Spoki: Unveiling a New Wave of Scanners through a Reactive Network Telescope

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Alberto Dainotti, Thomas C. Schmidt, Matthias Wählisch

USENIX Security, August 12, 2022

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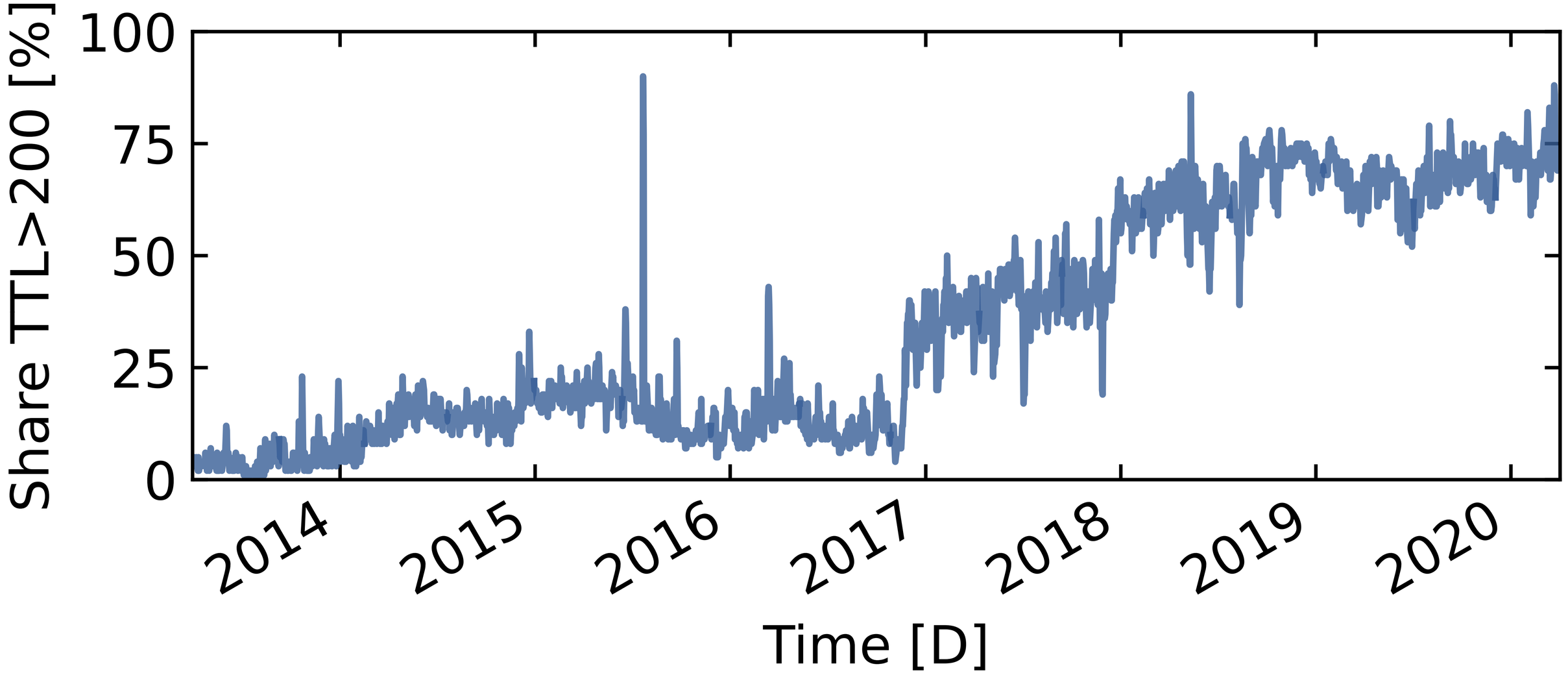
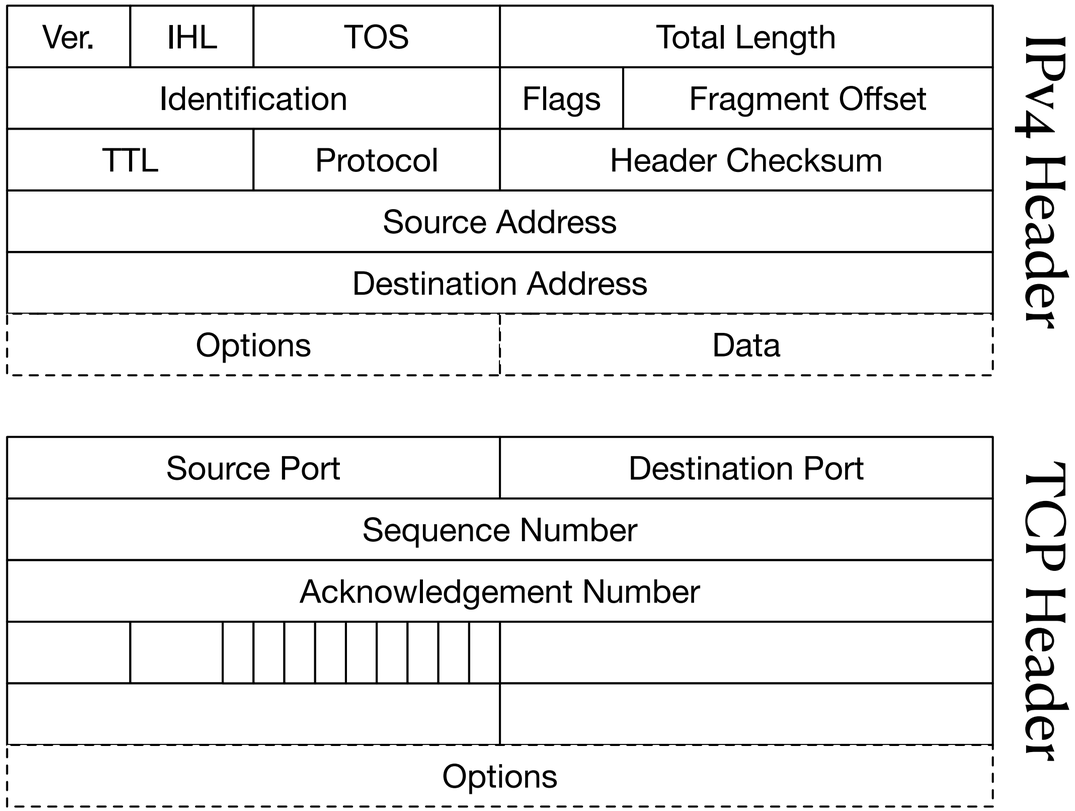
The Share of Irregular Packets is Increasing

UCSD Network Telescope: a /9 IPv4 prefix



What is a SYN Irregularity?

- Irregular packets show one or more of:
  - High TTL (≥200)
  - No TCP options
  - Fixed IP ID (54321)



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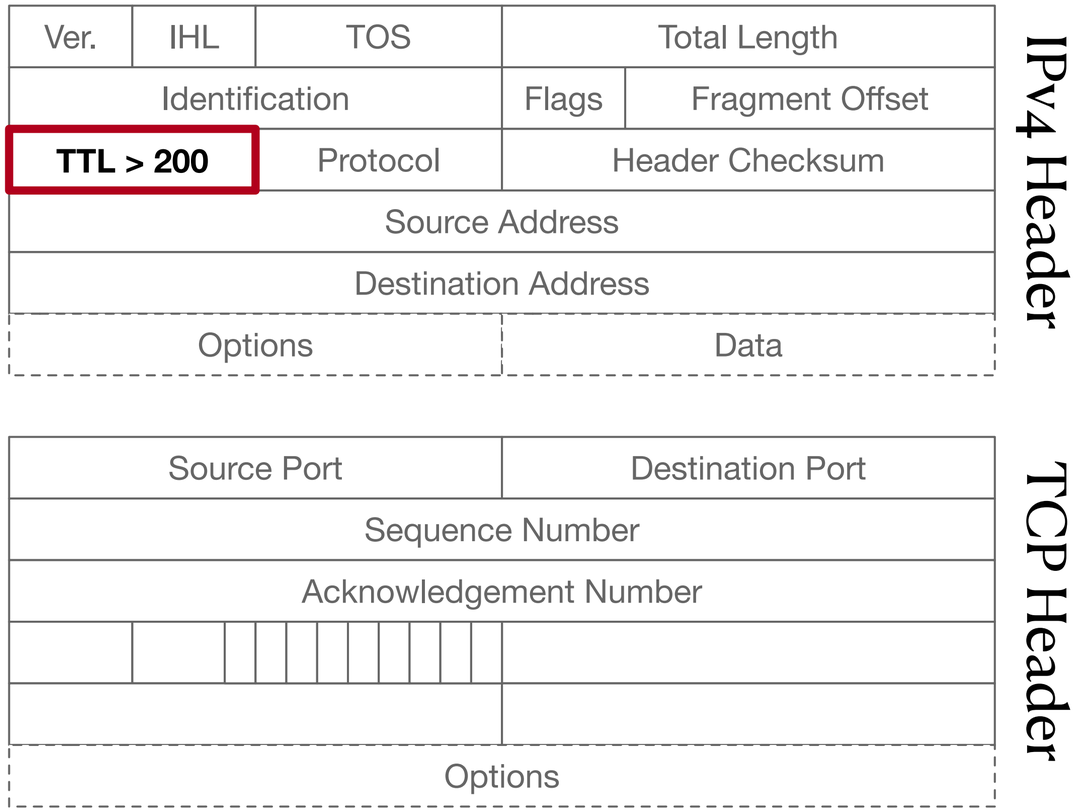

