

# A Longitudinal View at the Adoption of Multipath TCP (MPTCP)

[mptcp.io](https://mptcp.io)

Tanya Shreedhar

Postdoctoral Researcher  
University of Edinburgh



<https://tanyashreedhar.github.io/>



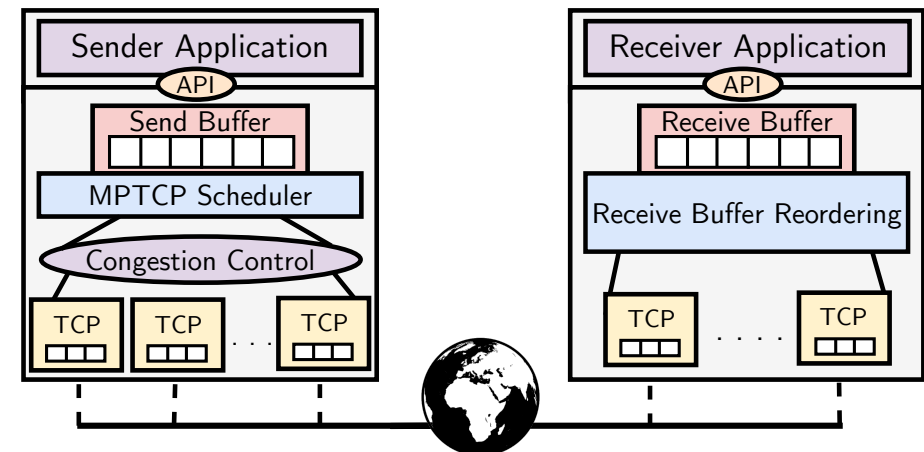
[tanya.shreedhar@ed.ac.uk](mailto:tanya.shreedhar@ed.ac.uk)

# Multipath TCP (MPTCP)

MPTCP is a *multipath* extension to TCP

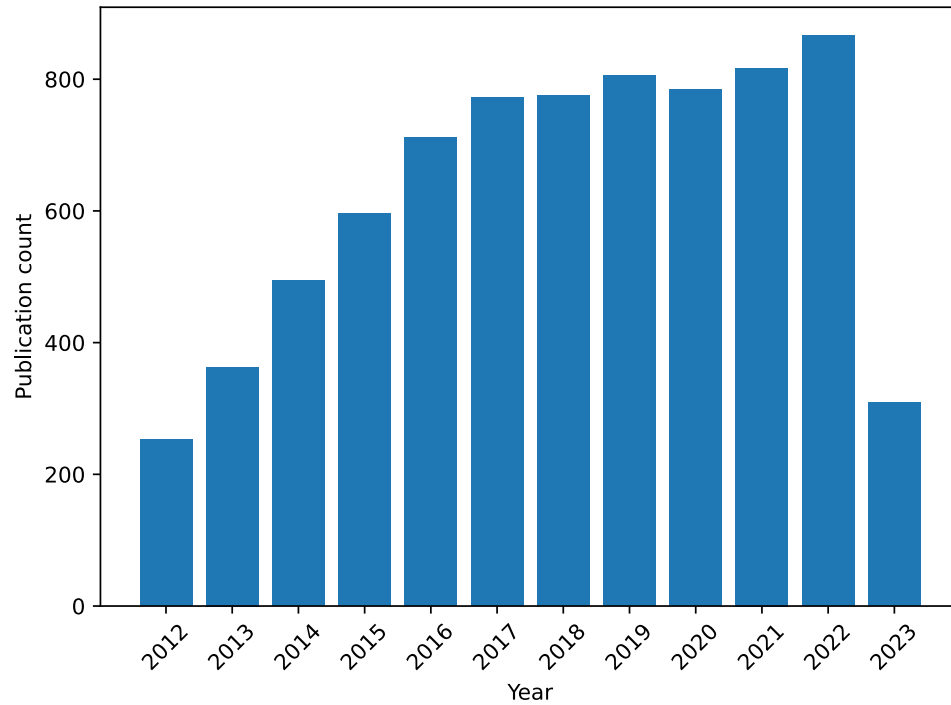
- Allows *n-to-m* TCP connections between end-hosts
- Originally proposed in 2013 (RFC 6824) and standardized in March 2020 (RFC 8684)

- Benefits over TCP
  - Improve aggregated **throughput**
  - Improve **resilience** to losses
  - Provides **seamless** mobility



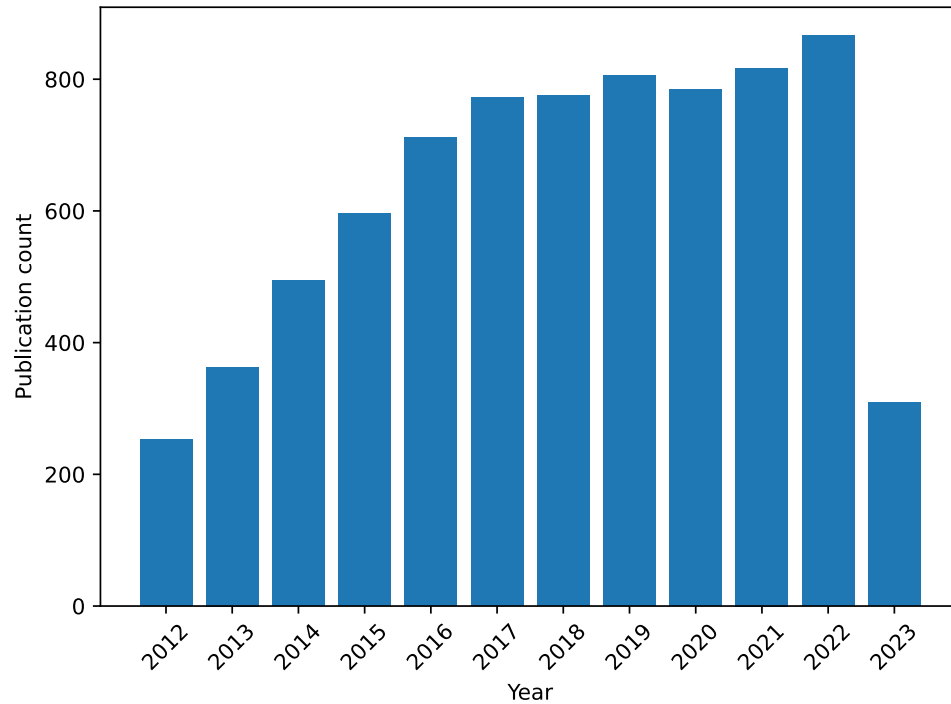
# A Thrust Towards MPTCP Usage

Significant research effort in past decade to make MPTCP efficient



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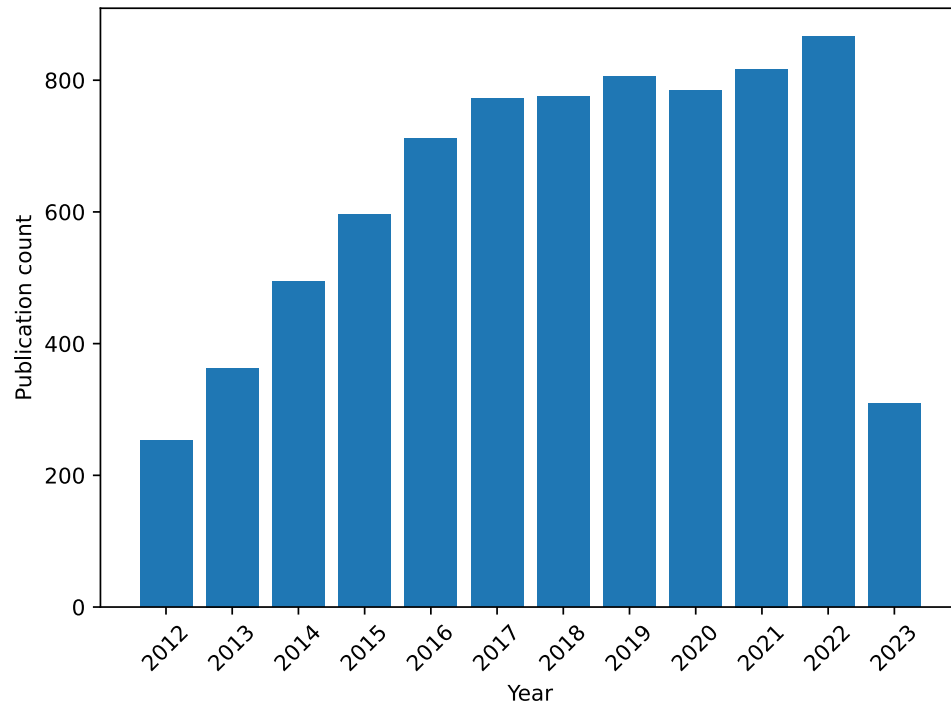
Large organizations have been using MPTCP for several years

- Apple uses MPTCP in iOS, Siri, Music, WiFi-Assist...
- Korea Telecom uses MPTCP to achieve Gigabit speeds over LTE+WiFi
- ...

# A Thrust Towards MPTCP Usage

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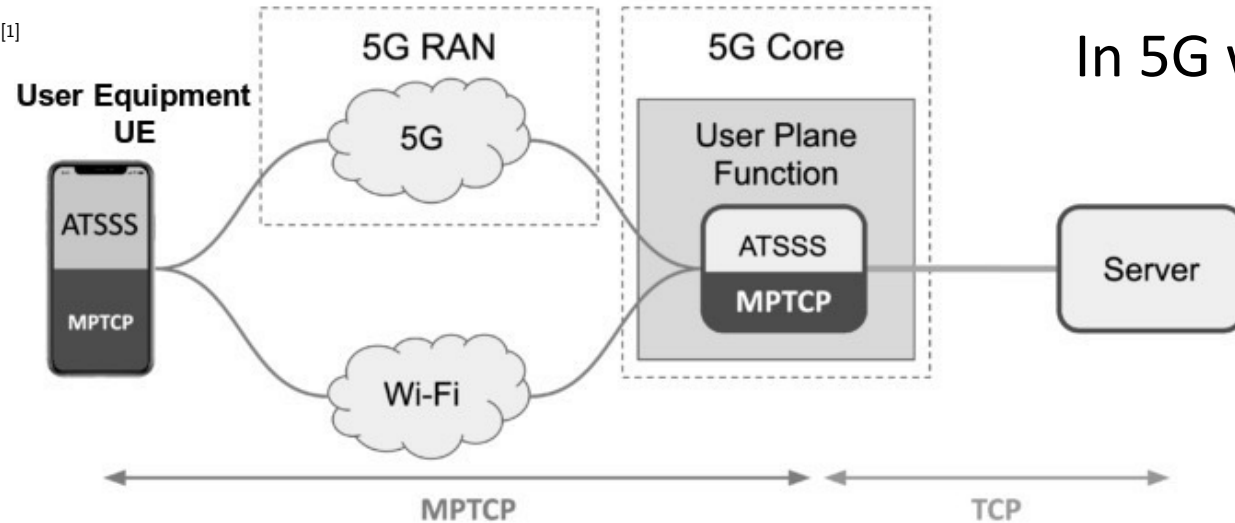
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MPTCPv1 is available (and enabled) in Linux kernel  $>v5.6$  (March 2020)

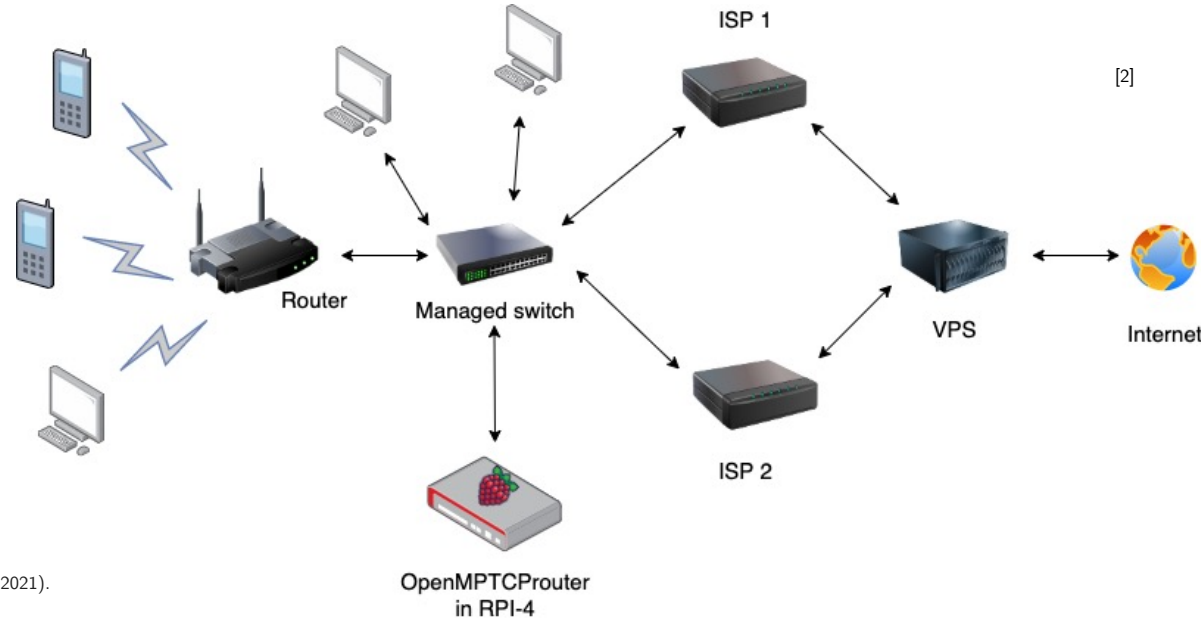
# Utility of MPTCP

MPTCP has become de-facto for L4 multiplexing

[1]



