# Multipathed, Multiplexed, Multilateral Transport Protocols

## Decoupling transport protocols from what's below

Catherine (Kate) Pearce
Sr Security Consultant, Cisco Security Services
Feb 22, 2016

# Who?

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  - @secvalve

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- Sr. Security Consultant (Customer Focused)

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- Distinguishing Features:

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ALL OPINIONS ENTIRELY MY OWN.
NO official Cisco representations of any kind

MPTCP changes

***fundamental assumptions***

about

***how TCP works****

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*Use it to break things today*

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*Use it to break things today*

*Adapt to it for tomorrow*

QUIC also changes

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# 2 Simple Examples: #1

192.168.88.165 - PuTTY

```
root@deb7min2:~# curl 192.168.88.164
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# 2 Simple Examples: #1

Snorby - Dashboard - Chro... | [Terminal - pst@pst-virtual-... | Terminal - pst@pst-virtual-... | Capturing from Pseudo-dev...

Capturing from Pseudo-device that captures on all interfaces [Wireshark 1.6.7 ]

File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help

Filter: tcp.port == 80 Expression... Clear Apply

| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 80 | 12.278794 | 192.168.88.165 | 192.168.88.164 | TCP | 88 | 34668 > http [SYN] Seq=0 Win=29200 Len=0 MSS=1460 SACK_PERM=1 TSval=1249 |
| 81 | 12.278839 | 192.168.88.164 | 192.168.88.165 | TCP | 88 | http > 34668 [SYN, ACK] Seq=0 Ack=1 Win=28560 Len=0 MSS=1460 SACK_PERM=1 |
| 82 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] [ACK] Seq=1 Ack=1 Win=58432 Len=0 TSval=12490113 TSecr=1247 |
| 83 | 12.279003 | 192.168.88.165 | 192.168.88.164 | HTTP | 166 | GET / HTTP/1.1 |
| 84 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] [AC 0 TSval=12474351 TSecr=124 |
| 85 | 12.280095 | 192.168.88.165 | 192.168.88.164 | TCP | 88 | 39757 > http [SY 460 SACK_PERM=1 TSval=1249 |
| 86 | 12.280111 | 192.168.88.164 | 192.168.88.165 | TCP | 92 | http > 39757 [SY Len=0 MSS=1460 SACK_PERM=1 |
| 87 | 12.280222 | 192.168.88.165 | 192.168.88.164 | TCP | 92 | 39757 > http [AC TSval=12490113 TSecr=1247 |
| 88 | 12.280338 | 192.168.88.164 | 192.168.88.165 | TCP | 76 | [TCP Window Upda ck=1 Win=85696 Len=0 TSval |
| 89 | 12.283984 | 192.168.88.164 | 192.168.88.165 | HTTP | 548 | HTTP/1.1 200 OK |
| 90 | 12.284014 | 192.168.88.165 | 192.168.88.164 | TCP | 76 | 39757 > http [AC =0 TSval=12490114 TSecr=12 |
| 91 | 12.284045 | 192.168.88.165 | 192.168.88.164 | TCP | 88 | [TCP Dup ACK 90# k=461 Win=88576 Len=0 TSva |
| 92 | 12.284064 | 192.168.88.164 | 192.168.88.165 | TCP | 88 | [TCP Dup ACK 89# Ack=1 Win=85696 Len=0 TSva |
| 93 | 12.284073 | 192.168.88.165 | 192.168.88.164 | TCP | 76 | 39757 > ht 6 Len=0 TSval=12490114 TSe |
| 94 | 12.284077 | 192.168.88.165 | 192.168.88.164 | TCP | 76 | 34668 > http [F Len=0 TSval=12490114 TSec |
| 95 | 12.284086 | 192.168.88.165 | 192.168.88.164 | TCP | 76 | [TCP Dup ACK 93# k=461 Win=88576 Len=0 TSva |
| 96 | 12.284091 | 192.168.88.164 | 192.168.88.165 | TCP | 76 | http > 39757 [F 6 Len=0 TSval=12474352 TSe |
| 97 | 12.284099 | 192.168.88.165 | 192.168.88.164 | TCP | 76 | 39757 > http [AC =0 TSval=12490114 TSecr=12 |
| 98 | 12.284103 | 192.168.88.164 | 192.168.88.165 | TCP | 76 | http > 34668 [F Len=0 TSval=12474352 TSec |
| 99 | 12.284126 | 192.168.88.165 | 192.168.88.164 | TCP | 76 | 34668 > http [AC 0 TSval=12490114 TSecr=124 |

Mark Packet (toggle)
Ignore Packet (toggle)
Set Time Reference (toggle)
Manually Resolve Address
Apply as Filter
Prepare a Filter
Conversation Filter
Colorize Conversation
Follow TCP Stream
Follow SSL Stream
Copy
Decode As...
Print...
Show Packet in New Window

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| 83 | 12.279003 | 192.168.88.165 | 192.168.88.164 | HTTP | 166 | GET / HTTP/1.1 |
| 84 | 12.279256 | 192.168.88.164 | 192.168.88.165 | TCP | 76 | http > 34668 [ACK] Seq=1 Ack=79 Win=57152 Len=0 TSval= |
| 94 | 12.284077 | 192.168.88.165 | 192.168.88.164 | TCP | 76 | 34668 > http [FIN, ACK] Seq=79 Ack=1 Win=88576 Len=0 T |
| 98 | 12.284103 | 192.168.88.164 | 192.168.88.165 | TCP | 76 | http > 34668 [FIN, ACK] Seq=1 Ack=80 Win=85696 Len=0 T |
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Follow TCP Stream

Stream Content

```
GET / HTTP/1.1
User-Agent: curl/7.26.0
Host: 192.168.88.164
Accept: */*
```

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**Wait, What!?!!**

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File Edit View Go Capture

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Stream Content

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GET / HTTP/1.1
User-Agent: curl/7.26.0
Host: 192.168.88.164
Accept: */*
```

**Wait, What!?!!**

# 2 Simple Examples: #2

```
# nc 192.168.1.25 3000
```

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```
root@deb7min-LEFT:/home/username# netstat --tcp
Active Internet connections (w/o servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      1 10.2.2.111:43272       192.168.1.25:3000       SYN_SENT
tcp        0      1 10.3.3.111:33145       192.168.22.145:3000     SYN_SENT
tcp        0      1 10.1.1.111:43769       192.168.1.25:3000       SYN_SENT
tcp        0      1 10.1.1.111:52605       192.168.22.145:3000     SYN_SENT
tcp        0      0 192.168.1.34:50818     192.168.1.25:3000       ESTABLISHED
tcp        0      1 192.168.1.34:34095     192.168.22.145:3000     SYN_SENT
tcp        0      1 10.3.3.111:36916       192.168.1.25:3000       SYN_SENT
tcp        0      1 10.2.2.111:40284       192.168.22.145:3000     SYN_SENT
tcp6       0      0 2601:6:1700:168:2:40378 2601:6:1700:168:20:3000 ESTABLISHED
tcp6       0      0 2601:6:1700:168:2:41699 2601:6:1700:168:20:3000 ESTABLISHED
```

# 2 Simple Examples: #2

```
root@deb7min-LEFT:/home/username# netstat --tcp
Active Internet connections (w/o servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      1 10.2.2.111:43272       192.168.1.25:3000       SYN_SENT
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```

**Err?**

# *What's going on here?*

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→ *Let's talk about upcoming transport protocols*

Introduction ✔

# Background

(TCP, Why Change it?)

MPTCP
Background Redux
QUIC
Implications
Conclusion and Takeaways

(Why NOT to change TCP)

# Multiplexing

| ~ Layer | Technique | Endpoint | Endpoint Definition |
|---|---|---|---|
| 1 | Uniplex | Wire | Implicit |
| 1/2 | Circuit Switching | Physical Wire Address | Local Network Address |
| 3 | Packet Switching | Routed Logical Address | Routable Network Address (Mac/IP) |
| 4 | Packet Switched Transport | Software Logical Port (linked to a single logical network address) | Routable Network Address<br>+ Transport Protocol<br>+ Port |
| 4+ | Multipath Networking | Process with a Logical Connection Identifier. (Linked to n logical network addresses + transports) | + Multipath Protocol Identifier<br>+ Connection Identifier<br><br>(Transport & Network Agnostic – as long as one given) |
| 5 / 6 / 7 | N/A | URI/URL | URI/URL (Transport-agnostic) |

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Workarounds & New Application protocols

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??????

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Workarounds & New Application protocols

# Why do you care?

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- Familiar Problems
  - Address Space Exhaustion
  - Route Table Explosion

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- Familiar Problems
  - Address Space Exhaustion
  - Route Table Explosion
- “New” Problems
  - NAT Table Explosion
  - Client-Controlled routing - Route Arbitrage and Swarming

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These technologies are more culture shock than direct vulnerability / concern

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Personally, I like them, and want them to succeed

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These technologies are more culture shock than direct vulnerability / concern

Personally, I like them, and want them to succeed

Network tools and operators, need to be ready

# Current TCP is rather limited

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Doesn’t support use cases for:

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Networks need multipath, but there's more than one way to do it

1. MPTCP Extends TCP to Multiplex
2. QUIC IGNORES TCP to handle it itself

But, these technologies change the way the internet behaves

Introduction ✔
Background (Why Change TCP) ✔

# MPTCP

Background Redux (Why NOT to change TCP)
QUIC
Implications
Conclusion and Takeaways

# Earlier:

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Doesn’t support use cases for:

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**AND**: it works over existing infrastructure

- (it ***IS*** TCP… just more so)

**BUT**: nothing much else understands it

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- TCP implements connections between IP:PORT & IP:PORT, "*without regard to path*"
- NOT between endpoint A and endpoint B
- In the past this was a distinction without a difference, but not any more

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- **An MPTCP Connection** is defined by a connection ID

- It is composed of multiple *streams, where each stream is a regular* TCP connection (with an option strapped on)

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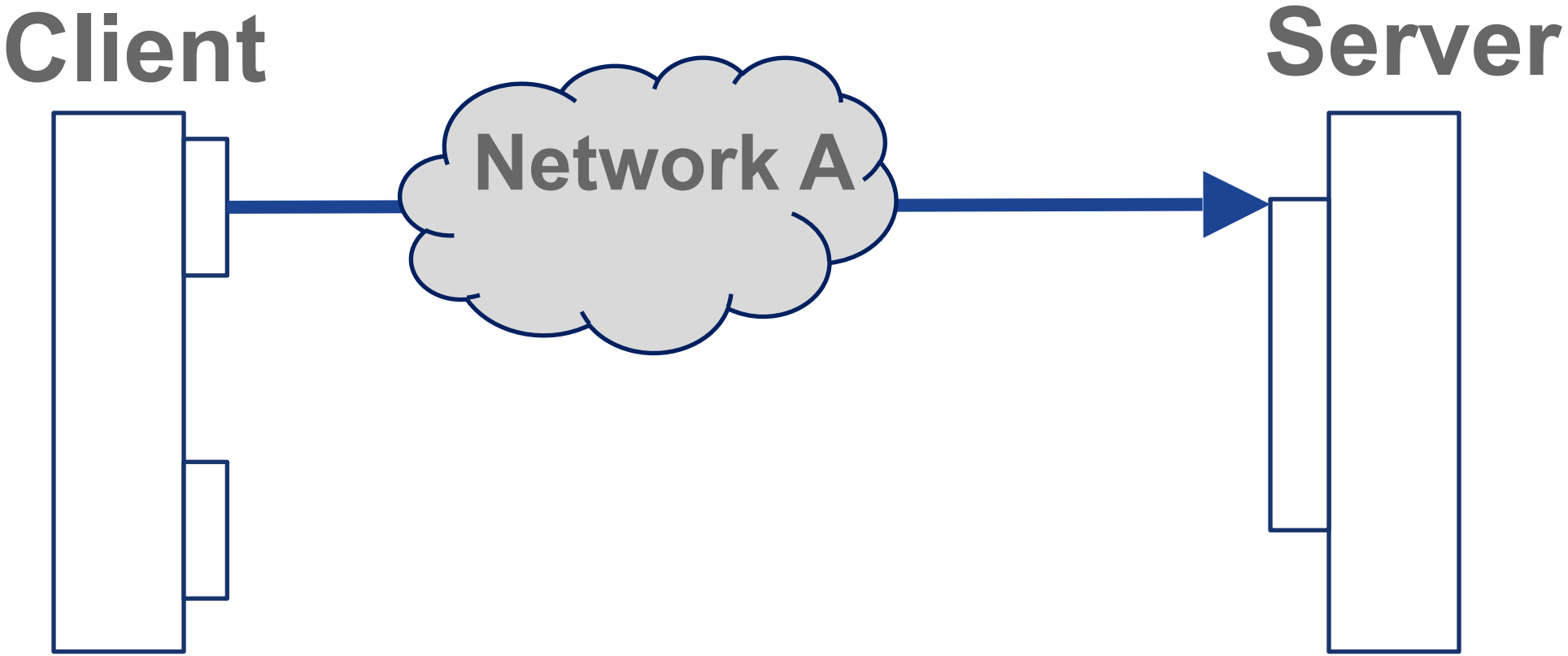
# MPTCP – Simple Case




MPTCP connection looks like TCP so far…

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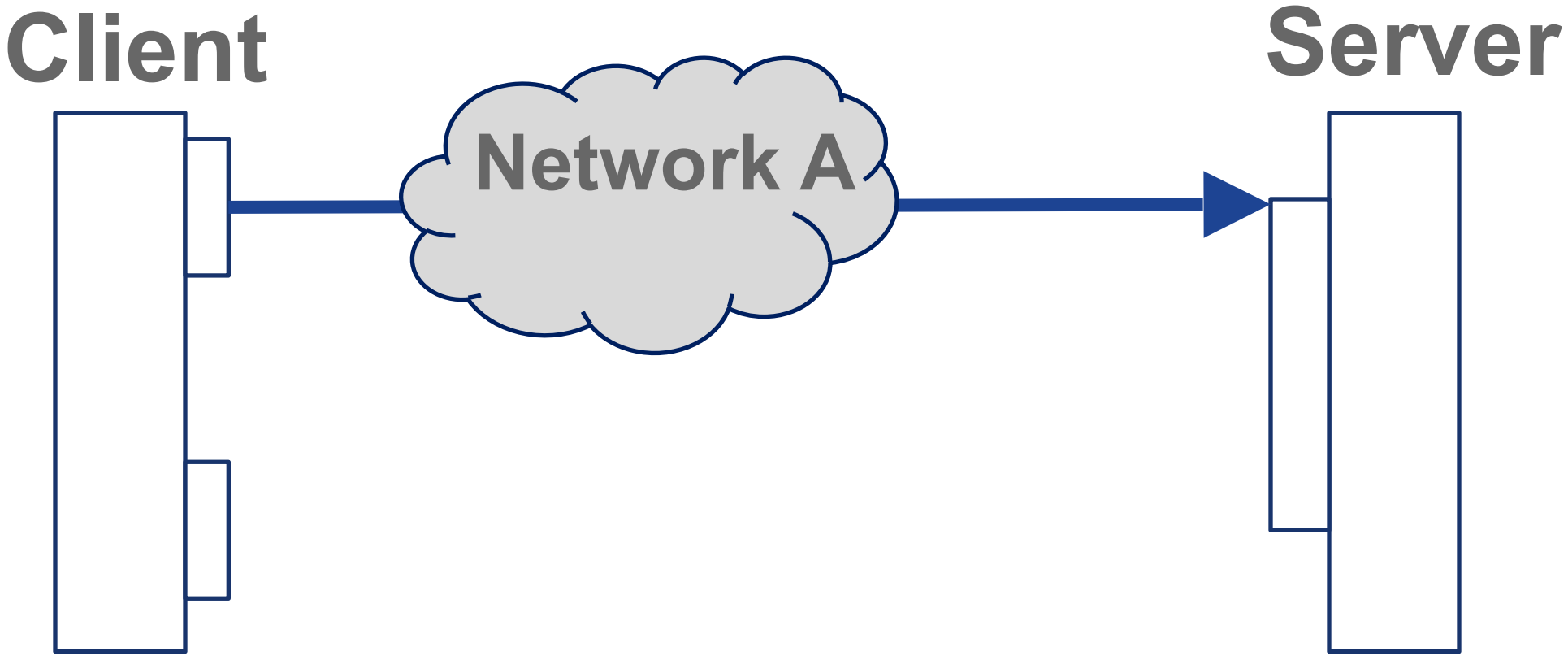

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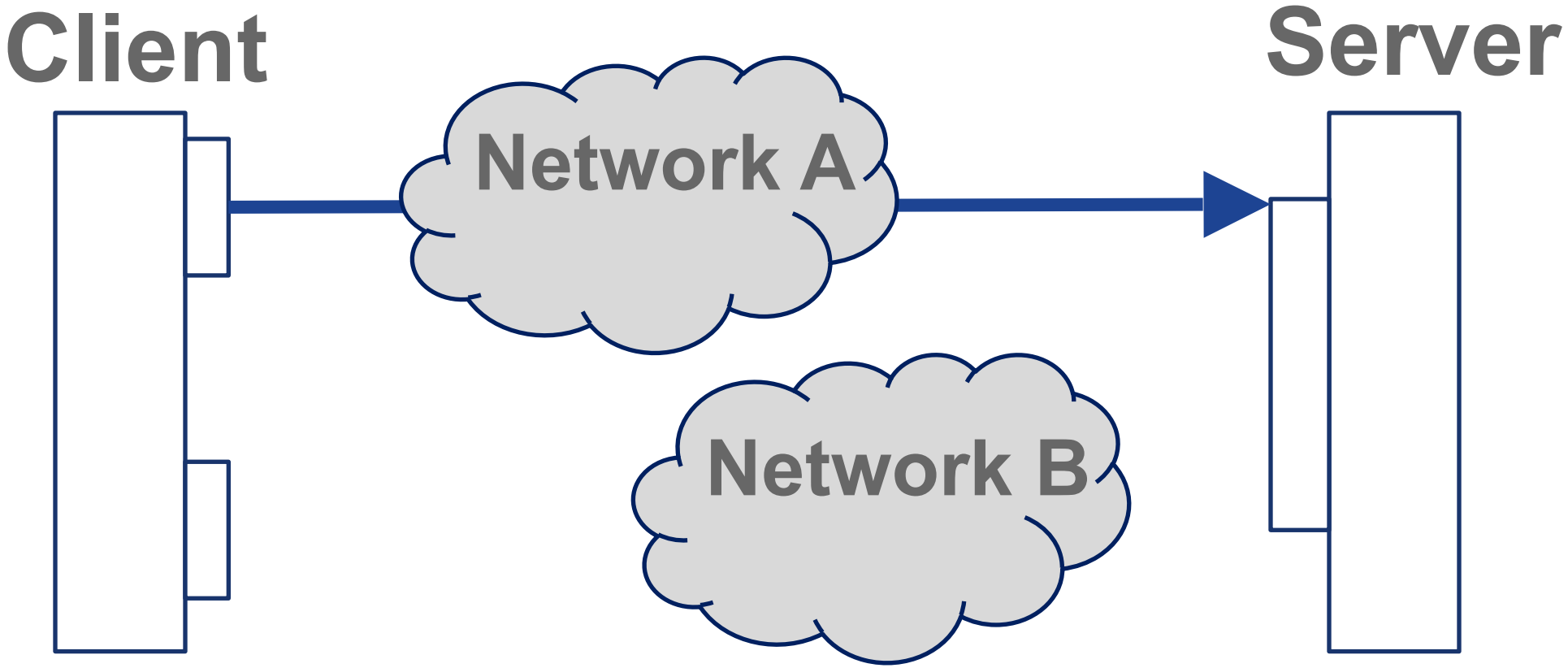

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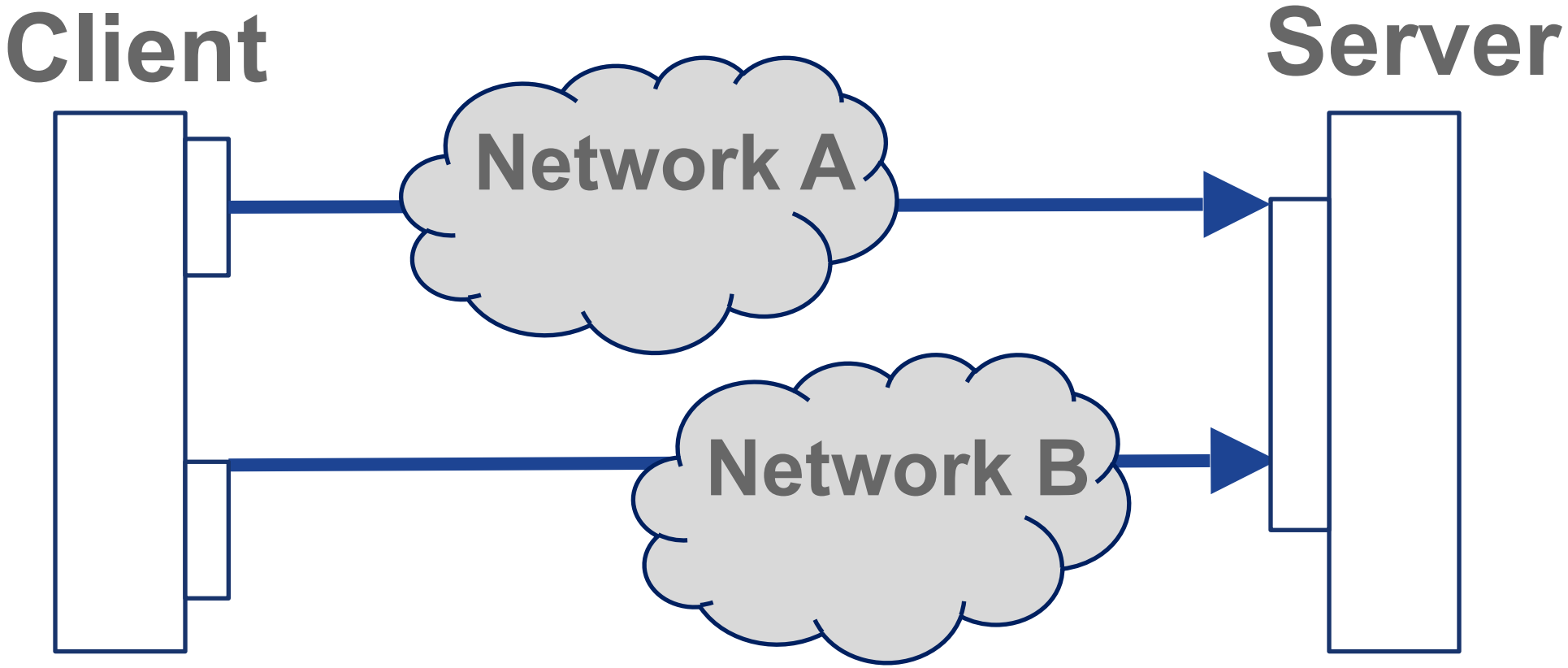

