{j=1}^{N}[(C_{t,j} - \overline{C_t})(D_{t,j} - \overline{D_t})]}{\sqrt{\sum_{j=1}^{N}(C_{t,j} - \overline{C_t})^2 \times \sum_{j=1}^{N}(D_{t,j} - \overline{D_t})^2}}$$

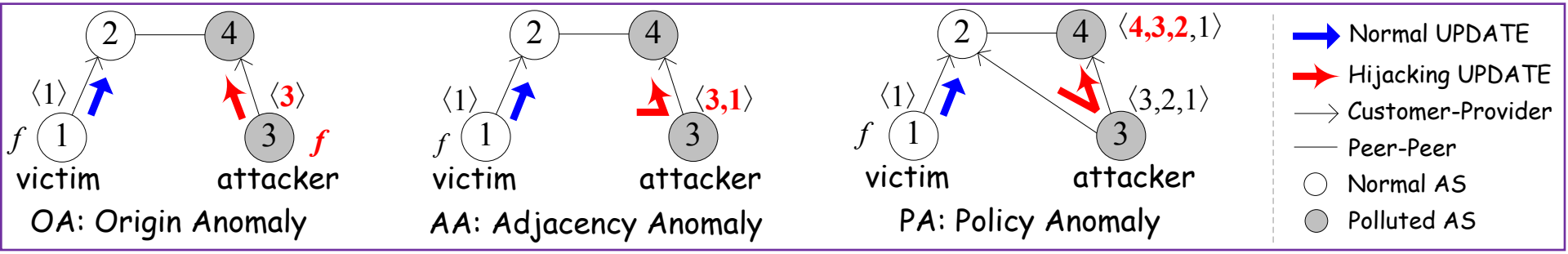
Identification of Prefix Hijacking

- Prefix hijacking: $F_t \rightarrow 1.0$, (F_t >= threshold **μ**)



Type of Anomalies

- AS-path p = $\langle a_n , \dots , a_{i+1} , a_i , a_{i-1} , \dots , a_0 \rangle$
  - OA: Origin Anomaly
    - Anomalous origin AS: $p_a = \langle a_0 , f \rangle$
  - AA: Adjacency Anomaly
    - Anomalous AS pair in AS-path: $p_a = \langle a_j , a_{j-1} \rangle$
  - PA: Policy Anomaly
    - Anomalous AS triple in AS-path: $p_a = \langle a_{j+1} , a_j , a_{j-1} \rangle$



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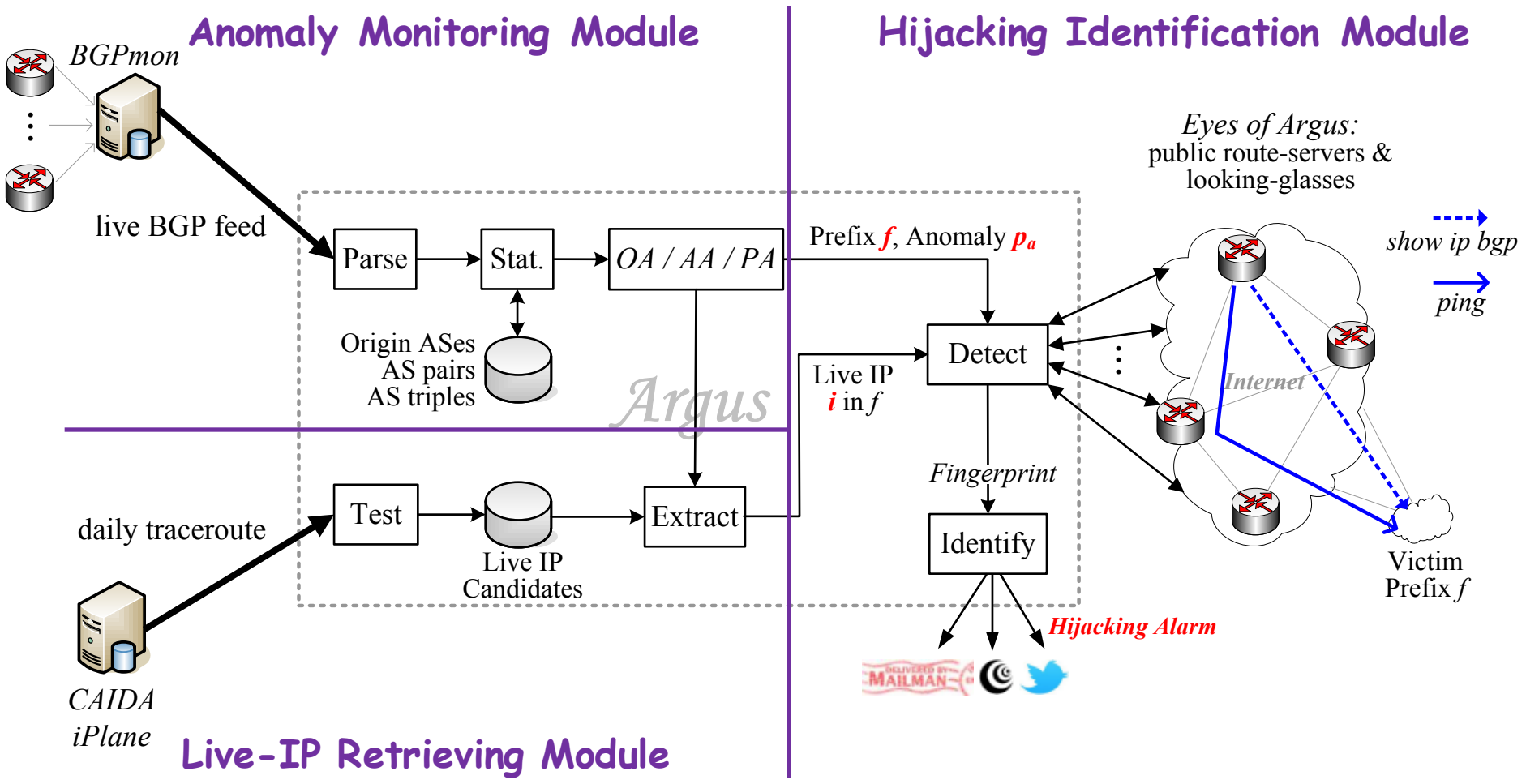
Architecture of Argus



