My TCP ain't your TCP - ain't no TCP?

How new implementations speed up the internet
... and make engineers drink

Simon Lindermann

Miele & Cie KG / Freelancer

Demo Traces

https://cloud.local-area.network/index.php/s/7Ojmw9hhnDf9yBb

https://bit.ly/2Iae7A7 (Shortlink)

About me?

- Working and learning in IT since 2006
  - Employer: Miele Germany
  - Network Architect
  - Part time freelancer

Contact

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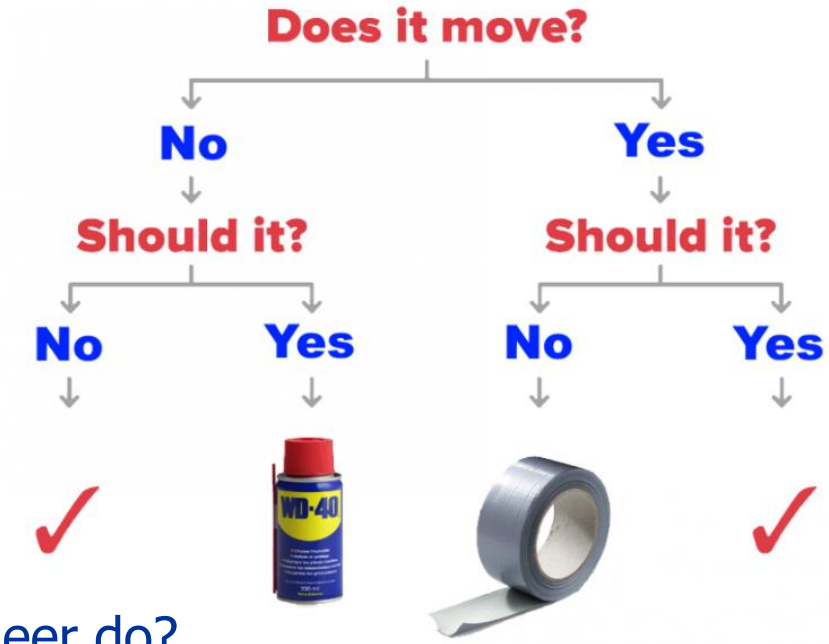
Shark Pointer

LaserShark Pointer



What would an engineer do?

No revolution, but evolution

Algorithms

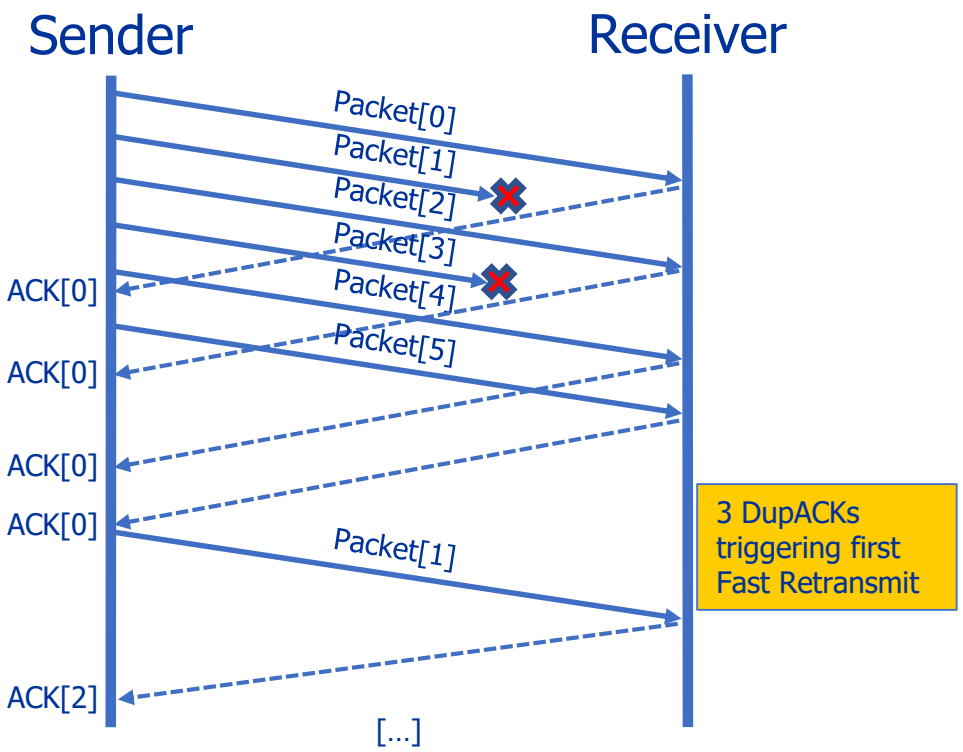
- TCP Tahoe
- TCP Reno
- TCP New Reno
- (TCP SACK)

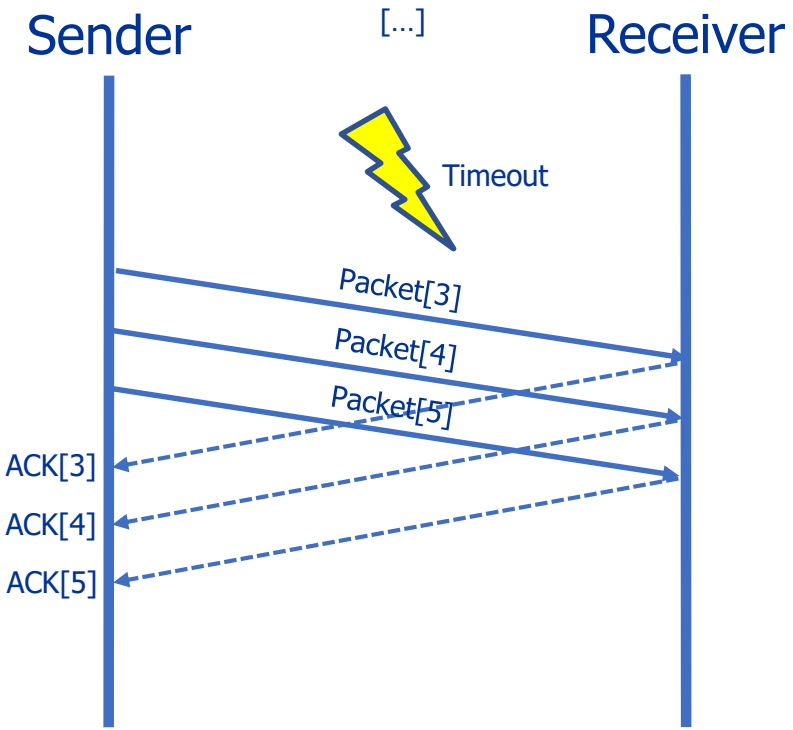
Components

- Slow Start
- Additive Increase Multiplicative Decrease (AIMD)
- Fast Retransmit
- Fast Recovery
- Partial ACK
- Selective ACK