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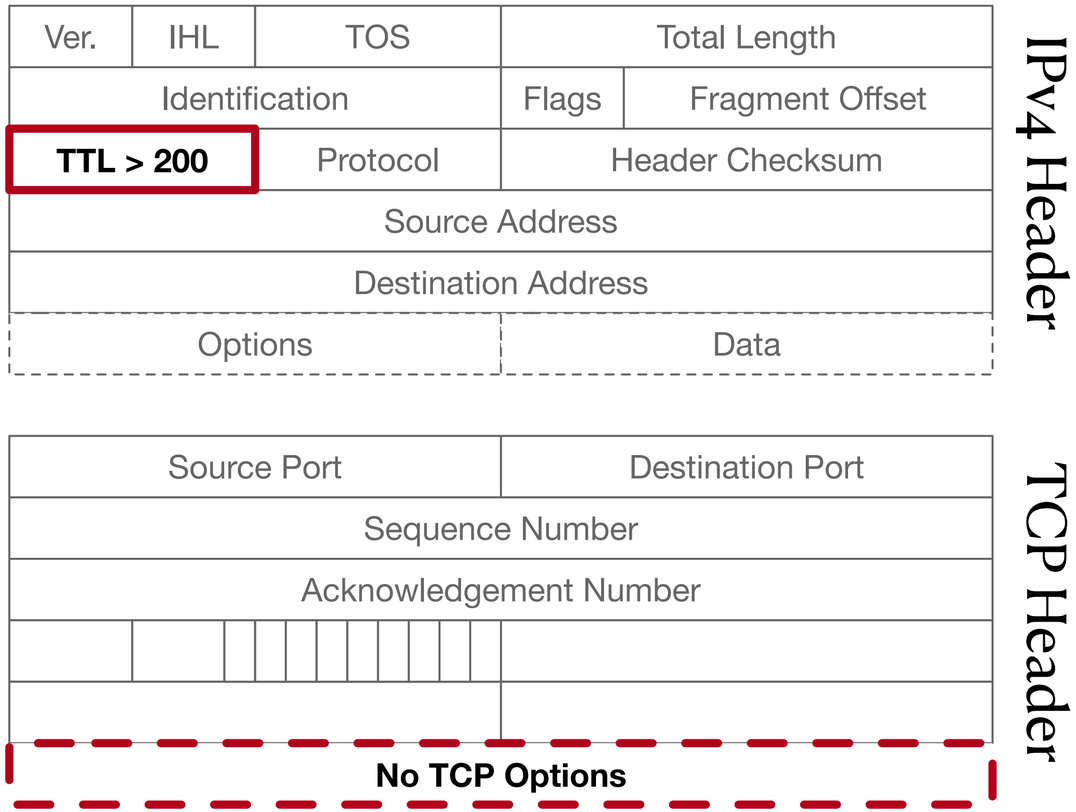

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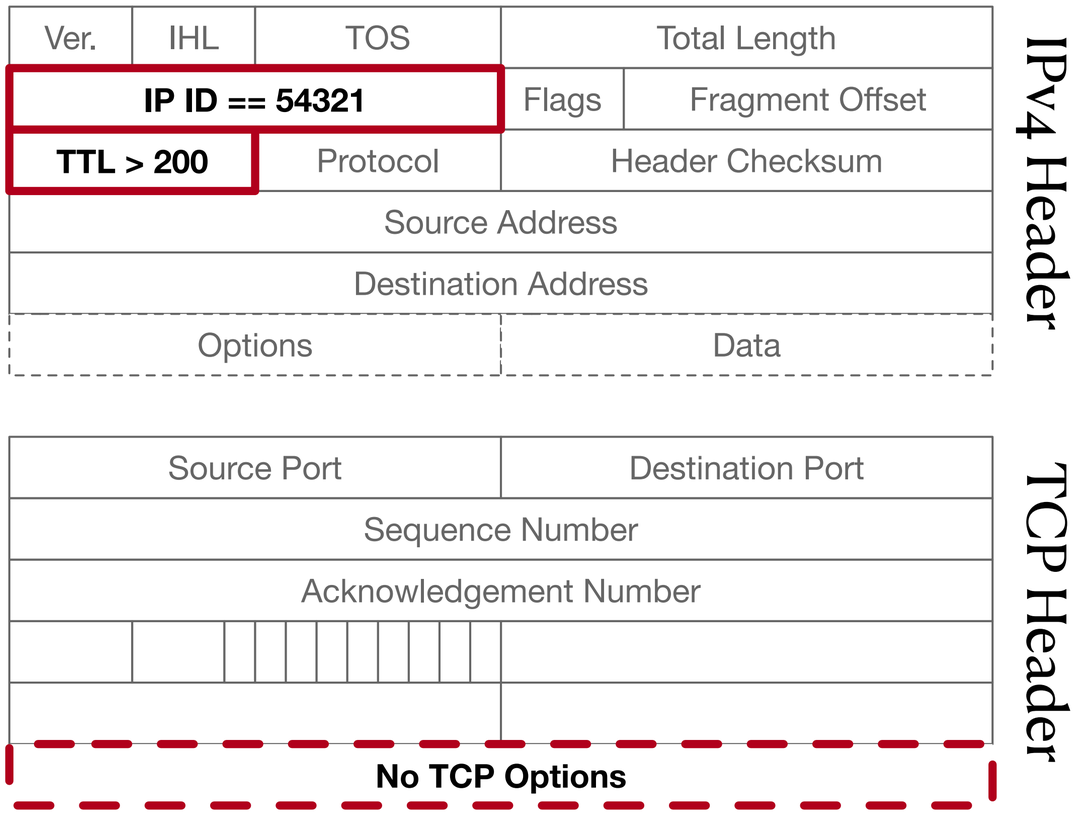

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Is this observation specific to the UCSD network telescope?

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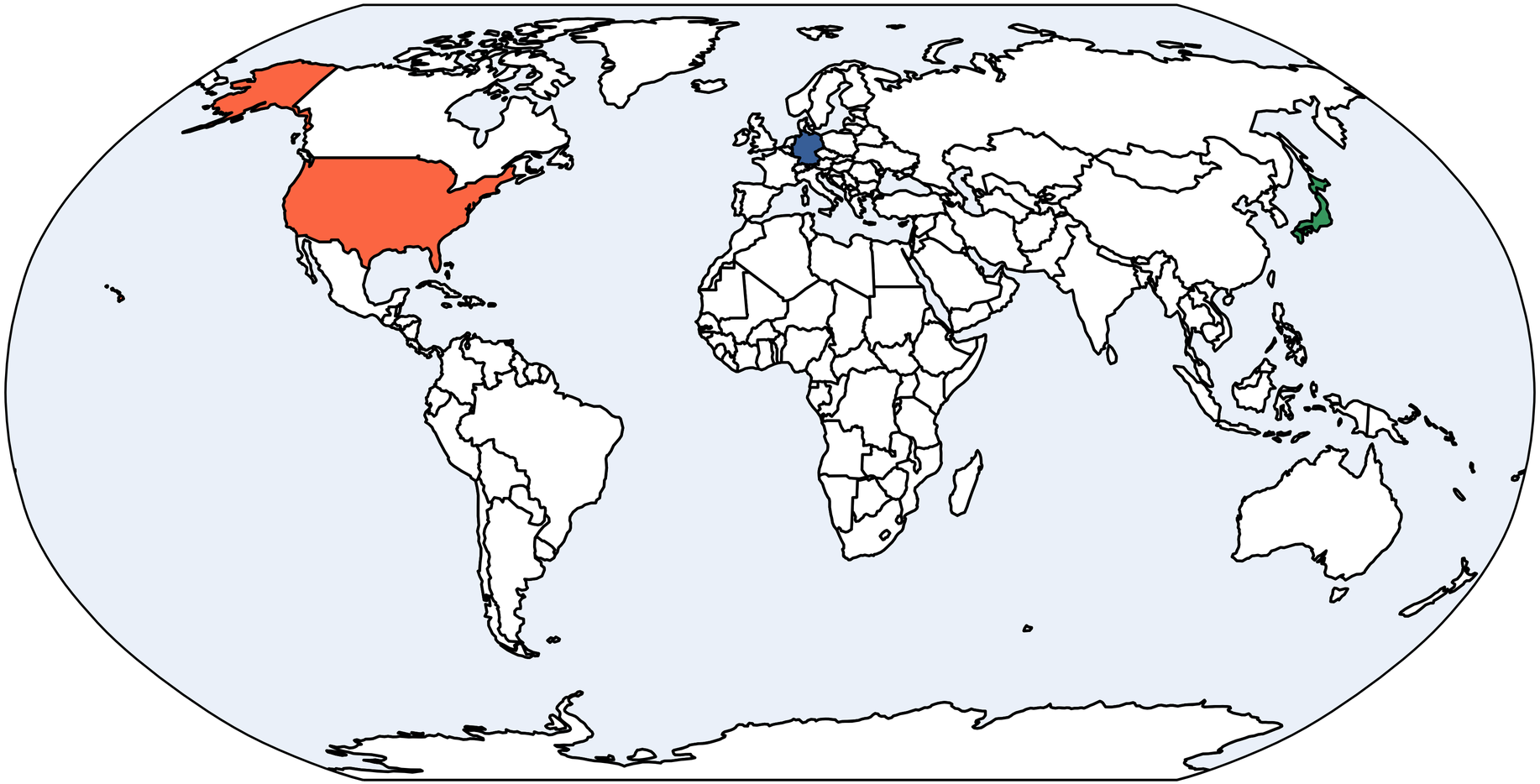
A Global Phenomenon



