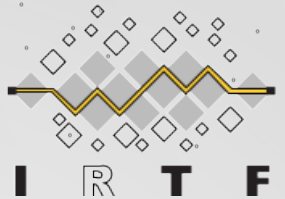
Applied Networking Research Workshop 2020



Evaluating the Impact of Path Brokenness on TCP

Korian Edeline, Benoit Donnet

INTERNET ARCHITECTURAL GUIDELINES

"… there is no architecture, but only a tradition, which was not written down for the first 25 years …"

UNIFORM OPERATIONS

"…in an ideal situation there should be **one**, and only one, **protocol at the Internet level**[…]but there can be a need for gradual transition from one version of IP to another…"

"…the community believes that the goal is connectivity, the tool is the Internet Protocol, and **the intelligence is end to end** rather than hidden in the network."

END-TO-END

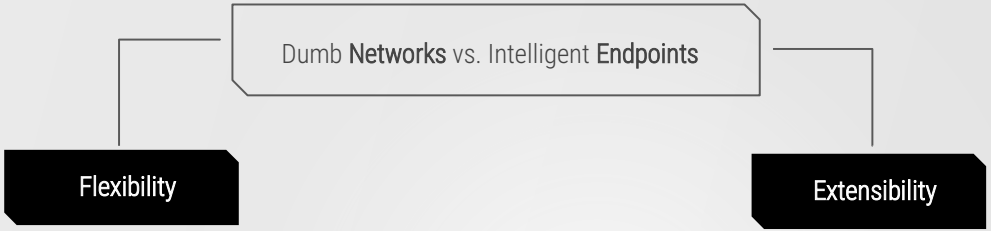
NO GLOBAL CONTROL

"…nobody owns the Internet, **there is no centralized control**[…]. Its evolution depends on rough consensus about technical proposals, and on running code."

RFC 1958

THE END-TO-END PRINCIPLE

End-to-End Arguments in System Design, Saltzer, Reed & Clark, 1981



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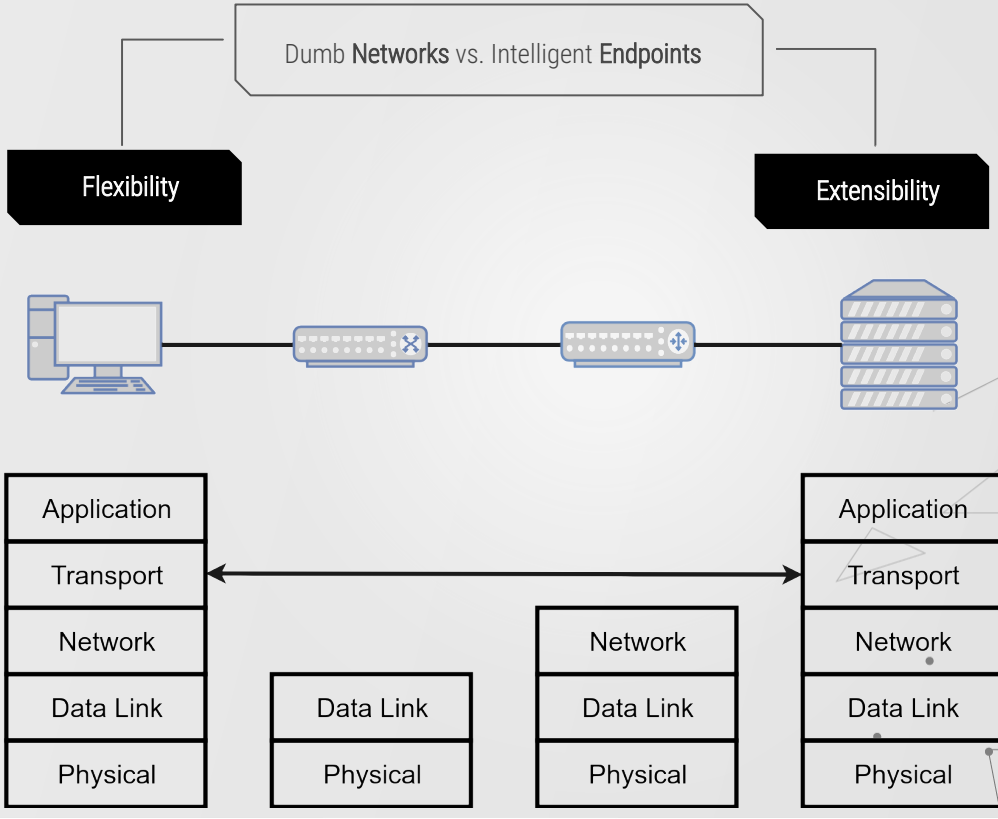

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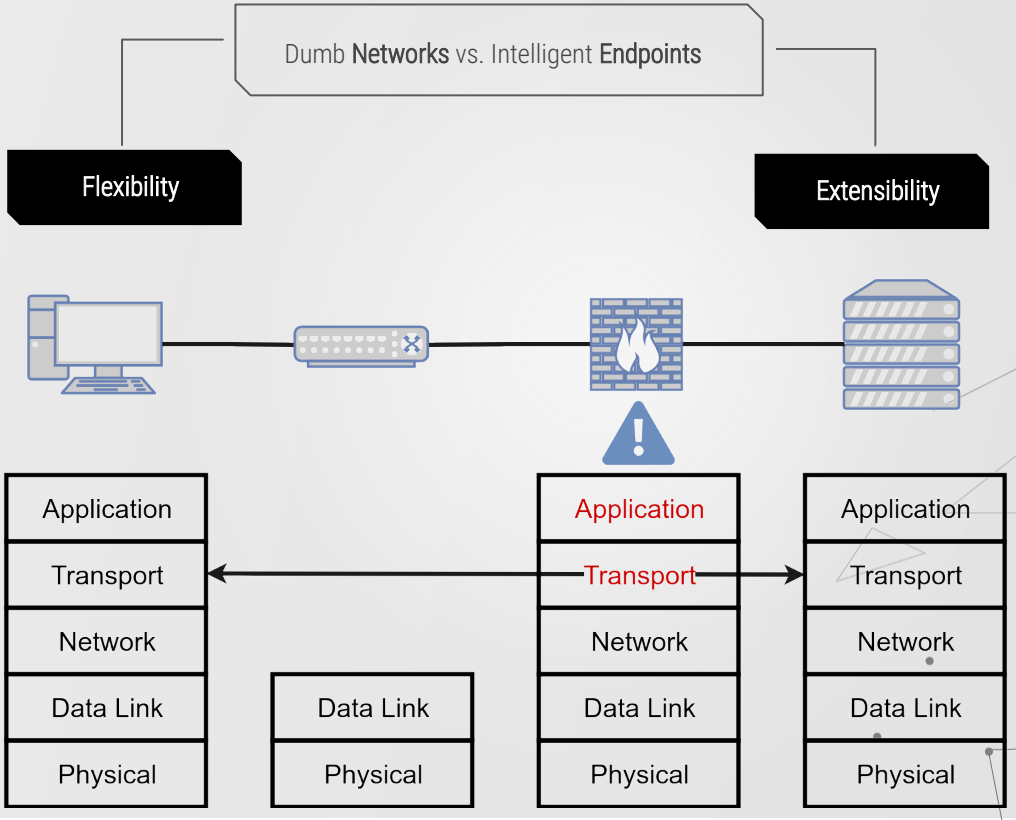