System Deployment

- From May 2011, launched >1 years
- Live BGP feed collected from ~130 peers
  - BGPmon: http://bgpmon.netsec.colostate.edu/
  - 10GB BGP UPDATE /day, 20Mbps peak
- 389 eyes, in 41 transit AS

- Online notification services
  - (AS-4847) Mailing list
  - (AS-13414, AS-35995) Twitter
  - (AS-4538) Website, web service APIs

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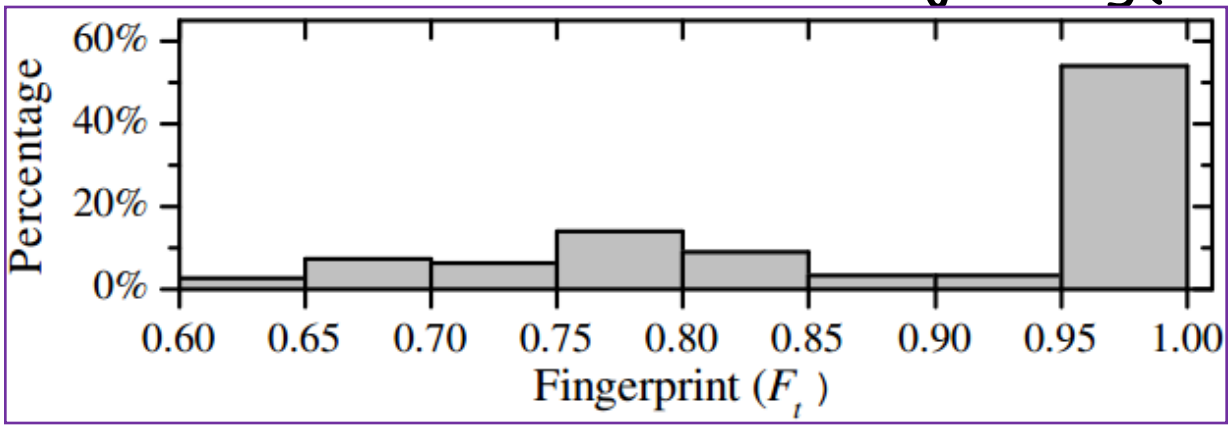
Argus is Online

- 40k anomalous route events
- 220 stable hijackings
  - Duration of $F_t >= \mu$ in more than T seconds
  - μ: fingerprint threshold of hijacking(0.6)
  - T: duration threshold of stable hijacking(10sec)

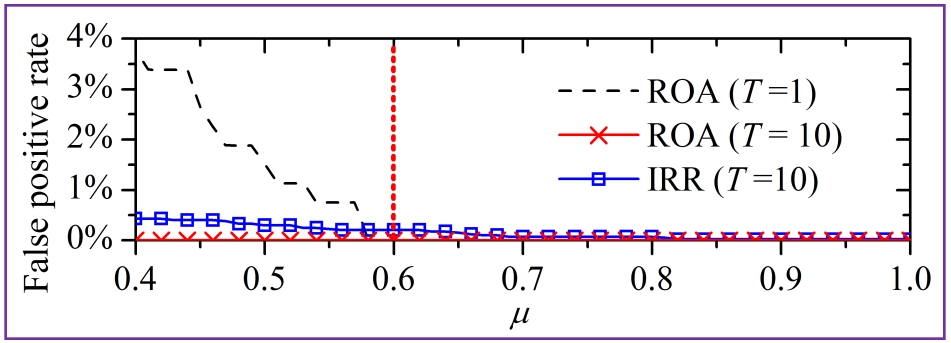


Fingerprint (F_t) distribution of all stable hijackings.

