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Unpacking Internet Ossification: A Large-Scale Study of Path-Impairing Middleboxes Across IPv4 and IPv6

Fahad Hilal, Taha Albakour, Oliver Gasser, Kevin Vermeulen

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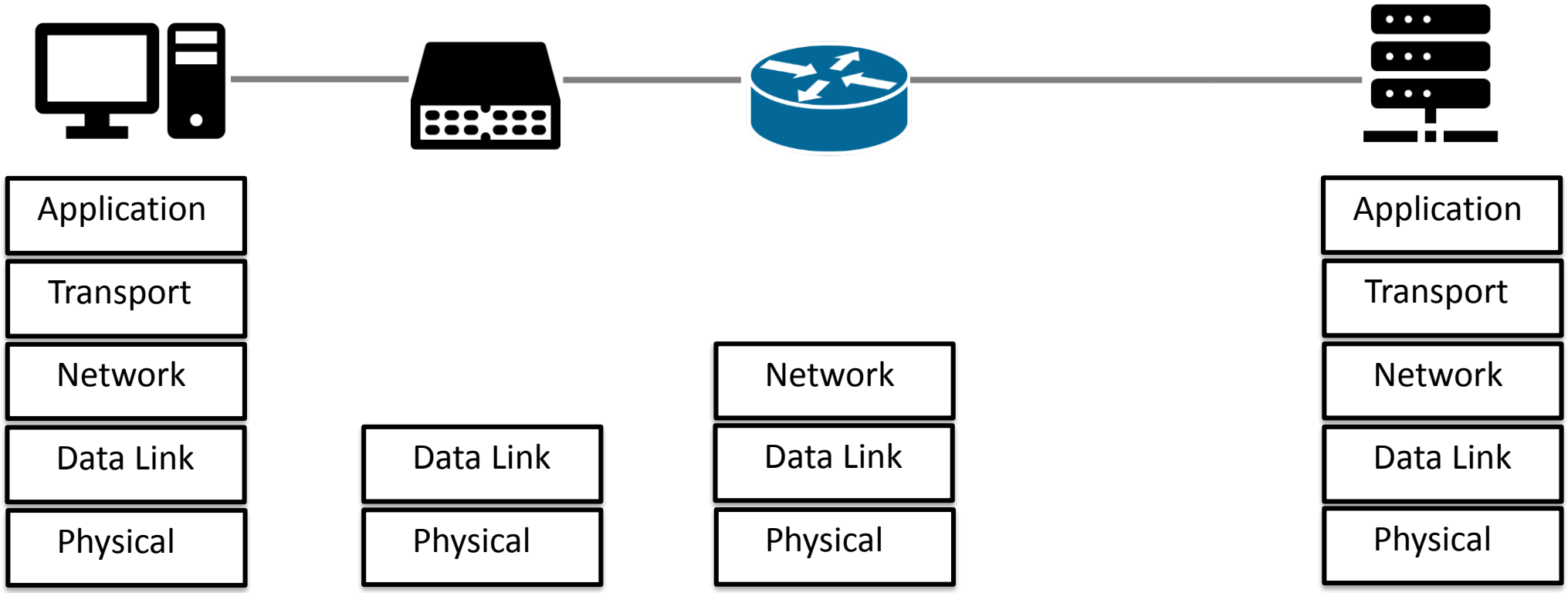
MAX PLANCK INSTITUTE FOR INFORMATICS

IPinfo

ÉCOLE POLYTECHNIQUE

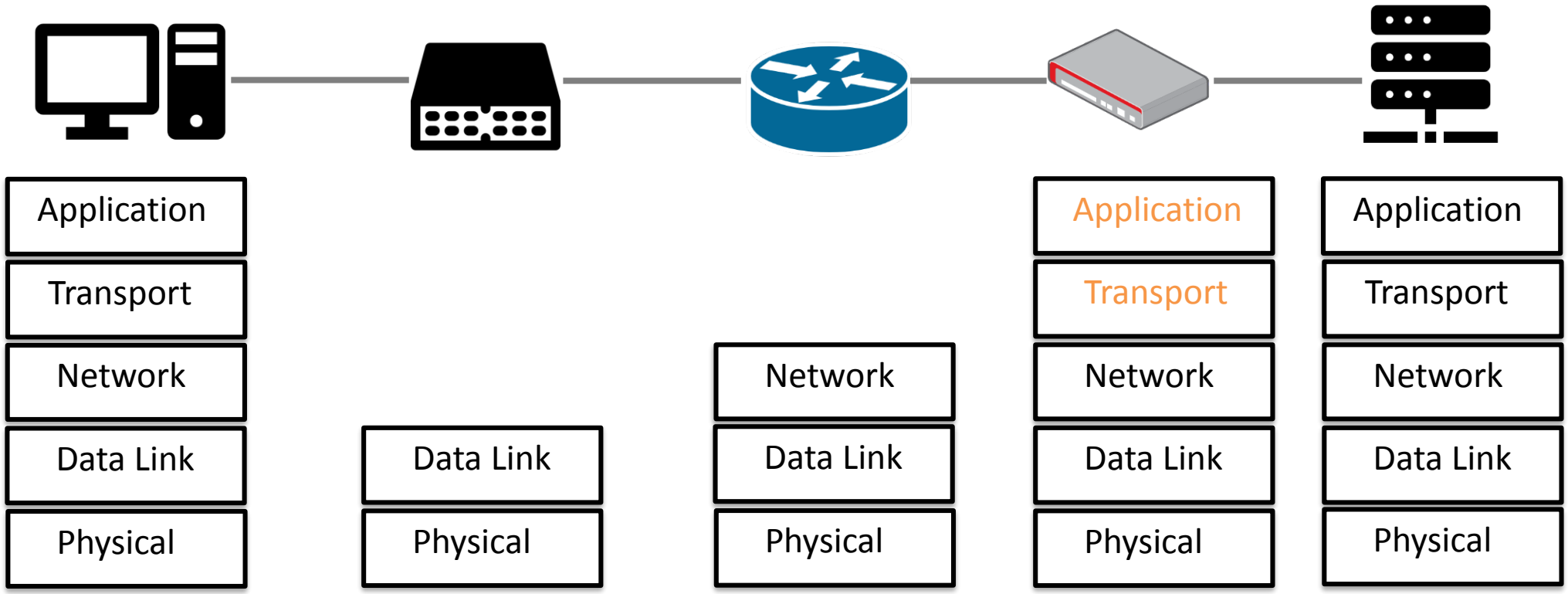
The Traditional Internet-End-to-End Principle

- Simplicity in middle, intelligence at ends



Growing Complexity-Middleboxes

- Internet as ***deployed***, no longer as ***designed***



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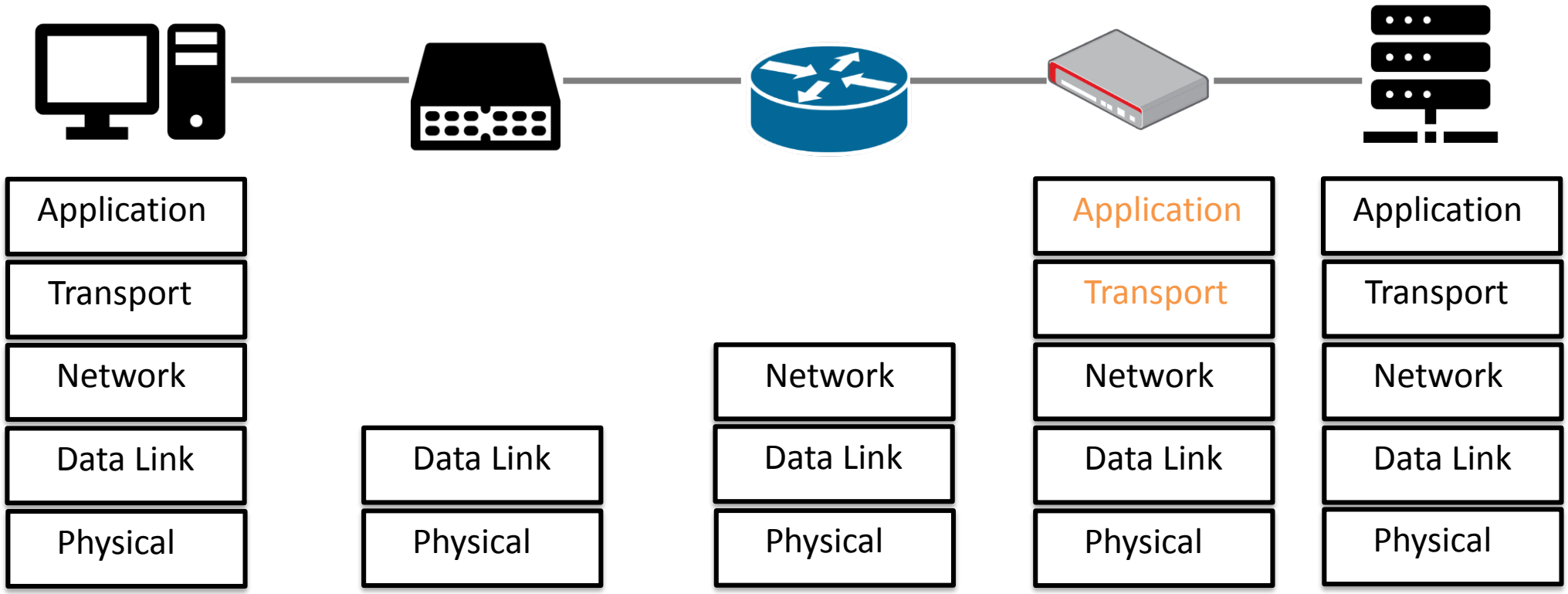