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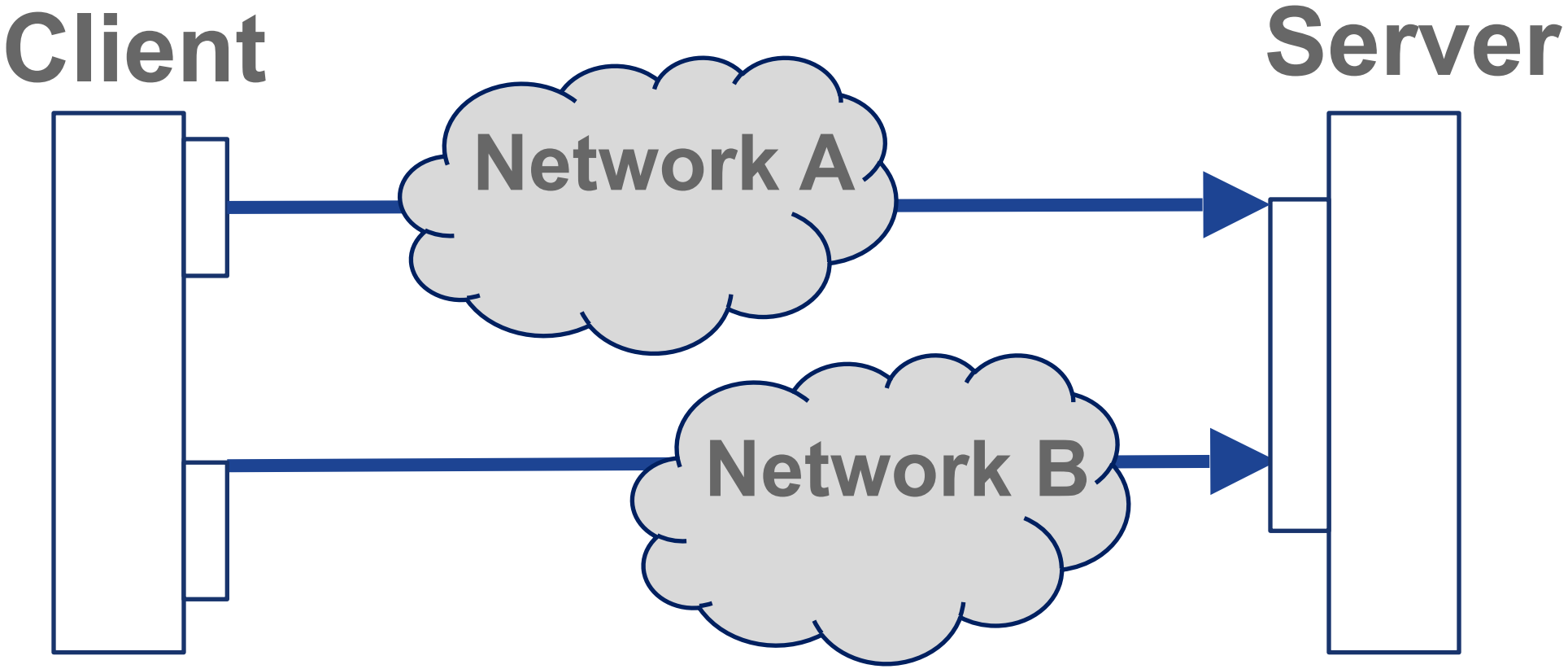


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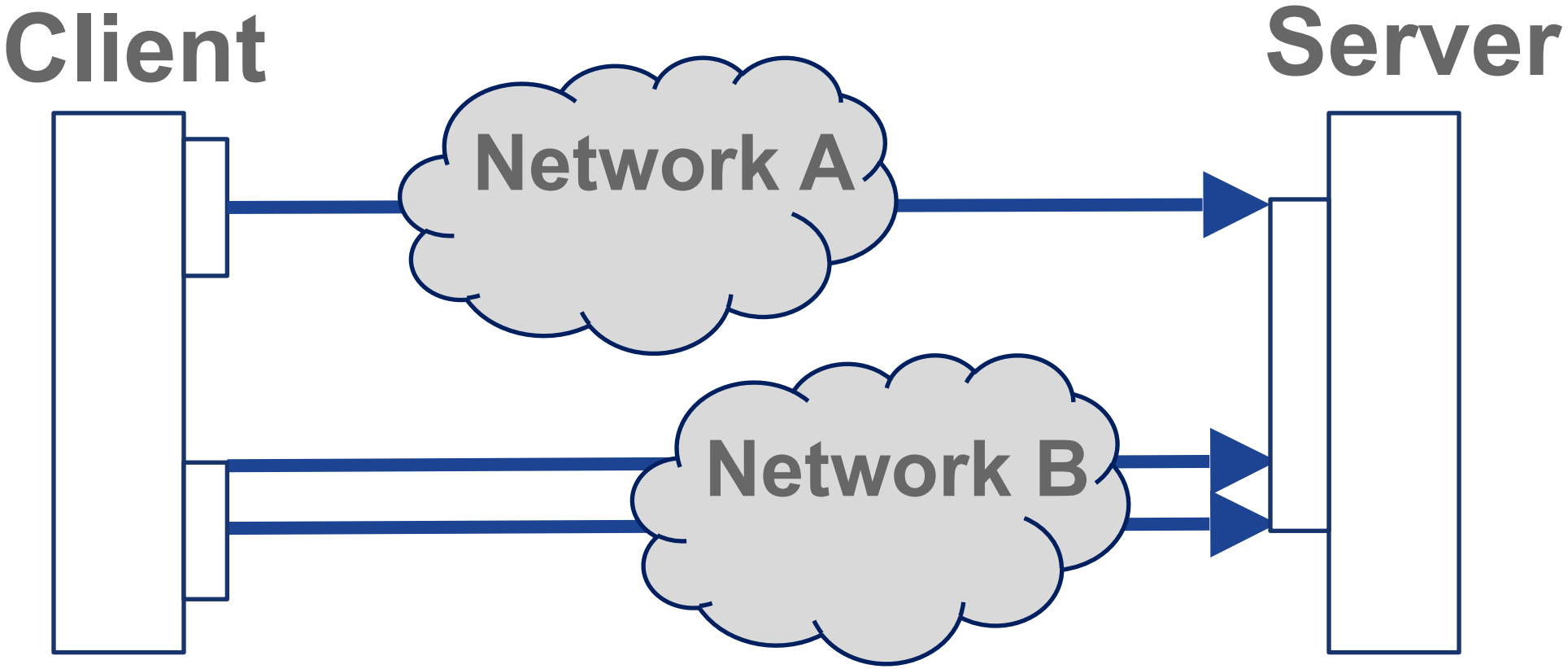


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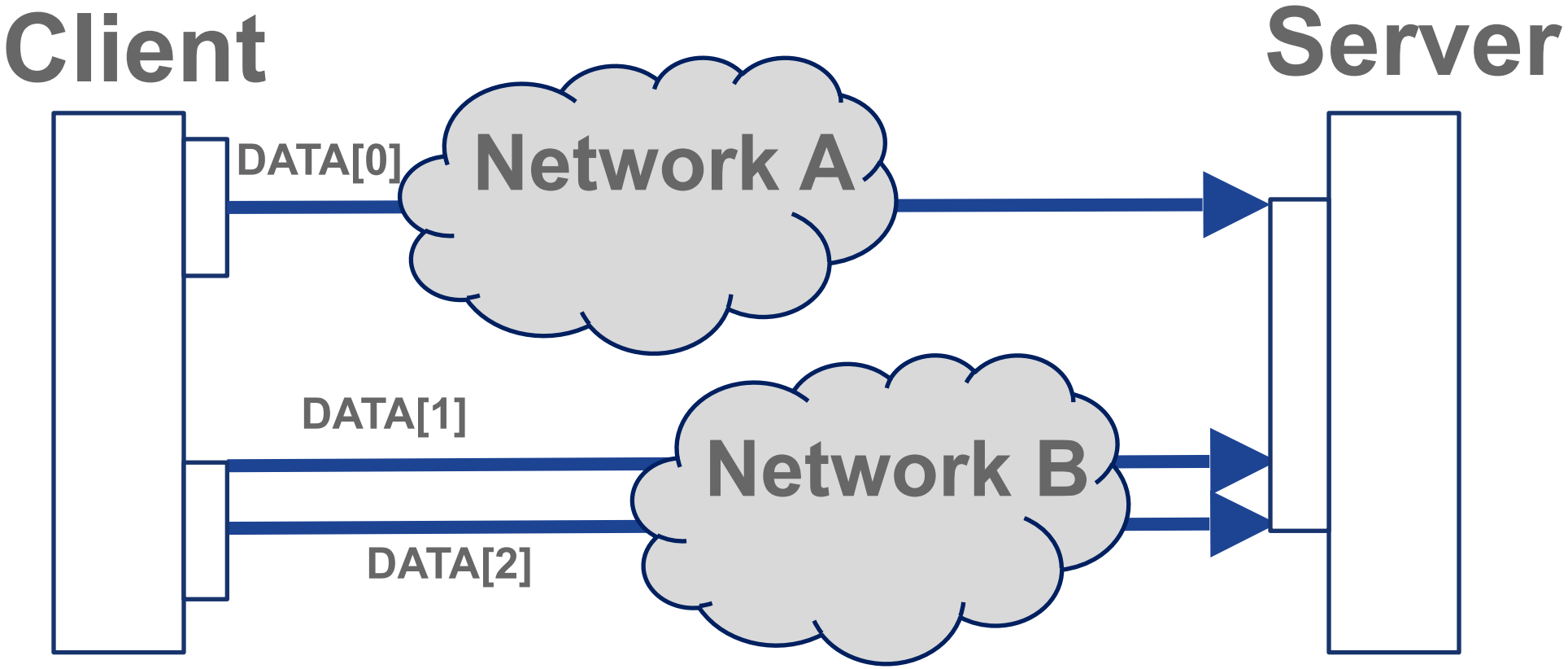
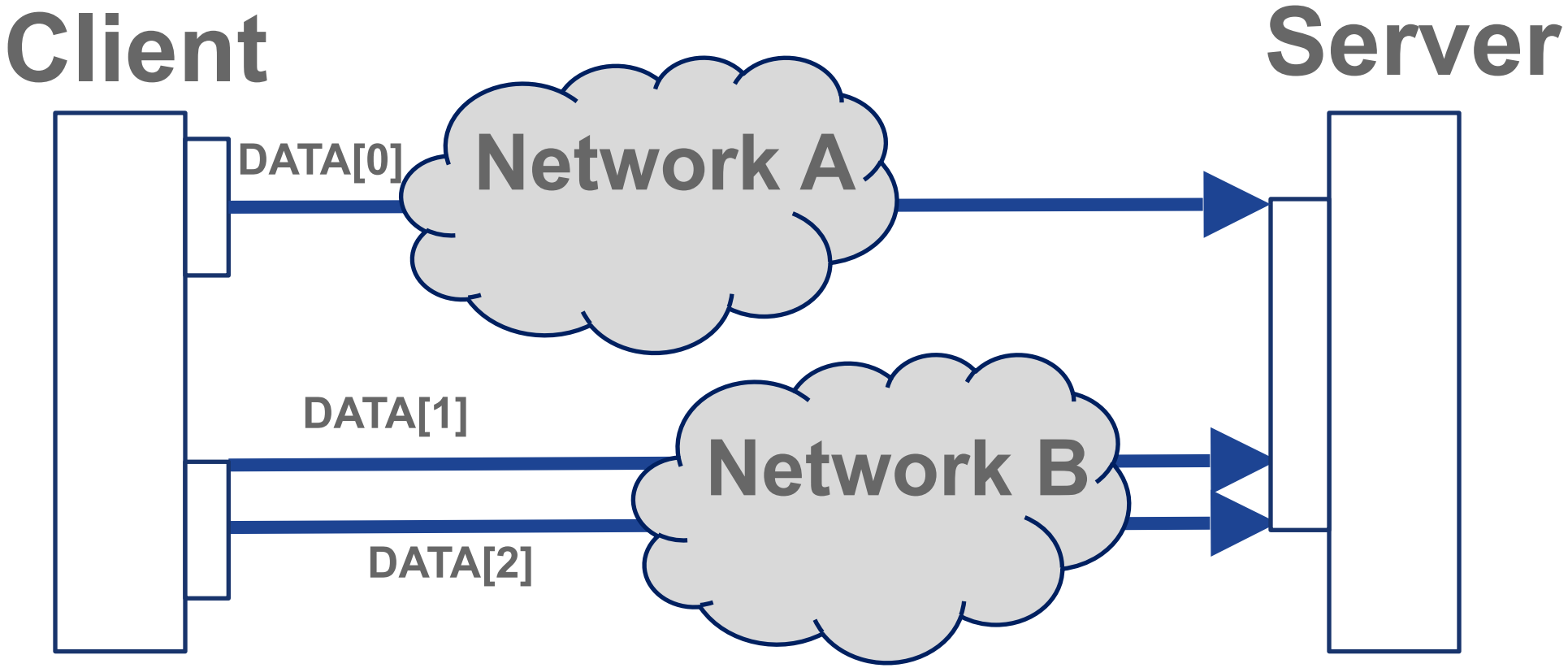


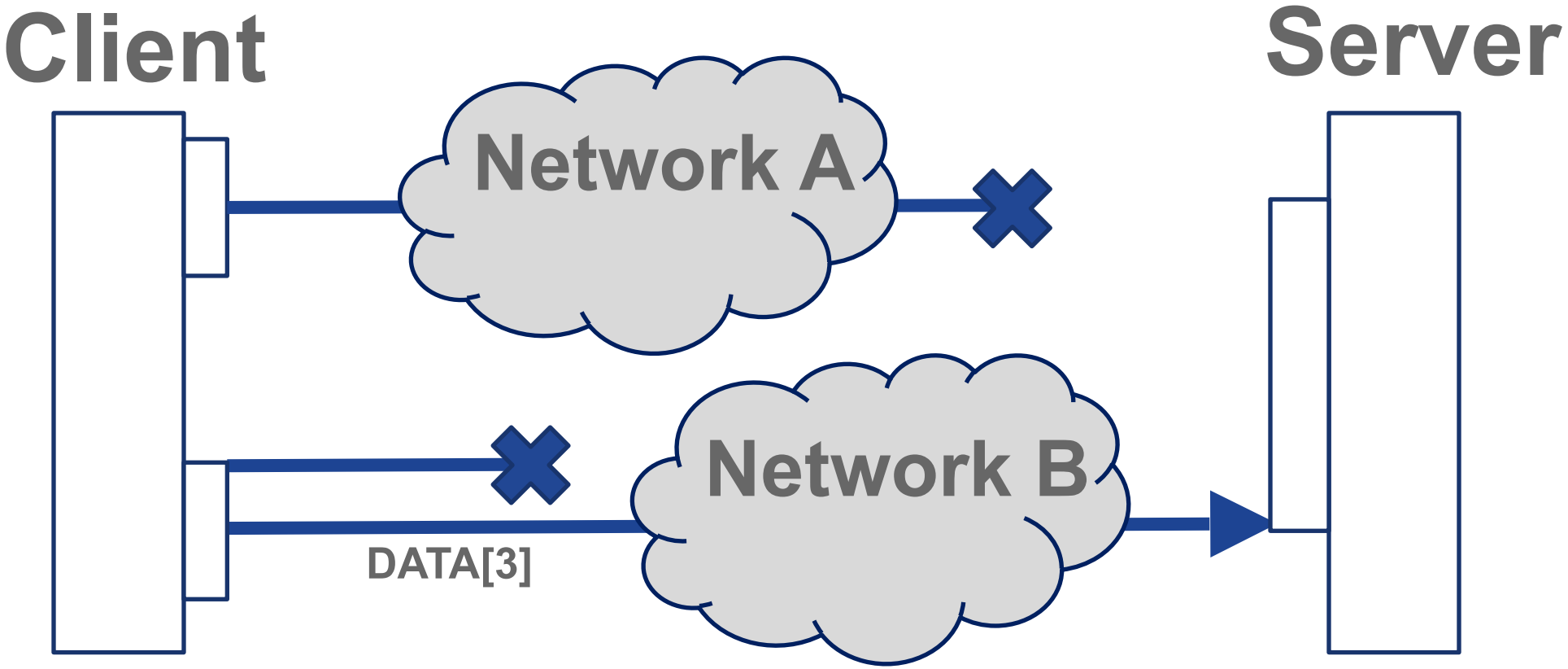

N different TCP connections, contributing to ***ONE*** logical data flow… data flows through any/all

# MPTCP – Simple Case



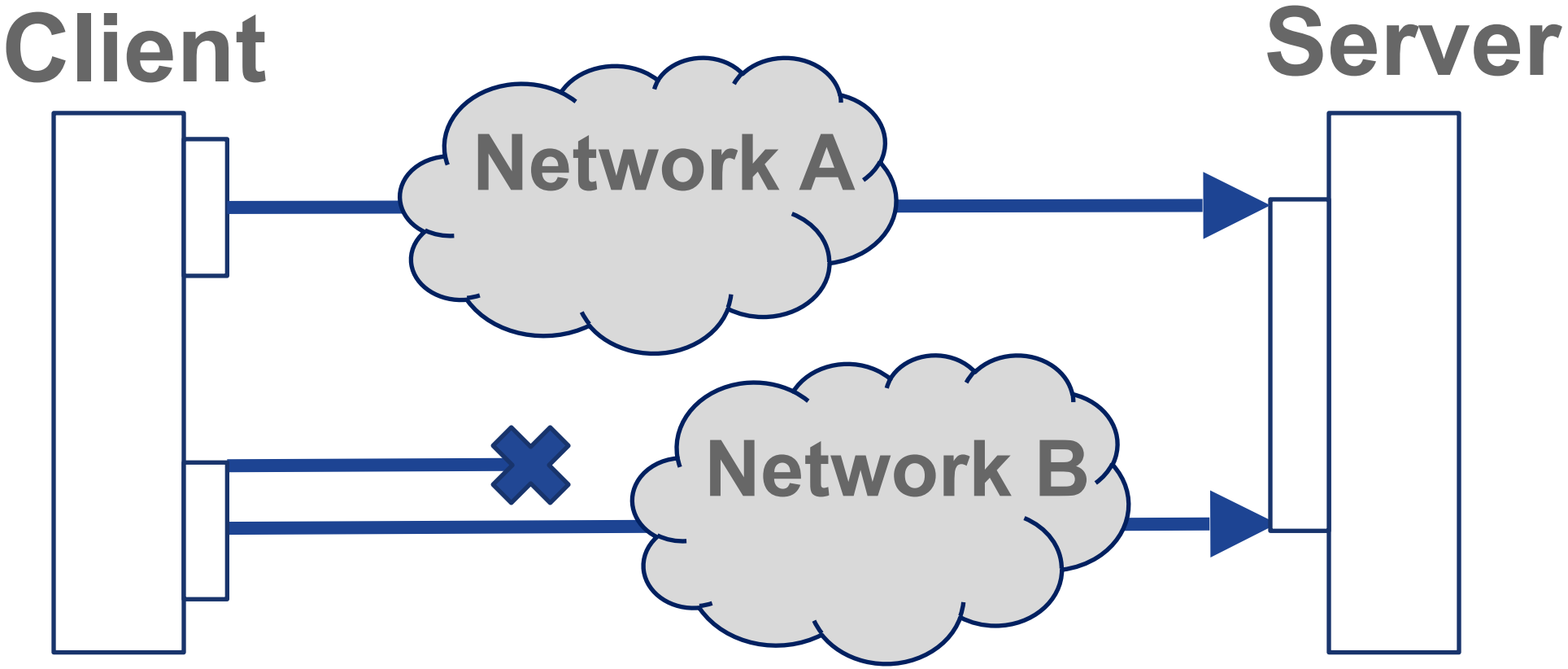

**Sender** of a packet can choose to use any flow *(this will be important)*

# MPTCP – Simple Case



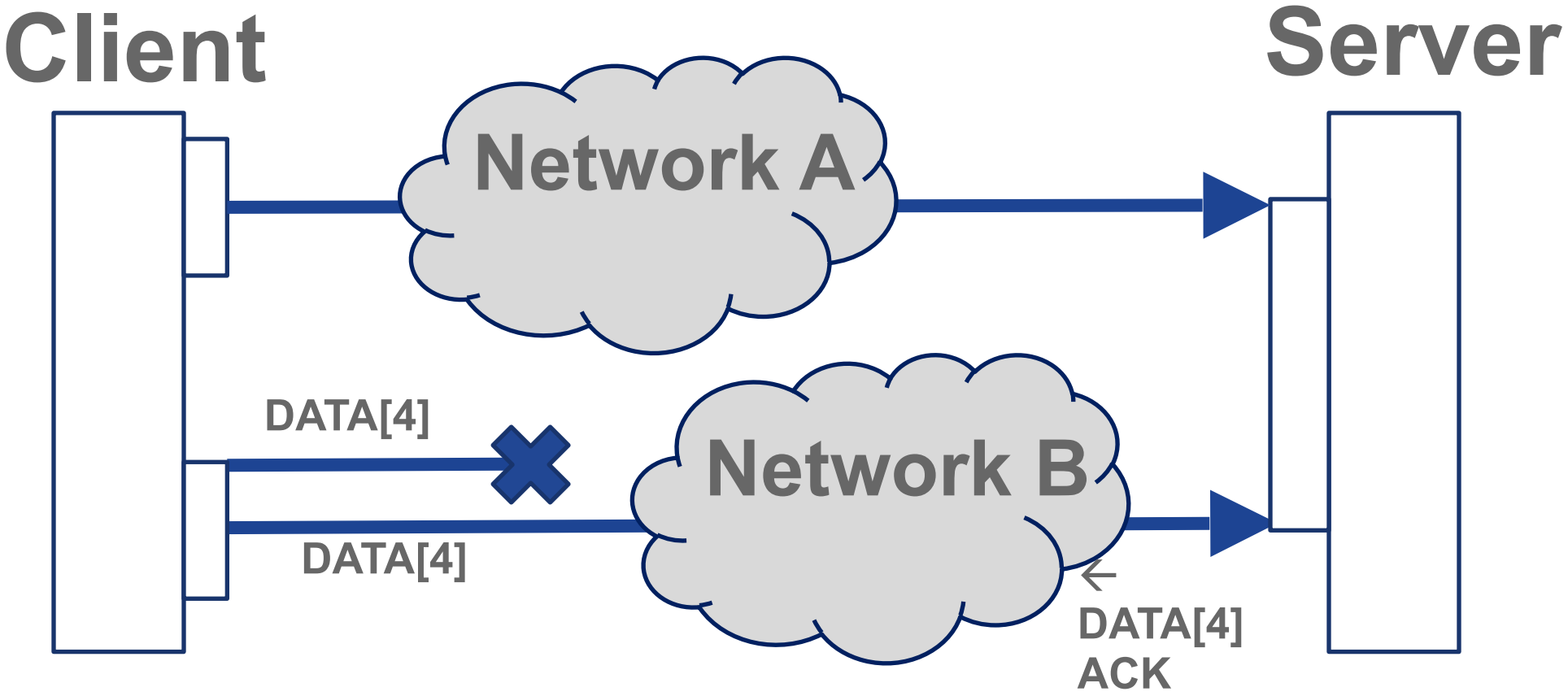

Any subset of connections can drop, overall flow continues.