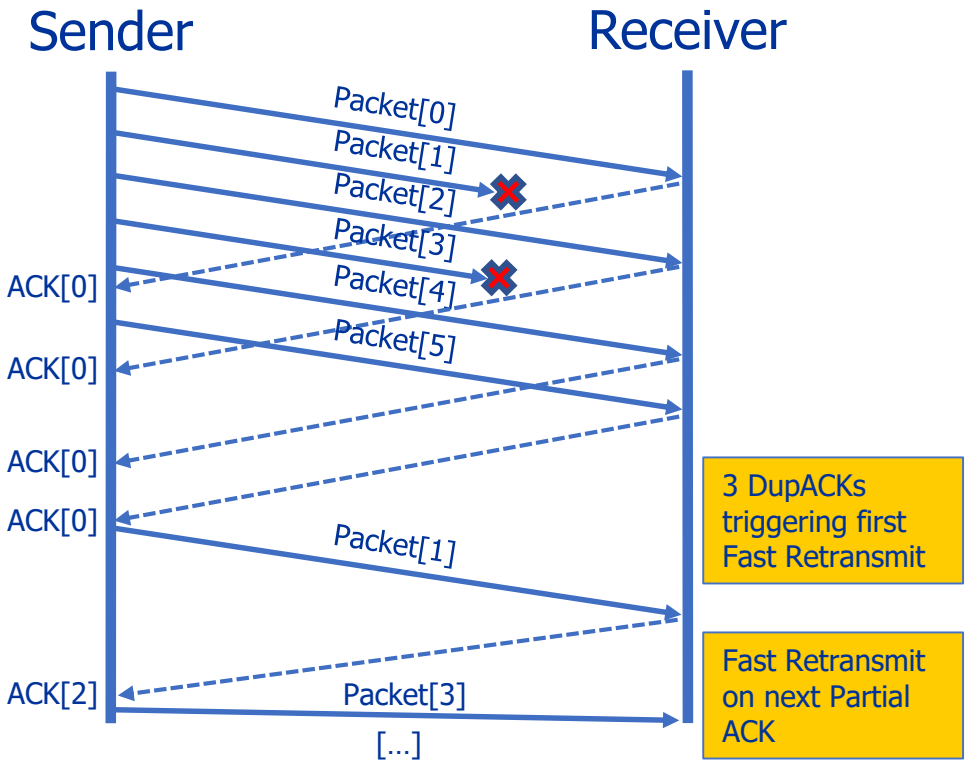
Check out my talk from 2018 for this stuff!

Signaling loss in the old days…





TCP New Reno: Partial ACK



- Partial ACKs trigger Fast Retransmits of multiple lost segments
- Second lost segment gets retransmitted immediately after the **first** Partial ACK

TCP SACK

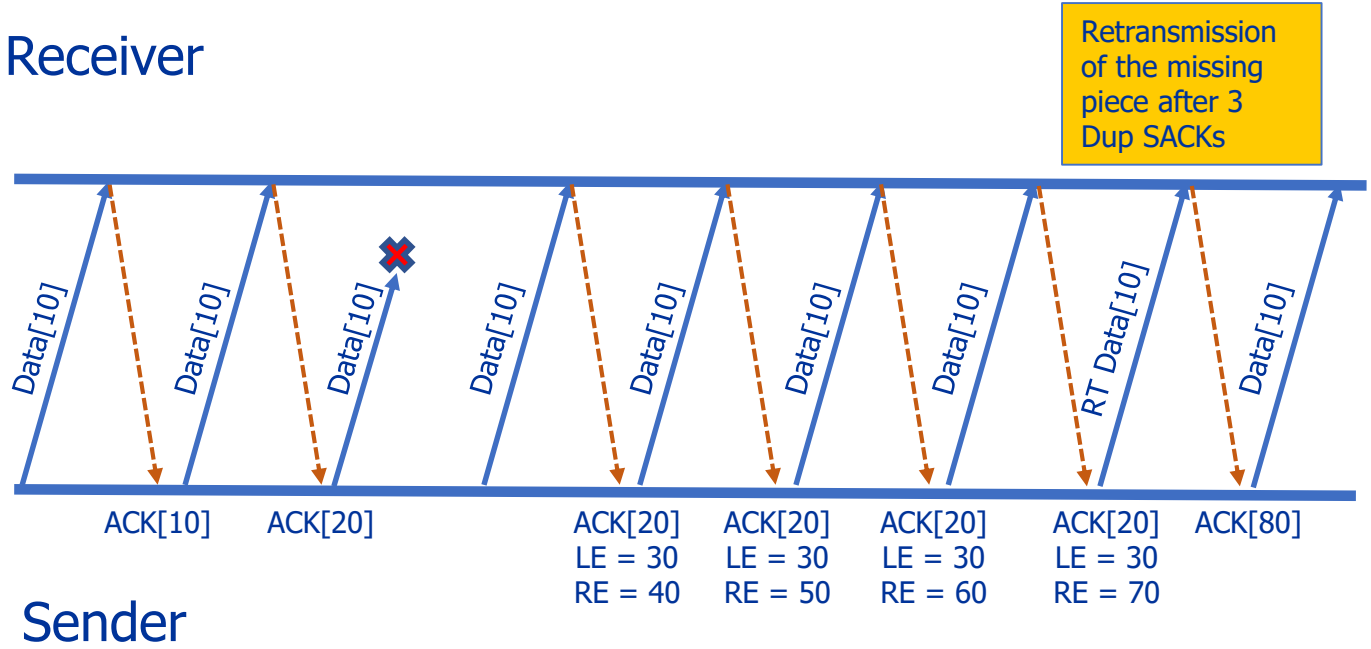
RFC 2018

"TCP may experience poor performance when multiple packets are lost from one window of data."

[…]

"The receiving TCP sends back SACK packets to the sender informing the sender of data that has been received. The sender can then retransmit only the missing data segments."

TCP SACK


Receiver
Retransmission of the missing piece after 3 Dup SACKs
Data[10]
Data[10]
Data[10]
Data[10]
Data[10]
Data[10]
Data[10]
RT Data[10]
Data[10]
ACK[10]
ACK[20]
ACK[20]
LE = 30
RE = 40
ACK[20]
LE = 30
RE = 50
ACK[20]
LE = 30
RE = 60
ACK[20]
LE = 30
RE = 70
ACK[80]
Sender

Demo

- Open Trace in your Wireshark:

"sack_and_dsack.pcap"

OK, that’s the old stuff!

Lets think outside the box!

But now - Revolution!

Multipath TCP (MPTCP)

- RFC 6182 / 6824
- Latest implementations (suggested) https://tools.ietf.org/html/draft-ietf-mptcp-rfc6824bis-17