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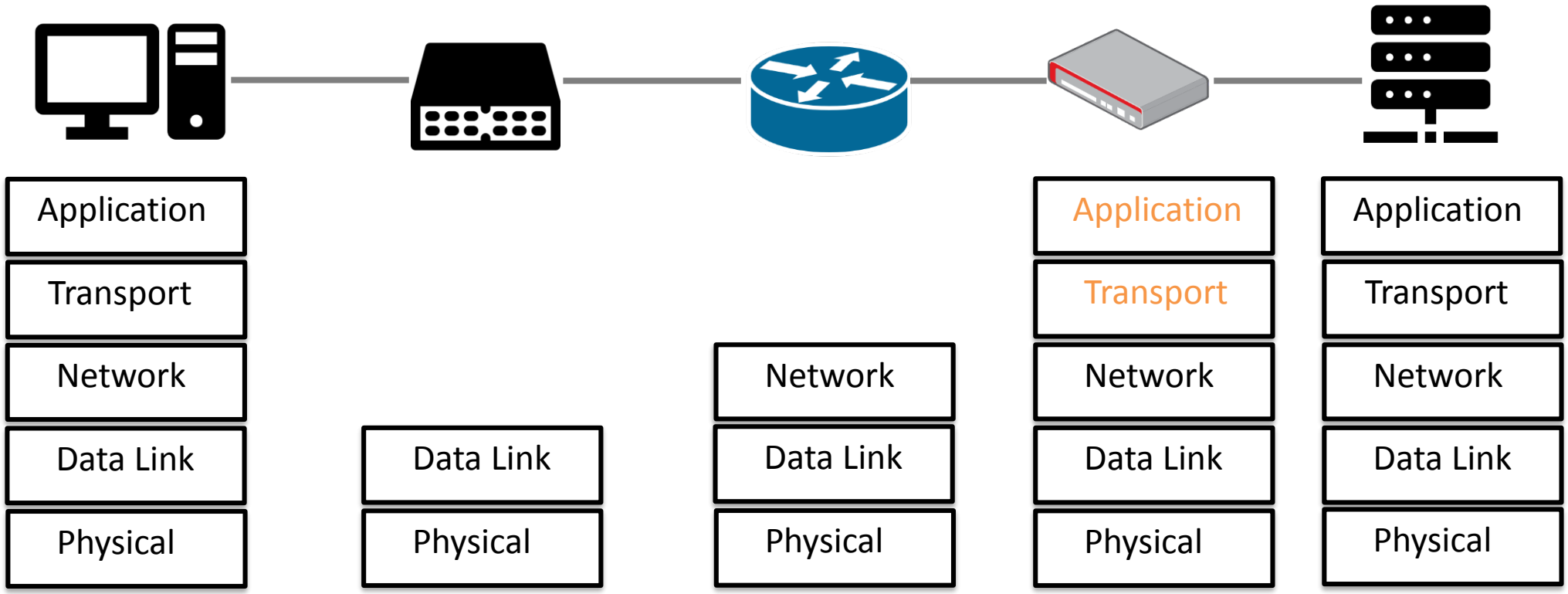
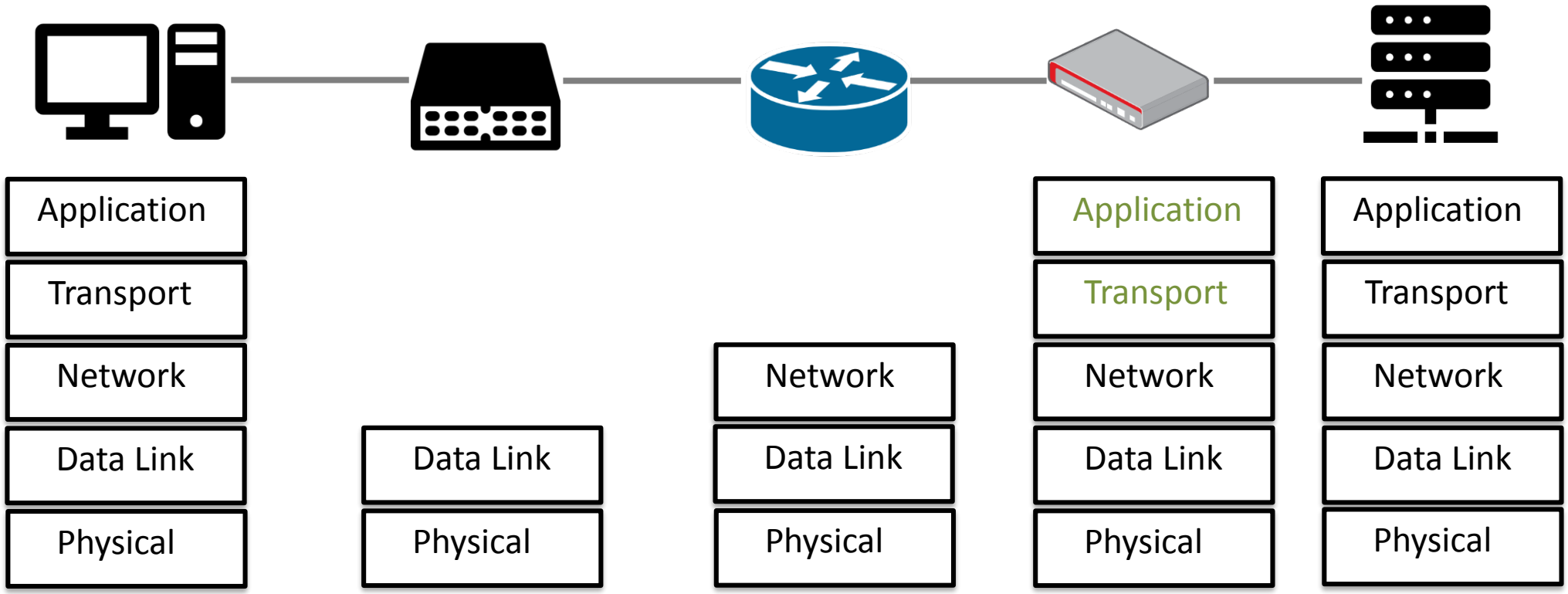


Growing Complexity-Middleboxes

- Internet as ***deployed***, no longer as ***designed***
- ***Invasion*** of ***middleboxes***
  - Inspect, filter, modify
  - Thwart attacks, expand address space, balance resources



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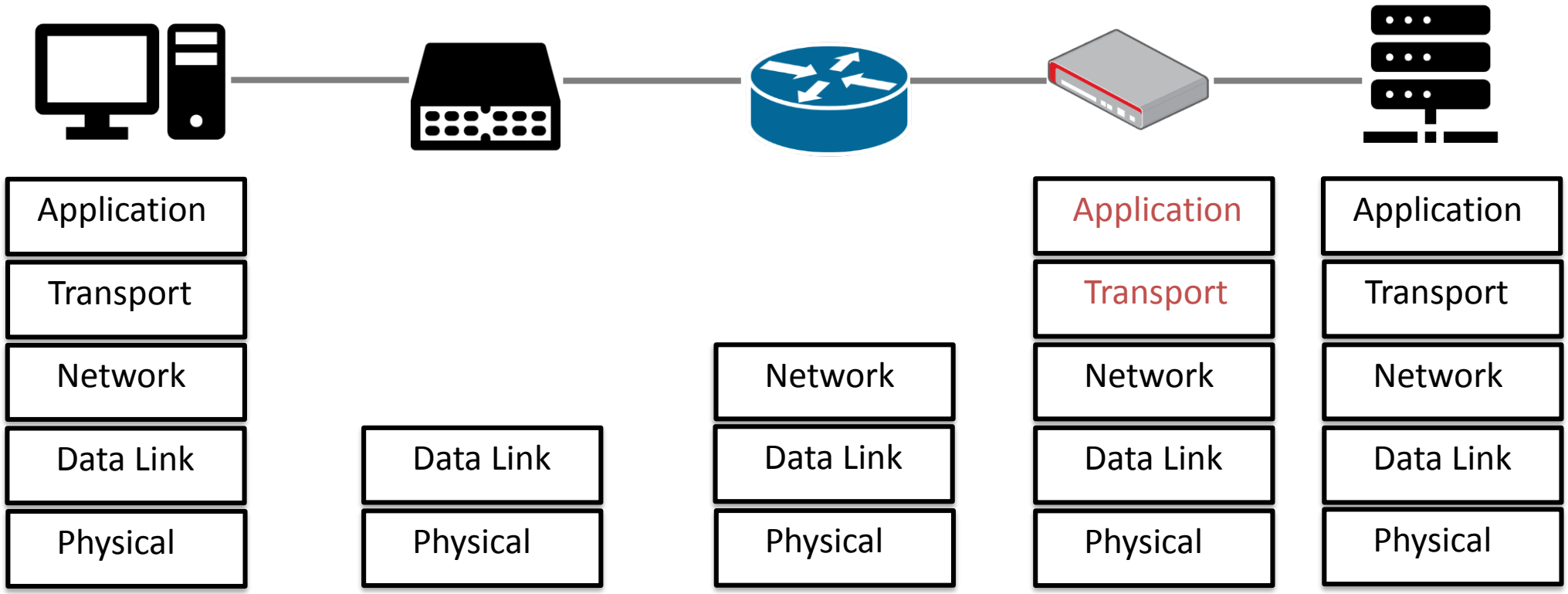
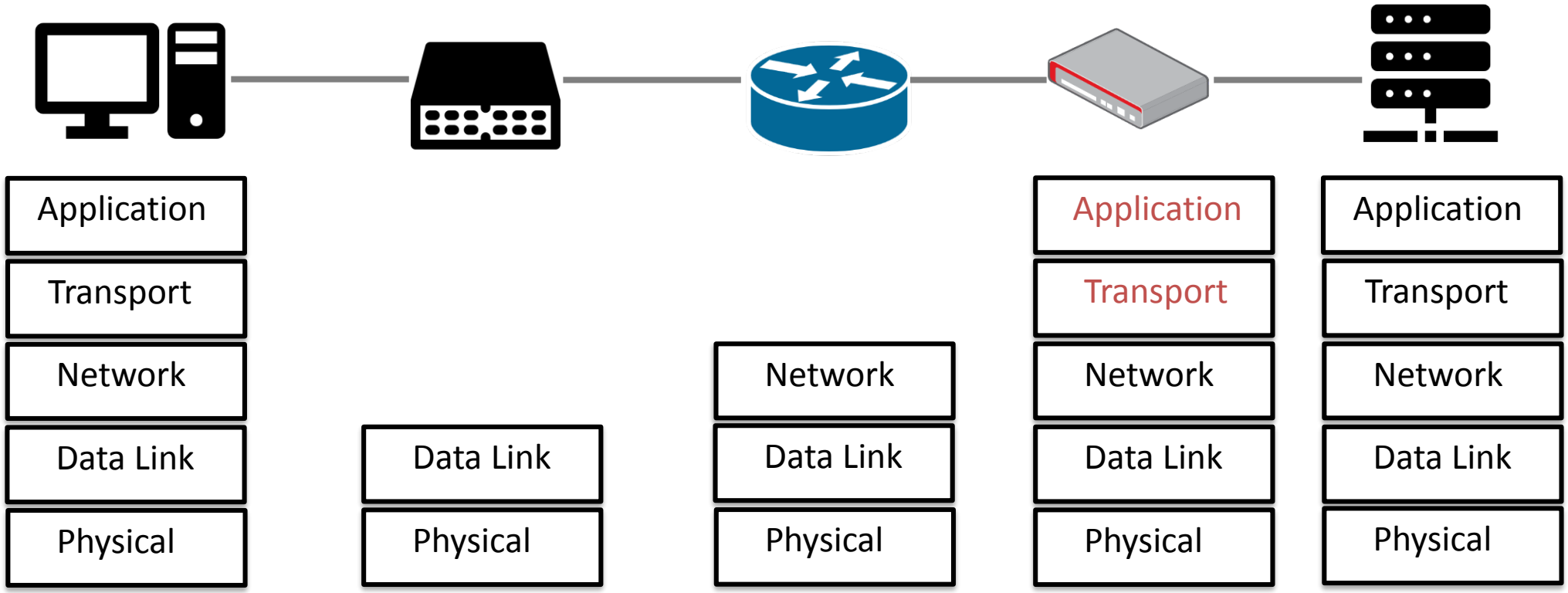


Growing Complexity-Middleboxes

- Internet as ***deployed***, no longer as ***designed***
- ***Invasion*** of ***middleboxes***
  - Ossification
    - DCCP, SCTP standardized,
    - ***Failed*** to be deployed at large scale



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- Path-Impairing middleboxes (MBs)
  - Unexpected alterations ***(impairments)*** to TCP/IP packet headers
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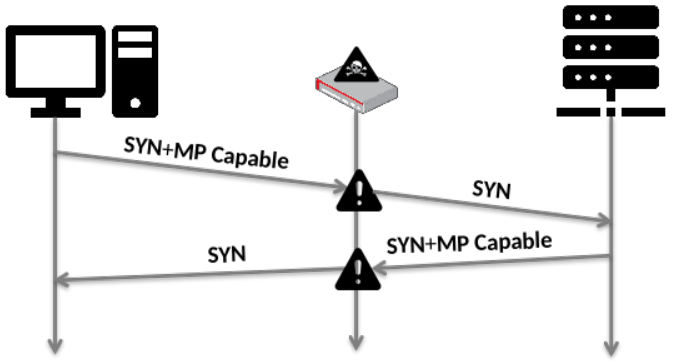