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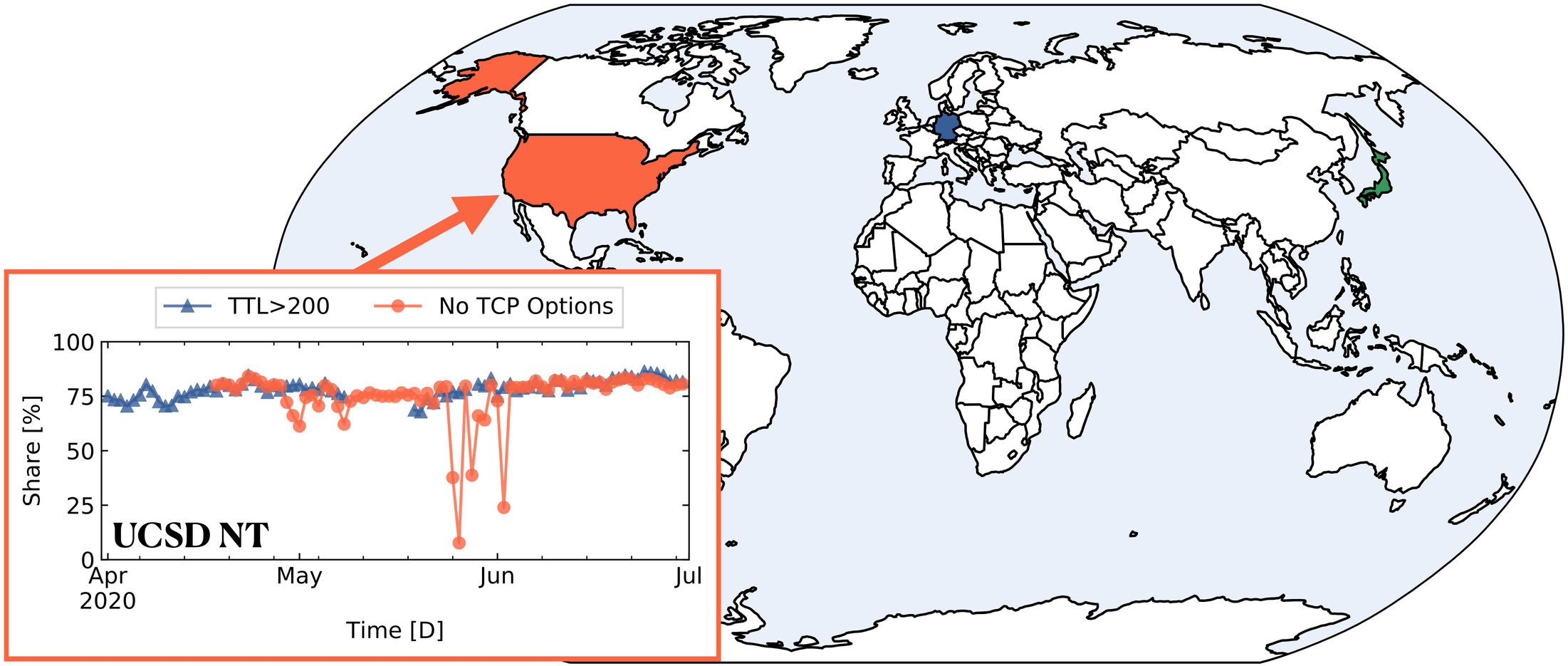

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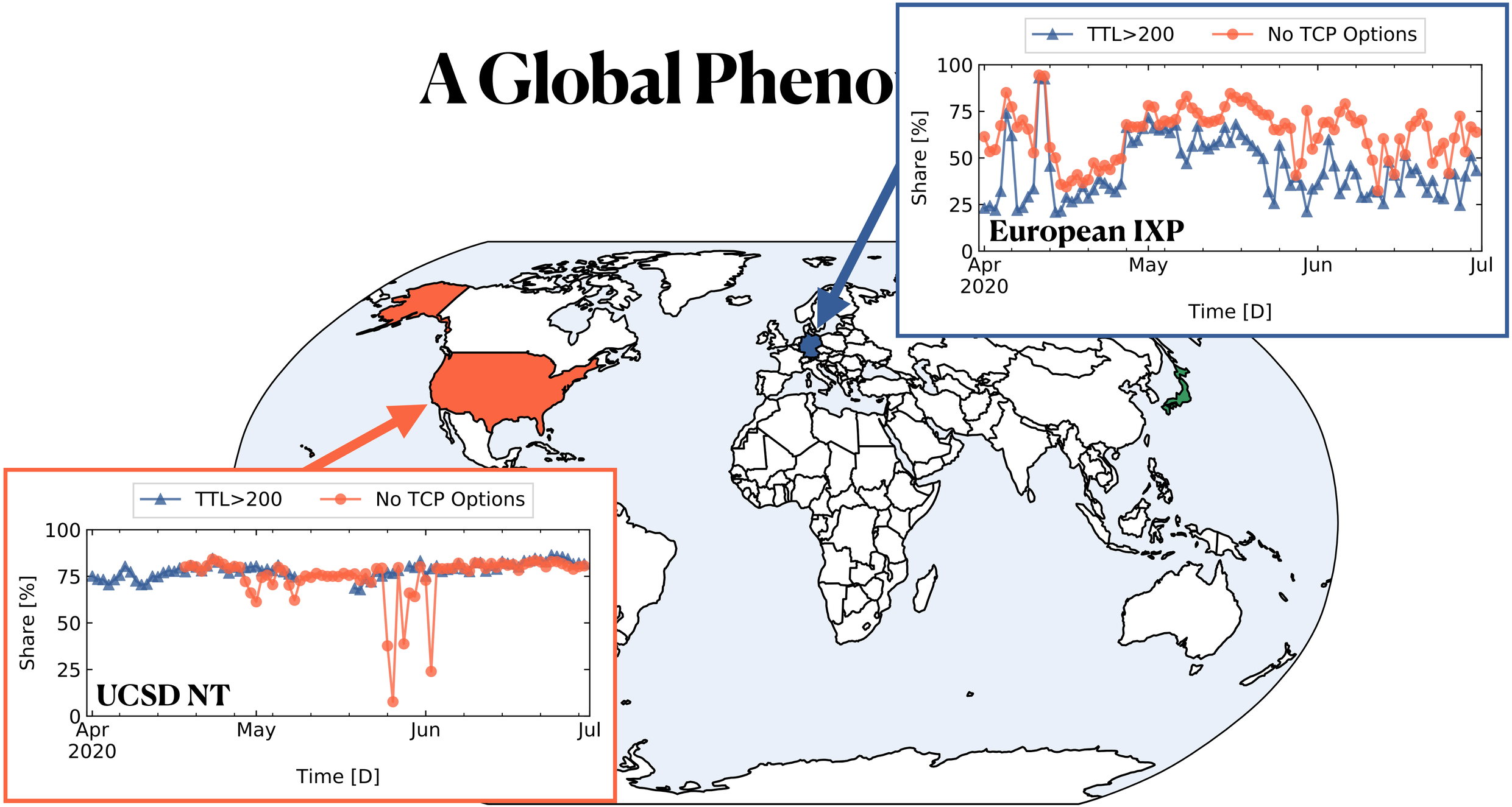

