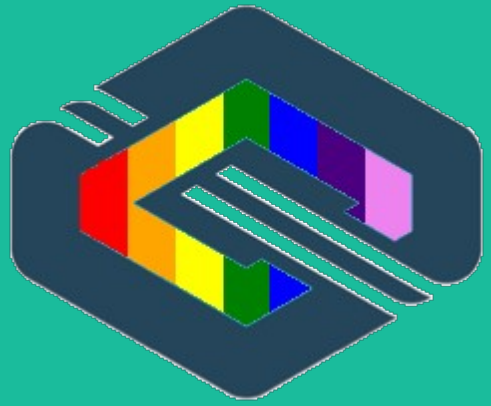


Multipath QUIC: Design and Evaluation

Quentin De Coninck, Olivier Bonaventure
quentin.deconinck@uclouvain.be

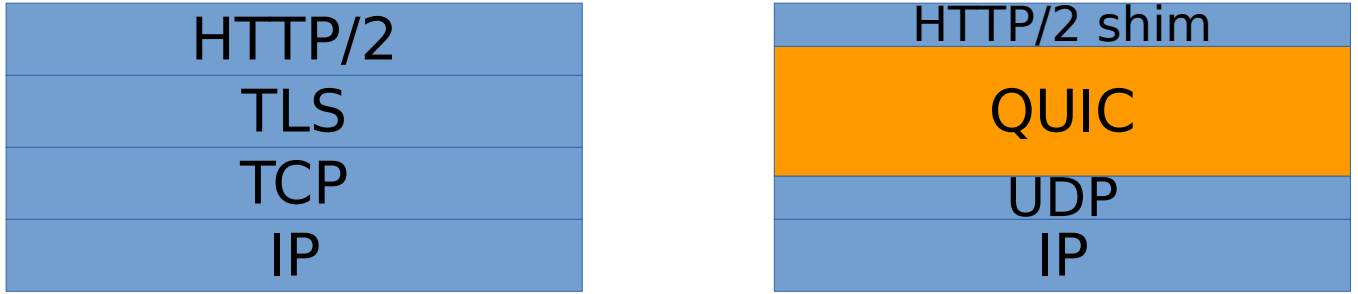
multipath-quic.org

UCL Université catholique de Louvain

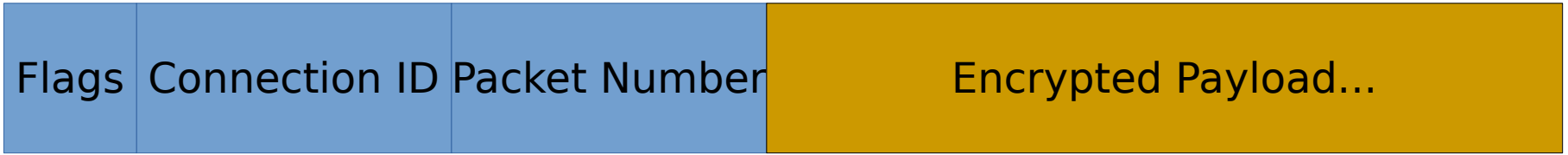
fnrs LA LIBERTÉ DE CHERCHER

QUIC = Quick UDP Internet Connection

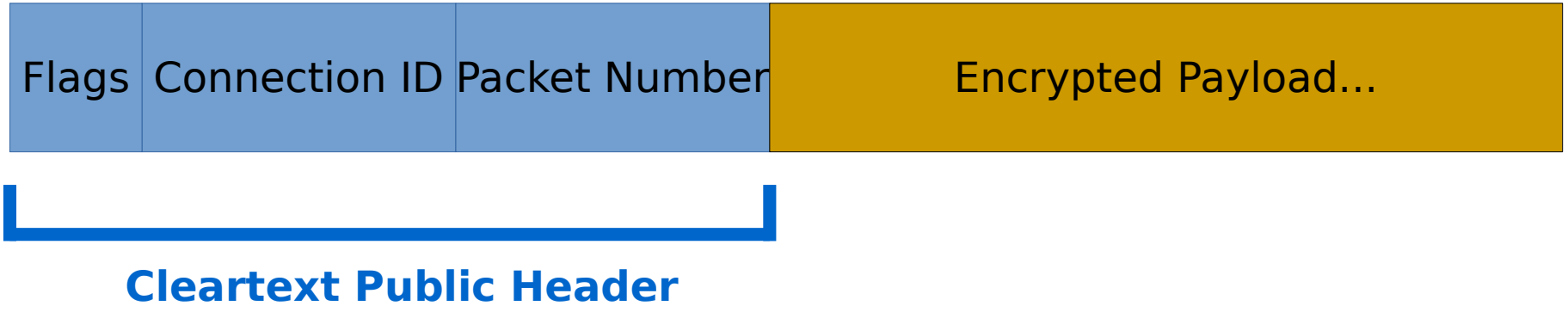
- **TCP/TLS1.3 atop UDP**
- **Stream multiplexing → HTTP/2 use case**
- **0-RTT establishment (most of the time)**



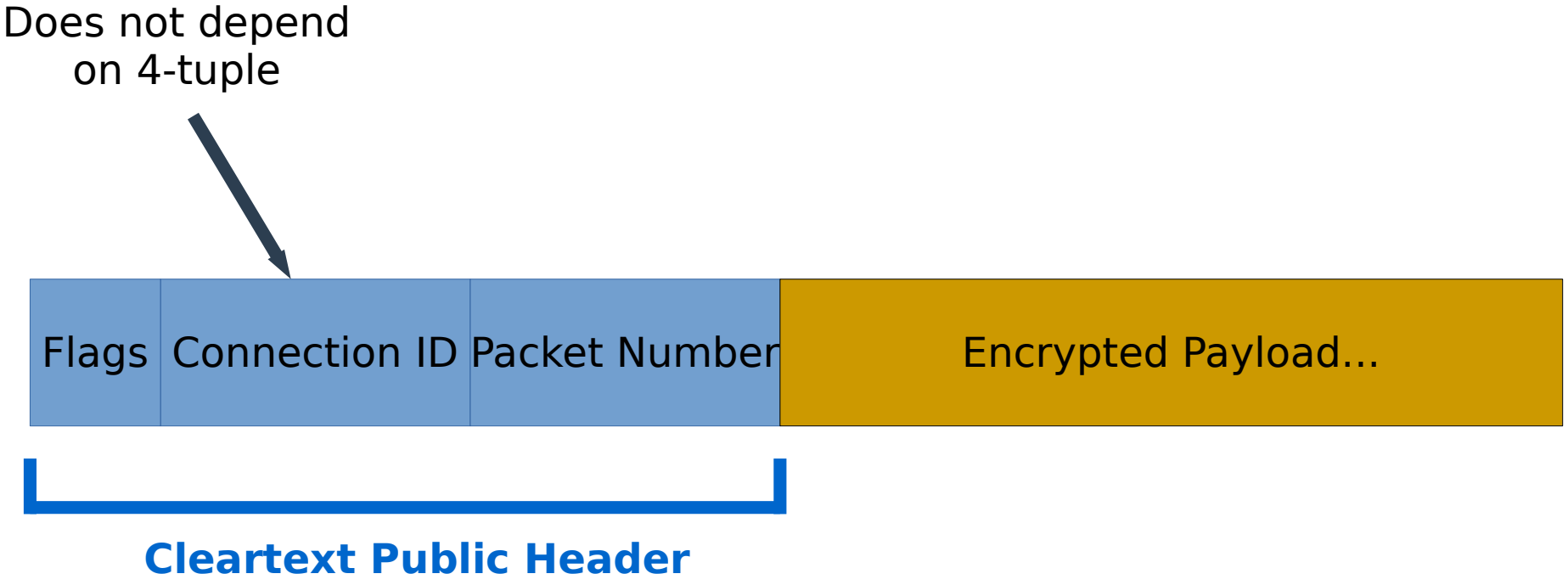
QUIC Packet



QUIC Packet


Flags
Connection ID
Packet Number
Encrypted Payload...
Cleartext Public Header

QUIC Packet


Does not depend
on 4-tuple
Flags
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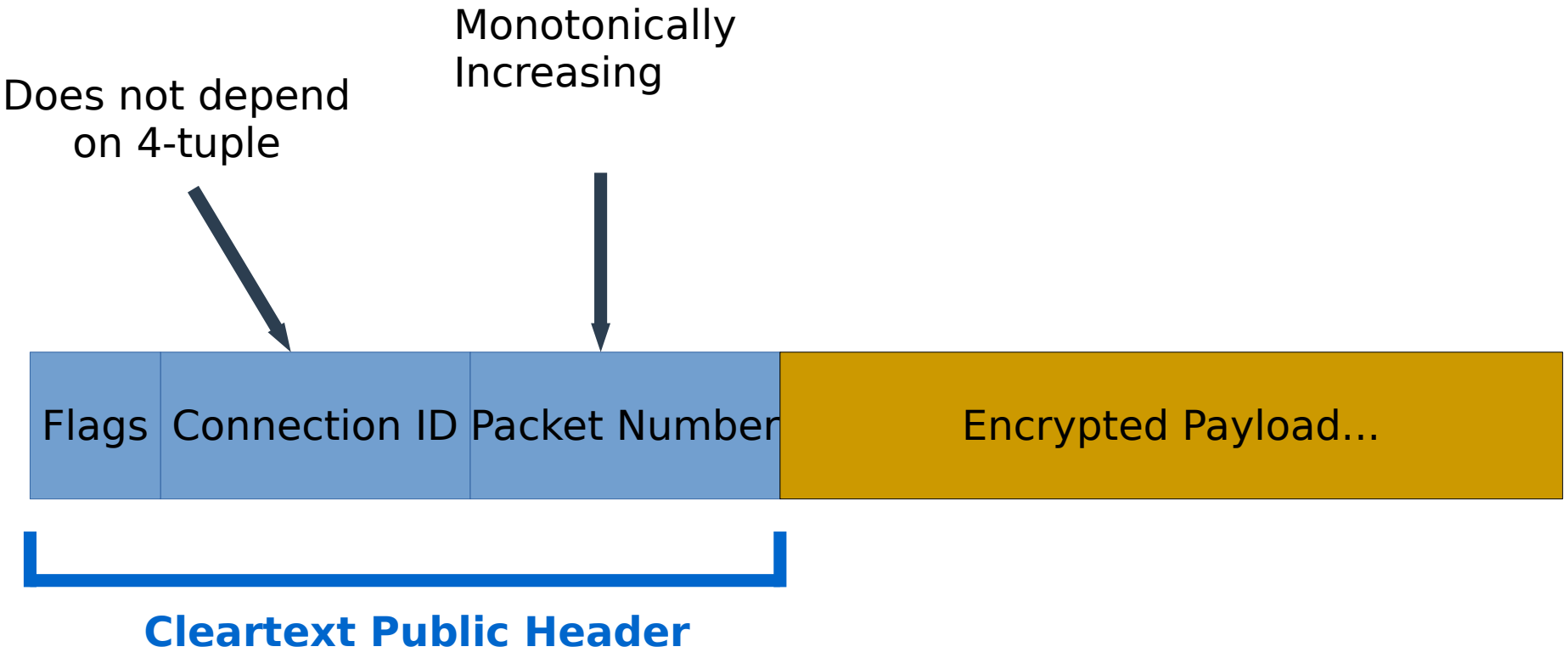
QUIC Packet


Monotonically
Increasing
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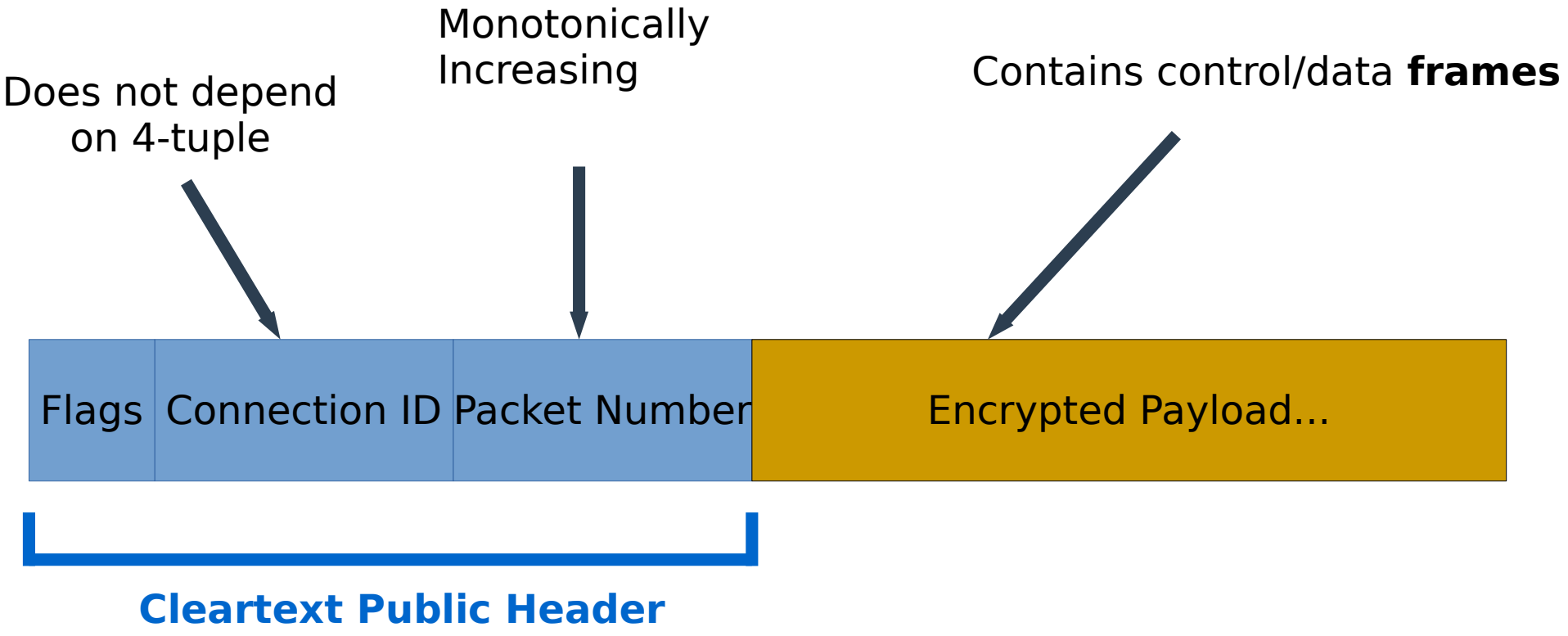
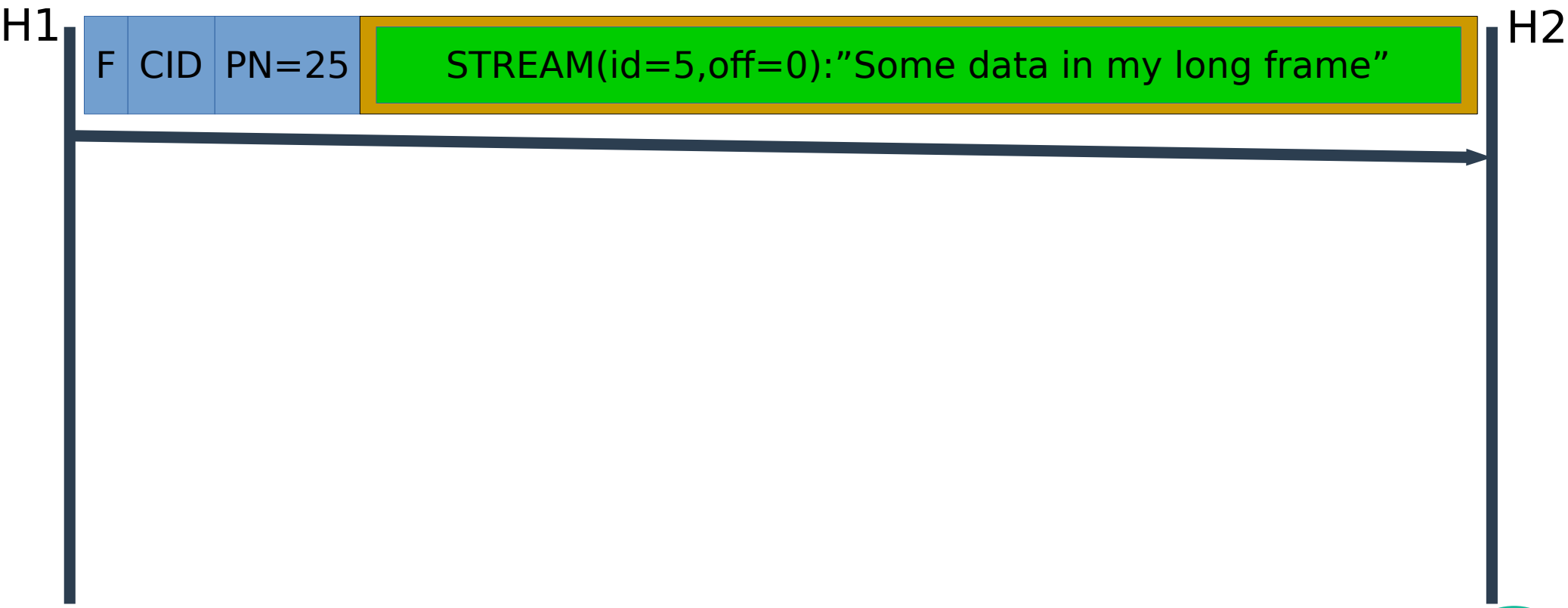
QUIC Packet