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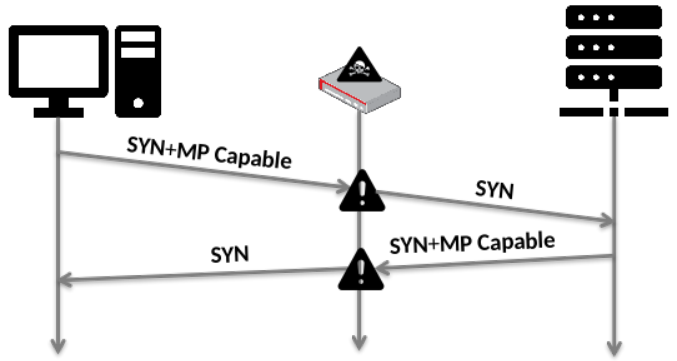

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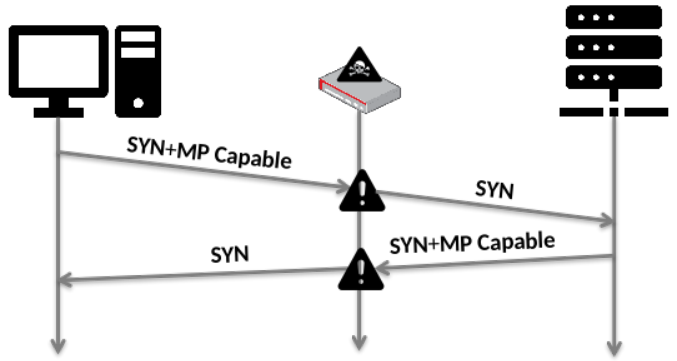

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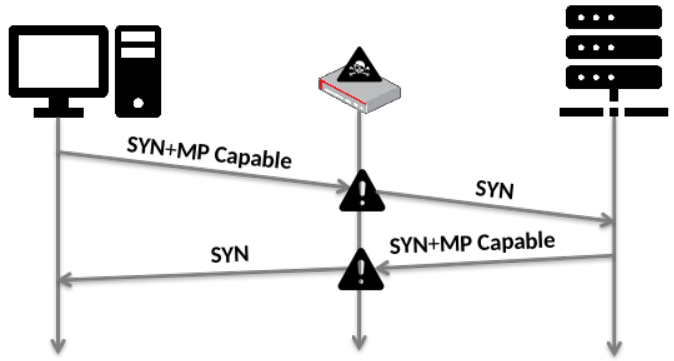

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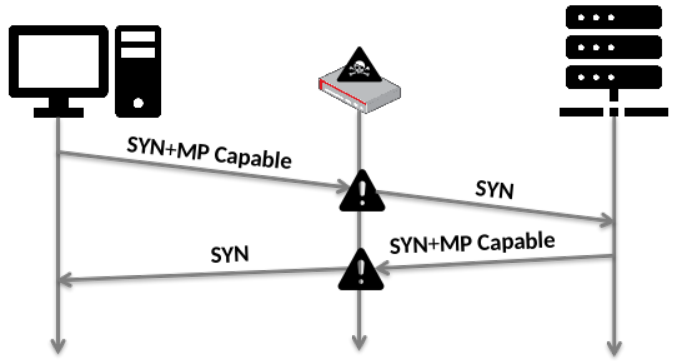
      - Root ***causes***?



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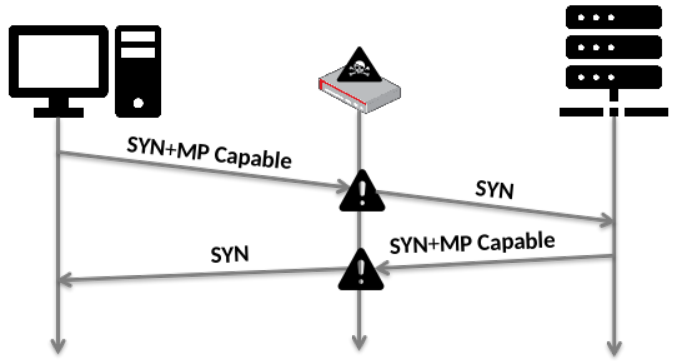
      - Root ***causes***?
      - Stability?



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- Are path-impairing MBs ***stable*** over short and long periods?
- How can we engage with network ***operators*** to aid de-ossification?

Measurement Setup-Yarrpbox

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- **Features**
  - Internet-scale path-impairing MB detector [1]
    - On-path Impairments
    - ***Approx. topl.*** position of path-impairing MB

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- **Features**
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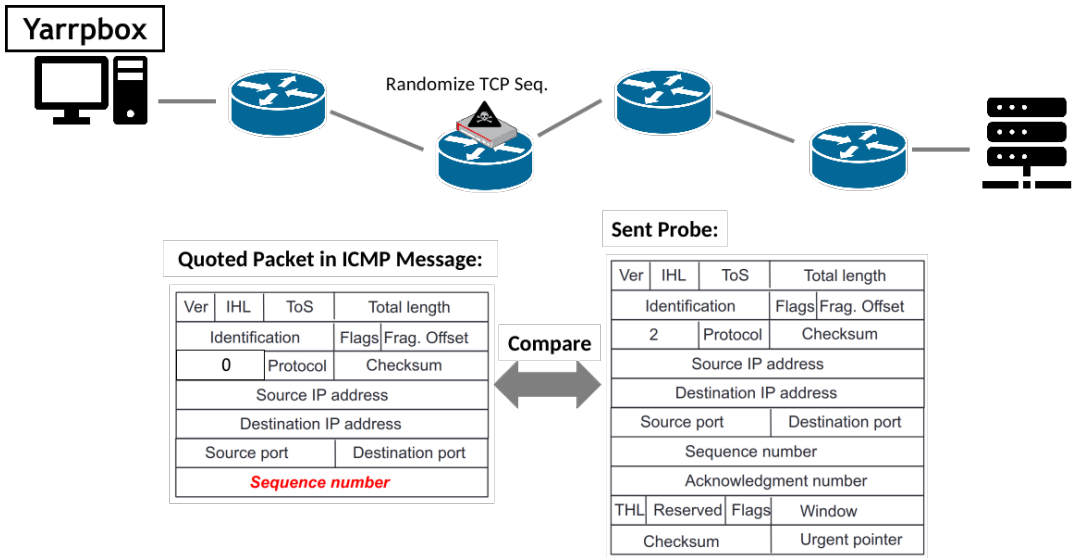
    - ***Approx. topl.*** position of path-impairing MB
- **Operation**
  - TTL-limited probes -> ICMP msgs -> packet state on Internet paths



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Analysis Heuristic-Path Impairing MB Behavior Taxonomy

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- **Categories**
  - Feature Disabling (DF), Disrupted Traffic (DT), Negotiation Disruption (ND) [1]

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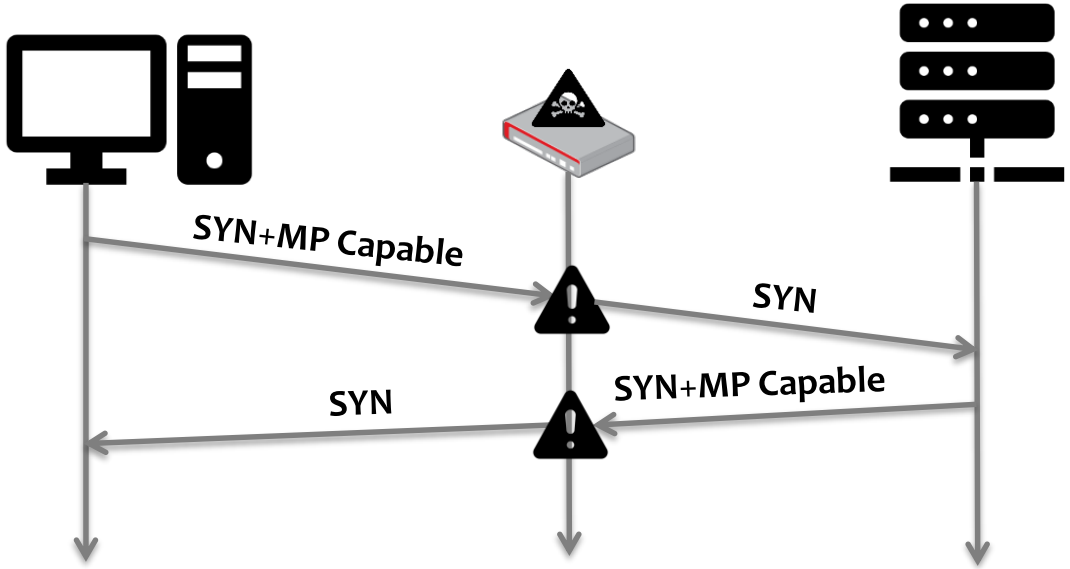
Analysis Heuristic-Path Impairing MB Behavior Taxonomy



- **Disabling Features (DF)** [1]

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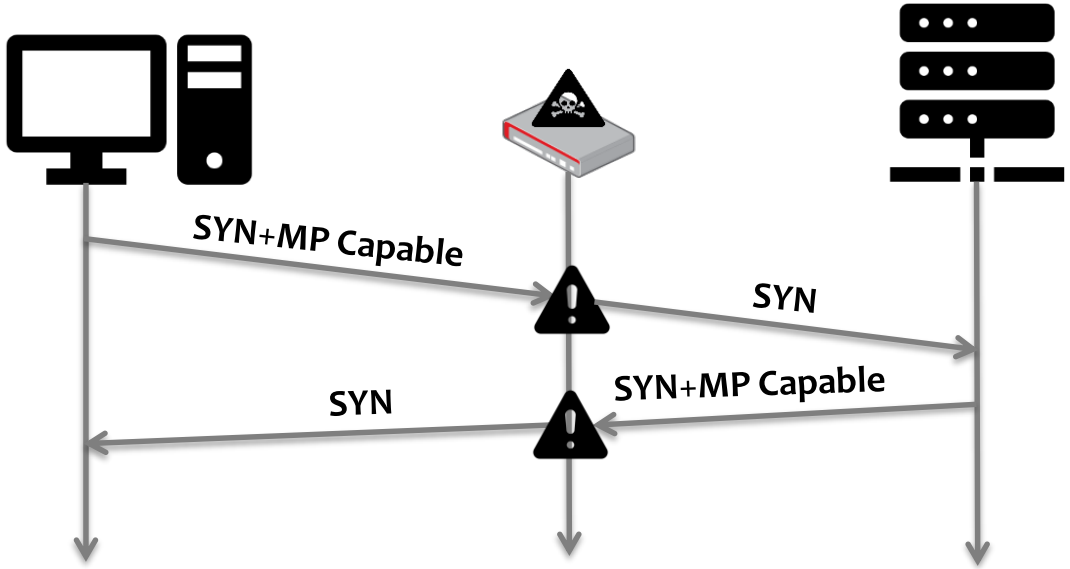

