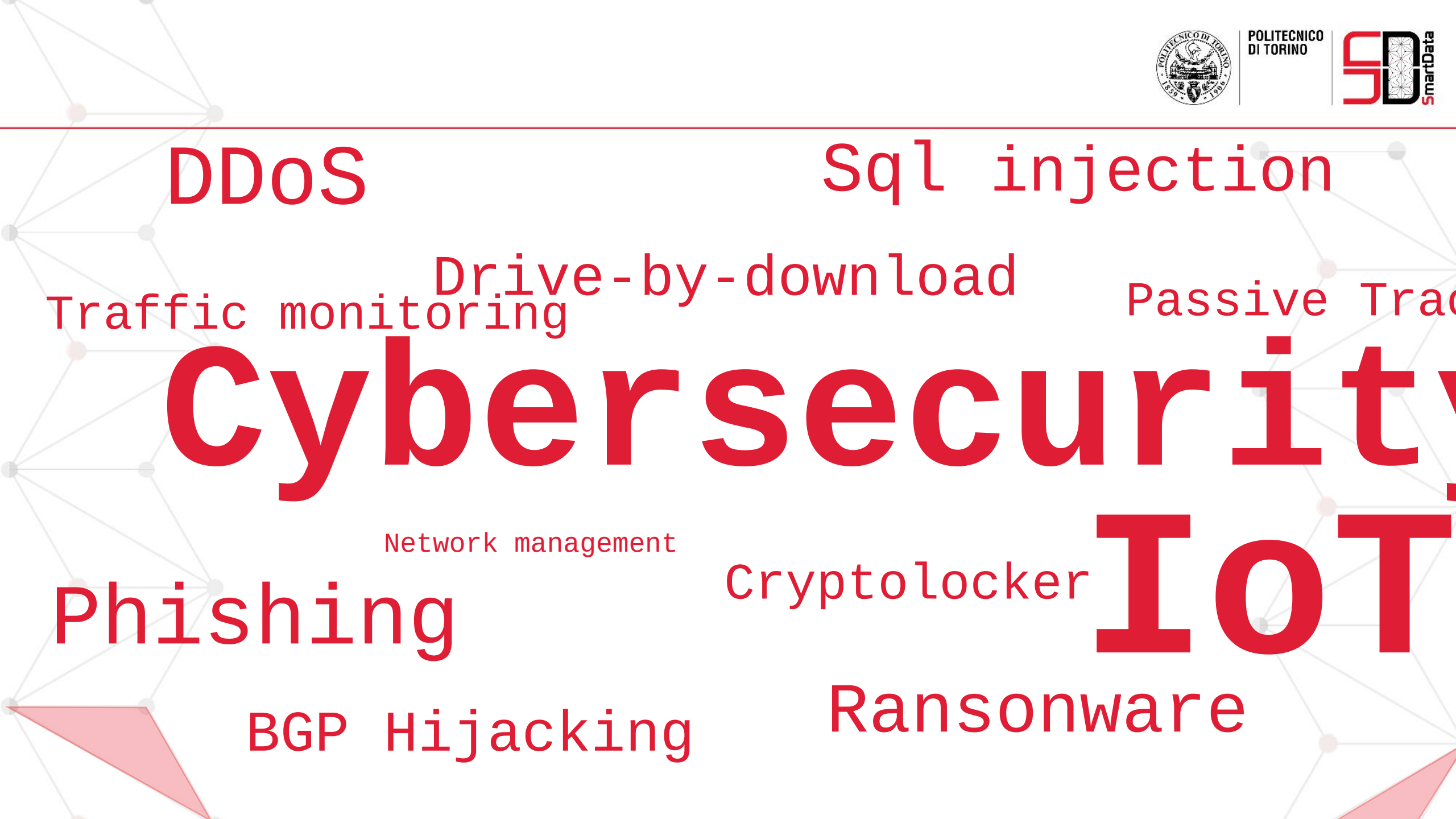
Darknets for Security Monitoring @ Polito

Idilio Drago
SmartData@PoliTo
https://smartdata.polito.it


DDoS
Sql injection
Drive-by-download
Traffic monitoring
Passive Trac
Cybersecurity
IoT
Network management
Cryptolocker
Phishing
Ransonware
BGP Hijacking

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Collect Data

- Active crawling
  - Web pages
  - Social networks (FB, Instagram, tripadvisor…)
- Passive probes
  - Up to 100 Gb/s with off-the-shelf hw
  - 5+ years of historical logs from ISP and campus networks
- Darknets
  - From 2 different countries
- Hon

Process Data

- Supervised ML
  - trees, forests, NN, GAN,…
  - For traffic classification
  - For malware detection
  - For user characterization
  - …
- Unsupervised ML
  - Clustering, Rule Mining
  - For anomaly detection
  - For lowering complexity
  - …

Solve problems

- System characterization
  - How does [dropbox|Skype|YouTube|…] work?
- User Characterization
  - How does Alice use [Dropbox|Instagram|YouTube]?
- Cybersecurity
  - How does Trudy abuse of [DNS, servers, cloud, news…]

Generation → Acquisition → Storage → Analysis

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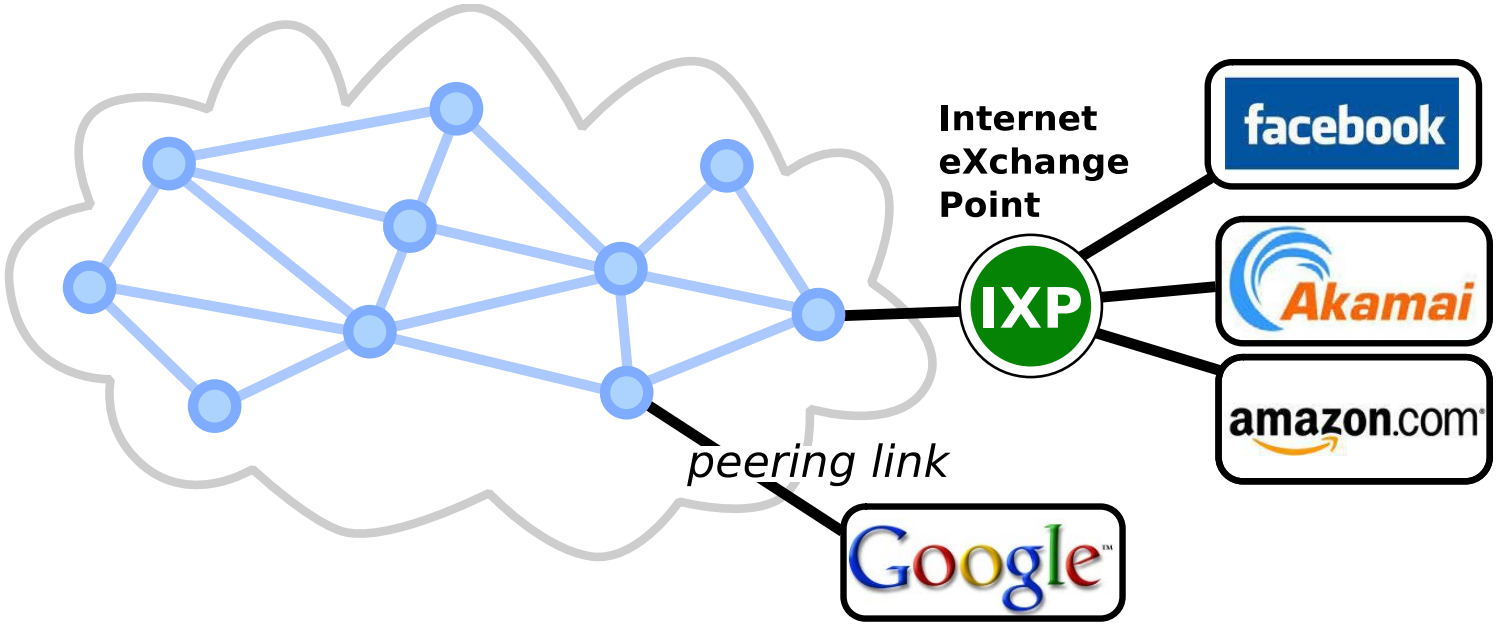
Generation

is

GOAL: make it as **automatic** as possible

Internet Traffic Monitoring @ Polito

Monitoring approach



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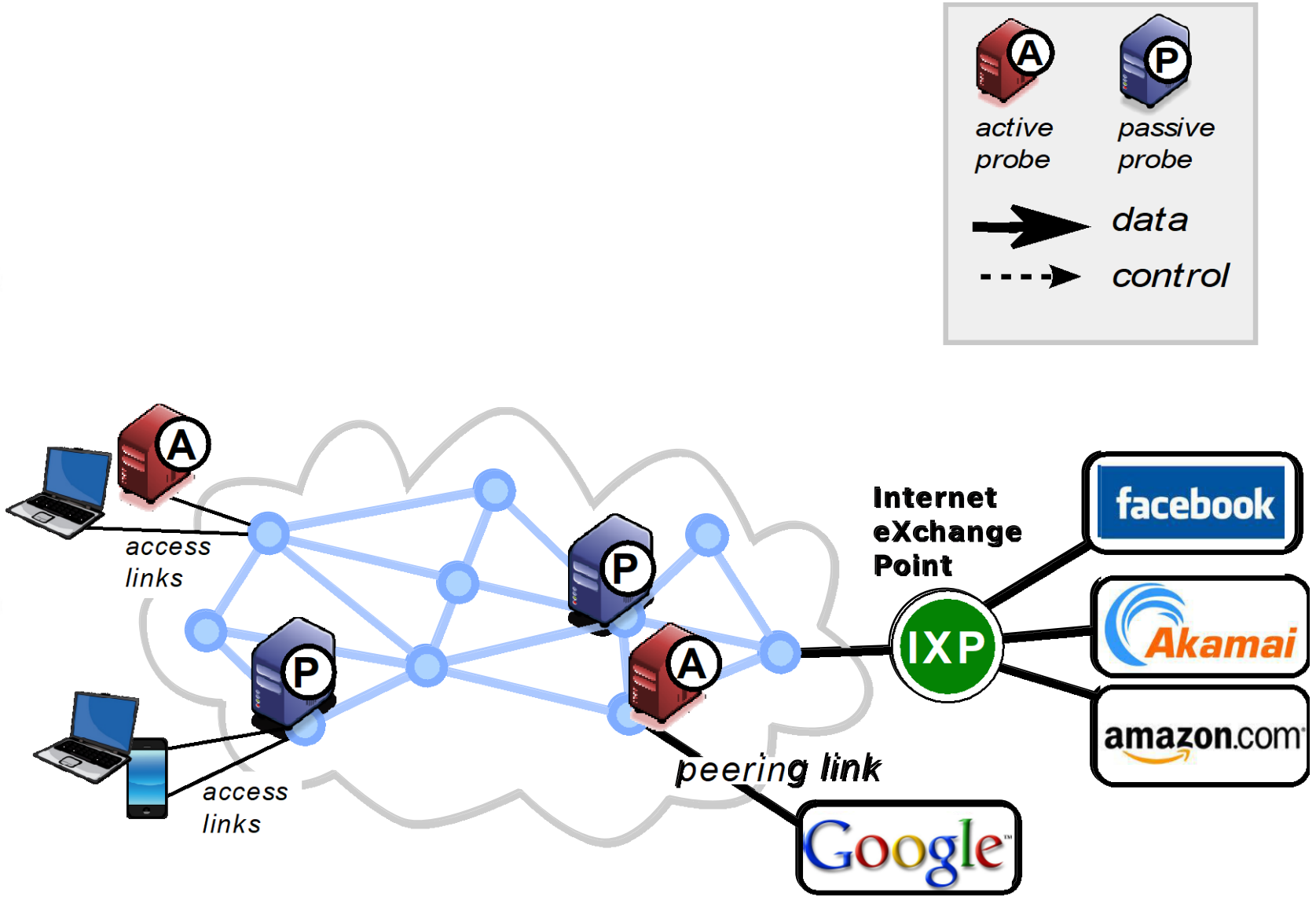

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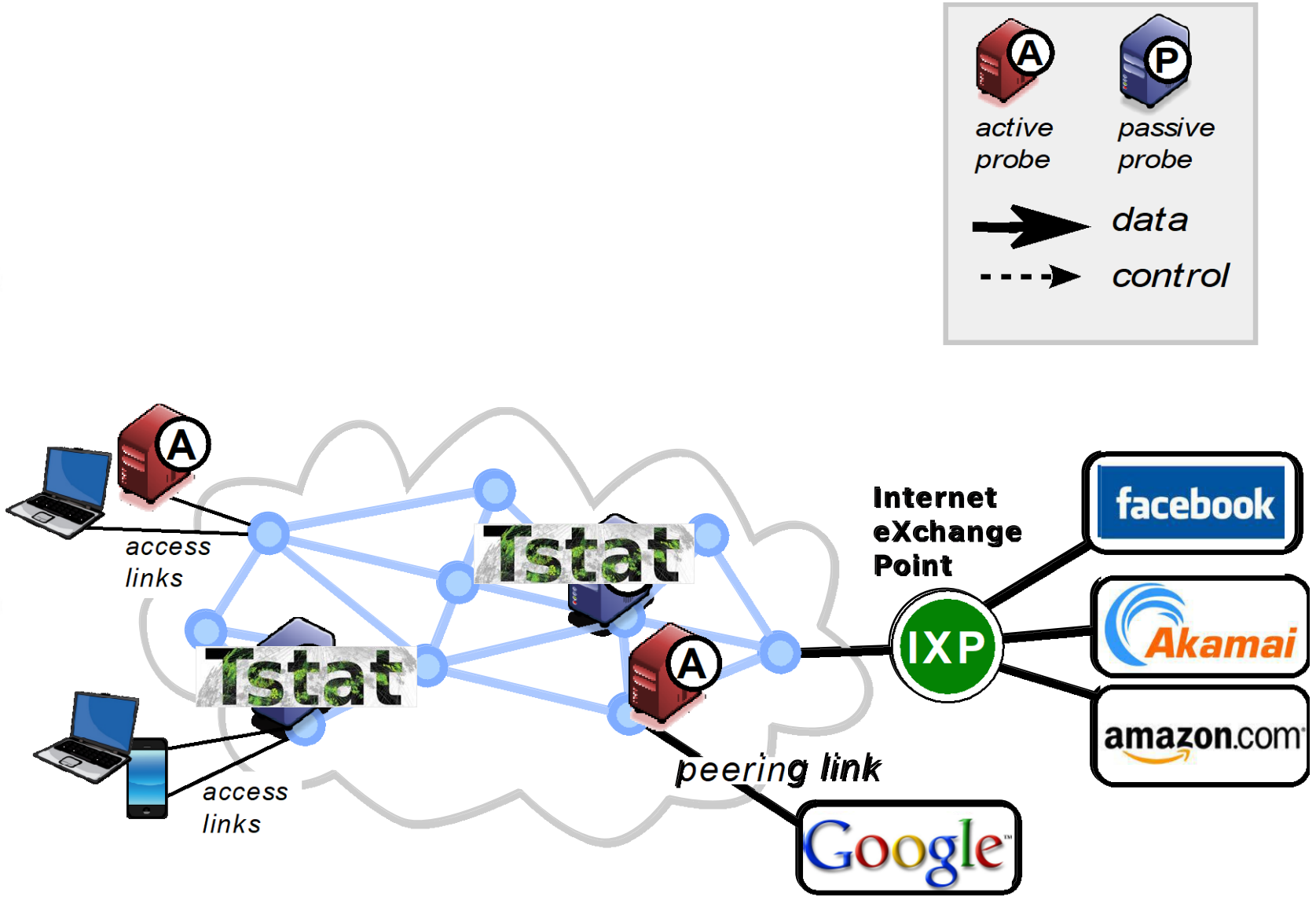

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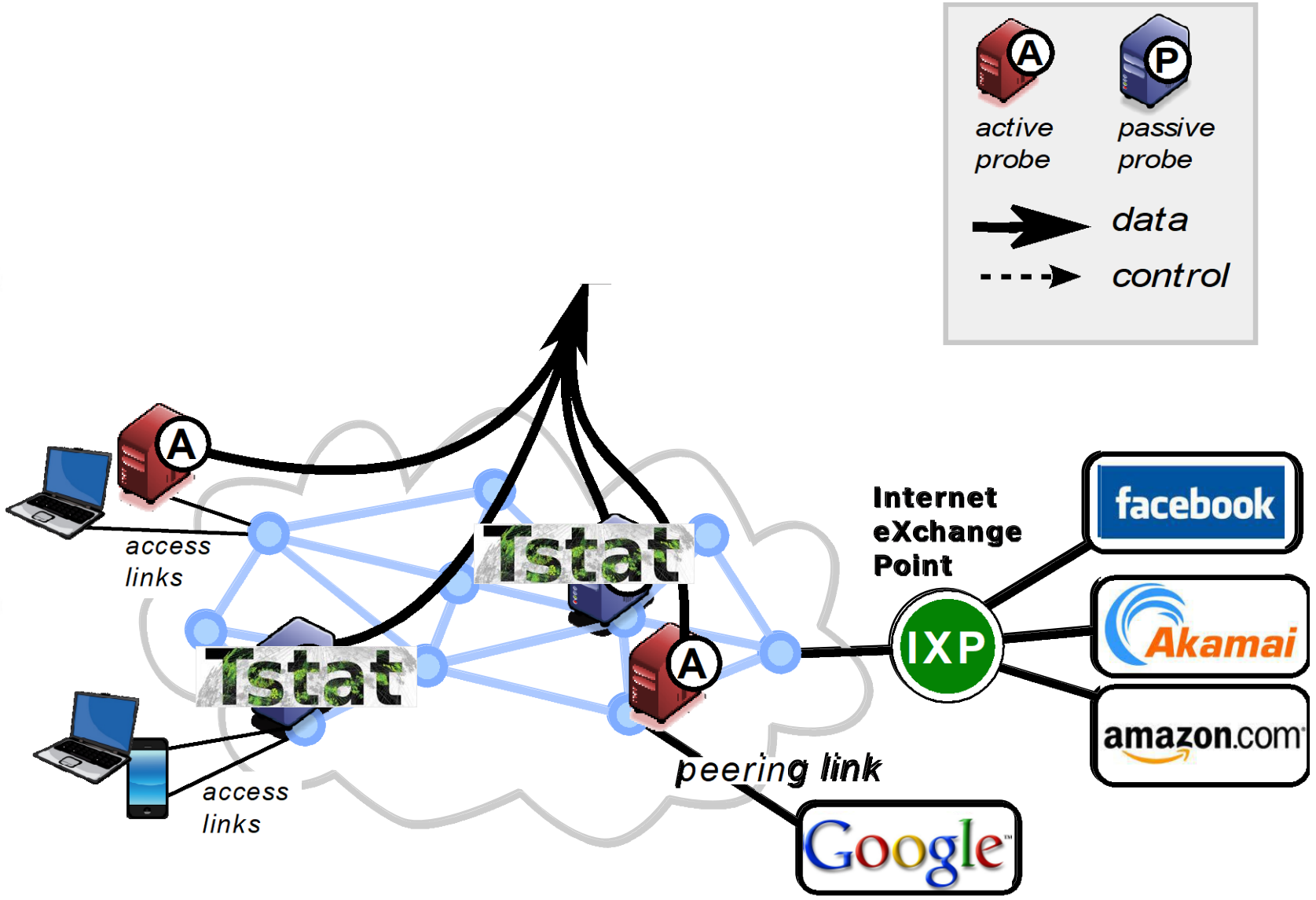