# MPTCP – Simple Case



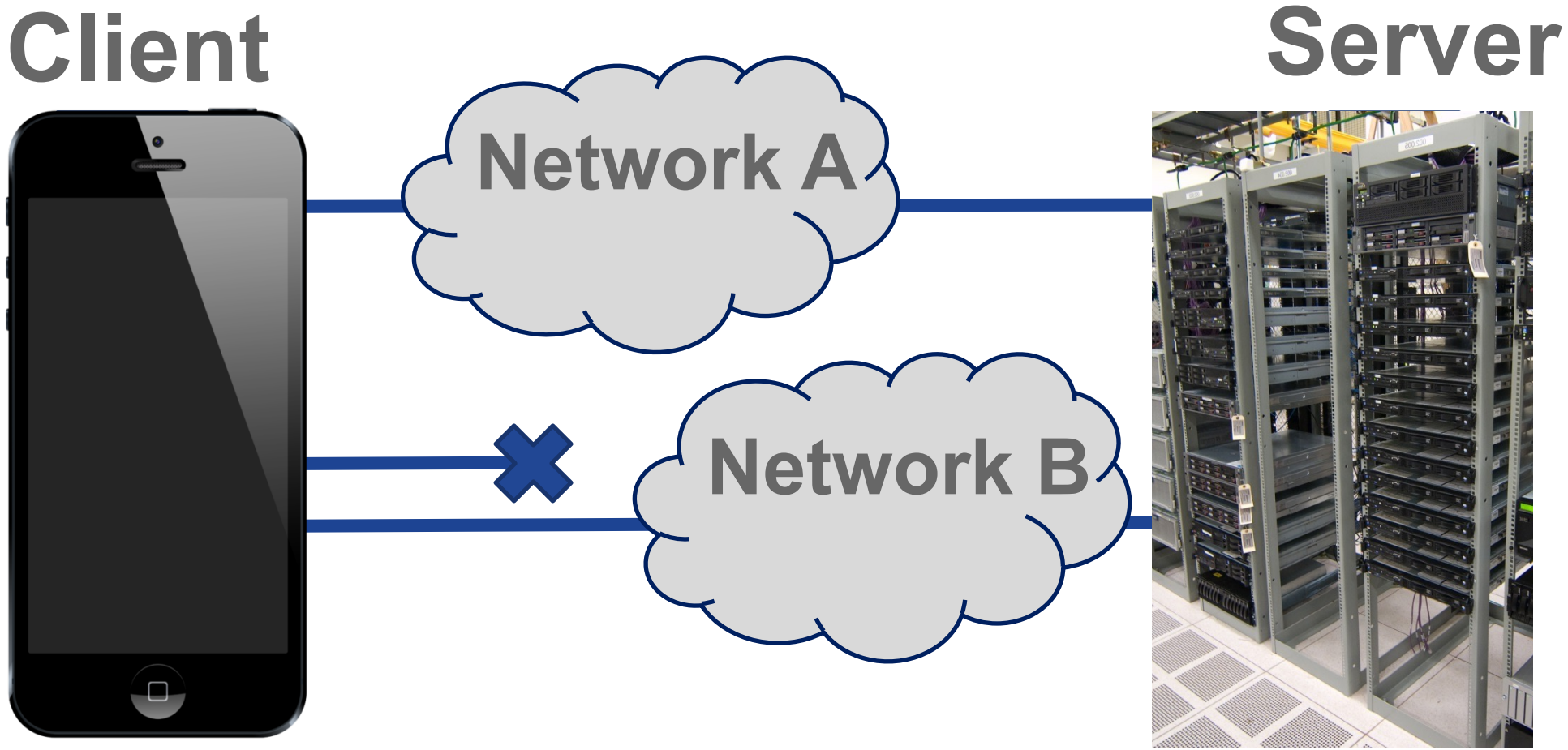

Connections can be re-added at any time

# MPTCP – Simple Case




Un-ACK'd data can be quickly resent over a different flow… first ACK is good enough!

# MPTCP – Basic Use Cases




For seamless roaming

For high availability

# How is MPTCP implemented? – TCP Option

<table>
<tr><td>Bits 0 - 7</td><td>Bits 8 - 15</td><td>Bits 16 - 23</td><td colspan="2">Bits 24 - 31</td></tr>
<tr><td colspan="2">Source Port</td><td colspan="3">Destination port</td></tr>
<tr><td colspan="5">TCP Sequence Number</td></tr>
<tr><td colspan="5">TCP Acknowledgement Number (if Ack Set)</td></tr>
<tr><td>Data Offset</td><td>Reserved</td><td>TCP Flags (Ack, Syn etc)</td><td colspan="2">Window Size</td></tr>
<tr><td colspan="2">Checksum</td><td colspan="3">Urgent Pointer (if URG Set)</td></tr>
<tr><td>0x1e (MPTCP Option Type)</td><td>Length</td><td>Subtype</td><td>MPTCP Ver</td><td>MPTCP Flags</td></tr>
<tr><td colspan="5">Remaining MPTCP Subtype Data</td></tr>
<tr><td colspan="5">Packet DATA</td></tr>
</table>

# What does it look like?

- Packet Breakdown - WireShark

Filter: tcp | Expression... | Clear | Apply | Save

| No. | Time | Source | Destination | Protocol | Length | Info | MPTCP |
|---|---|---|---|---|---|---|---|
| 7 | 26.23 | 192.168.110.10 | 192.168.110.30 | TCP | 86 | 41974 > qip-msgd [SYN] Seq=0 Win=5120 | Multipath Capable |
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```
▷ Checksum: 0x6c1b [validation disabled]
▽ Options: (32 bytes), Maximum segment size, SACK permitted, Timestamps, No-Operation (NOP), Window scale, Multipath TCP
  ▷ Maximum segment size: 256 bytes
  ▷ TCP SACK Permitted Option: True
  ▷ Timestamps: TSval 39509940, TSecr 0
  ▷ No-Operation (NOP)
  ▷ Window scale: 7 (multiply by 128)
  ▽ Multipath TCP: Multipath Capable
      Kind: Multipath TCP (30)
      Length: 12
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      .... 0000 = Multipath TCP version: 0
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        1... .... = Checksum required: 1
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**Option 30 (0x1E)**

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  - Fullmesh – n:n (all to all)
  - Ndiffports – 1-1 interfaces, n-1 ports

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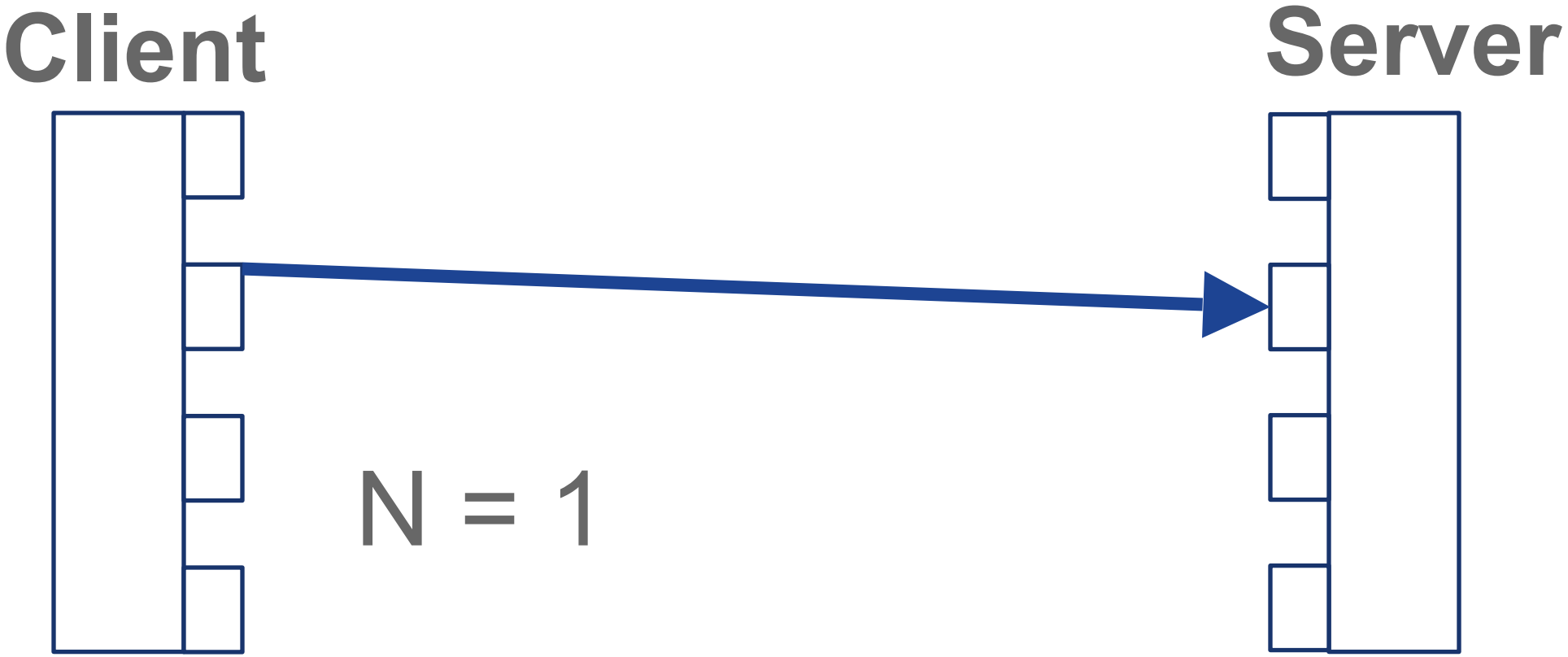
  - Ndiffports – 1-1 interfaces, n-1 ports

- This is in the **TCP stack**… application layers get MPTCP for free (mostly)

# Path Management - ndiffports


N different source ports,
1 destination port

# Path Management - ndiffports

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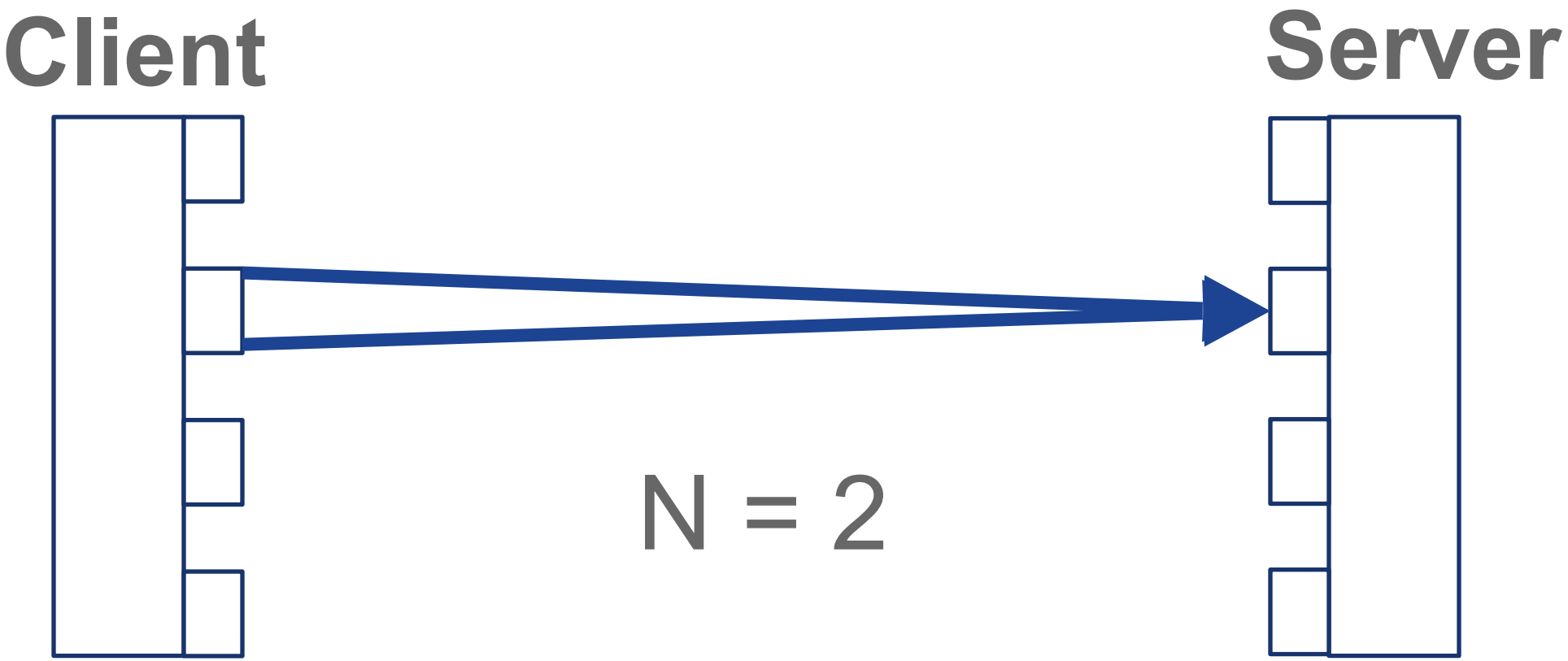


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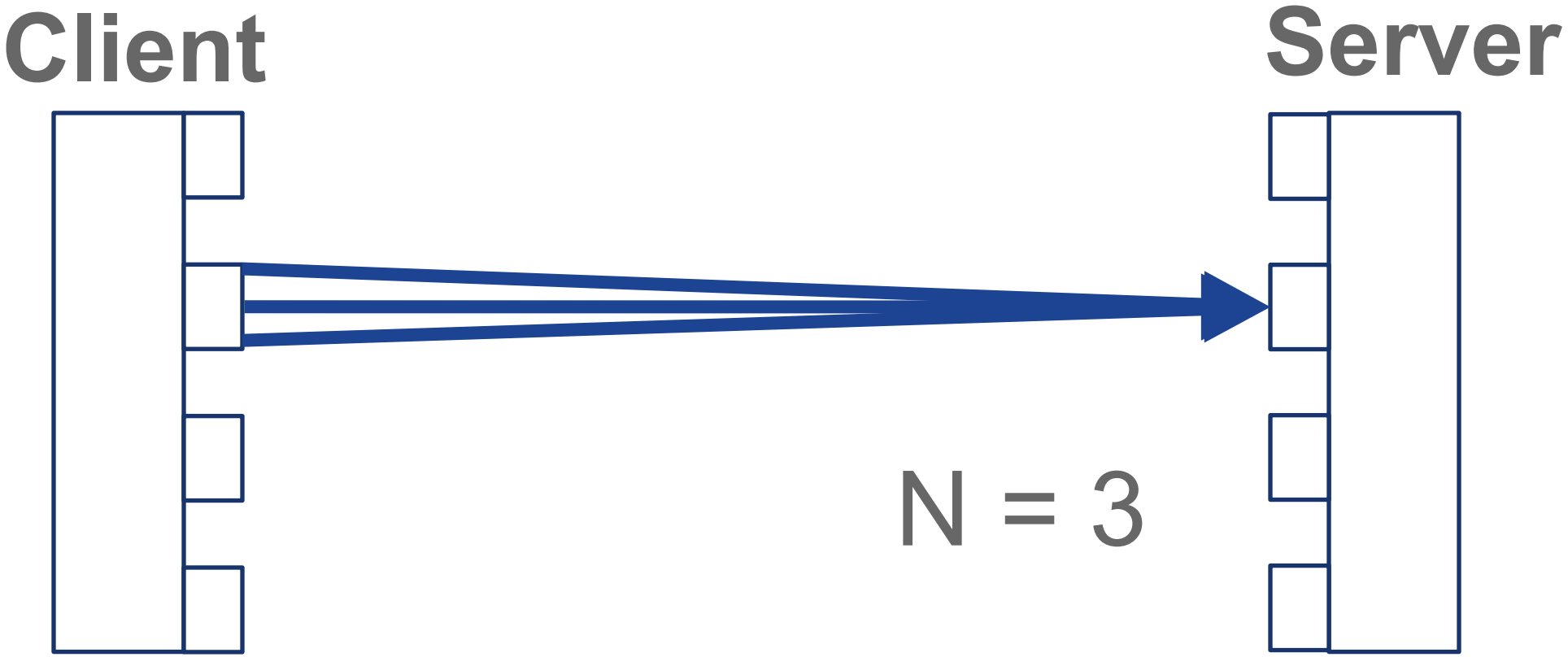


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# Path Management - fullmesh


All possible paths used

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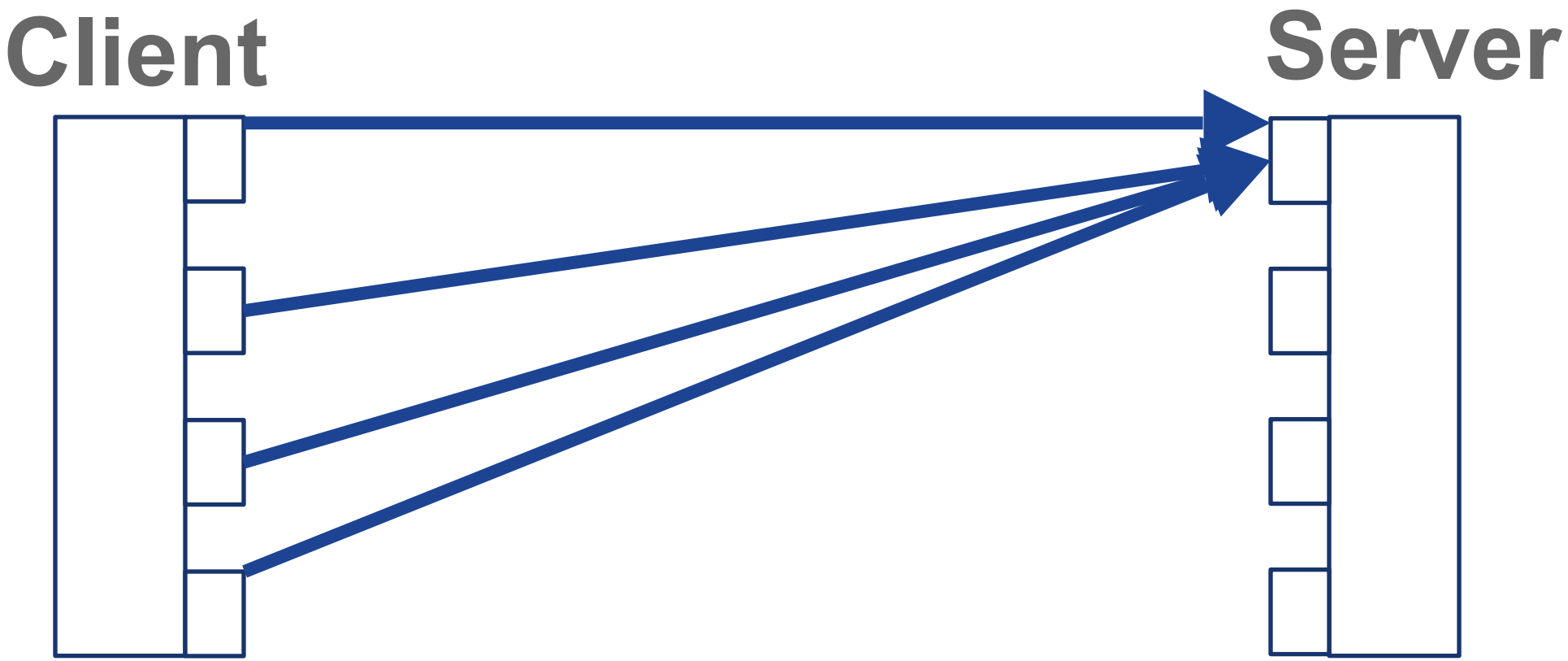


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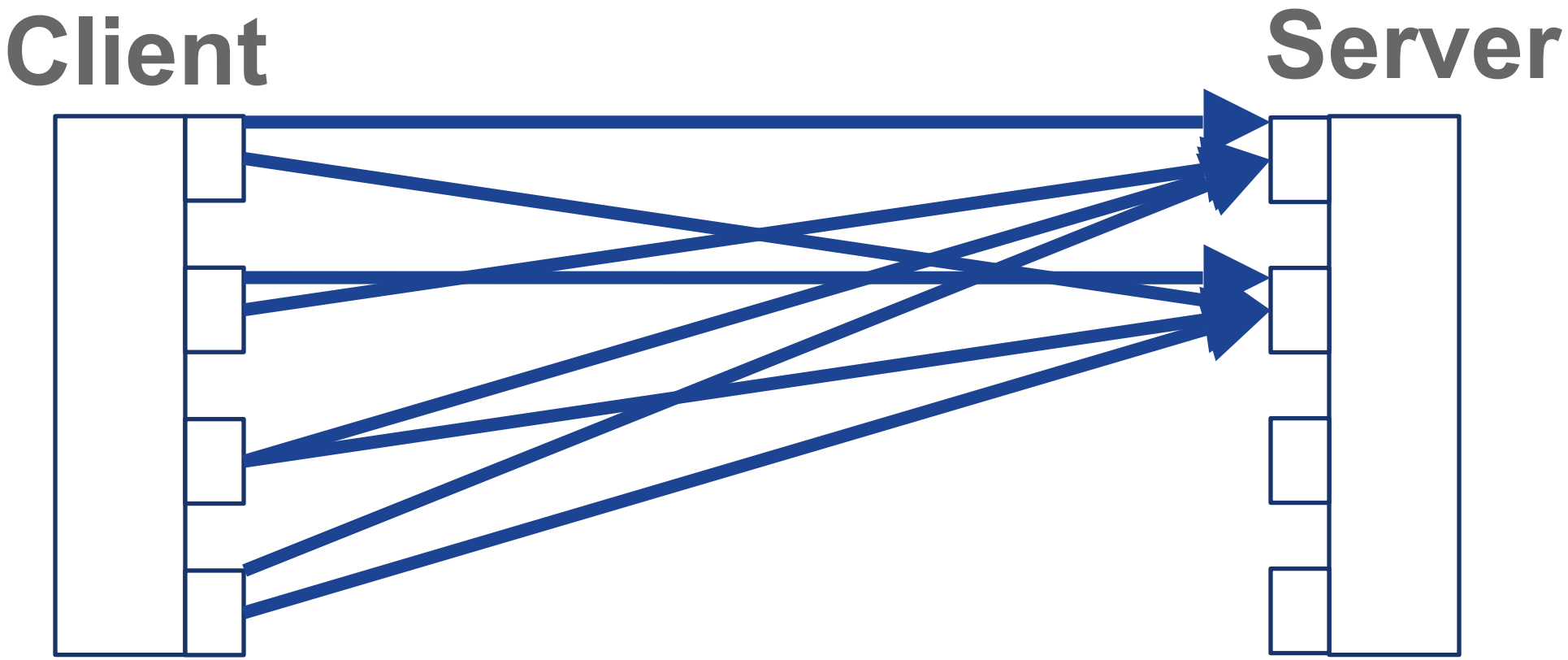