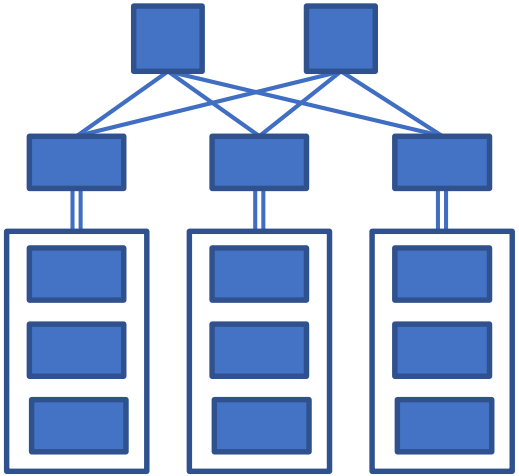
Motivation

Networks becoming multipath

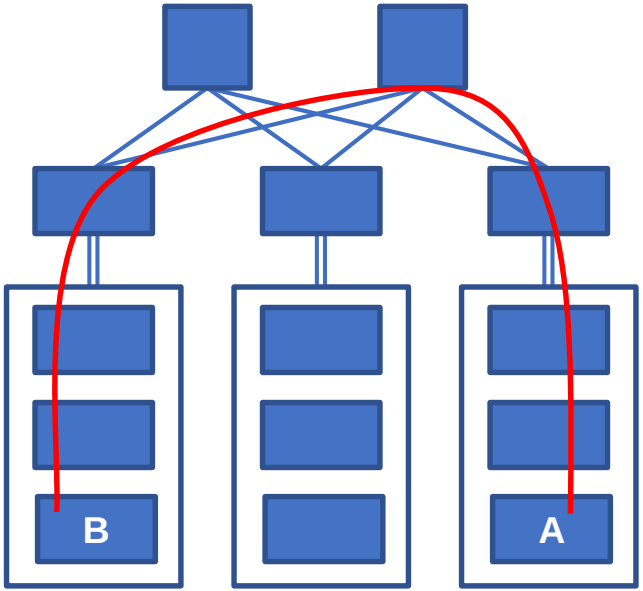
- Link aggregation
- High availability

Redundant networks

- Mobile phones utilizing Wifi & 4G
- Multi-homed Servers



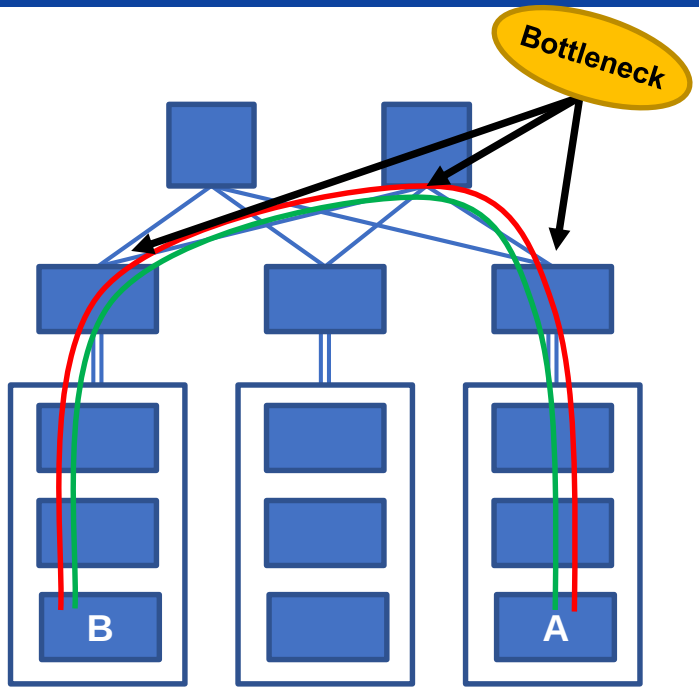
Flow distribution (1/2)



Server A to Server B

- Load balancing across links usually based on
  - MAC addresses
  - IP addresses
- Single TCP flow

Flow distribution (2/2)



Server A to Server B

- Load balancing across links usually based on
  - MAC addresses or
  - IP addresses

- 2nd TCP flow, same SRC/DST

TCP Statements

- TCP only uses a single path regardless of the network topology
- It's always tied to a single SRC and DST address of client and server
  - If one or the other changes → Connection break!

Deployment goals of recent MPTCP implementation

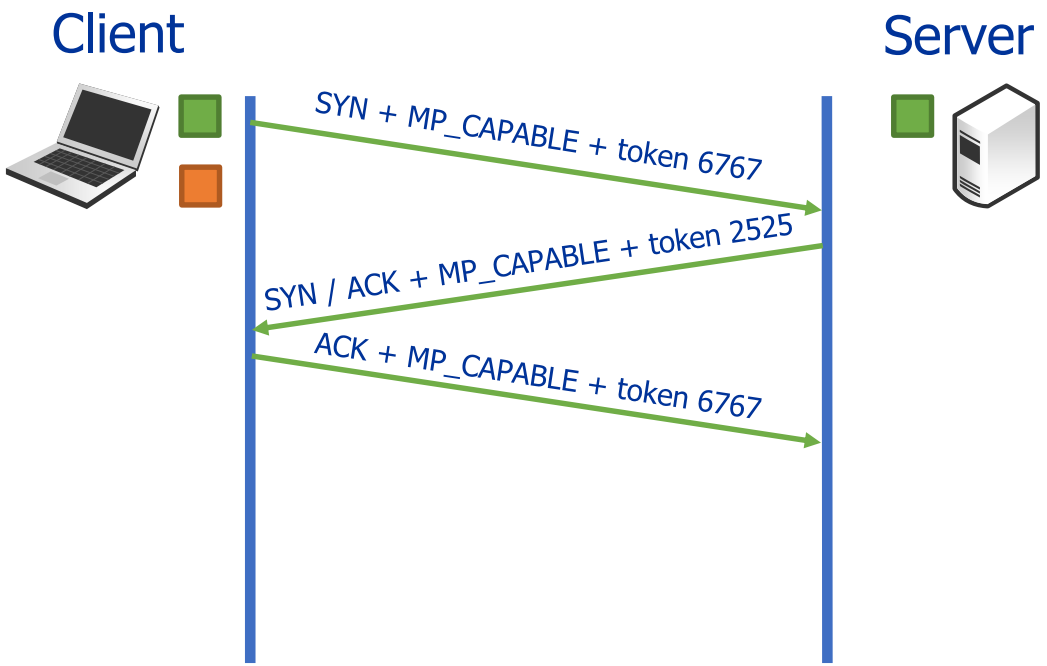
- TCP needs to evolve and utilize multiple paths for the same data transport

- It MUST meet the following criteria:
  1) Support unmodified applications
  2) Work on todays networks
  3) Work whenever TCP works, or fallback to TCP

Easy peasy!

… or not?