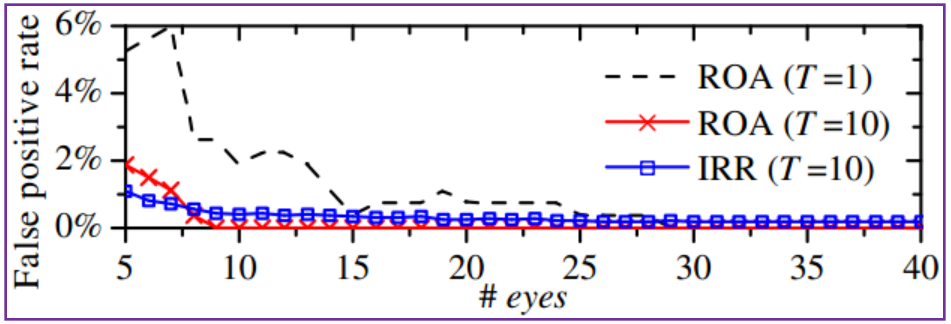
False Positive

- Directly contact network operators (March-April, 2012)
  - 10/31 confirmed our hijacking alarms
  - No objection

- ROA: Route Origin Authorization
  - 266 anomalies with ROA records
  - False positive 0%
    (μ=0.6, T=10, #eyes=40)

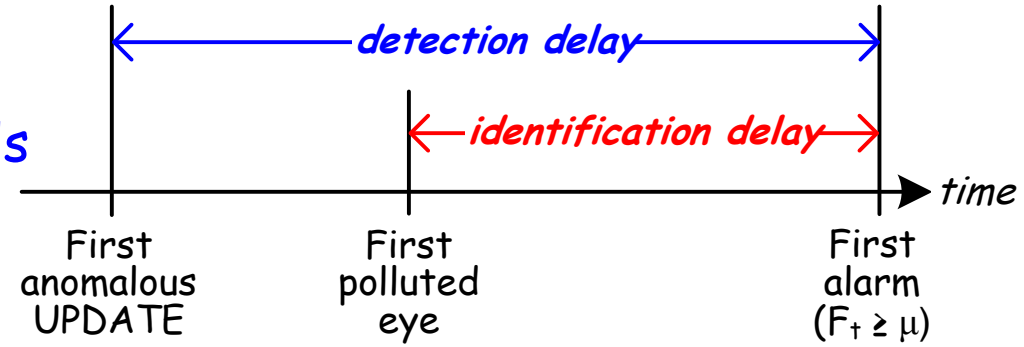


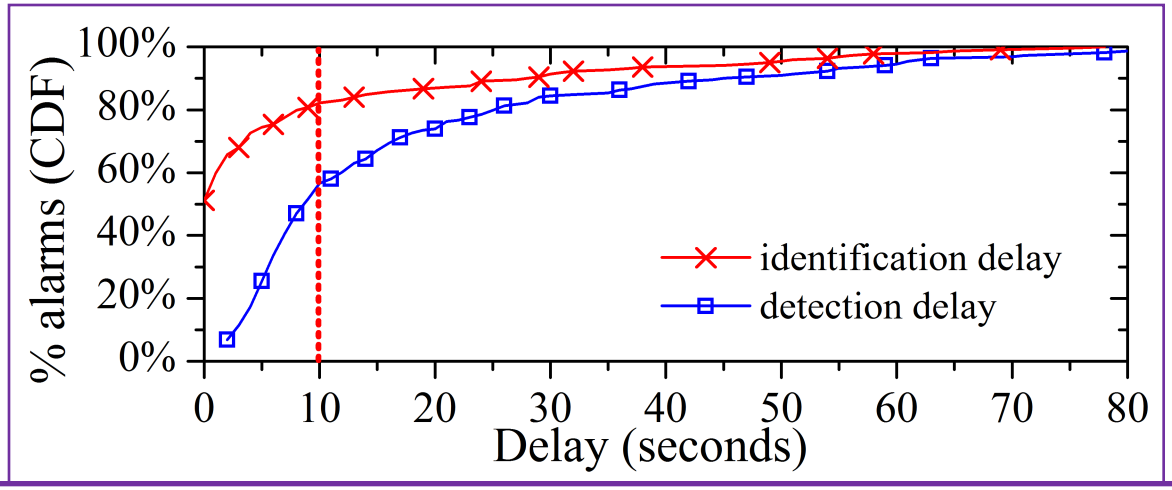
- IRR: Internet Routing Registry
  - 3988 anomalies with IRR records
  - False positive 0.2%
    (μ=0.6, T=10 , #eyes=40)



