

Communication Networks - Assignment 03

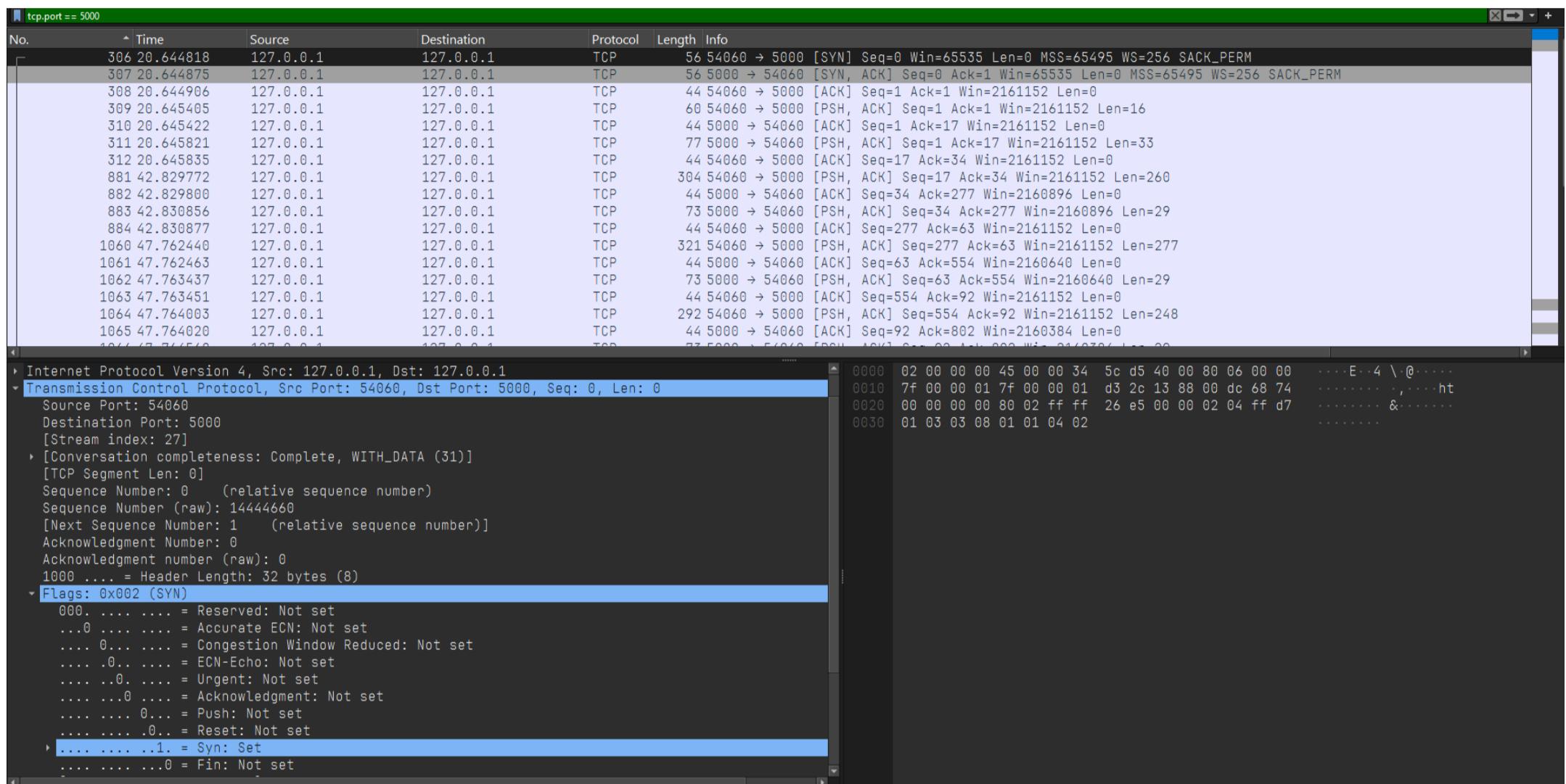
שם שותף ראשון: עלआ אלדון ابو חגלה

ת.ז שותף ראשון: 322231580

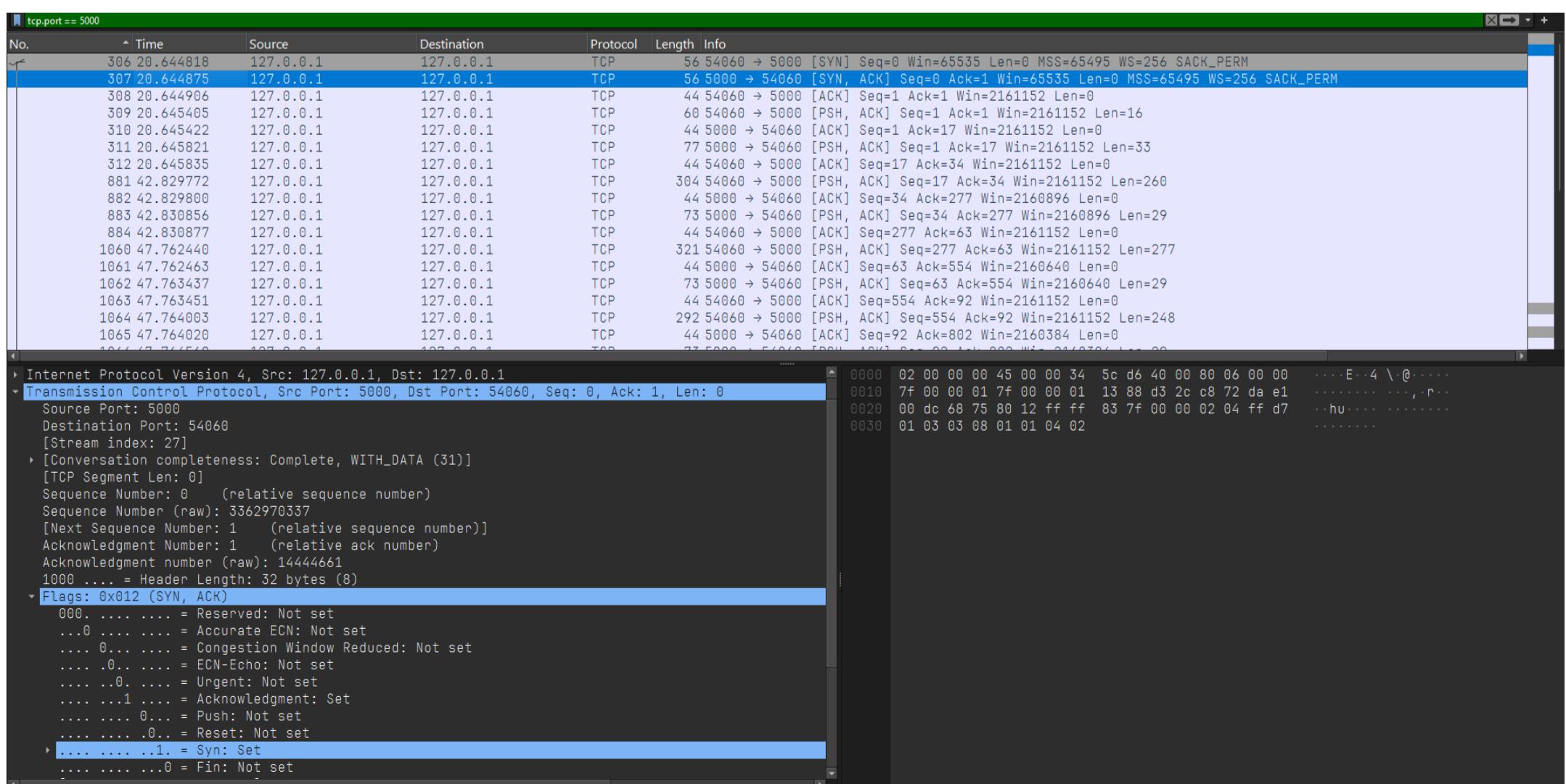
שם שותף שני: עידן בהן

ת.ז שותף שני: 322541327

Wireshark Screenshots



In the screenshot above, we can observe that the first packet sent by the client after the opening of port 5000 is a SYN packet, intended for initializing a connection between the client and the server.



In this screenshot, the server replies with a **SYN/ACK** packet, indicating that it accepts the client's request to initialize a connection.

No.	Time	Source	Destination	Protocol	Length	Info	Hex	Dec
306	20.644818	127.0.0.1	127.0.0.1	TCP	56	54060 → 5000 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM	0000 02 00 00 00 45 00 00 28	... E ..(\ @ ...
307	20.644875	127.0.0.1	127.0.0.1	TCP	56	5000 → 54060 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM	0010 7f 00 00 01 7f 00 00 01 , ,hu
308	20.644906	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1 Ack=1 Win=2161152 Len=0	0020 c8 72 da e2 50 10 20 fa	..r .P
309	20.645405	127.0.0.1	127.0.0.1	TCP	60	54060 → 5000 [PSH, ACK] Seq=1 Ack=1 Win=2161152 Len=16		
310	20.645422	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=1 Ack=17 Win=2161152 Len=0		
311	20.645821	127.0.0.1	127.0.0.1	TCP	77	5000 → 54060 [PSH, ACK] Seq=1 Ack=17 Win=2161152 Len=33		
312	20.645835	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=17 Ack=34 Win=2161152 Len=0		
881	42.829772	127.0.0.1	127.0.0.1	TCP	304	54060 → 5000 [PSH, ACK] Seq=17 Ack=34 Win=2161152 Len=260		
882	42.829800	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=34 Ack=277 Win=2160896 Len=0		
883	42.830856	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=34 Ack=277 Win=2160896 Len=29		
884	42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0		
1060	47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277		
1061	47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0		
1062	47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29		
1063	47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0		
1064	47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248		
1065	47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0		
					77	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=20		

Here, in packet **308**, we observe that the client replies with an **ACK**, which is necessary to finally begin the data exchange, this process is called the **three-way handshake**, and is necessary for initiating secure and reliable TCP connections between two endpoints. At this point, the client is allowed and ready to send data to the server.