Commercial solutions enabling aggregated connections for non-MPTCP devices



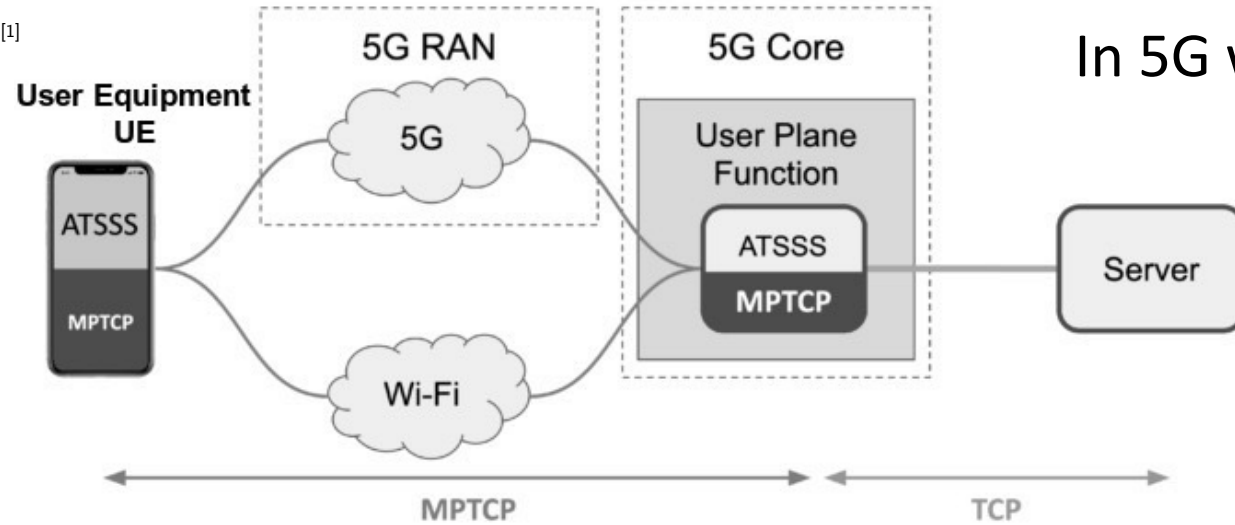
[1] Pokhrel, Shiva Raj, and Anwar Walid. "Learning to harness bandwidth with multipath congestion control and scheduling." *IEEE Transactions on Mobile Computing* (2021).

[2] <https://www.openmptcprouter.com/>

# Utility of MPTCP

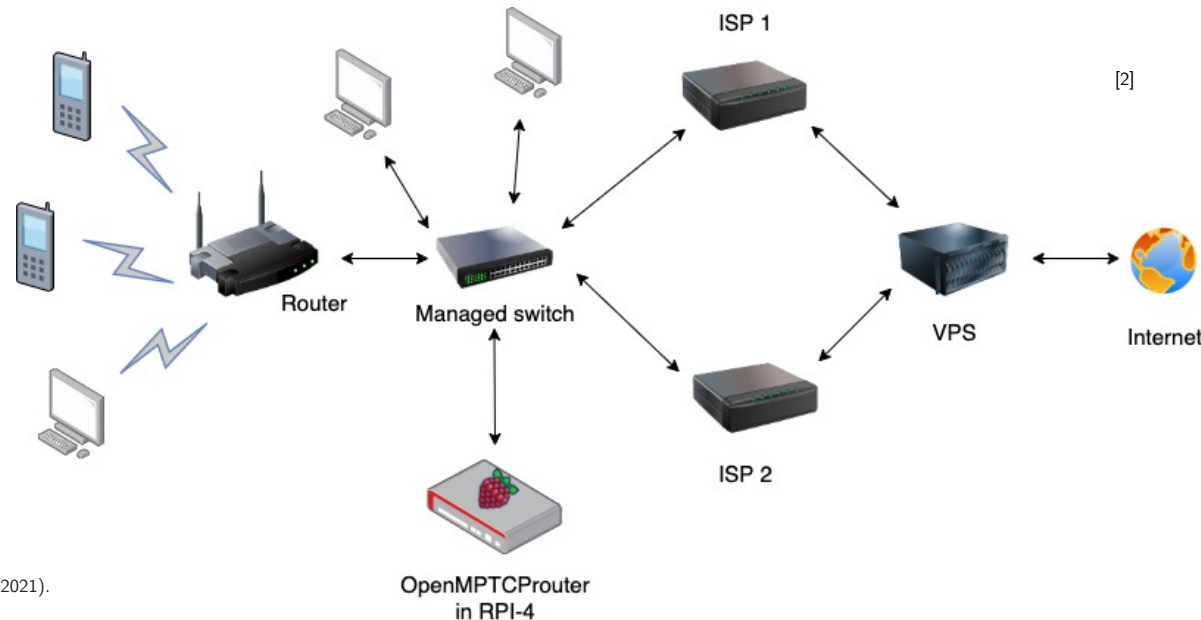
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[1]



In 5G with ATSSS [3GPP [Specification # 24.193](#)]

Commercial solutions enabling aggregated connections for non-MPTCP devices



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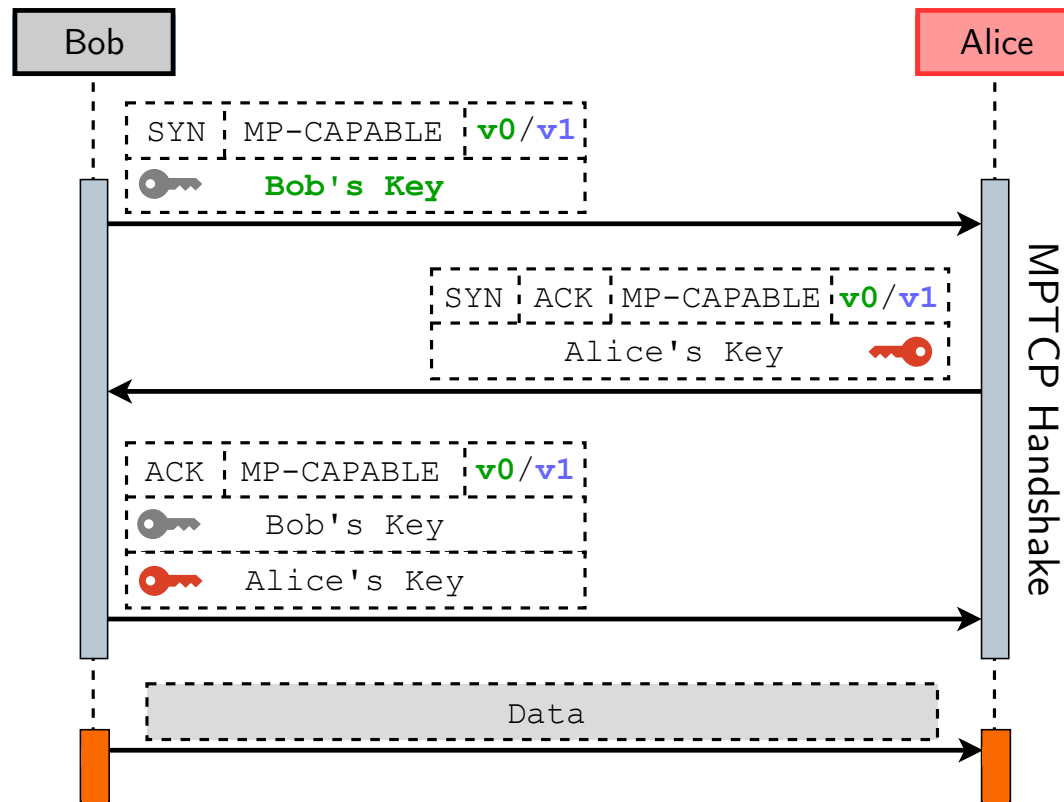
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Yet there is no Internet-wide study analyzing MPTCP adoption and challenges!