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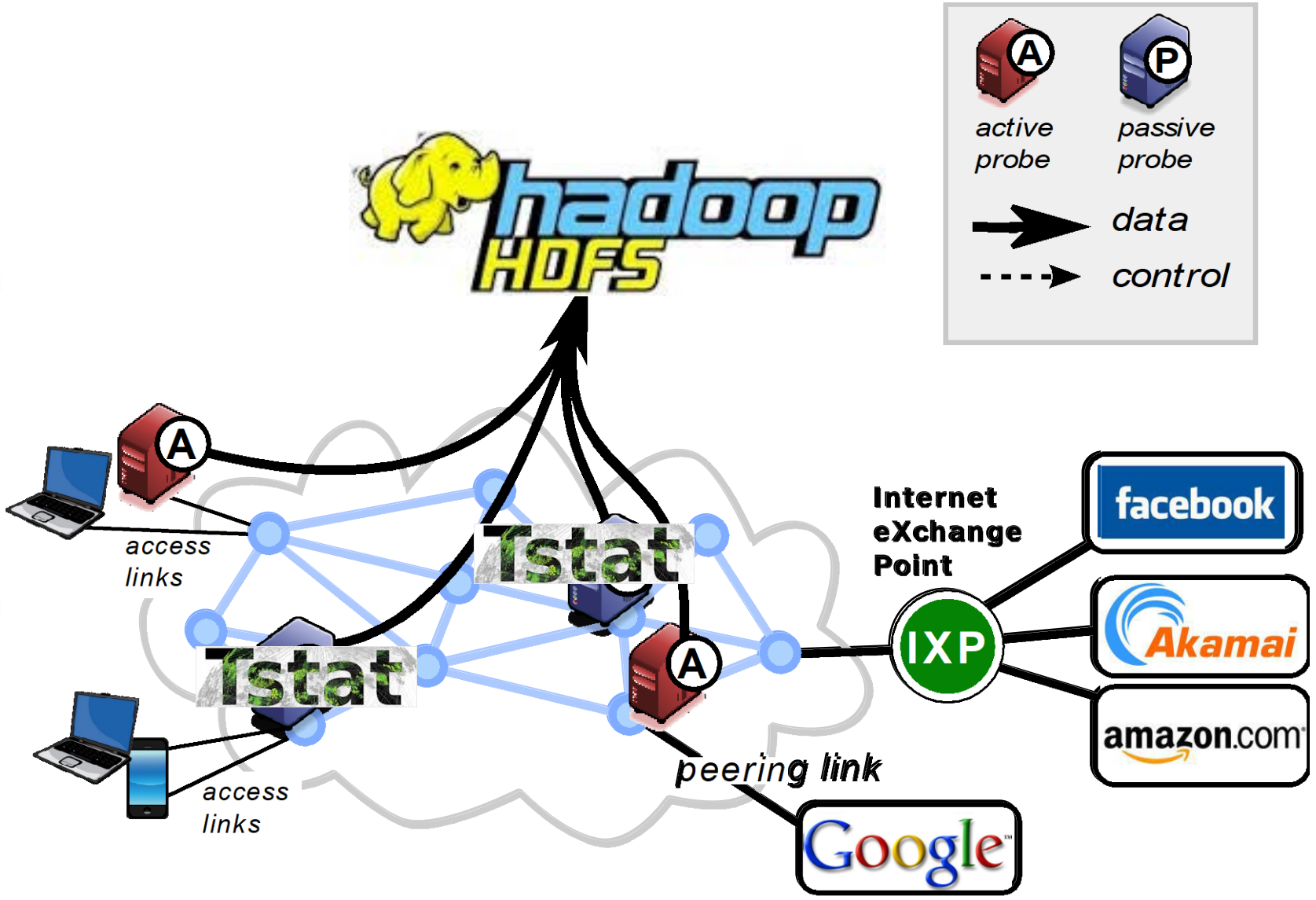

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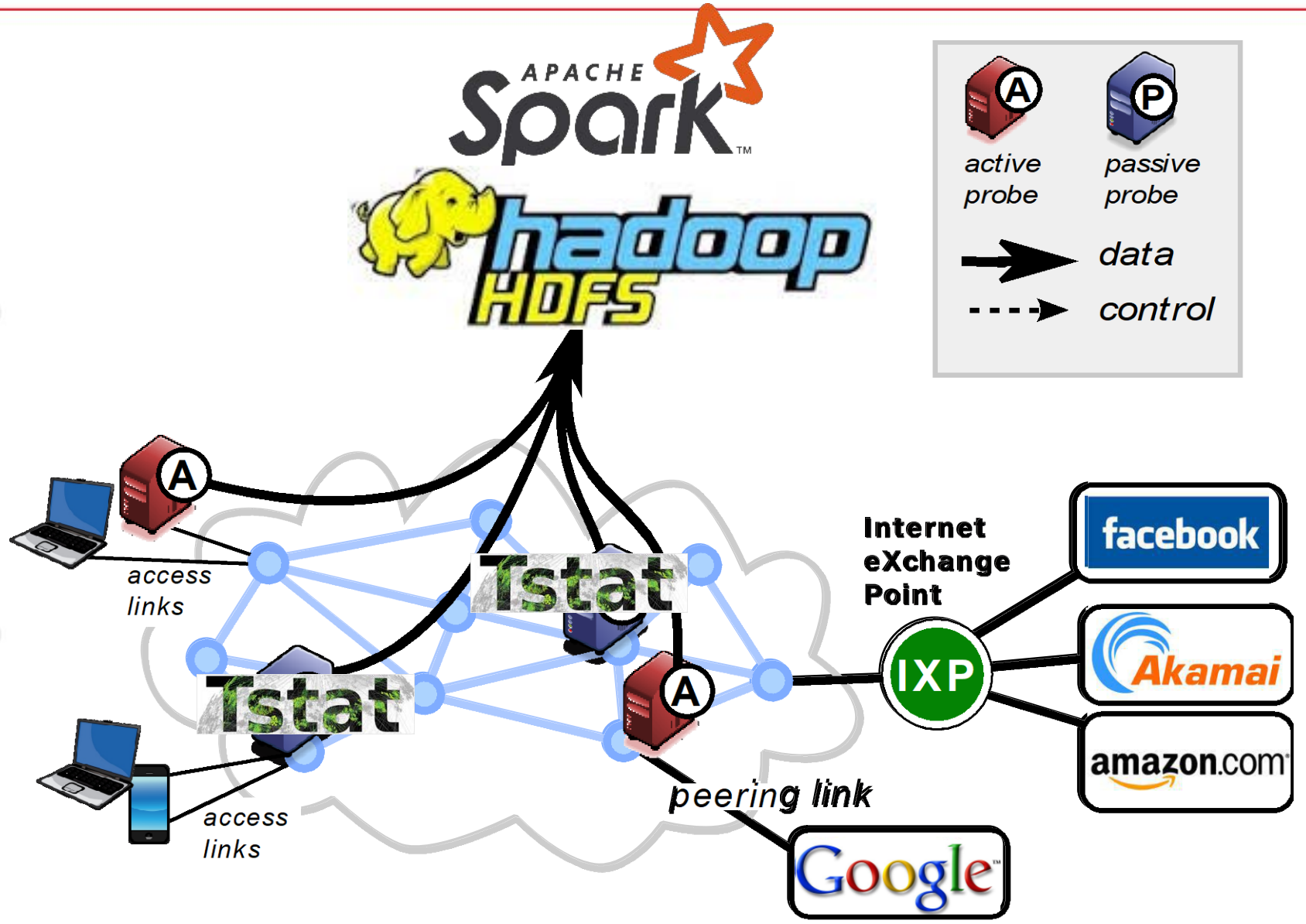

Tstat: Polito passive probe

- Statistical Analysis at IP/UDP/TCP
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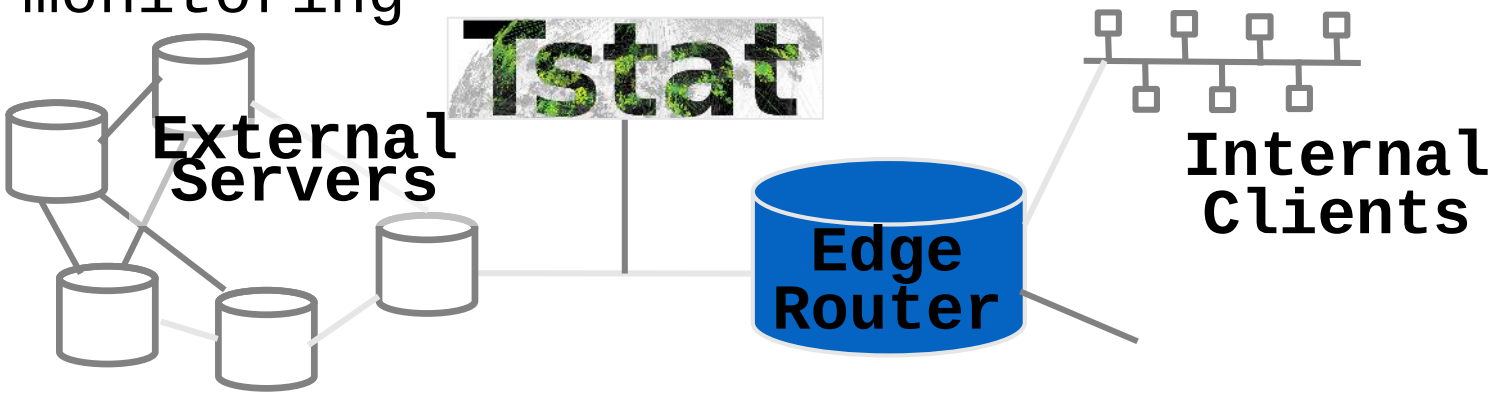
  - Rebuild bidirectional flow connections
  - Features real-time analysis (pcap, DAG, DPDK)
  - Offers persistent and scalable monitoring



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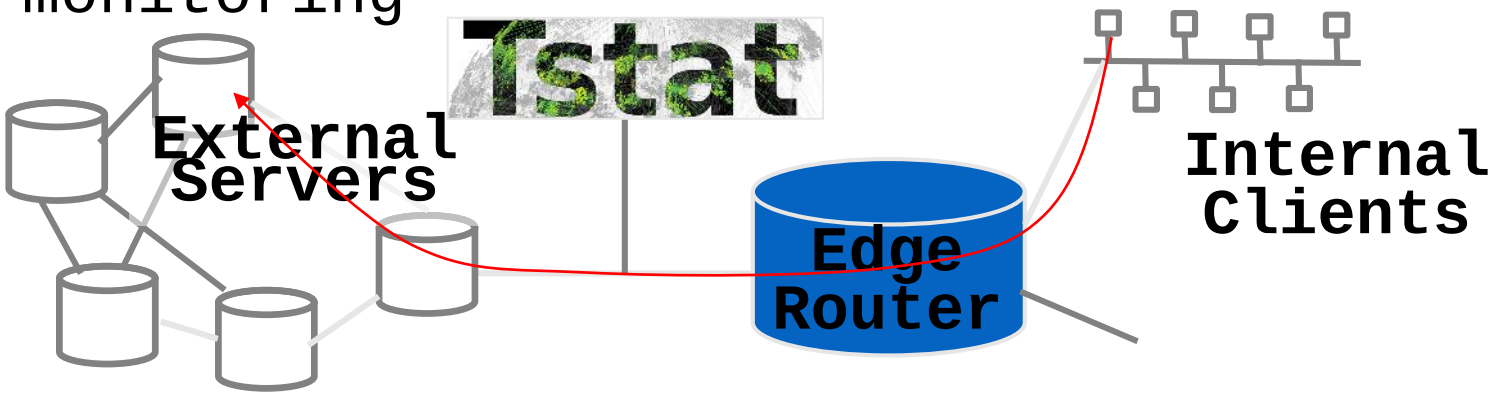

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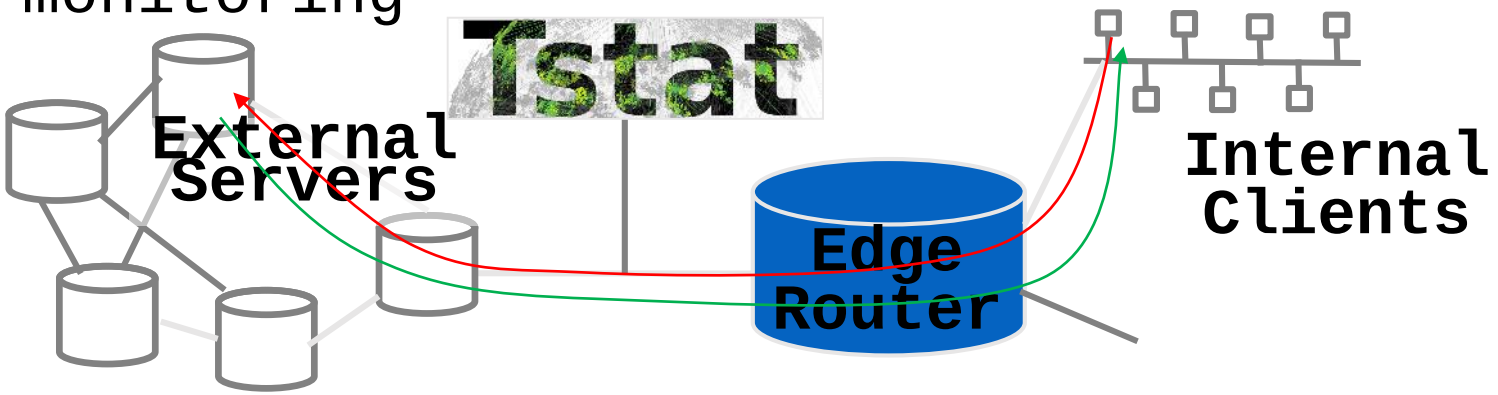

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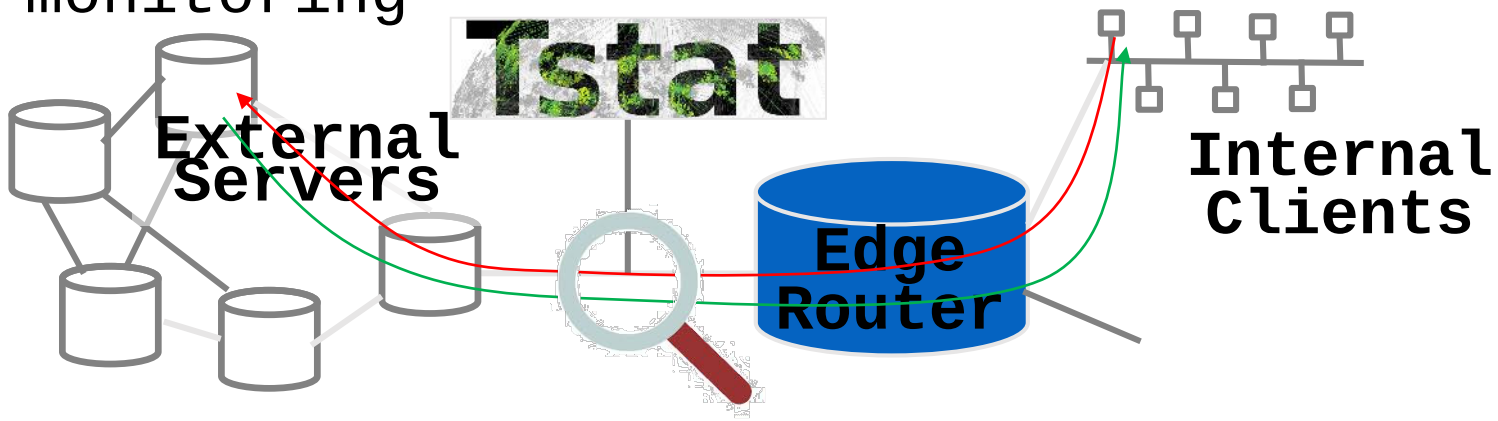