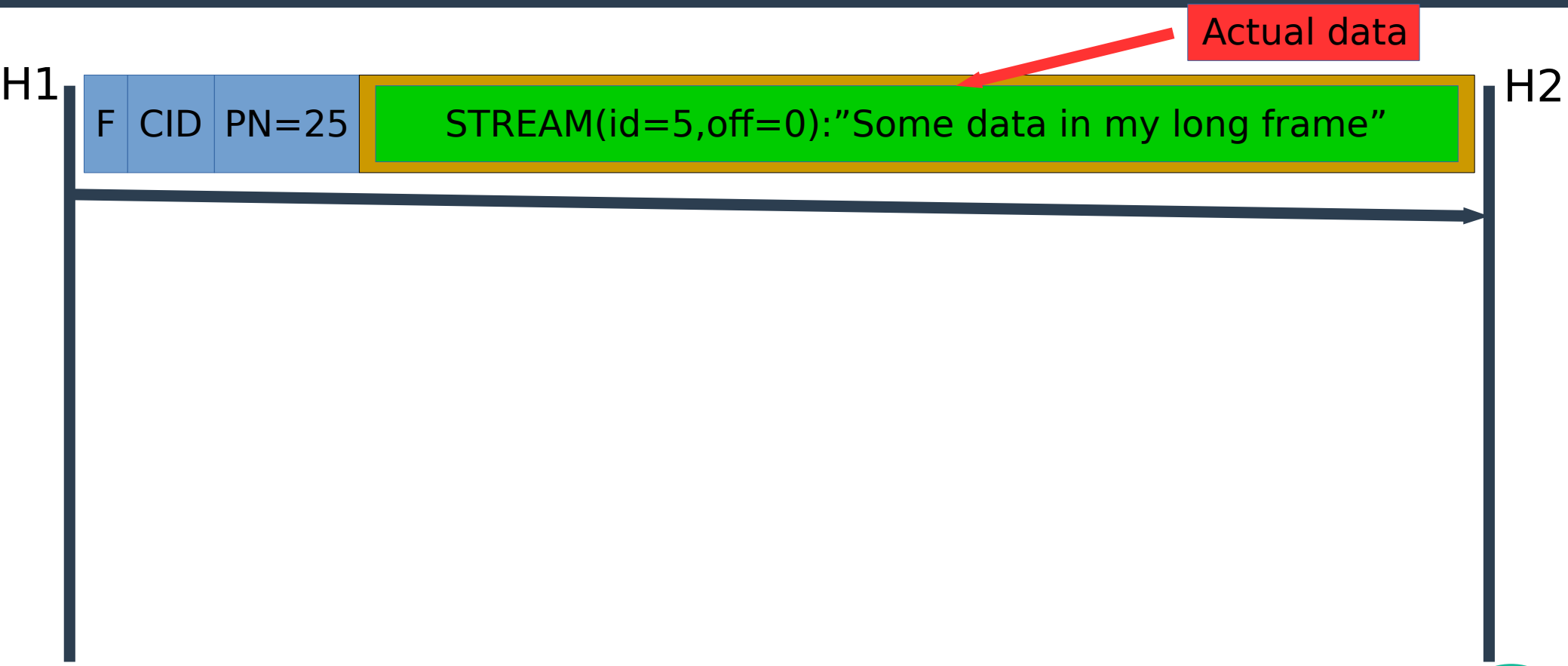

Does not depend on 4-tuple
Monotonically Increasing
Contains control/data **frames**
Flags
Connection ID
Packet Number
Encrypted Payload...
Cleartext Public Header

QUIC Data Transfer

QUIC Data Transfer



QUIC Data Transfer



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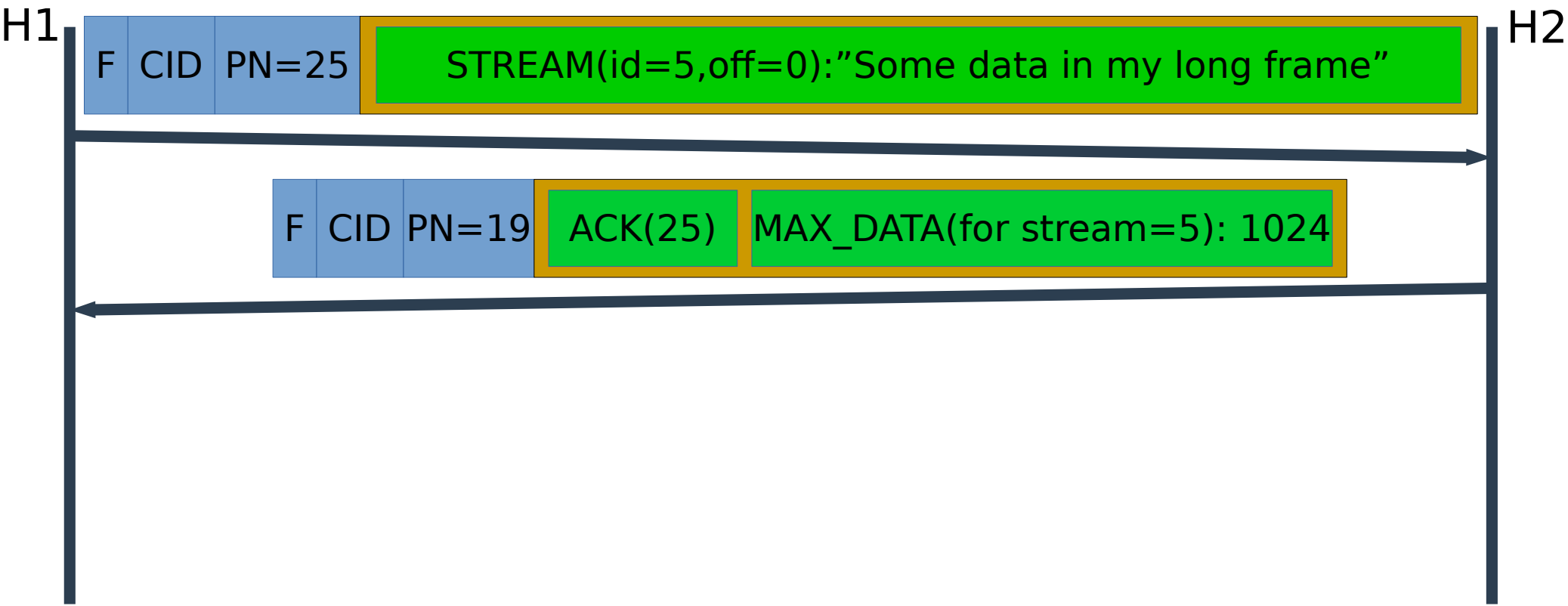

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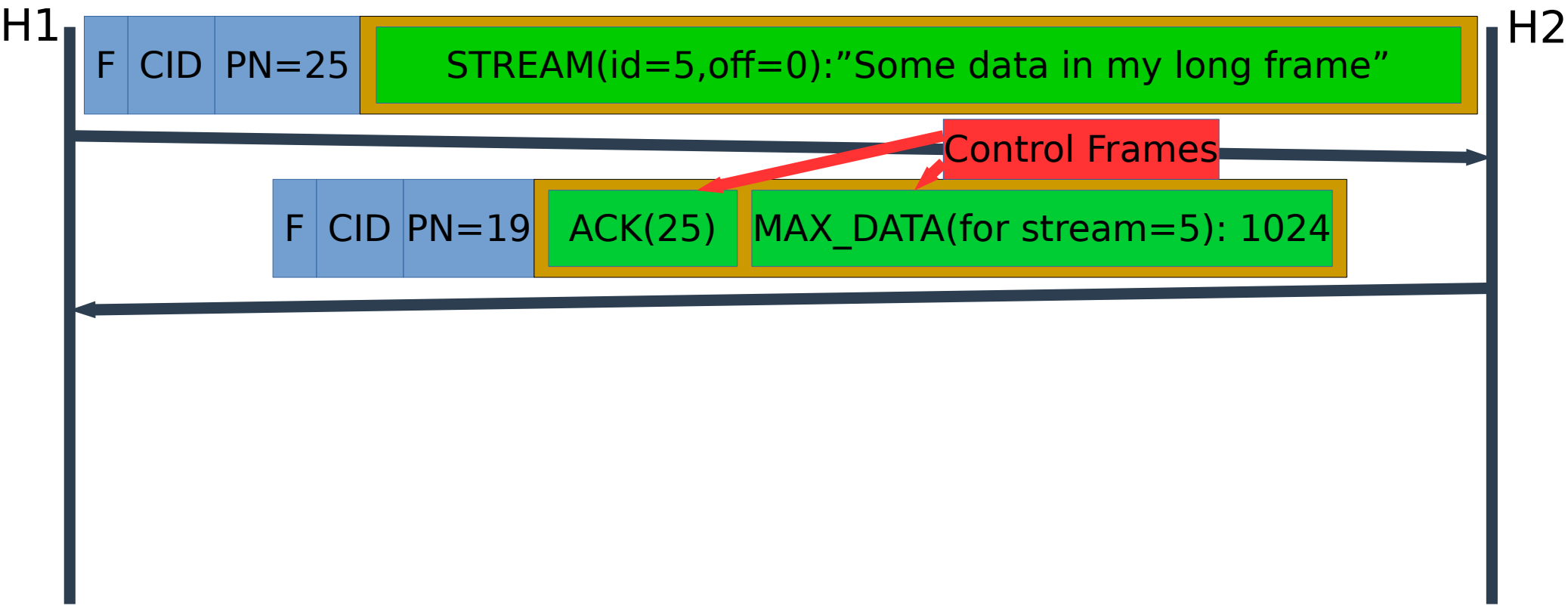