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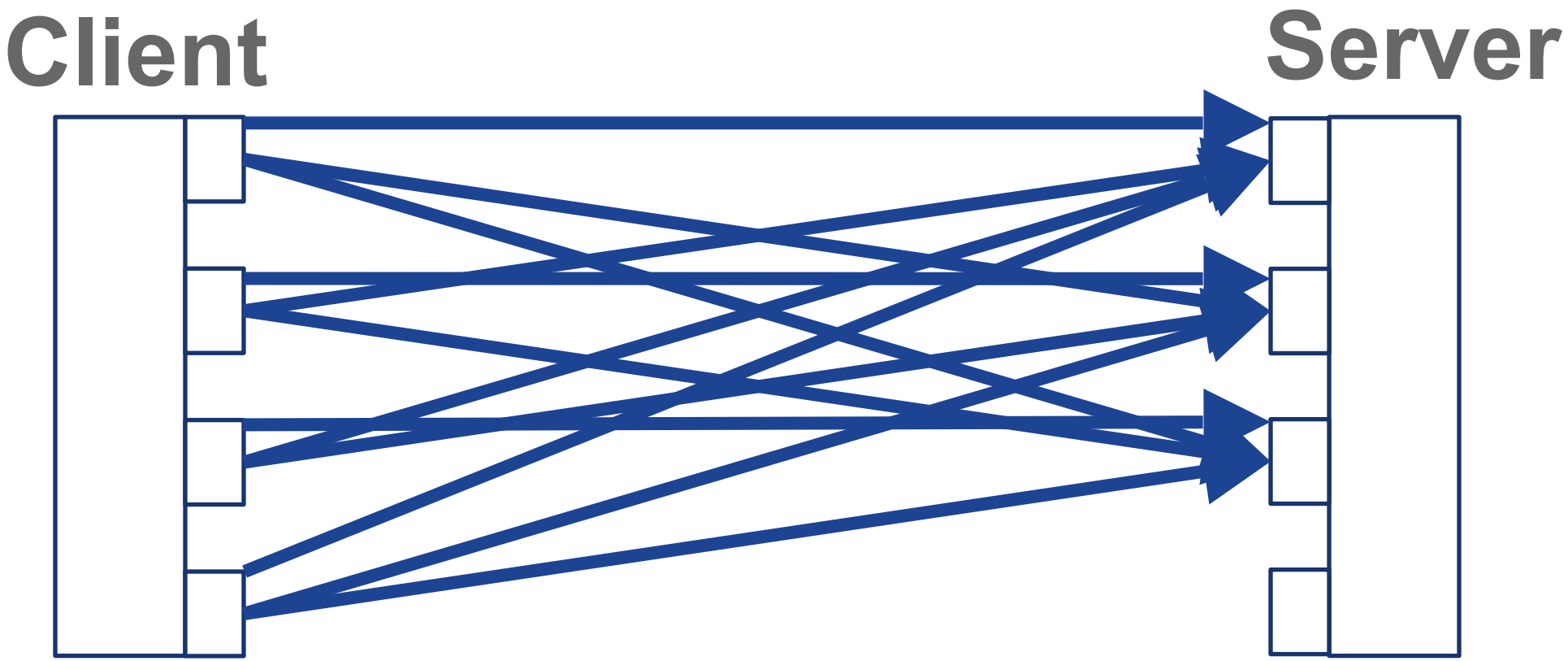


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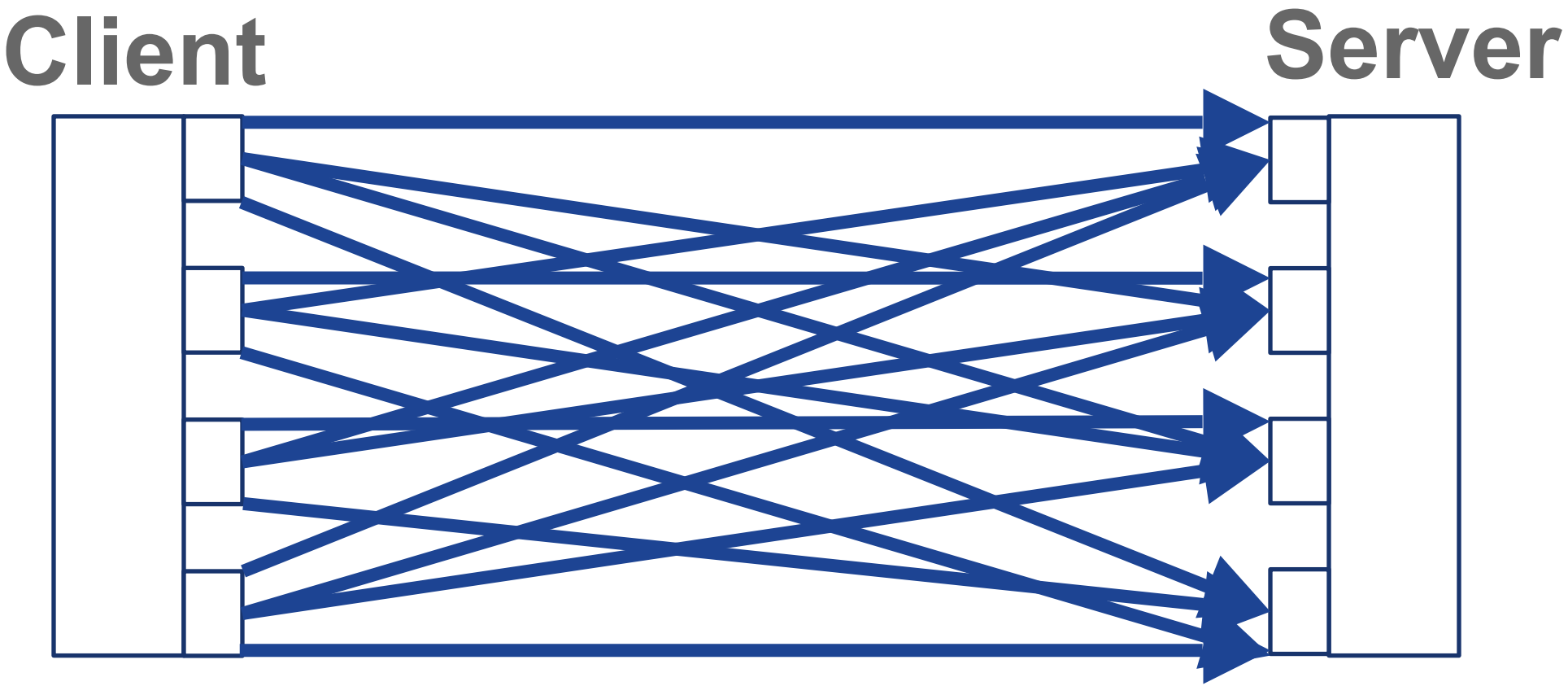


All possible paths used

Introduction ✔
Background (Why Change TCP) ✔
MPTCP ✔

# Background Redux (Why NOT TO change TCP)

QUIC
Implications
Conclusion and Takeaways

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- Chicken and egg deployment

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If you can’t change TCP what’s left?

- SCTP?
  - Same problems, but amplified
- UDP?
  - But it doesn’t do ANYTHING fancy?
  - Exactly.

Introduction ✔
Background (Why Change TCP) ✔
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Background Redux (Why NOT TO change TCP) ✔

# QUIC

Implications
Conclusion and Takeaways

# QUIC
# (Quick UDP Internet Connections)

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- You thought MPTCP developed fast?

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## (Quick UDP Internet Connections)

- You thought MPTCP developed fast?

- QUIC was even QUIC-ker
  - Already in use on many Google properties
  - Youtube, Google search, and more
  - Likely several percent of your traffic

# Current TCP is rather limited

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Makes a lot of round trips

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**UDP transport protocol**

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- *No OS requirements*
- *Fast Evolving*

# QUIC connection – Latency Reduction

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- 0-RTT Connection establishment (1 sometimes)

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- 0-RTT Connection establishment (1 sometimes)
- FEC-based packet-loss recovery
- Flow Control at both connection and stream level
- Certificate and header compression

# QUIC connection – Benefits

- Google claims:
  - 30% reduction in video rebuffers
  - 10% reduction in page load times

https://peering.google.com/#/learn-more/quic

# QUIC connection - Overview

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- UDP Port 80 and 443

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- UDP Port 80 and 443

- Upgrade headers in HTTP:
  - Alternate-Protocol: [port]:quic
  - Alternate-Protocol: 443:quic

# QUIC Infodump 0% [Starting…]

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- Quic isn’t simple.
  - Read the RFC, docs, and source

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- I'm going to RACE through some details to show the complexity of QUIC

# QUIC Infodump 5% [x----------] Packet Types

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- Regular Packets
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# Packet Structure- Overview

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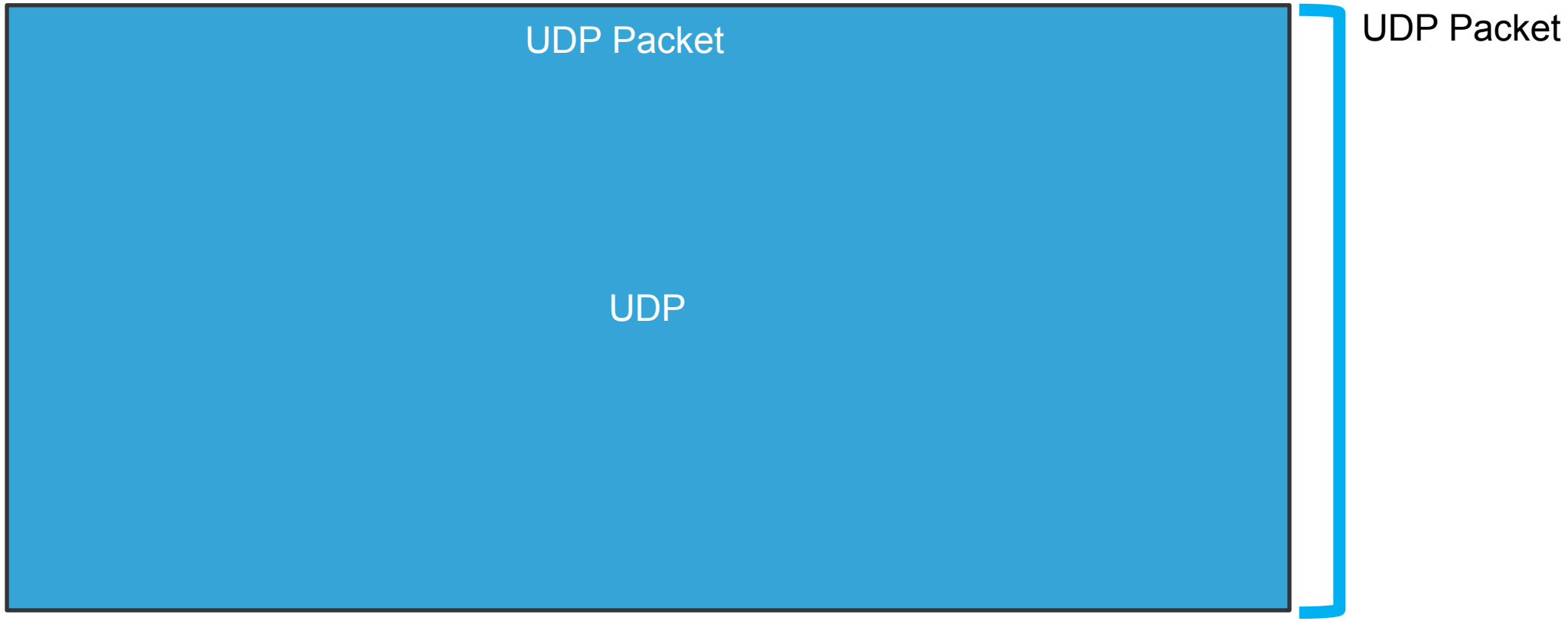

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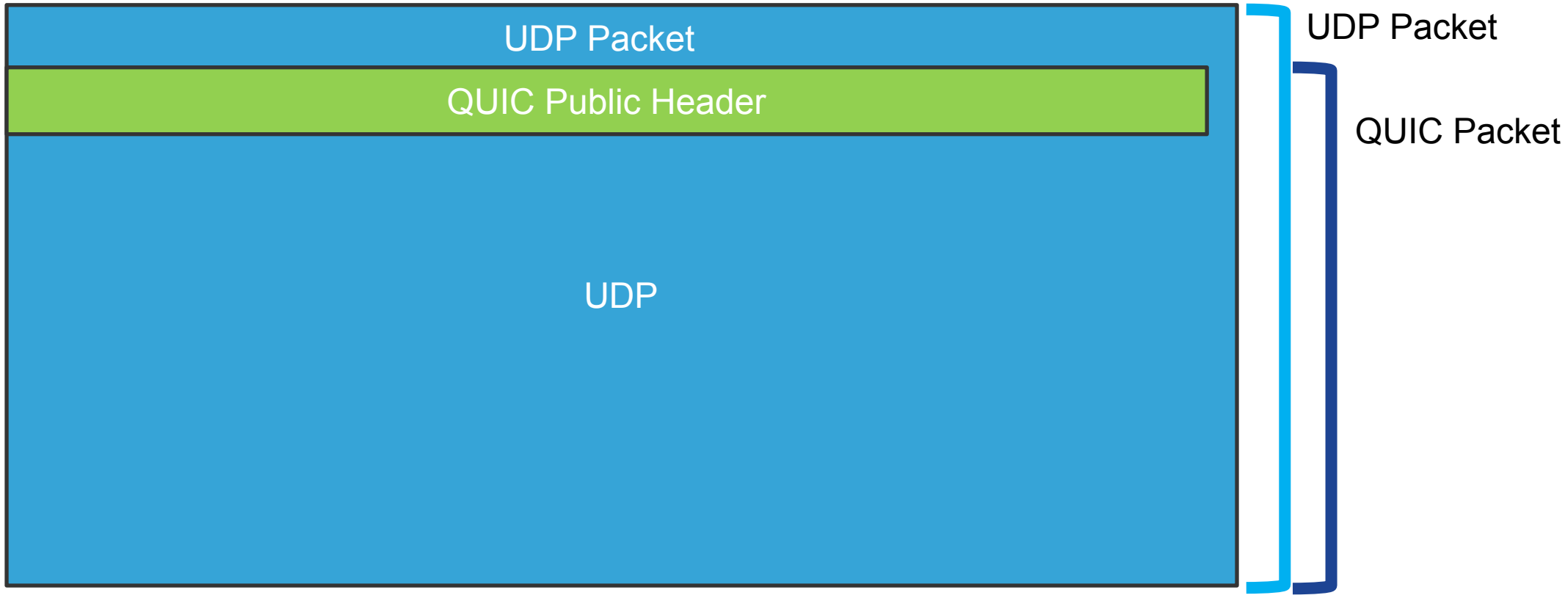

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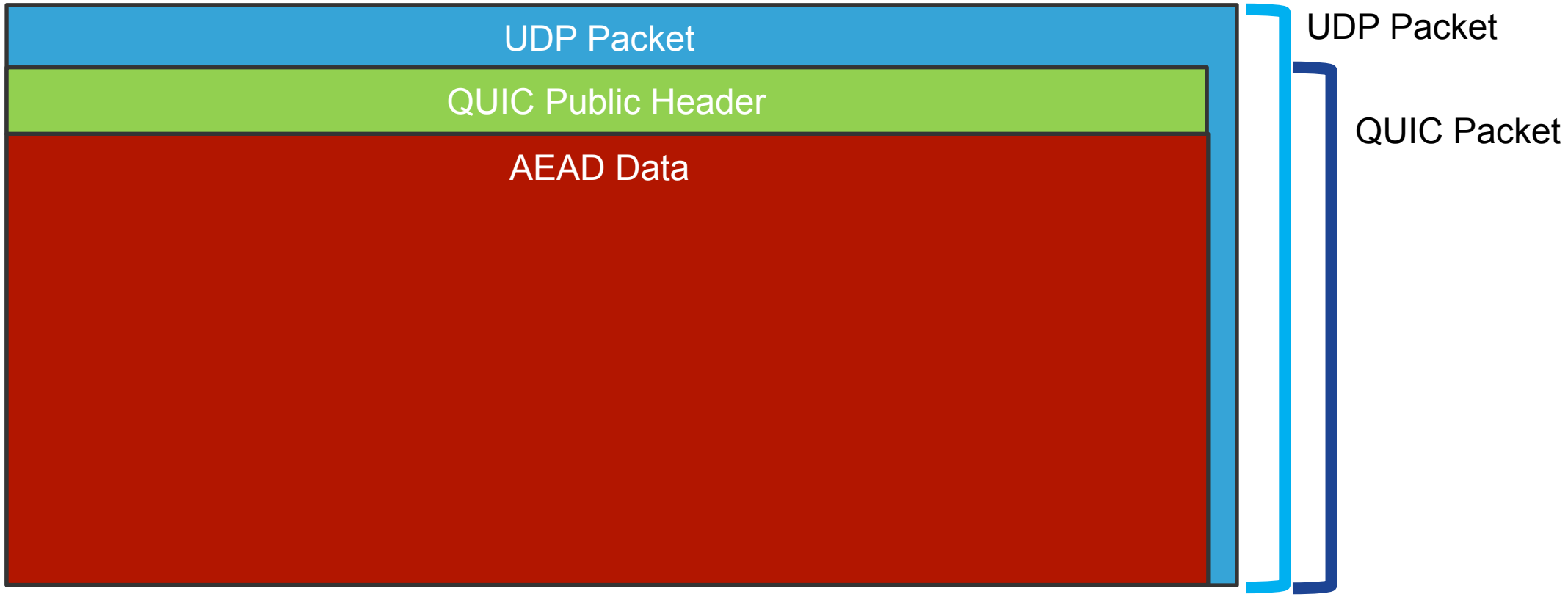

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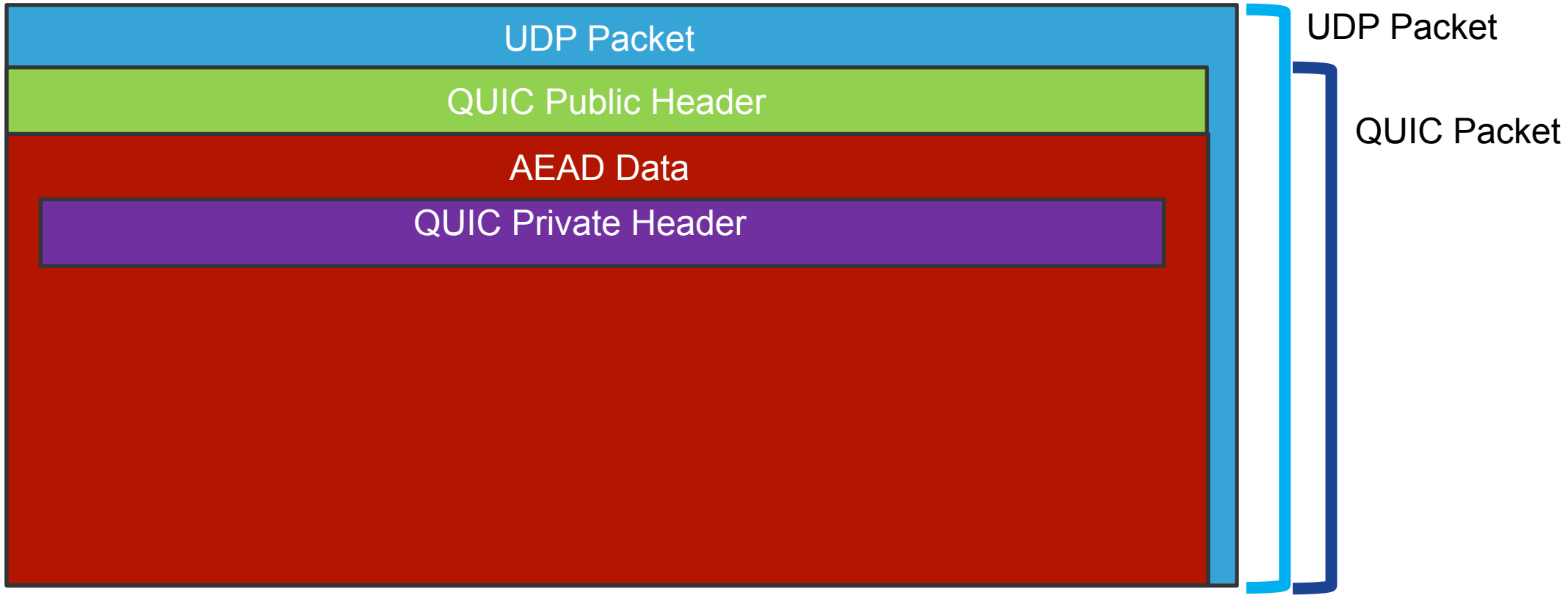

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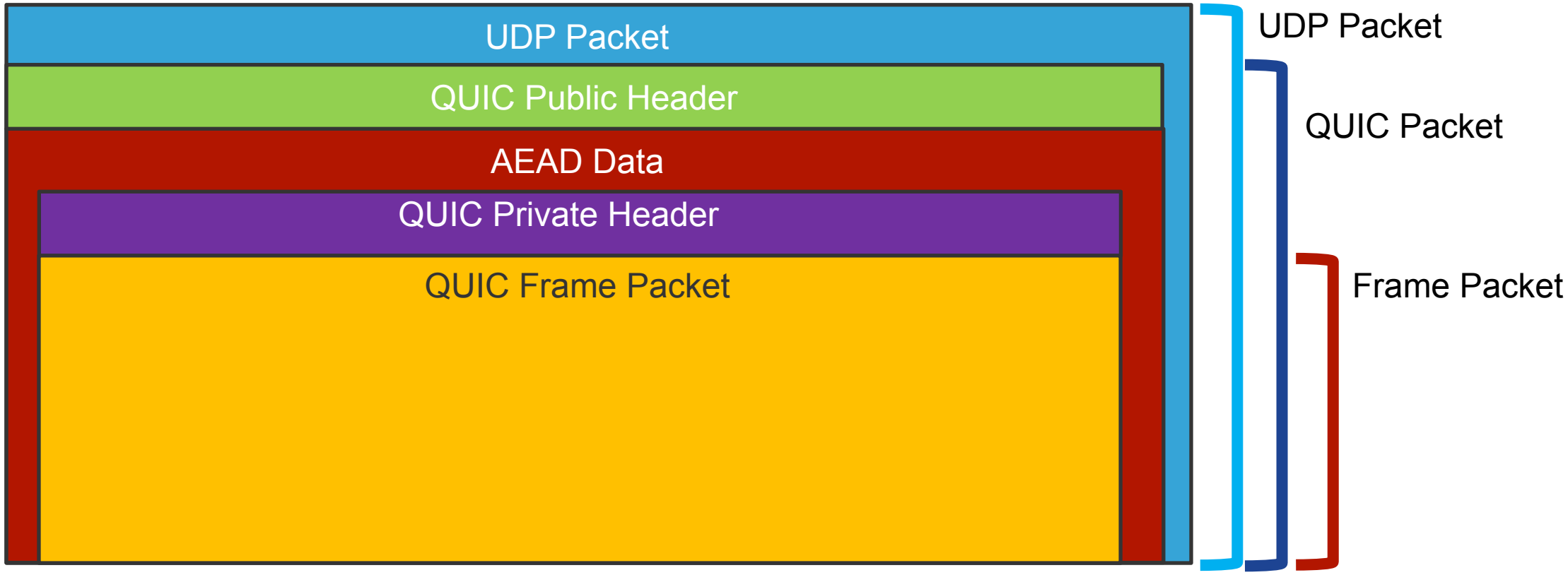