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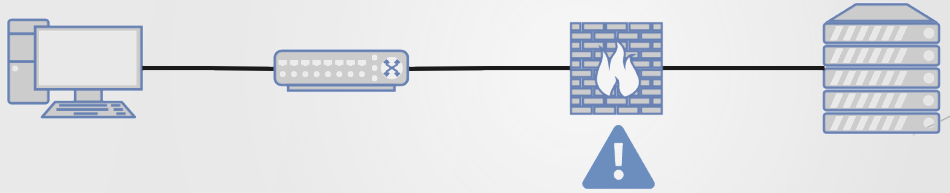
Dumb **Networks** vs. Intelligent **Endpoints**

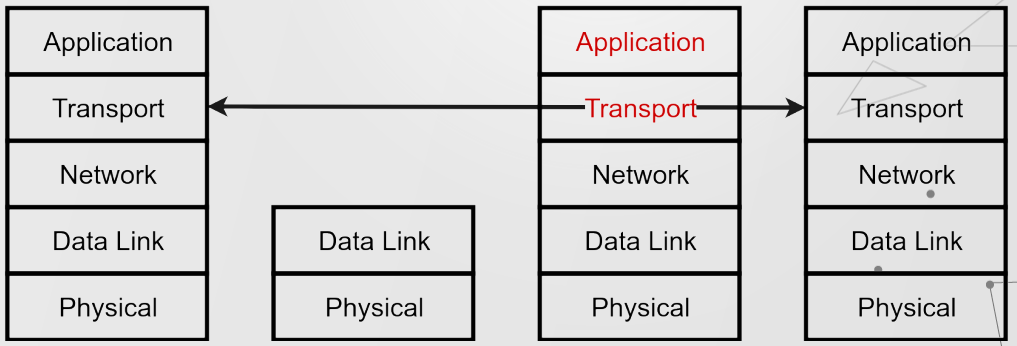
Flexibility

Extensibility



A **middlebox** is a computer networking device that transforms, inspects, filters, or otherwise manipulates traffic for purposes other than packet forwarding.

RFC 3234



THE END-TO-END PRINCIPLE

End-to-End Arguments in System Design, Saltzer, Reed & Clark, 1981

Dumb **Networks** vs. Intelligent **Endpoints**

Flexibility

Extensibility

Ossification

of the network infrastructure

Innovation

Deployment of new TCP features and new transport protocols is crippled by middleboxes

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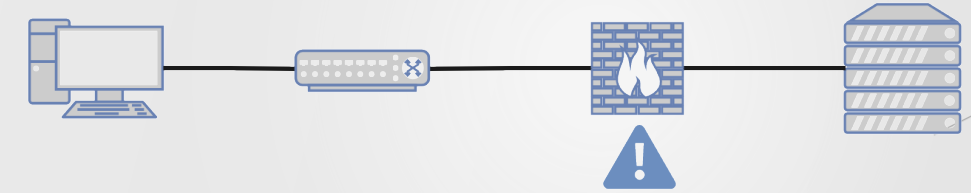
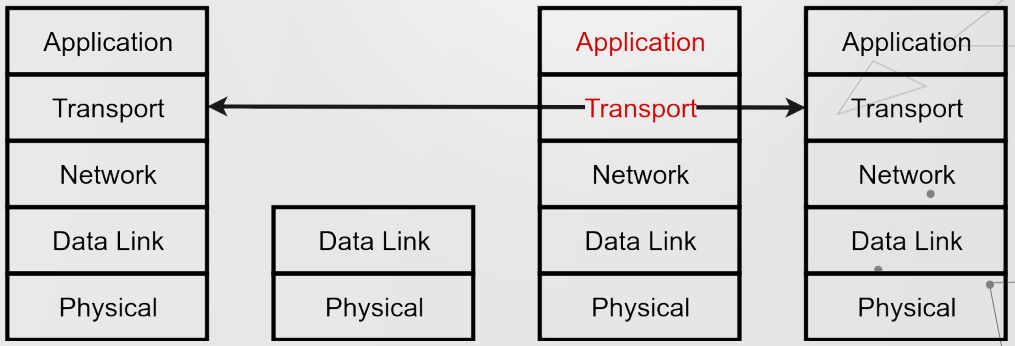
RFC 3234





BACKGROUND

The Middlebox Problem

FROM PATH CONDITIONS ...

A **path condition** is a functional description of an action performed by an intermediary device on a packet, on a given path.

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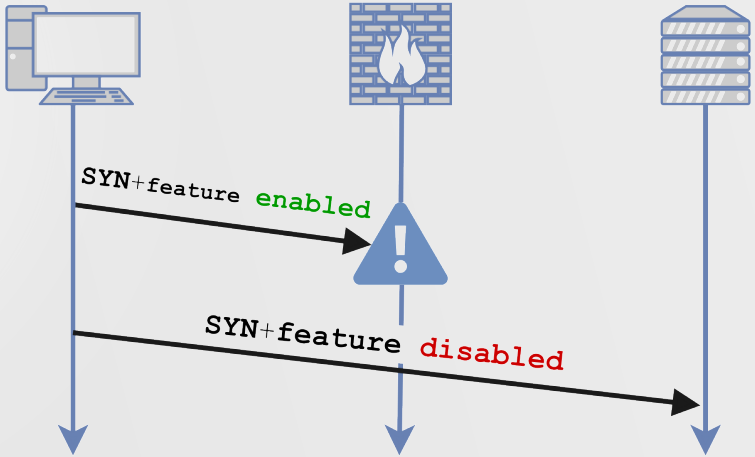
`feature.blocked`



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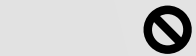

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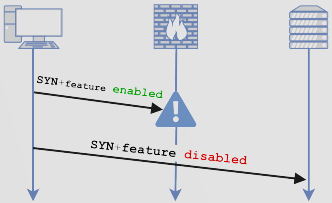

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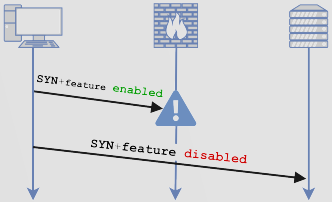