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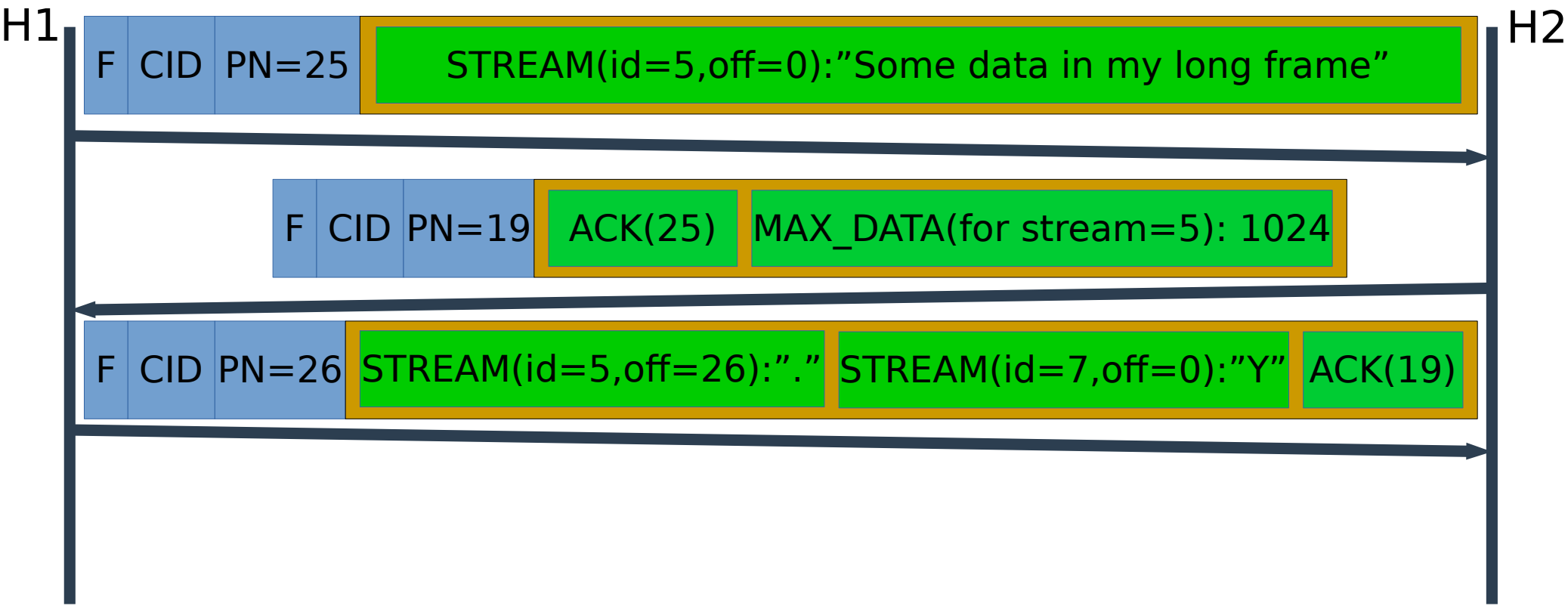
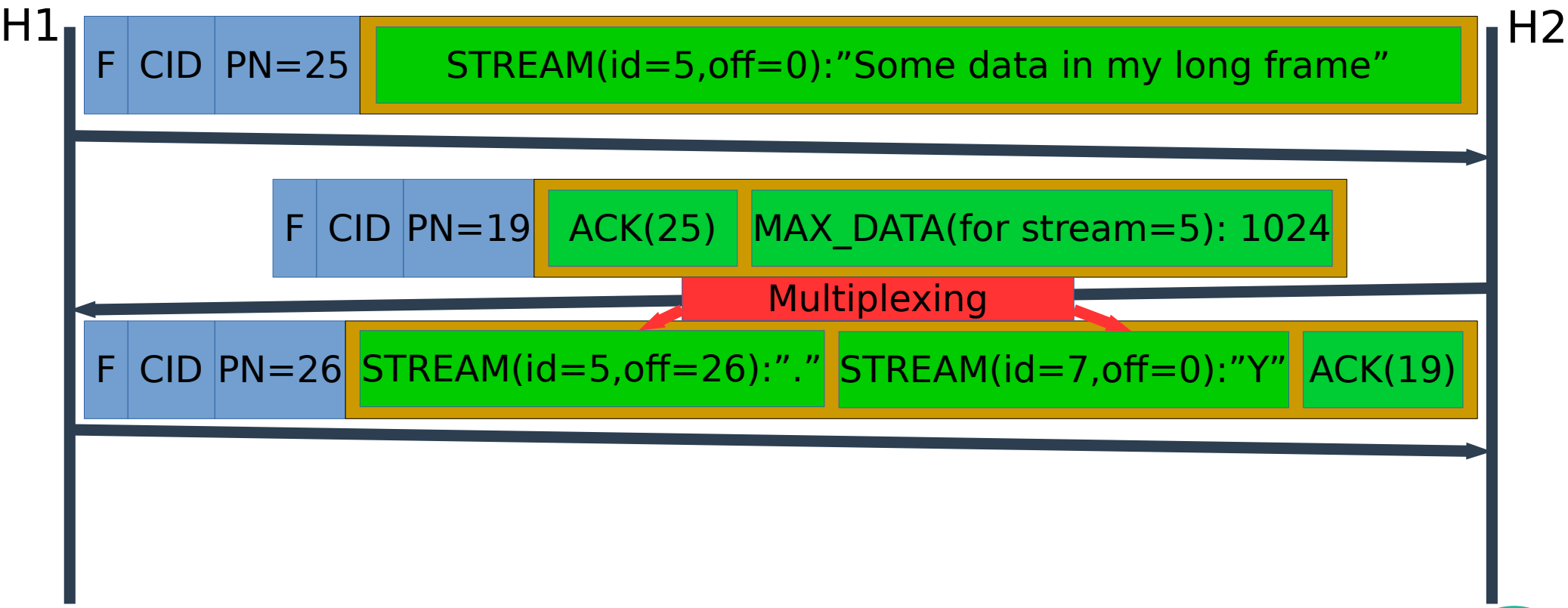
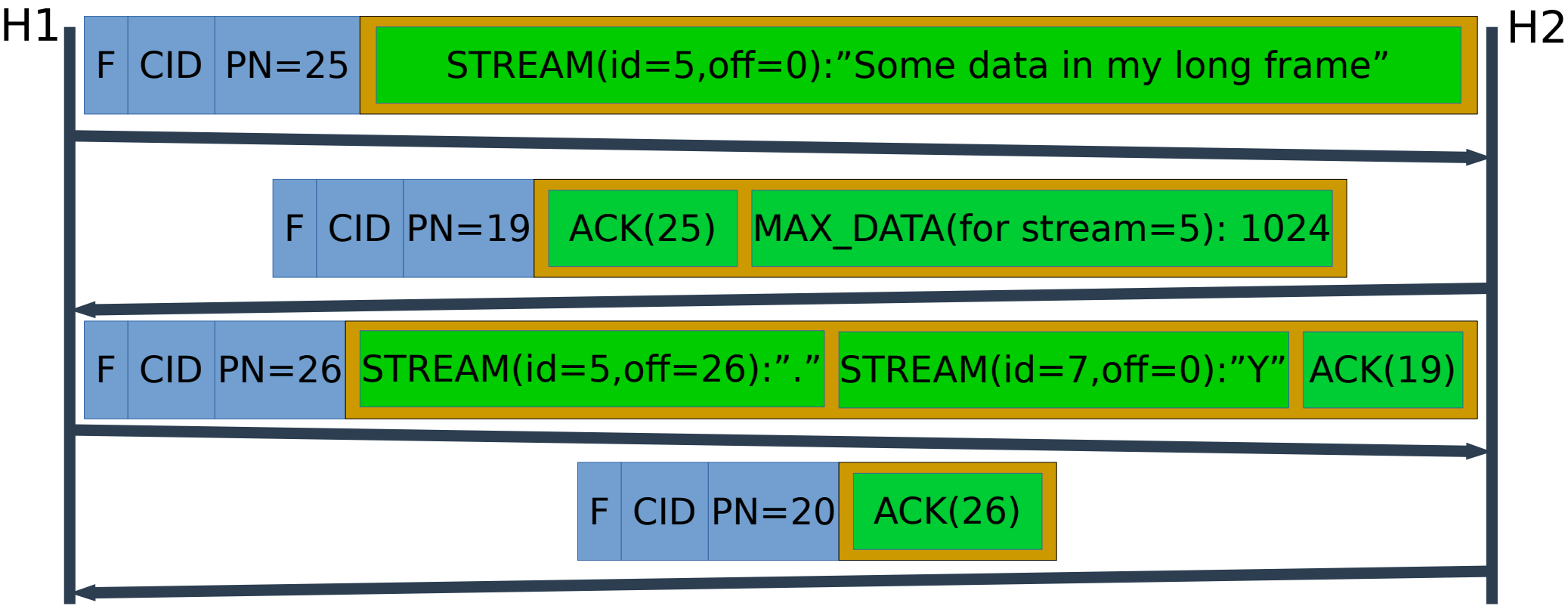


QUIC Data Transfer



QUIC Data Transfer



Why Multipath QUIC?

- **QUIC assumes a single-path flow**

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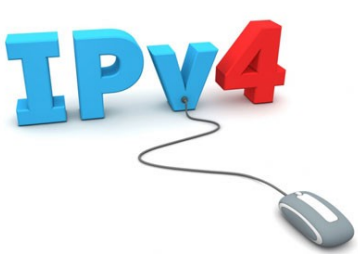


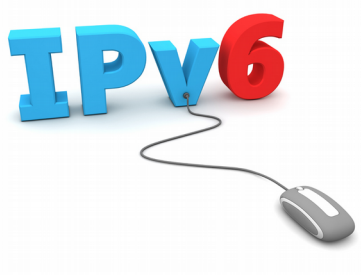

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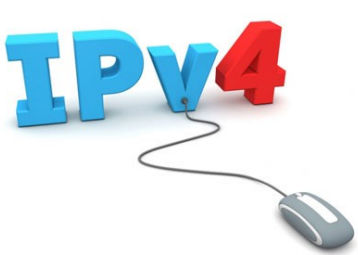
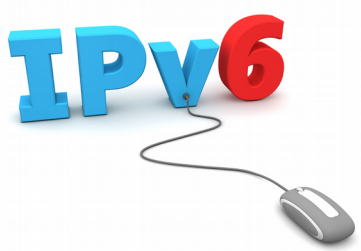
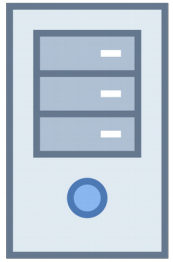


- **Multipath QUIC**
  - Bandwidth aggregation
  - Seamless network handover
    - Can try new WiFi while keeping using LTE

Design of Multipath QUIC

- **Connection is composed of a set of paths**



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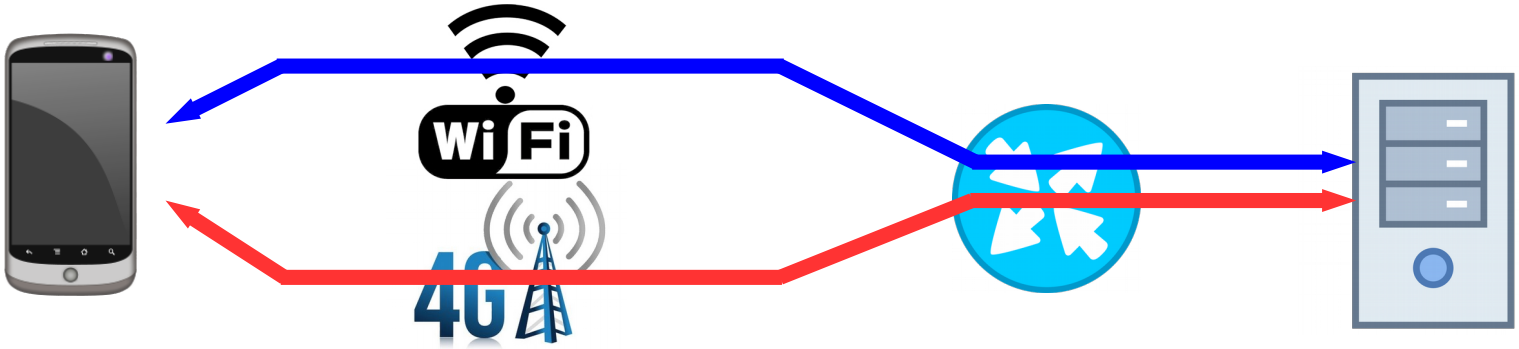

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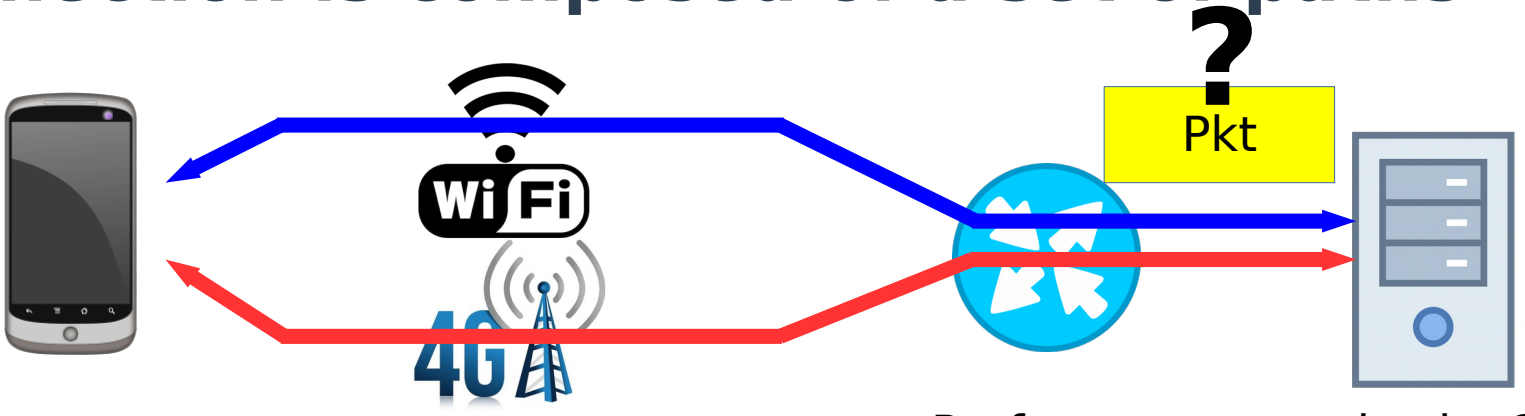

Performance monitoring?
Loss detection?
Path congestion control?

Design of Multipath QUIC

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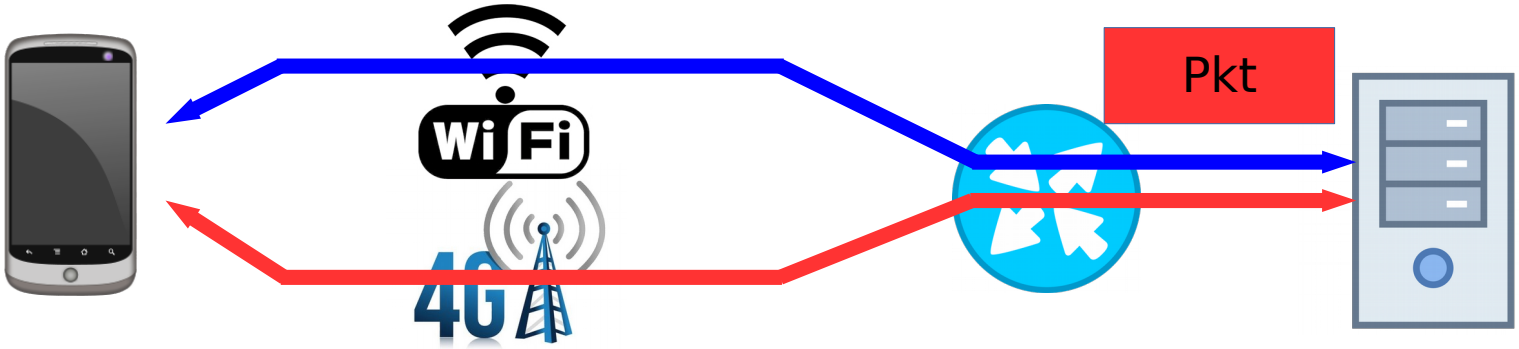