# Support for MPTCP in the Internet

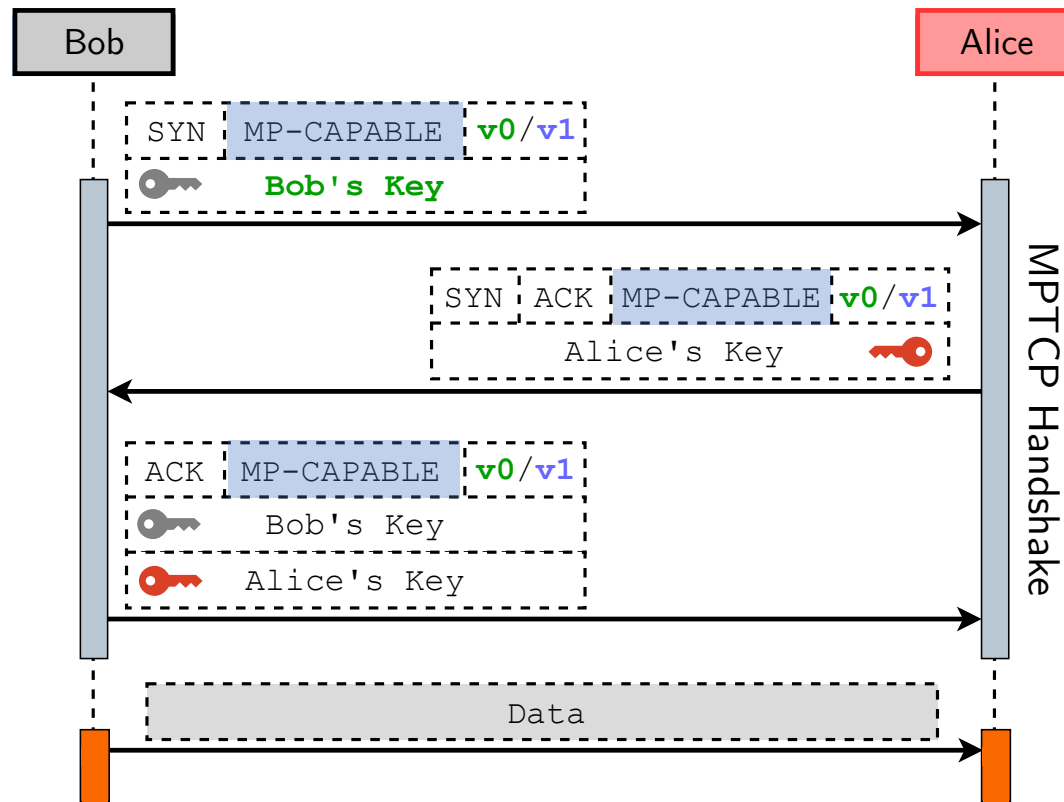


# Scanning for MPTCP Support



MPTCP connection establishment leverages TCP's three-way handshake

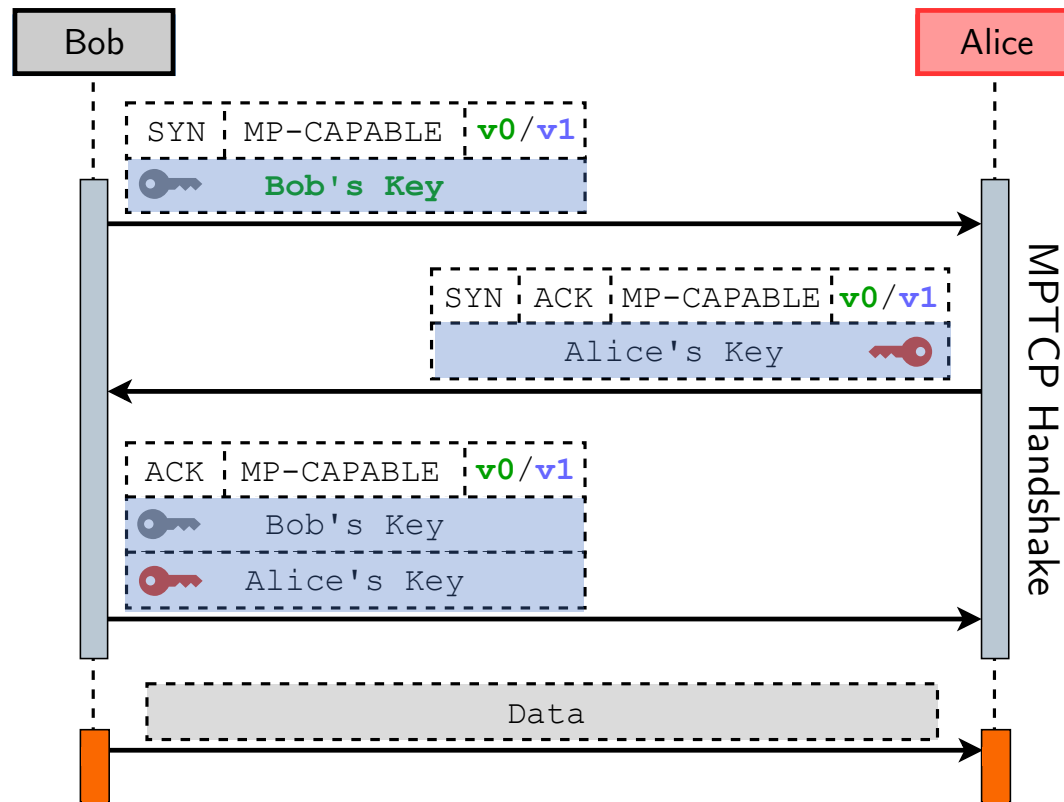
# Scanning for MPTCP Support



MPTCP connection establishment leverages TCP's three-way handshake

- Both hosts must send MP\_CAPABLE flag to denote MPTCP capability

# Scanning for MPTCP Support

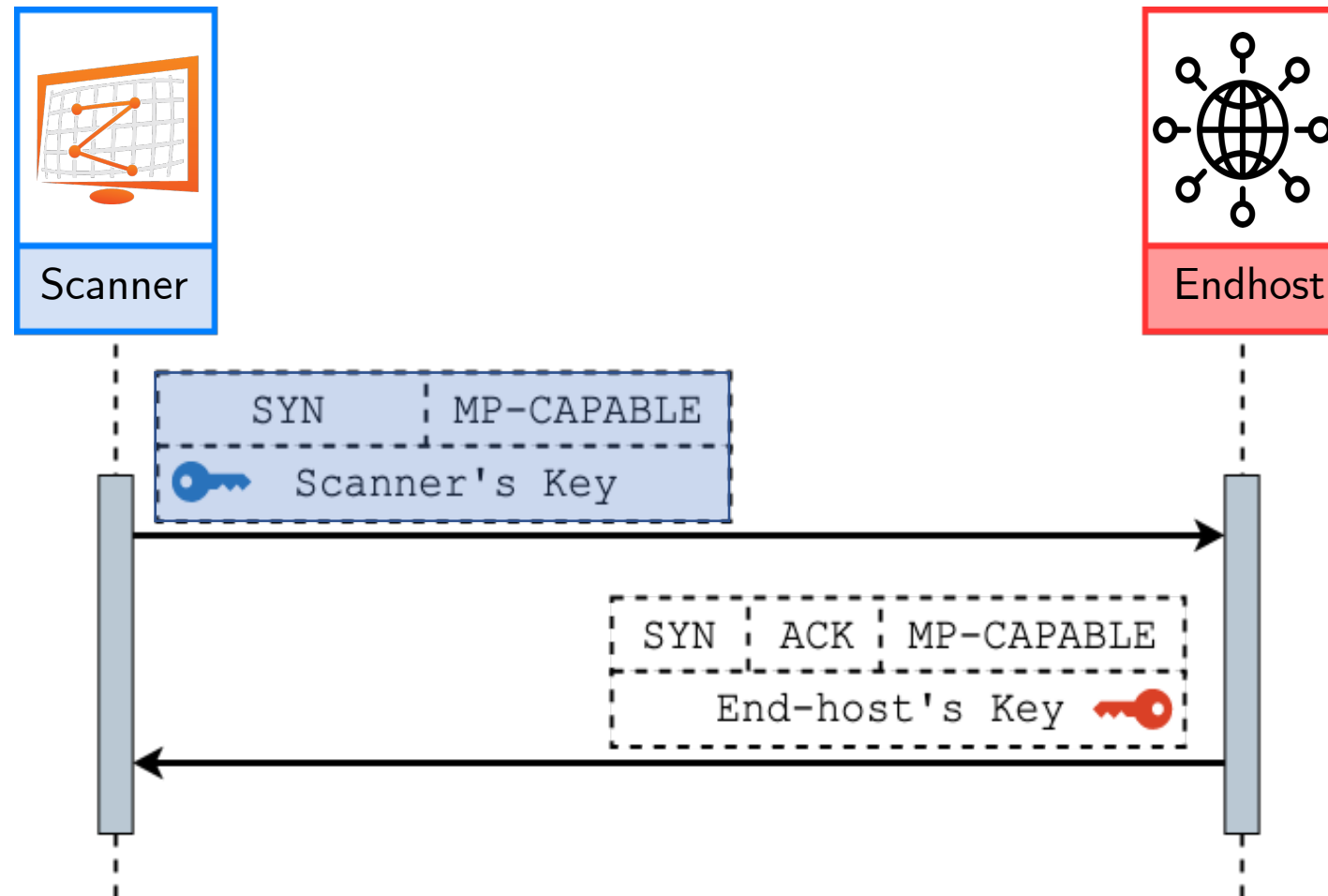


MPTCP connection establishment leverages TCP's three-way handshake

- Both hosts must send MP\_CAPABLE flag to denote MPTCP capability
- MPTCP Key is a random 64-bit sequence