Delay-220 Stable hijackings

- Detection delay
  - 60% less than 10 seconds
- Identification delay
  - 80% less than 10 seconds
  - 50% less than 1 second





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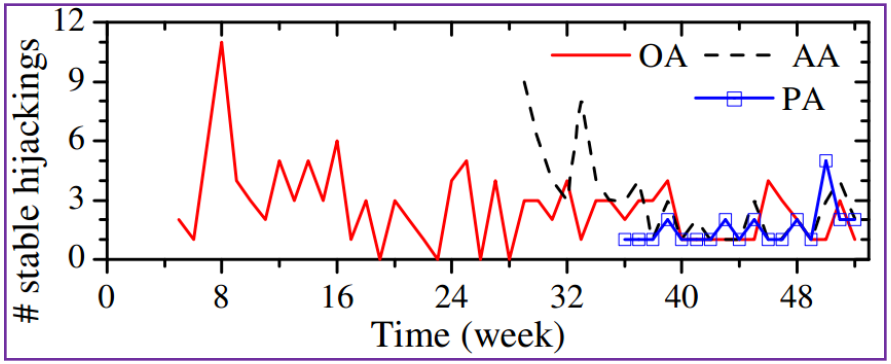
Statistics - Overview

- Adjacency/Policy based hijacking do exists

	Total	OA (origin AS)	AA (Adjacency)	PA (Policy)
Anomalies	40k	20k	6.7k	13.3k
Hijackings	220	122	71	27

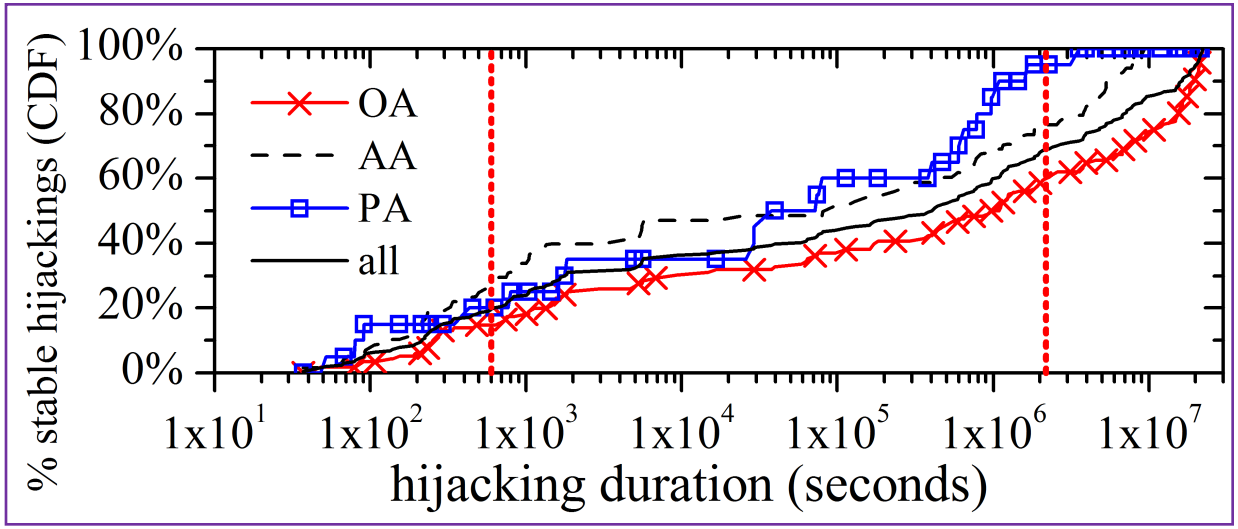
Total # of route anomalies and stable hijackings in one year.



Weekly # of stable hijackings.