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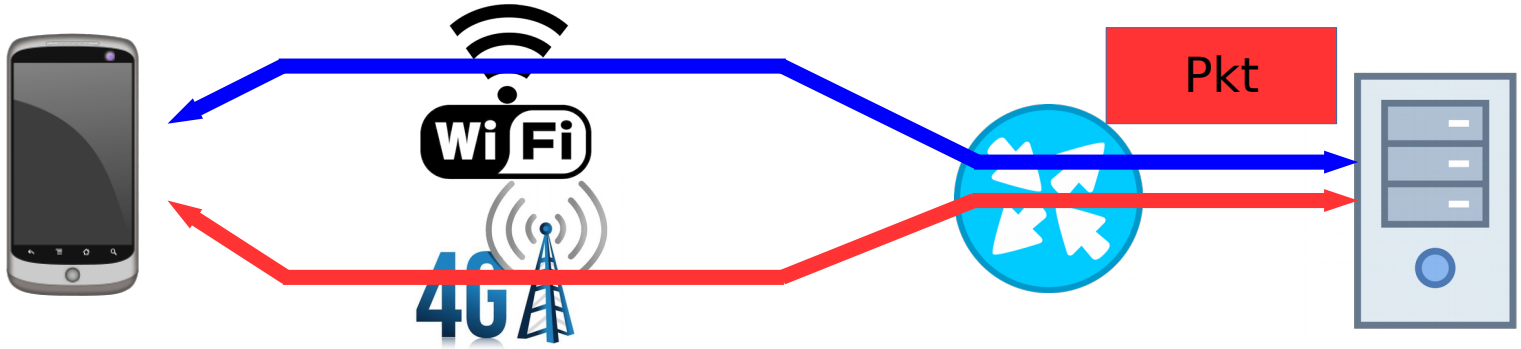

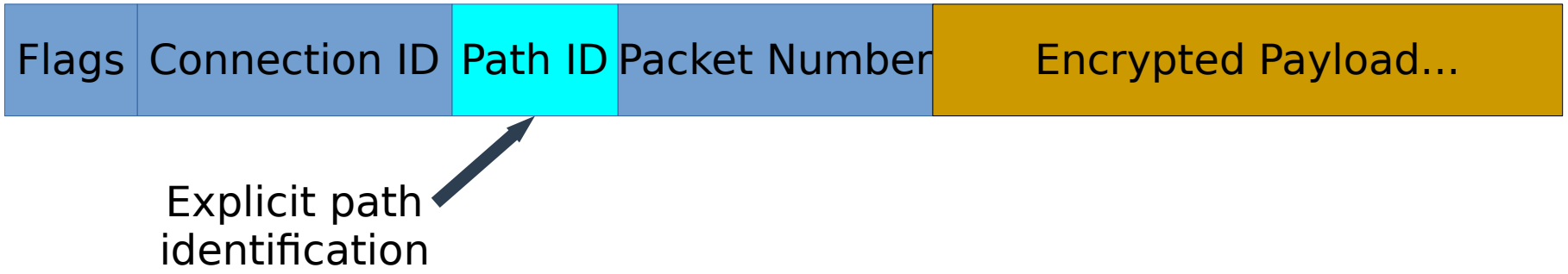

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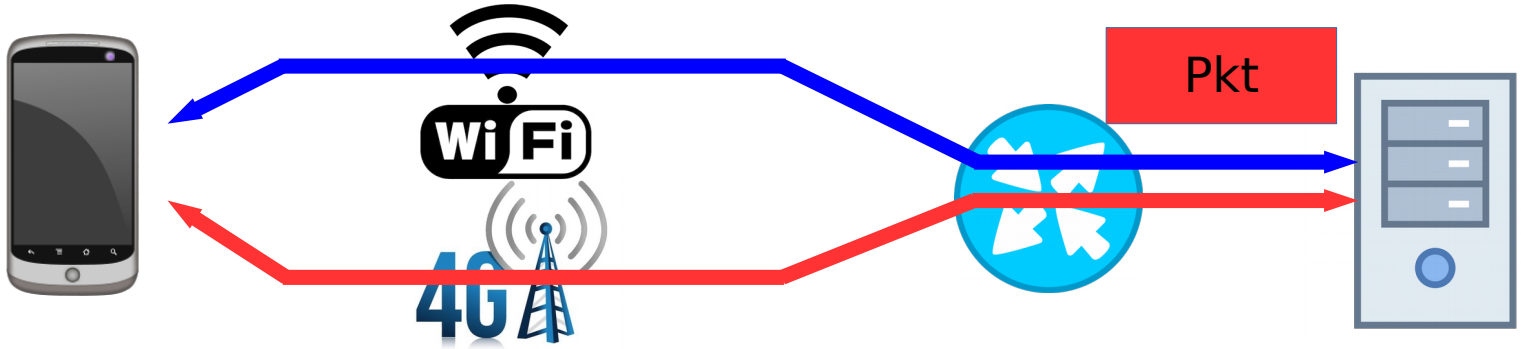

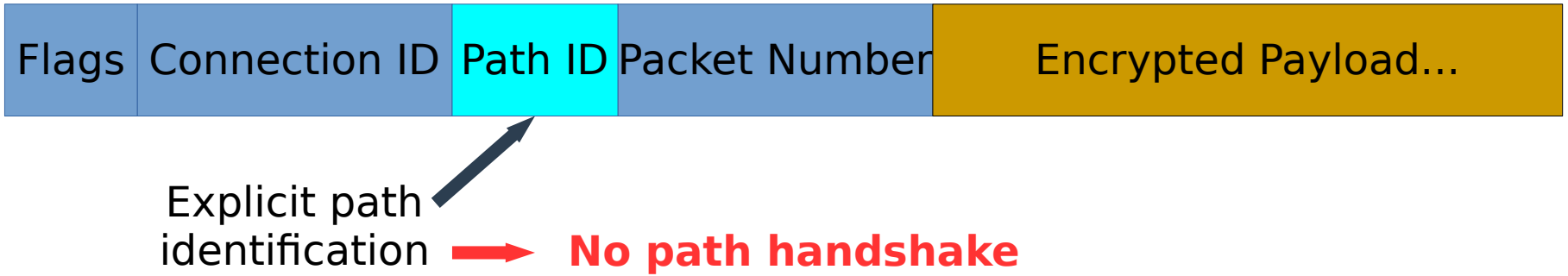

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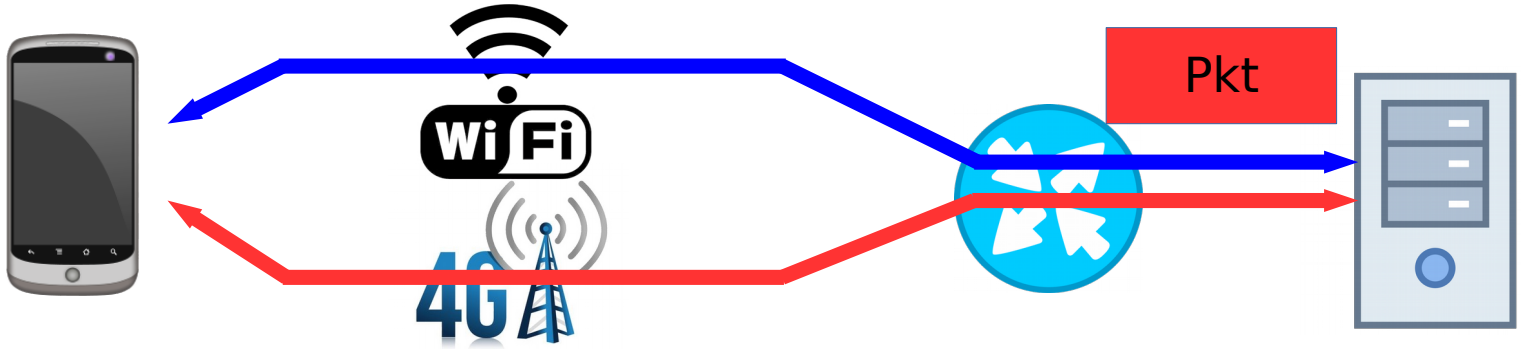
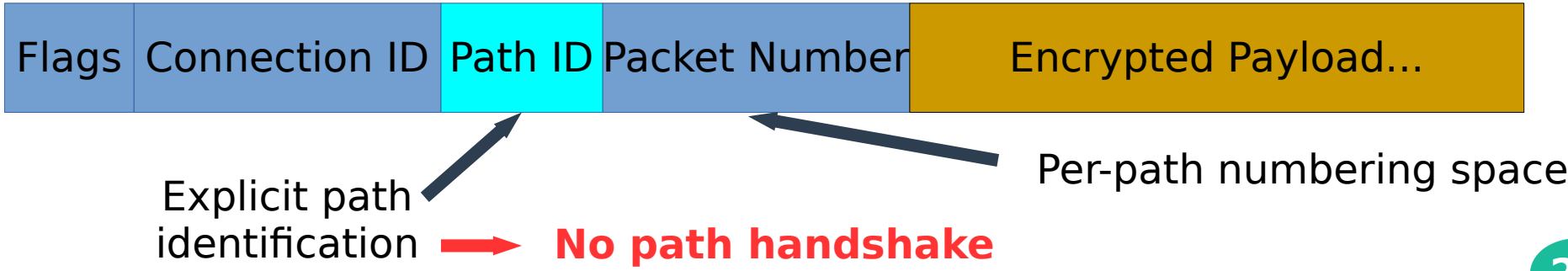
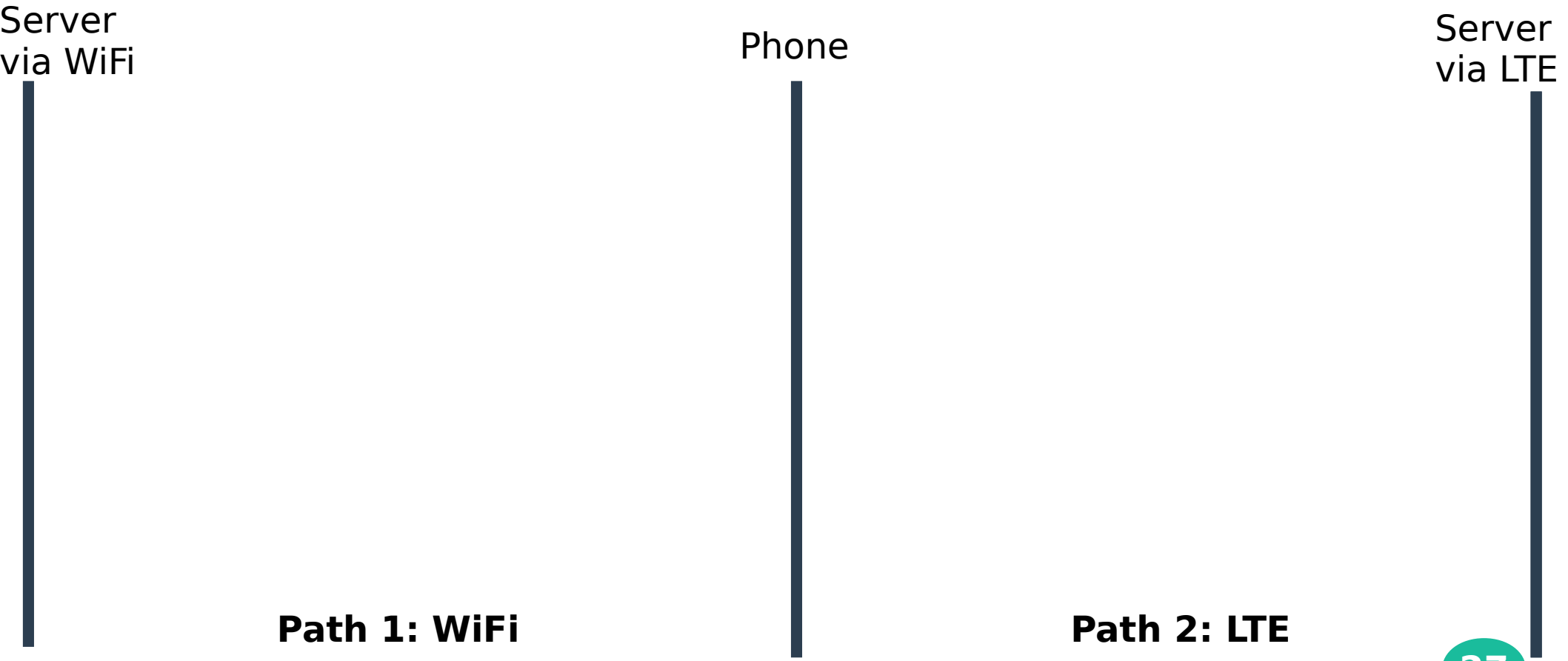




Multipath QUIC Data Transfer



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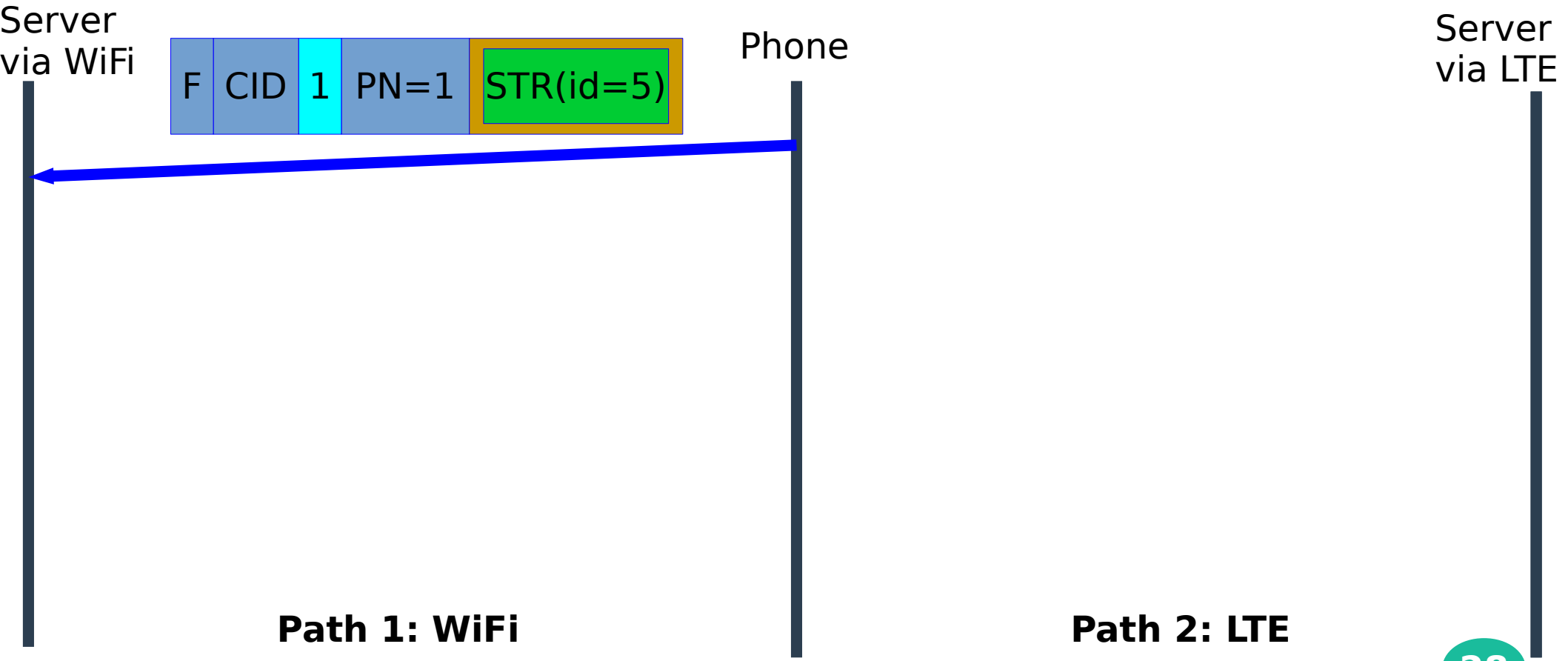