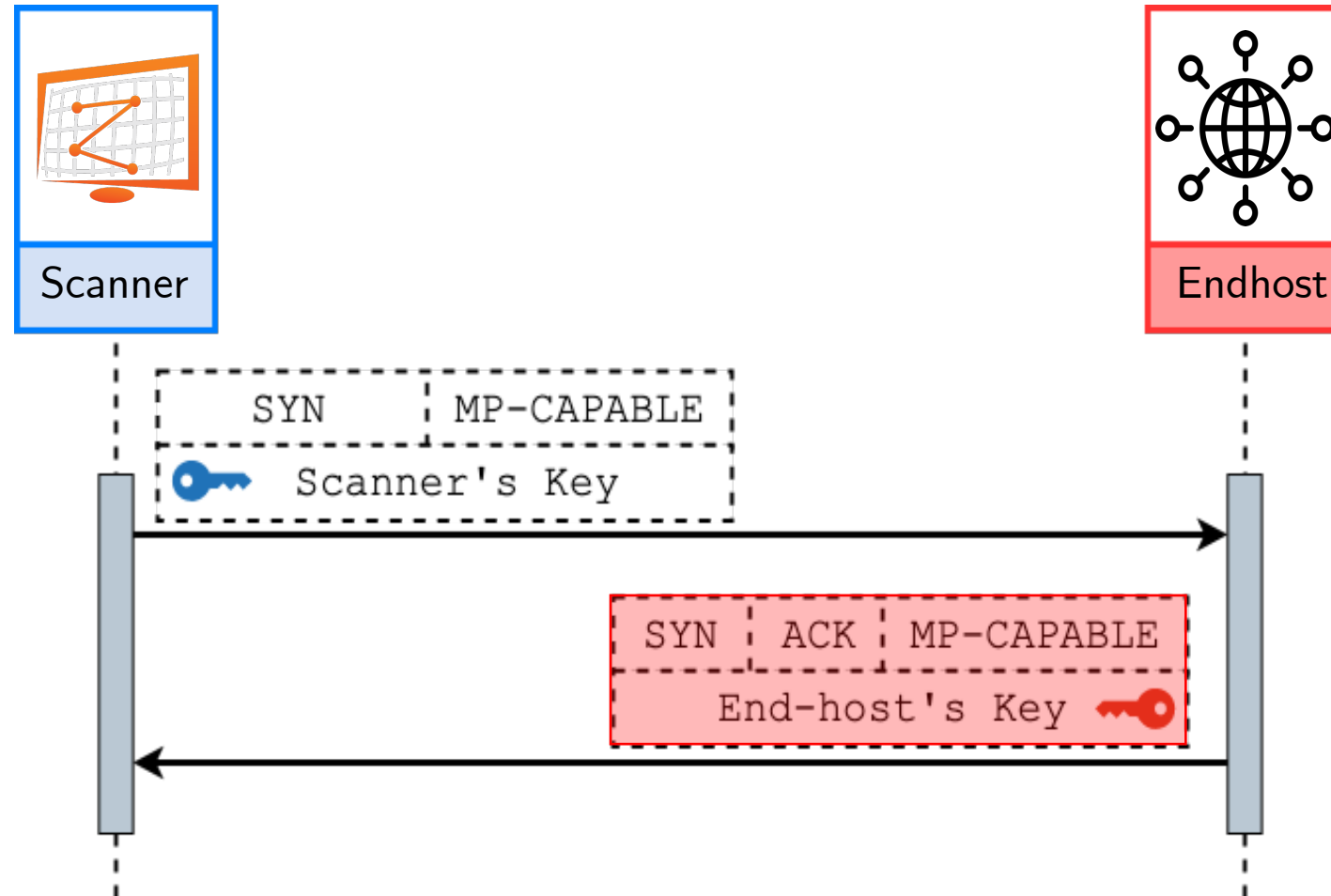
# Scanning for MPTCP Support

## ZMap Scanning Approach



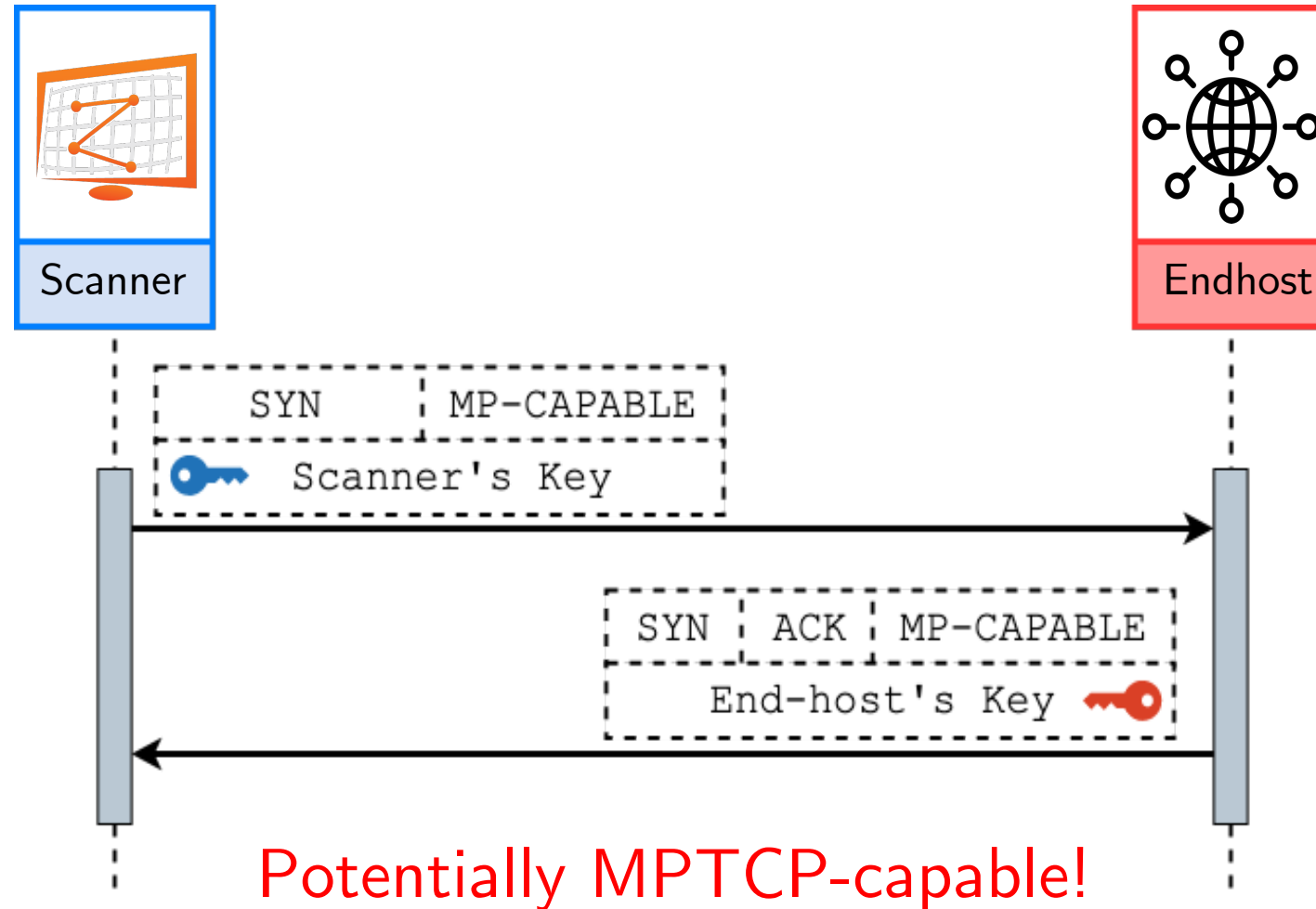
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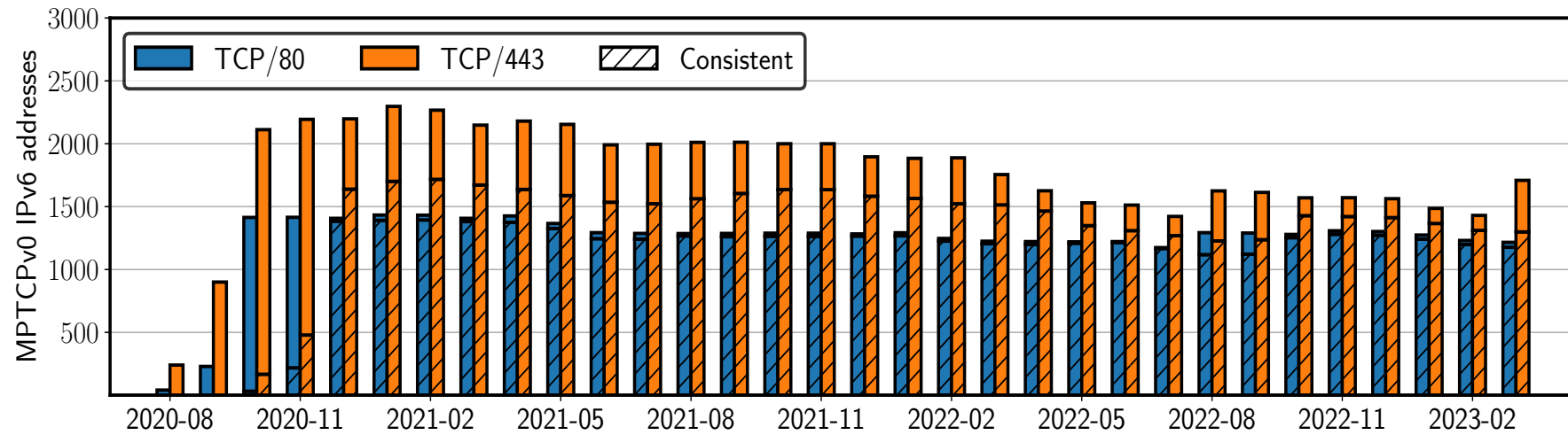
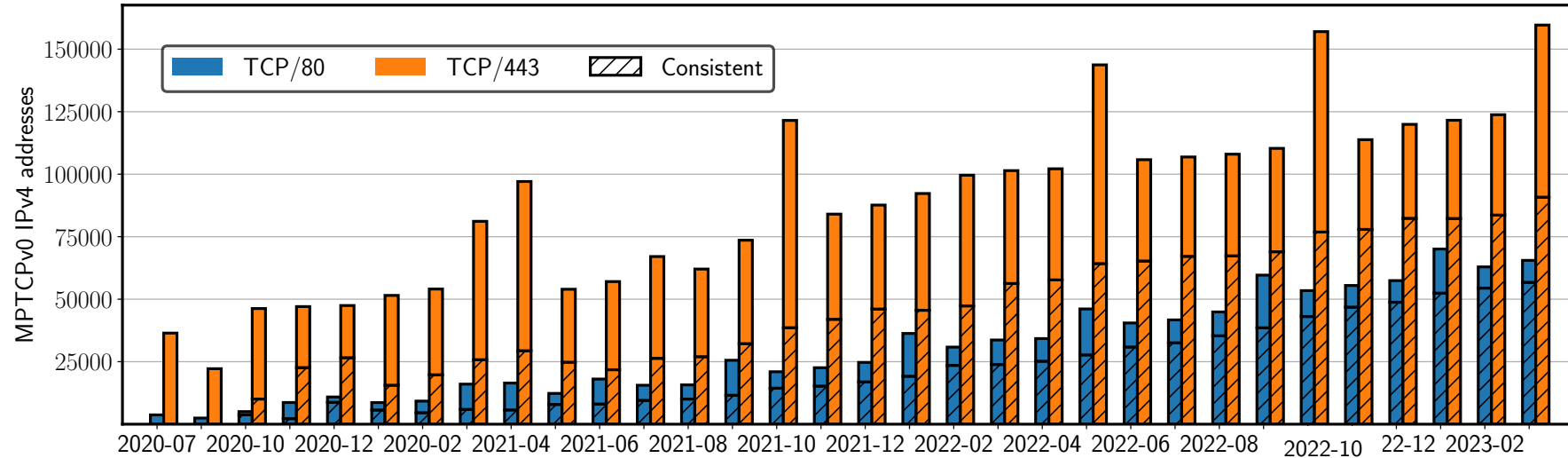


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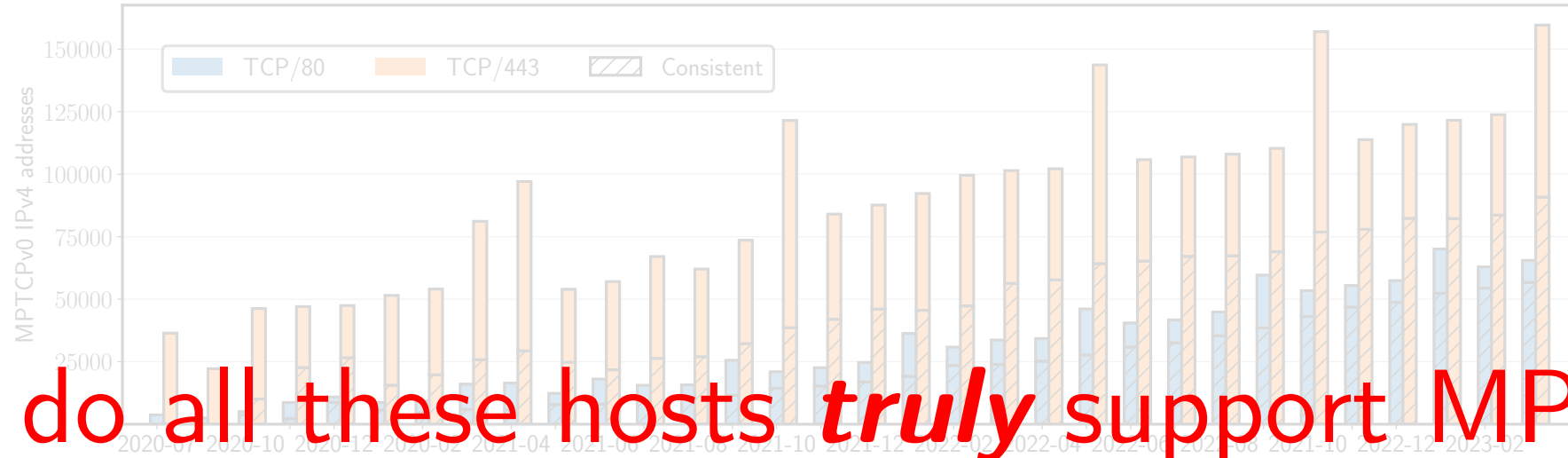
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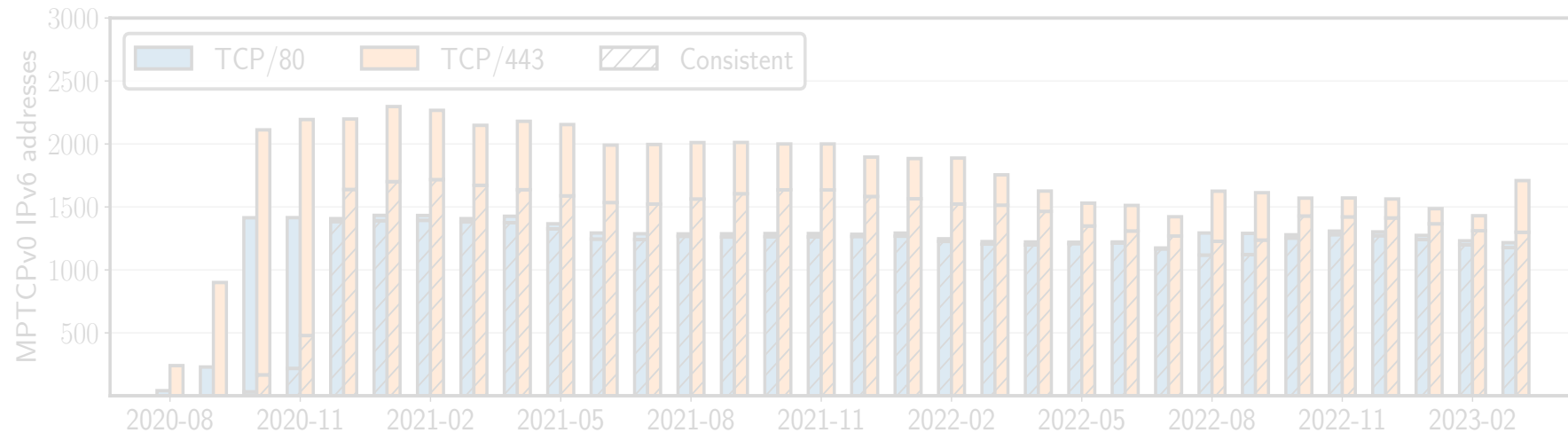
# MPTCPv0 Support in-the-wild



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But do all these hosts *truly* support MPTCP?