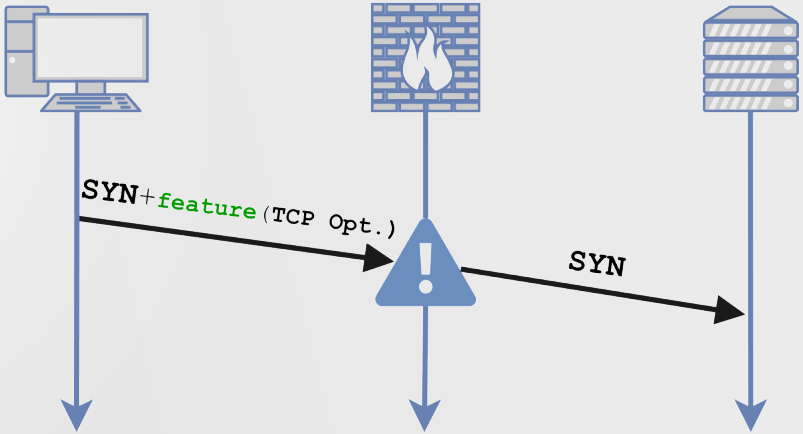

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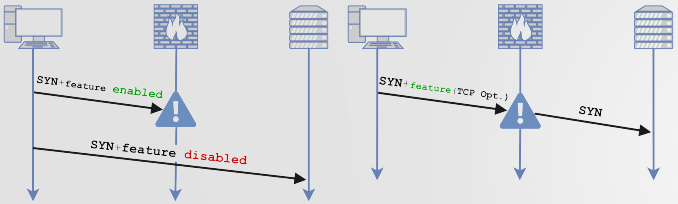

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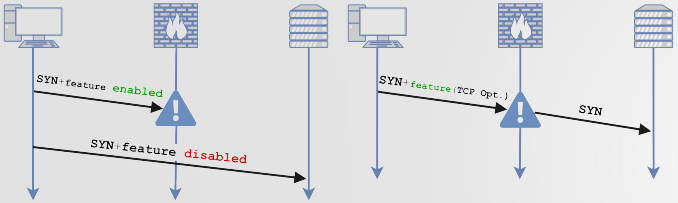

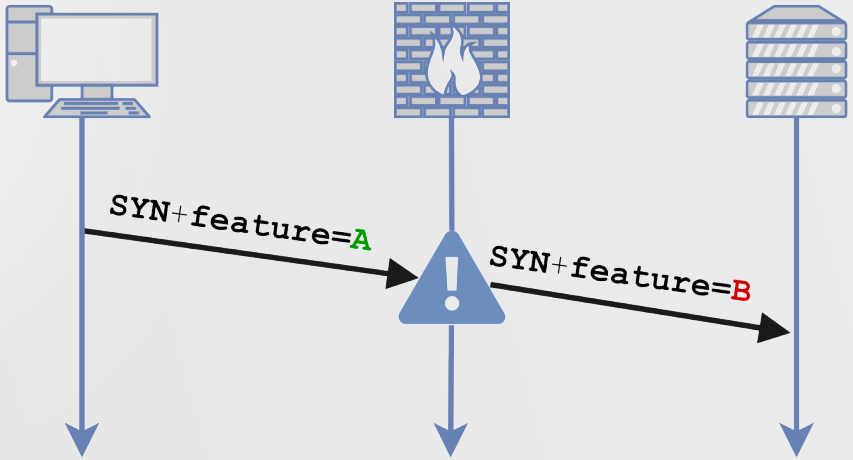

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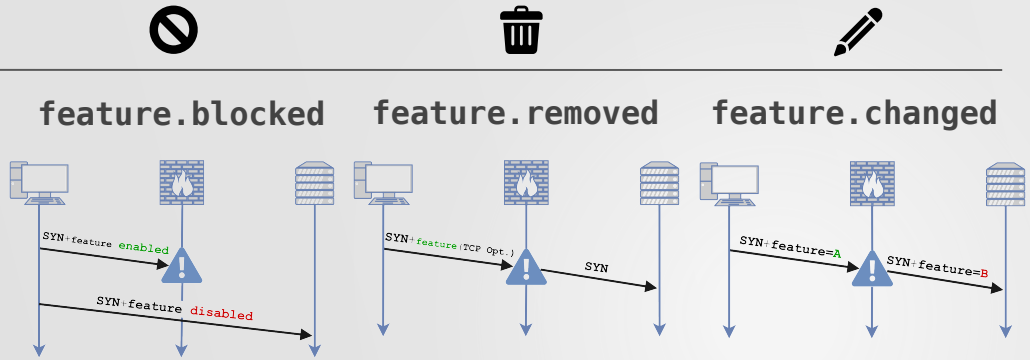

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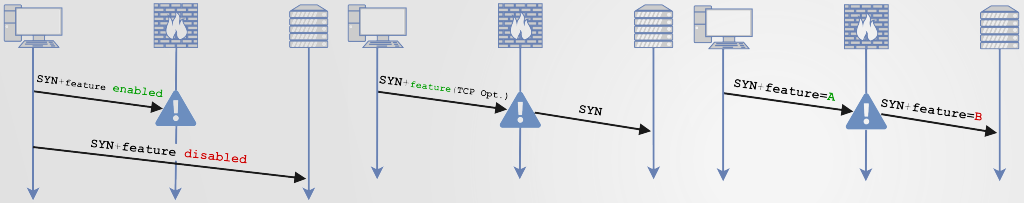

WHY?

SECURITY **PERFORMANCE** **PACKET MARKING**

… TO PATH IMPAIRMENTS

A **path impairment** is a middlebox-induced connectivity issue, a decrease, or shortfall of Quality-of-Service (QoS), on a given path

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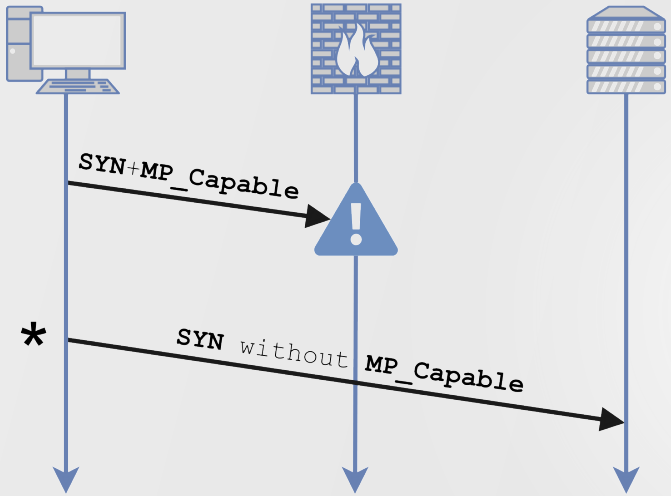

Feature not supported
TCP Normalization

BLOCKED TRAFFIC

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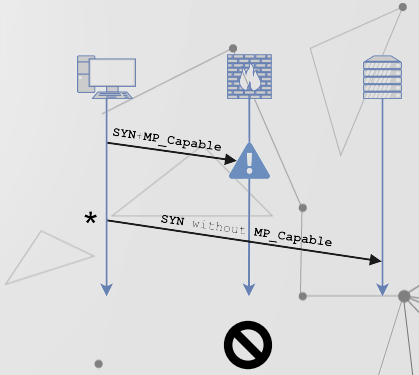