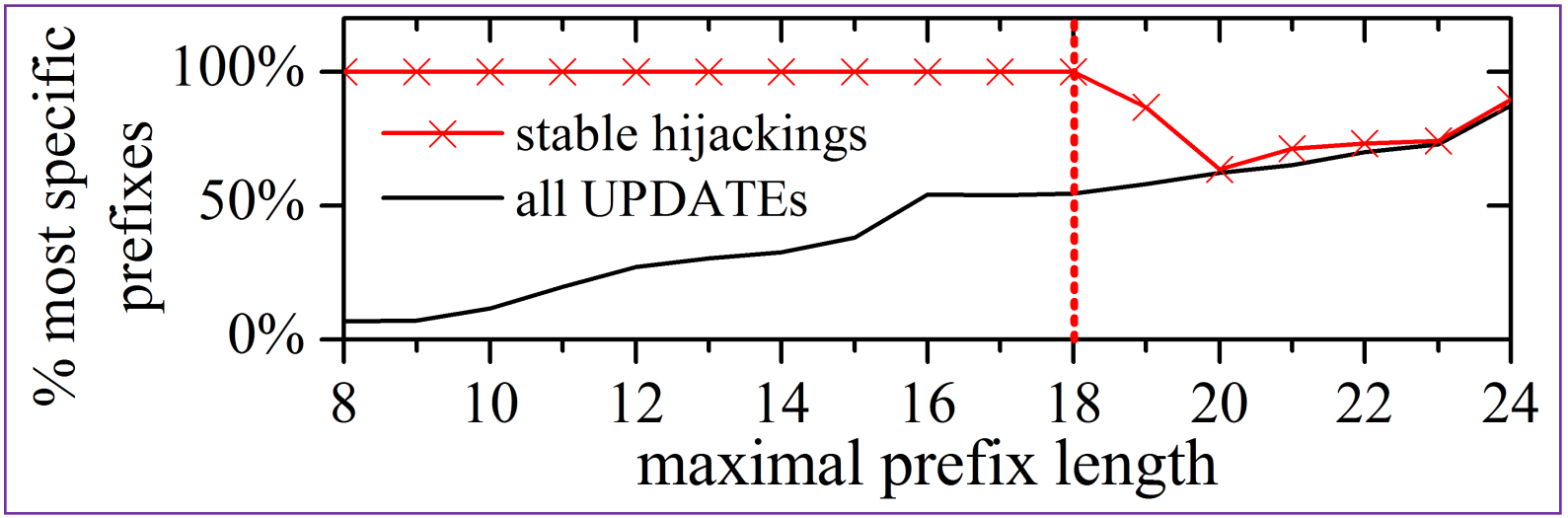
Statistics - Hijacking duration

- Stable hijacking duration: live time of anomalous route
  - 20+% hijackings last <10 minutes
  - Long hijackings also exist



Statistics - Prefix length

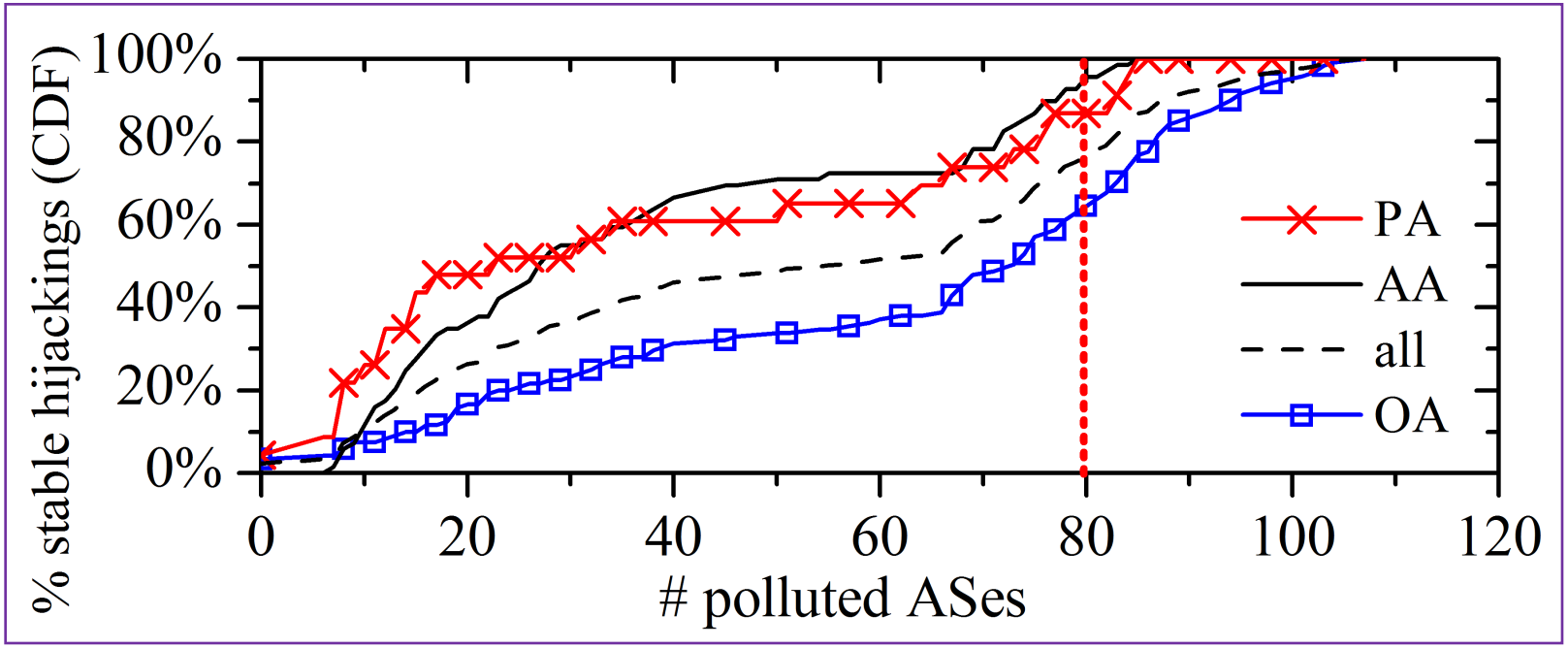
- Stable hijackings with most specific prefix
  - 91% hijacked prefixes are most specific
  - 100% hijacked prefixes with length <= 18 are most specific



