Communication Networks 2
Exercise 3 - Multipath TCP

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Problem 1 Fundamentals I

Explain the general idea and the basic concept of MPTCP. What are MPTCPs two main applications?

Solution:
The general idea behind MPTCP is to use several IP enabled network interfaces at the same time for the same MPTCP connection. Traditional TCP connections have exactly one starting point and exactly one endpoint, an MPTCP connection theoretically has unlimited starting and end points. Potential advantages are increased throughput by sending/receiving on multiple IP enabled interfaces in parallel, the transition of a connection between different network interfaces and an increased fault tolerance by using one of the interfaces as backup.

An MPTCP connection consists of several TCP connections (called *subflows*), that can be opened and closed at will. Data can be sent over any of the active subflows, depending on the MPTCP mode.

The two main applications are smartphones and datacenters.

Problem 2 Fundamentals II

Name and explain the three operating modes of MPTCP.

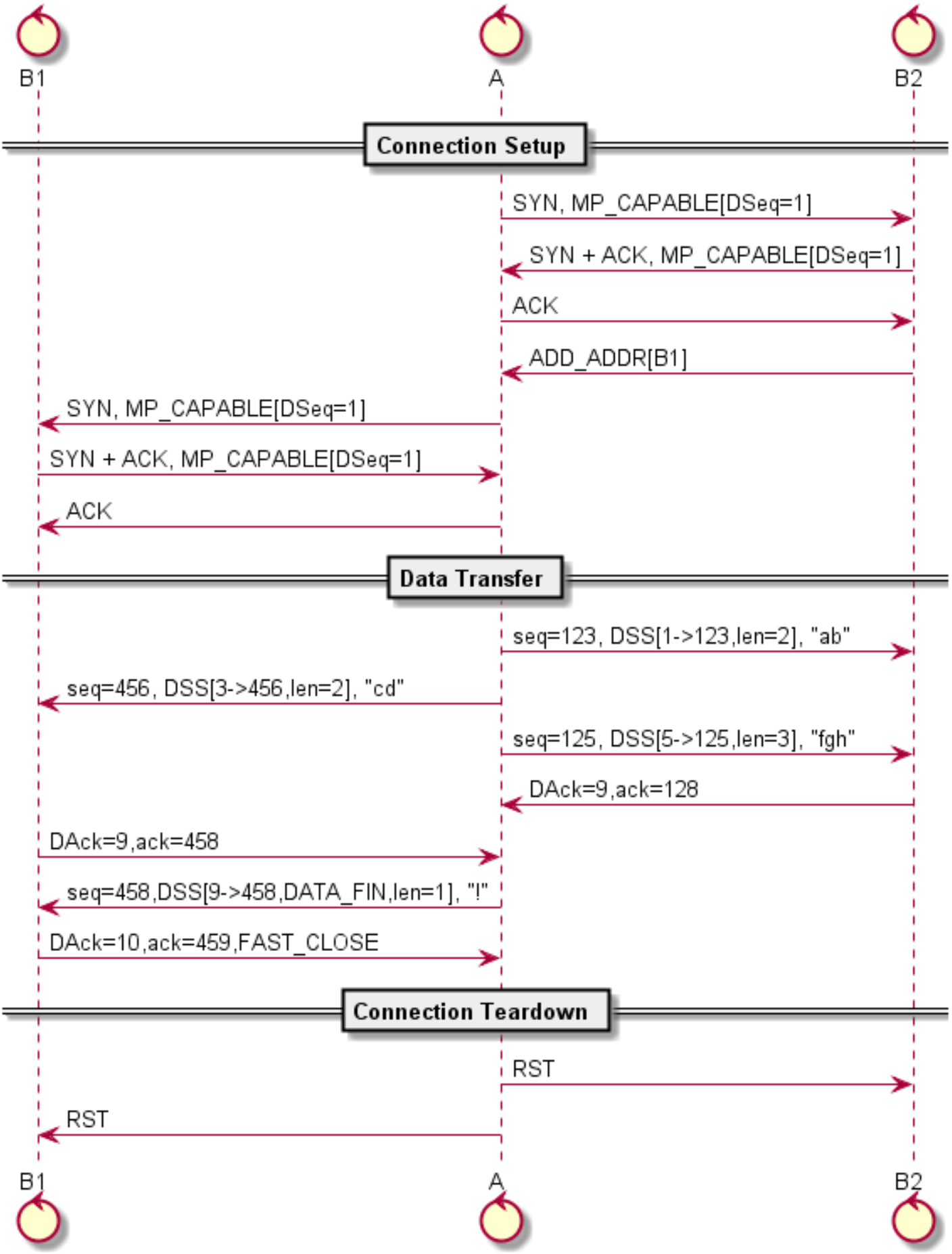
Solution:

- *Full Mode*: Subflows are established for all available IP-enabled interfaces and data is sent over all established subflows.
- *Backup Mode*: Subflows are established for all available IP-enabled interfaces but data is sent over only one subflow.
- *Single Path Only*: A subflow is only established for one IP-enabled interface, data is sent over this one subflow.