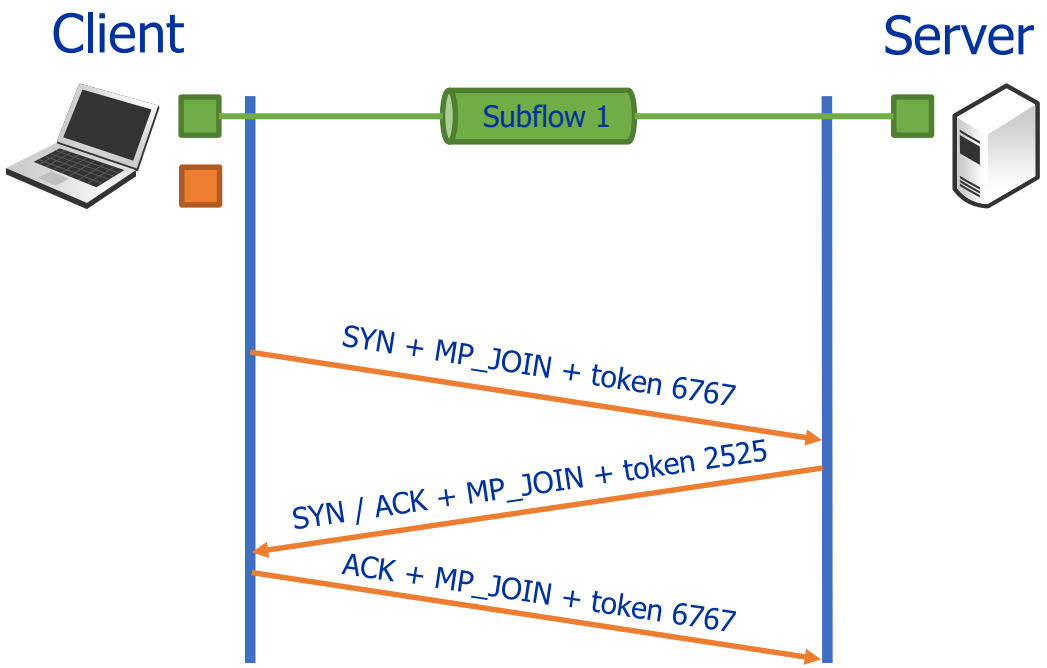
MPTCP Session Setup



Connection identifier

- analog to emphemeral TCP ports
- Used to associate multiple subflows

MPTCP Session Setup



Connection identifier

- similar to emphemeral TCP ports
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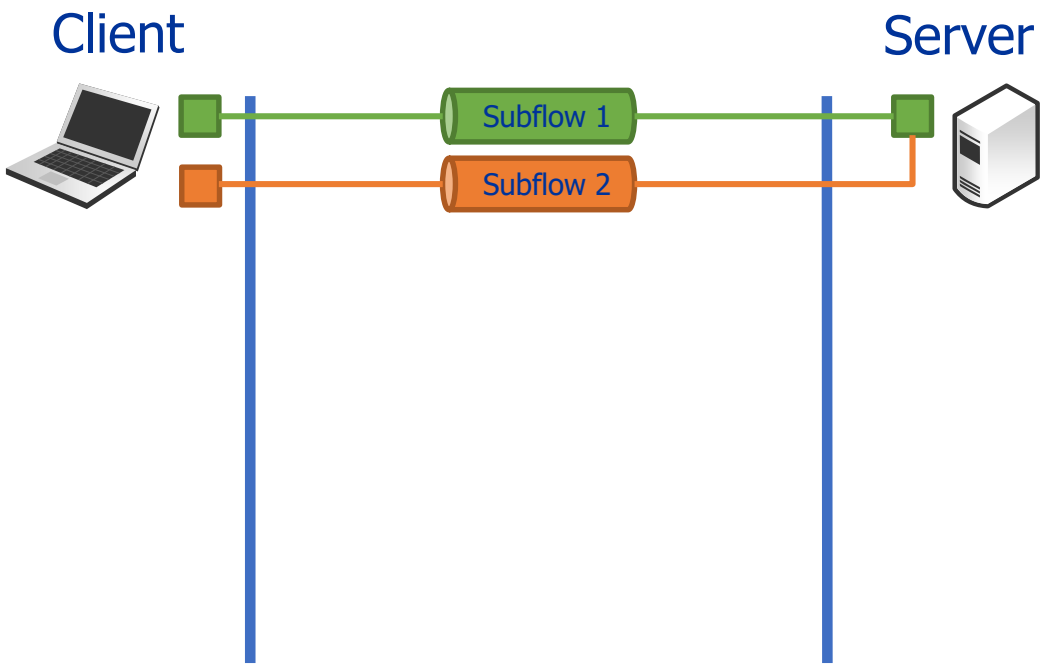
MPTCP Session Setup



Connection identifier

- similar to emphemeral TCP ports
- Used to associate multiple subflows

The packet

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Byte 0								**Byte 1**								**Byte 3**								**Byte 4**							
Version				Header len				TOS								Total length															
Identification																Flags				Fragment Offset											
TTL								Protocol								Header Checksum															
Source IP																															
Destination IP																															
Source Port																Destination Port															
SEQ Number																															
ACK Number																															
Header len				Reserved				Code bits								Window size															
Checksum																Urgent pointer															
Options																															
Data																															

The packet

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Byte 0								**Byte 1**								**Byte 3**								**Byte 4**							
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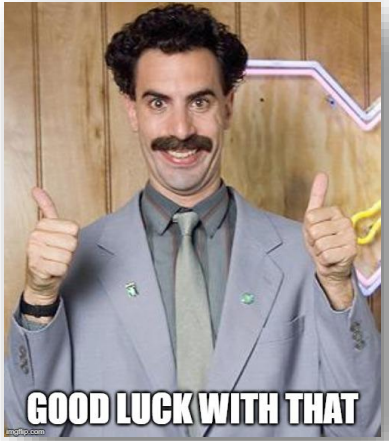
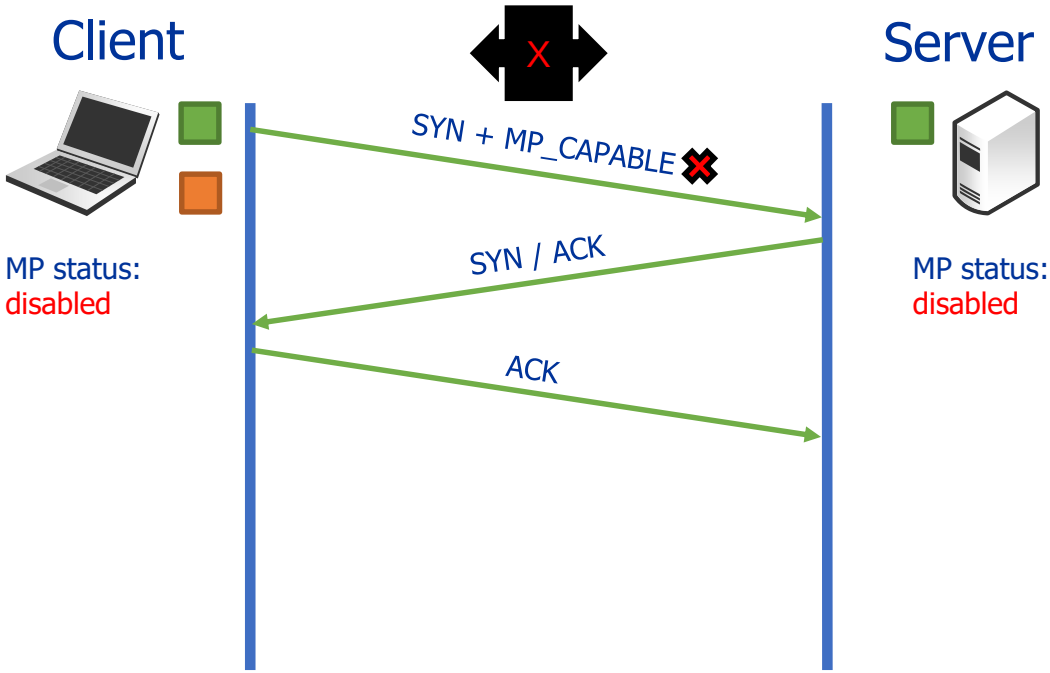
Data																															

The packet

0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31
Byte 0	**Byte 1**	**Byte 3**	**Byte 4**
Version	Header len	TOS	Total length
Identification		Flags	Fragment Offset
TTL	Protocol	Header Checksum	
Source IP			
Destination IP			
Source Port		Destination Port	
SEQ Number			
ACK Number			
Header len	Reserved	Code bits	Window size
Checksum		Urgent pointer	
Options			
Data			



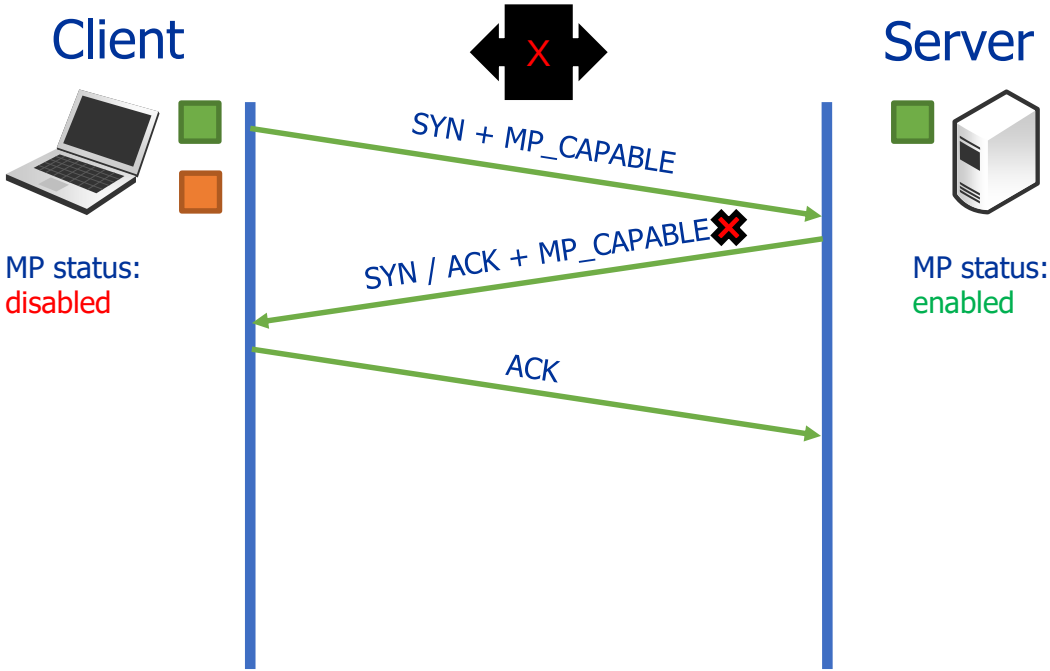
Nasty middle boxes



Middle boxes can drop TCP options:

a) SYN MP_CAPABLE

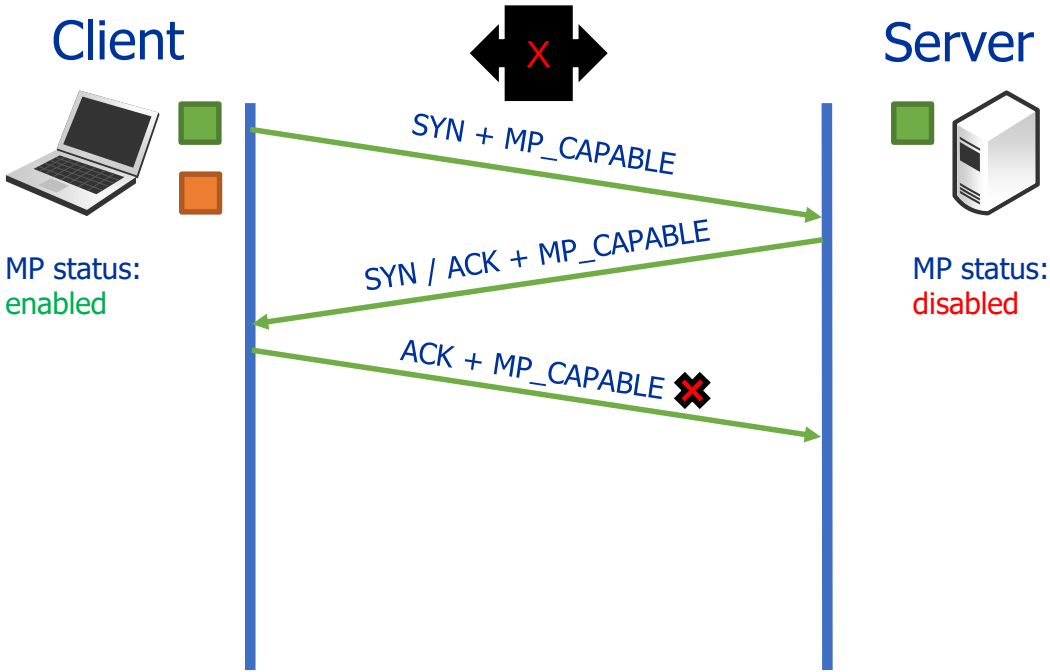
Nasty middle boxes



Middle boxes can drop TCP options:

b) SYN / ACK MP_CAPABLE

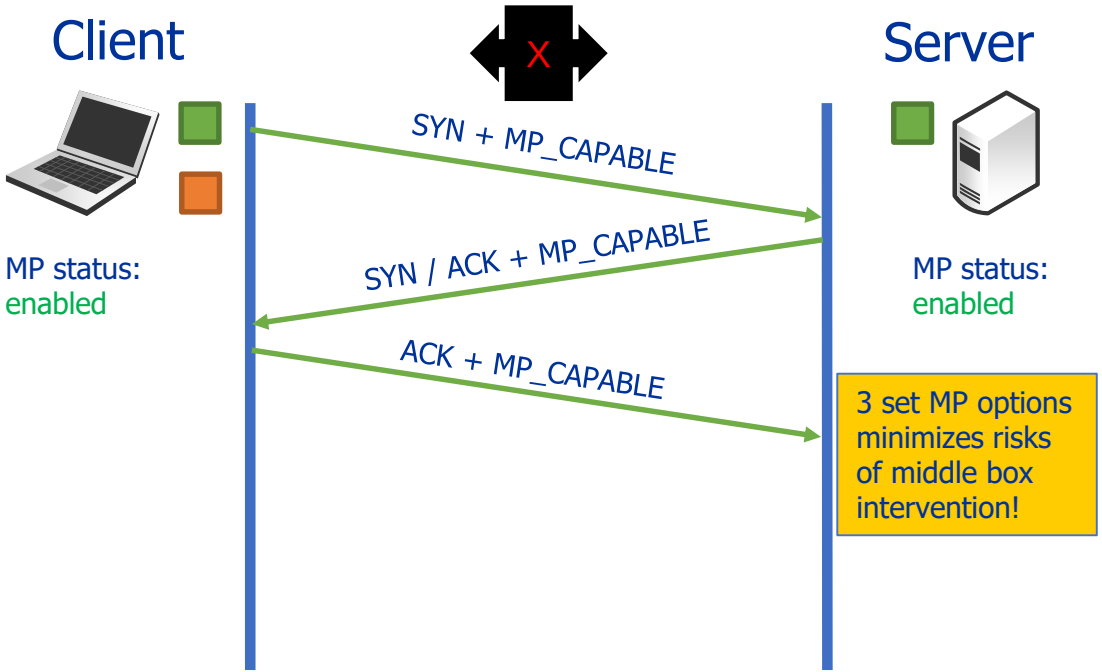
Nasty middle boxes



Middle boxes can drop TCP options:

c) ACK MP_CAPABLE

Nasty middle boxes



Summary

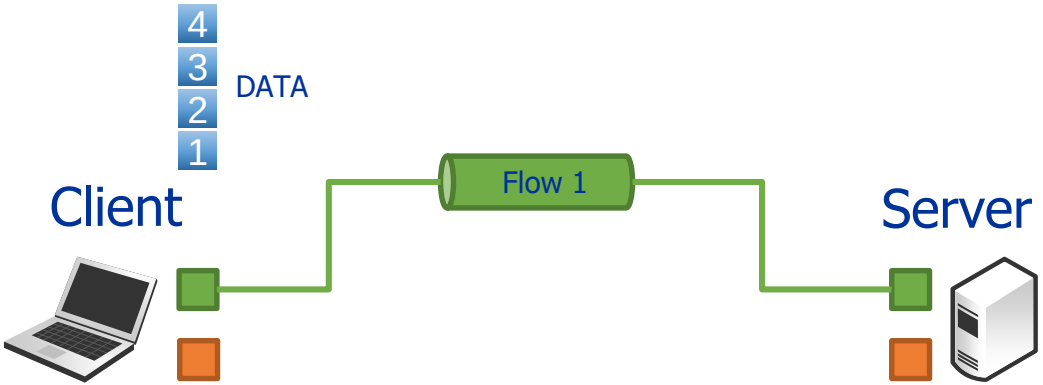
Don't expect the path between two endpoints is always the same!

Have a fallback option available!

Demo

- Live Demo

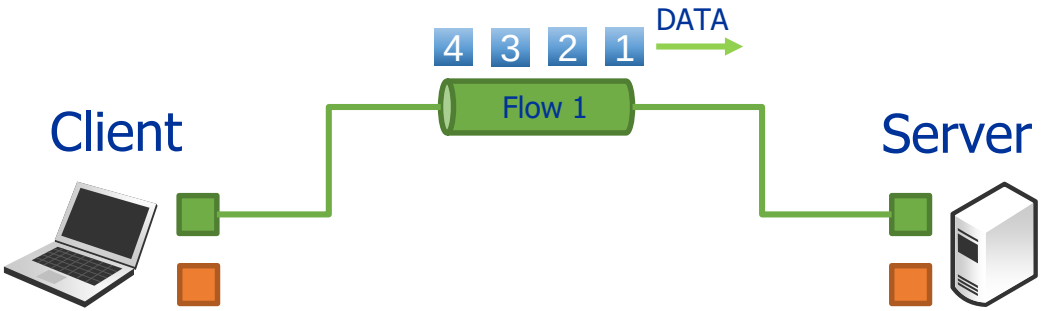
How to send Data?