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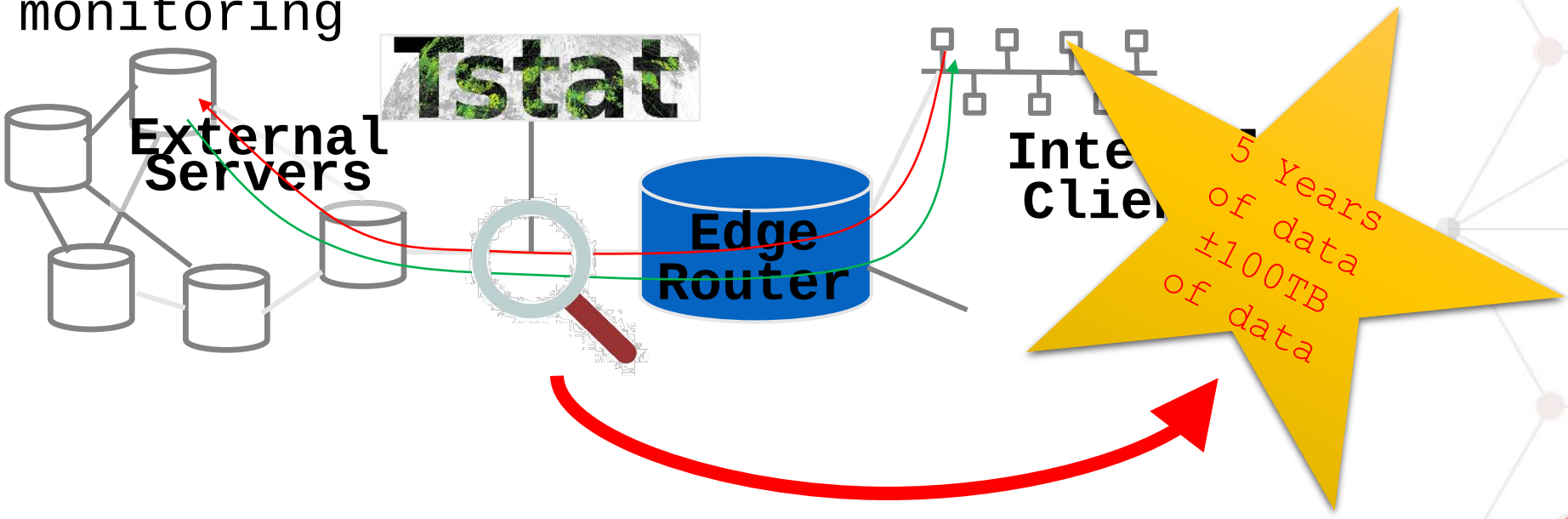
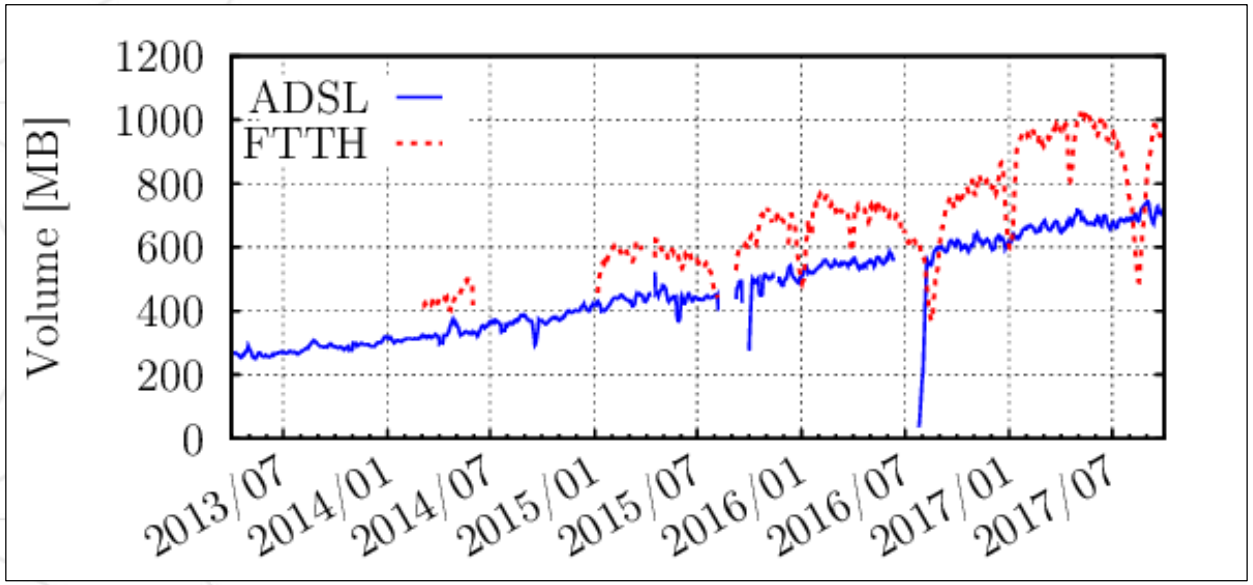


The Internet over the years



"Cost" of a broadband subscriber per day

Trevisan, M.; Giordano, D.; Drago, I.; Mellia, M.; Munafo', M., *Five years at the edge*, in: ACM CoNEXT 2018

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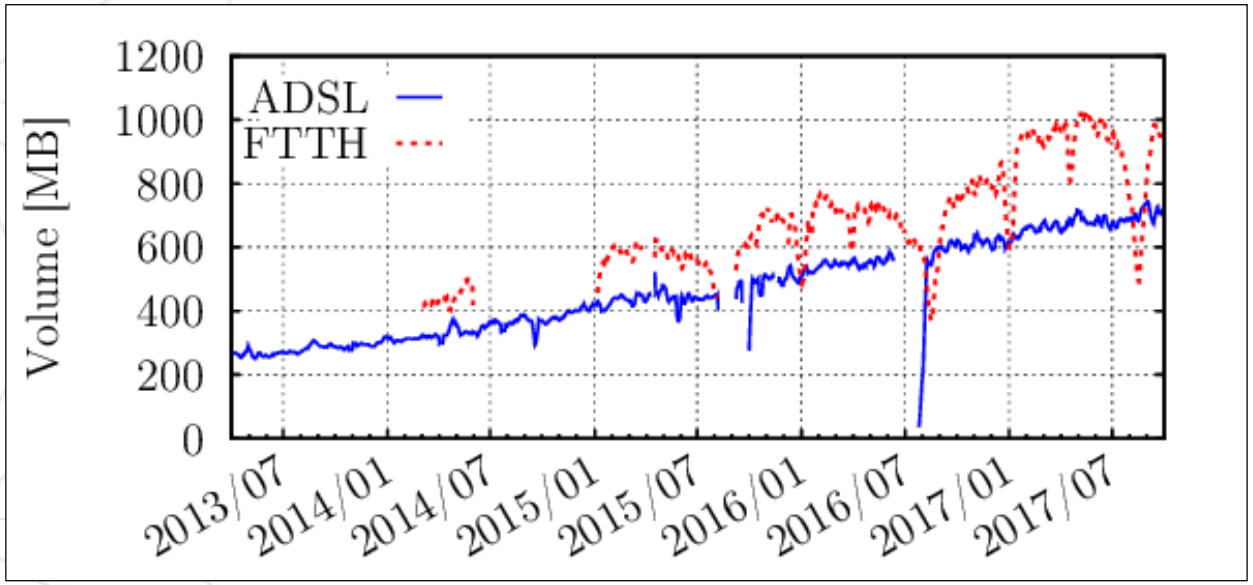

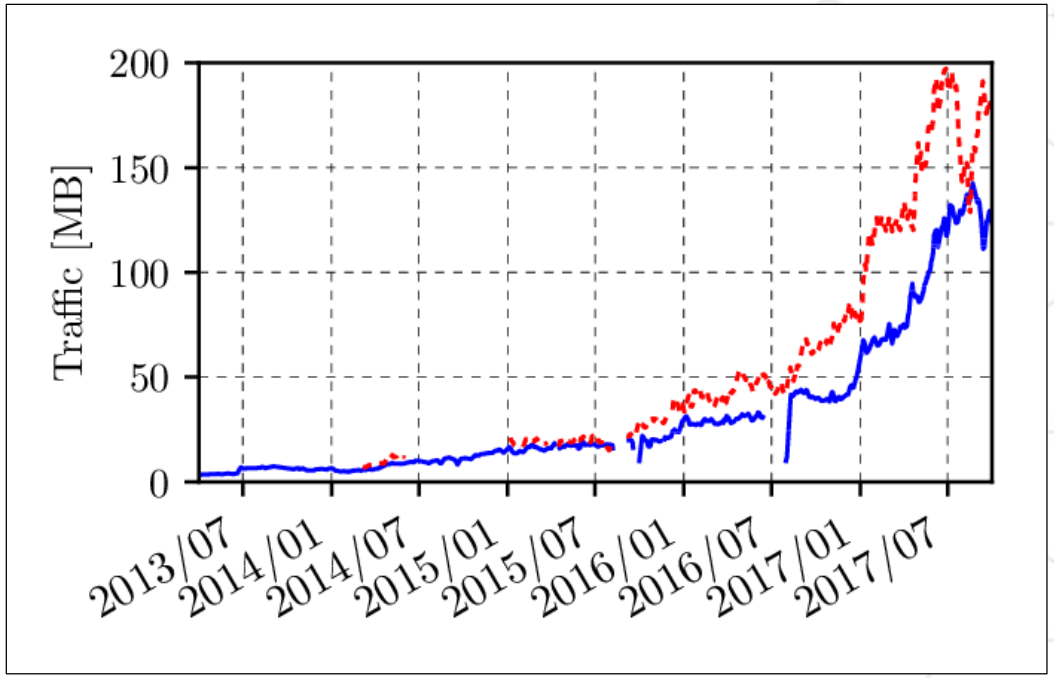

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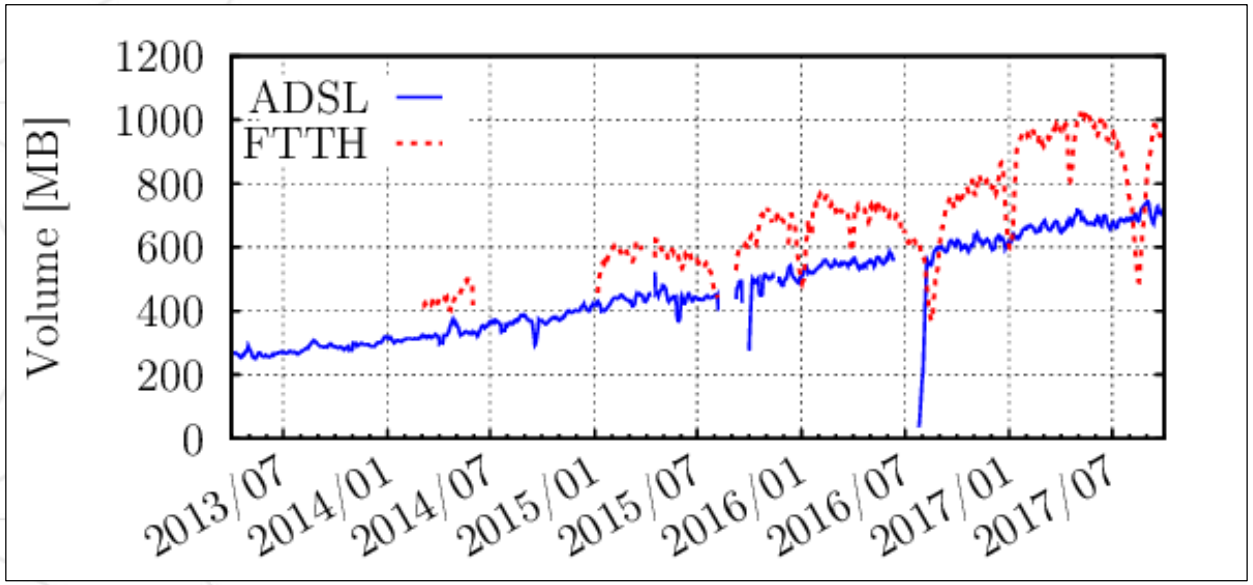

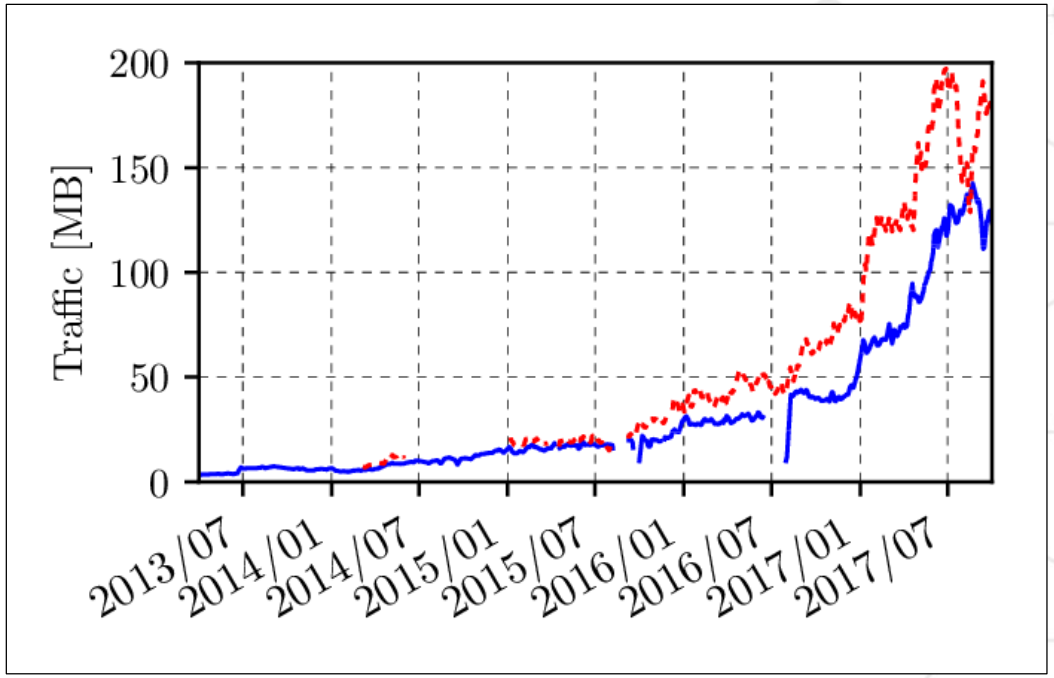

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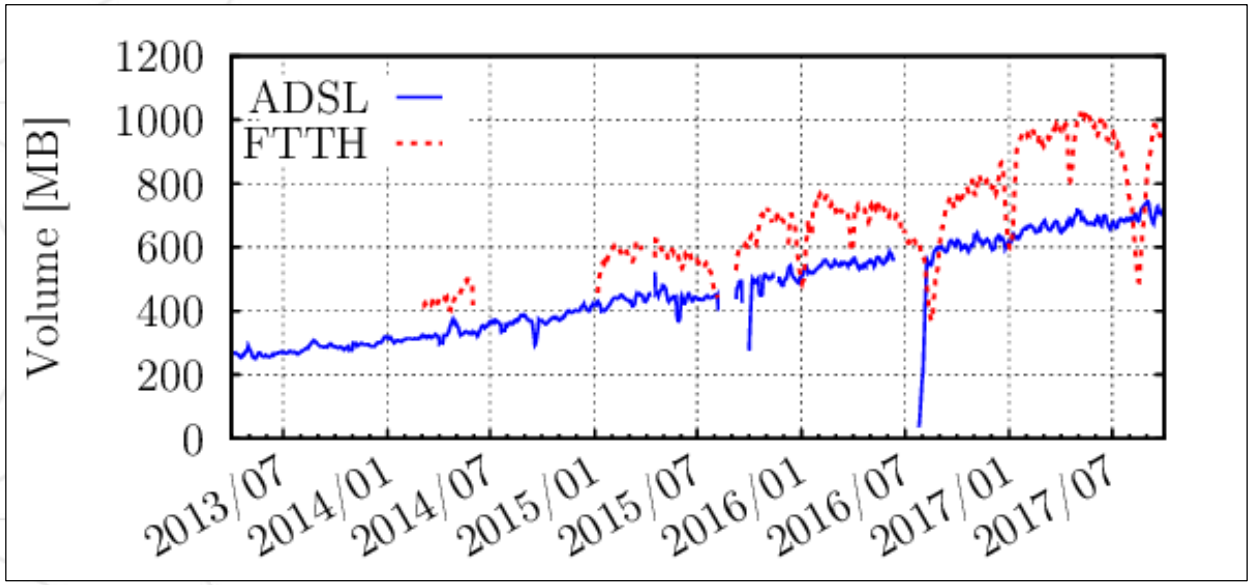