- **Disabling Features (DF)** [1]
  - TCP opts. removal, ECN disable

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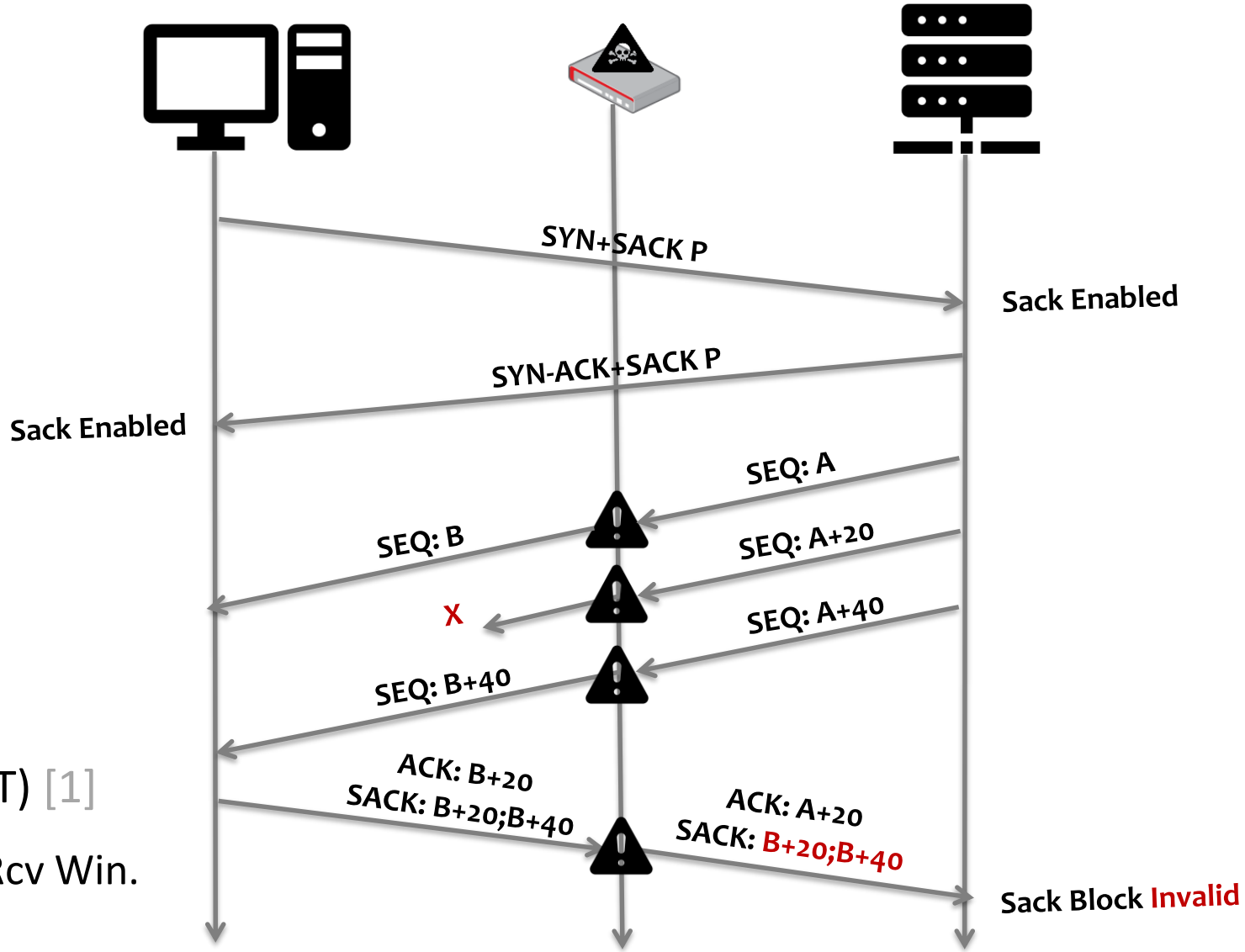

- **Disrupted Traffic** (DT) [1]
  - TCP Seq No., TCP Rcv Win.

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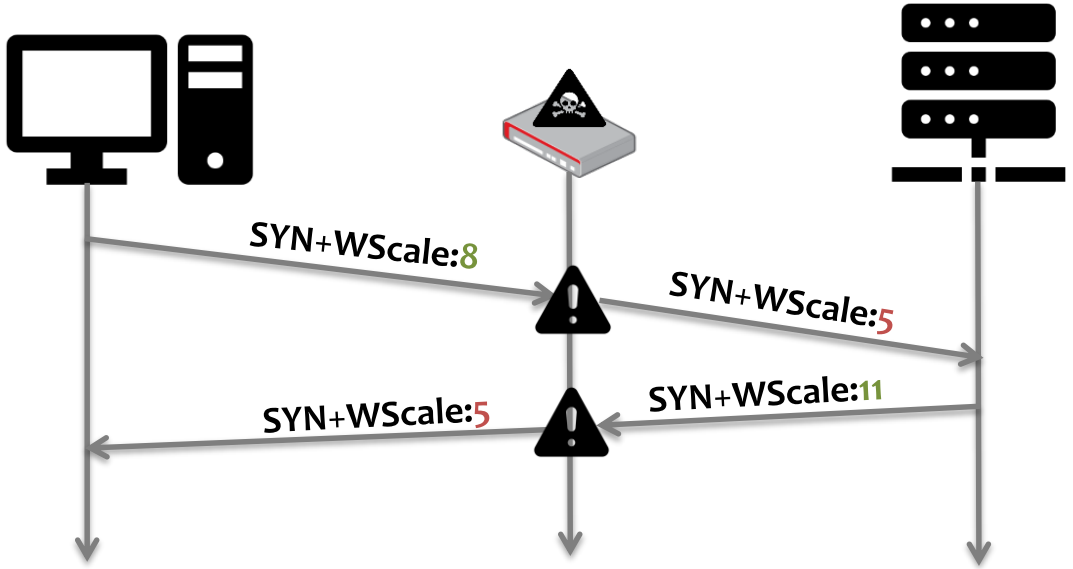

- **Negotiation Disruption (ND)** [1]
  - TCP WScale, SACK P.

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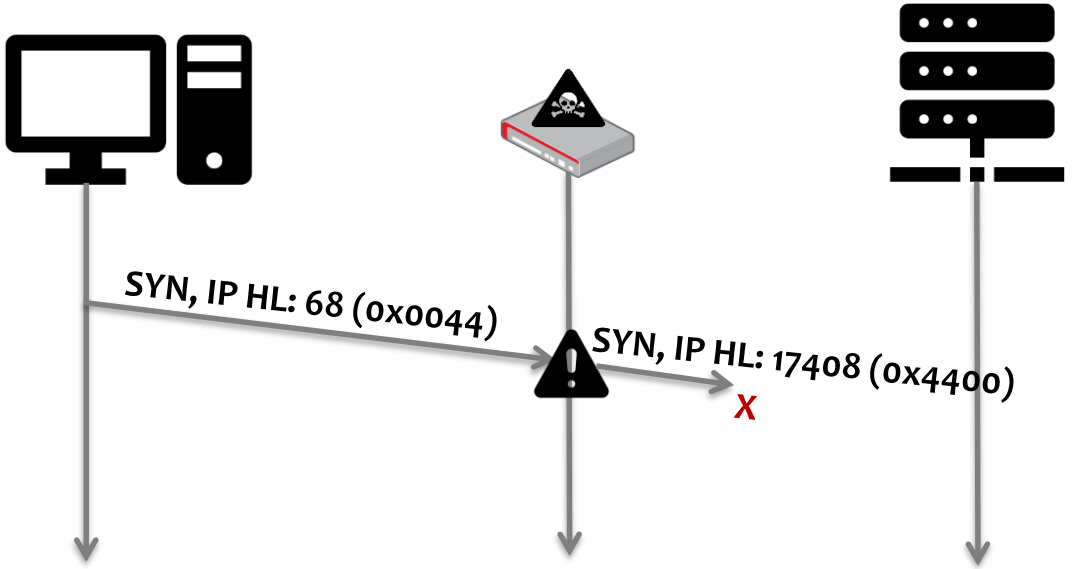
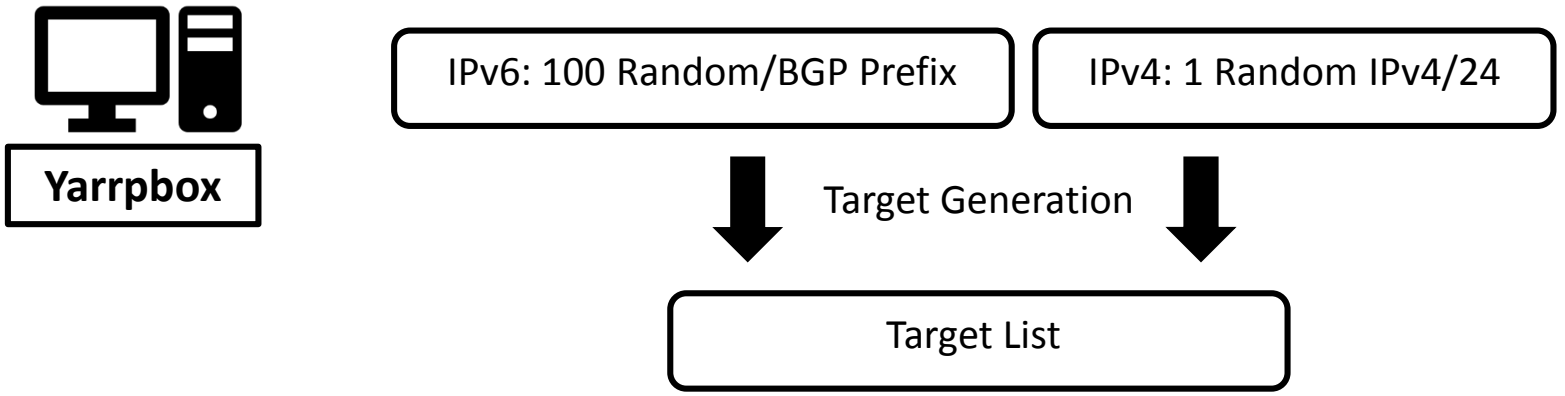


- **Potential for blocks (PB)**
  - Sole IP HL alterations
    - Often byte order flips

Measurements and Results

Measurements

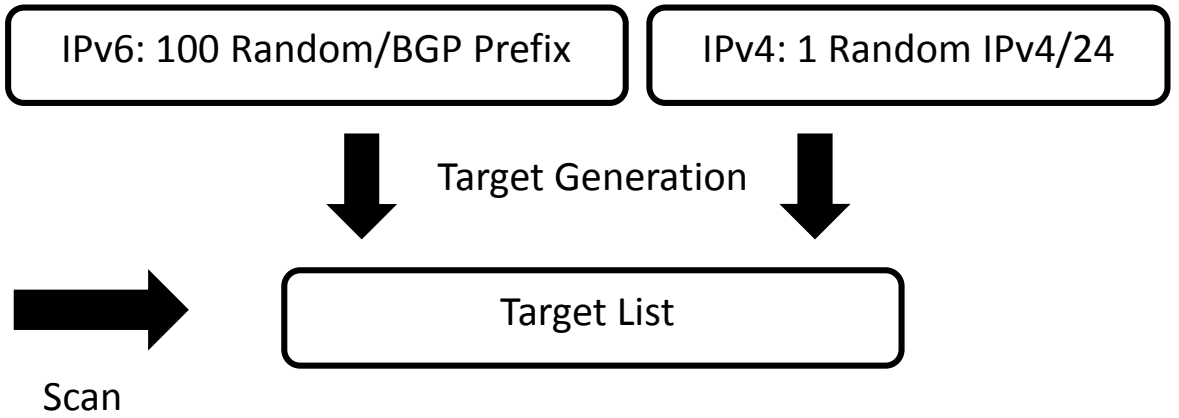


Measurements

Yarrpbox

Ver	HL	TOS	Total Length
Identification		Fl.	Frag. Offset
TTL	Protocol	Checksum	
Source IP			
Destination IP			