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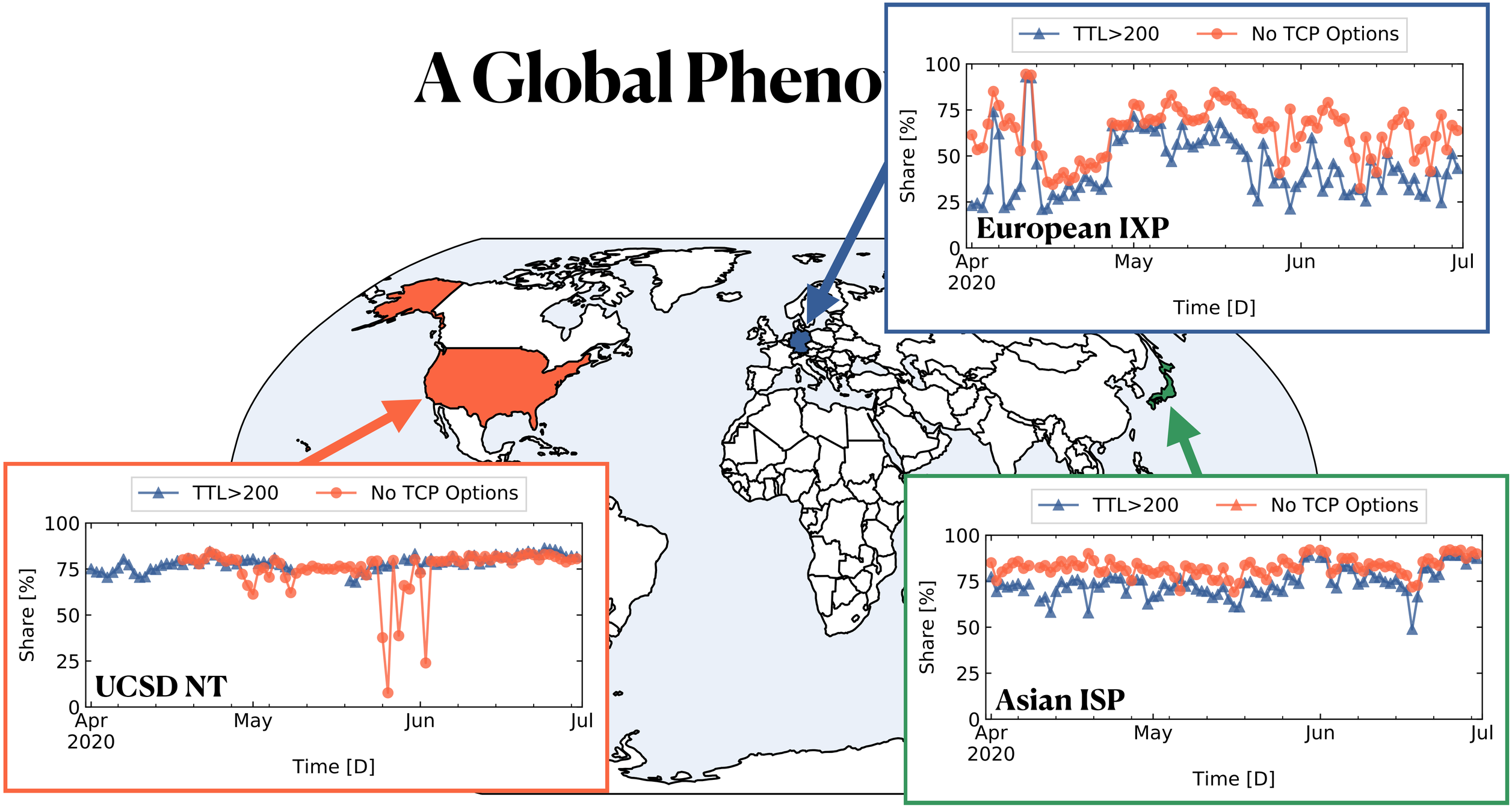

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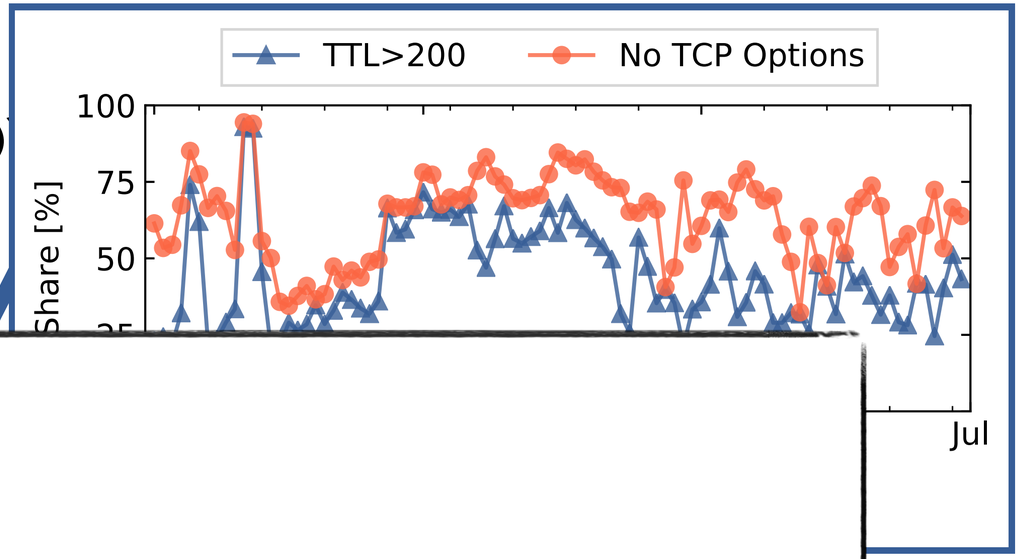
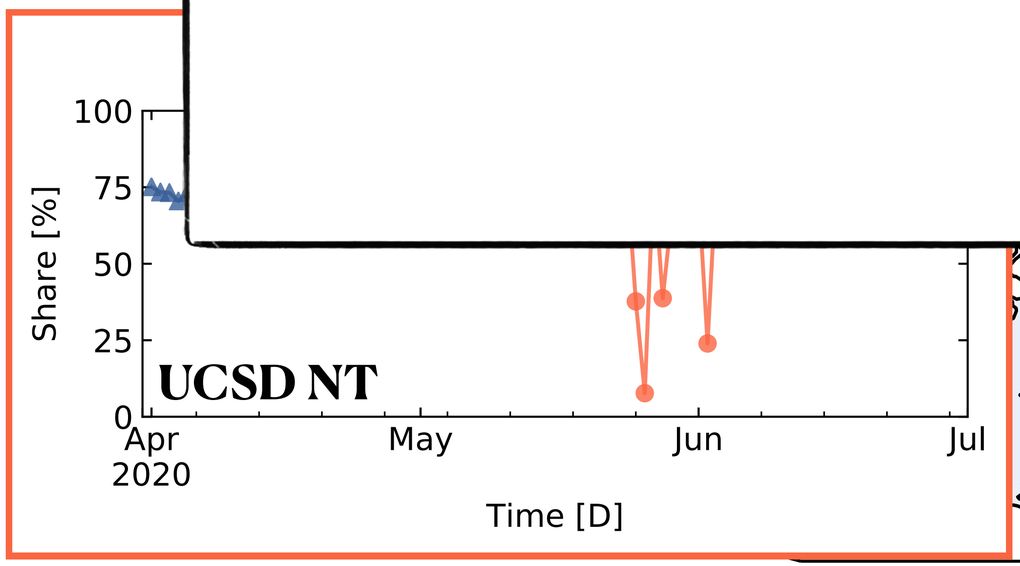
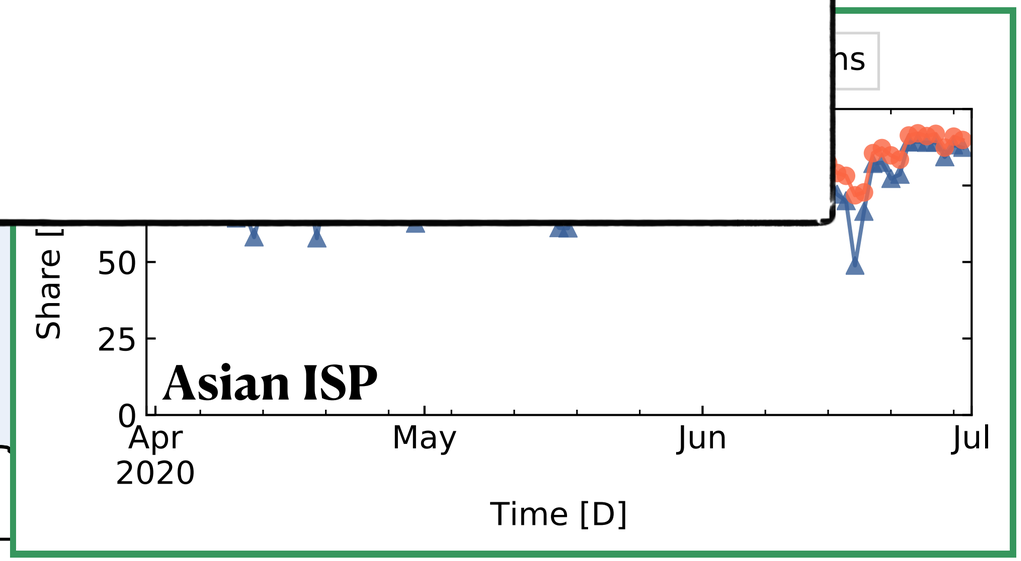


Do these packets pose a threat?





Background: Stateless Scanning

"Scan the Internet in less than 1 hour on commodity hardware!"

- Increases scan speeds by avoiding local state
  - Hand-crafted probes sent via raw sockets
  - Recognize replies via SYN cookies

- Popularized by **ZMap** around 2013
- Abused by **Mirai** in 2016

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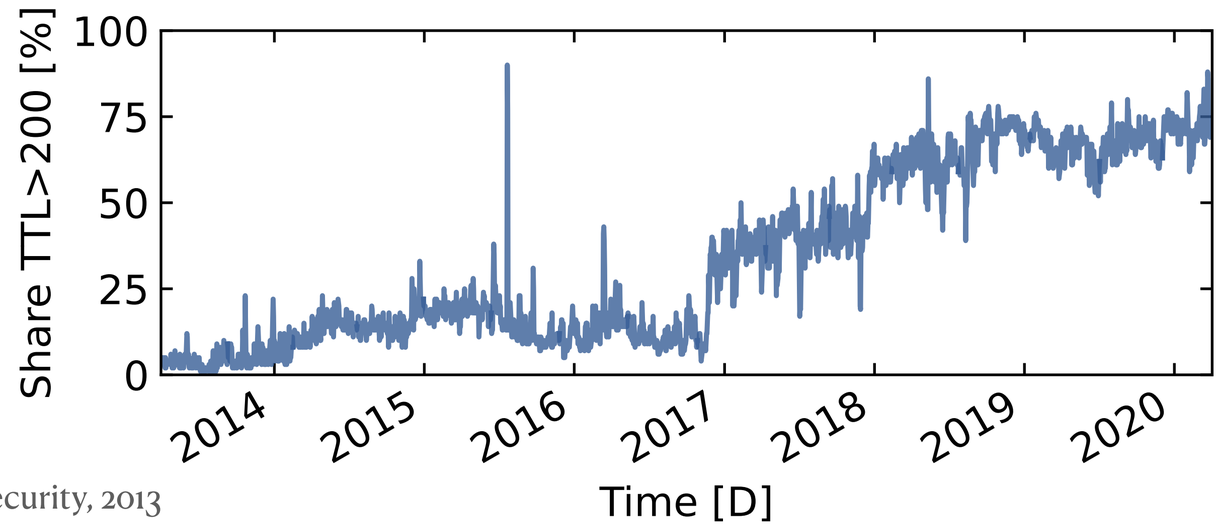