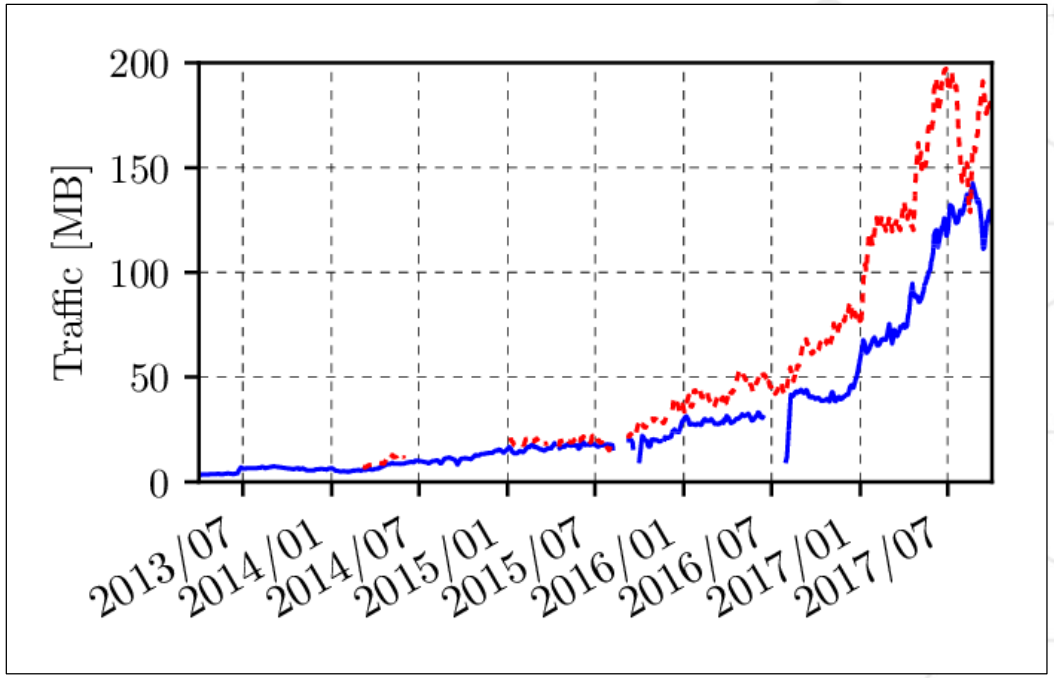

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- These are benign services, which do not try to evade the monitoring
- Algos to identify traffic even when encryption is in place

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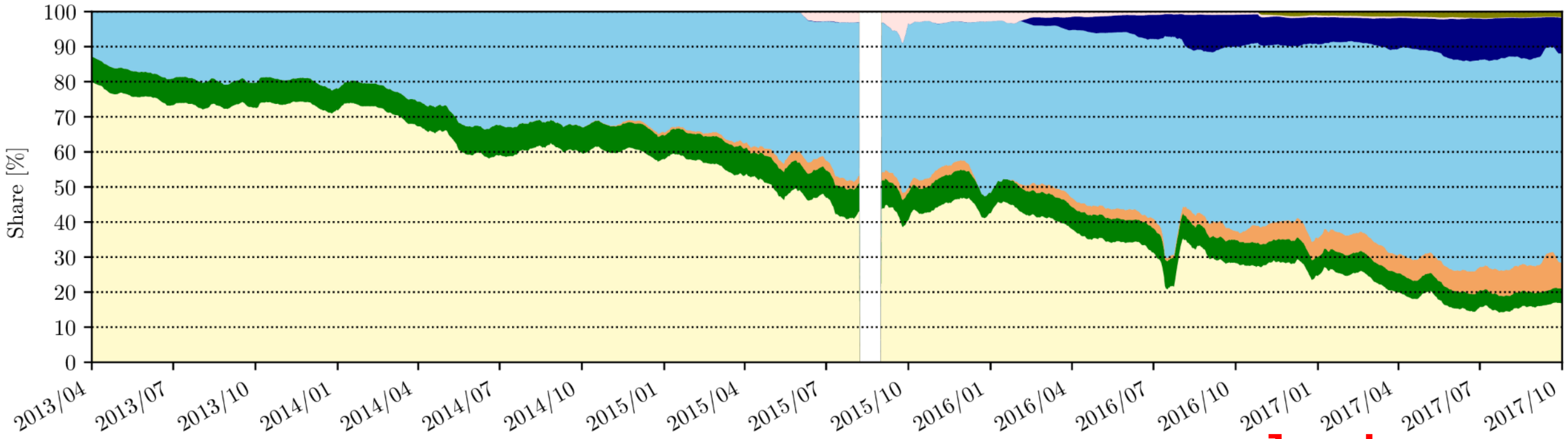
Protocol usage over the years



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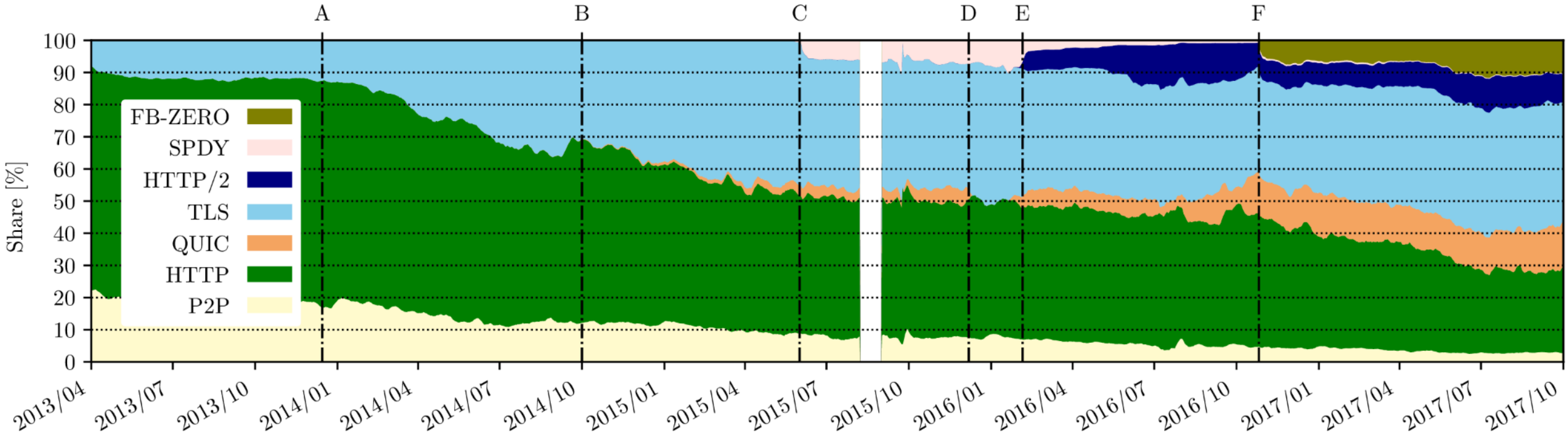

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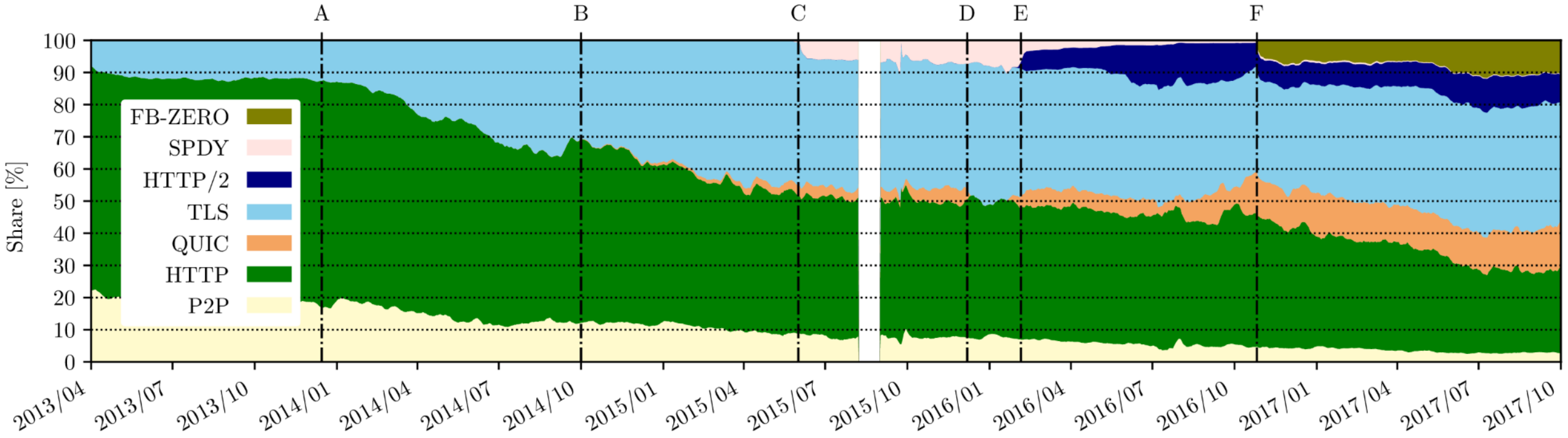

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- These figures miss what is actual users' traffic and what is unsolicited/background/malicious traffic

Unanswered incoming traffic

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- **Low volume, high numbers of flows**
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  - Users’ routine on-line/off-line
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- Yet letting people perform analysis in our premises is generally fine

~~Darknets @Polito~~

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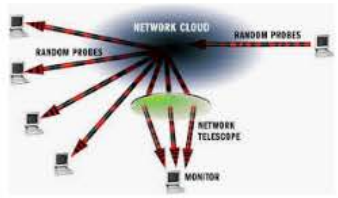

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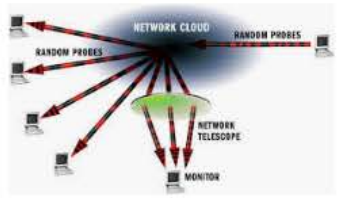

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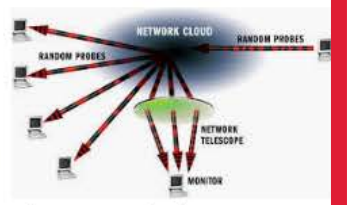

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Why?

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- From ISPs (and our IT) we get questions such:
  - What is this weird activity on port X ?
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  - Anyone vulnerable to Y ?
  - Latest one: Is my network sending traffic to darknets? Which nodes?
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- With passive TSTAT traces we perform post-mortem analysis
  - Often too little information for stealth cases (not the big scans)
- **Darknets and Honeypots**
  - Get context on unsolicited traffic we see in production
  - Transfer knowledge from our lab to other networks (!?)

Data sources

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- Internet darknet @Polito
  - GaRR Autonomous System
  - Few IP addresses – **now 3 x /24 IPv4 (to be expanded in GaRR)**
  - Long-term: any unused IP addresses @polito (even temporarily)
  - **IP addresses recently used in production**

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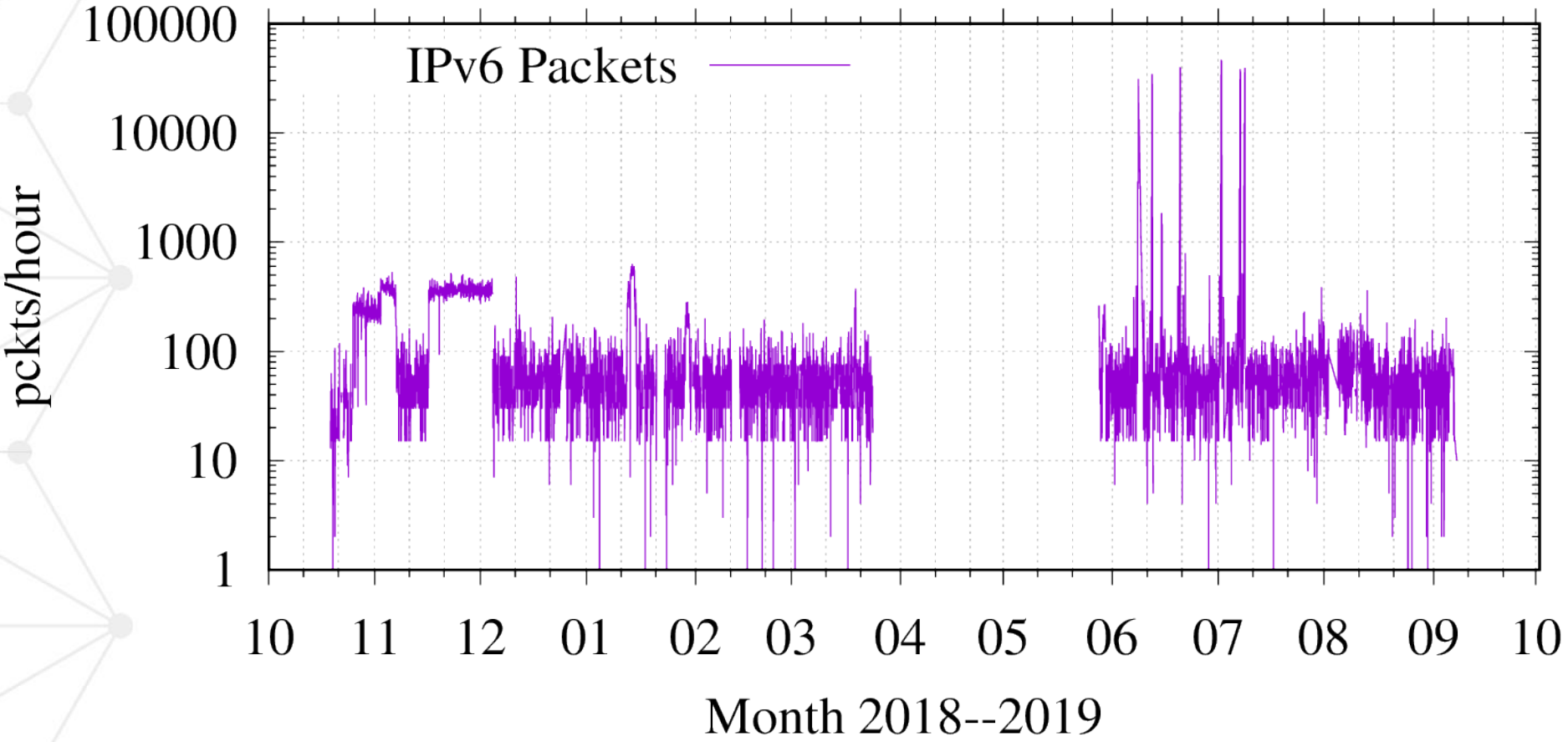
  - Long-term: any unused IP addresses @polito (even temporarily)
  - **IP addresses recently used in production**
- Internet darknet @RNP (BR)
  - **/19 IPv4**
  - **/33 + /48 IPv6**
  - **IPv4** allocated to production traffic few years ago

IPv6 (baseline)



- Dominated by researchers (mostly ICMPv6)
  - e.g., reverse lookup: yhu-ca.**caida**.ebox.ca, **caida-gw**.ip6.gtt.net
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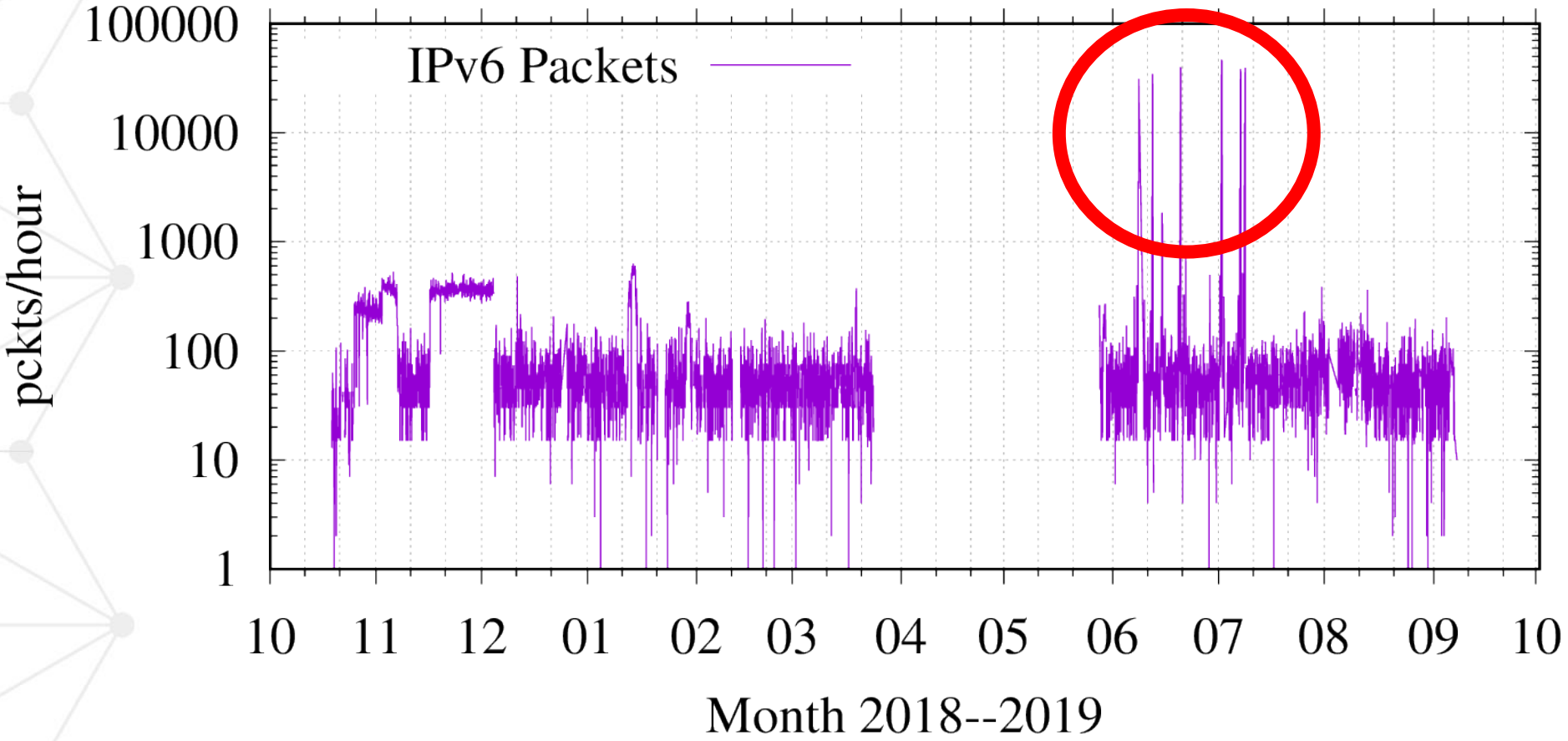