Problem 3 Work Flow

Fill in the schematic MPTCP message exchange on the next page, attempting to send 'abcdefgh!' from *A* to *B*. Assume no package loss. Note: You only need to add packages in the *Connection Teardown* phase.

Solution:
Important Remark


B1
A
B2
Connection Setup
SYN, MP_CAPABLE[DSeq=1]
SYN + ACK, MP_CAPABLE[DSeq=1]
ACK
ADD_ADDR[B1]
SYN, MP_CAPABLE[DSeq=1]
SYN + ACK, MP_CAPABLE[DSeq=1]
ACK
Data Transfer
seq=123, DSS[1->123,len=2], "ab"
seq=456, DSS[3->456,len=2], "cd"
seq=125, DSS[5->125,len=3], "fgh"
DAck=9,ack=128
DAck=9,ack=458
seq=458,DSS[9->458,DATA_FIN,len=1], "!"
DAck=10,ack=459,FAST_CLOSE
Connection Teardown
RST
RST
B1
A
B2

a) The Data ACK is analogous to the behavior of the standard TCP cumulative ACK – indicating how much data has been successfully received (with no holes).

b) The Data ACK specifies the next data sequence number it expects to receive.

c) c.f. *RFC 6824*, page 28

Problem 4 Information Exchange

How is MPTCP information exchanged? What problem can occur regarding the exchange? How is that problem handled?

Solution:
MPTCP options are exchanged encoded in a newly specified TCP option. Even though adding a new option is the intended way of extending TCP, some middleboxes might still remove any unknown TCP options. If the TCP option used to transport the MPTCP information is removed en route, MPTCP automatically falls back to TCP because without the MPTCP information the End Systems do not know whether or not the other side supports MPTCP.

Problem 5 Sequence Numbers

How are sequence numbers handled in MPTCP and why? What problem still persists, how is it detected and handled?

Solution:
There are two levels of sequence numbers, *Data* and *TCP*. The *TCP* sequence numbers identify data within every individual subflow (which are classical TCP connections) while *Data* sequence numbers are used to reassamble data sent over different TCP subflows. The two levels are necessary because TCP does not allow for gaps in sequence numbers, which would happen if there was only one level of sequence numbers and an MPTCP connection would spread data across multiple subflows.

A problem might occur if a middlebox inserts bytes into the bytestream. In this case, the mapping between data sequence numbers and TCP sequence numbers is thrown off. MPTCP detects changes to the payload by inserting its own checksum and reverts to traditional TCP if bytes are inserted or removed.

Problem 6 Middleware Characteristics

Complete the partially filled middleware characteristic table below.

Solution:

	Violates End2End?	Layer	Alters IP Header?	Alters TCP Header?	Alters Payload?	Interferes?
Router	No	3	Yes	No	No	No
Switch	No	2	No	No	No	No
NAT	Yes	3	Yes	Yes	No	Yes
NAT with ALG	Yes	5	Yes	Yes	Yes	Yes
Hub	No	1	No	No	No	No

Problem 7 MPTCP Failure

What would *not* cause an MPTCP connection to fail?
◯ One of the involved Endsystems does not support MPTCP.
◯ A middlebox on the path removes all unknown TCP options.
◯ A router on the path does not support MPTCP.
◯ The payload of packages is changed.

Solution:
◯ One of the involved Endsystems does not support MPTCP.
◯ A middlebox on the path removes all unknown TCP options.
⊗ A router on the path does not support MPTCP.
◯ The payload of packages is changed.
MPTCP operates on Layer 4, a router, as we refer to it in this lecture, refers to an L3 device and as such does not interact with the MPTCP protocol at all.

Problem 8 MPTCP Architecture

What is *not* part of the MPTCP architecture?
◯ Congestion Control
◯ Control Plane
◯ Data Plane
◯ 4-way Handshake
◯ Fast Close

Solution:
◯ Congestion Control
◯ Control Plane
◯ Data Plane
⊗ 4-way Handshake
◯ Fast Close
Both TCP and MPTCP use a 3-way handshake, a 4-way handshake is for example incorporated in SCTP.

Problem 9 MPTCP Advantadges

MPTCP provides the following benefits over TCP
◯ Framing of Messages
◯ Multi Streaming
◯ Adaptive Flow Control
◯ Multi Homing

Solution:
◯ Framing of Messages
◯ Multi Streaming
◯ Adaptive Flow Control

⊗ Multi Homing
Multi Homing is one of if not the key feature of MPTCP.

Problem 10 MPTCP Objectives

What is not an objective of MPTCP?
◯ To work on unmodified applications
◯ To work over all current networks
◯ To work where TCP works
◯ To reduce the latency of connections

Solution:
◯ To work on unmodified applications
◯ To work over all current networks
◯ To work where TCP works
⊗ To reduce the latency of connections