Source Port	Dest. Port (80,443)
Sequence Number	
Acknowledgement Number	
DO / RSVD / SYN,ECE, CWR	Window Size
Checksum	Urgent Pointer
TCP Options (MSS, SACK P, MP CAPABLE, TMSP)	



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IPv6: 100 Random/BGP Prefix

IPv4: 1 Random IPv4/24

Target Generation

Scan

Target List

Analysis

Path-Impairments

Path-Impairing MBs

Affected Paths, Prefixes

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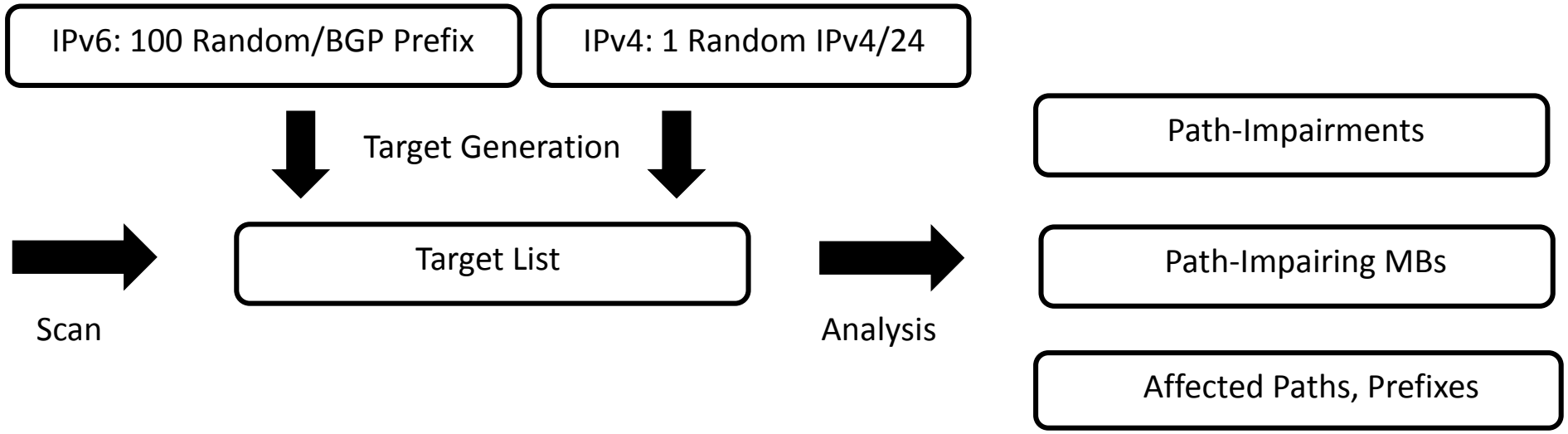

- **Tested paths**
  - IPv6: 251.6M, IPv4:156.9M
  - 3x paths, 10x more on-path ASes

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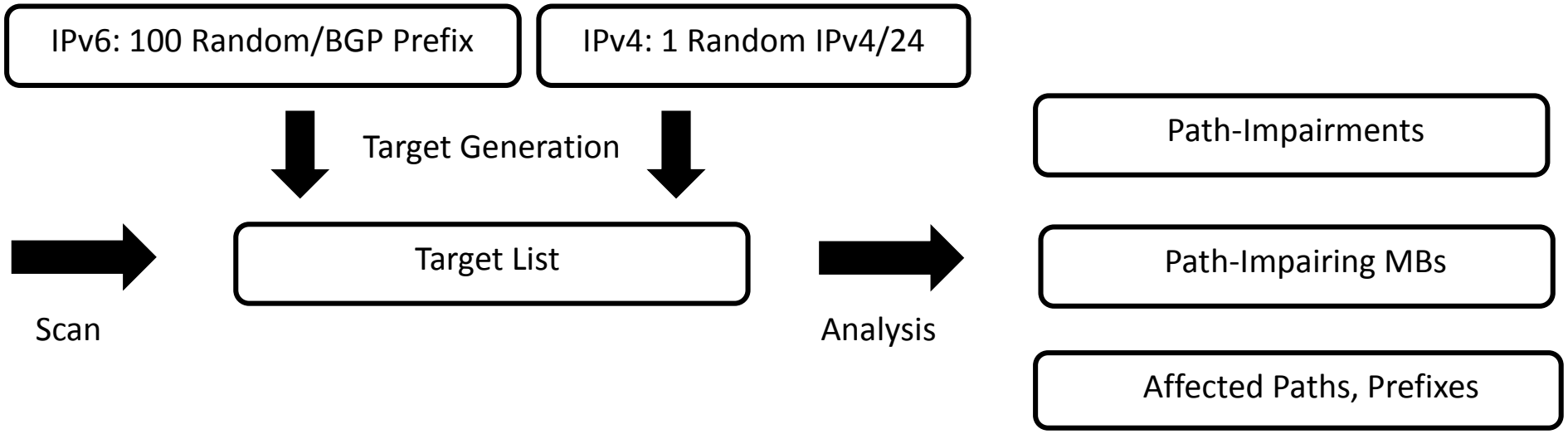

- **Path-impairing MBs**
  - IPv6: 778 in 241 ASes, IPv4: 5.8k in 1.8k ASes

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Yarrpbox

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MassDNS

Tranco Top 1M Domains

Resolve

IPv6 addresses

IPv4 addresses

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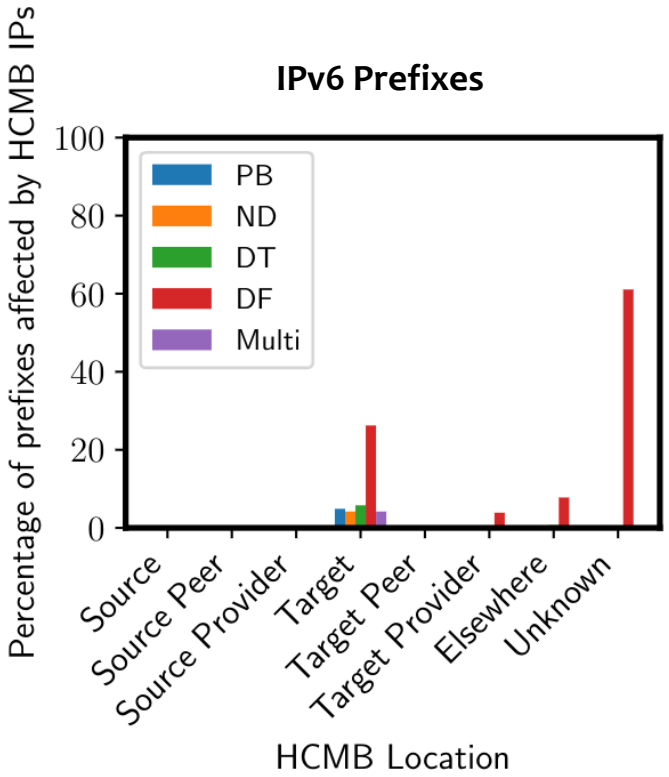

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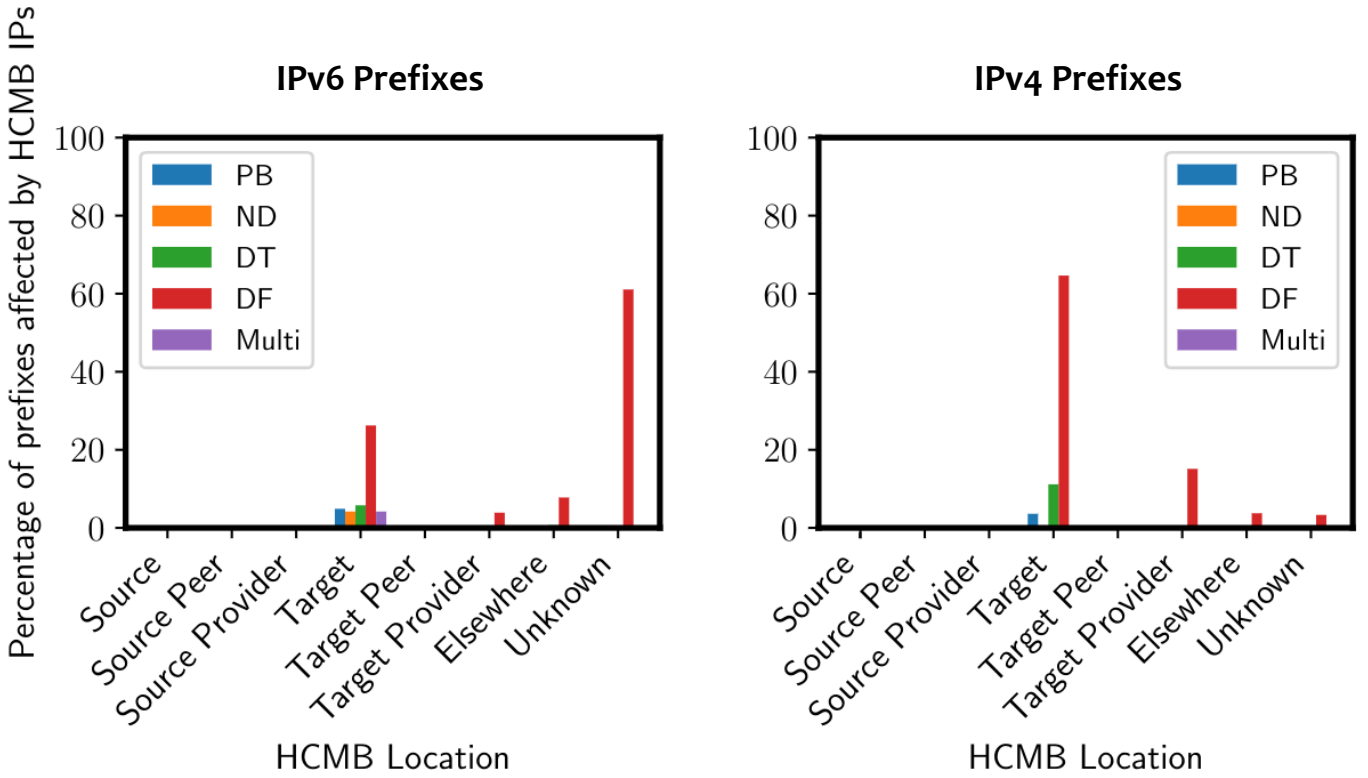