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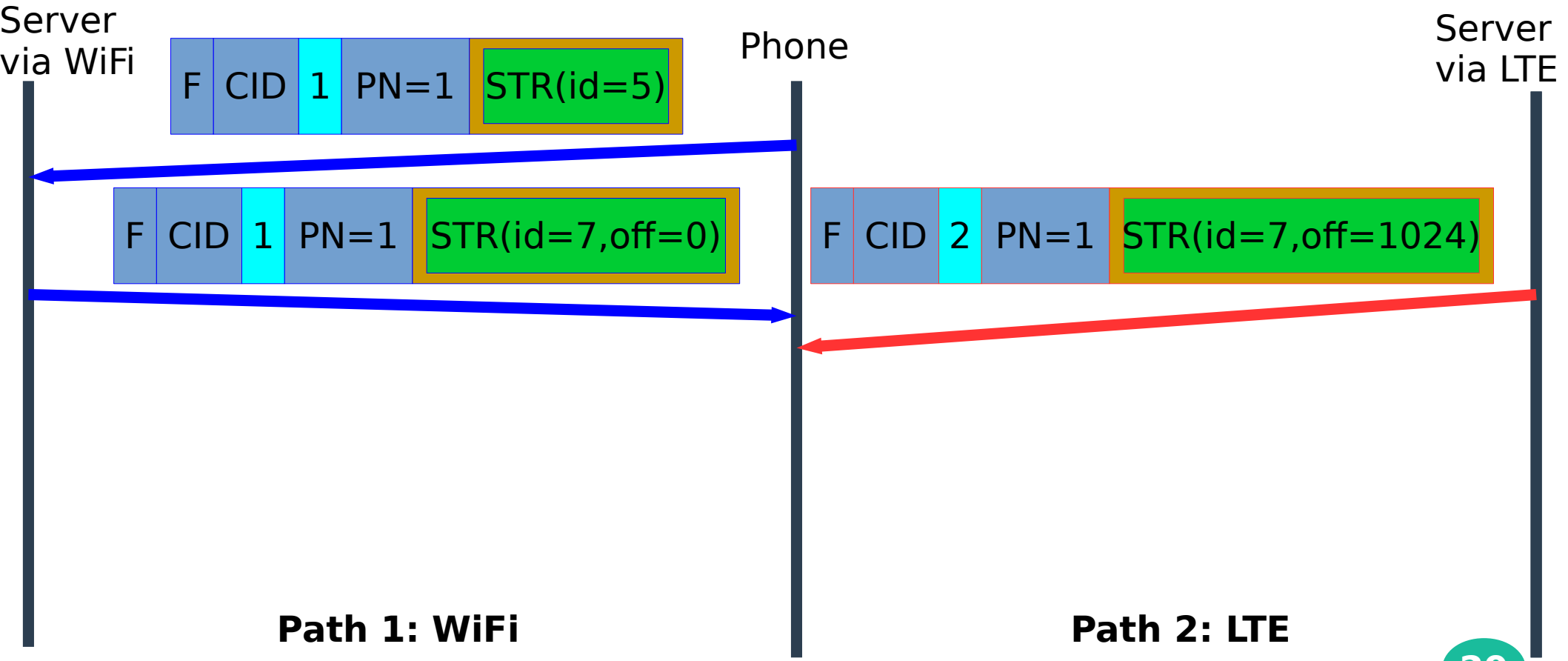

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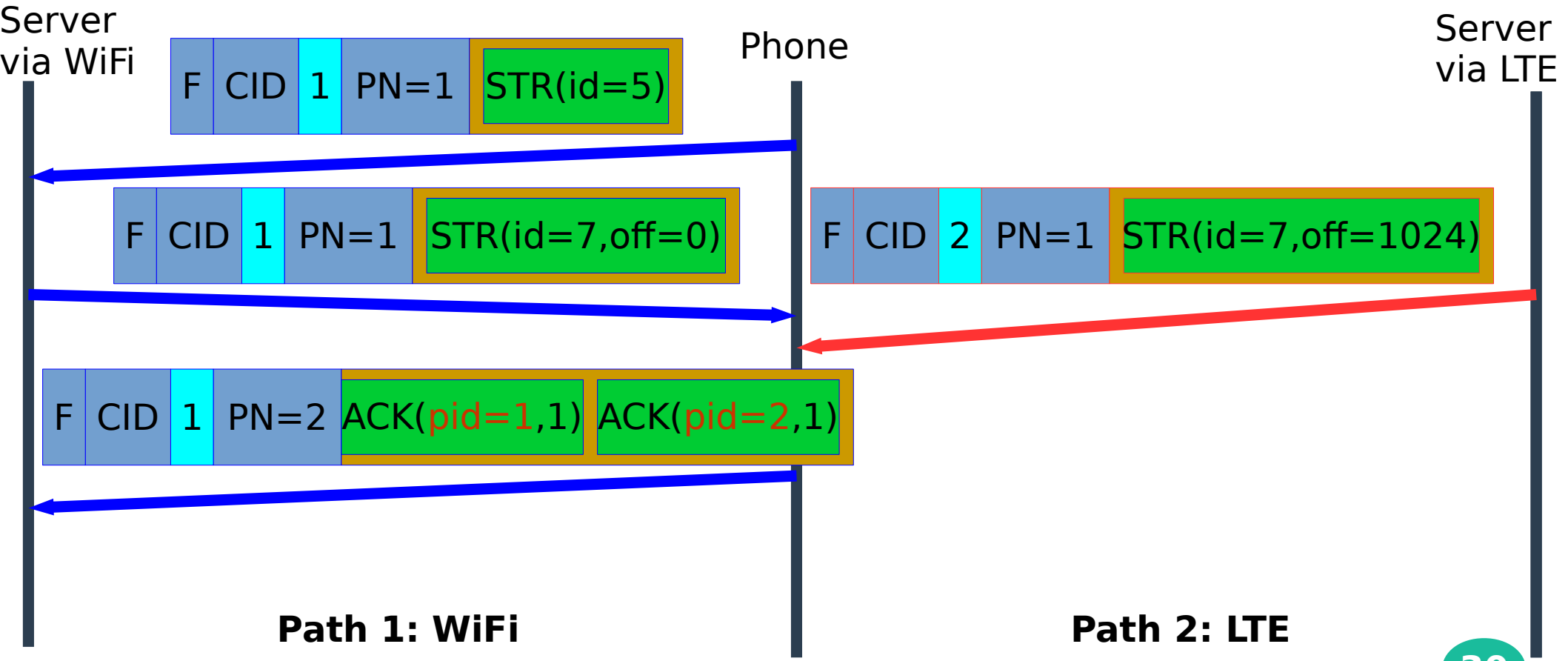

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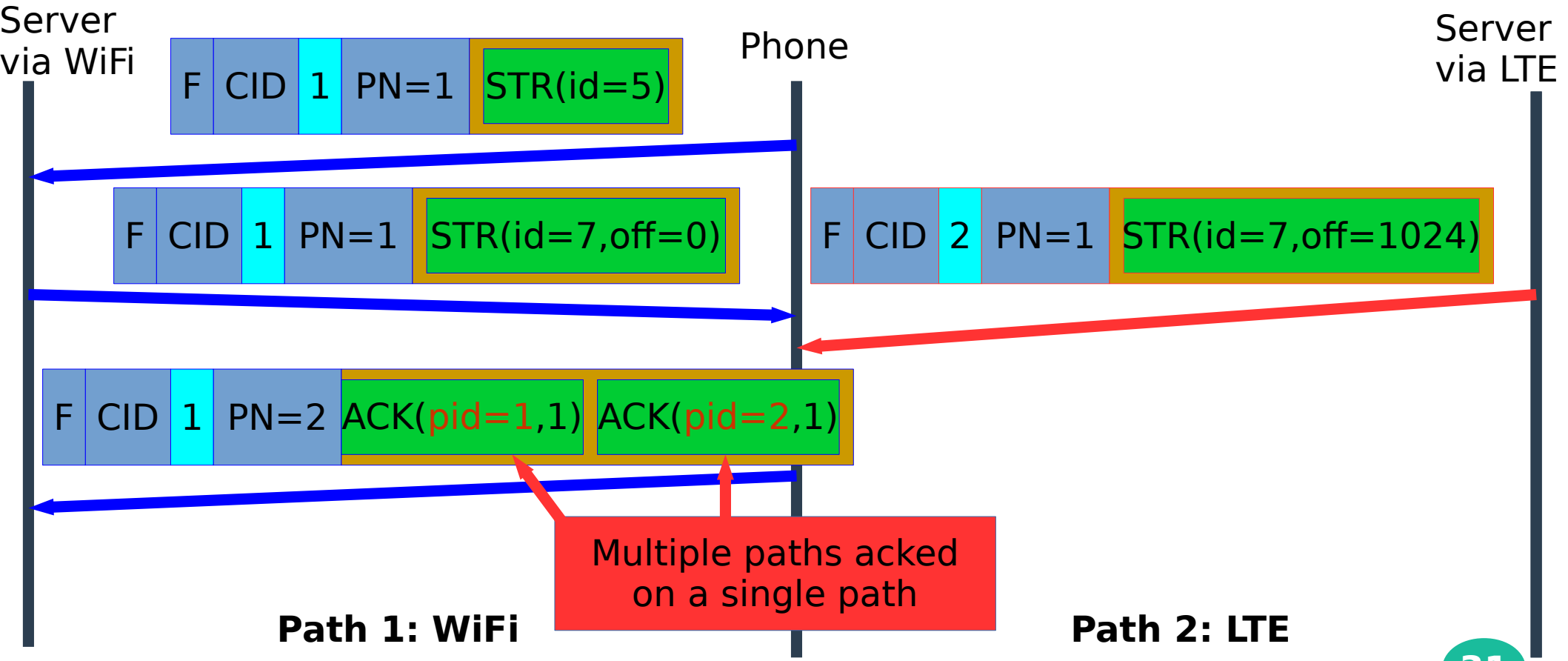


Multipath Mechanisms

- **Path management**

IP1

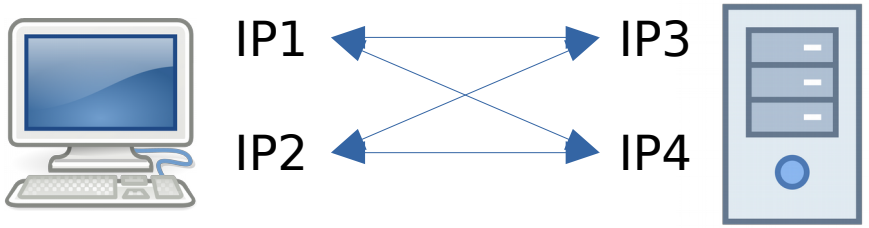
IP2

IP3

IP4

Multipath Mechanisms

- **Path management**



Multipath Mechanisms

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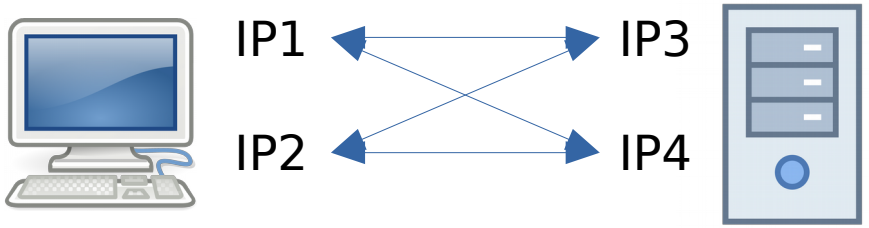
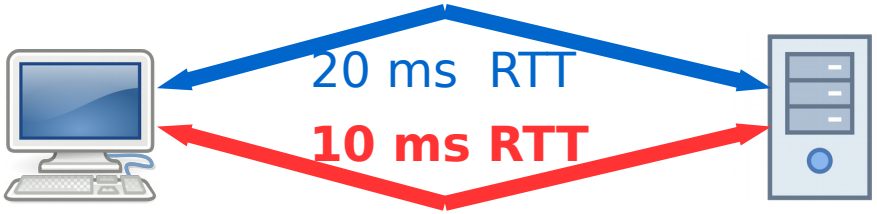


- **Packet scheduling**



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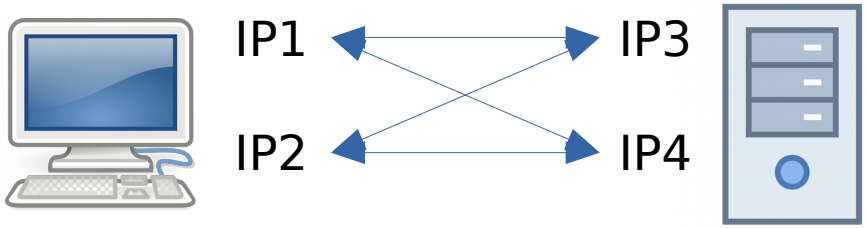

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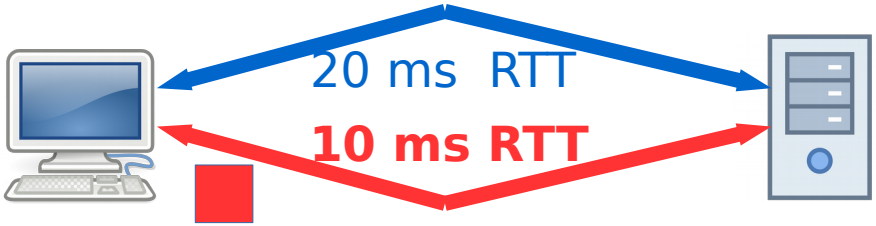