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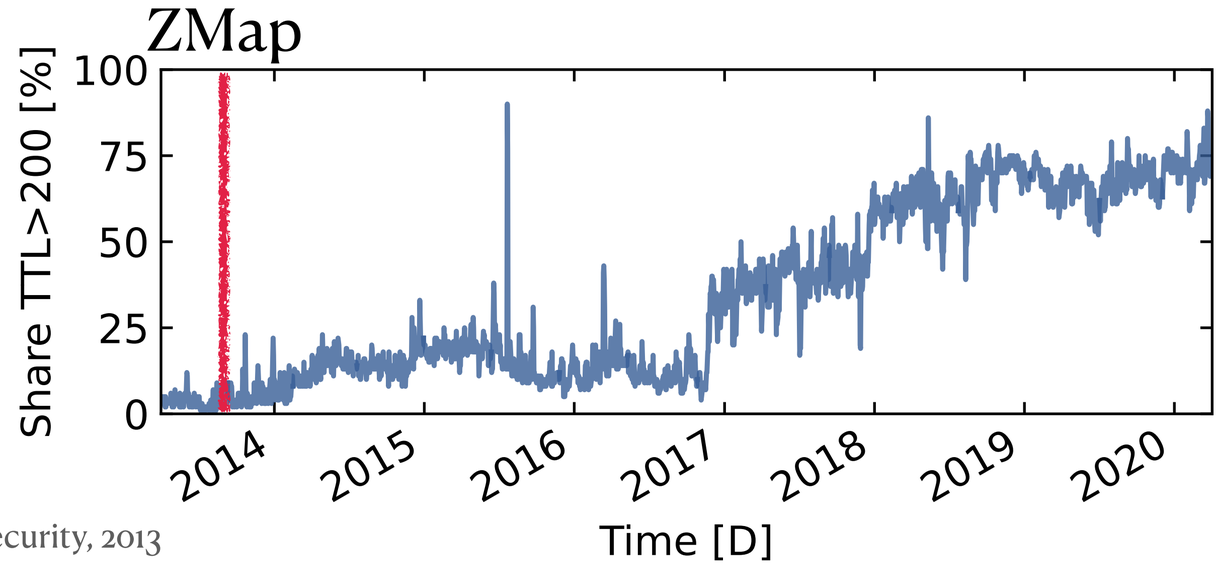

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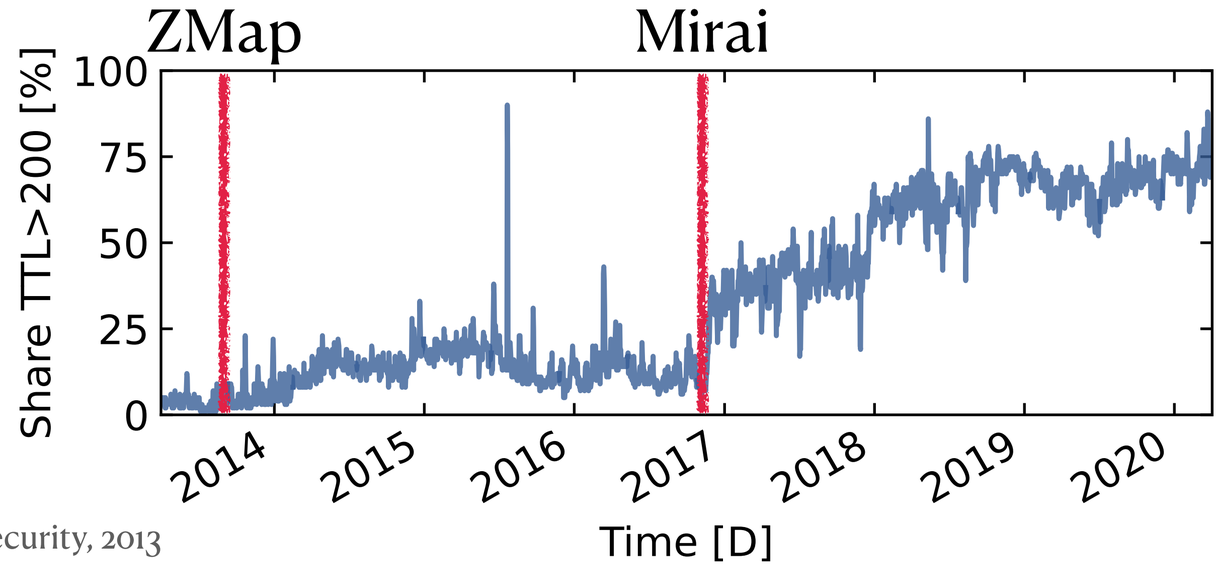

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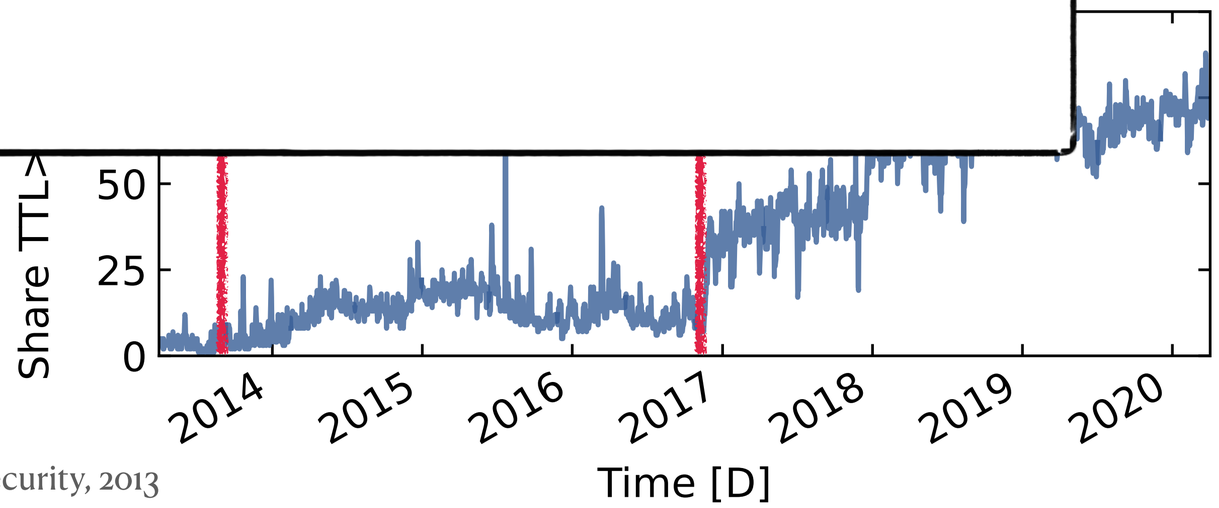
How can stateless scanning be abused?



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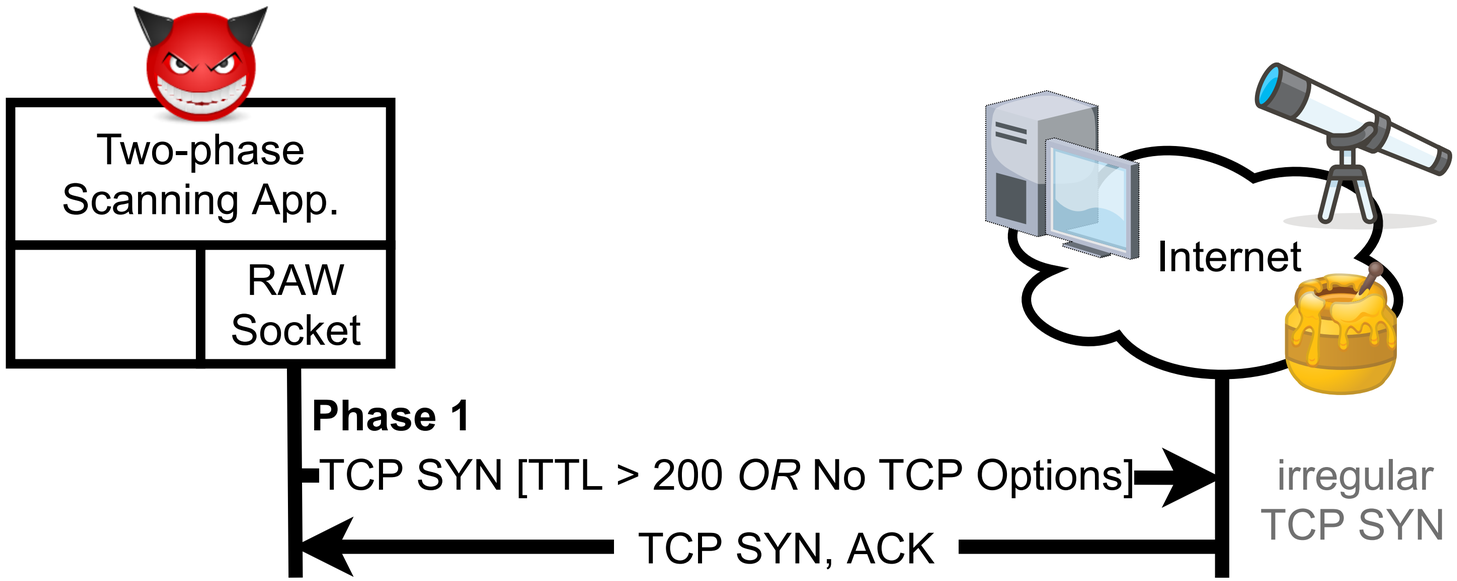
Two-phase Scanning