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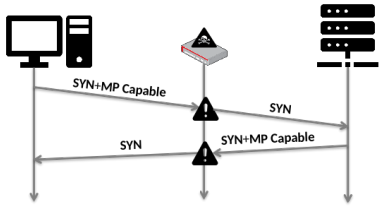
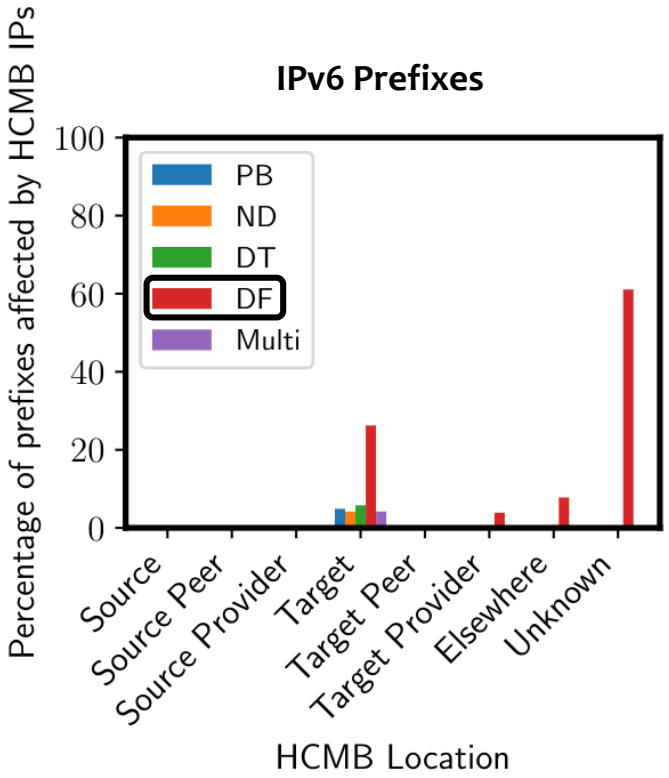
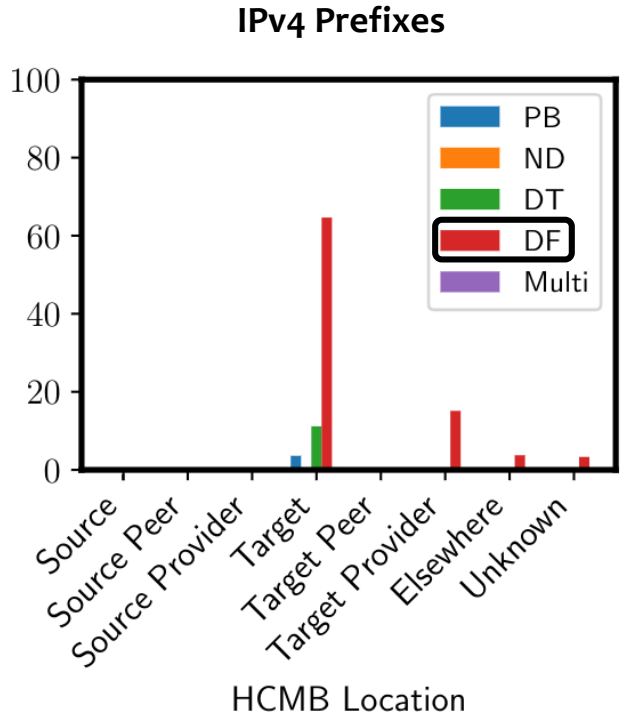


Disabling Features





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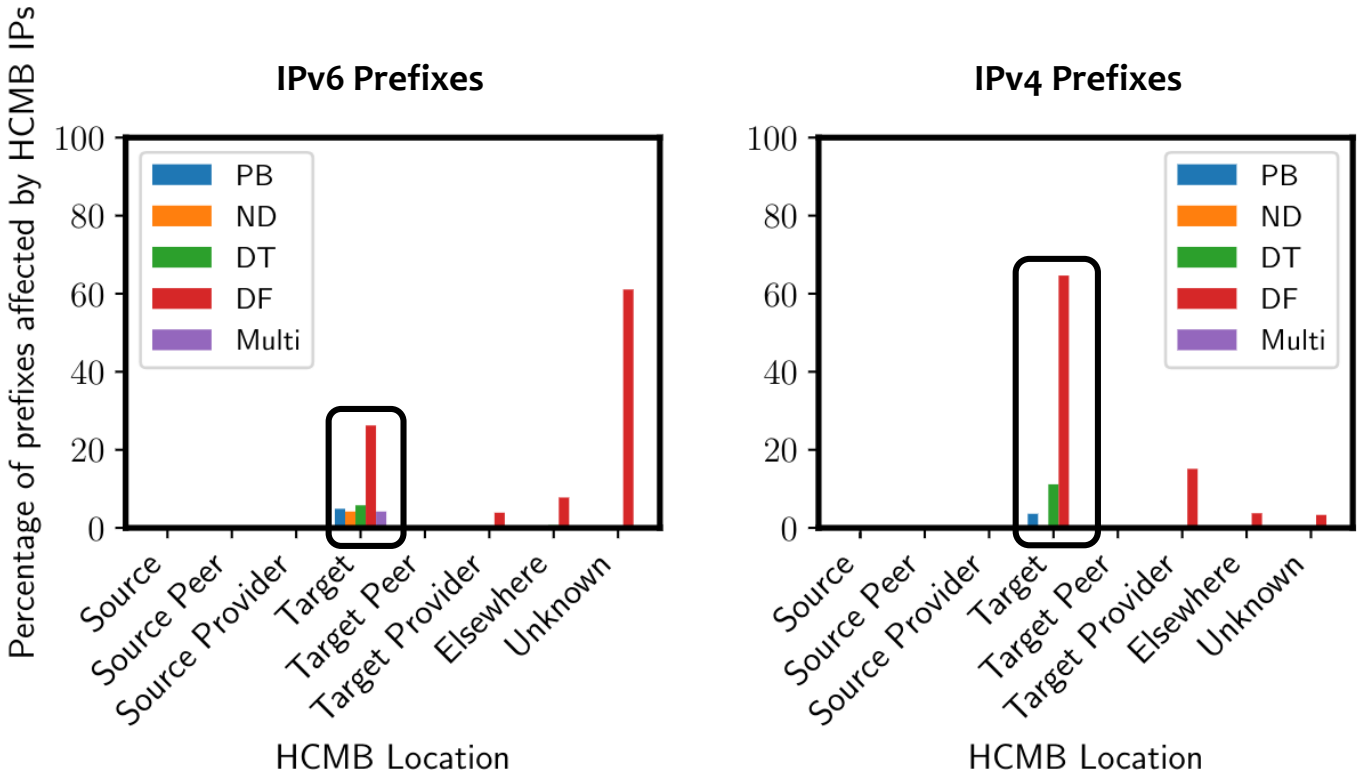

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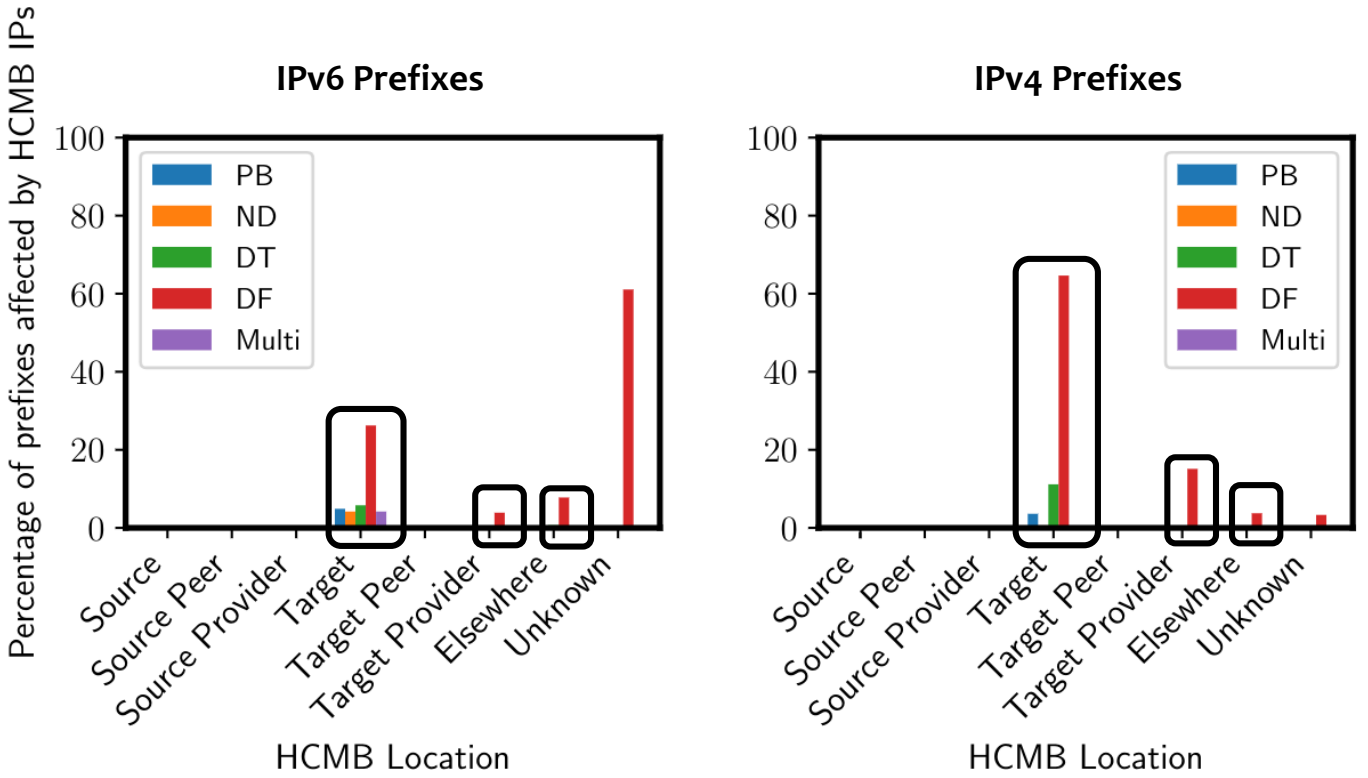

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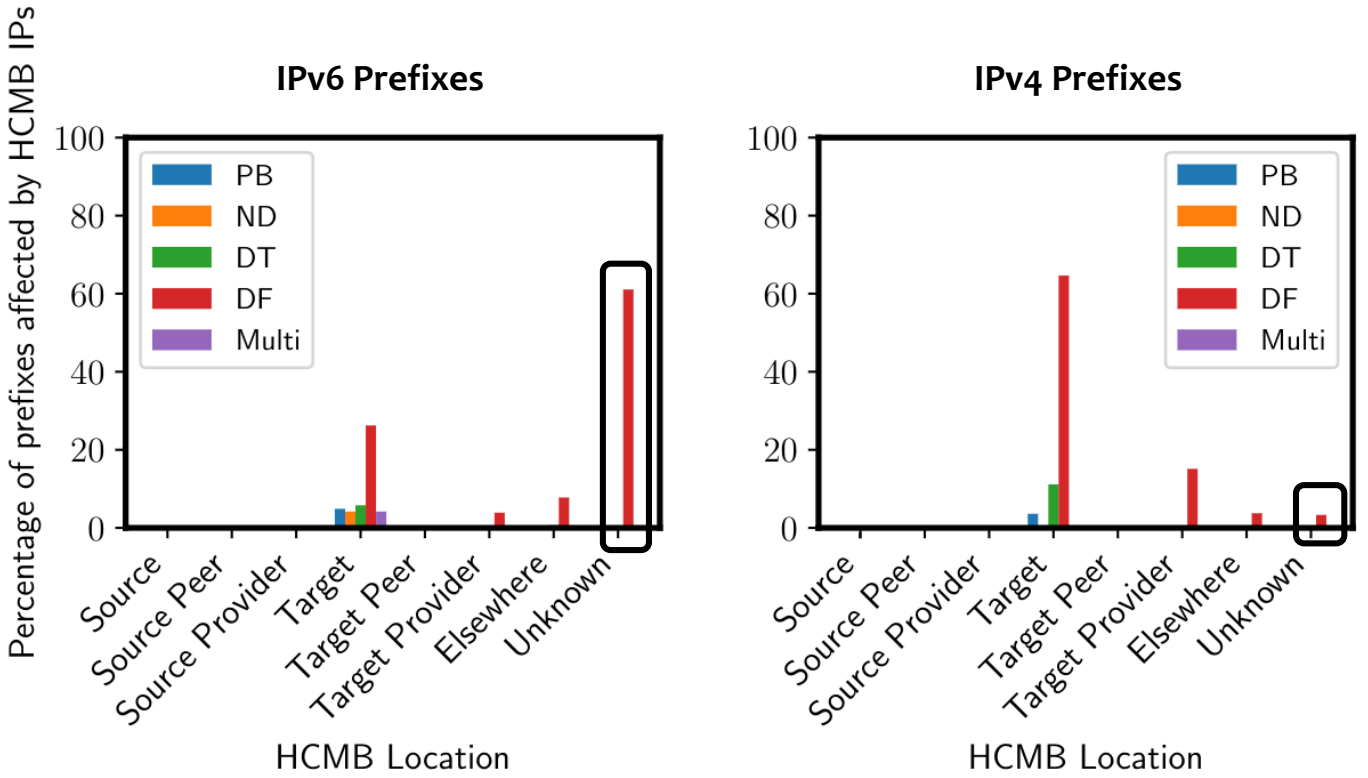