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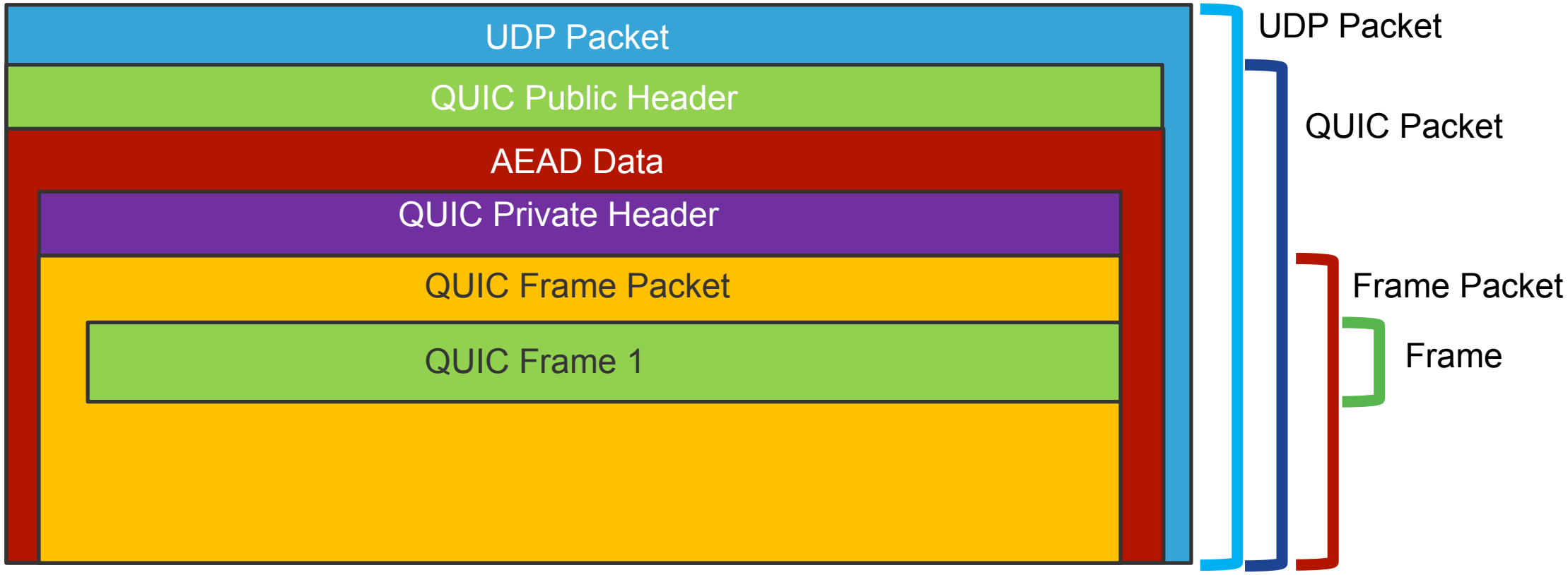

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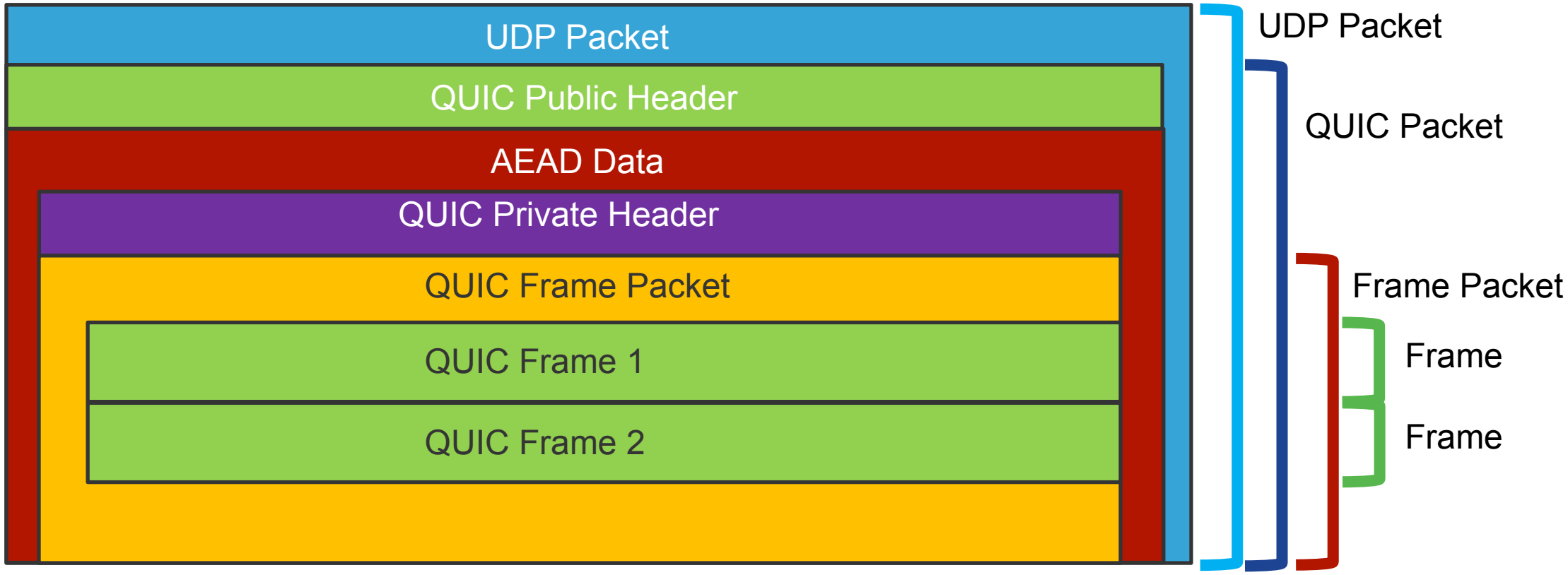

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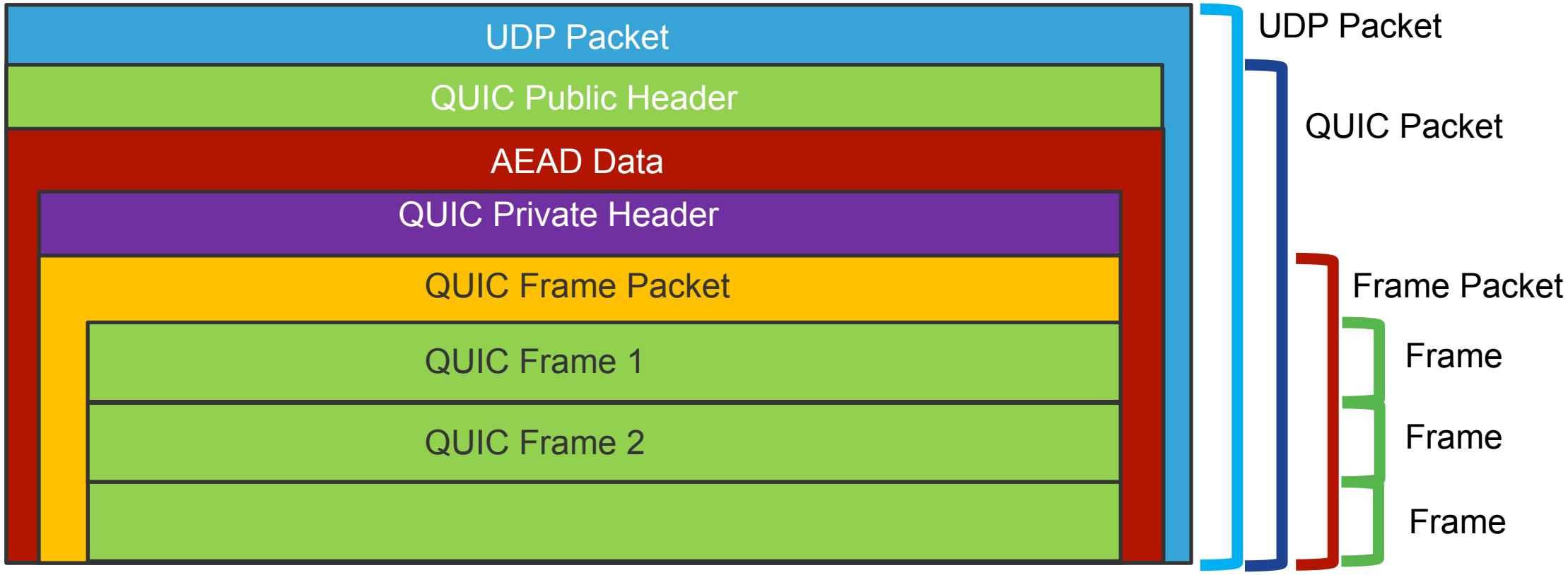

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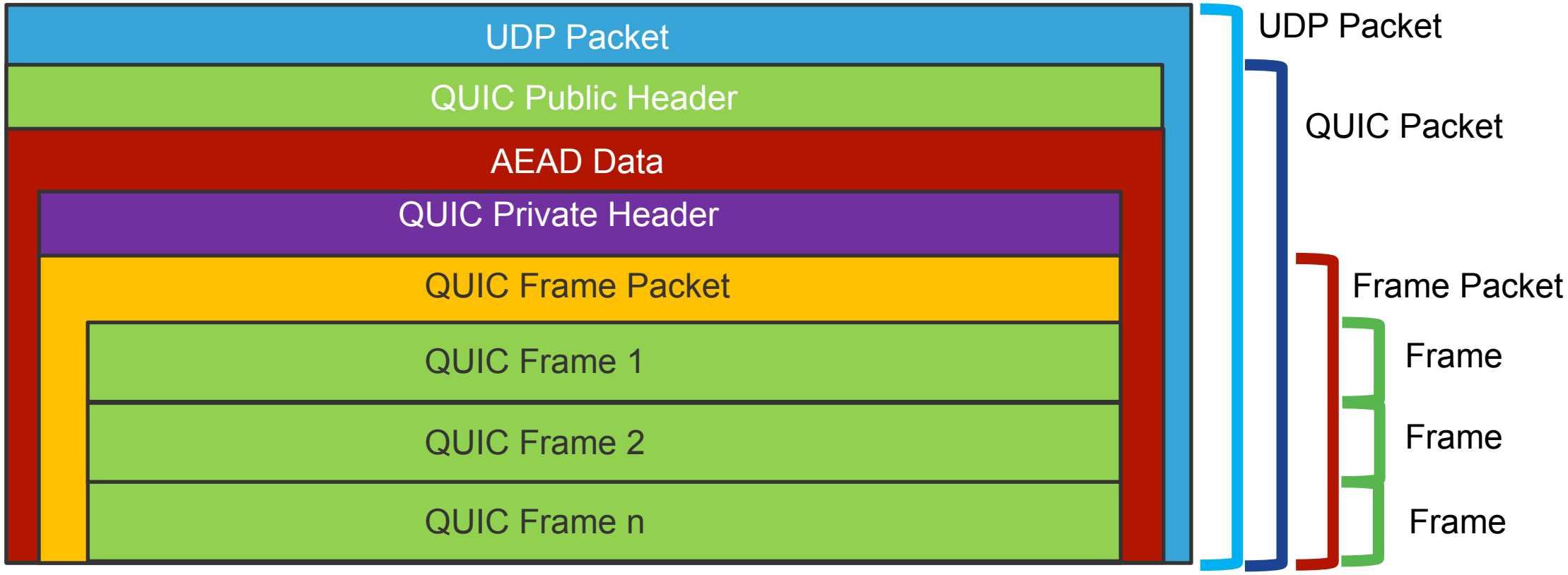

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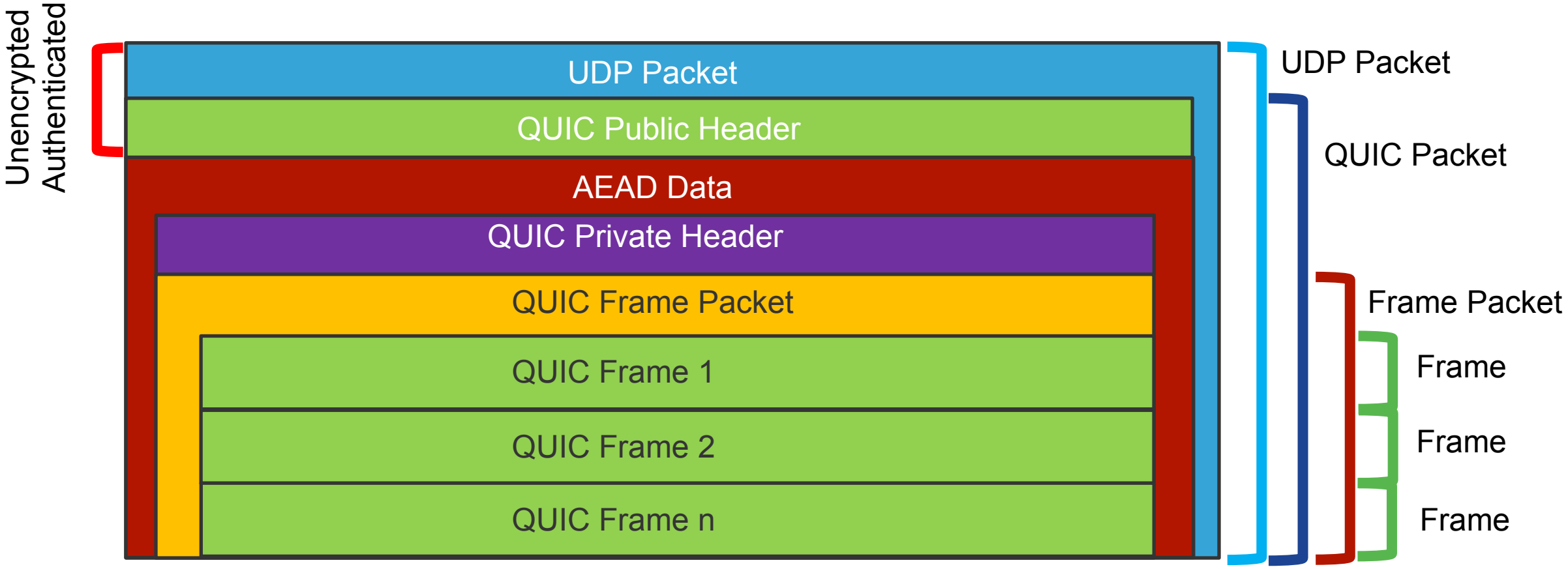

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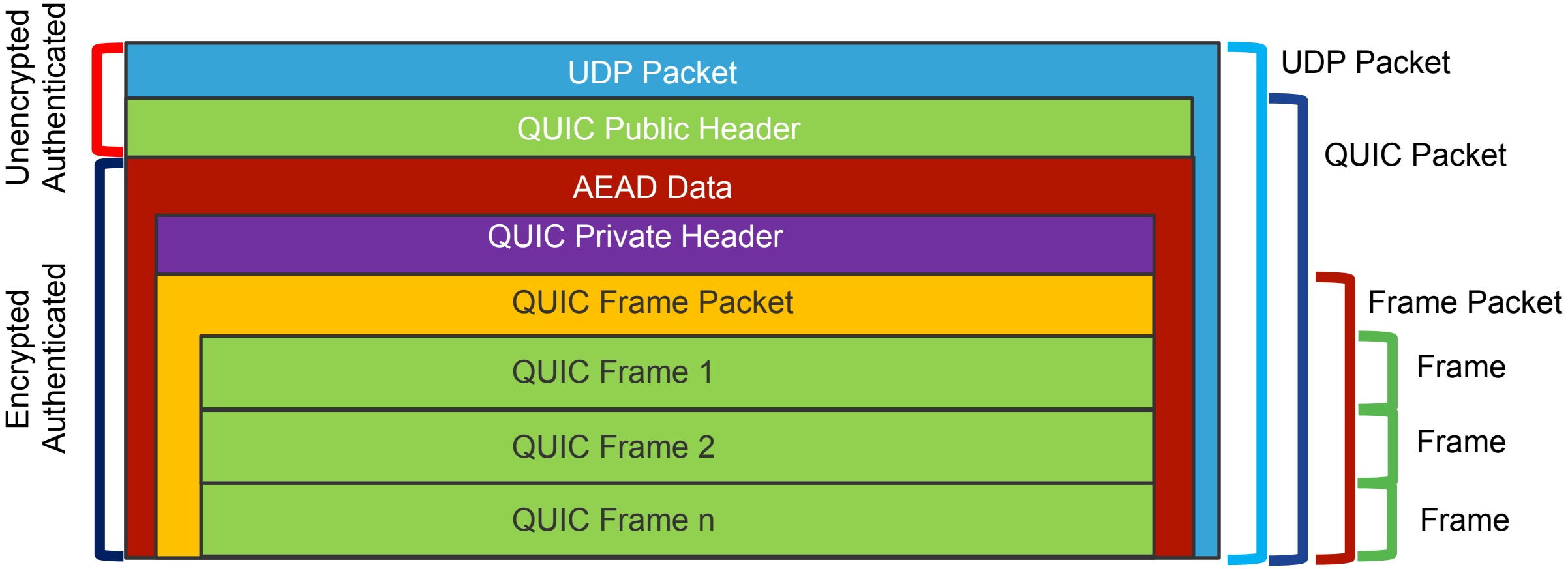

# QUIC Infodump 14% [--x----------]
# Packet Structure- Overview

# QUIC Infodump 14% [--x----------]
# Packet Structure- Overview

- ONE QUIC Connection

# QUIC Infodump 14% [--x----------]
# Packet Structure- Overview

- ONE QUIC Connection
- ONE QUIC Packet

# QUIC Infodump 14% [--x----------]
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- ONE QUIC Connection
- ONE QUIC Packet

*Contains*

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- ONE QUIC Connection
- ONE QUIC Packet

*Contains*

- 0-1 Frame Packets

# QUIC Infodump 14%[--x----------]
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- ONE QUIC Connection

- ONE QUIC Packet

*Contains*

- 0-1 Frame Packets

*Each containing*

# QUIC Infodump 14% [--x----------]
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- ONE QUIC Connection

*Contains*

- N Streams

- ONE QUIC Packet

*Contains*

- 0-1 Frame Packets

*Each containing*

- N frames

# QUIC Infodump 14% [--x----------]
# Packet Structure- Overview

- ONE QUIC Connection

*Contains*

- N Streams

- ONE QUIC Packet

*Contains*

- 0-1 Frame Packets

*Each containing*

- N frames

# QUIC Infodump 17% [---x----------]
# Packet Structure- Overview

# QUIC Infodump 17% [---x----------]
# Packet Structure- Overview

- Two primary parts to a [regular] QUIC packet

# QUIC Infodump 17% [---x----------]
# Packet Structure- Overview

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  - Public Header (Authenticated, NOT Encrypted)

# QUIC Infodump 17% [---x----------]
# Packet Structure- Overview

- Two primary parts to a [regular] QUIC packet
  - Public Header (Authenticated, NOT Encrypted)
  - Private (Authenticated, Encrypted)

# QUIC Infodump 17% [---x----------]
# Packet Structure- Overview

- Two primary parts to a [regular] QUIC packet
  - Public Header (Authenticated, NOT Encrypted)
  - Private (Authenticated, Encrypted)

- AEAD (authenticated encryption and associated data) data directly after Public header, used to interpret Private data

# QUIC Infodump 25%[-----x----------] Headers

# QUIC Infodump 25% [-----x----------] Headers

- Public Header (Authenticated, NOT Encrypted)
  - Flags
  - Connection ID (Variable length, optional)
  - Packet Number (Variable length)
  - Version Header (If flag set)

# QUIC Infodump 25% [-----x----------] Headers

- Public Header (Authenticated, NOT Encrypted)
  - Flags
  - Connection ID (Variable length, optional)
  - Packet Number (Variable length)
  - Version Header (If flag set)

- Private (Authenticated, Encrypted)
  - Flags
  - FEC (Optional)
  - Frame or FEC Payload

# QUIC Infodump 40%[--------x----------] Frames

# QUIC Infodump 40% [--------x----------] Frames

- Frame Packet (contains frames)
  - Type
    - Special
    - Regular
  - N Frames

# QUIC Infodump 40% [--------x----------] Frames

- Frame Packet (contains frames)
  - Type
    - Special
    - Regular
  - N Frames
- FEC Packet
  - NULL-padded XOR of the data packets in the payload group
  - Payload group details in the Private header

# QUIC Infodump 47%[----------x---------] Frame Types

# QUIC Infodump 47%[----------x---------] Frame Types

- Control Frames
  - Padding
  - RST Stream
  - Connection Close
  - Goaway
  - Window Update
  - Blocked
  - Stop_waiting
  - Ping

# QUIC Infodump 47%[----------x---------] Frame Types

- Control Frames
  - Padding
  - RST Stream
  - Connection Close
  - Goaway
  - Window Update
  - Blocked
  - Stop_waiting
  - Ping

- Special Frames
  - Stream
  - Ack
  - Congestion feedback

- Most relevant:
  - Stream frame
  - ACK Frame

# QUIC Infodump 52% [----------x--------] Stream Frame

# QUIC Infodump 52% [----------x--------] Stream Frame

- Contained inside a frame packet

# QUIC Infodump 52% [----------x--------] Stream Frame

- Contained inside a frame packet
- Fields
  - Type (Frame header: flags about lengths of other items below)
  - Stream ID
  - Offset
  - Length (0+, optional, omission means full packet)

# QUIC Infodump 57%[----------x-------]
# ACK Frame

# QUIC Infodump 57%[----------x-------] ACK Frame

- Contained inside a frame packet

# QUIC Infodump 57%[----------x-------]
# ACK Frame

- Contained inside a frame packet
- Fields
  - Type (Frame header: flags about forms of other items below)
  - Largest Observed packet #
  - ACK Delay time
  - Timestamp Section (Used as congestion indicator)
  - Missing Packet Section (~NACK)
  - Revived Packet Section (Which did FEC revive)