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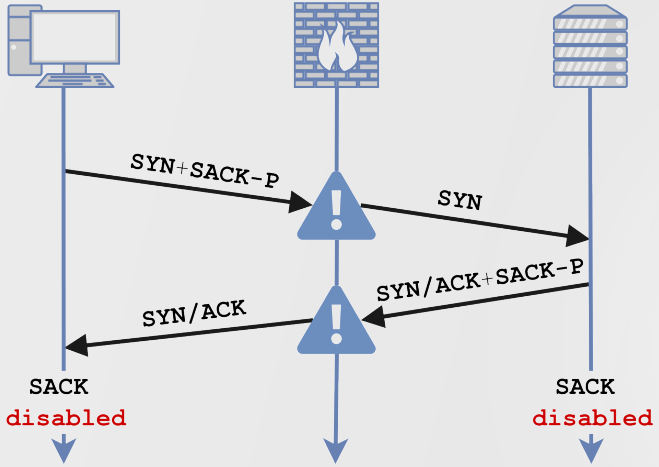
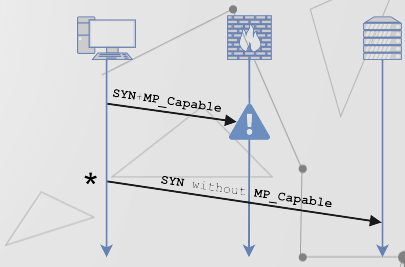


TCP Normalization



DISABLED FEATURE

BLOCKED TRAFFIC

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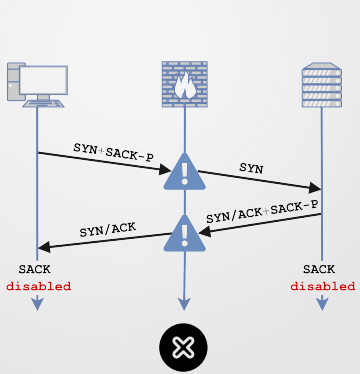

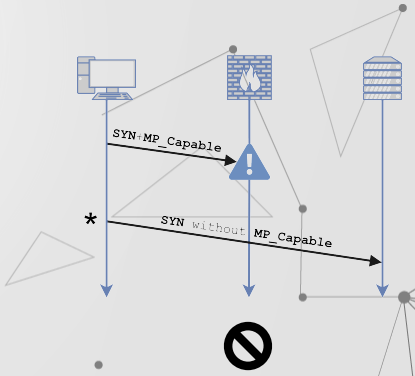

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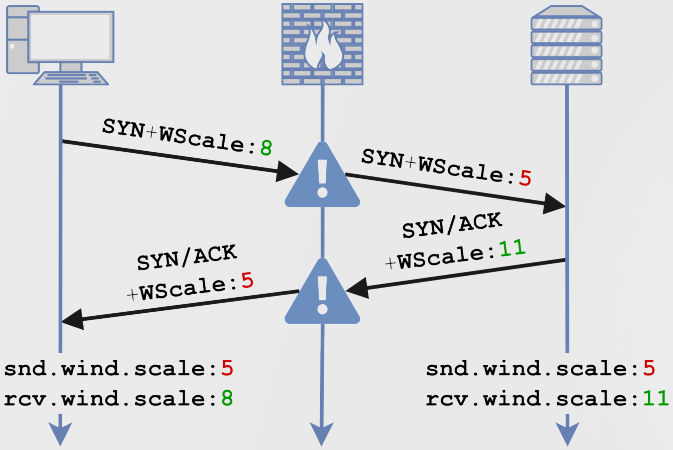
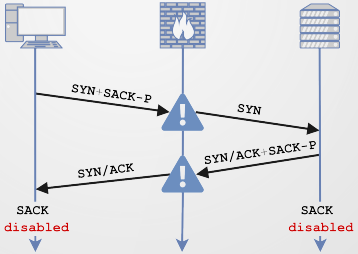
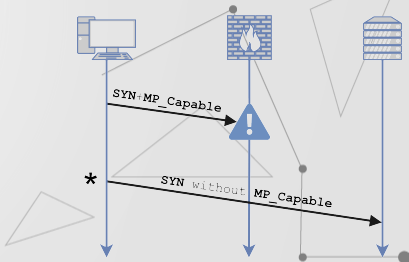


Malconfiguration
Rate Limiting





NEGOTIATION DISRUPTION

DISABLED FEATURE

BLOCKED TRAFFIC

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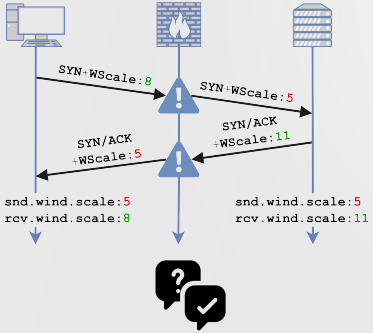

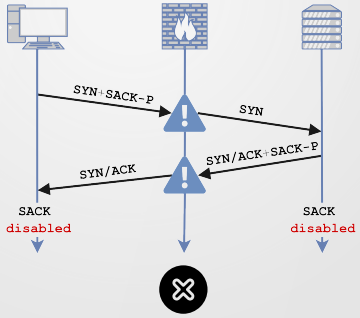

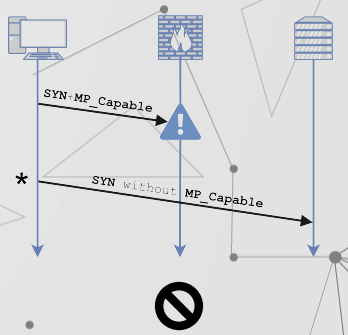

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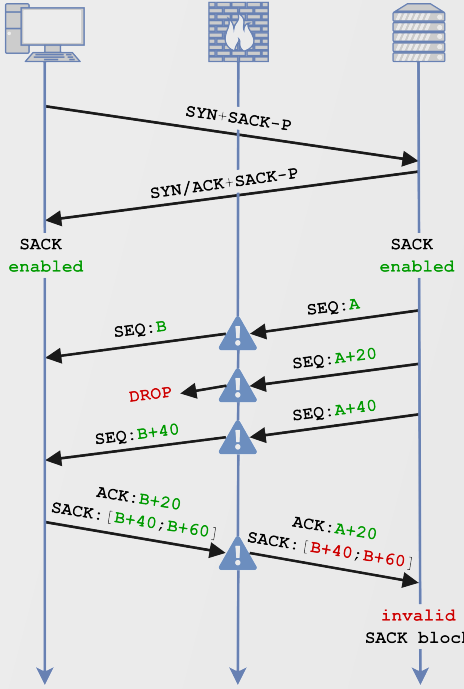
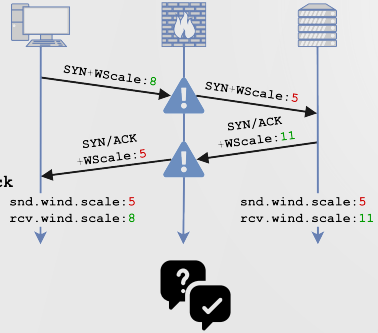
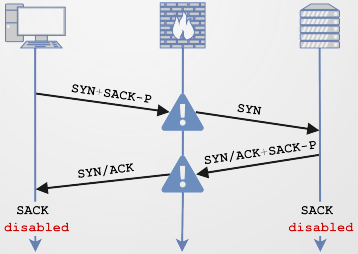
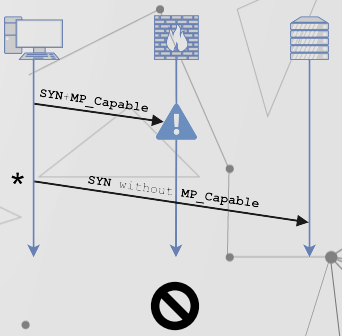