- First phase: Transport layer
  - Hand-crafted, stateless SYNs
  - *Identify responsive hosts*
- Second phase: Application layer
  - OS-level TCP handshake
  - *Deliver payloads & reconnaissance*



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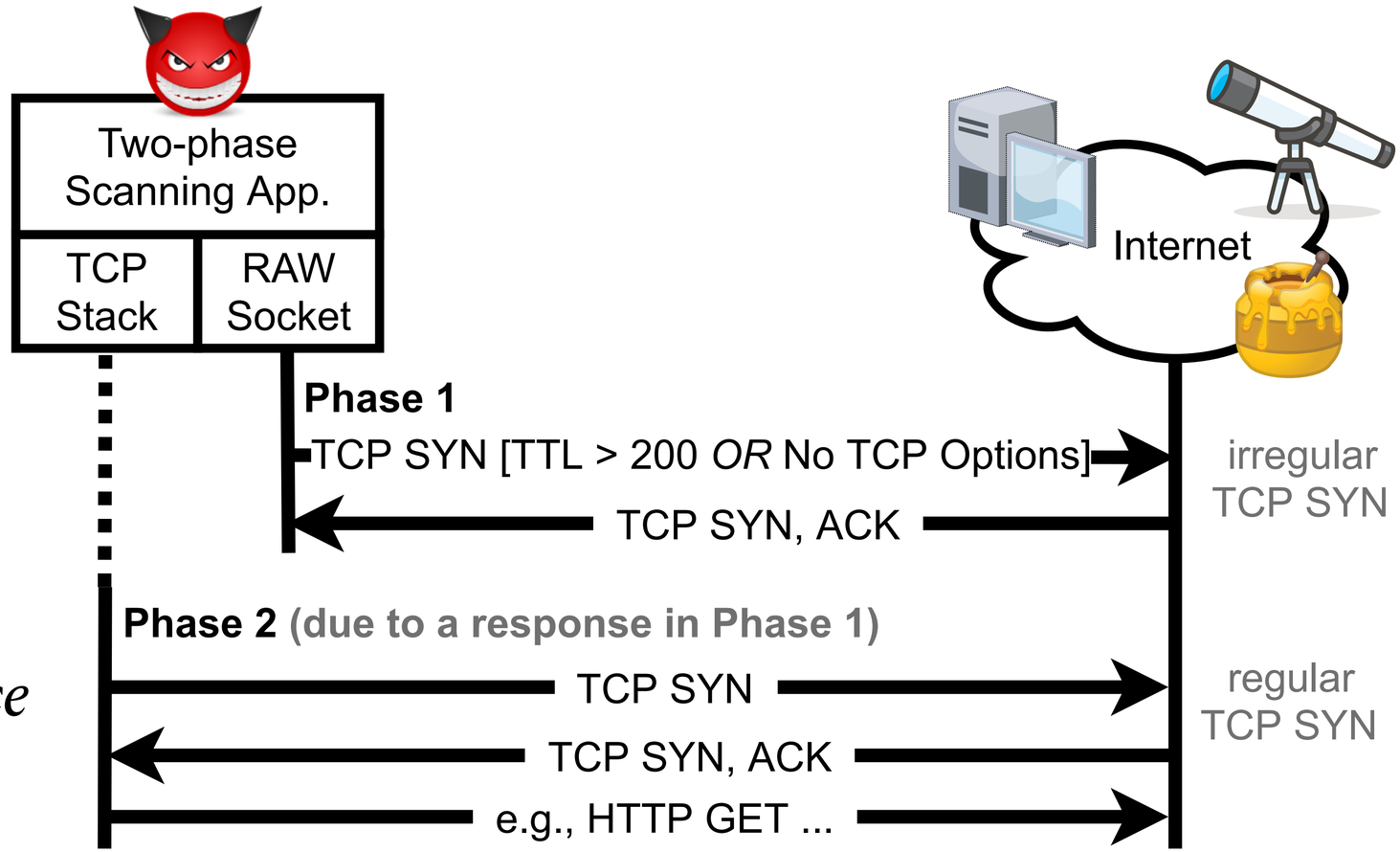


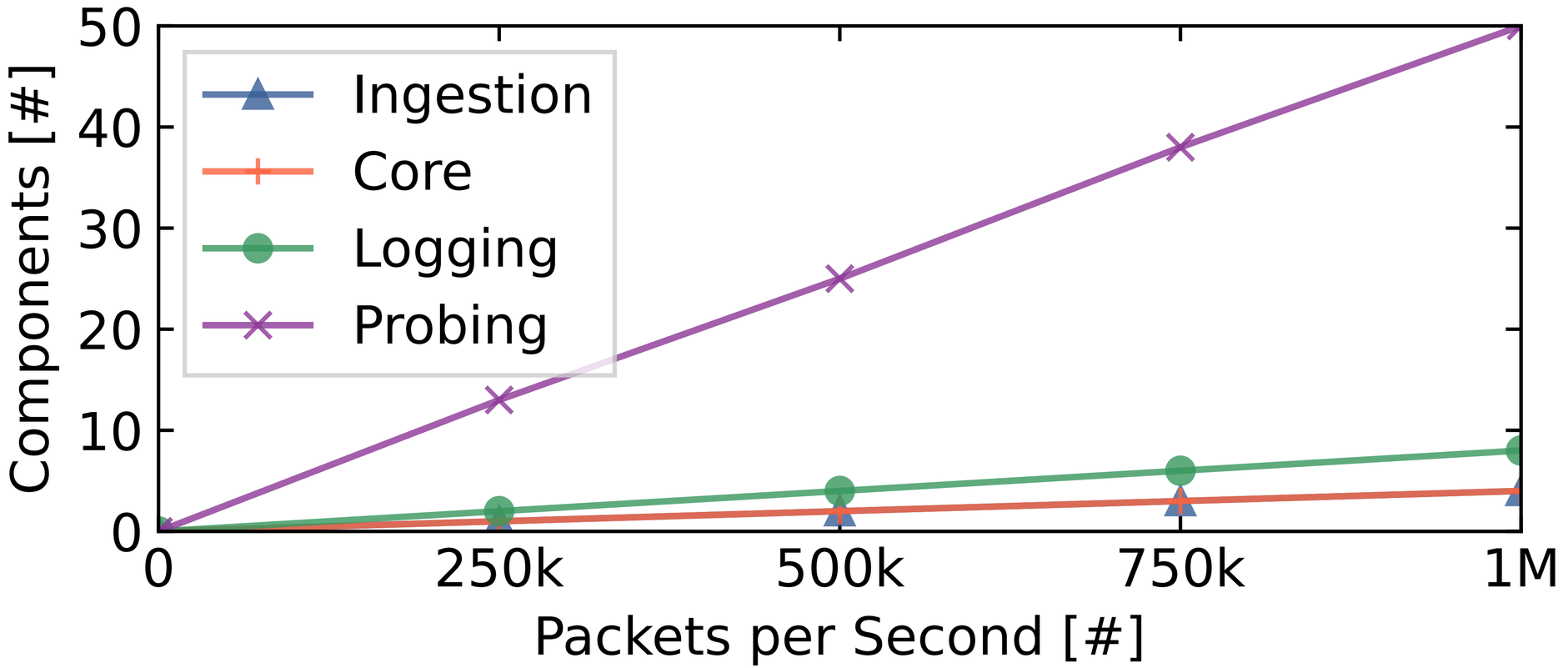
Spoki: Revealing Two-phase Scanners

- Spoki interacts with two-phase scanners in real time
  - Scalable system based on actors with the C++ Actor Framework (CAF)
  - Libtrace for packet ingestion, Scamper for probing
  - Collects payloads after accepting TCP connections
- Deployed in two /24 prefixes (US, EU)

- Published source code on GitHub (https://github.com/inetrg/spoki)

Spoki rate-limits probes and uses small packets to avoid participating in DoS.