# QUIC Infodump 65% [----------x------] Addressing

# QUIC Infodump 65% [----------x------] Addressing

- Connection ID
  - 64 bit, client chosen
  - Independent of Network Address
  - Source Address token (from previous connection)

# QUIC Infodump 65% [----------x------] Addressing

- Connection ID
  - 64 bit, client chosen
  - Independent of Network Address
  - Source Address token (from previous connection)
- Stream ID
  - Data flow WITHIN a connection

# QUIC Infodump 77% [----------x----]
# Cryptographic

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- Replaces, and Comparable to, TLS
  - Client reuses encryption parameters from previous connection

# QUIC Infodump 77% [----------x----] Cryptographic

- Replaces, and Comparable to, TLS
  - Client reuses encryption parameters from previous connection

- IP Spoofing protection
  - Requires an IP-validated Source Address Token, or negotiates a new one (0/1 RTT)
  - No trivial reflection attacks as in NTP/DNS

# QUIC Infodump 84%[----------x---]
# Forward Error Correction

# QUIC Infodump 84%[----------x---]
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- XOR of all packets in FEC block

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- XOR of all packets in FEC block
- FEC block size is variable

# QUIC Infodump 84%[----------x---]
# Forward Error Correction

- XOR of all packets in FEC block
- FEC block size is variable
- If “revived by FEC” then indicate this ID as NACK and REVIVED

# QUIC Infodump 93%[----------x]
# Connection Management

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- All connections assumed to be left in open state until user leaves page

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# QUIC Infodump 93%[----------x]
# Connection Management

- All connections assumed to be left in open state until user leaves page
- Address mobility supported
- Multipath planned, but not yet there

# QUIC Infodump 99% [----------x]
# HTTP/2 Integration

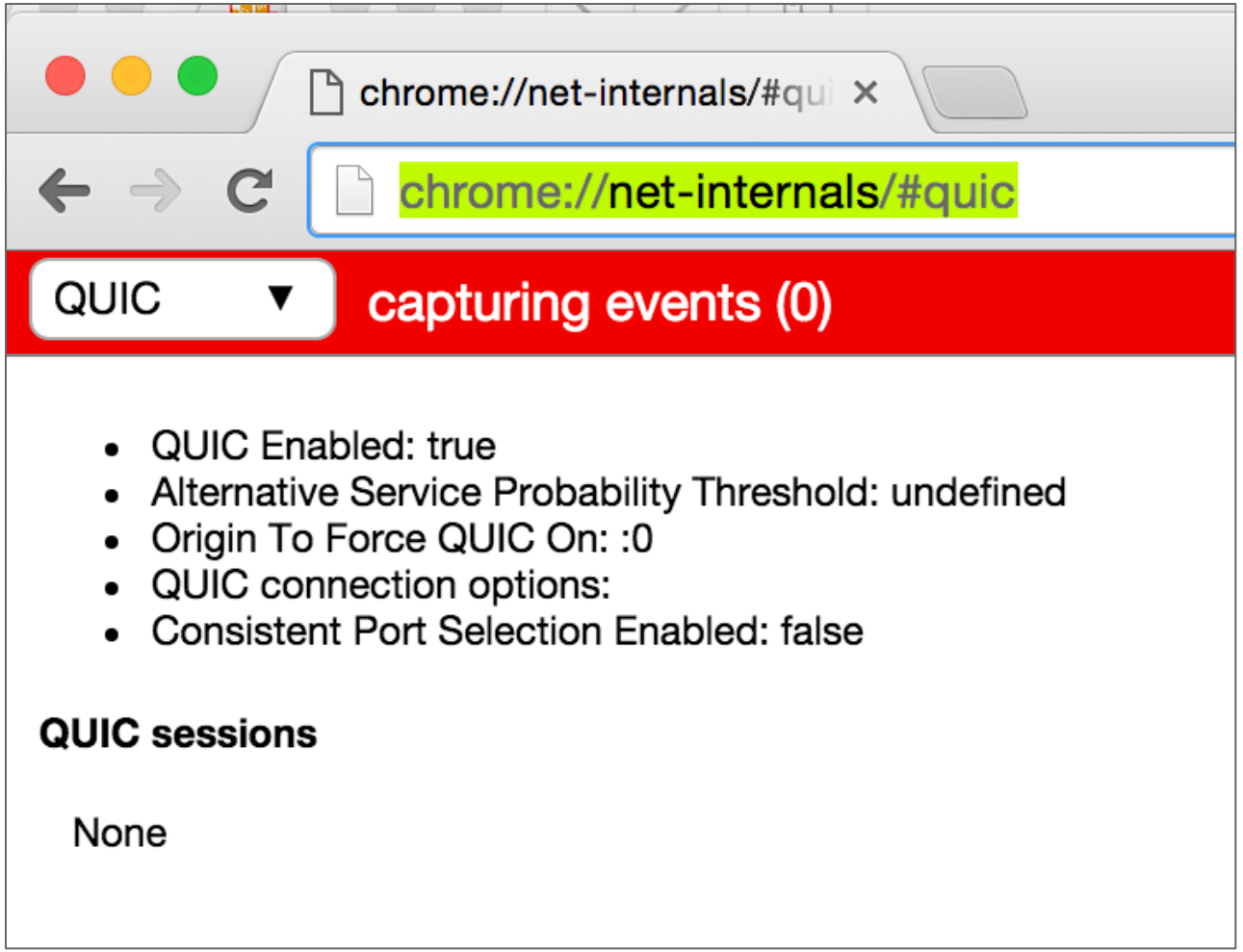
- QUIC intends to handle most HTTP/2 stream management

# QUIC Infodump 100% [ Finishing… ]
# Network Requirements

- UDP Unicast unimpeded
  - No filters
  - No Rate Limiters
- UDP NAT good practice
  - E.g. Timeouts set reasonably

# Debugging UIC

- Chrome:

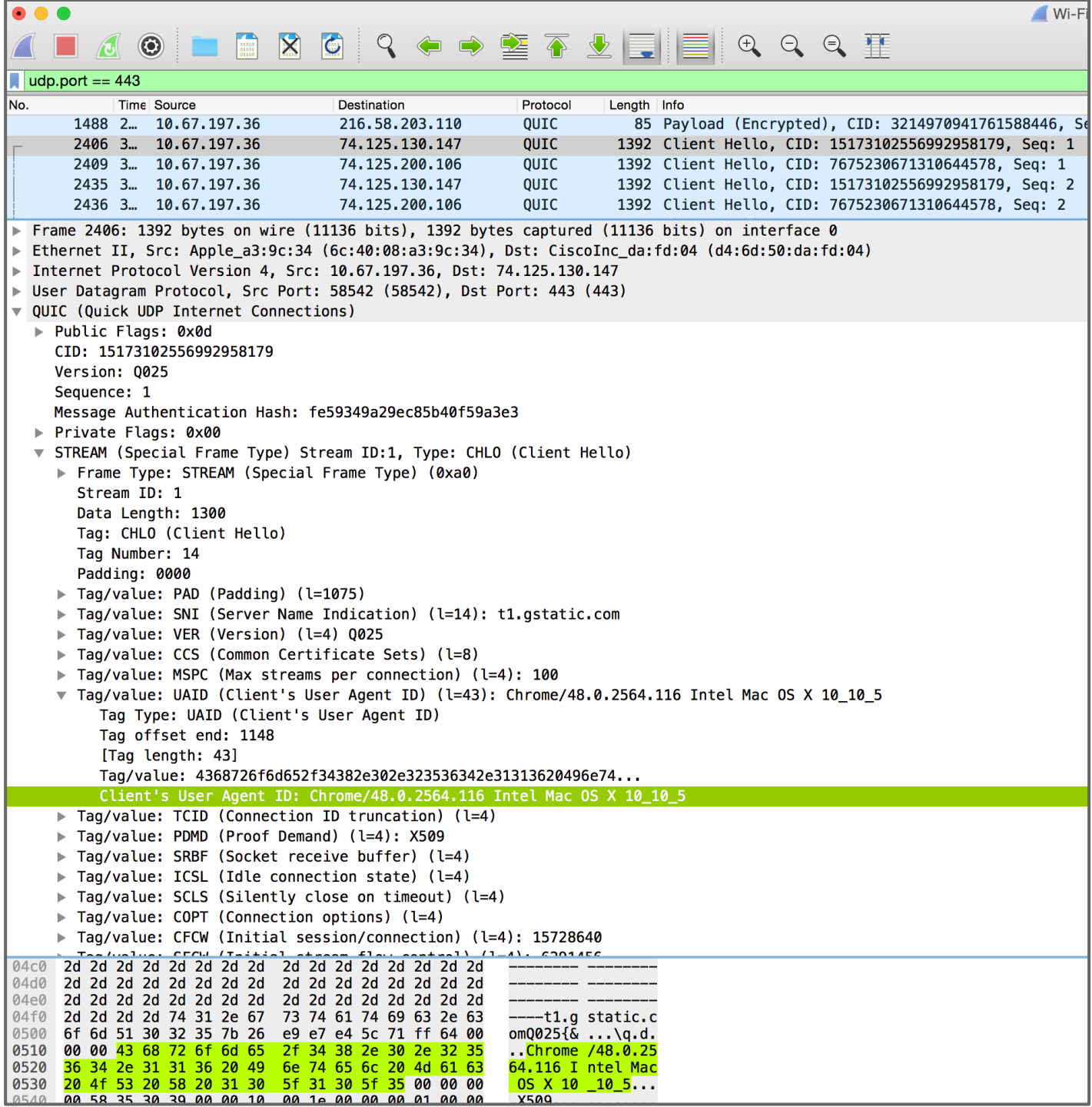



- chrome://net-internals/#quic

# Debugging QUIC

- Wireshark:

QUIC dissector =>



Introduction ✔
Background (Why Change TCP) ✔
MPTCP ✔
Background Redux (Why NOT TO change TCP) ✔
QUIC ✔

# Implications

Conclusion and Takeaways

# Was anyone thinking about the network environment?

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- The security and stability of MPTCP itself

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- What changes like this *could mean* for network security

# Was anyone thinking about the network environment?

- The security and stability of MPTCP itself

- What changes like this *could mean* for network security

… not so much

# Was anyone thinking about the network environment?

- T
- W
  ne

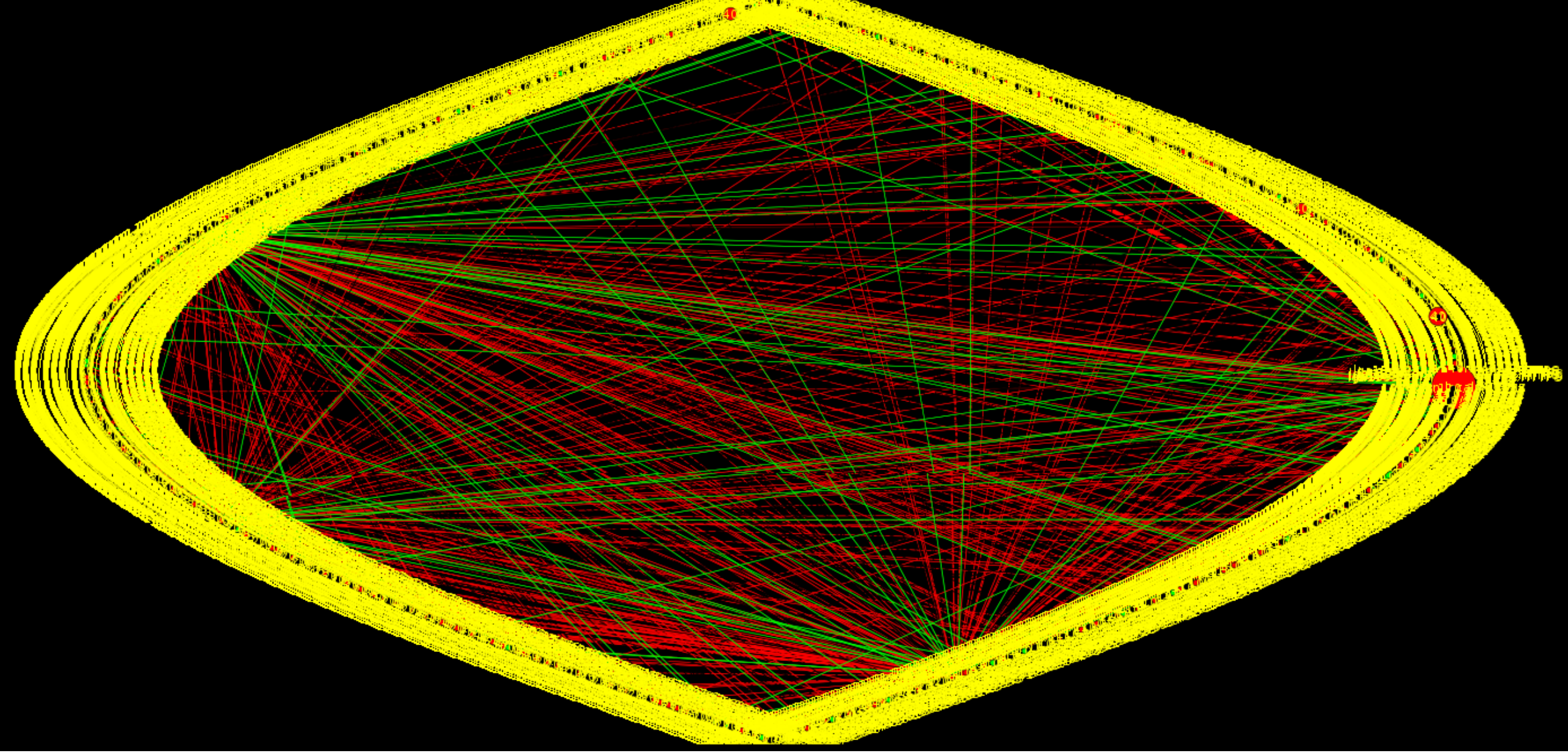
QUIC put more work into this

- Google also operates the network
- But they also put in "Protection" against network operator interference

ot so much

# What does it look like?

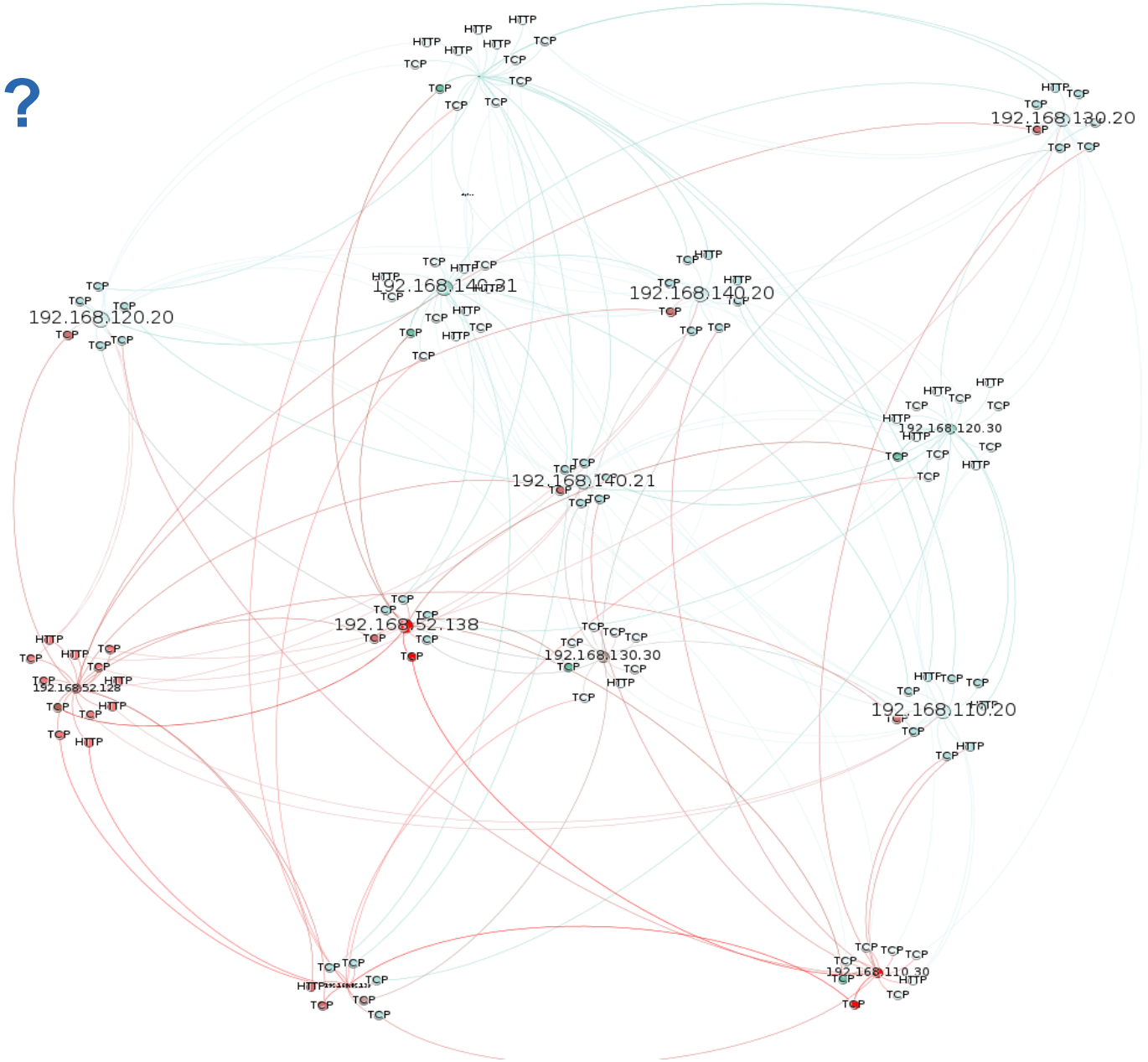
- On the network: If you don’t understand
- …



Each yellow blob is actually part of an address label

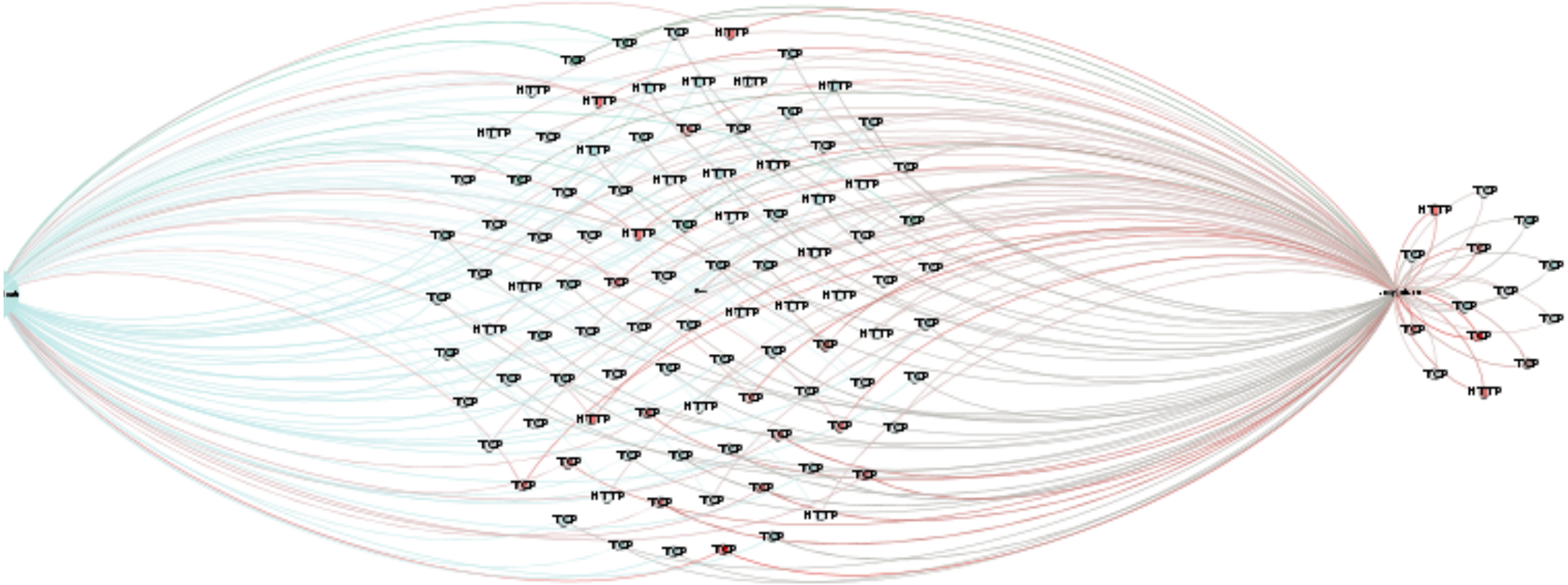
# What does it look like?