- 10% stable hijackings are sub-prefix hijacking

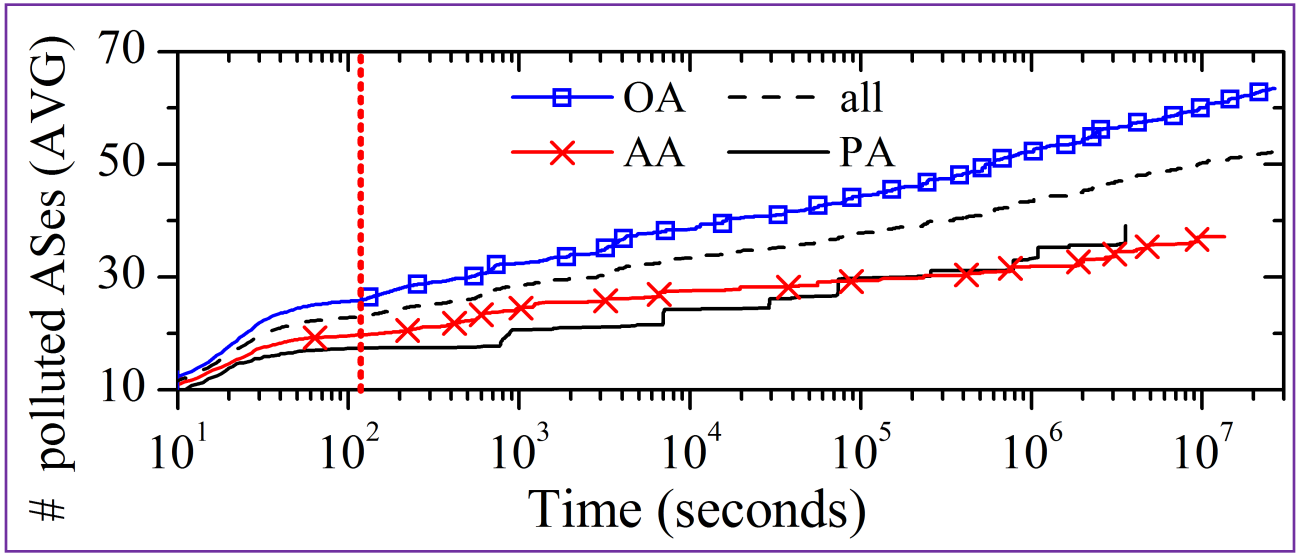
Statistics - Pollution scale

- 20% stable hijackings could pollute 80+ transit ASes



Statistics - Pollution speed

- 20+ transit ASes are polluted in 2 minutes



- For hijackings polluted 80+ transit ASes
  - 50% Internet are polluted within 20 seconds
  - 90% Internet are polluted within 2 minutes

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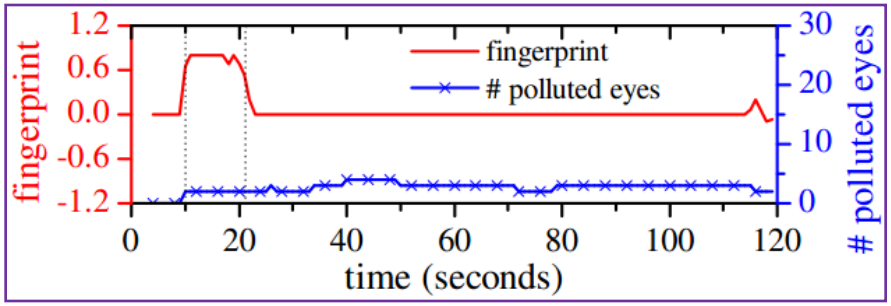
Case Studies

- OA hijackings (confirmed by email)
  - Missing route filters
  - Network maintenance misplay
  - Premature migration attempt
  - Sub-prefix hijacking
- AA hijackings (confirmed by email)
  - Mis-configuration in TE
  - AS-path poisoning experiment
- PA hijackings (verified in IRR)
  - Import policy violation
  - Export policy violation