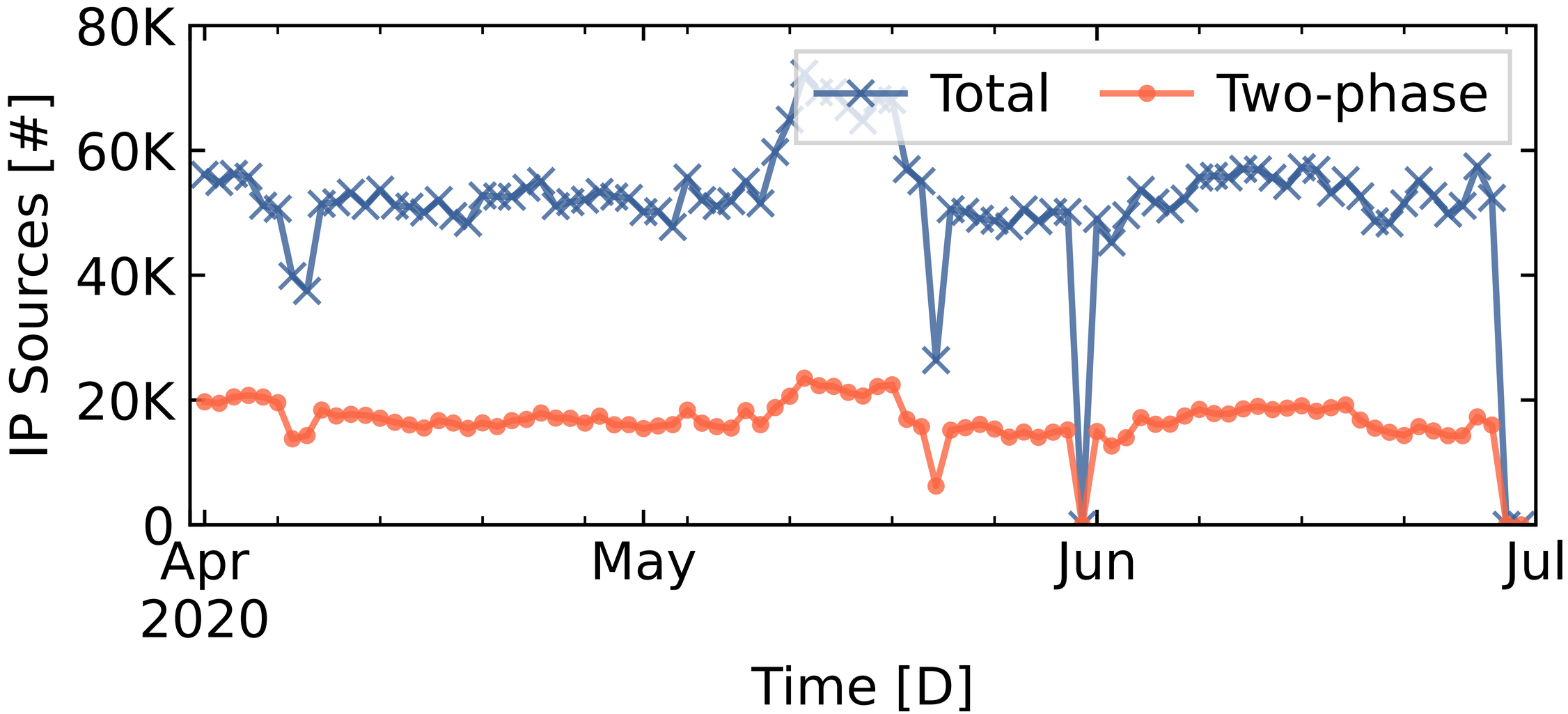
Scaling Up to 1 Million Probes Per Second



Parallel components allow Spoki to process large traffic volumes.

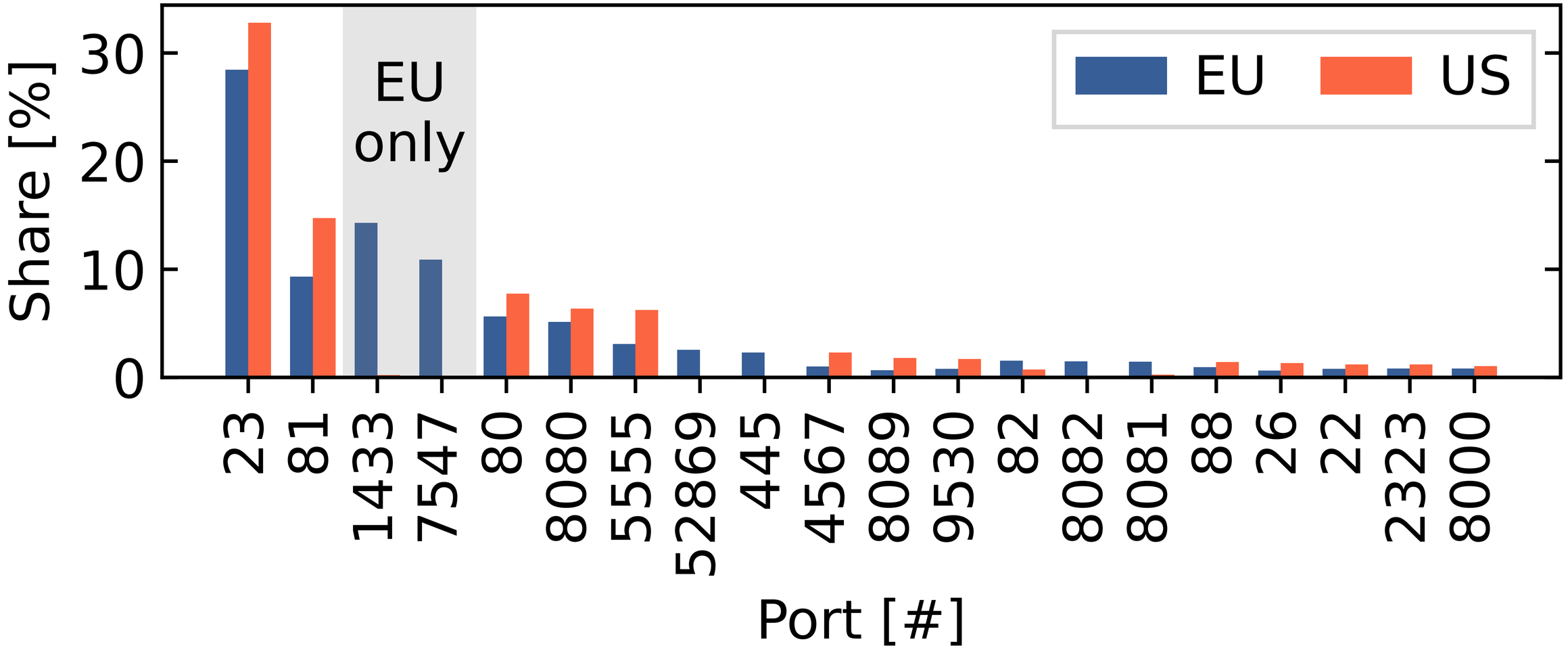
Share of Two-phase Sources

About 30% of sources send two-phase events each day.



Targeted Ports

Two ports are scanned exclusively in the EU.



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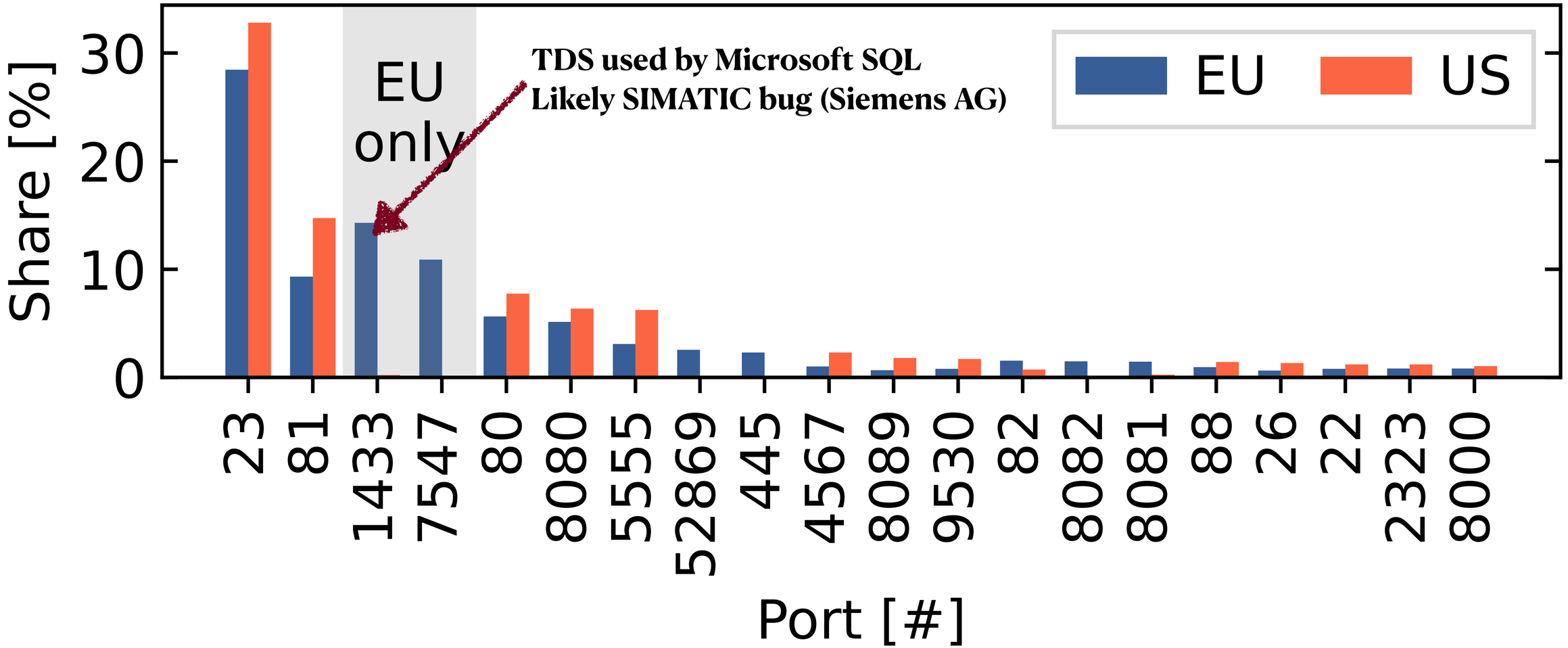