Fix TCP ISN Randomness



TRAFFIC DISRUPTION

NEGOTIATION DISRUPTION

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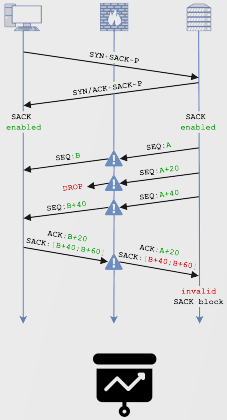

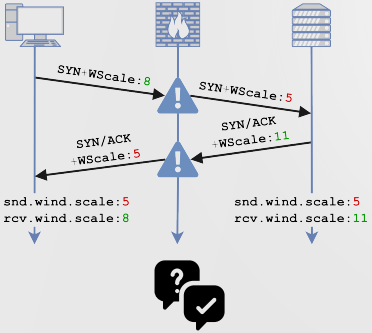

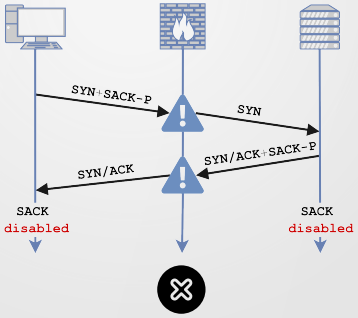

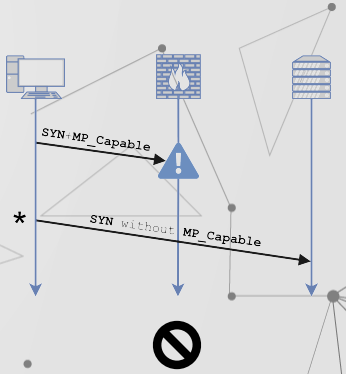

TRAFFIC DISRUPTION

NEGOTIATION DISRUPTION

DISABLED FEATURE

BLOCKED TRAFFIC

Path impairments in the wild

2% of deployed network devices are TCP/IP MBs

38.9% of networks paths are crossing middleboxes

6.5% of network paths are affected by TCP-breaking MBs

A bottom-up investigation of the transport-layer ossification, K.Edeline and B.Donnet, in Proc. IFIP Network Traffic Measurement and Analysis Conference (TMA), 2019

EXPERIMENTATION

Path Impairments Investigation

mmb: A VPP MIDDLEBOX

https://github.com/mami-project/vpp-mb

mmb: A VPP MIDDLEBOX

VPP (Vector Packet Processing) is a high-performance kernel - bypass framework developped by Cisco.

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mmb: A VPP MIDDLEBOX

Flexible

Intuitive

Fast

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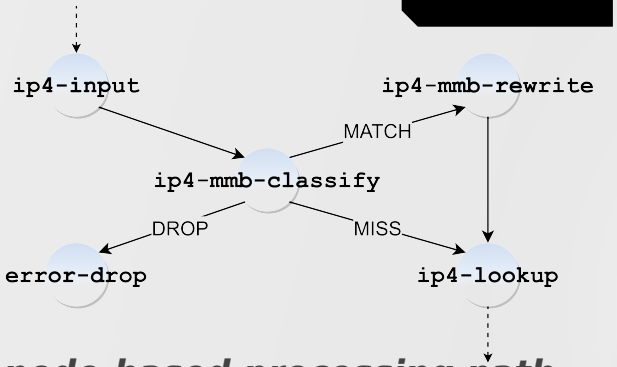
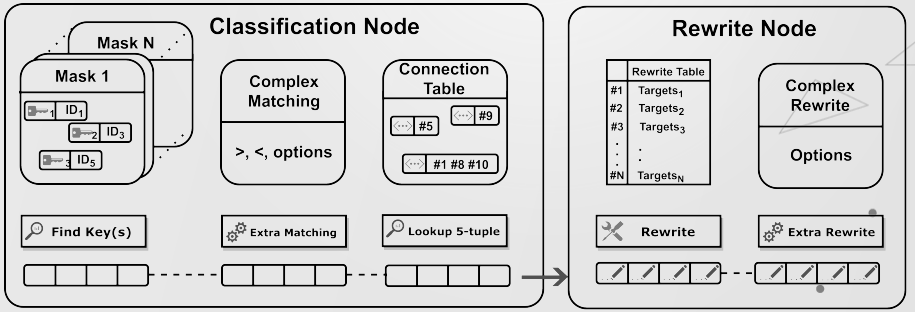


node-based processing path

```
# mmb <add-keyword> <match>  [<match>  ...  <match>]
                    <target> [<target> ... <target>]

<add-keyword> : add-stateless | add-stateful
<match>       : <field> <condition> <value>
<target>      : mod <field> <value> | add <field> <value>
                | strip [!] <field>  | map <field> <value>
                | shuffle <field>    | drop
```

CLI syntax



mmb software architecture

https://github.com/mami-project/vpp-mb

IMPACT OF PATH IMPAIRMENTS ON TCP

ECN	SACK	WScale
Explicit Congestion Notification	Selective Acknowledgment	Window Scaling Parameter

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How do path-impairing middleboxes affect the Quality-of-Service of TCP ?

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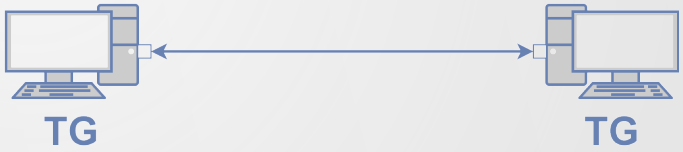

Direct

Indirect

IMPACT OF PATH IMPAIRMENTS ON TCP

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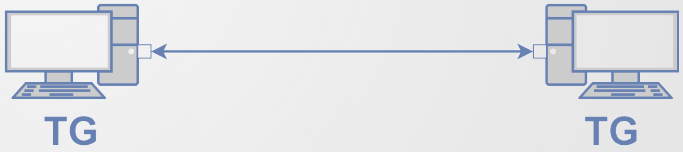
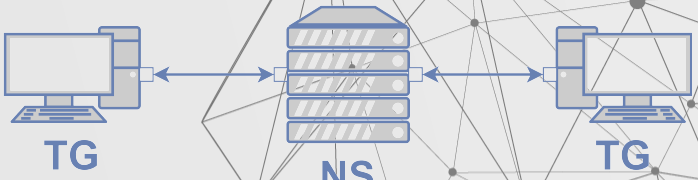