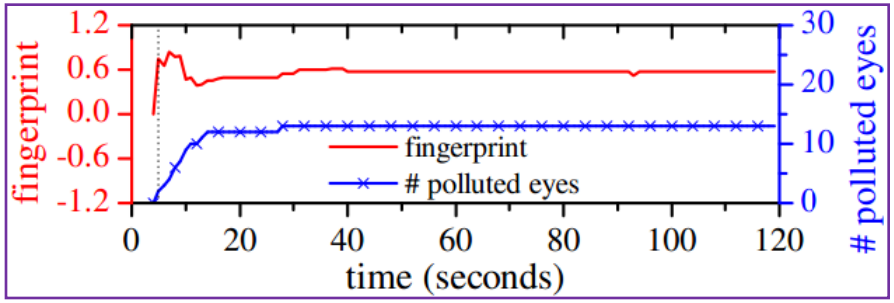
OA Hijackings

Time	Prefix	Normal Origin	Anomalous Origin	Duration	Delay
Nov. 27, 2011	166.111.32.0/24, …	AS-4538 CERNET, CN	AS-23910 CERNET-2, CN	10+ sec	10 sec
Mar. 20, 2012	193.105.17.0/24	AS-50407 Douglas, DE	AS-15763 DOKOM, DE	12 min	5 sec

- Missing route filters



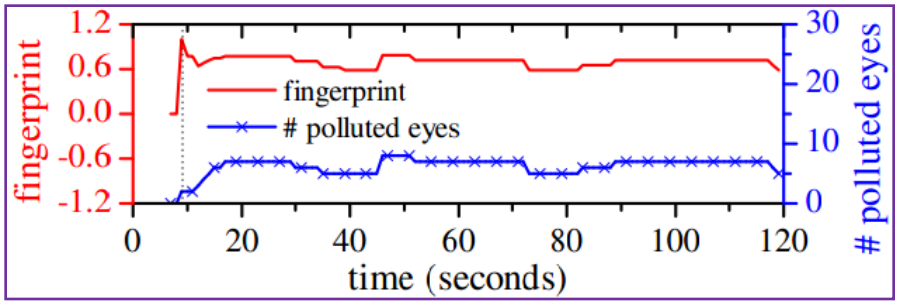
- Network maintenance misplay



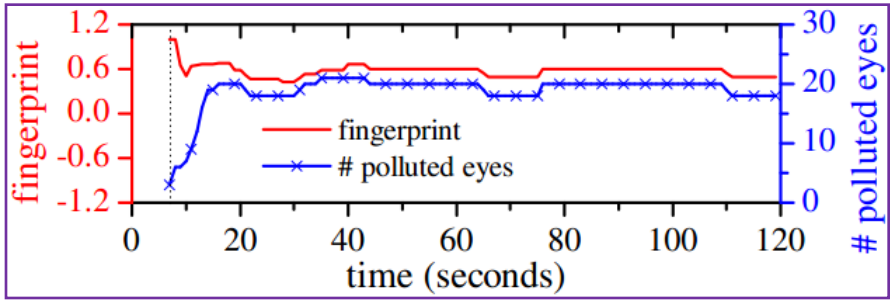
OA Hijackings

Time	Prefix	Normal Origin	Anomalous Origin	Duration	Delay
Apr. 04, 2012	91.217.242.0/24	AS-197279 WizjaNet, PL	AS-48559 Infomex, PL	17 min	9
Mar. 22, 2012	12.231.155.0/24 (in 12.128.0.0/9)	AS-7018 AT&T, US	AS-13490 Buckeye, US	16 min	7

- Premature migration attempt



- Sub-prefix hijacking



AA Hijackings

Time	Prefix	AS-path	Delay
Apr. 12, 2012	210.1.38.0/24	‹3043 174 38082 **38794** 24465›	12
Mar. 31, 2012	184.464.255.0/24	‹4739 6939 2381 **47065** 19782 47065›	4

- Mis-configuration in TE
  - AS-38794 (BB-Broadband, TH) is a new provider of AS-24465 (Kasikorn, TH)
- AS-path poisoning experiment [SIGCOMM '12]
  - BBN announces loop AS-paths ‹47065, x, 47065› for experimental purpose

PA Hijackings

Time	Prefix	AS-path	Delay
Apr. 19, 2012	77.223.240.0/22	‹4739 24709 25388 **21021** 12741 47728›	9
Apr. 16, 2012	195.10.205.0/24	‹3043 174 20764 **31484** 3267 3216 35813›	5

- Import policy violation

IRR info. of AS-21021 (Multimedia, PL) :

import: from AS12741 action pref=150; accept AS12741
export: to AS12741 announce AS21021