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IPv4 sanity checks

The IPv4 darknets:

- **/15** in the Netherlands (baseline)
  (**30 GB of PCAPs/day**)
- **/19** in Brazil
  (**2.5 GB of PCAPs/day**)
- **3 /24** in Italy
  (**420 MB of PCAPs/day**)
- when comparing darknets, extract **samples of similar size (# IP addresses)**

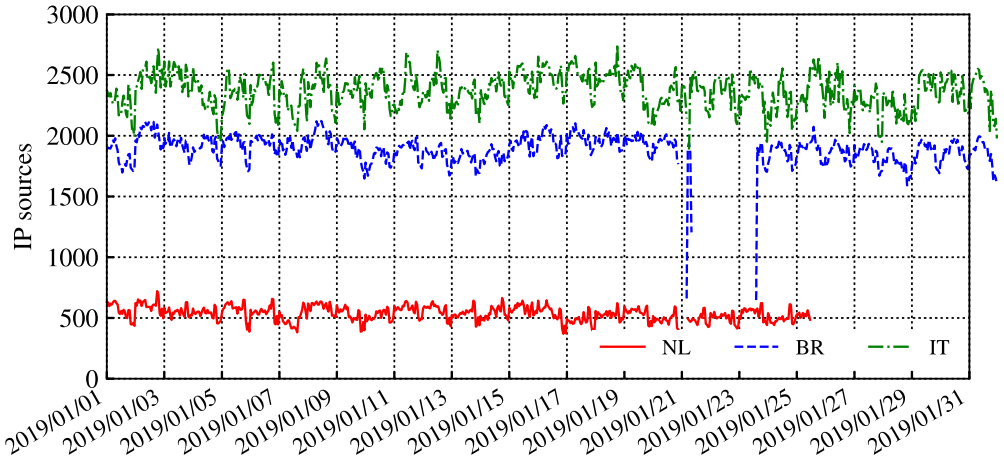
Methodology

- Get data from a large and more established darknet (@SurfNet)
- Compare traffic among the darknets
- Check if differences are inline with the literature
  - CAIDA/Merit‘s data [*]

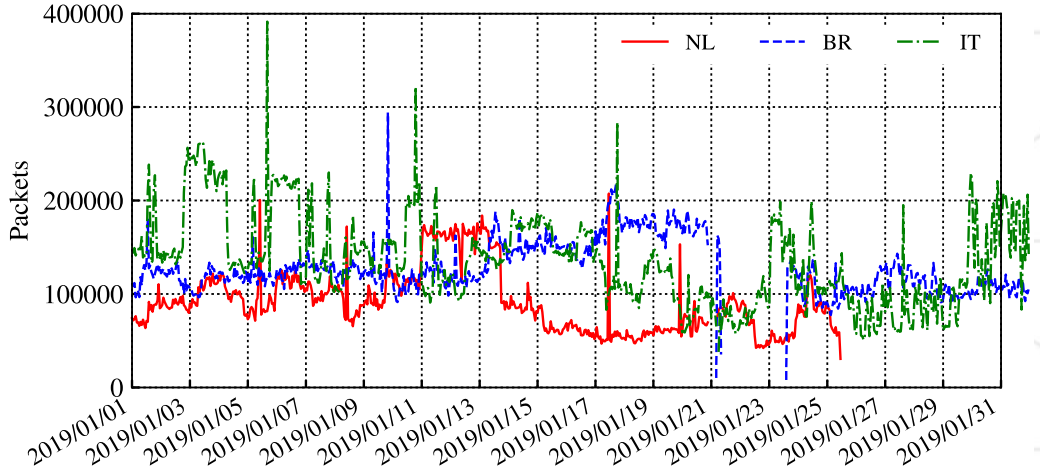
[*] K. Benson, A. Dainotti, K. Claffy, A. C. Snoeren, and M. Kallitsis, “Leveraging Internet Background Radiation for Opportunistic Network Analysis,” in Proc. of the IMC, 2015, pp. 423-436.

Temporal patterns

Top-talkers (at least 10 flows in 1-hour bin)



Number of distinct source IPs



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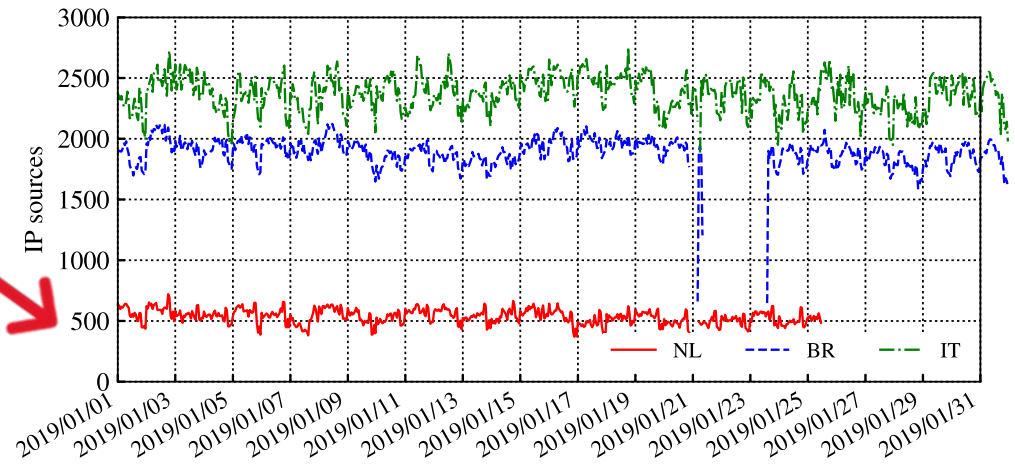

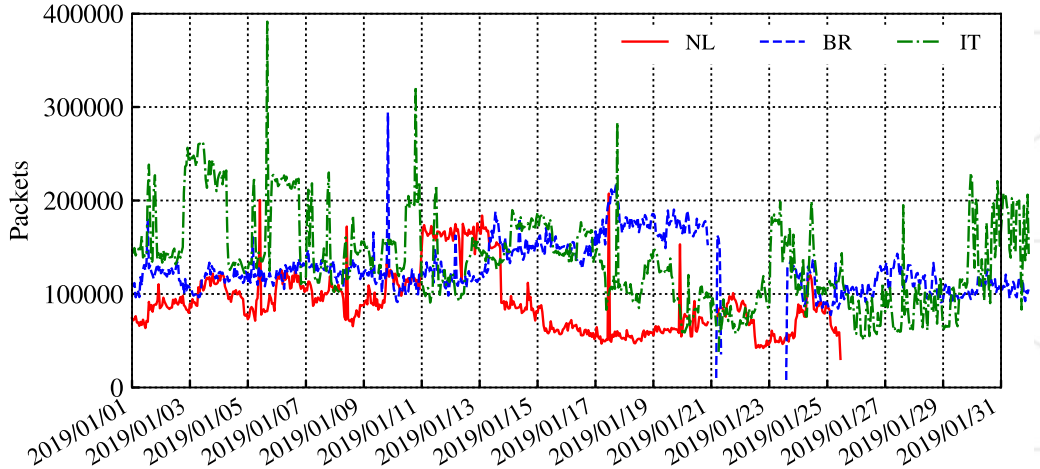

Number of distinct source IPs

Number of packets

#packets is **noisy and irregular**, and differs for darknets.
IP address of senders show a **more regular** distribution over time

Sources – countries

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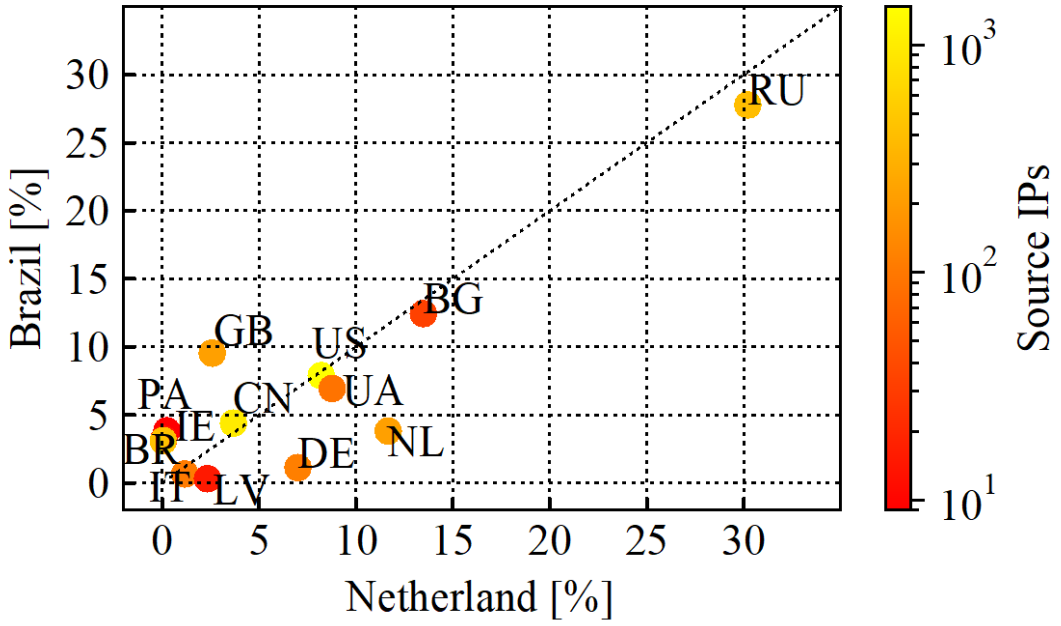


Packets from almost **all countries** are seen in **all** darknets

The **most active sources** are **similar**

Sources – ASes

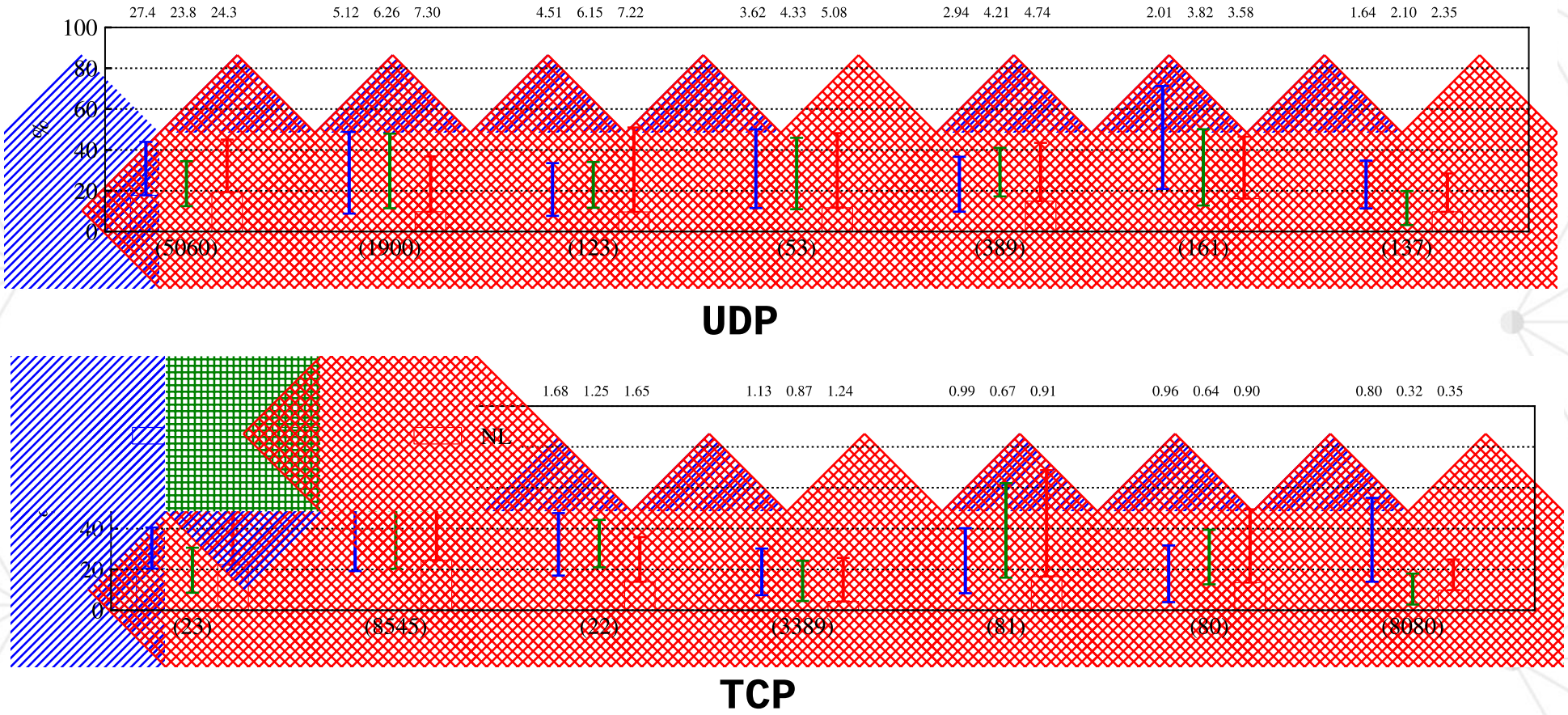
Top-talkers (at least 10 flows in 1-hour bin)

BR			NL			IT		
ASN	pkts (%)	IPs	ASN	pkts (%)	IPs	ASN	pkts (%)	IPs
49453	14.8	8	49505	10.57	15	43350	22.18	12
57043	10.72	15	**202325**	9.94	11	**204428**	7.17	24
202325	6.5	12	**204428**	7.52	20	**58271**	7.05	22
58271	5.18	19	**58271**	6.9	19	51852	6.69	5
204428	3.74	18	201912	5.8	8	**57043**	6.28	16

Very few IP addresses produce the largest amount of traffic

Most active ASes are visible in **all** darknets (mostly from **RU/CN/BG**)

Per-port breakdown

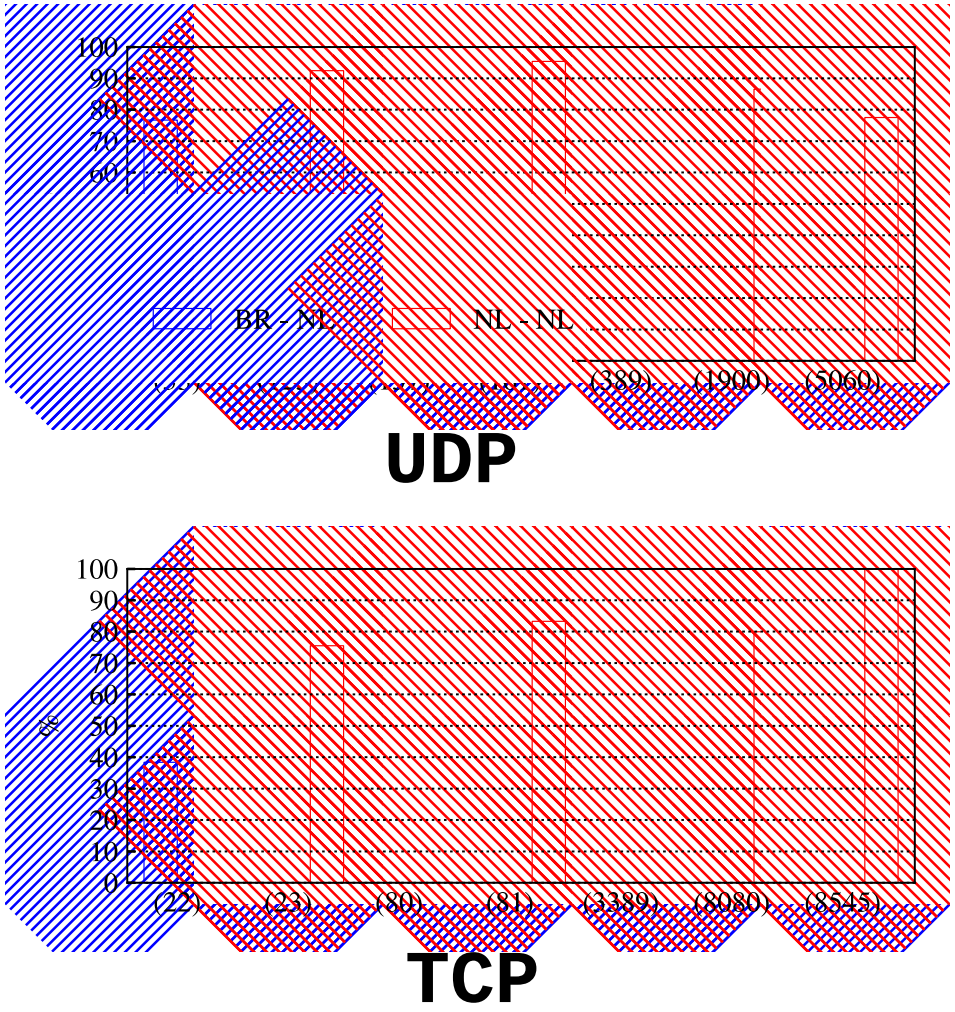


No big surprise either – the usual suspects are hit.

The most active IP produces the 10-20% of traffic

Per-port breakdown

How spread are the sources?