With regular TCP

Application passes Data to MPTCP

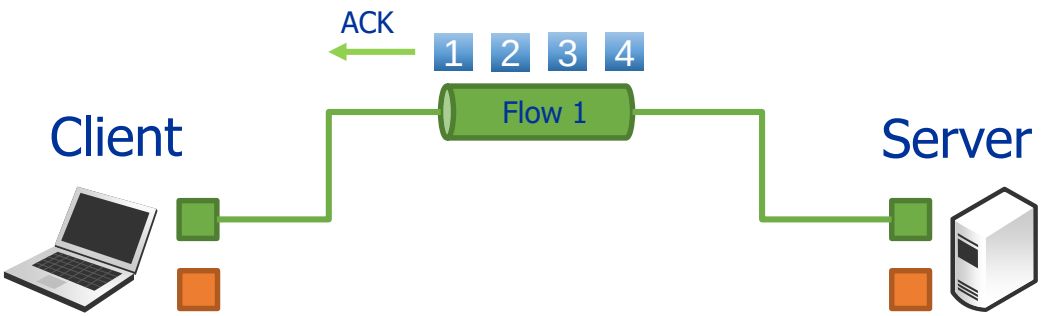
How to send Data?



With regular TCP

Data will be send over a single connection in the order of appearance

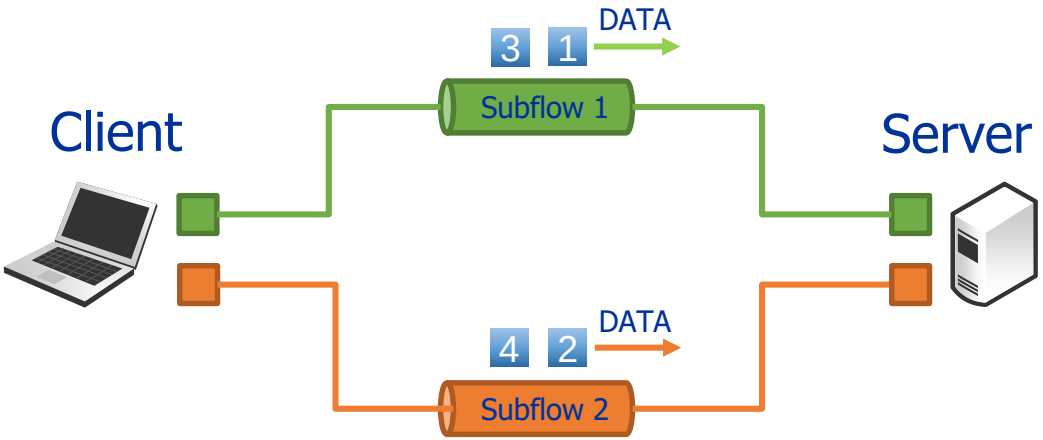
How to send Data?



With regular TCP

ACKs are going back in the order of received data

How to send Data?

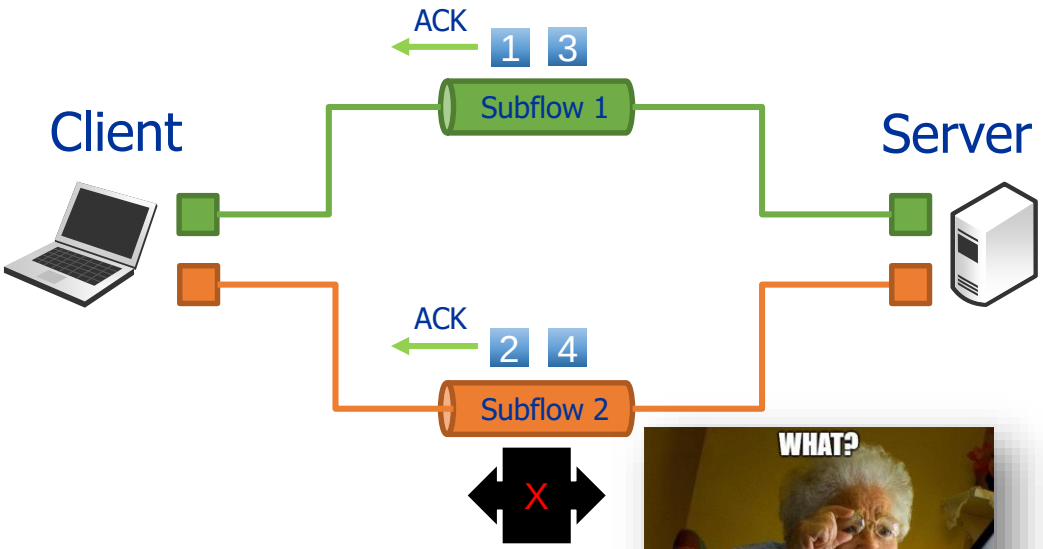


MPTCP Strawman design

Distribute Data evenly over all connections

No problem so far…

How to send Data?

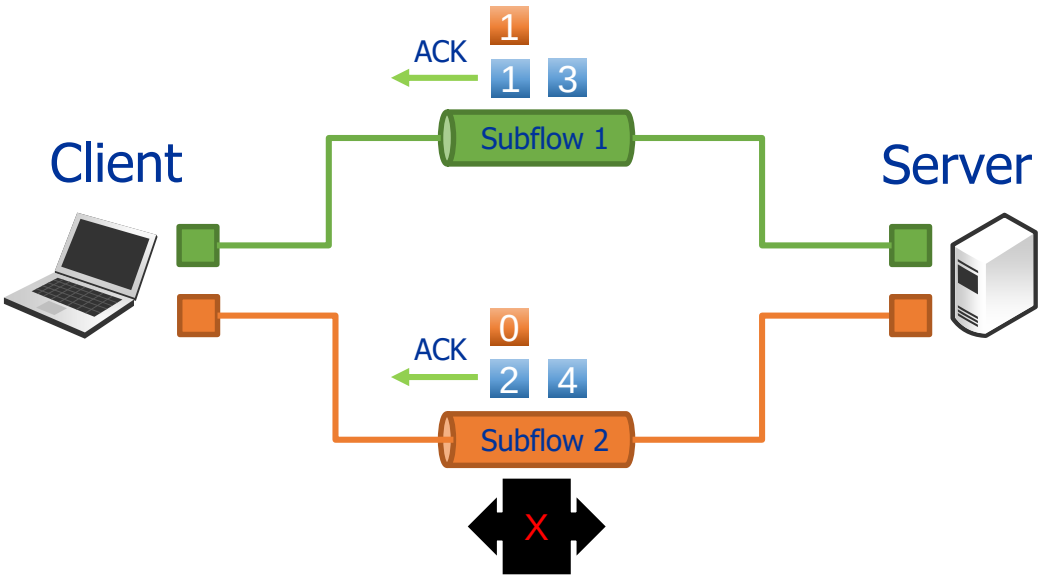


MPTCP Strawman design

Oh no, a middle box!

- Path 2 did not see Data 1
- ACK 2 cumulatively acknowledges Data 1 & 2

How to send Data?