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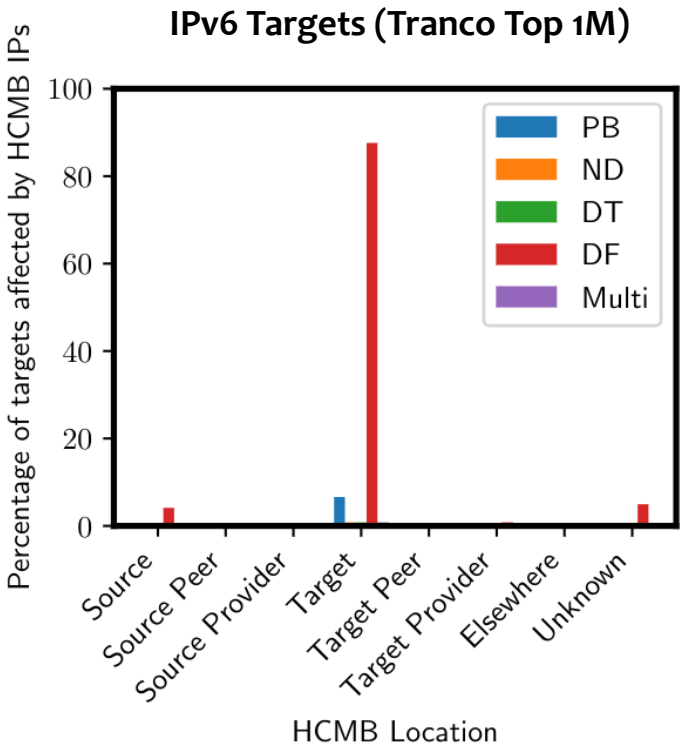

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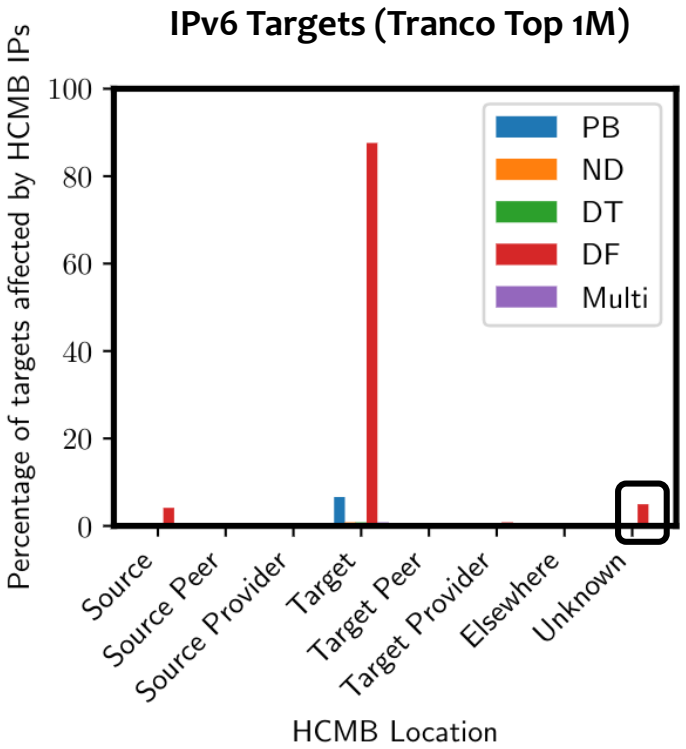

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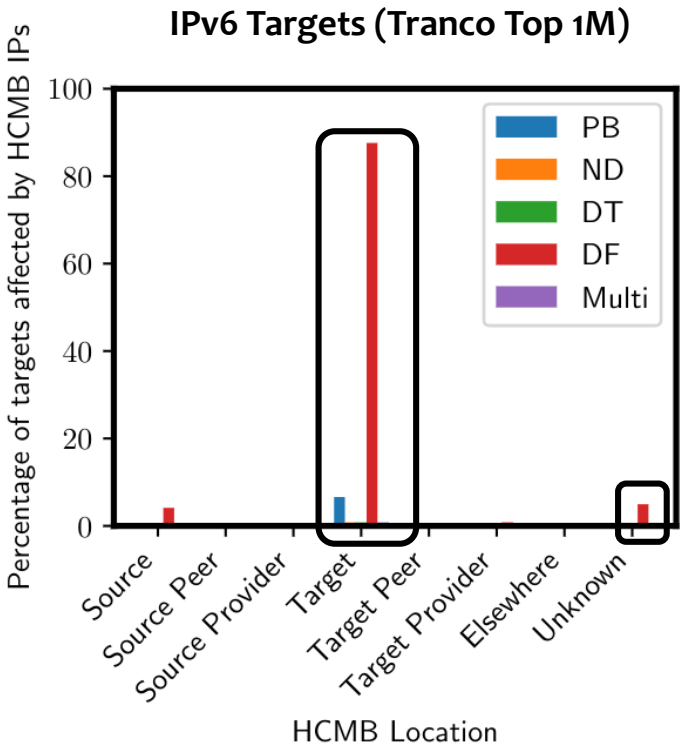

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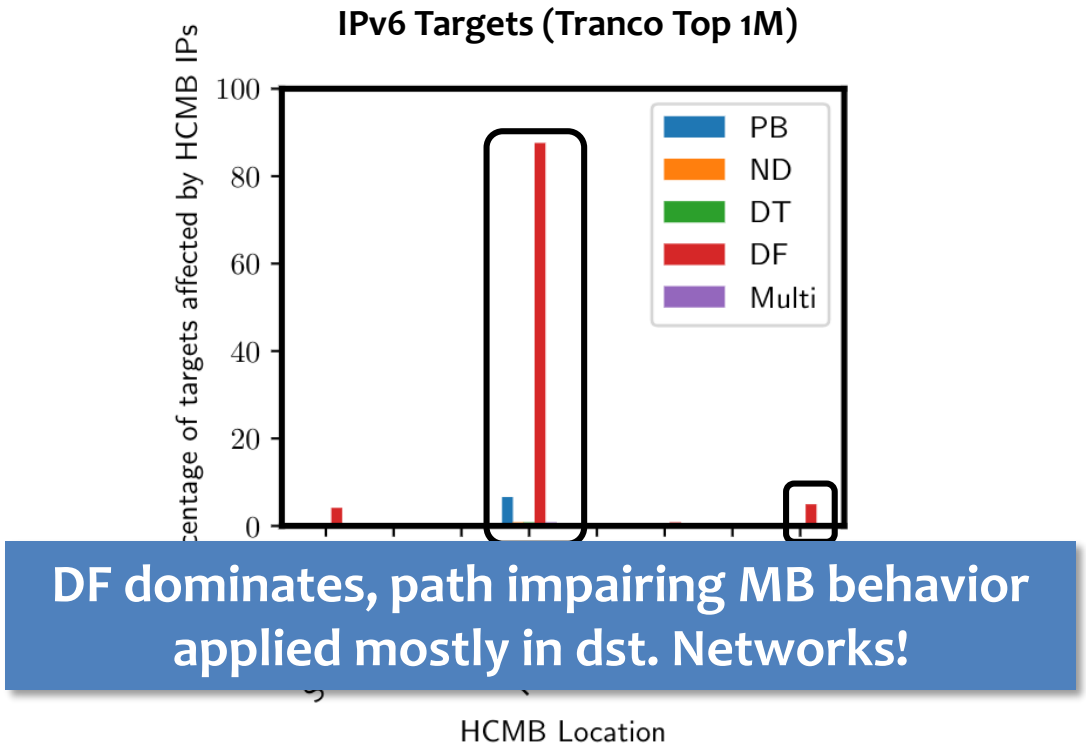

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UNIVERSITÄT DES SAARLANDES

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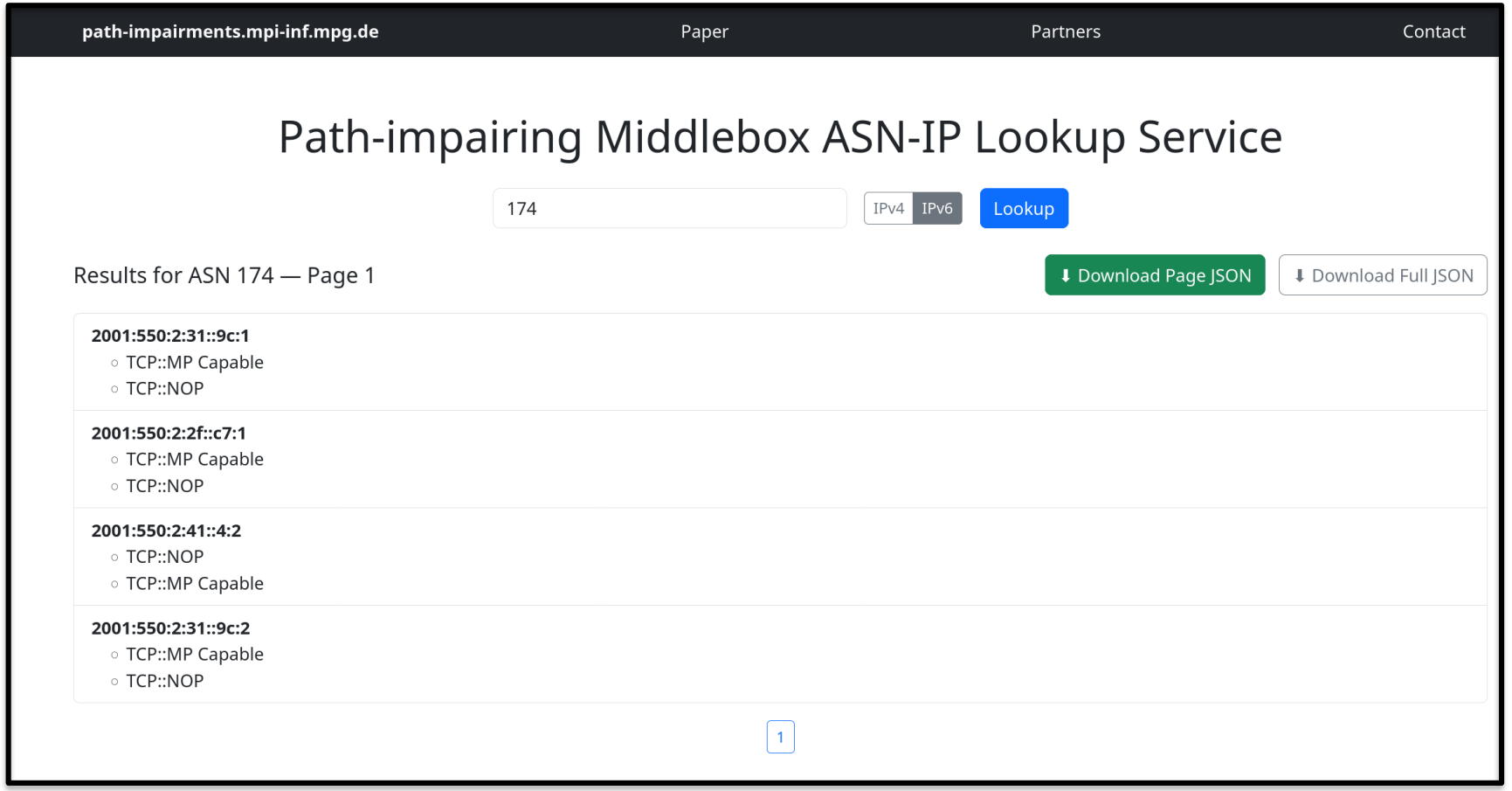