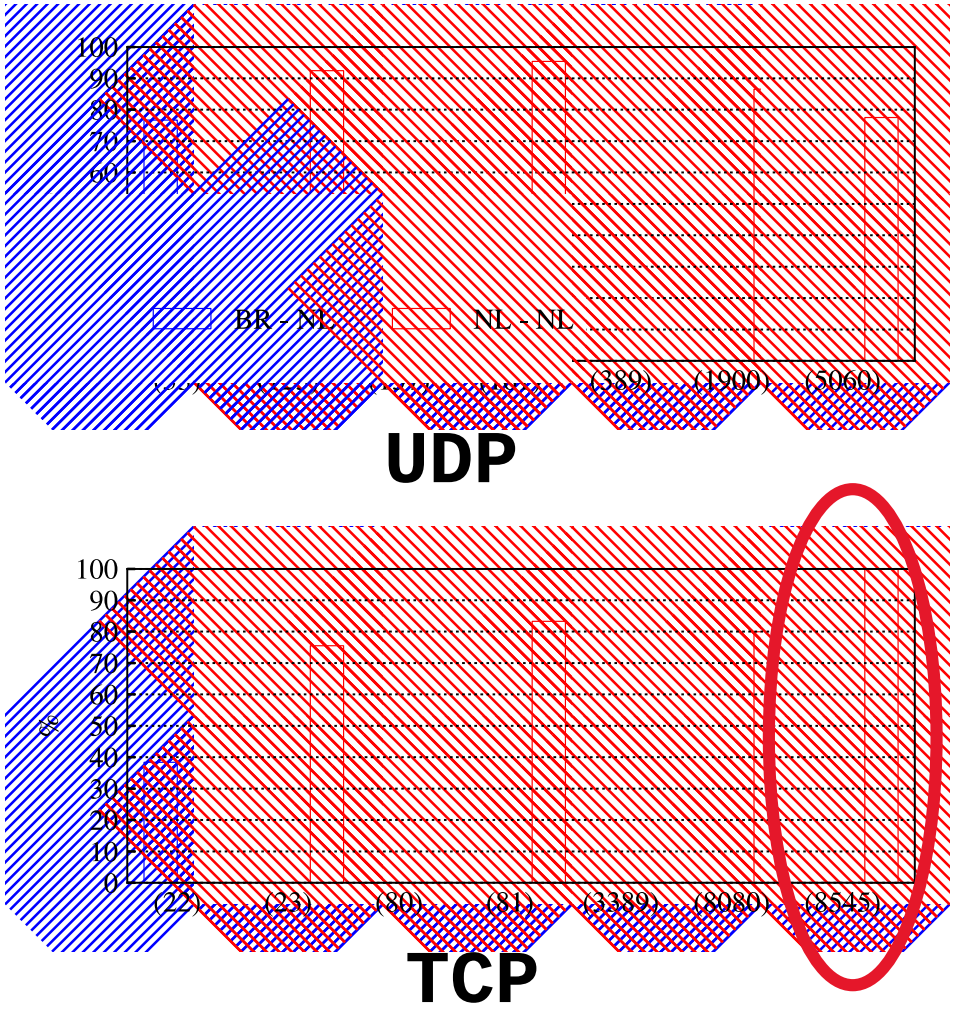


Jaccard Index to measure similarity between the traffic sources:

$$\frac{set(ASes_{BR}) \cap set(ASes_{NL})}{set(ASes_{BR}) \cup set(ASes_{NL})}$$

Per-port breakdown

How spread are the sources?



At least **half of the source ASes** are always visible on both darknets

TCP targets tend to be hit by **more distributed sources.**

Some exceptions

Summary

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- Major properties follow those reported in literature
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  - IP addresses used in production more recently
  - Few packets sent by large number of sources (tail of popularity dist.)
- BR and IT darknet are operative since Sept 2018
- Data can be shared for research purposes

Beyond the darknets

Getting even more dust

- **HoneyPort**
  - Deploying flexible honeypots for adding context to darknet traces

- **Why:**
  - **We would like to add meta-data to traffic as much as we can, e.g.,**
    - **These packets are someone scanning with tool X**
    - **This is MIRAI botnet**
    - **... in production: these packets were a follow up of that scan**
  - **We are still in explorative phase, not clear how far we can go**

Goals and methodology

- Understand why someone is contacting us
  - Engage attackers
  - Produce fingerprints
  - Seed models to classify the packets

- Low-interaction honeypots (specific tasks)
  - **e.g., Save first packets after TCP/TLS handshake**
  - e.g., COWRIE, a ssh honeypot collecting binaries and passwords
  - ...

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- High-interaction honeypots based on virtualization
  - Containers/VMs with realistic setup for high interaction
  - Build on top of **virtual machines** and **virtual networks**

Tones of honeypot options!

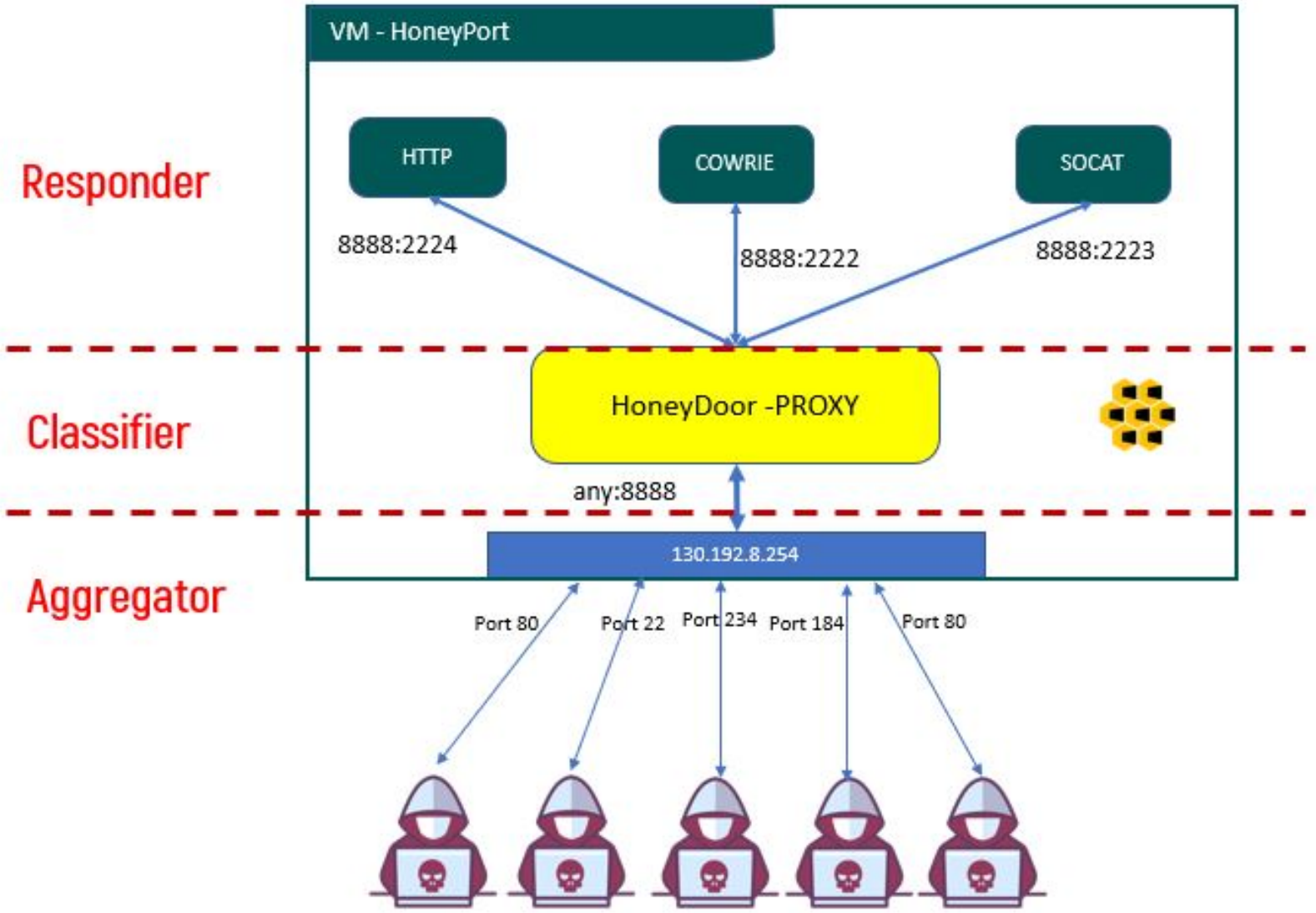
Tones of honeypot options!

Table III
CHRONOLOGICAL OVERVIEW AND CLASSIFICATION OF SERVER HONEYPOT SOFTWARE BY THEIR INTERACTION LEVEL TYPE. (+) INDICATES SOME ADDITIONAL SERVICES, (++) INDICATES MANY ADDITIONAL SERVICES, (*) MARKS VAGUE TIMESTAMPS.

Type	Software	Maintenance: First	Maintenance: Last	Free	Focus: Services / Applications	Focus: Design / Details
low	DTK [31]	1997	1999	✓	SMB, SSH, DNS, FTP, Netstat(++)	implement many known vulnerabilities
low	BOF [32]	1998	1999	✓	Back Orifice, Telnet, SMTP(+)	waste intruders time, easy deployment
low	NetFacade [42]	1998	2002*	✗	*not specified*	class C network emulation
low	CyberCop Sting [33]	1999	1999	✗	Telnet, FTP, SendMail, SNMP	emulating different network devices
low	Specter [44]	1999	2005	✓	SMTP, FTP, HTTP and Telnet(+)	commercial deployment, decoy files
low	Sandtrap [97]	2002*	2002*	✗	dialup modem	war dialing trapping
low	single-honeypot [43]	2002	2002	✓	*all ports, but no emulation*	mere logging, KISS architecture
low	HoneyWeb [98]	2002	2003	✓	HTTP	various web server header emulation
low	LaBrea [39]	2002	2003	✓	*all ports, but no emulation*	simple TCP tarpit by SYN/ACK
low	SMTPot [38]	2002	2003	✓	SMTP	spam accumulation, KISS
low	THP [46]	2002	2003	✓	SSH (shell), HTTP, FTP	coexistence honeypot and real services
low	Jackpot [35]	2002	2004	✓	SMTP	delay spam, utilizing spam databases
low	FakeAP [79]	2002	2005	✓	802.11b AP beacons	p.o.c wireless honeypots
low	HoneyBot [34]	2002*	2007*	✓	SSH, SMTP, FTP, HTML(++)	windows vulnerabilities and GUI
low	BigEye [8]	2003	2003	✓	HTTP, FTP	emulation of different web servers
low	Spamhole [59]	2003	2003	✓	SMTP	silent dropping of emails
low	Spampot [90]	2003	2003	✓	SMTP	platform independence
low	HoneyPerl [36]	2003	2003	✓	HTTP, FTP, SMTP, Telnet(+)	extensibility by modules
low	Decoy Server [45]	2003*	2003	✗	SMTP, POP3	fake email server traffic
low	Smoke Detector [8]	2003*	2004*	✗	FTP, HTTP, IMAP, SSH, SMB(++)	honeypot as a hardware
low	NetBait [41]	2003	2007*	✗	*not specified*	honeypot as a service
low	HoneyD [28]	2003	2008	✓	HTTP, POP3, SMTP, FTP(+)	emulating heterogeneous networks
low	KFSensor [58]	2003	2015	✗	HTTP, SMTP, MSSQL, FTP(+)	commercial deployment of honeypots
low	SpamD [56]	2003	2015*	✓	SMTP	tarpit against spam
low	HOACD [15]	2004	2004	✓	*compare HoneyD*	live bootable CD (HoneyD, Arpd)
low	ProxyPot [57]	2004*	2004*	✓	SMTP	email spammer identification
low	Impost [37]	2004	2004	✓	*all ports, but no emulation*	full packet sniffing
low	Kojoney [63]	2005	2006	✓	SSH (shell activity)	first dedicated SSH honeypot
low	Mwcollect [53]	2005	2009	✓	*compare Nepenthes, Honeytrap*	merging Nepenthes and Honeytrap
low	Nepenthes [47]	2005	2009	✓	FTP, HTTP, TFTP, MSSQL(++)	capture worm payload
low	GHH [70]	2005	2013	✓	HHTP-Apache, PHP, MSSQL	crawler and search engines
low	Honeytrap [51]	2005	2015	✓	HTML, FTP(+), *dyn. emulation*	attacks via unknown protocols
low	HoneyPoint [96]	2006	2014	✗	*not specified*	ICS/Scada, back tracking intruders
low	Dionaea [49]	2009	2013	✓	SMB, FTP, SIP, MYSQL(++)	nepenthes successor, capture payload
low	Kippo [65]	2009	2014	✓	SSH (shell activity)	emulate entire shell interaction
low	Artemisa [78]	2010	2011	✓	VoIP, SIP	Bluetooth Malware
low	bluepot [81]	2010	2015	✓	Bluetooth	Bluetooth Malware
low	HoneySink [91]	2011	2011	✓	DNS, HTTP, FTP, IRC	bot sink holing
low	HoneyDroid [85]	2011	2014*	✓	*compare Kippo, HoneyTrap*	p.o.c Android OS honeypot
low	Glastopf [67]	2011	2015	✓	HTML, PHP, SQL	web applications, vulnerability types
low	Kojoney2 [64]	2012	2015	✓	SSH (shell activity)	applying Kojoneys lessons learned
low	Conpots [99]	2013	2015	✓	kamstrup, BACnet, modbus	ICS and SCADA architectures
low	IoTPOT [85]	2014*	2015	✓	telnet	IoT (ARM, MIPS, and PPC)
low	honeypot-camera [86]	2014	2015	✓	HTTP	Tornado Web, Webcam Server
low	Shockpot [87]	2014	2015	✓	Apache, Bash	Shellshock vulnerability
low	Cowrie [66]	2014	2015	✓	SSH (shell activity)	Kippos successor
low	Canarytokens [99]	2015	2016	✓	URLs, bitcoin, PDF	honeypot tokens
low	elastichoney [69]	2015	2015	✓	elasticsearch	elasticsearch RCEs
high	Sebek [97]	2003	2011	✓	Win32 and Linux systems	attackers OS activities, state-based
high	Honeywall [93]	2005	2009	✓	*compare Sebek*, CentOS	live bootable CD
high	HoneyBow [96]	2006	2007	✓	Win32 Systems	extraction of malware, state-based
high	Argos [92]	2006	2014	✓	Linux, Windows XP-7	0-day exploits identification, tainting
high	HIHAT [94]	2007	2007	✓	php-BB,-Nuke,-Shell,-Myadmin	PHP framework extension, state-based

- Usually very targeted
- We wanted something more general
- No fine-grained malware binaries, but traffic meta-data
- Inspiration from different honeypots, in particular from the **Dionaea honeypot**

HoneyPort Architecture



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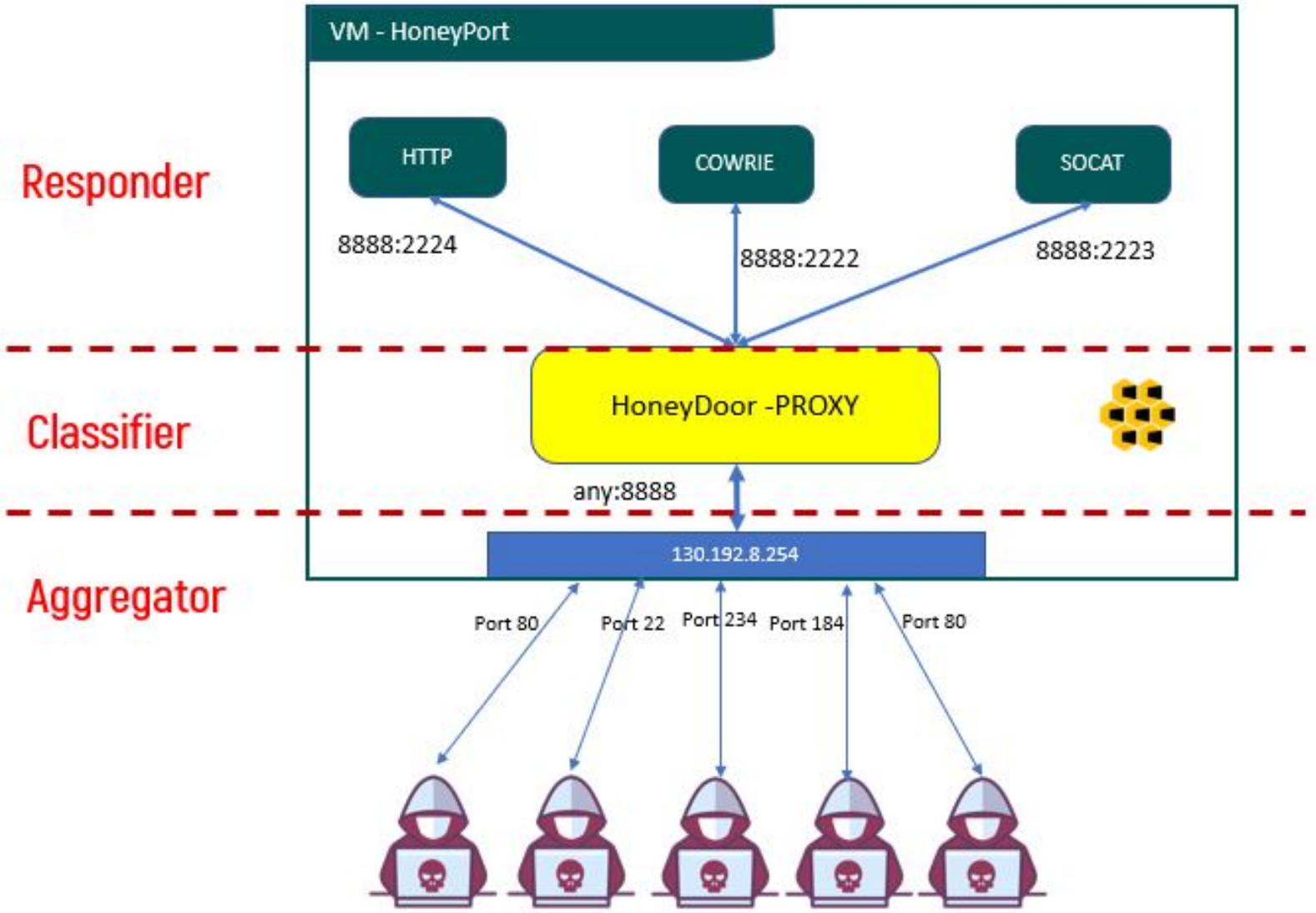