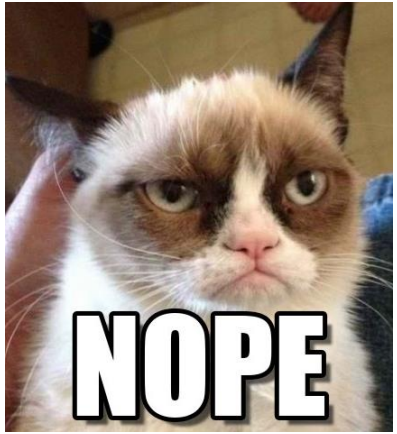
MPTCP Strawman design

Chances are middle box will:

a) Drop the ACK
b) Correct the ACK
c) RST the connection

The NOPES

- Don’t use TCP Sequence numbers across multiple flows
- Don’t expect the network to be as smart as your clients/servers

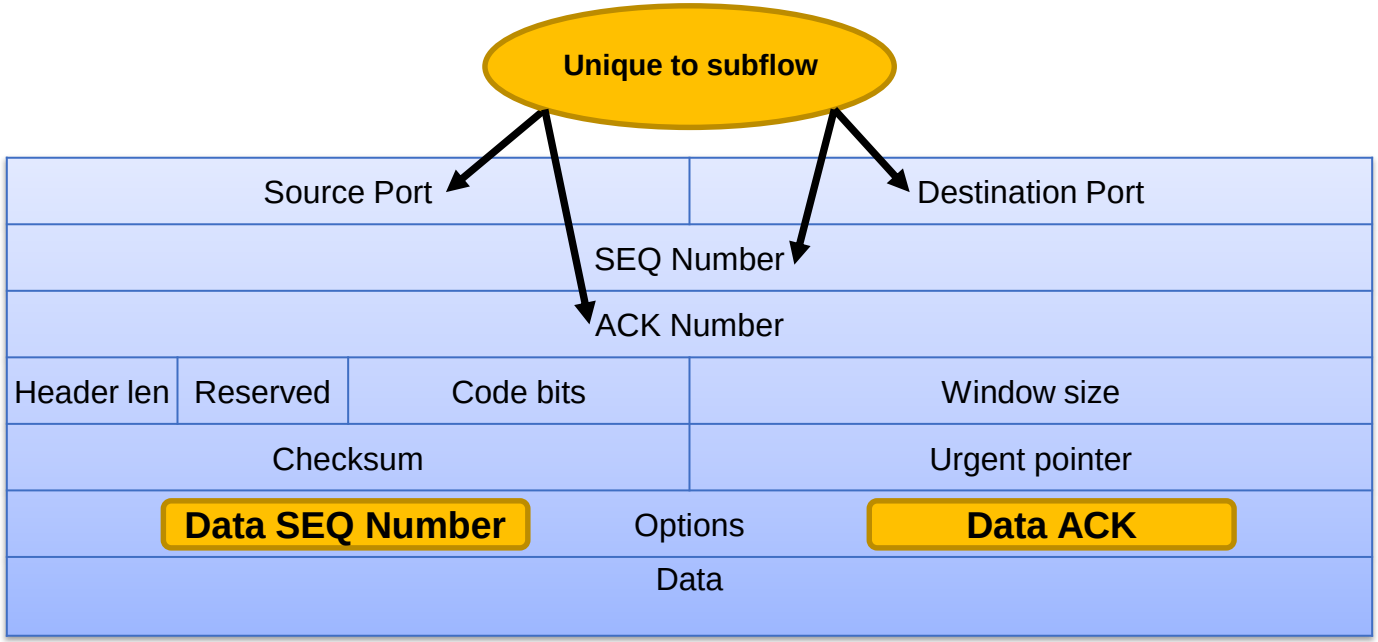


*RIP Grumpy Cat

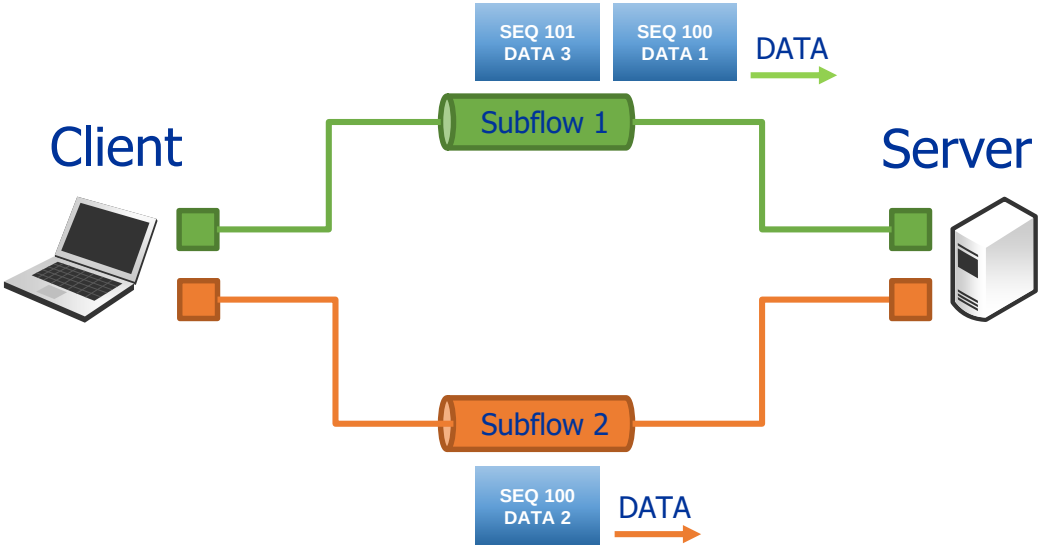
Instead

- Own sequence numbers for each subflow
  - Make MPTCP look like TCP with no gaps
- Additional data sequence numbers for MPTCP
  - Because reordering can still happen
- Additional data ACK for flow control