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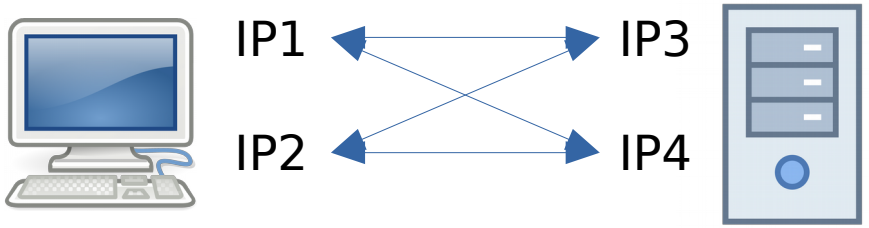

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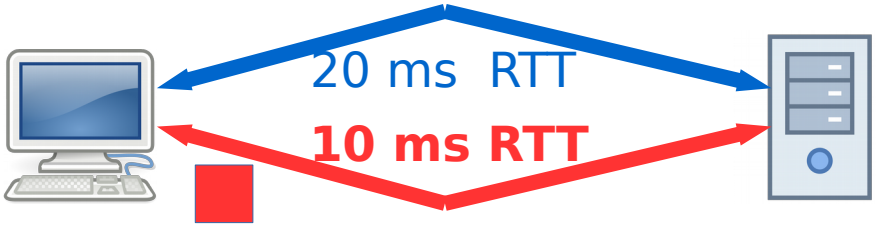

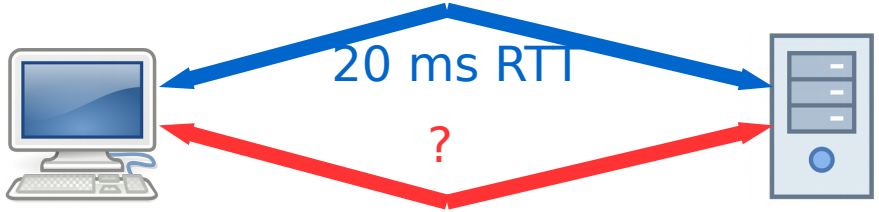

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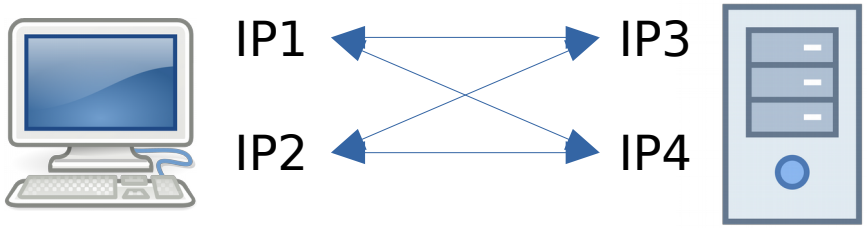

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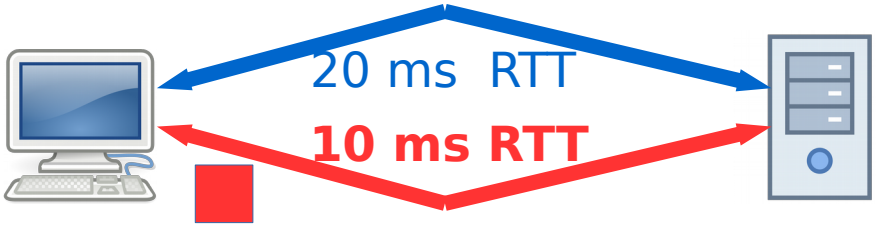

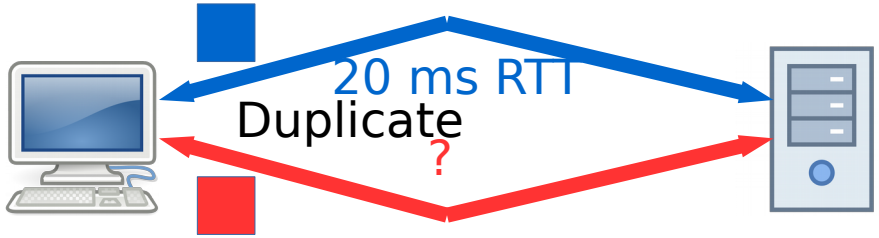

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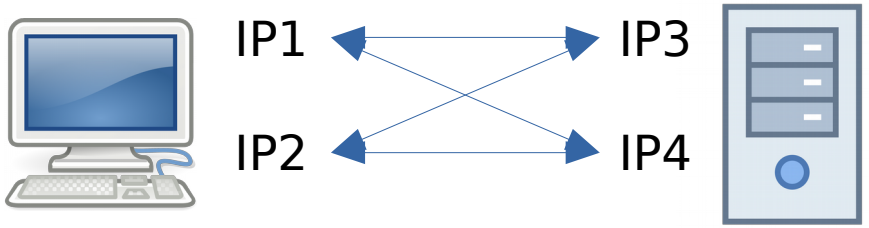

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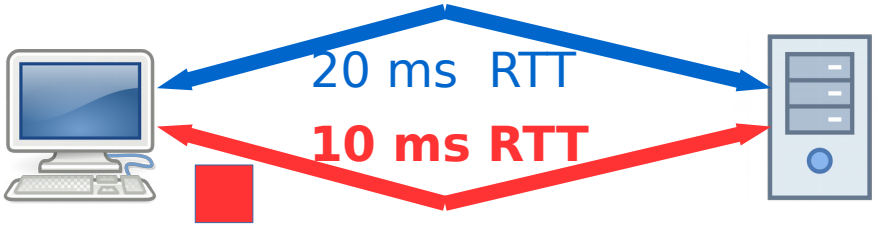
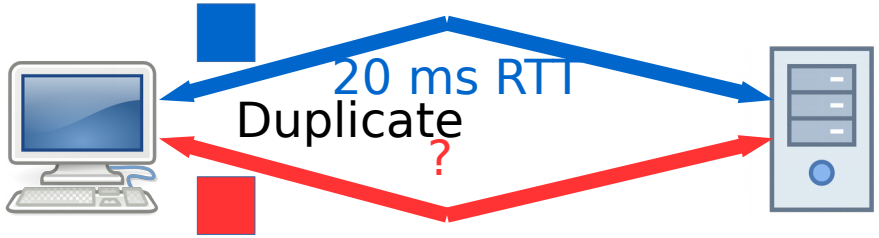
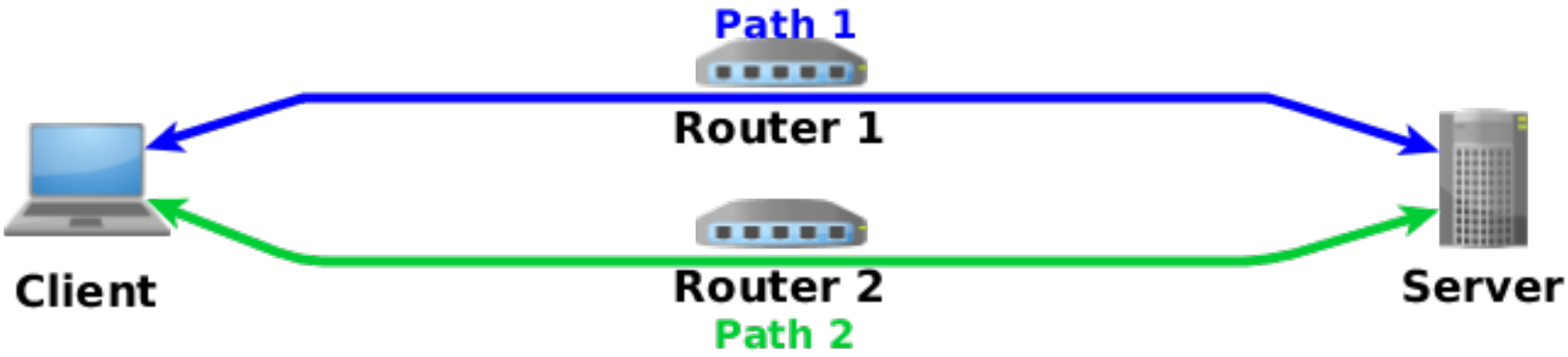




- **Congestion control**
  - Opportunistic Linked Increase Algorithm

Evaluation of Multipath QUIC

- **(Multipath) QUIC vs. (Multipath) TCP**
  - Multipath QUIC: quic-go
  - Linux Multipath TCP v0.91 with default settings
- **Mininet environment with 2 paths**



Evaluating Bandwith Aggregation

- **Download of 20 MB file**
  - Over a single stream
  - Collect the transfer time

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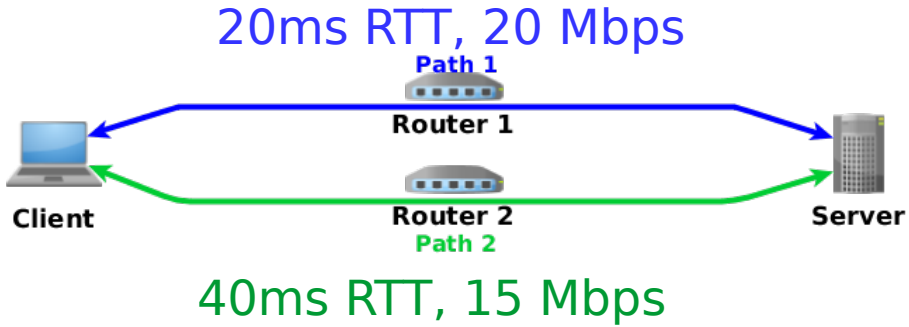
- **For a loss-free scenario**



Evaluating Bandwith Aggregation

- **Download of 20 MB file**
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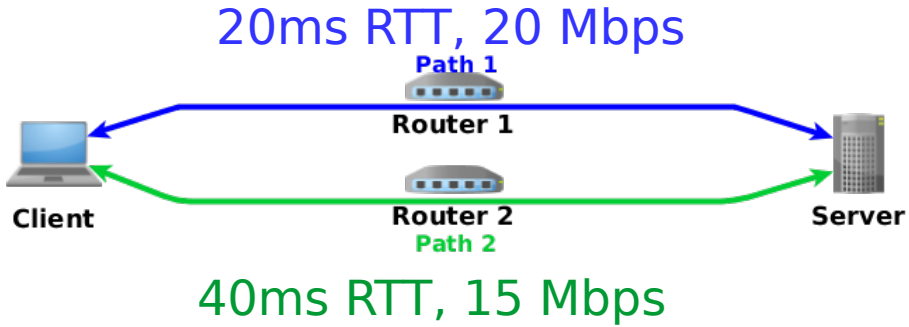
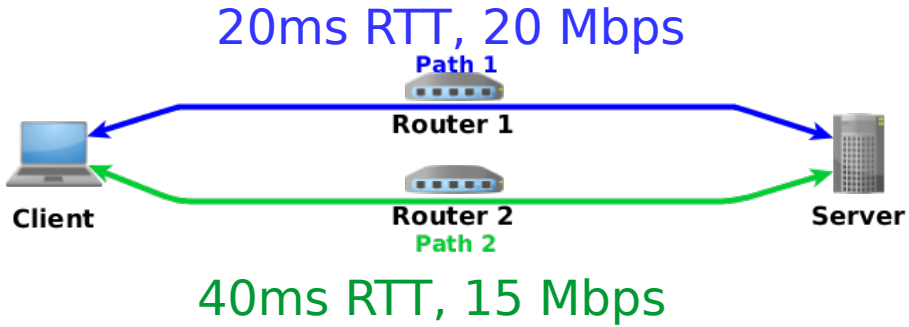
- **For a loss-free scenario**
  - MPQUIC has 13% speedup compared to MPTCP



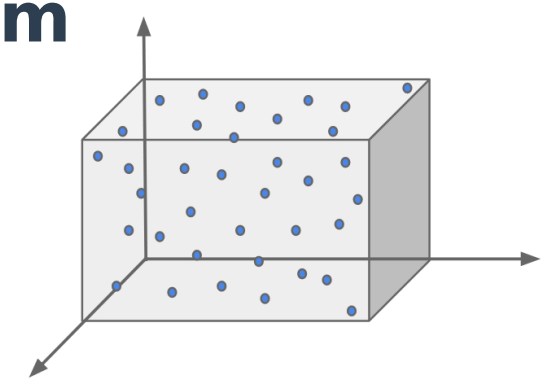
Evaluating Bandwith Aggregation

- **Download of 20 MB file**
  - Over a single stream
  - Collect the transfer time
- **For a loss-free scenario**
  - MPQUIC has 13% speedup compared to MPTCP
- **But what about other topologies?**



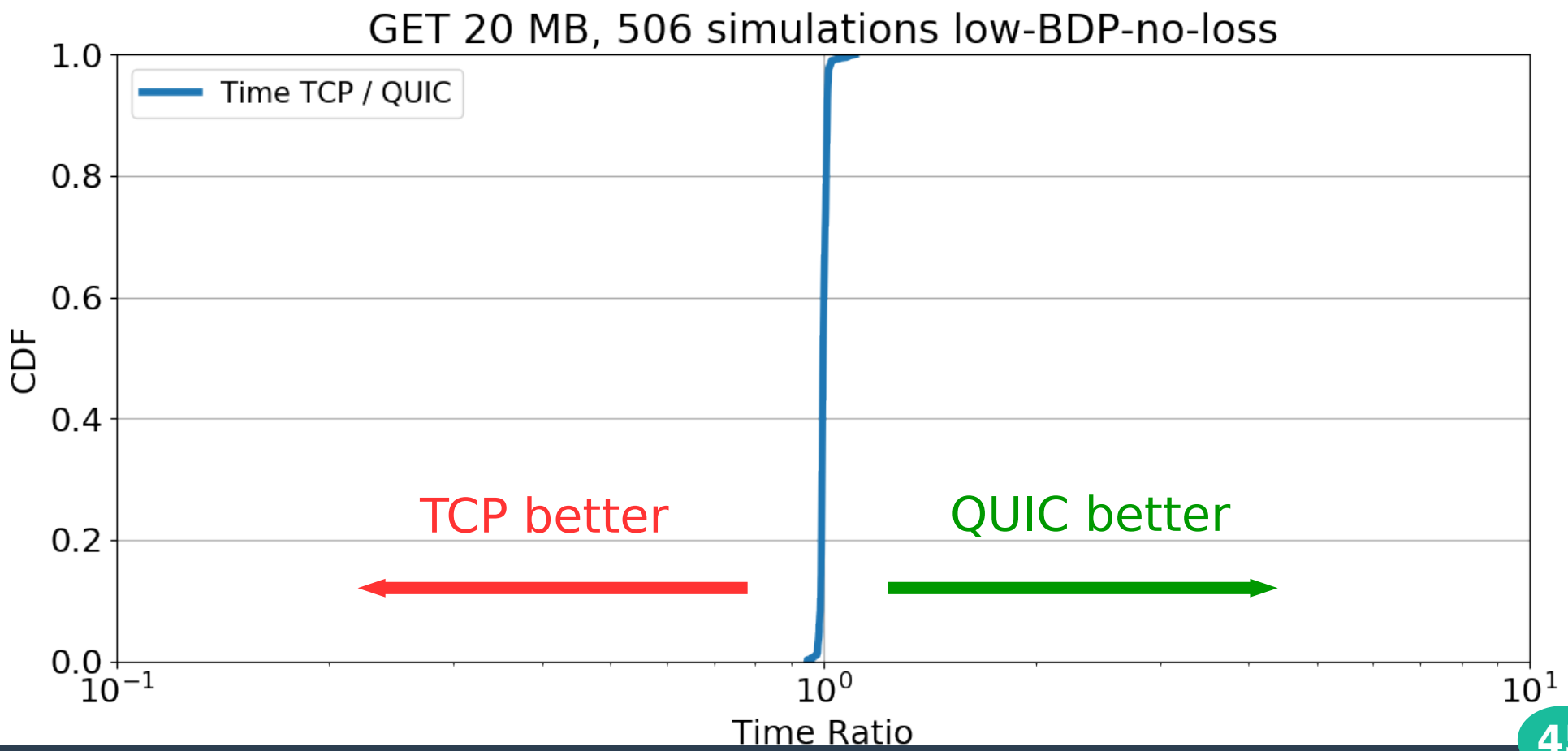
Evaluating Bandwidth Aggregation

- **Experimental design, WSP algorithm**
- **2x253 network scenarios**
  - Vary the initial path
- **Median over 15 runs**