- On the network: If you don't understand it, but you cluster IPs



# What does it look like?

- On the network: If you do understand



- But you can only do this when you can see & correlate **all** related flows…

# MPTCP and … Network Management

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- These protocols are agnostic of IPv4 and IPv6, happily use both

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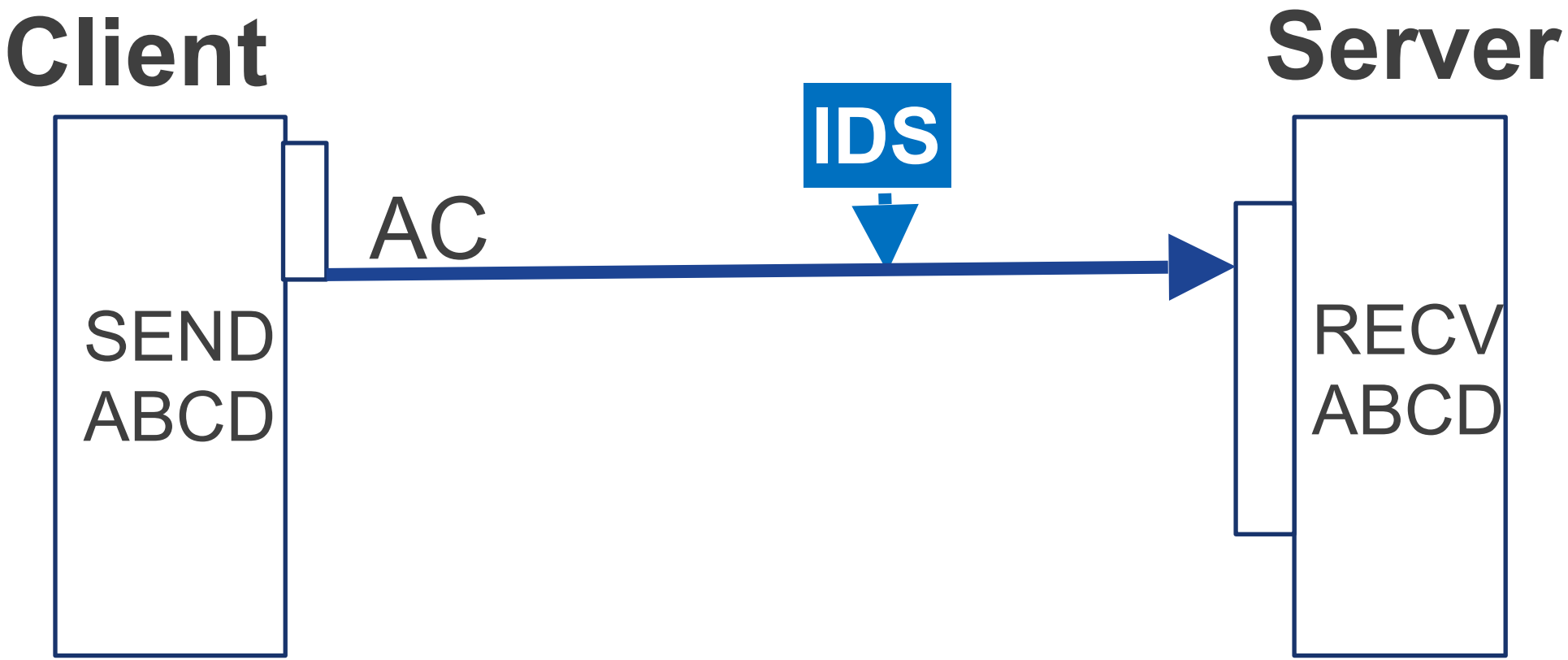
- If tool doesn't understand MPTCP, flows look like unrelated TCP streams
- If tool doesn't understand QUIC, flows look like unrelated UDP flows

# Monitoring – Cross-path fragmentation



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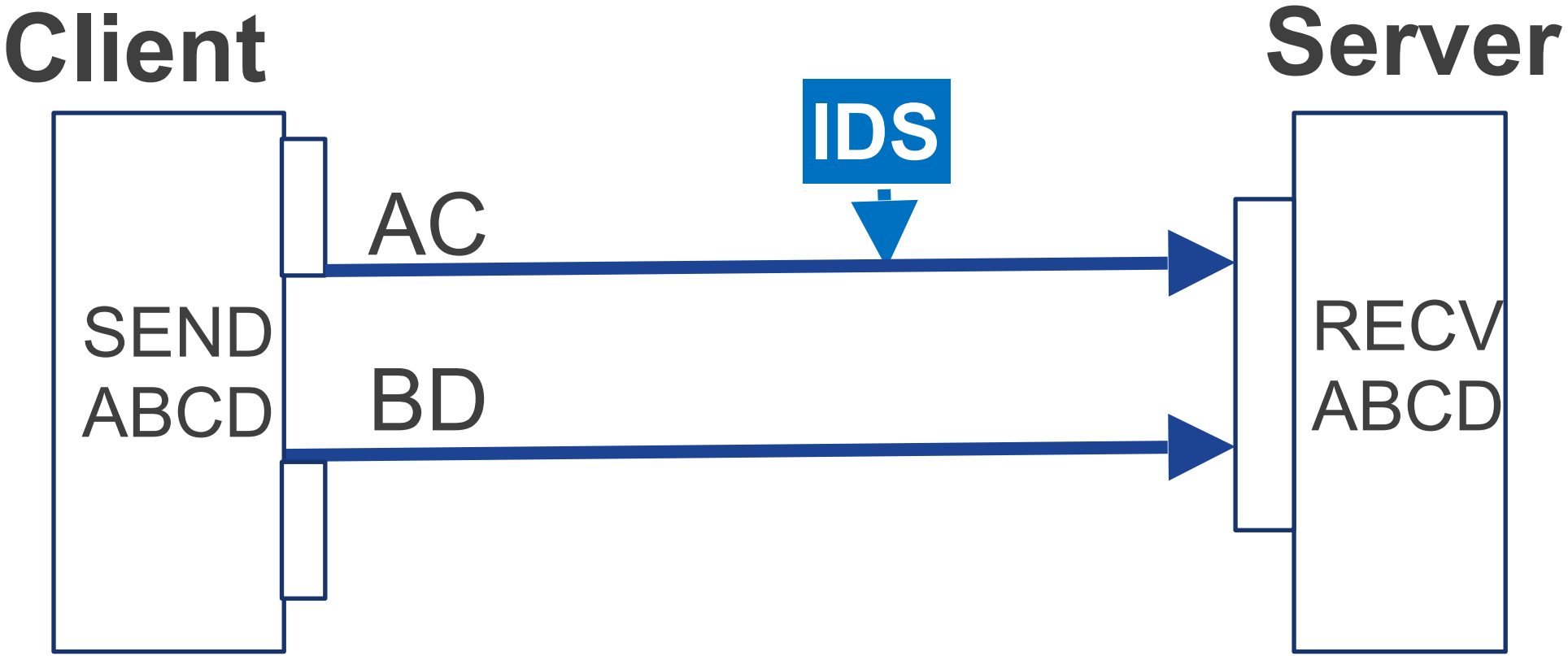

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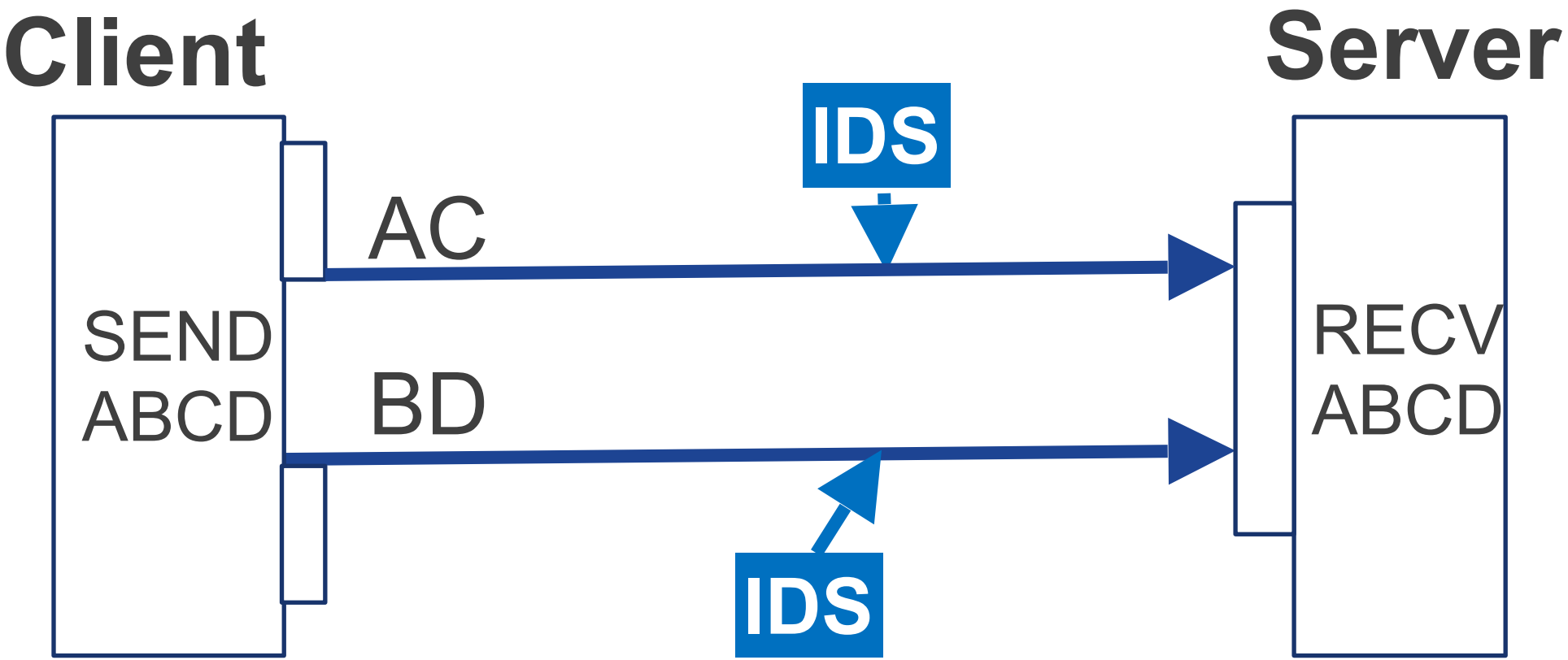

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  - Four interfaces each: 16 flows

- What about virtual interfaces, VPNs, proxies, load balancers..

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Insert Route redundancy and/or Proxies to be mean

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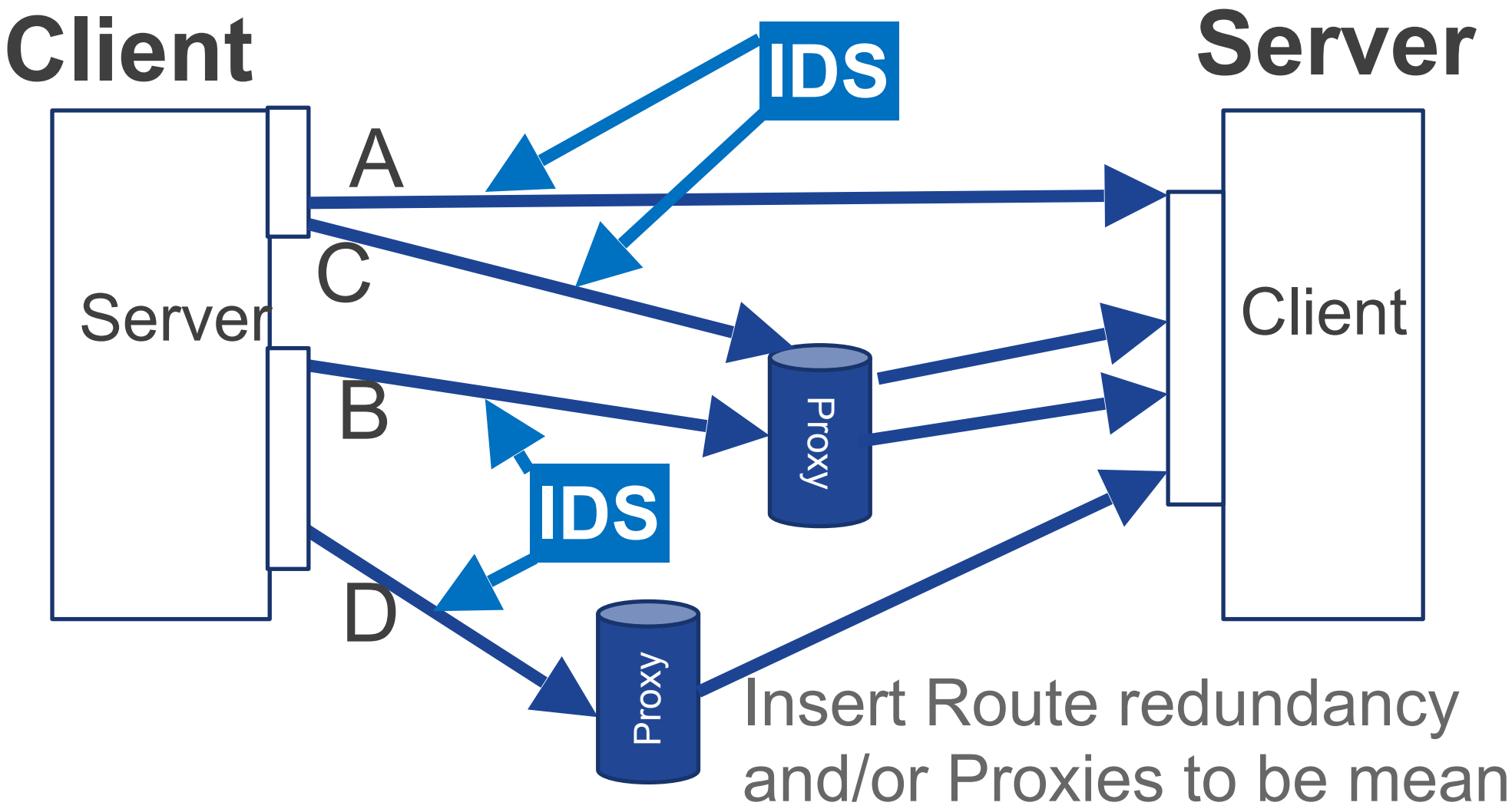


Insert Route redundancy and/or Proxies to be mean

# Multipath and … Network monitoring

- How would your CGNAT handle an [illegible] increase in connections as [illegible]
- [illegible]
- What about virtu[illegible] proxies, load balancers..

*In trying to solve address exhaustion with NAT do we risk state processing exhaustion?*

# Because of these…

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- Cross-path

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- Cross-path
- Moving target

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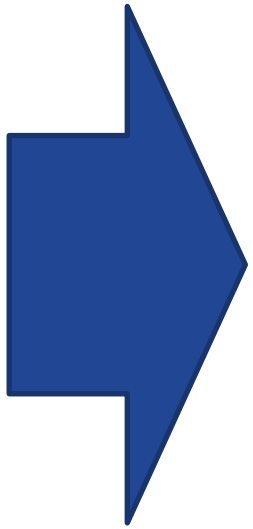

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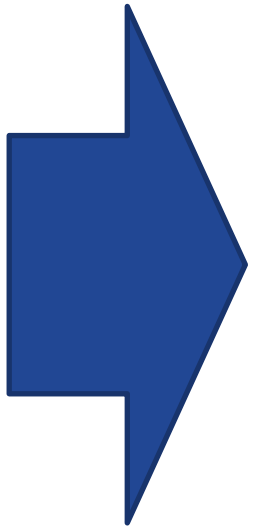

## … if your approach to network management requires *any* of these…

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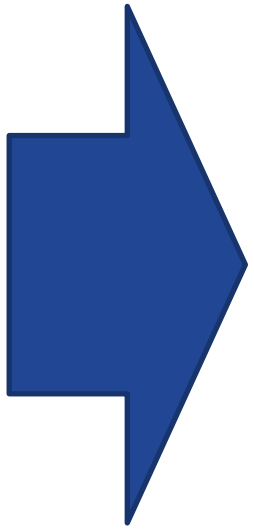

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- See all app layer data in a TCP stream

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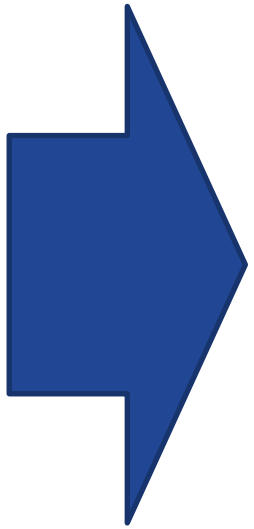

**… if your approach to network management requires *any* of these…**

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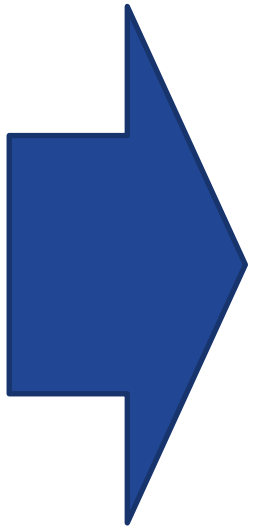

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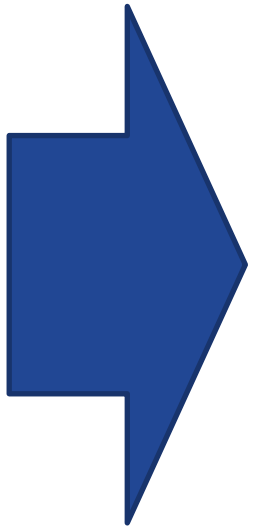

## … if your approach to network management requires *any* of these…

- See all app layer data in a TCP stream
- Associate logical sessions to IP addresses
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- Differentiate clients from servers based on connection direction

## …then something is probably going to break

# Key Effects

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- "Reverse" connections

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A ~~few~~ lot of slides back…

- The **packet *sender* decides** which data goes down which path.

*“The Net interprets censorship as damage and routes around it.”*

John Gilmore, 1993

*“Multipath interprets modification as damage and routes around it.”*

Kate Pearce, 2014

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A ~~few~~ lot of slides back…

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- Normal/benign clients won't choose pathological fragmentation schemes

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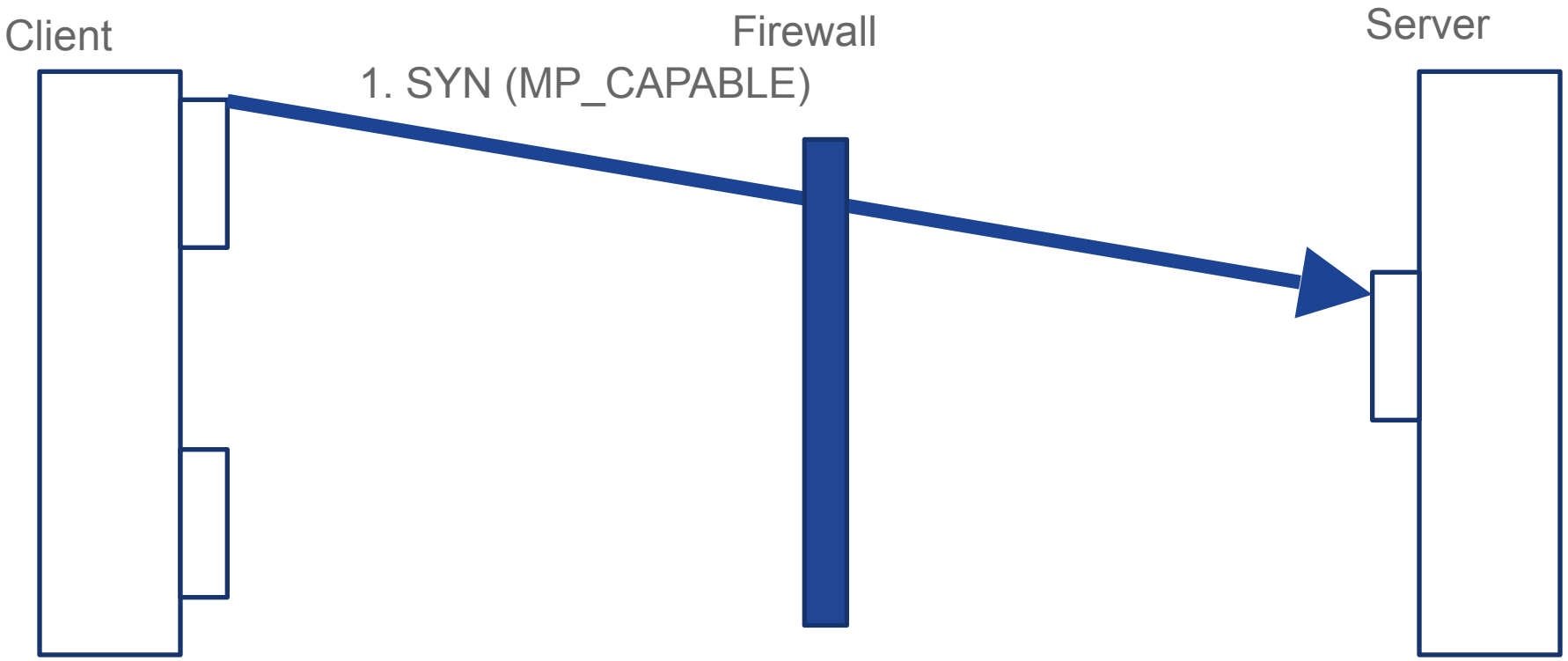
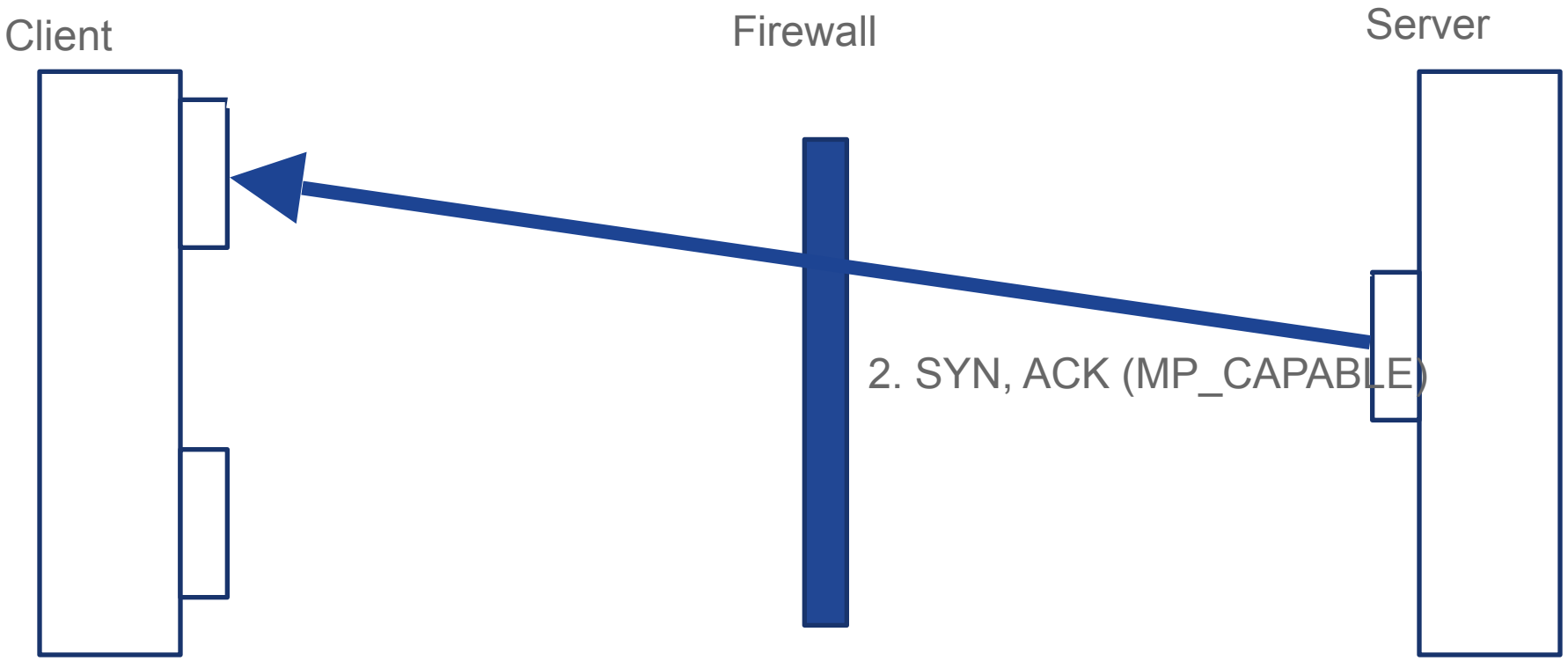
- How’d you like an outbound incoming connection?