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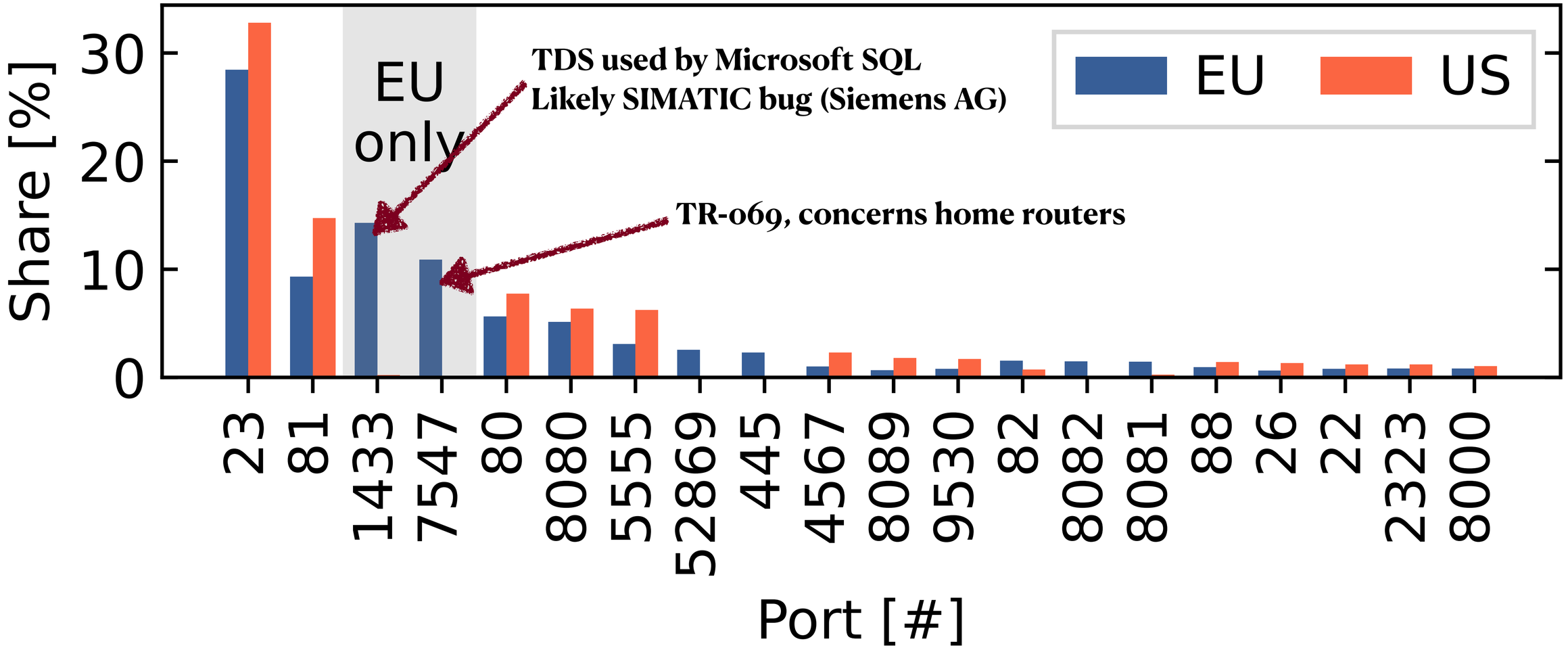

TCP Payloads

- TCP payloads are not available in traditional telescopes
- We scan payloads for *downloaders*: shell code that downloads malware

Event Type	EU		US	
ASCII	2,155,751	58.6%	1,984,444	80.4%
HEX	1,478,556	40.2%	339,217	13.8%
Downloader	42,303	1.2%	143,309	5.8%

- Sample names and types match known malware such as the Mozi P2P-botnet
- Spoki detected 15% of the samples earlier than VirusTotal (26% benign, 59% old)

The Maliciousness of Two-Phase Scanners

Malware distribution clearly points at malicious intent. Can we validate our findings?

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Approach 1: Semi-Manual Analysis

- Reveals malicious payloads such as:

Port	Attack
1433	TDS, SQL, SIMATIC
7545	TR-069, routers
5555	ADB crypto miner
9530, 4567	Embedded devices
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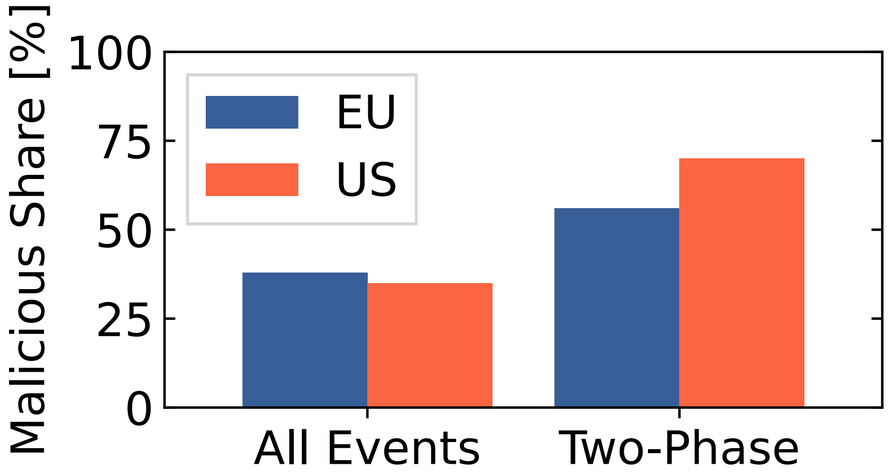
Approach 2: Query GreyNoise

- Classifies IPs into: *malicious*, *benign*, and *unknown*
- Two-phase events have a higher share of malicious sources:



Geographical Scanning Locality

- Scanners focus on different ports in Europe and the USA
- Different vendors and deployments attracts different attacks

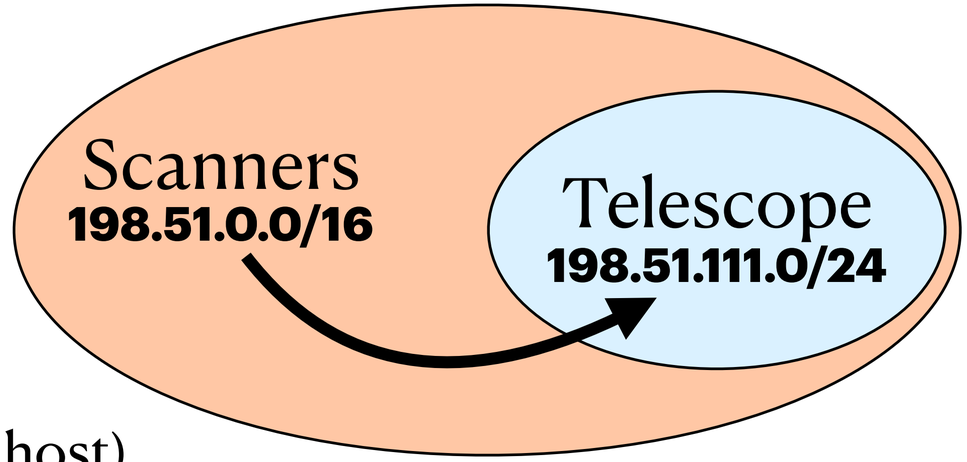
	EU		US	
Payload Prefix	**Share**	**Ports**	**Share**	**Ports**
TDS7 Pre-login	74.52%	1433	1.16%	1443
TLS Client Hello	4.55%	443, 8443	37.80%	443, 8443
ADB Connect	4.97%	5555	37.01%	5555
SMB Negotiate	11.04%	445	–	
PSQL/UPnP	0.35%	5432	3.10%	5432, 5000
TSAP	0.45%	102	1.42%	102
MongoDB	0.27%	27017	1.21%	27017
Unknown	0.16%	28967	1.15%	28967

Targets non-ASCII payloads

TDS: Tabular Data Stream used by Microsoft SQL
ADB: Android Debug Bridge
TSAP: Transport Service Access Point protocol port, used for x.400, X.500; vulnerabilities in a variety of SIMATIC devices

Topological Scanning Locality

- Six of the top-ten source prefixes in the EU share a /16 with our /24 vantage point
  - This scanning behavior is associated with botnets
  - A similar locality cannot be observed in the US



- Crosscheck (sampled) traffic at a European IXP
  - Local, irregular SYNs in 370 prefixes (150 packets per host)
  - Very focused: 96% target 23, 7547, 8291 (multiple sources identified as MiktoTik routers)

- No correlation of /16 local, irregular SYNs at an Asian ISP

Takeaways

- Spoki makes two-phase scanners visible
- Irregular SYNs dominate SYNs on the Internet: ~75%
- Two-phase scans
  - … act as a catalyst
  - … are used for malicious activities
  - … follow locality patterns
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  - … follow locality patterns ➞ Ensure your data fits your deployment
  - … have detectable signatures ➞ Can be tracked and their packets filtered

Thank you for your attention!

Find the paper, code, and artifacts at:
https://spoki.secnow.net

Contact: raphael.hiesgen@haw-hamburg.de