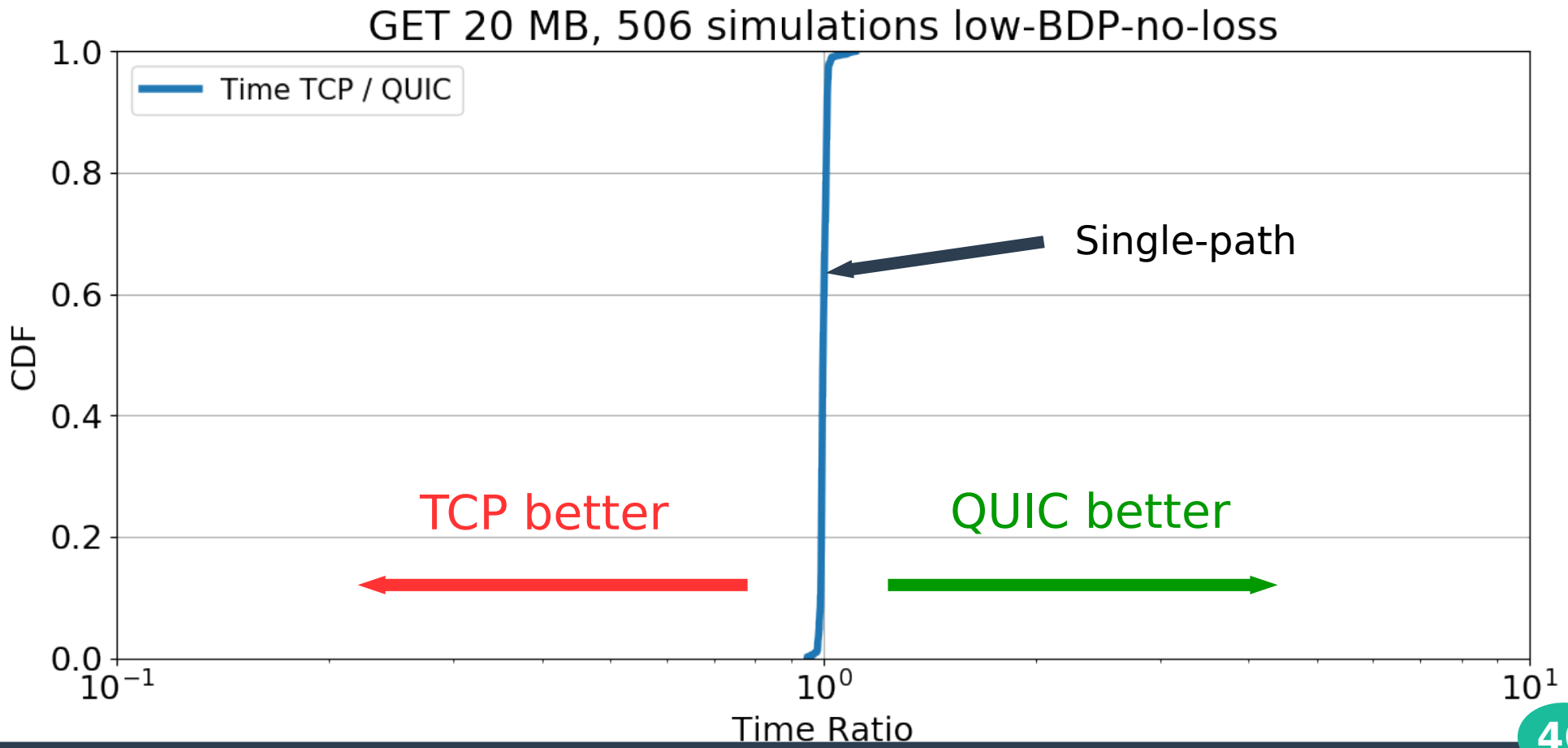


Factor	Minimum	Maximum
Capacity [Mbps]	0.1	100
Round-Trip-Time [ms]	0	50
Queuing Delay [ms]	0	100
Random Loss [%]	0	2.5

Large File Download – No Loss



Large File Download – No Loss



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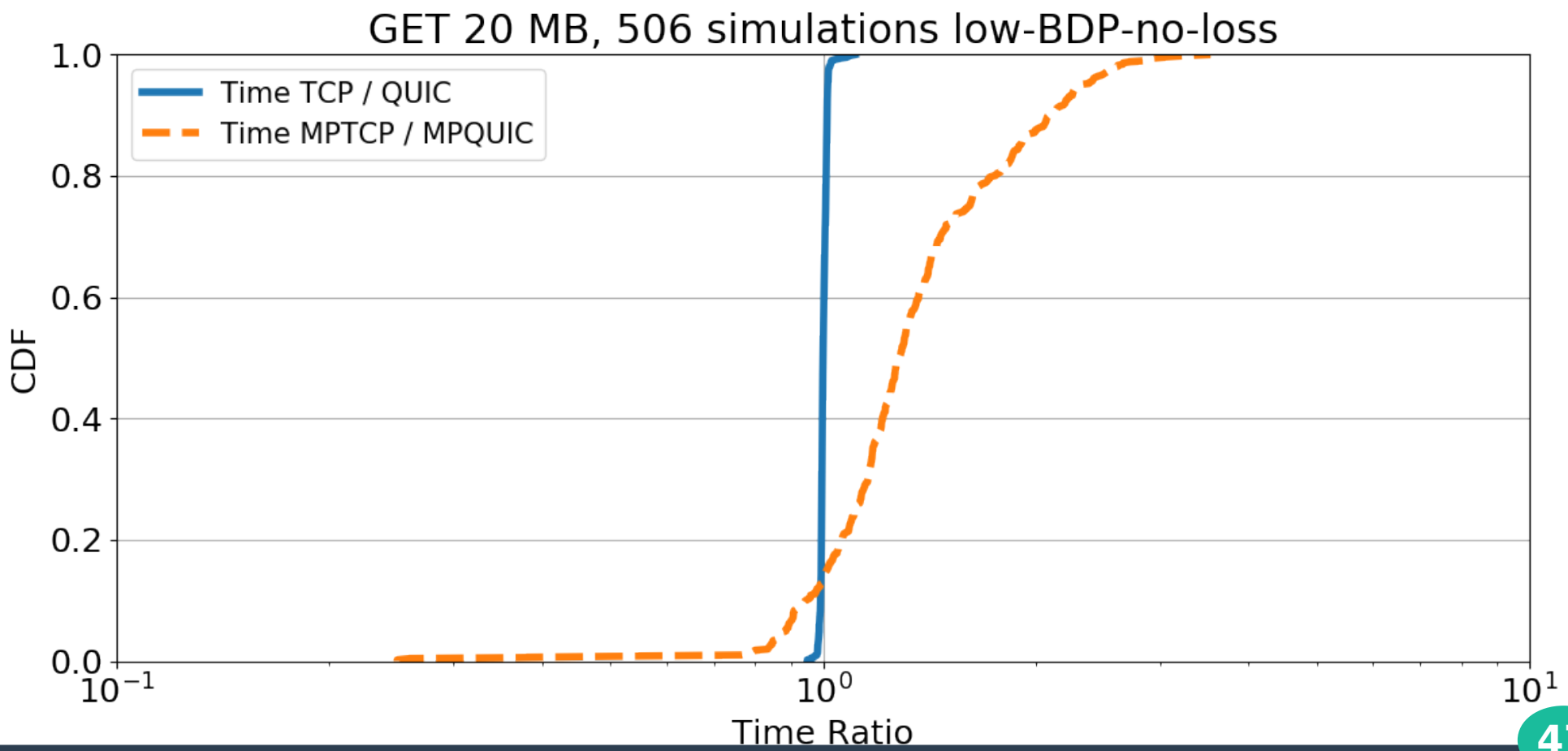

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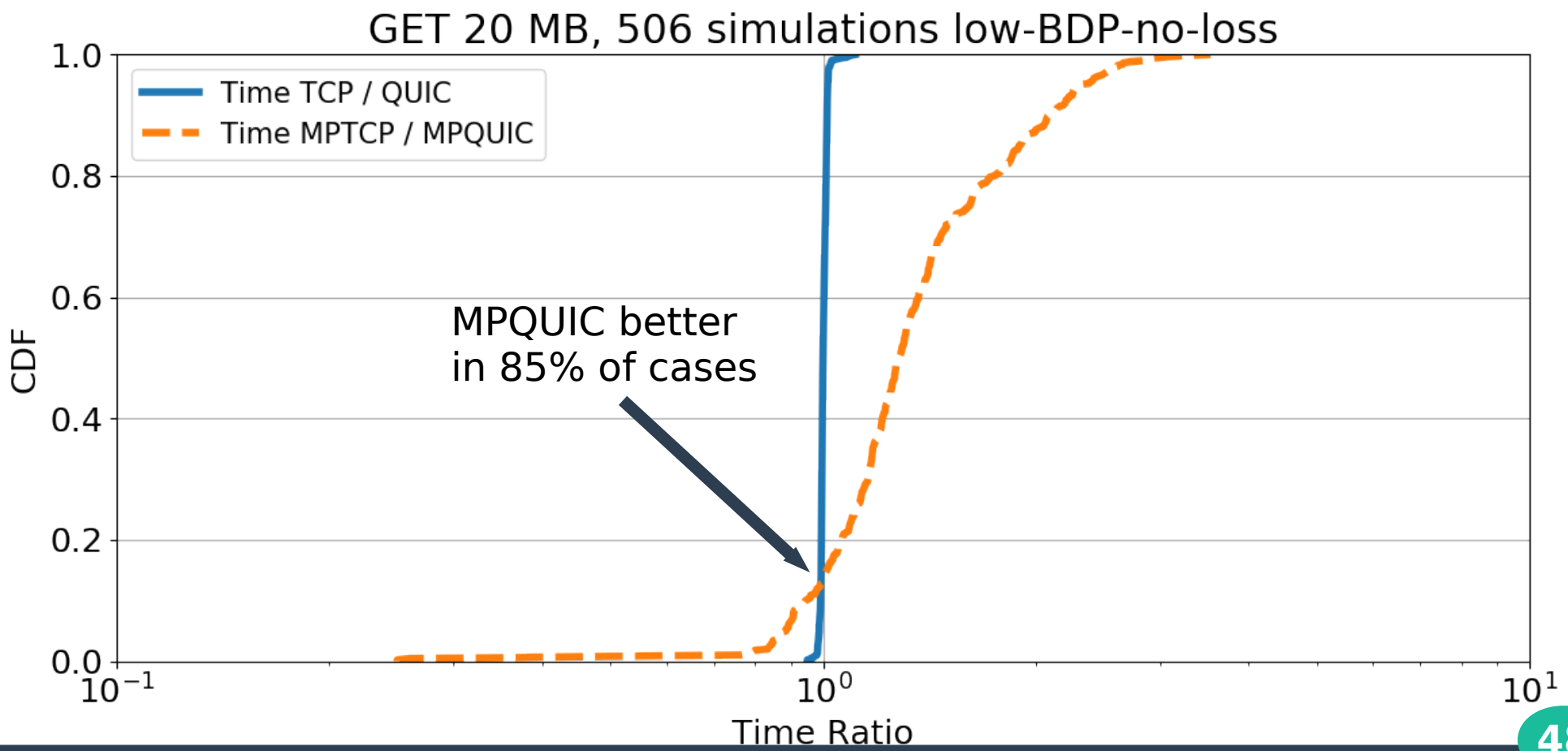