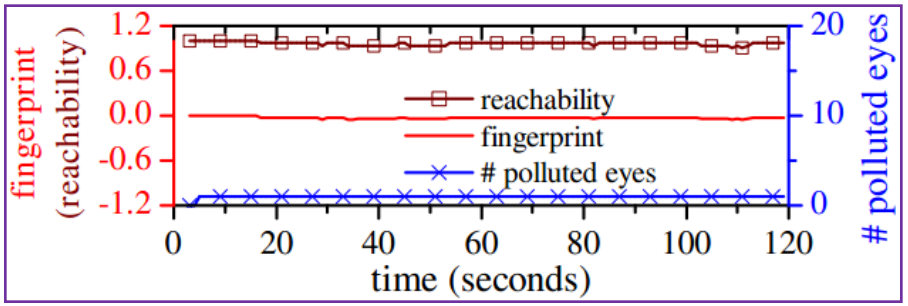
- Export policy violation

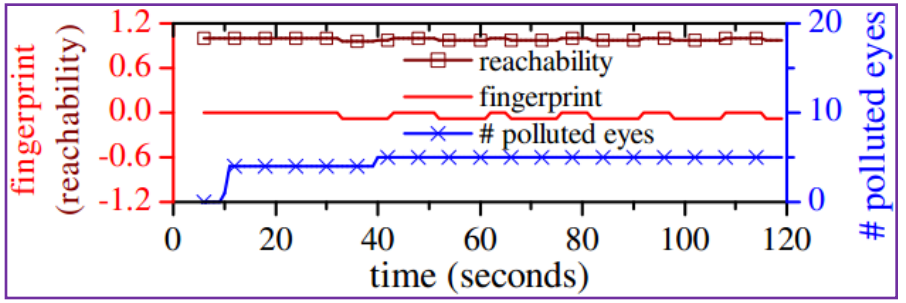
IRR info. of AS-31484 (OOO Direct Tele., RU):

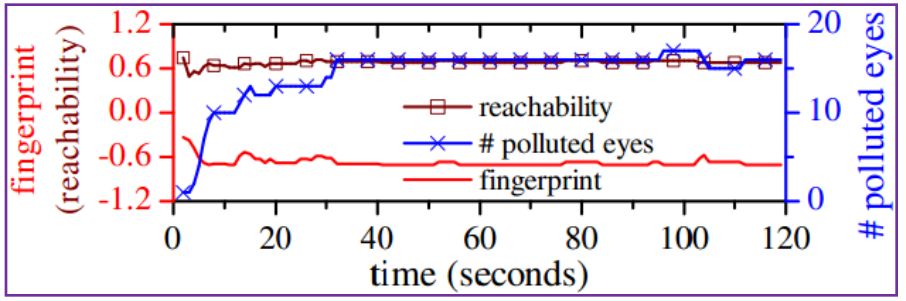
remarks: --- Uplinks ---
import: from AS3267 action pref=85; accept ANY
export: to AS3267 announce AS31484 AND AS196931
import: from AS20764 action pref=85; accept ANY
export: to AS20764 announce AS31484 AND AS196931

Non-hijacking Anomalies

- TE using BGP anycast
  - 193.0.16.0/24 (DNS root-k) suddenly originated by AS-197000 (RIPE)
  - $F_t \rightarrow 0$, $D_t = 1$
- TE with backup links
  - AS-12476 (Aster, PL) announced prefix to a new provider AS-6453 (Tata, CA)
  - $F_t \rightarrow 0$, $D_t = 1$
- Route migration
  - Prefix owmer changed from AS-12653 (KB Impuls, GR) to AS-7700 (Singapore Tele)
  - $F_t \rightarrow -1$







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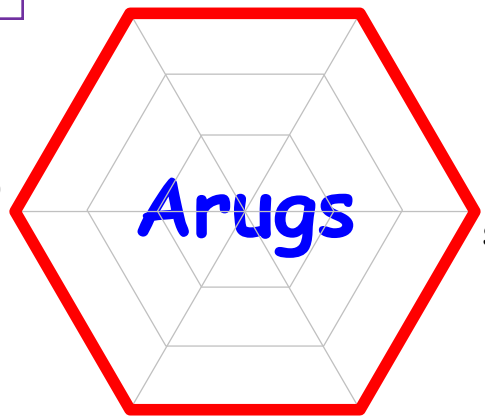
Conclusion of Our Contributions

- 80% delay <10 seconds
- 20% stable hijackings last <10 minutes, some can pollute 90% Internet in <2 minutes

- OA, AA, PA anomalies
- ROA, IRR, email confirmation



- show ip bgp, ping
- Public available external resources

- Anomaly driven probing
- Monitoring the whole Internet

- Live BGP feed from BGPmon
- Victims can be noticed through several channels

- 10% stable hijackings are sub-prefix hijacking

One year's Internet detection practice.