- L4 proxy (MiTM)

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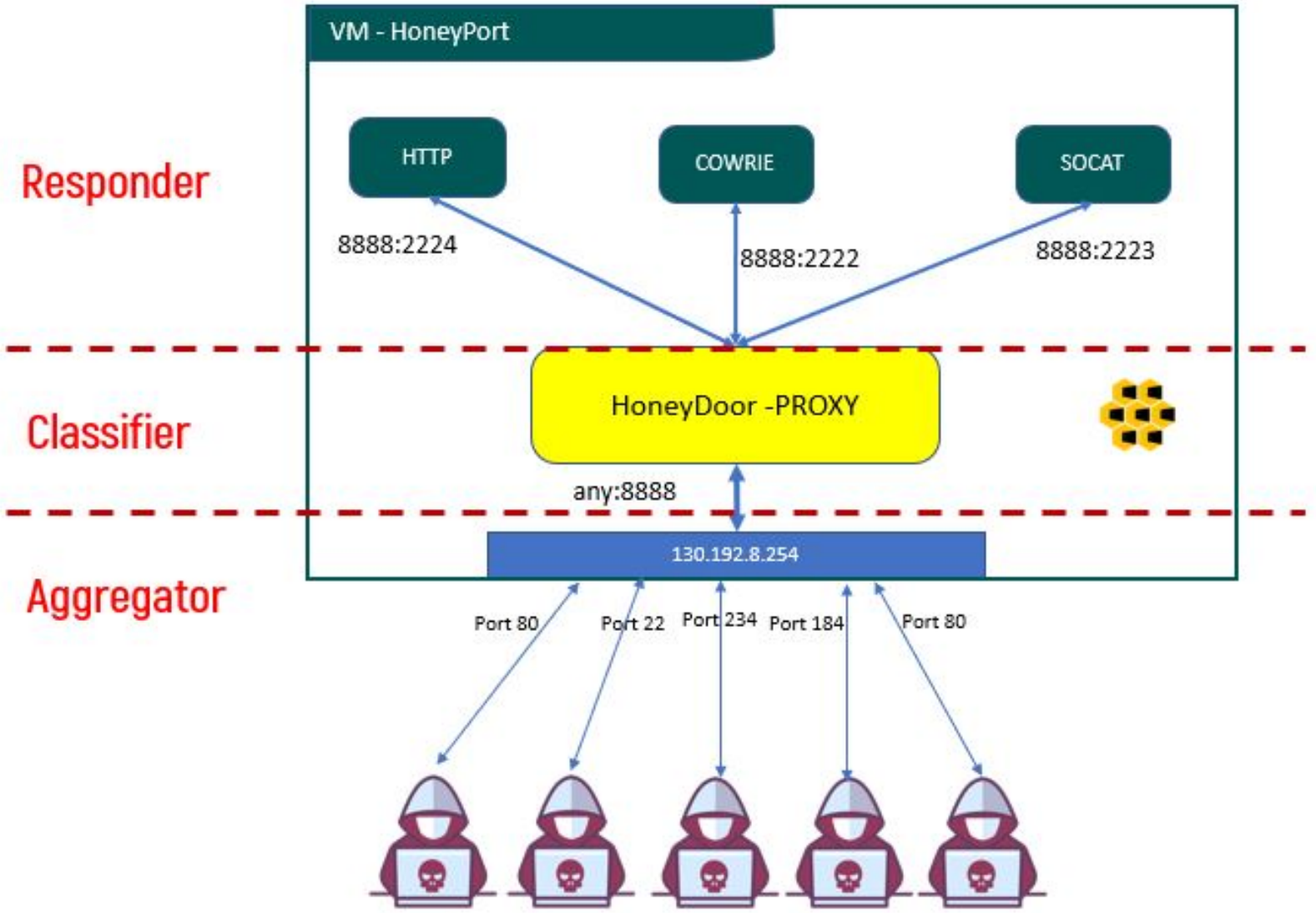

- L4 proxy (MiTM)
- Keep context & packets
- Steer traffic to backends
- e.g, SSH on port 2222 will end in Cowrie
- e.g., web request on port 2222 will end on webserver

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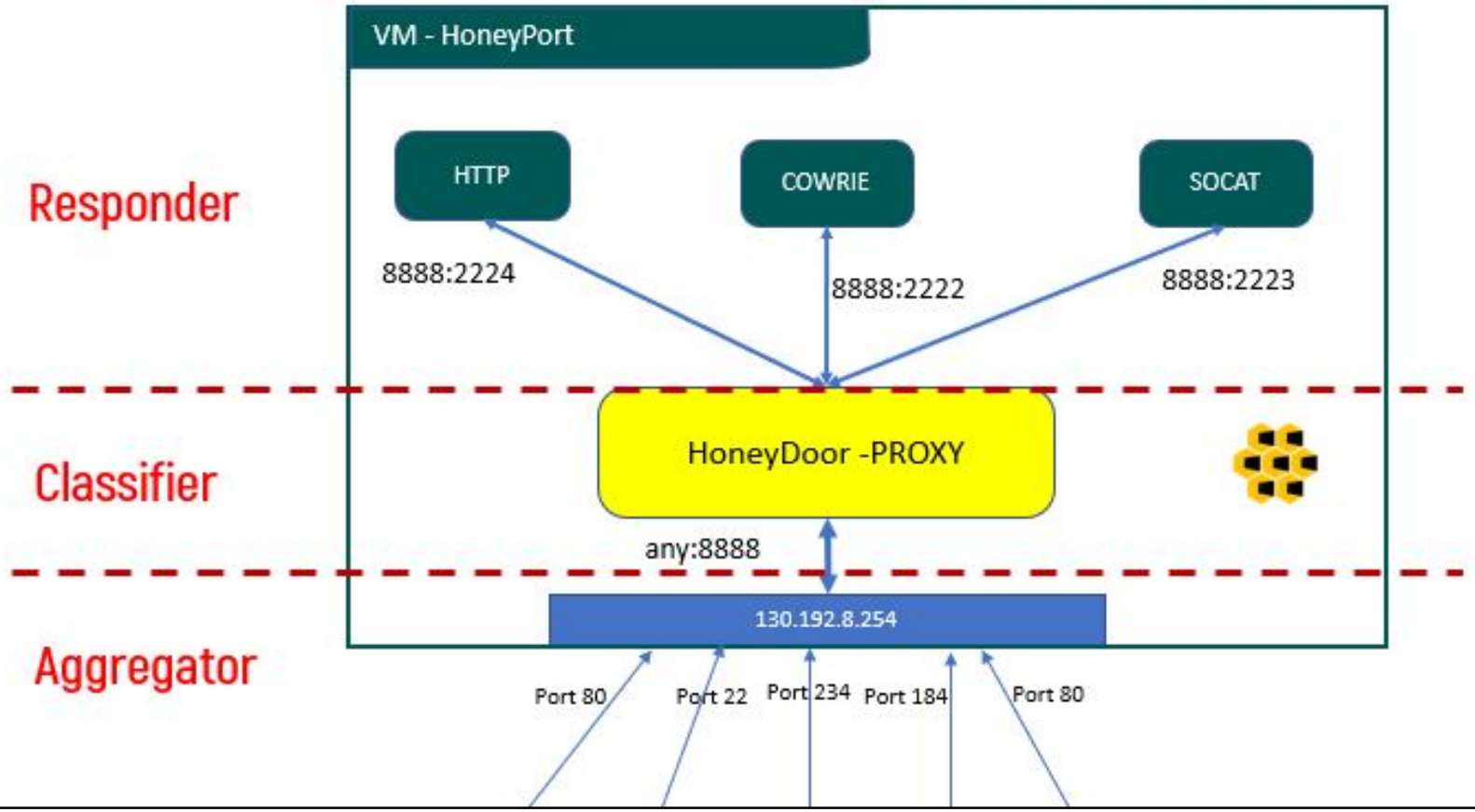

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- e.g, SSH on port 2222 will end in Cowrie
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- Flexible deployment of the most “suitable” honeypot
- Rotate in the IP addresses in the space to avoid blacklisting
- Incrementally learn how to answer incoming packets

HoneyPort – Initial data

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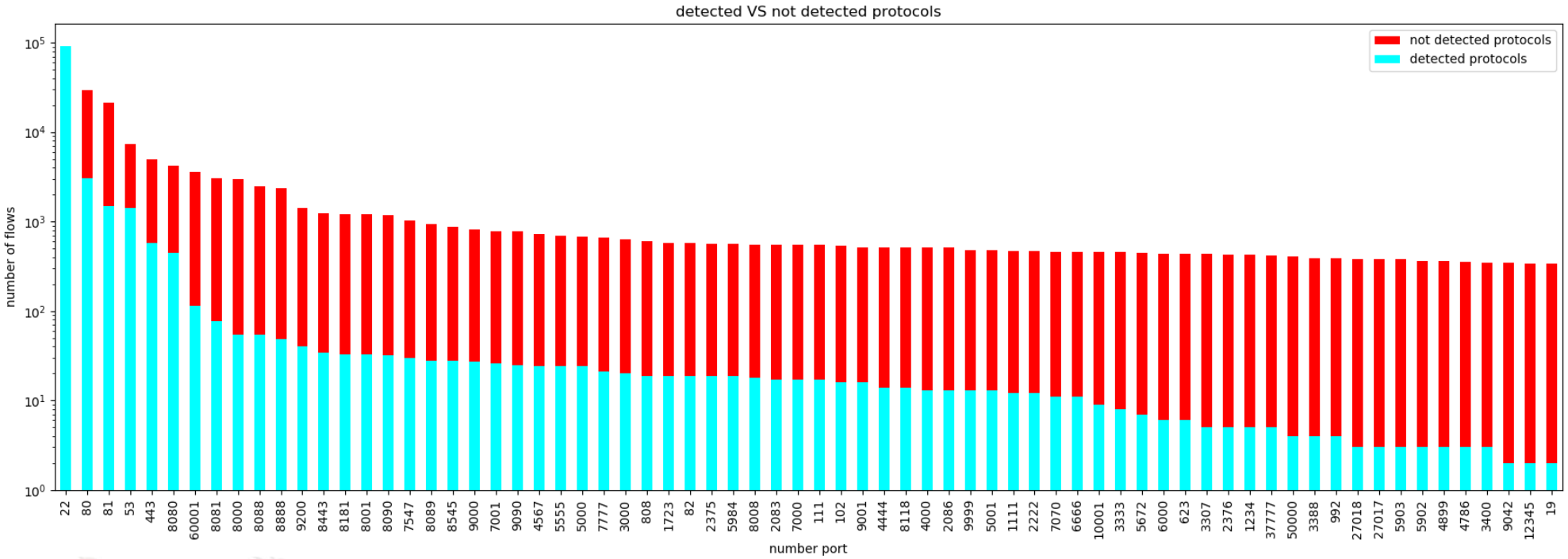

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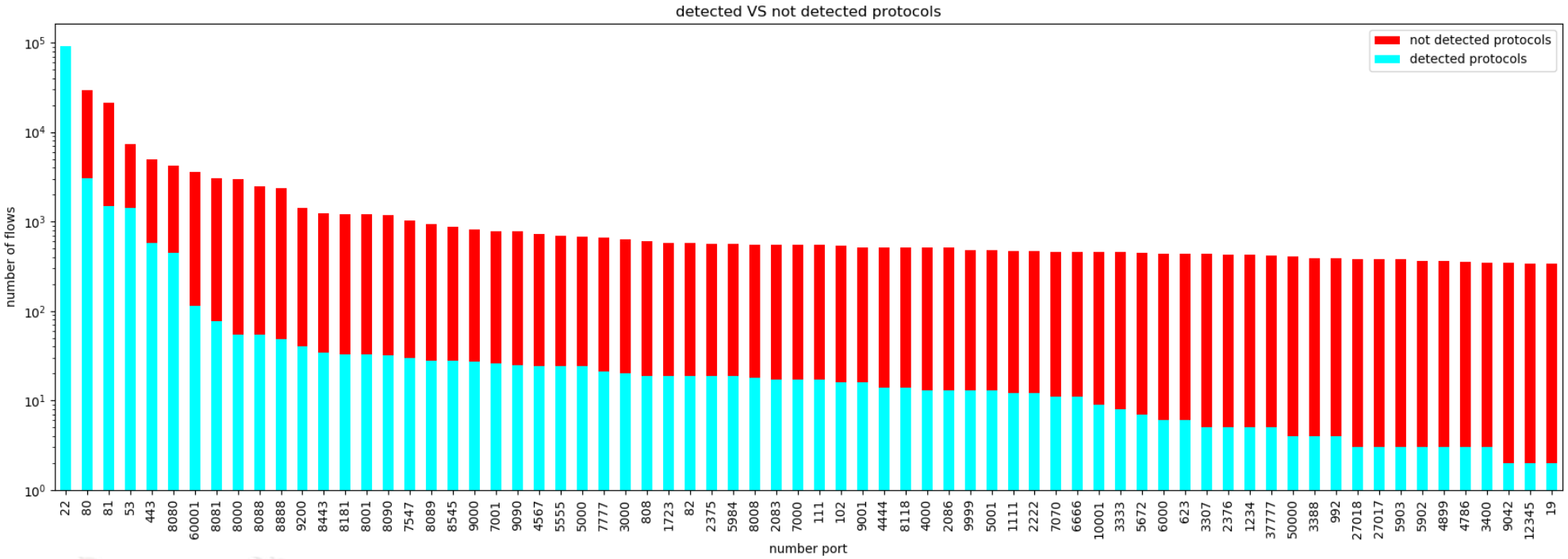

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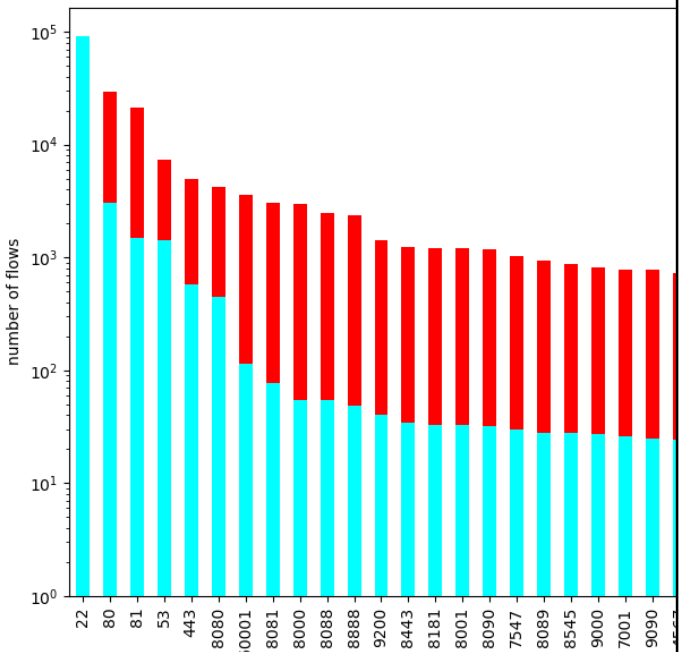