Direct



Indirect

LFNs ⚙ **Delay** ⚙ **Loss** ⚙ **Congestion**

IMPACT OF PATH IMPAIRMENTS ON TCP

ECN SACK WScale

Explicit Congestion Notification

Selective Acknowledgment

Window Scaling Parameter

	ECN IP bits
Not-ECT	00
ECT(1)	01
ECT(0)	10
CE	11

Path impairments scenarios without congestion:

IMPACT OF PATH IMPAIRMENTS ON TCP

	ECN IP bits
Not-ECT	00
ECT(1)	01
ECT(0)	10
CE	11

ECN

Explicit Congestion Notification

SACK

Selective Acknowledgment

WScale

Window Scaling Parameter

Path impairments scenarios without congestion:

Disabled ECN

`ip.ecn.changed.11`
with fallback mechanism

Blocked ECN

`tcp.ecn.blocked`

Broken ECN

`ip.ecn.changed.11`
fallback-proof

IMPACT OF PATH IMPAIRMENTS ON TCP

ECN

Explicit Congestion Notification

SACK

Selective Acknowledgment

WScale

Window Scaling Parameter

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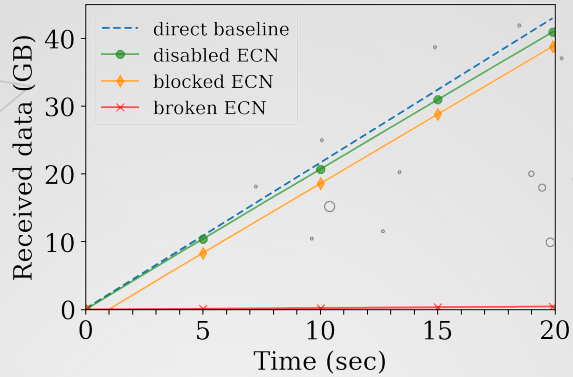

IMPACT OF PATH IMPAIRMENTS ON TCP

ECN
Explicit Congestion Notification

SACK
Selective Acknowledgment

WScale
Window Scaling Parameter

Path impairments scenarios without congestion:

Disabled ECN
`ip.ecn.changed.11`
with fallback mechanism

Blocked ECN
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Path impairments scenarios with congestion:

Enabled ECN

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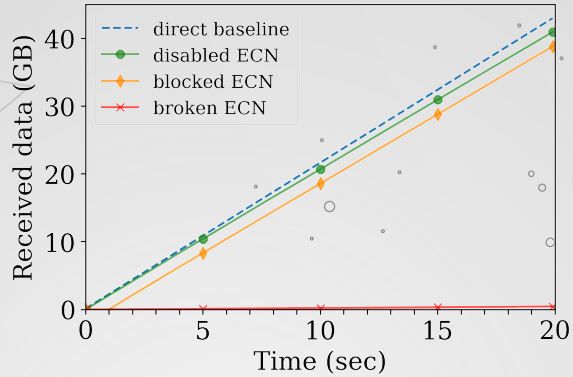

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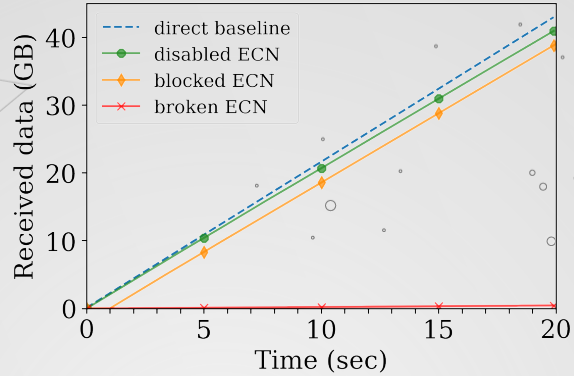

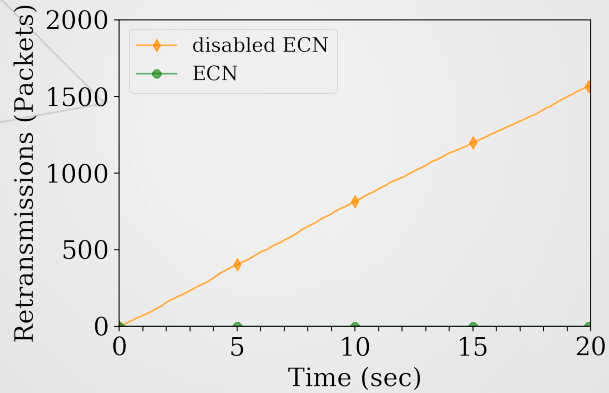

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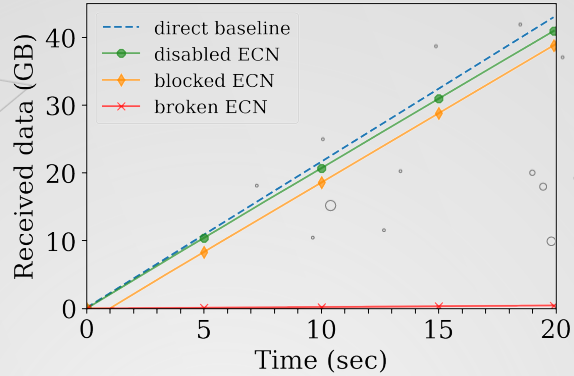
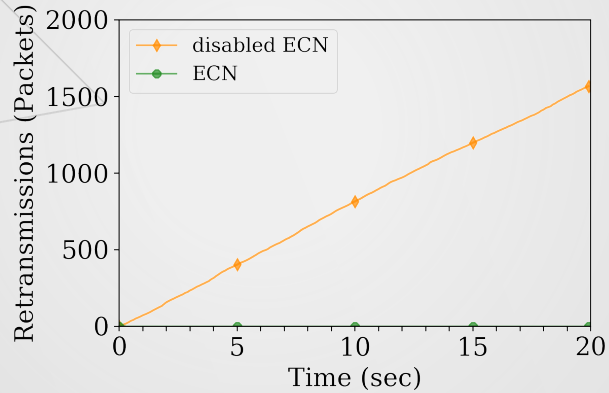
Broken ECN slows down the connection to 1 MSS / RTT

Disabling ECN

Disabling ECN per default is not the solution





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Path impairments scenarios with artificial loss:

Enabled SACK

SACK-enabled flows

Disabled SACK

`tcp.opt.sackok.removed`

Broken SACK

`tcp.seqnum.changed`

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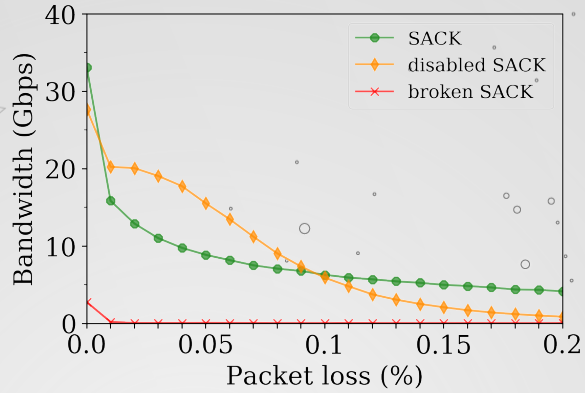