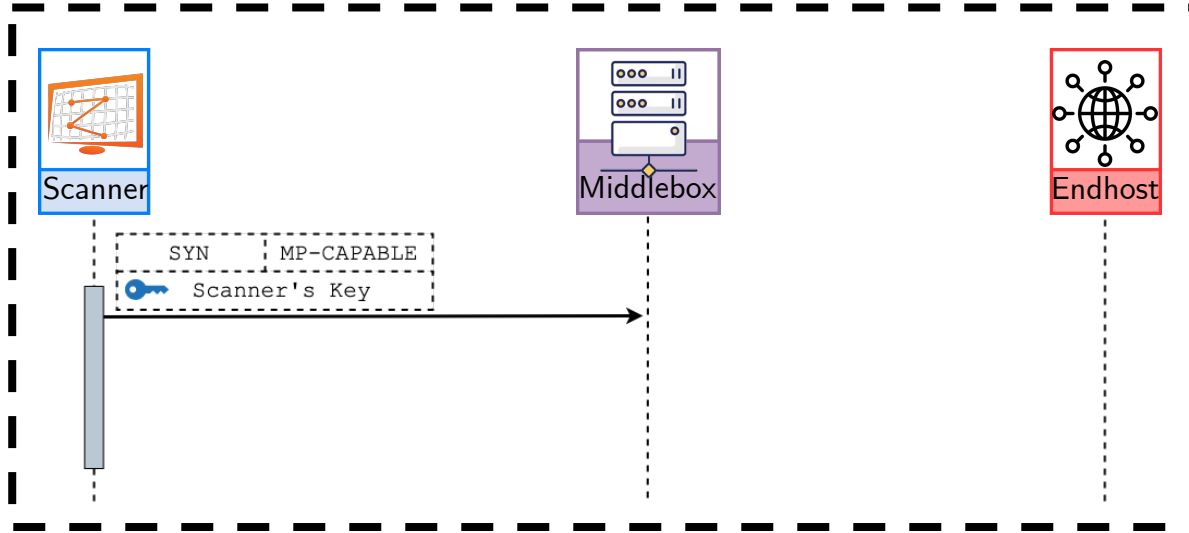


# MPTCP over Middleboxes



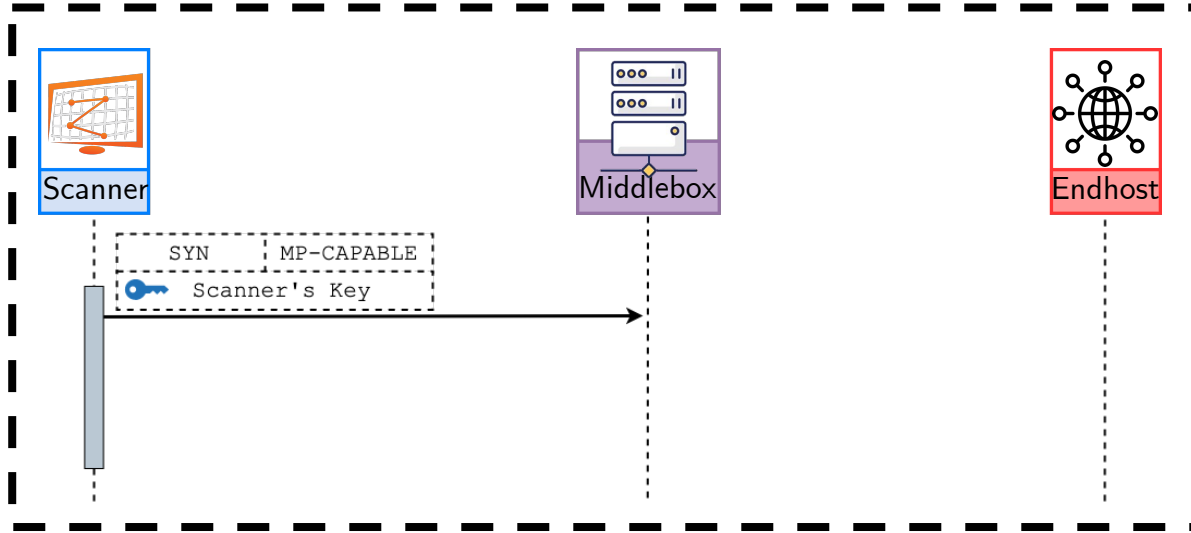
# MPTCP over Middleboxes

Rule 1: Drop

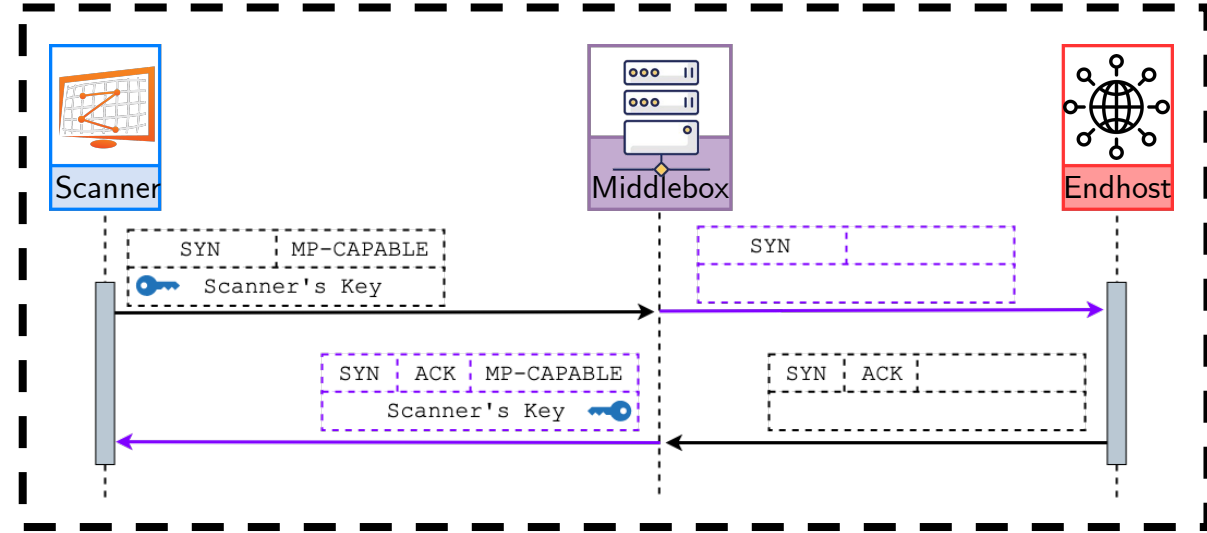


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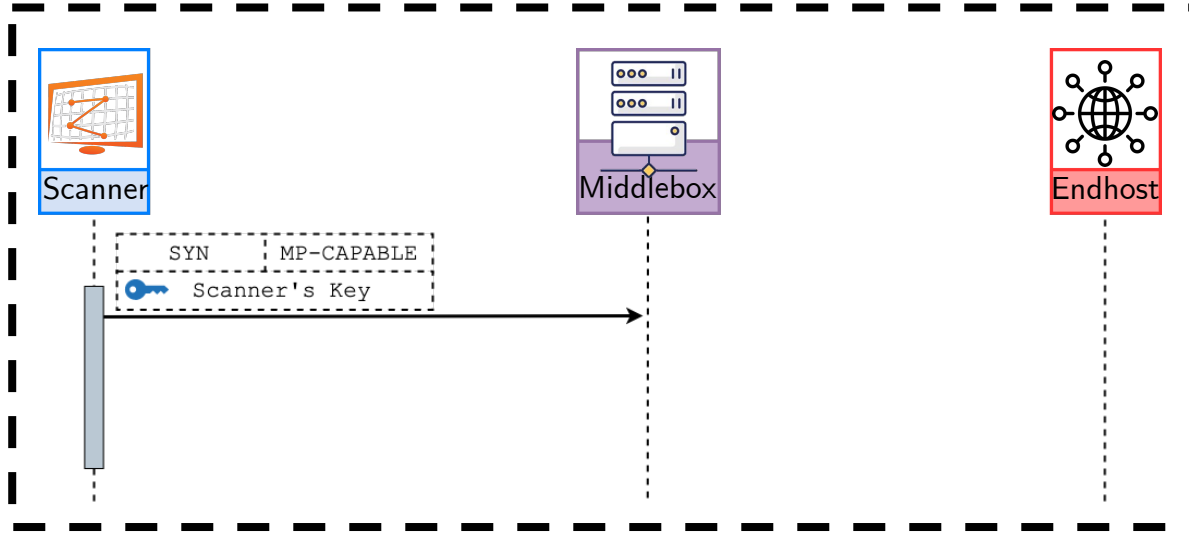


Rule 2: Mirror

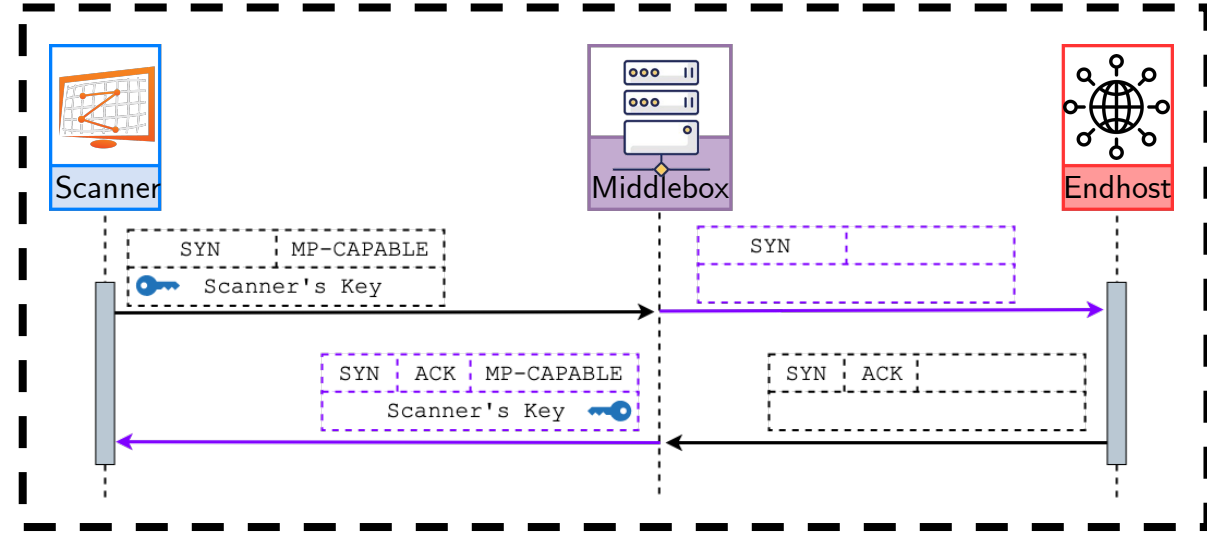


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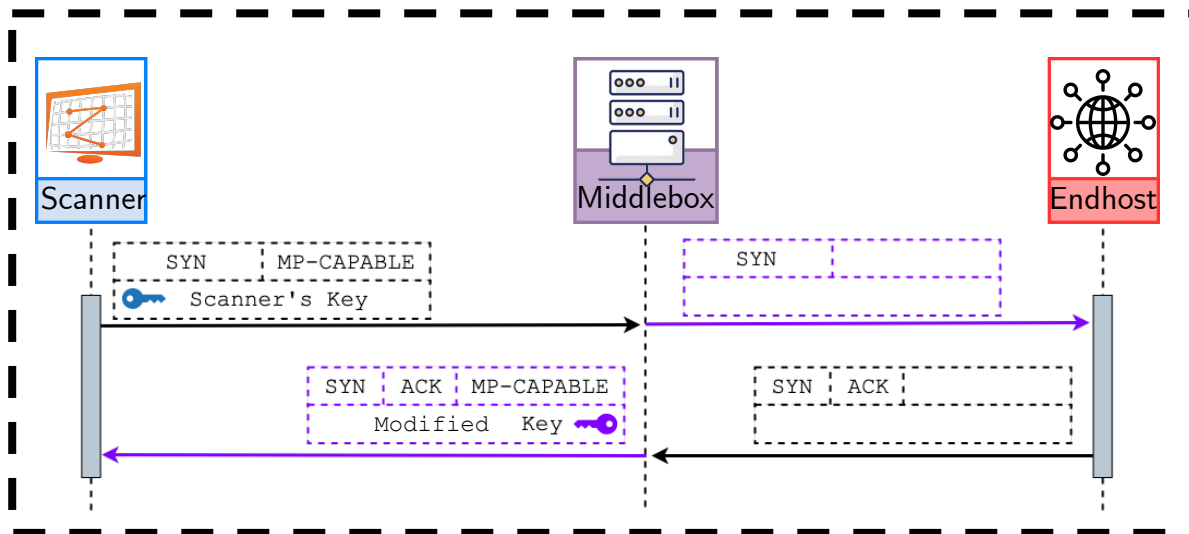
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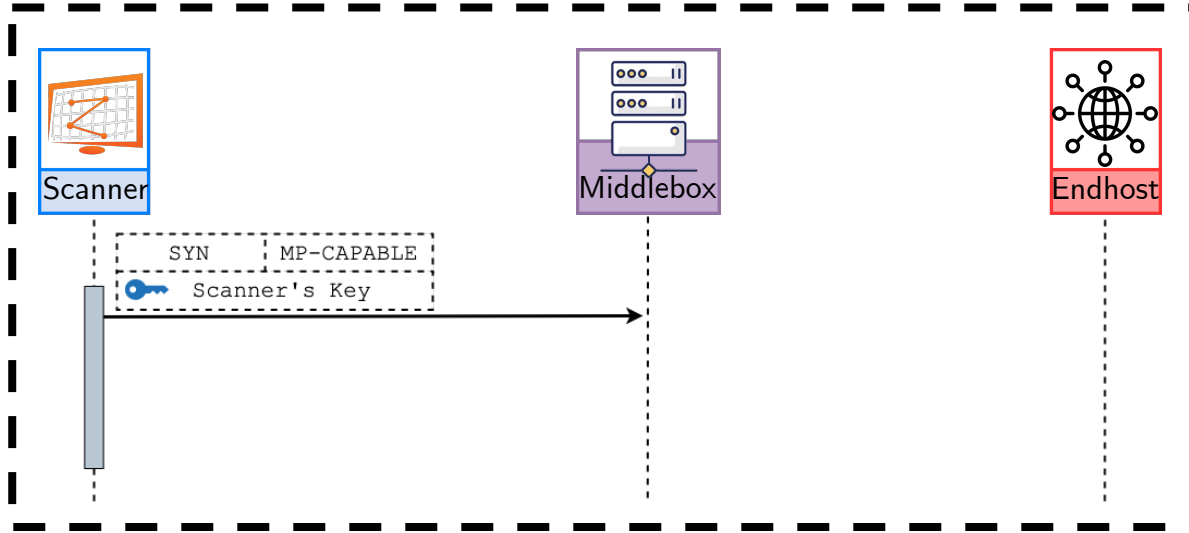