MPTCP Header



Sending data across subflows

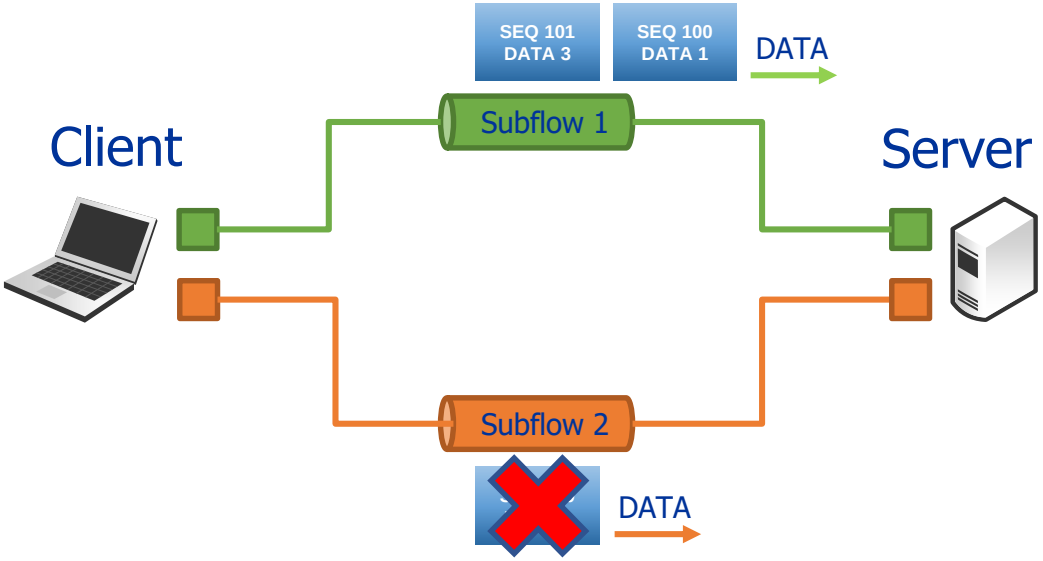


MPTCP data transmission

Sequence Numbers are unique per subflow

Data Sequence Numbers are shared across all subflows

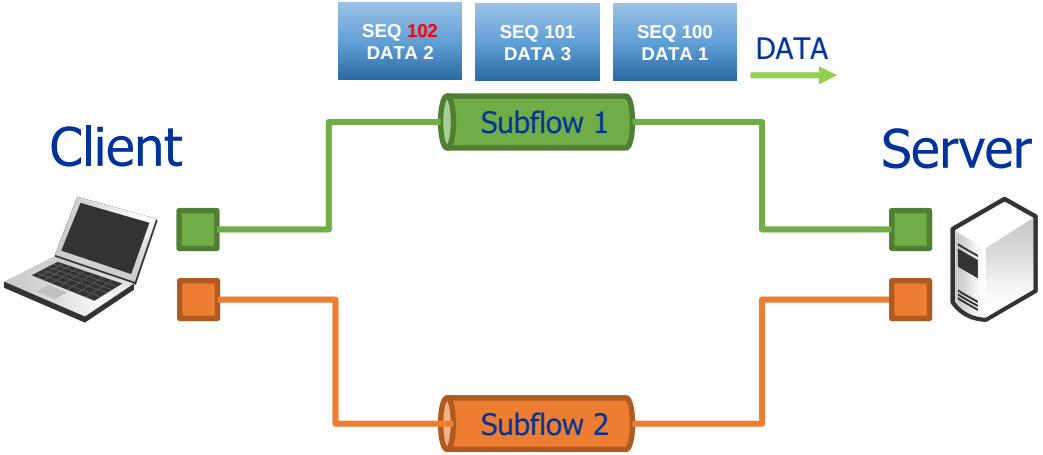
How to react on packet loss?



MPTCP data transmission

Subflow 2 experiences packet loss

How to react on packet loss?



MPTCP data transmission

Data will be retransmitted on subflow 1

Demo

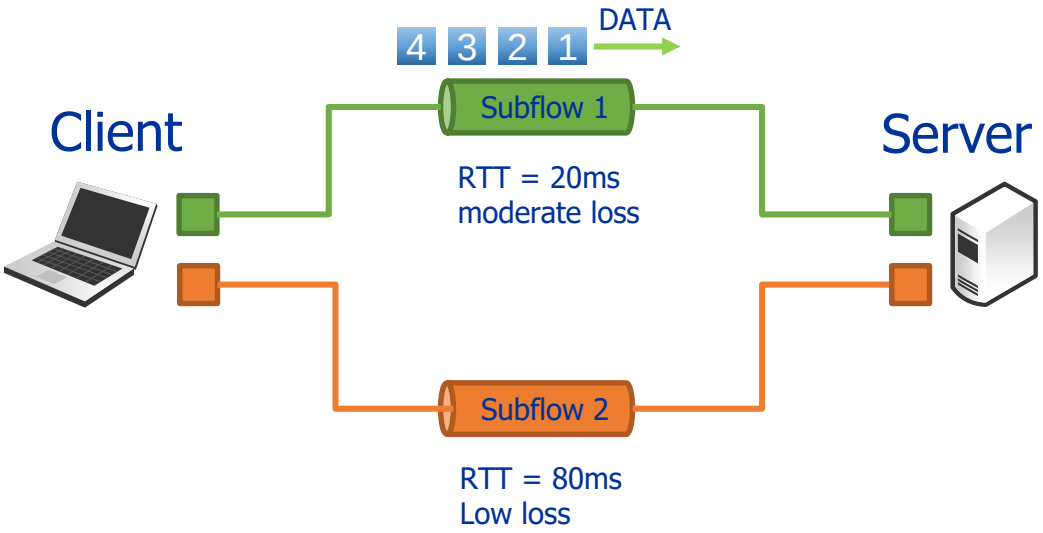
- Open Trace in your Wireshark:

"mptcp_client01.pcap"

MPTCP Options

Value	Symbol	Name
0x0	**MP_CAPABLE**	Multipath Capable
0x1	**MP_JOIN**	Join Connection
0x2	**DSS**	Data Sequence Signal (Data ACK and data sequence mapping)
0x3	**ADD_ADDR**	Add Address
0x4	**REMOVE_ADDR**	Remove Address
0x5	MP_PRIO	Change Subflow Priority
0x6	MP_FAIL	Fallback
0x7	MP_FASTCLOSE	Fast Close
0xf	(PRIVATE)	Private Use within controlled testbeds

MPTCP Scheduler



Which path to use when?

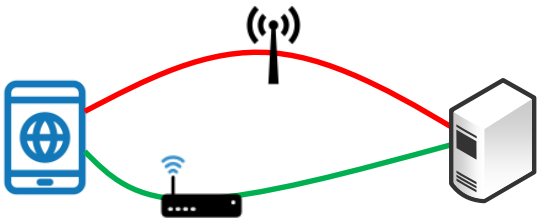
Use the least congested path with the lowest RTT

However:

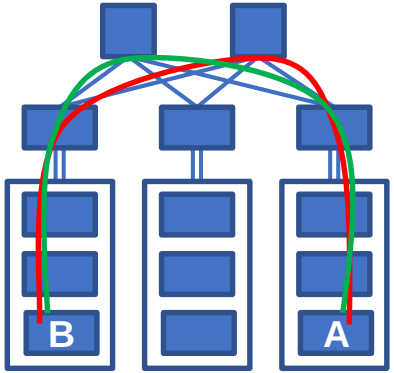
MPTCP throughput should never be less then best possible TCP throughput on a single path

Main MPTCP Use Cases

- Mobile phone
  - Improved stability



- Datacenters
  - Improved throughput



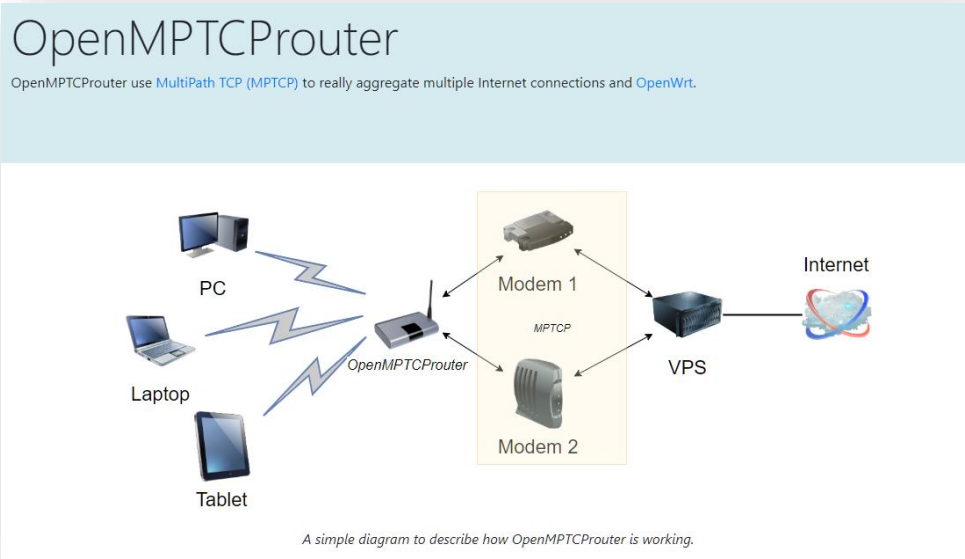
Who is using it today?

- Linux kernel (MultipathTCP-Linux)
- Apple iOS and macOS
- Citrix load balancers
- FreeBSD (FreeBSD-MPTCP)
- Oracle Solaris
- …

You might try!

- MPTCP doesn’t require the application to be adjusted
- You do not need to change your network

Want to play at home?



https://www.openmptcprouter.com/

References

- https://tools.ietf.org/html/rfc6182
- https://tools.ietf.org/html/draft-ietf-mptcp-rfc6824bis-17
- https://tools.ietf.org/html/rfc8041

- https://multipath-tcp.org/
- https://youtu.be/k-5pGlbiB3U
- https://youtu.be/bwh5pr2uxgQ
- https://arxiv.org/abs/1601.06043

- https://github.com/Neohapsis/mptcp-abuse

Thank you

Questions? Compliments? Wisdoms?

Please use the Guidebook App to provide feedback.

Contact

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