# MPTCP and … Firewalls



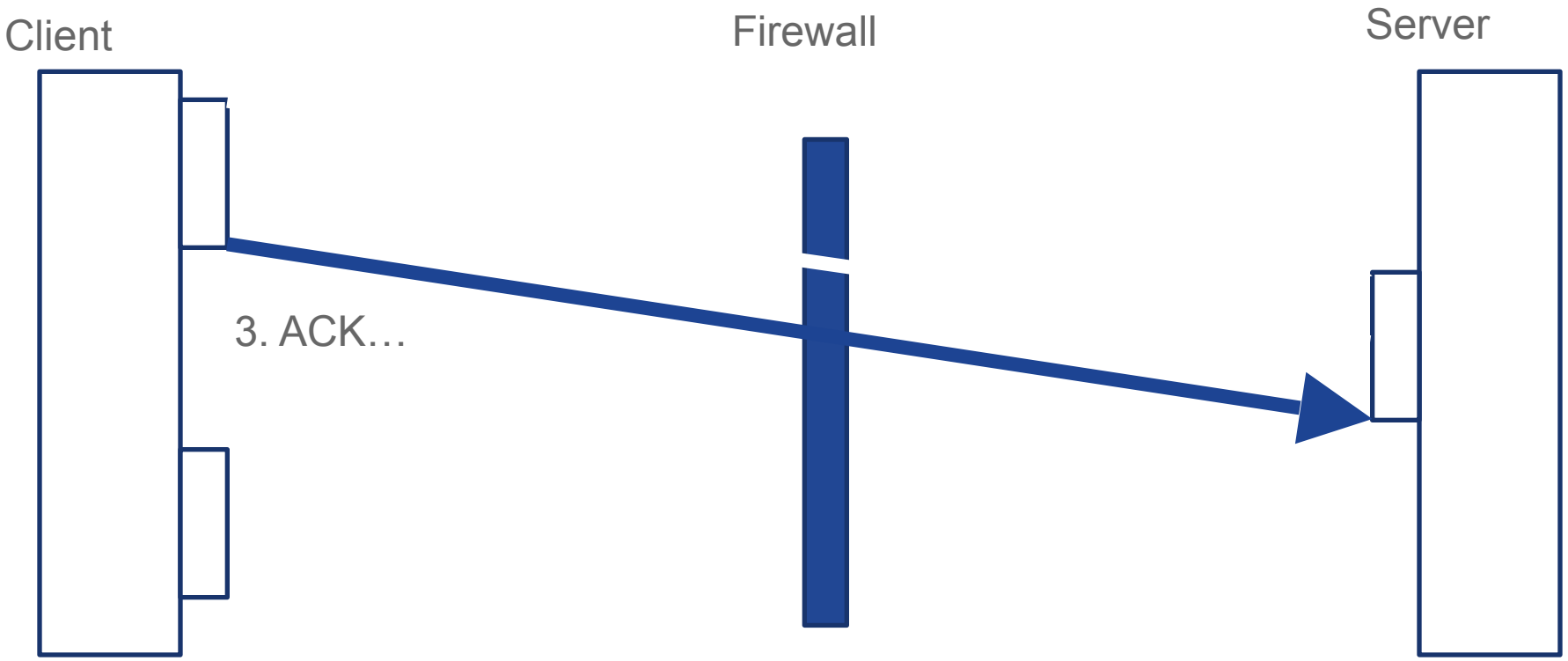

- MPTCP connection looks like TCP so far…

# MPTCP and … Firewalls



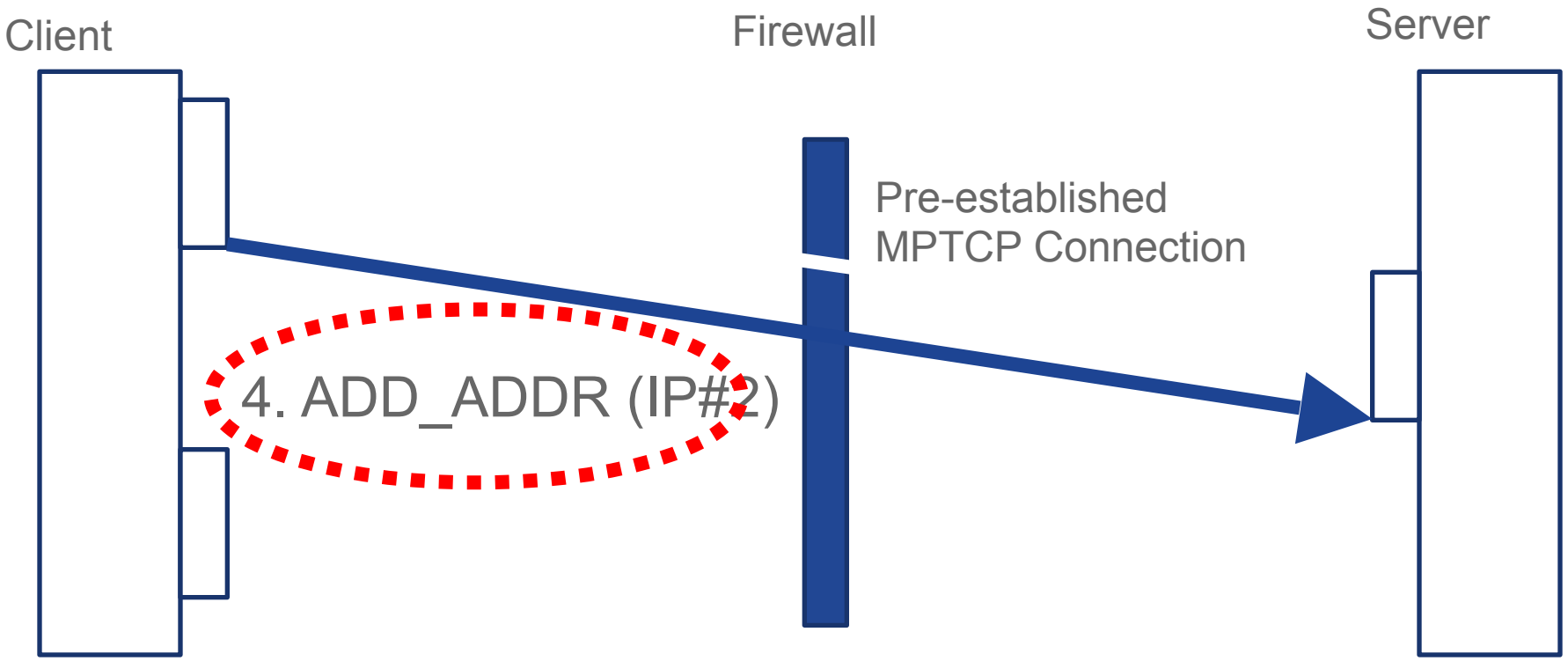

- Still seems pretty standard, albeit with extra TCP OPTIONS

# MPTCP and … Firewalls



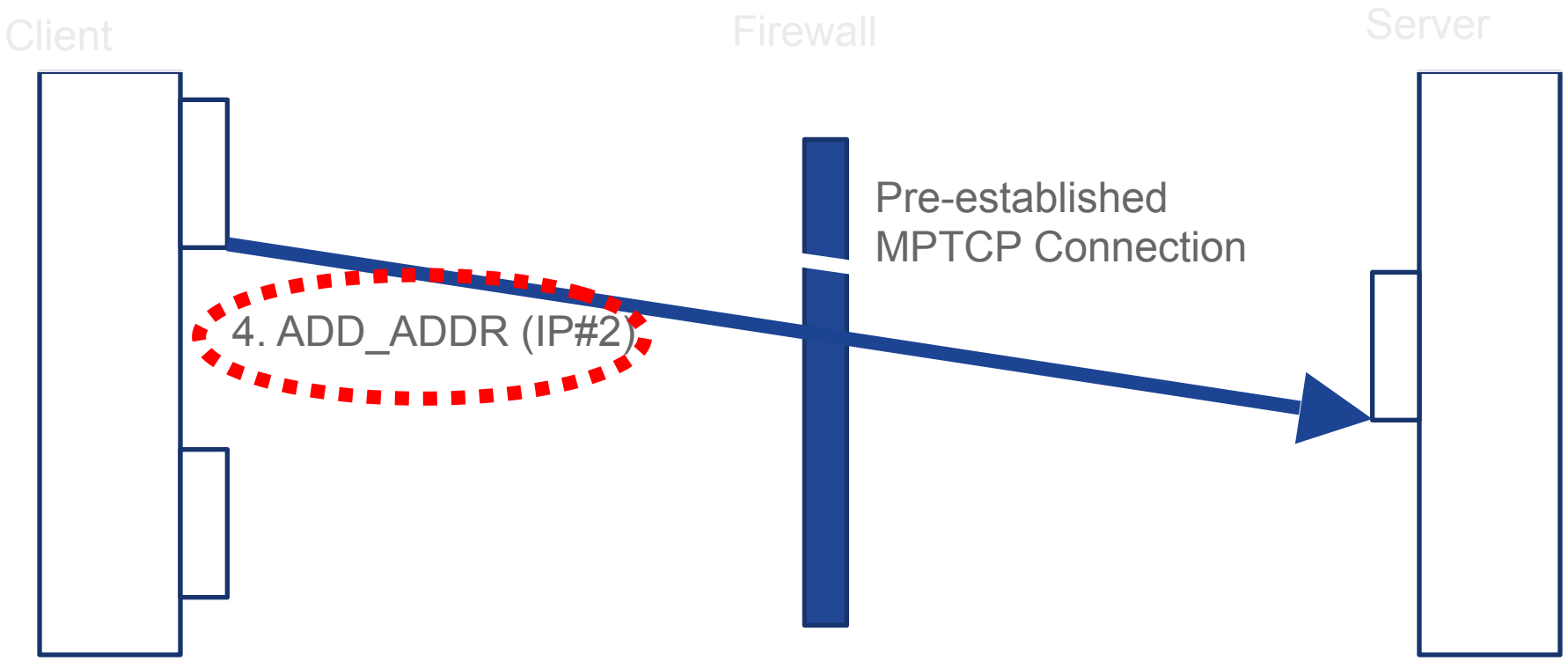

- OK, so it’s a TCP connection with an additional options… so what?

# MPTCP and … Firewalls



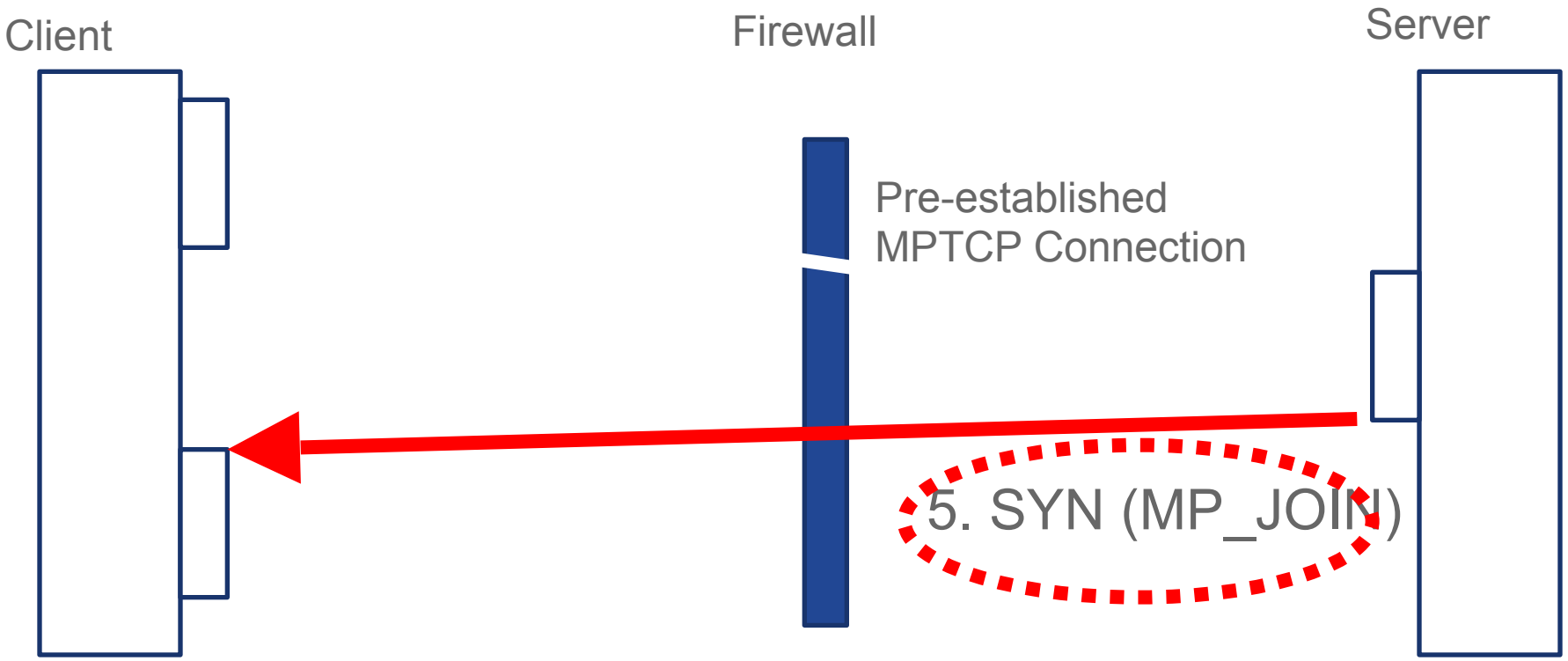

- Well, what if the client tells the server about a new address?

# MPTCP and … Firewalls




- Now, the “Internal” host <u>may</u> set up a connection to the advertised address

# MPTCP and … Firewalls



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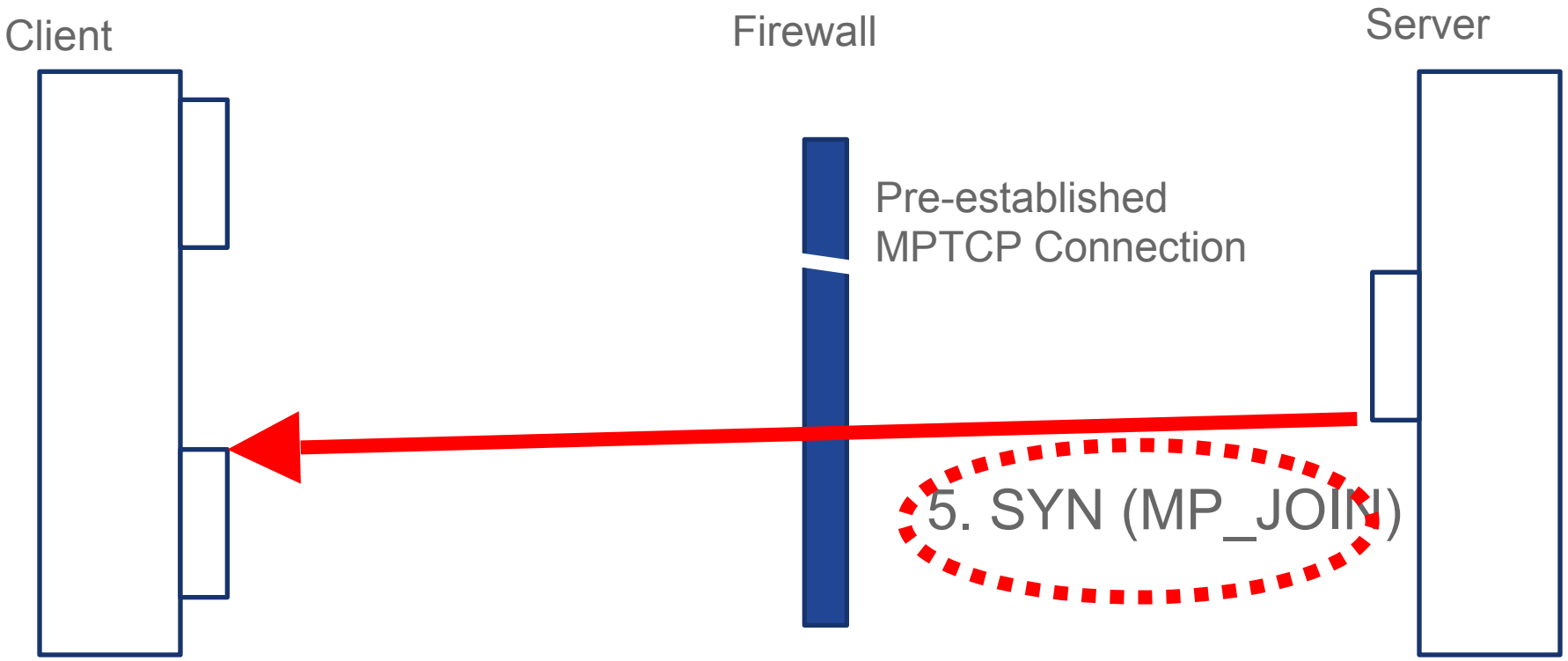


- Is this new connection incoming or outgoing?

# MPTCP and … Firewalls


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- I don't fully trust my ISP or Cellular company…

# Multipath and … Privacy

- Multipath shifts power towards endpoints, and away from infrastructure & ISP's
- I don't fully trust my ISP or Cellular company…
- But they probably don't trust each other either!

Introduction ✔
Background (Why Change TCP) ✔
MPTCP ✔
Background Redux (Why NOT TO change TCP) ✔
QUIC ✔
Implications ✔

# Conclusion and Takeaways

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  - NO
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  - NO
  - NO

# Key Insights- Multipath

- The (IP) network's job is to transmit data from end to end. (?)

*“Within each network,* ***communication may be disrupted due to unrecoverable mutation of the data*** *or missing data.* ***End-to-end restoration procedures are desirable to allow complete recovery from these conditions****.”*

[CERF, VINTON G., and ROBERT E. KAHN. "A Protocol for Packet Network Intercommunication." (1974).]

# Key Insights – Content Inspection

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Many network management approaches rely too much on

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Many network management approaches rely too much on

- Metadata
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# Key Insights – Content Inspection

Many network management approaches rely too much on

- Metadata
- Data inspection
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The Internet wasn't designed to validate your control over network data flows.

# Technical Takeaways

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- Address != connection endpoint

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- Address != connection endpoint
- State exhaustion could become the new address exhaustion
- Multipath tech breaks assumptions many didn’t even know we were making

# Conclusions

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- Multipath communication confounds business & security models relying on stateful inspection or lookup

# Conclusions

- Multipath communications are awesome, and they're coming
- Multipath communication confounds business & security models relying on stateful inspection or lookup
- Now is the time for network security and network management to prepare

# References and Links

- MPTCP:

- Raiciu, C. et al., 2012. How hard can it be? designing and implementing a deployable multipath TCP. NSDI, (1). Available at: https://www.usenix.org/system/files/conference/nsdi12/nsdi12-final125.pdf.
- ACM Queue - Multipath TCP, Decoupled from IP, TCP is at last able to support multihomed hosts - Christoph Paasch and Olivier Bonaventure, UCL - http://queue.acm.org/detail.cfm?id=2591369
- IETF Working group - http://datatracker.ietf.org/wg/mptcp/

- QUIC

- https://peering.google.com/#/learn-more/quic
- https://www.chromium.org/quic
- https://tools.ietf.org/html/draft-tsvwg-quic-protocol-02
- https://tools.ietf.org/html/draft-tsvwg-quic-loss-recovery-01

# Questions?

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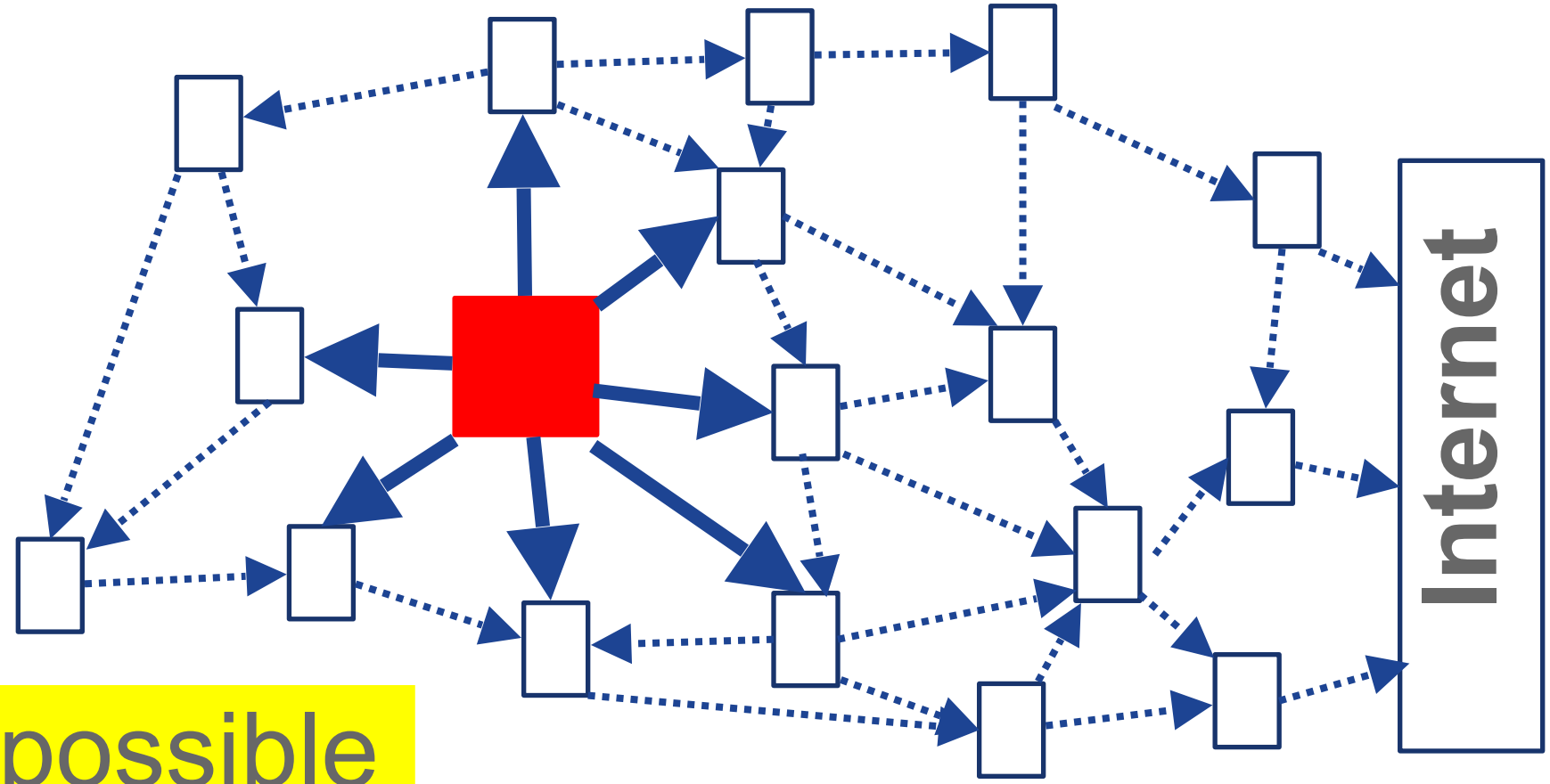
# Path Management – mesh networks




All possible paths can be used ***at the same time***