Rule 3: Proxy

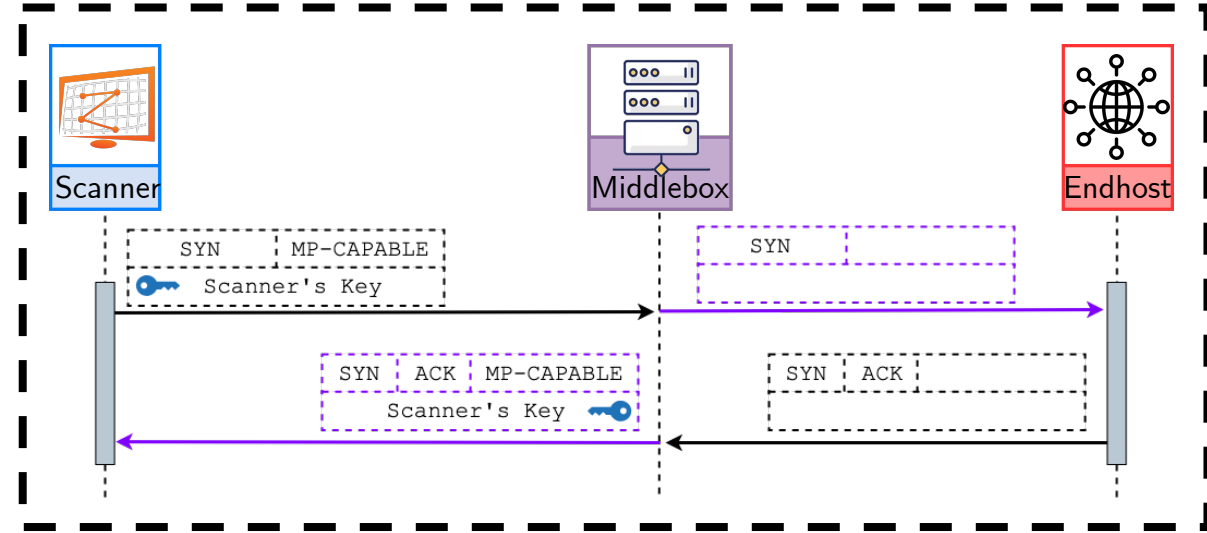


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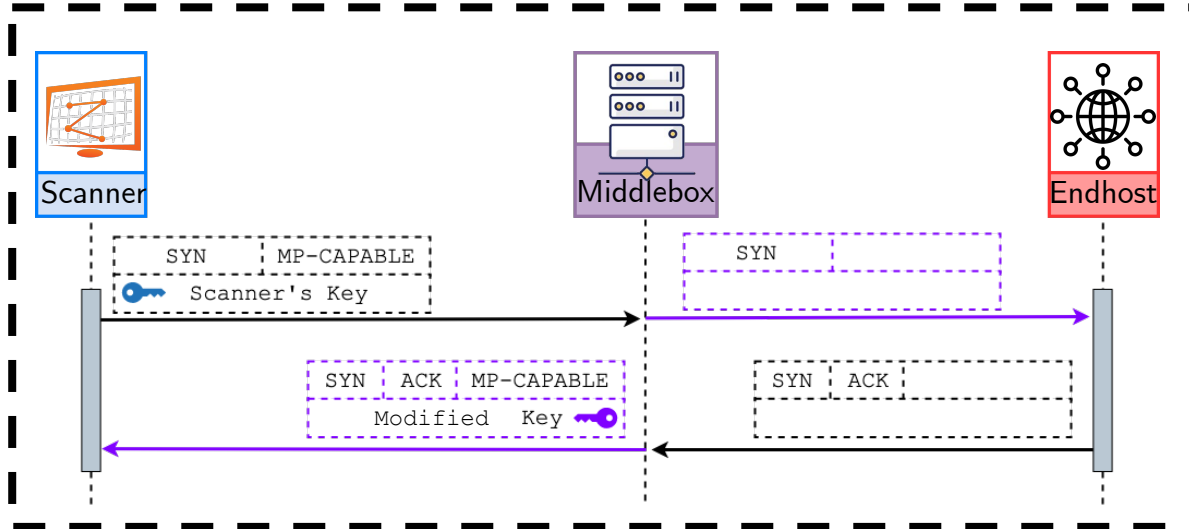
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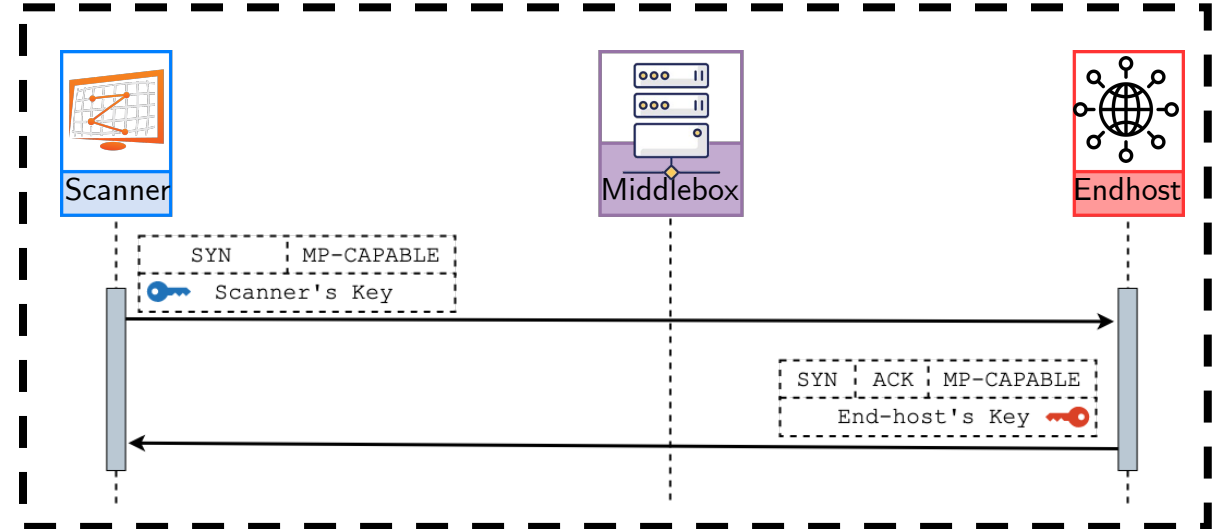
Rule 2: Mirror



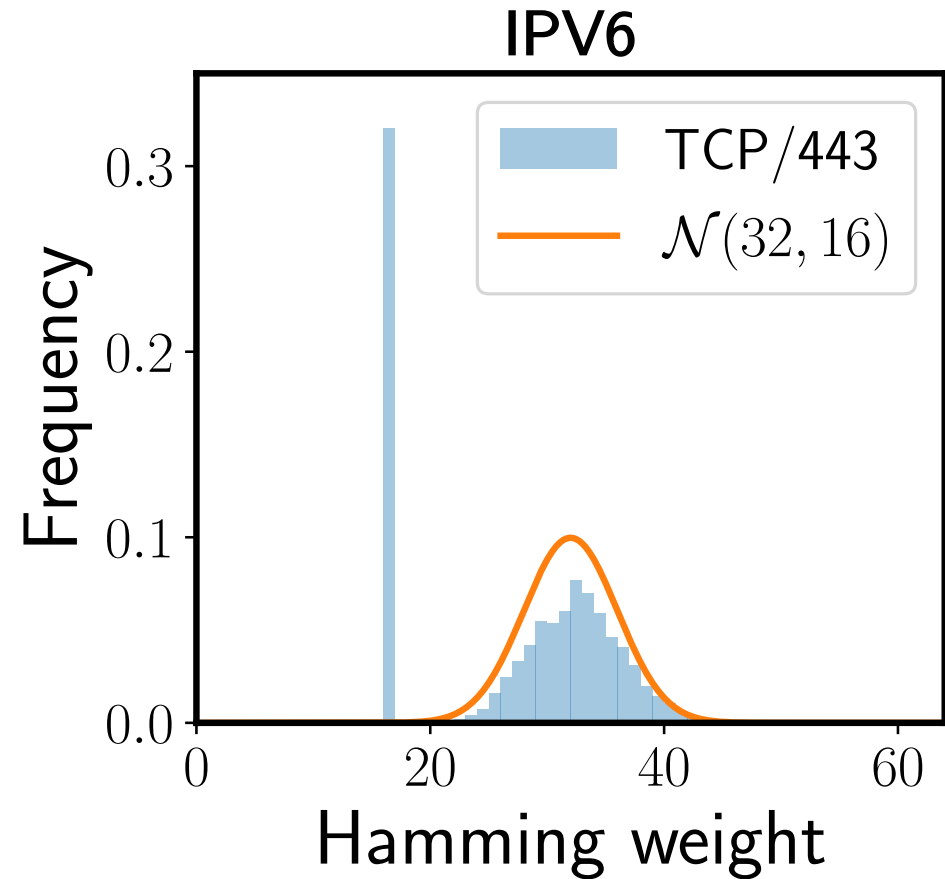
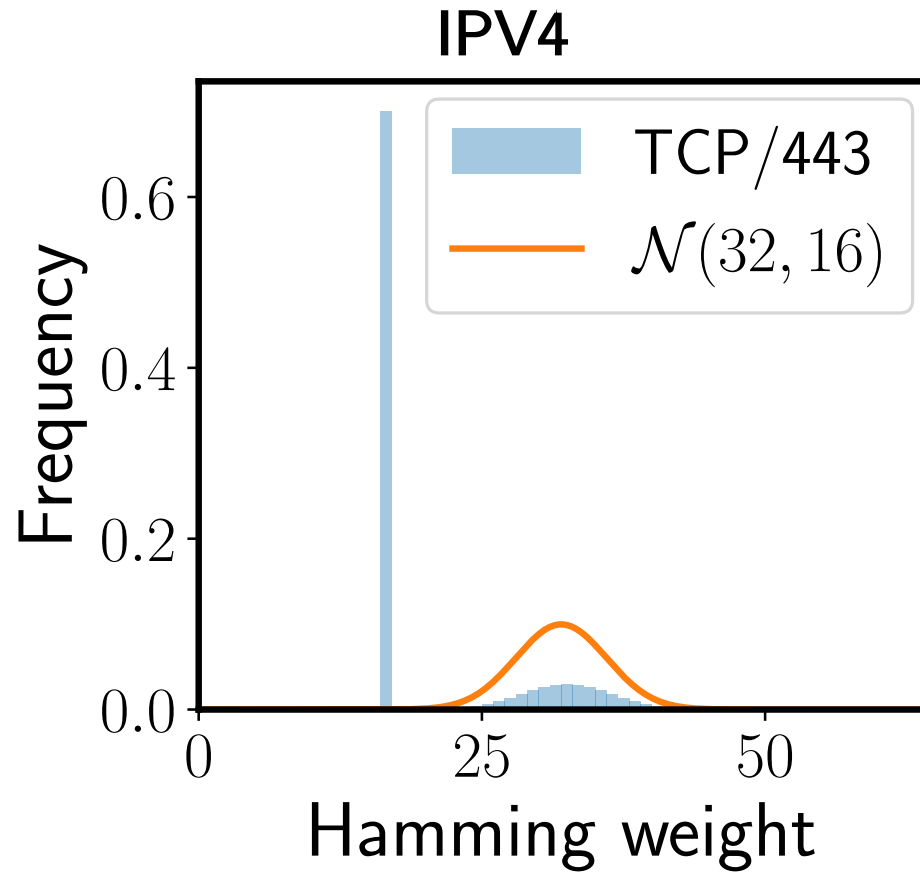
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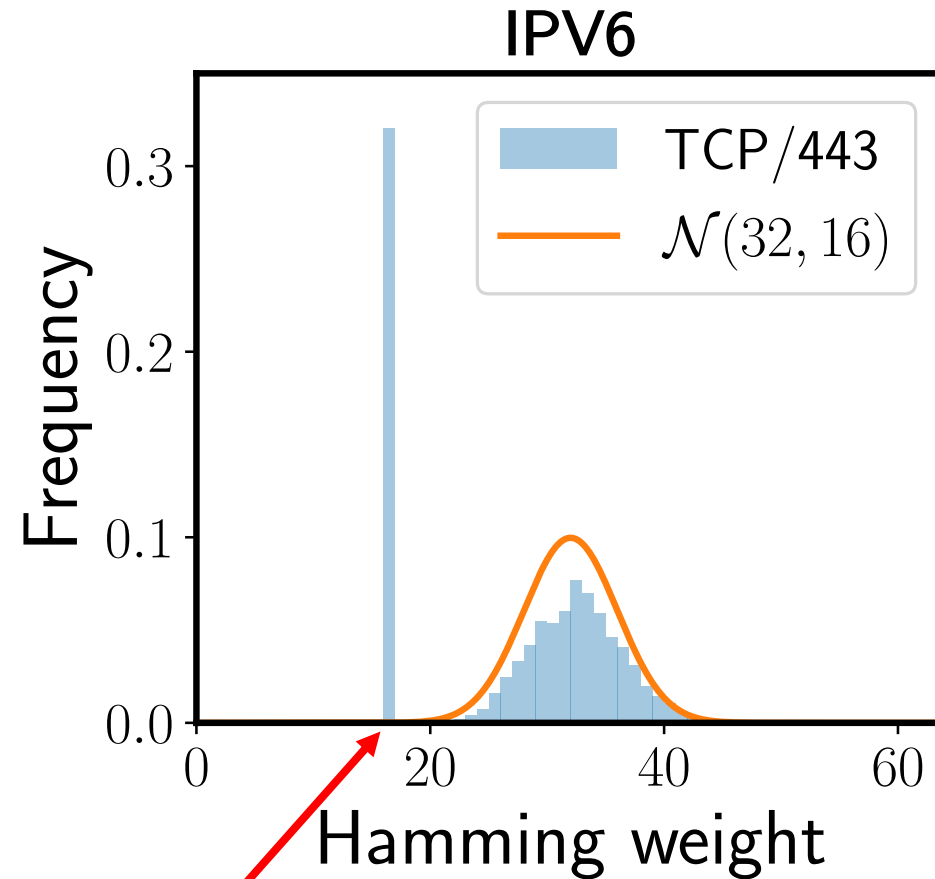
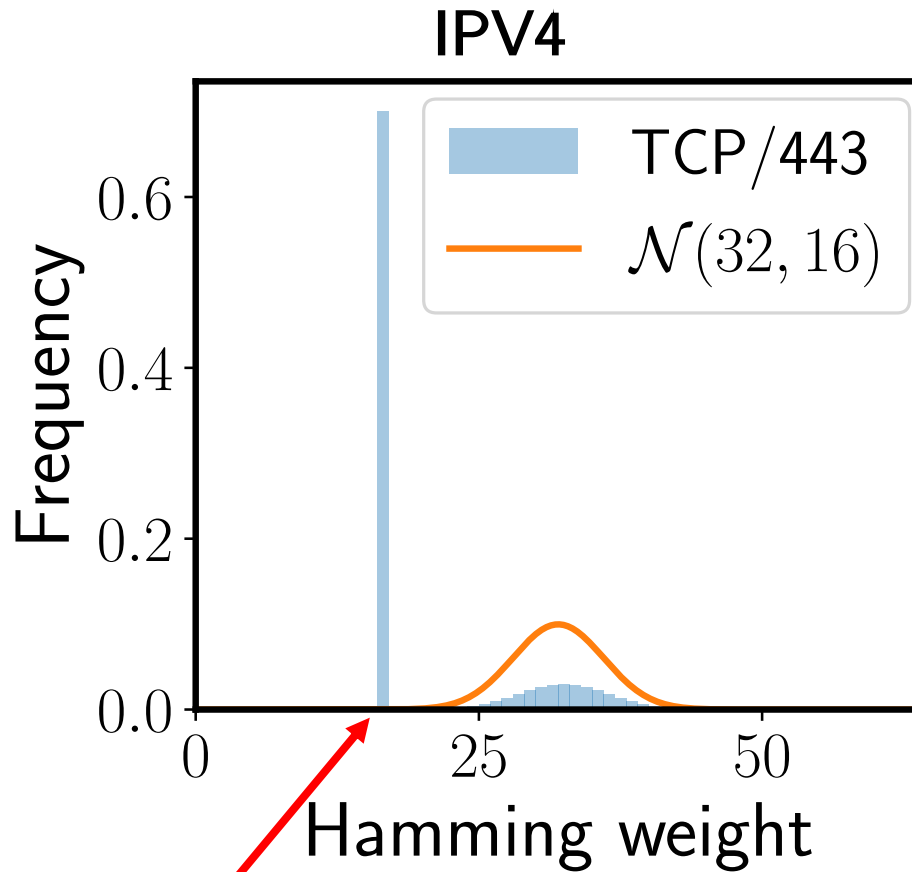
Rule 4: Pass-through