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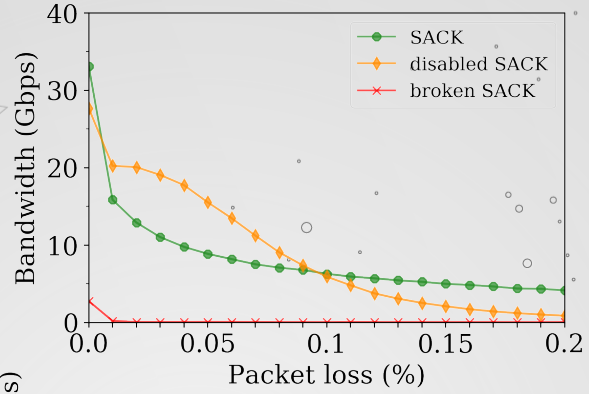

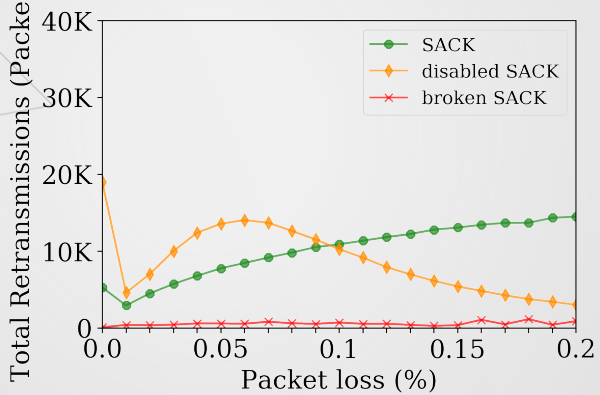

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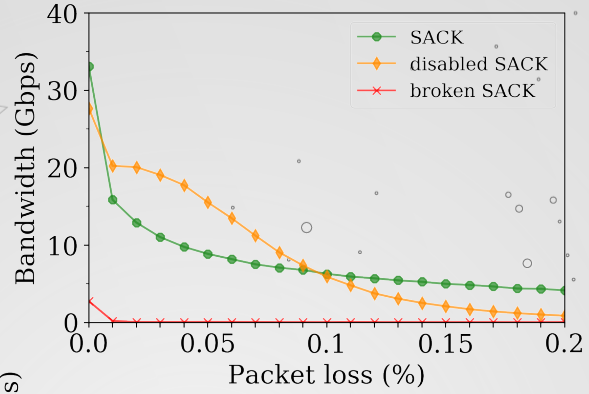
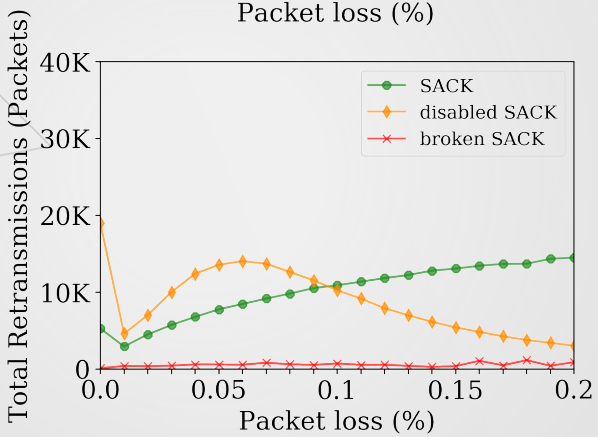
Broken SACK

Broken SACK **stalls the connection** when receiver generates a SACK block

Disabled SACK

Disabled SACK reduce TCP throughput for loss rates greater than 0.09%





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TCP Receive Window : $[0 ; 2^{16}-1] * 2^{WScale}$

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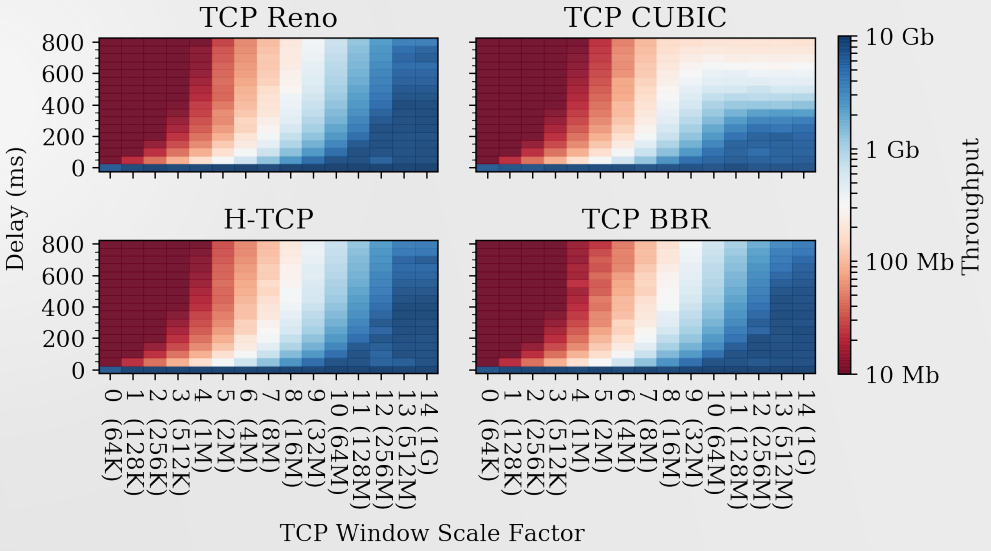

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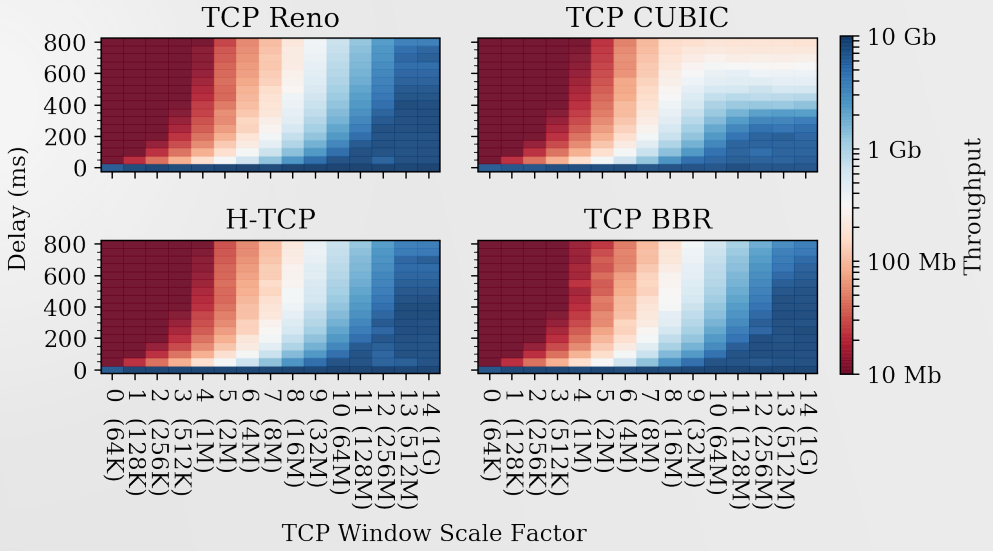
Wscale Impairment