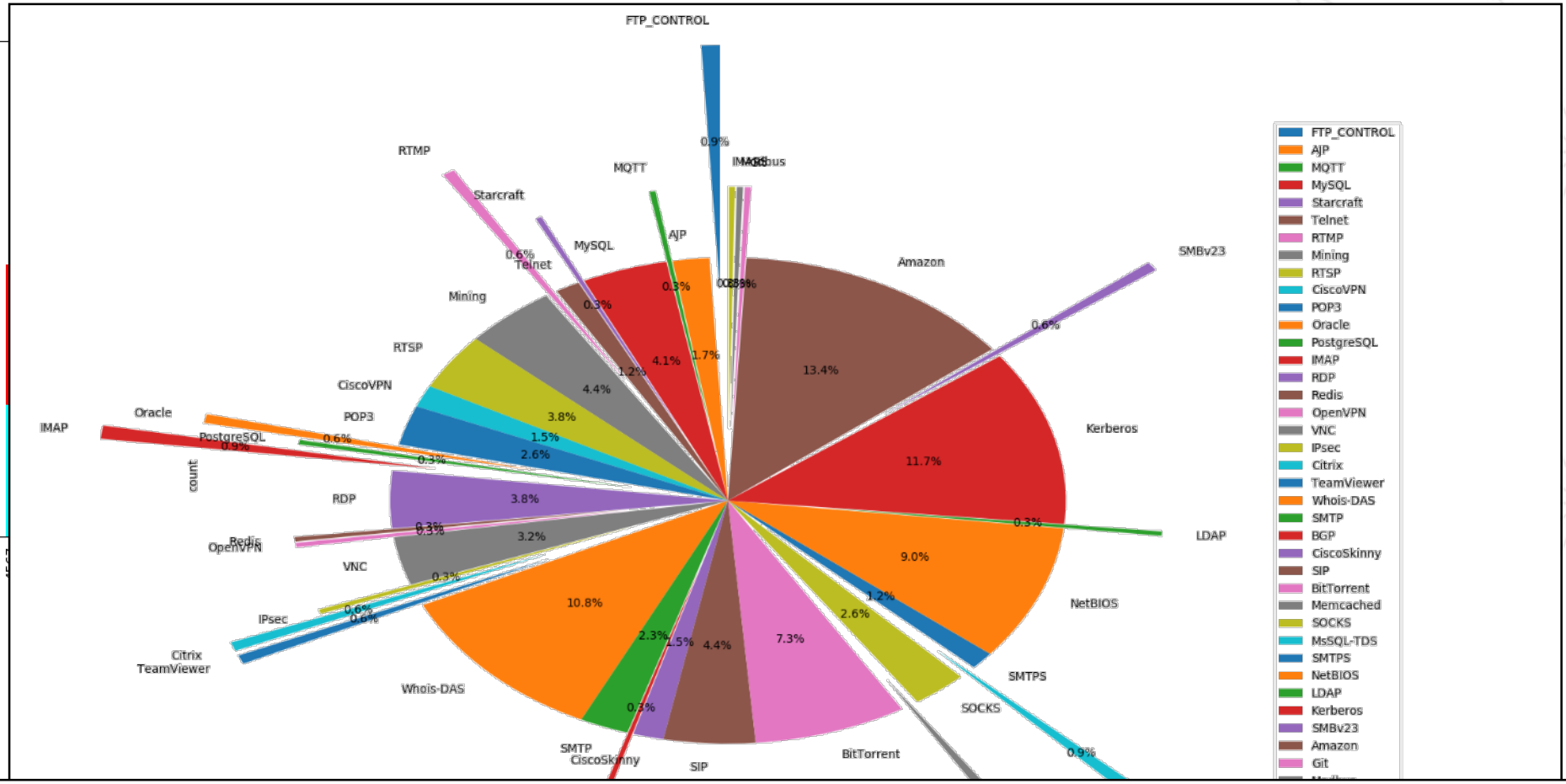

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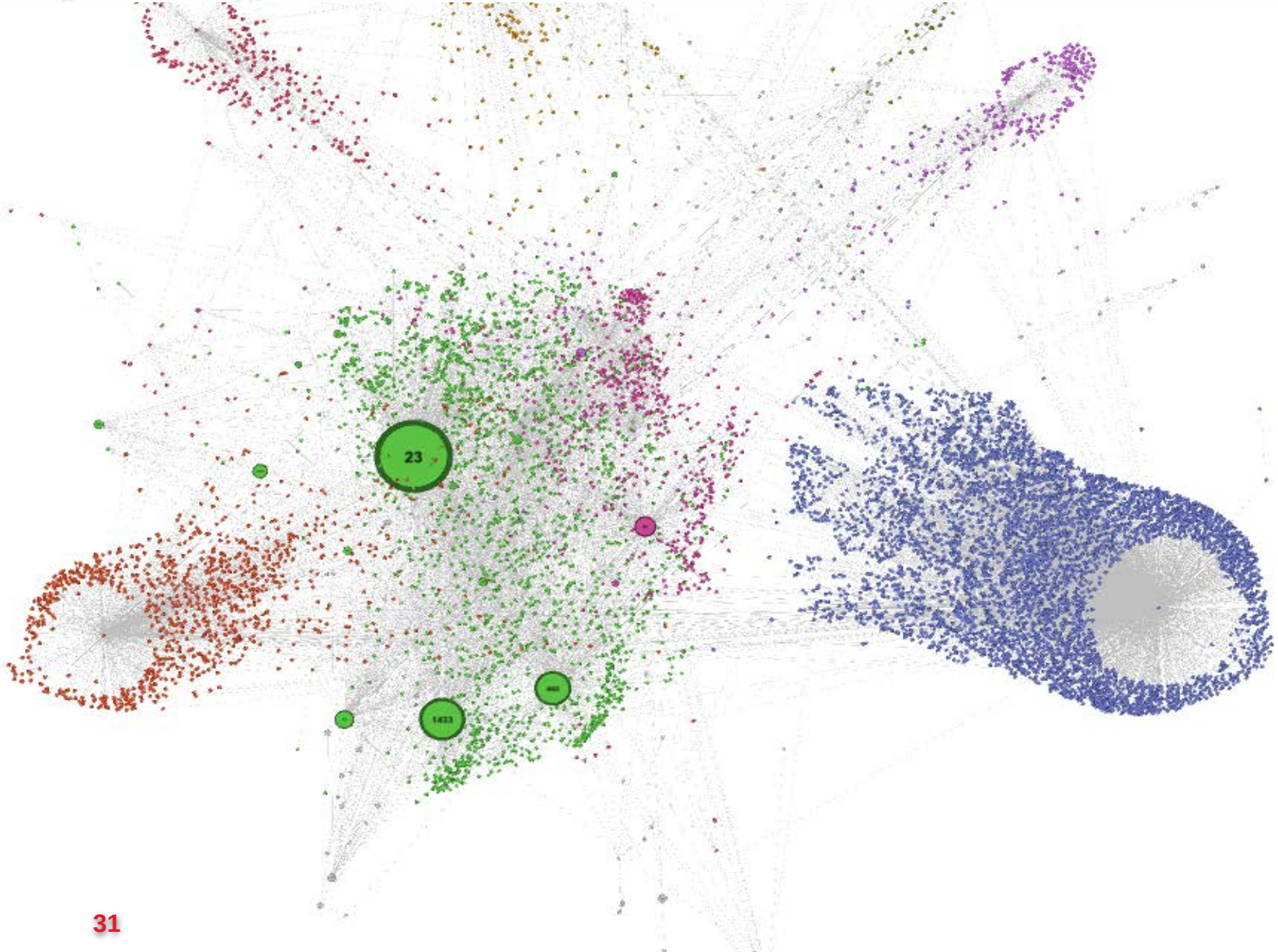
Many open points/questions

- **Match the scanner with follow-up flows**
  - Not always the same IP address
- Temporal effects
  - The more you answer, the more you get
  - Quality of what you get? (becoming are a known honeypot)
- How to match honeypot traffic with darknet traffic?
- For many protocols, what to answer is not clear yet
  - What should I answer to a DNS request?
- Backscattering/spoofed identification

Grouping Origins (ongoing)



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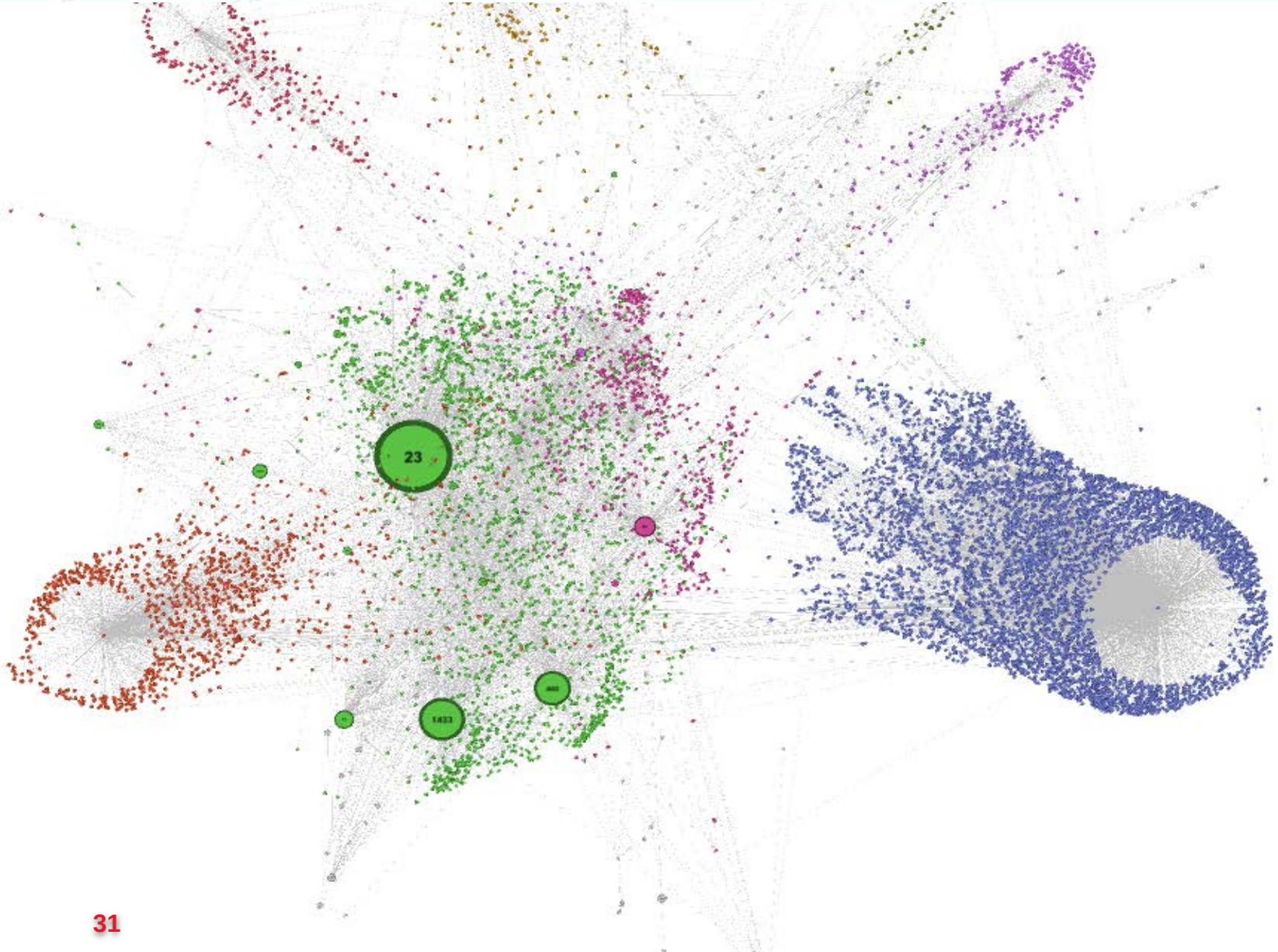

- From different darknets

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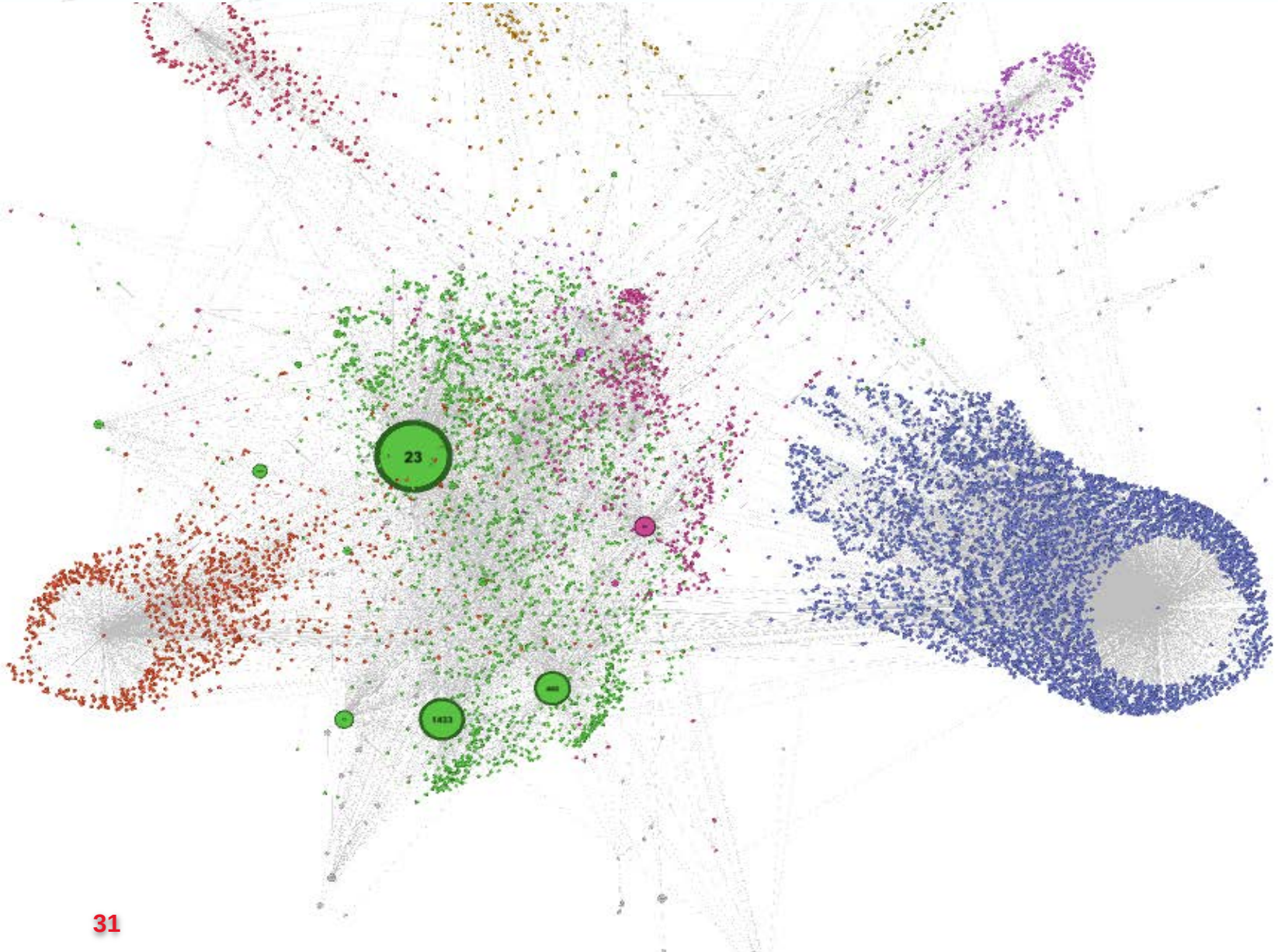

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- Groups of ASes doing similar activity simultaneously

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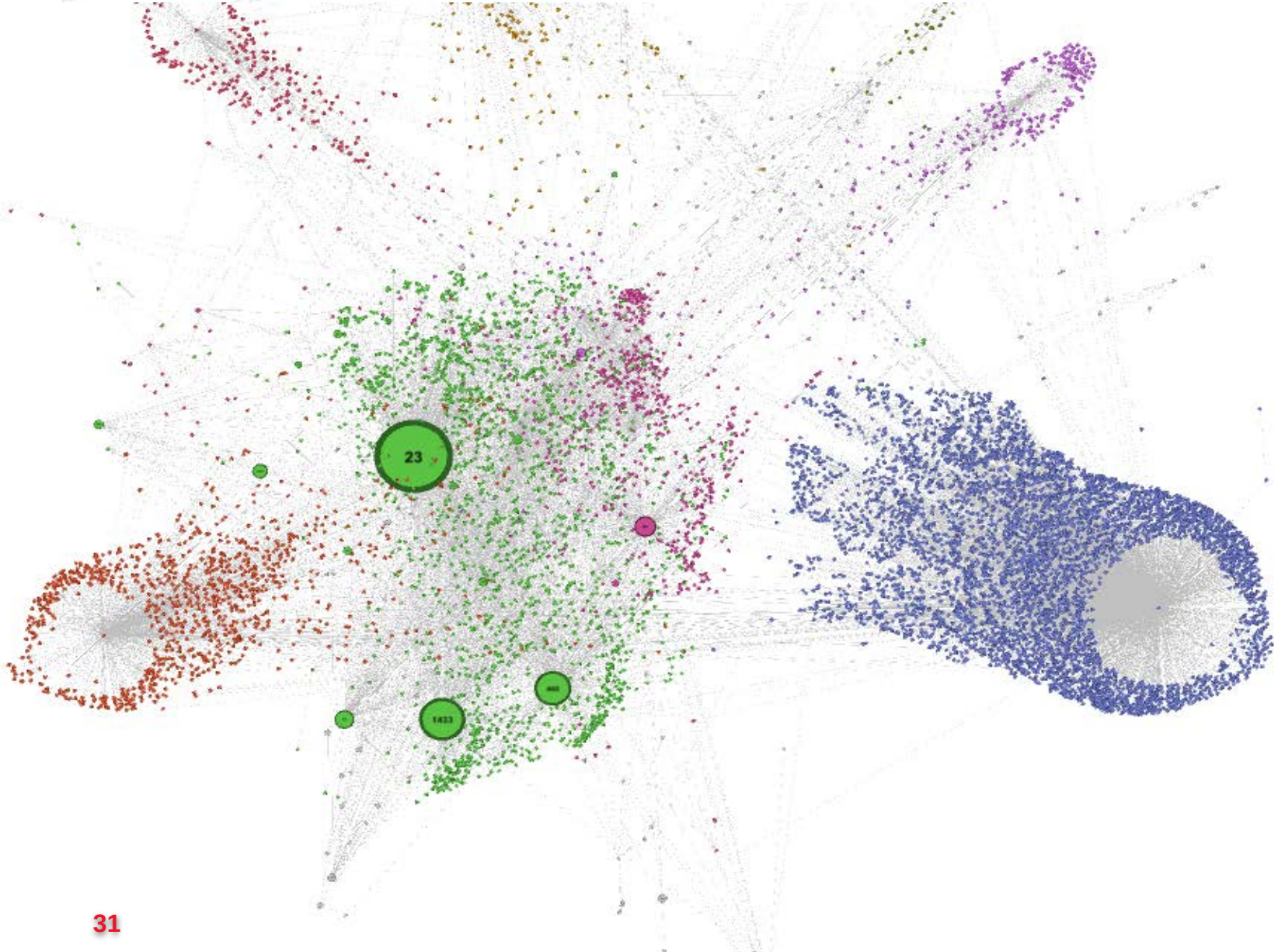

- From different darknets
- Groups of ASes doing similar activity simultaneously
  - e.g., port scans
  - e.g., groups that send packets to single port
  - e.g., groups sending few packets everywhere (e.g., backscaterring)


Perguntas
Fragen
Domande
Galdera
Otázky
Questions
Spørgsmål
Pertanyaan
kysymykset
Frågor
Spørsmål
Cwestiynau
вопросы
Preguntes
Sorular
Въпроси
Vragen
Pytania