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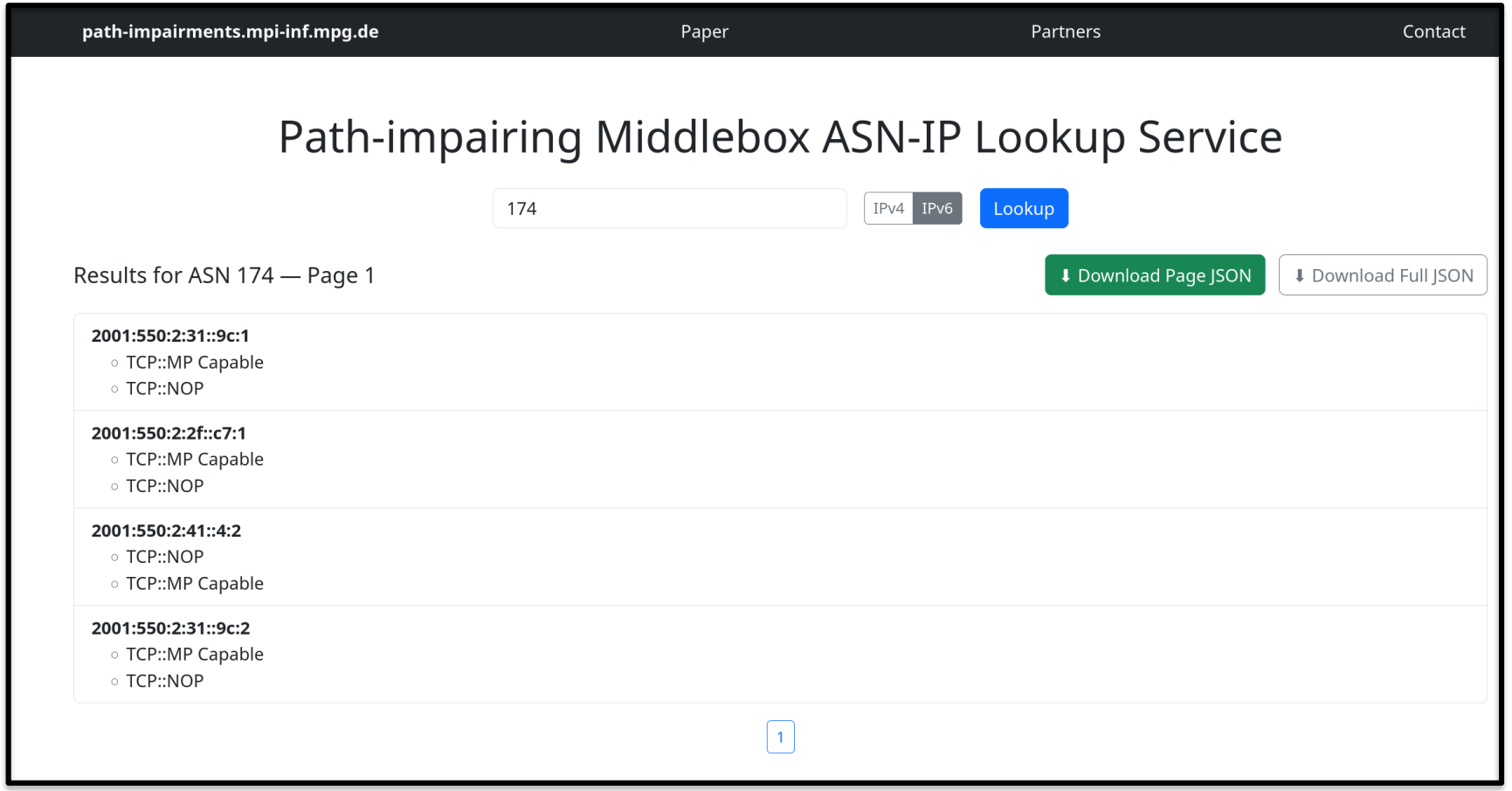

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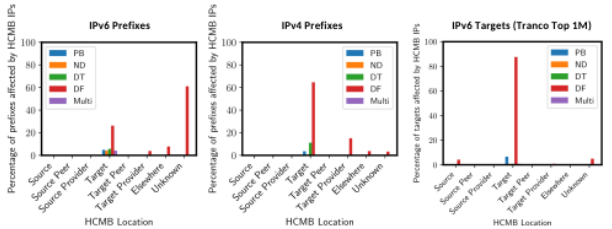

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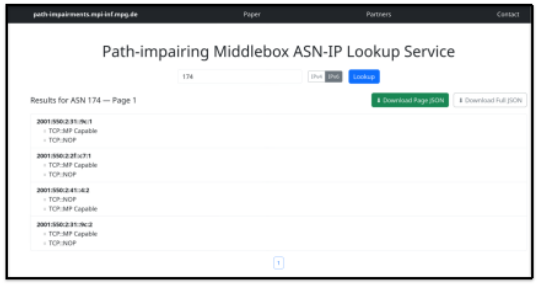

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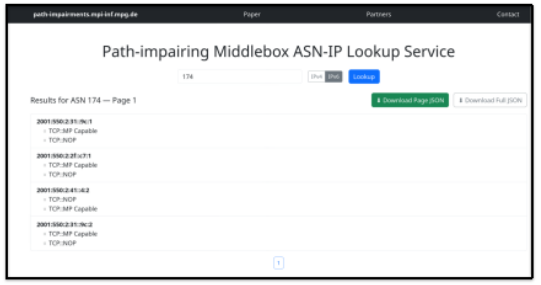

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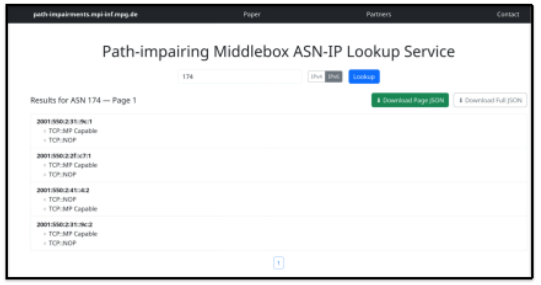

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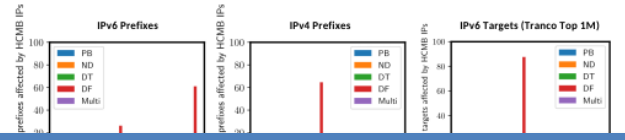

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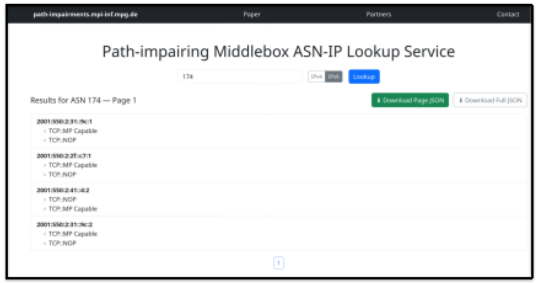

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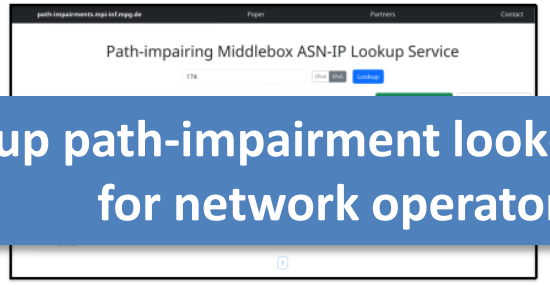
[2] www.cisco.com/c/en/us/td/docs/security/asa/asa98/asdm78/firewall/asdm-78-firewall-config/conns-connlimits.html
[3] docs.paloaltonetworks.com/pan-os/11-2/pan-os-web-interface-help/device/device-setup-session/tcp-settings.
[4] www.cisco.com/c/en/us/support/docs/ip/transmission-control-protocol-tcp/116519-technote-mptcp-00.html
[5] support.citrix.com/external/article?articleUrl=CTX461232-tcp-option-lost-when-traffic-go-through-tcp-type-load-balancelb-vserver&language=en_US
[6] support.checkpoint.com/results/sk/sk114666

Device defaults potentially one (unintended) cause of impairments!

Towards Deossification

- ASN -> Path-impairing MB *look-up service*



Set up path-impairment look-up service for network operators!

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Questions?

Results-Path-Impairing MB Behaviors and Positioning

- Extracted from CAIDA AS Relationship
- **Impaired paths**
  - IPv6: DF (88%) PB (9%), IPv4: DF (95%)
    - *MP Capable* (DF) removals dominate (*NOP-based* overwriting)

DF dominates, path-impairments applied mostly in dst. networks!

Results-Path-Impairing MB Affected Domains

Address Family	Affected Domains	Affected Paths
IPv6	150 (0.05%)	0.24%
IPv4	8.9k (1%)	1%

- 99.4% only IPv4 affected,
  - *6.1%* have *AAAA*,

Switching addr. families could allow impairment-free paths!

Results-Causes of Path-Impairments

- **Examine vendor docs. (MPTCP handling)**
  - Firewall vendors *allow* TCP option filtering [1, 2, 3]
    - Palo Alto [3], Cisco [4], Citrix [5], CheckPoint [6] *defaults*
      - Remove/replace TCP options,
        - eg. MPTCP with *NOPs* [4]

[1] www.juniper.net/documentation/us/en/software/junos/cli-reference/topics/ref/statement/security-edit-tcp-options.html
[2] www.cisco.com/c/en/us/td/docs/security/asa/asa98/asdm78/firewall/asdm-78-firewall-config/conns-connlimits.html
[3] docs.paloaltonetworks.com/pan-os/11-2/pan-os-web-interface-help/device/device-setup-session/tcp-settings.
[4] www.cisco.com/c/en/us/support/docs/ip/transmission-control-protocol-tcp/116519-technote-mptcp-00.html
[5] support.citrix.com/external/article?articleUrl=CTX461232-tcp-option-lost-when-traffic-go-through-tcp-type-load-balancelb-vserver&language=en_US
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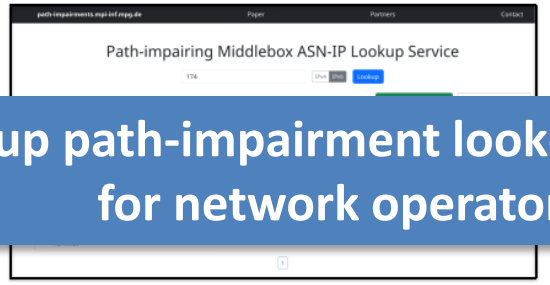

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