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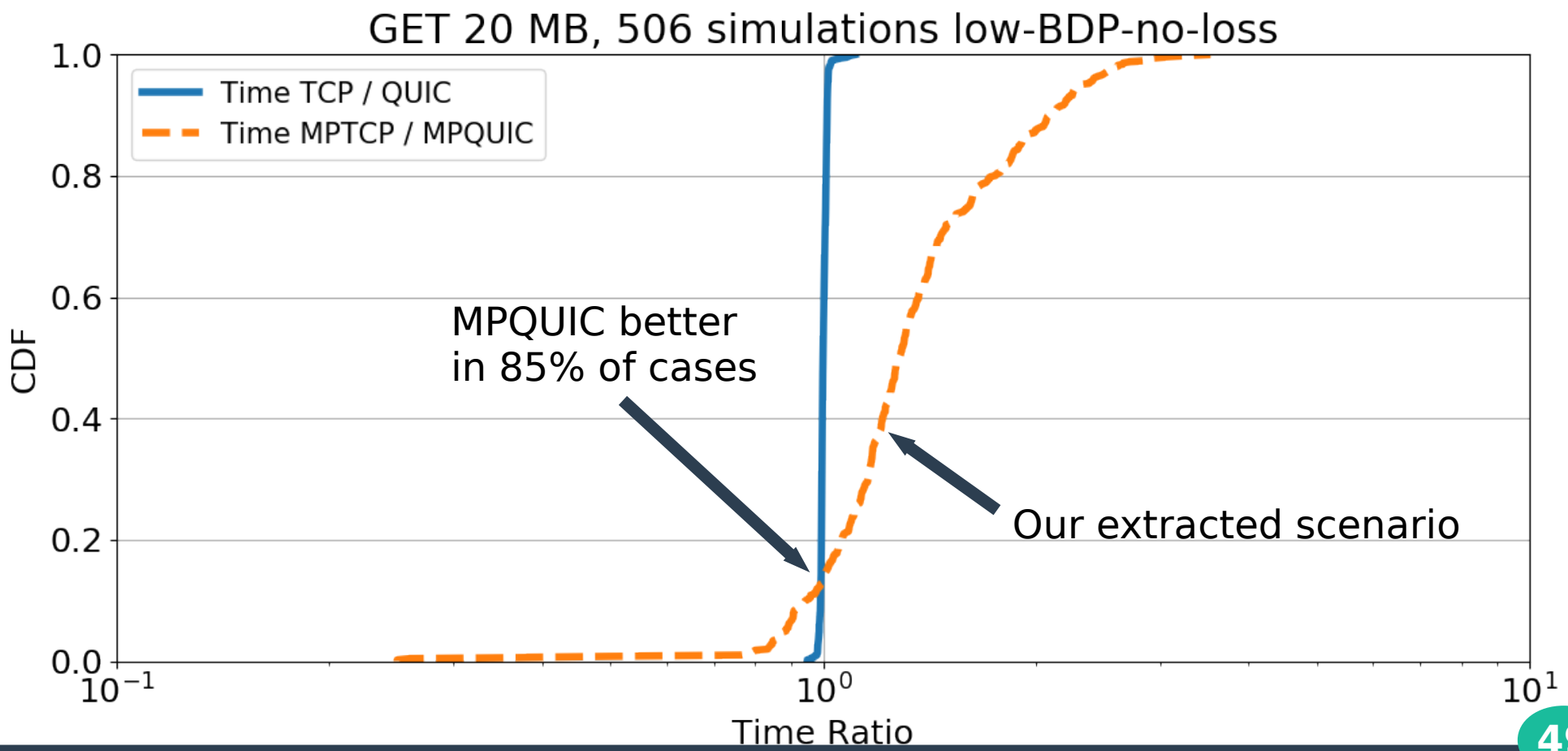

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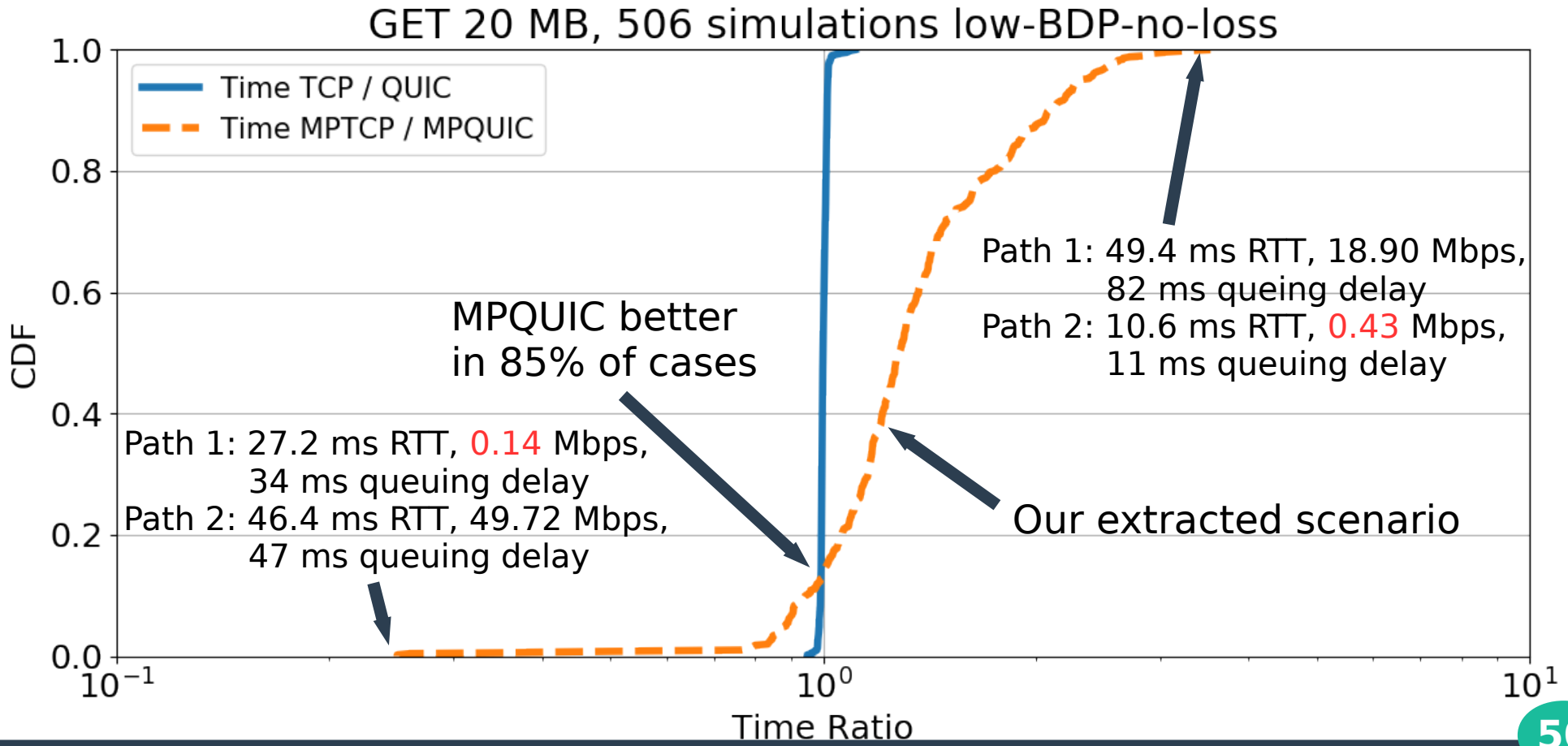

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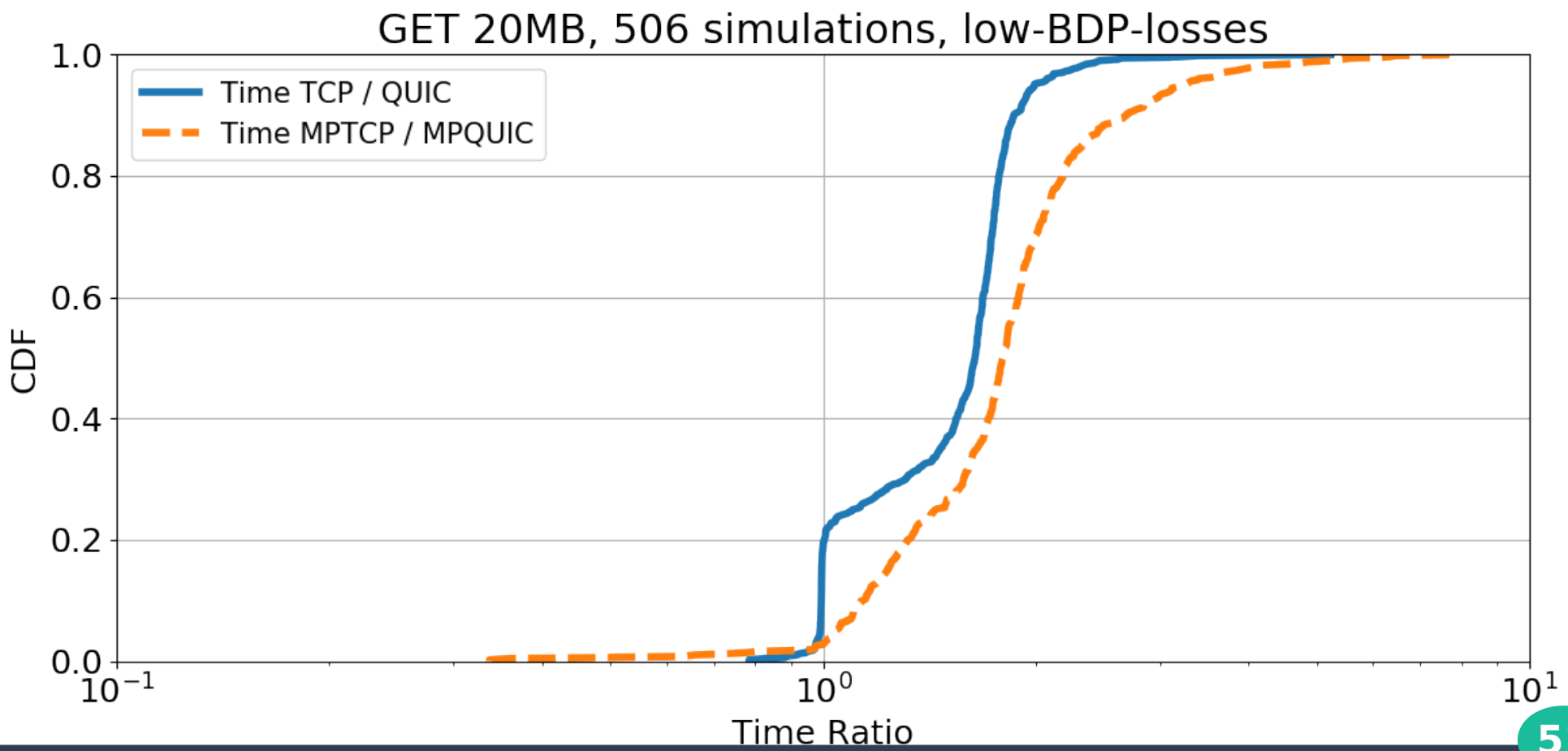

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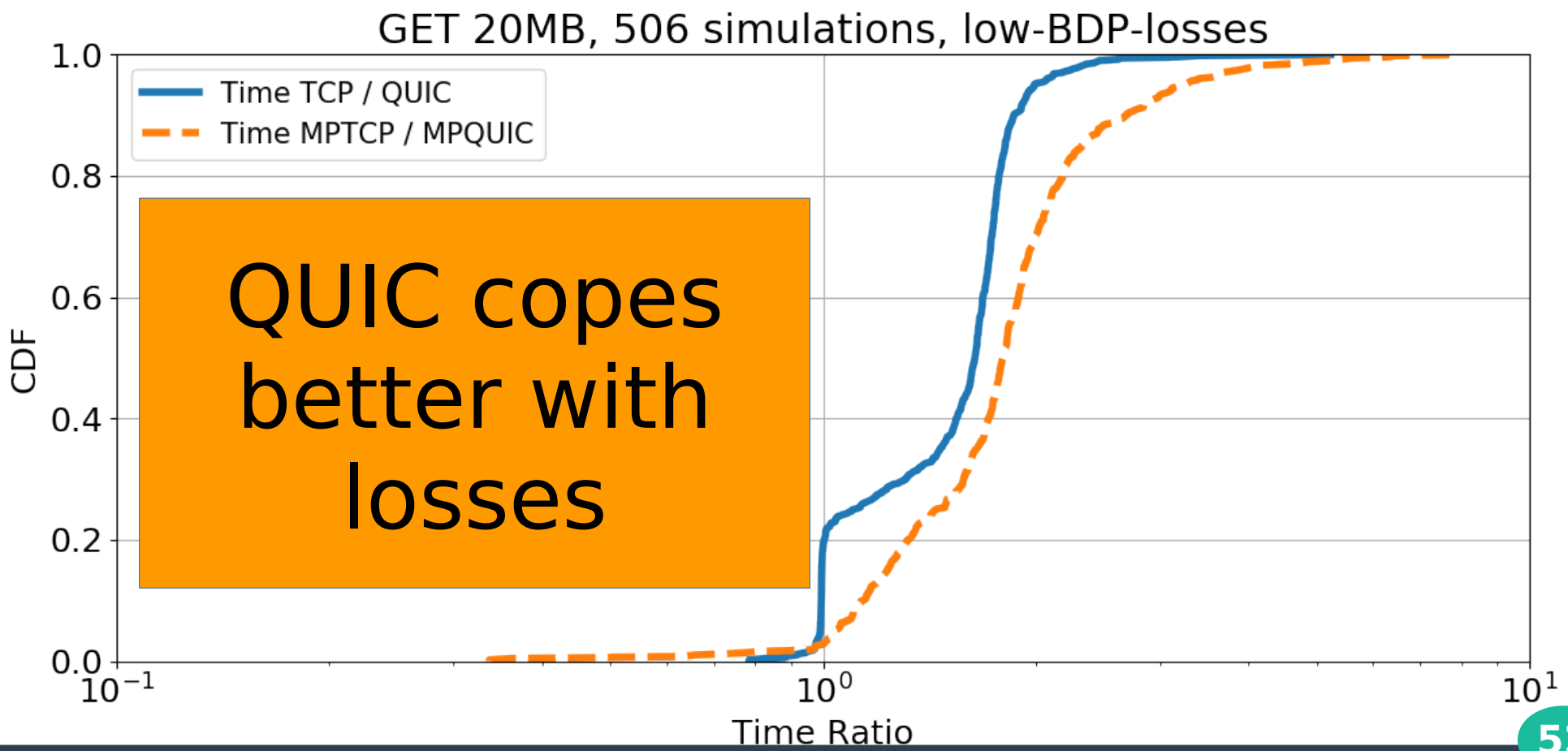


Additional Results (see paper)

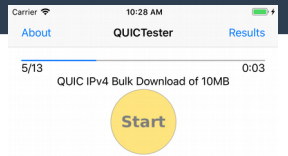
- **QUIC benefits more of Multipath than TCP**
- **Bandwidth aggregation in high BDP**
  - MPQUIC still better performs than MPTCP
- **Short file transfers**
  - (MP)QUIC better thanks to its low latency handshake
- **Network handover**
  - MPQUIC can be very efficient
  - New frame to communicate path state

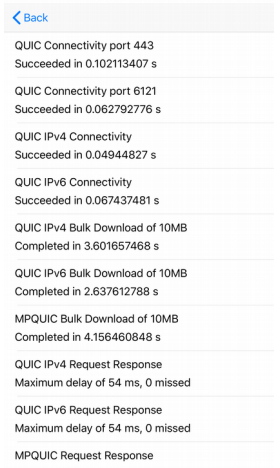
Conclusion

- **Multipath should be part of any transport protocol**
  - Most devices are multihomed
- **Designed and implemented Multipath QUIC**
  - Source code + artifacts + IETF draft available
  - See multipath-quic.org
- **Multipath more promising with QUIC than TCP**

What’s Next?

- **Perform tests in actual networks**
  - Does (MP)QUIC work in **your** networks?
  - Does MPQUIC provides better performances?
  - Application running on iOS11
    - https://itunes.apple.com/fr/app/quictester/id1322019644?mt=8
  - Feel free to provide feedback :-)





QUICTester

Thanks!

multipath-quic.org