# Impact of Middleboxes on Scans



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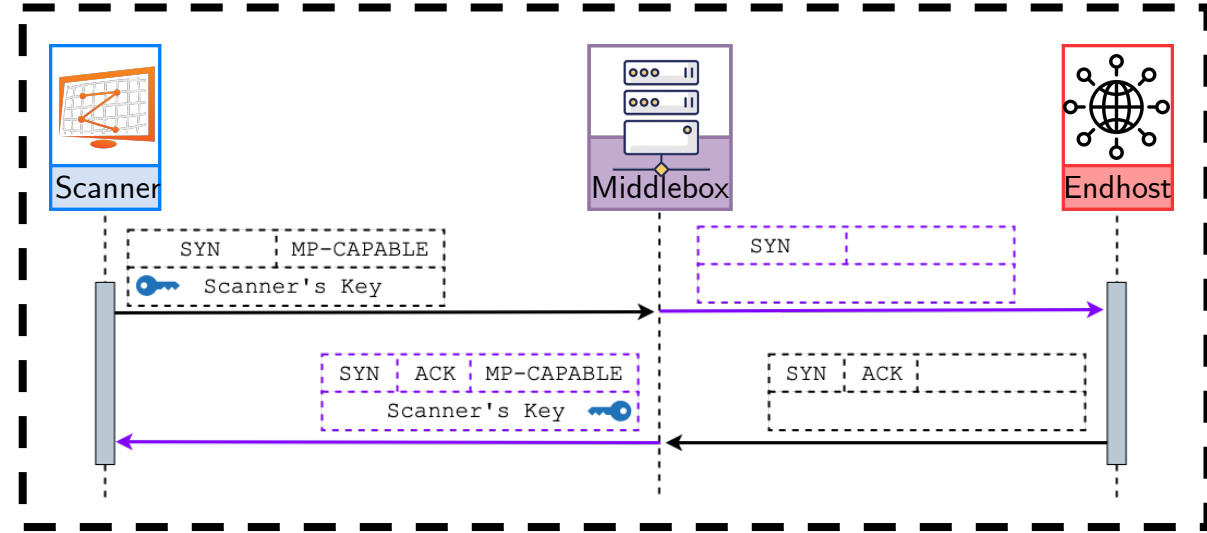


ZMap-based MPTCP identification is severely affected by middleboxes

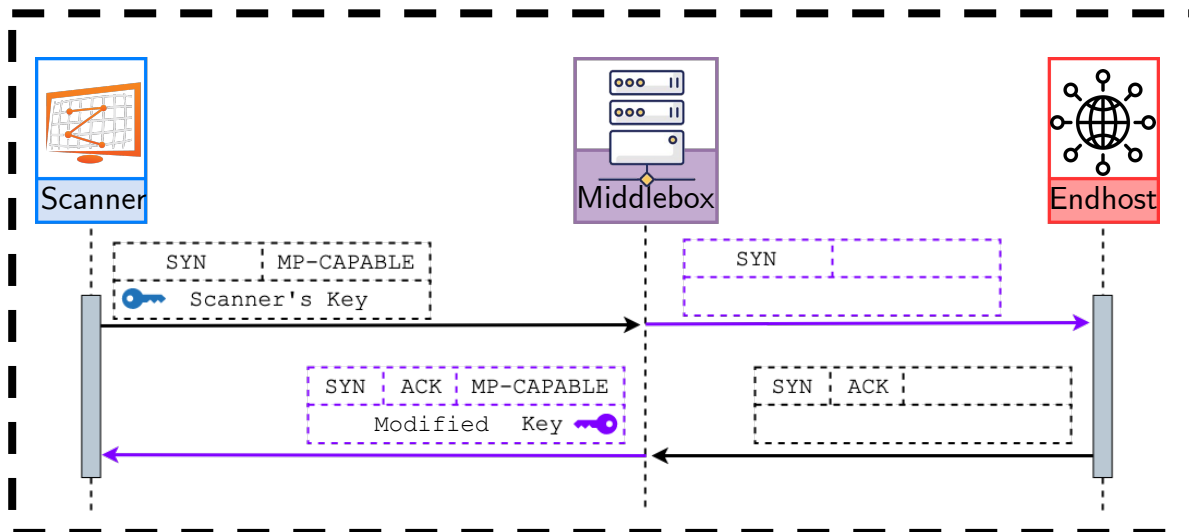
# Impact of Middleboxes on Scans

Judging presence of middleboxes from mirrored sender's key value is not completely effective

Rule 2: Mirror



Rule 3: Proxy





# Analyzing True Support of MPTCP

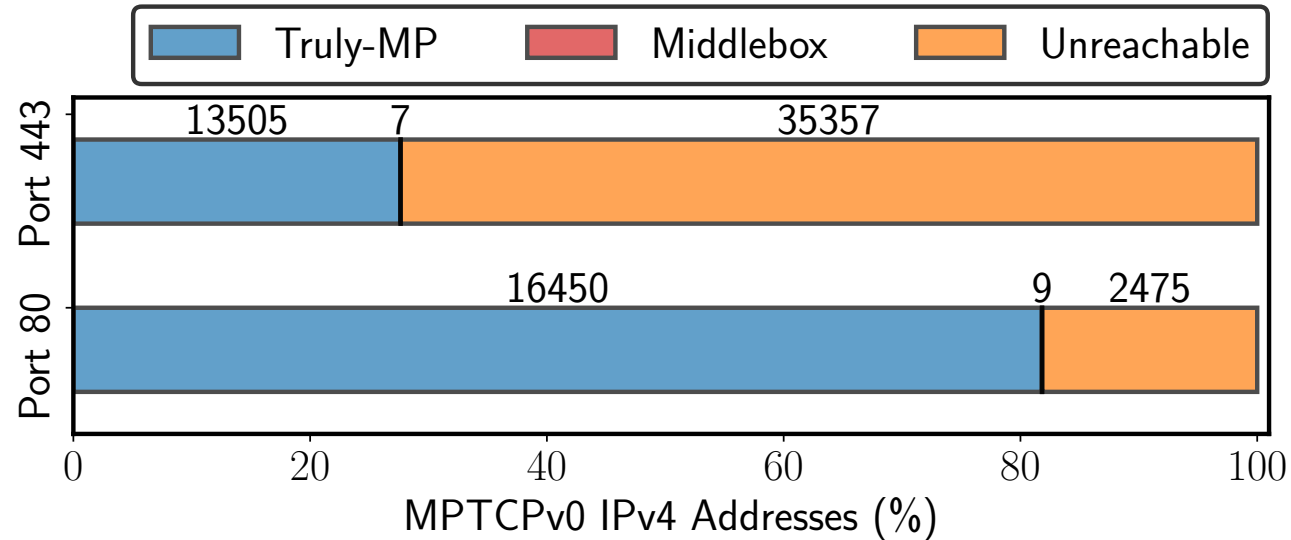
Triggered Tracebox towards all potentially MPTCP hosts from ZMap

- Allows us to detect middleboxes that modified TCP options between end-hosts

Three broad categories:

1. Target host modified MPTCP options → True MPTCP
2. Intermediate hop modified MPTCP option → Middlebox-affected
3. Target did not respond → Unresponsive

# True MPTCPv0 Support in the Internet



- Large number of MPTCP hosts in IPv4 are transient
- Only 7 and 9 middlebox-affected hosts in IPv4
- MPTCP support is increasing in both IPv4 and IPv6