Clipped and Stripped Wscale have a direct impact on **maximum achievable throughput**

In the future

Higher throughputs might become a problem as Higher BDPs are not supported by TCP



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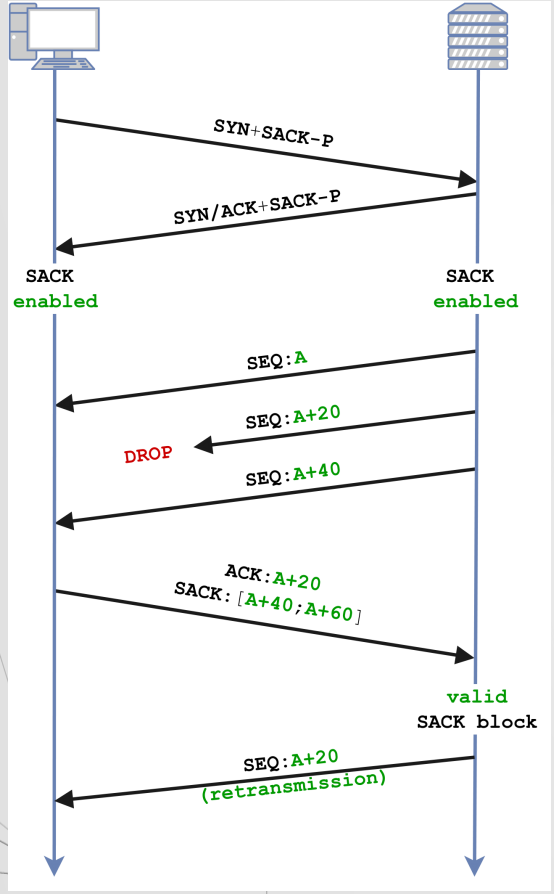
QUIC

UDP-based splitted layer transport

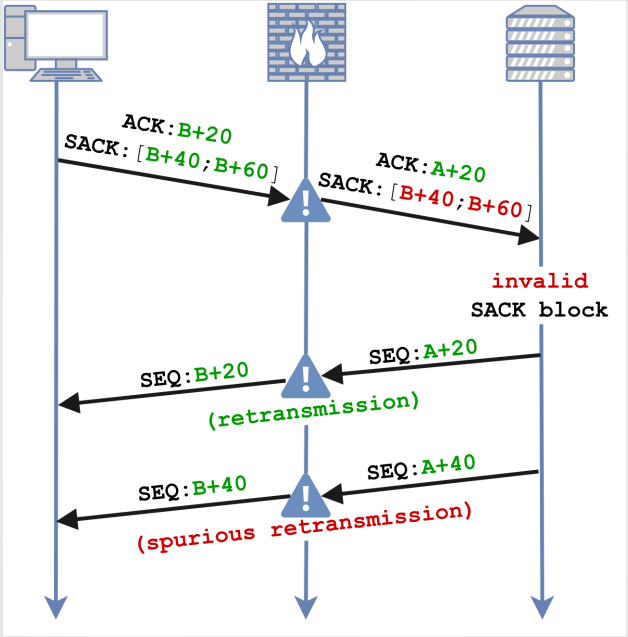
THANKS

korian.edeline@uliege.be

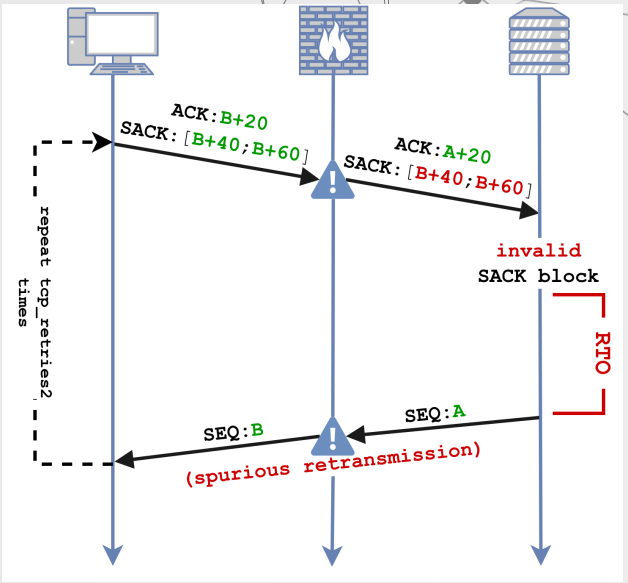
SACK



Normal SACK

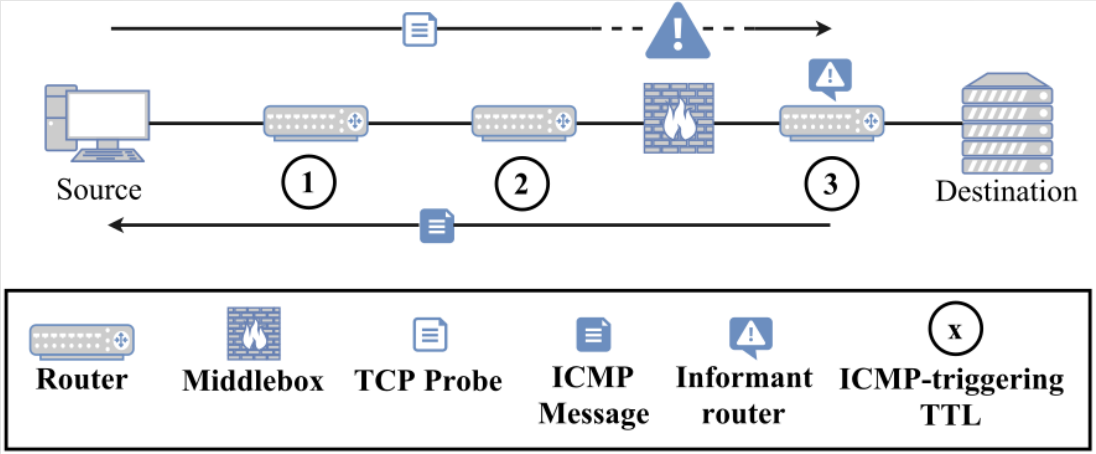


Broken SACK
(spurious retransmission)



Broken SACK (RTO)

tracebox



- **RFC 792** : “The internet header plus the first 64 bits”
- **RFC 1812** : “as much [...] as possible” (< 576 B)

Testbed specifications

- Intel Xeon E5-2620 2.1GHz, 16 Threads, 32GB RAM
- Intel XL710 2x40GB NICs
- Huawei CE6800 switch
- Debian 9