IPv4

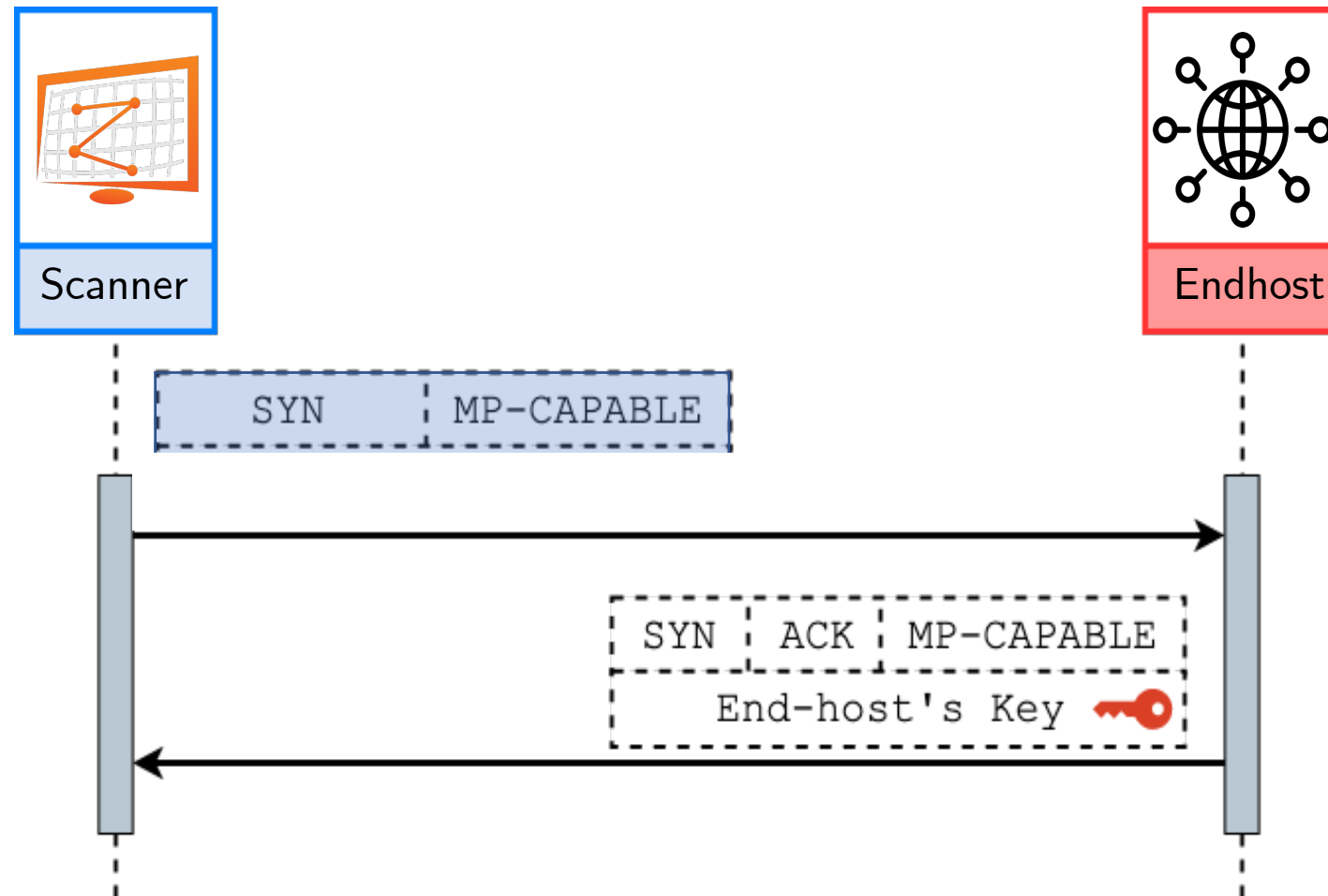
Port 80:  $\approx 16.5k$  Port 443:  $\approx 13.5k$

IPv6

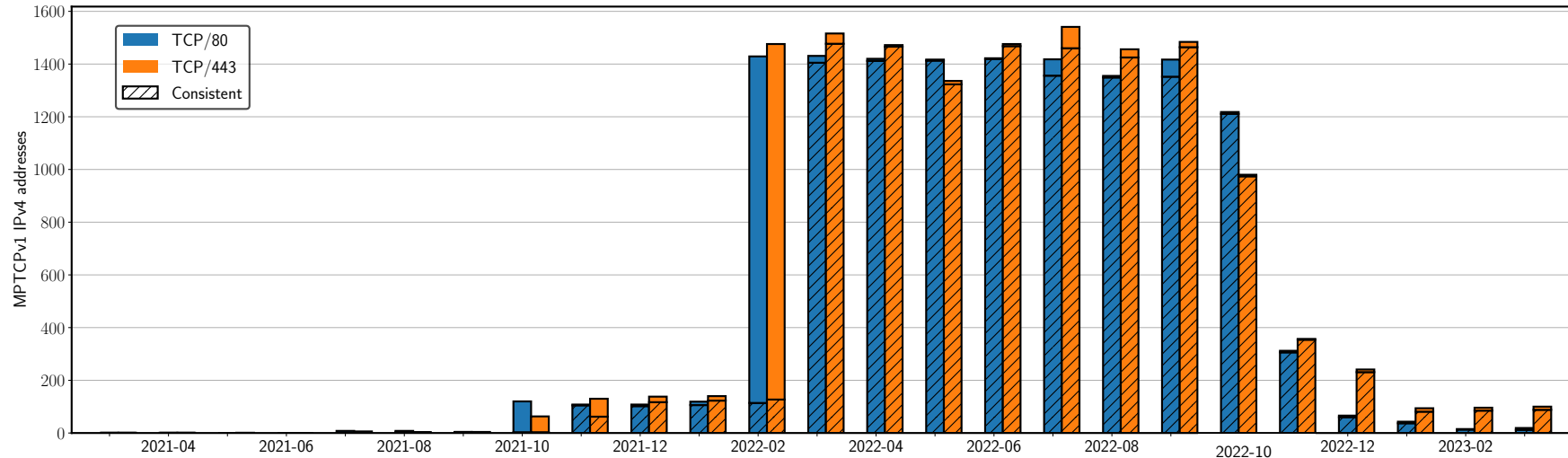
Port 80:  $\approx 1k$  Port 443:  $\approx 1k$

# Scanning for MPTCPv1 Support

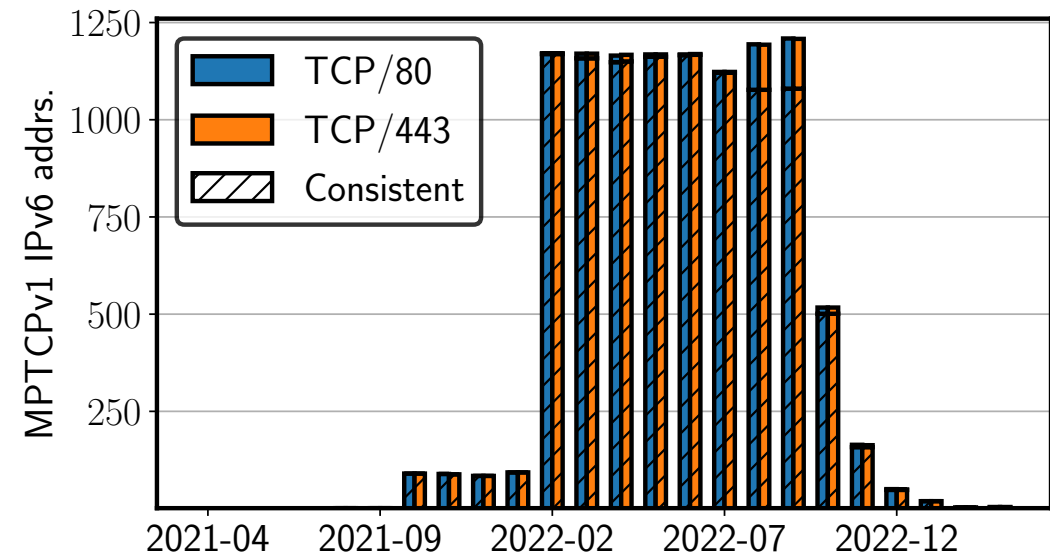
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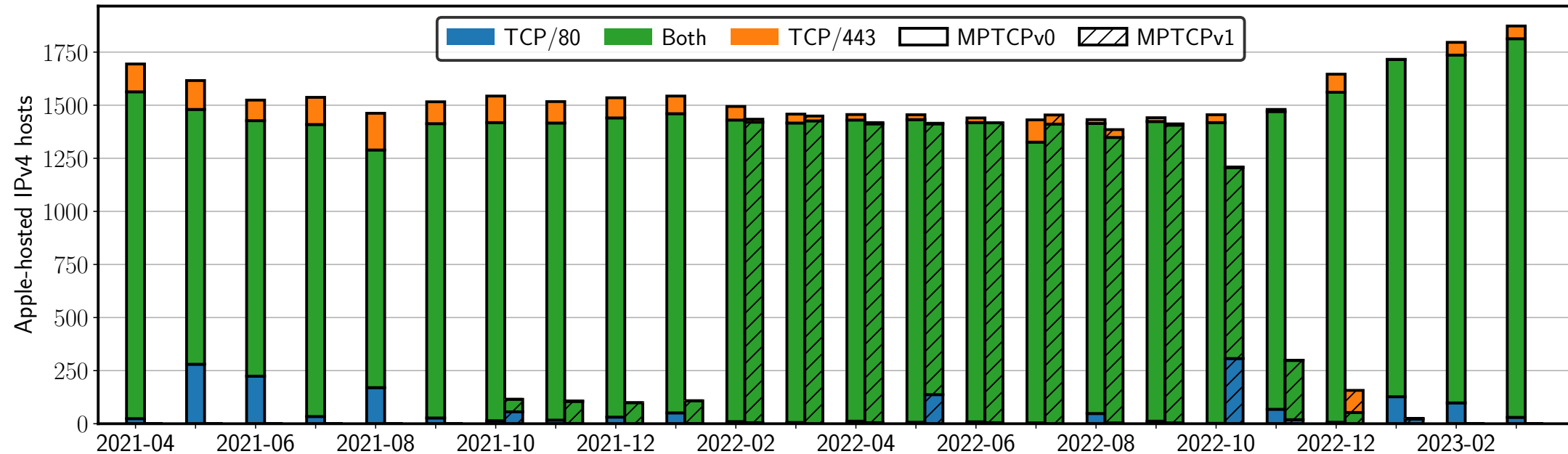
# MPTCPv1 Support in-the-wild



- MPTCPv1 non-existent till Oct 2021
- MPTCPv1 not affected by middleboxes
- Larger consistent responsive in MPTCPv1 compared to MPTCPv0 for both IPv4 and IPv6



# Apple Case Study



- No MPTCPv1 till October 2021
- MPTCPv0 support is relatively consistent over Ports 80/443
- Different versions for different (non-overlapping) services

# Thank you!

## Summary

- Simply standardizing a protocol doesn't guarantee its popular use
- Middleboxes can severely impact (i) MPTCP usage, (ii) MPTCP adoption accuracy, (iii) MPTCP performance
- MPTCPv1 is more robust and widely available but MPTCPv0 is still more popular
- Solutions like MP-QUIC might be better suited as they don't rely on header extensions

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### Analyzing MPTCP adoption in the Internet

By Tanya Shreedhar on 23 Aug 2022

Category: Tech matters

Tags: Guest Post, IPv4, IPv6, measurement, multipath, TCP

2 Comments

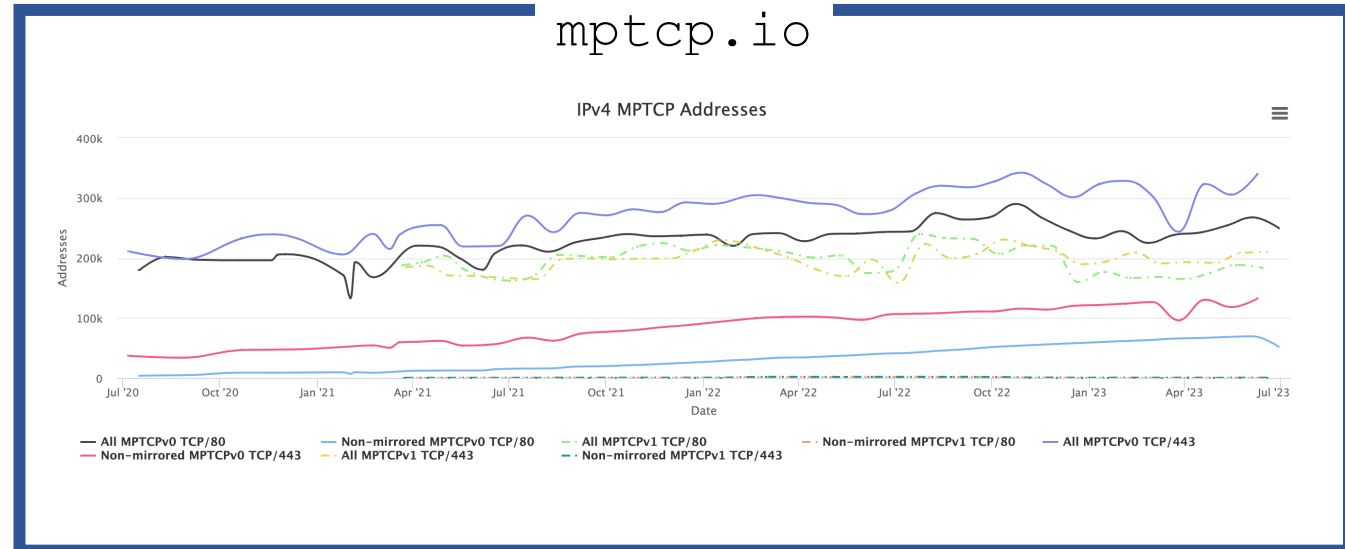
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Photo by Bruno Kelzer on Unsplash

Multipath TCP (MPTCP) has been in development since 2013 (RFC 6824) and has seen significant interest from researchers and industries alike. The protocol aims to use multiple available network paths between endpoints simultaneously.

Several organizations have publicly announced MPTCP incorporation within their products and services, including:



email: [info@mptcp.io](mailto:info@mptcp.io)