No.	Time	Source	Destination	Protocol	Length	Info	Hex	Dec
306	20.644818	127.0.0.1	127.0.0.1	TCP	56	54060 → 5000 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM	0000 02 00 00 00 45 00 00 28	... E ..(\ @ ...
307	20.644875	127.0.0.1	127.0.0.1	TCP	56	5000 → 54060 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM	0010 7f 00 00 01 7f 00 00 01 , ,hu
308	20.644906	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1 Ack=1 Win=2161152 Len=0	0020 c8 72 da e2 50 10 20 fa	..r .P
309	20.645405	127.0.0.1	127.0.0.1	TCP	60	54060 → 5000 [PSH, ACK] Seq=1 Ack=1 Win=2161152 Len=16		
310	20.645422	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=1 Ack=17 Win=2161152 Len=0		
311	20.645821	127.0.0.1	127.0.0.1	TCP	77	5000 → 54060 [PSH, ACK] Seq=1 Ack=17 Win=2161152 Len=33		
312	20.645835	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=17 Ack=34 Win=2161152 Len=0		
881	42.829772	127.0.0.1	127.0.0.1	TCP	304	54060 → 5000 [PSH, ACK] Seq=17 Ack=34 Win=2161152 Len=260		
882	42.829800	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=34 Ack=277 Win=2160896 Len=0		
883	42.830856	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=34 Ack=277 Win=2160896 Len=29		
884	42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0		
1060	47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277		
1061	47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0		
1062	47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29		
1063	47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0		
1064	47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248		
1065	47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0		
					77	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=20		

In packet number **881**, we may observe a packet containing the text that the client has sent over to the server, the text states:

Hello server! Ariel University student sending message!

No.	Time	Source	Destination	Protocol	Length	Info
306	20.644818	127.0.0.1	127.0.0.1	TCP	56	54060 → 5000 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
307	20.644875	127.0.0.1	127.0.0.1	TCP	56	5000 → 54060 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
308	20.644906	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1 Ack=1 Win=2161152 Len=0
309	20.645405	127.0.0.1	127.0.0.1	TCP	60	54060 → 5000 [PSH, ACK] Seq=1 Ack=1 Win=2161152 Len=16
310	20.645422	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=1 Ack=17 Win=2161152 Len=0
311	20.645821	127.0.0.1	127.0.0.1	TCP	77	5000 → 54060 [PSH, ACK] Seq=1 Ack=17 Win=2161152 Len=33
312	20.645835	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=17 Ack=34 Win=2161152 Len=0
881	42.829772	127.0.0.1	127.0.0.1	TCP	304	54060 → 5000 [PSH, ACK] Seq=17 Ack=34 Win=2161152 Len=260
882	42.829800	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=34 Ack=277 Win=2160896 Len=0
883	42.830856	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=34 Ack=277 Win=2160896 Len=29
884	42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
1060	47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
1061	47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
1062	47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
1063	47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
1064	47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
1065	47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
1066	47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
1067	47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
1736	87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
1737	87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
1738	87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=121 Ack=1112 Win=2160128 Len=29
1739	87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
1800	02.020477	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0

0101 = Header Length: 20 bytes (5)

- Flags: 0x018 (PSH, ACK)
 - 000 = Reserved: Not set
 - ...0 = Accurate ECN: Not set
 - 0.... = Congestion Window Reduced: Not set
 -0.... = ECN-Echo: Not set
 -0.... = Urgent: Not set
 -1.... = Acknowledgment: Set
 -1.... = Push: Set
 -0.... = Reset: Not set
 -0.... = Syn: Not set
 -0.... = Fin: Not set

[TCP Flags:AP...]

Window: 8441

[Calculated window size: 2160896]

[Window size scaling factor: 256]

Checksum: 0xcd19 [unverified]

[Checksum Status: Unverified]

Urgent Pointer: 0

► [Timestamps]

► [SEQ/ACK analysis]

TCP payload (29 bytes)

► Data (29 bytes)

Data: 7b22535441545553223a20224f4b222c202241434b223a20224d30227d

In this screenshot, we may observe the server successfully receiving and processing the message sent by the client, and then proceeding to reply with a packet number 883 containing an ACK message, and a status code OK for the reception of the segment M0, indicating to the client that the first (and only) segment has been received successfully, so there is no need for any retransmissions.

The reason that only one segment has been sent, is because the size of the data of the text sent by the client simply does not exceed the server's max_msg_size parameter, it is actually below it, therefore, only one segment was needed here.

No.	Time	Source	Destination	Protocol	Length	Info
312	20.645835	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=17 Ack=34 Win=2161152 Len=0
881	42.829772	127.0.0.1	127.0.0.1	TCP	304	54060 → 5000 [PSH, ACK] Seq=17 Ack=34 Win=2161152 Len=260
882	42.829800	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=34 Ack=277 Win=2160896 Len=0
883	42.830856	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=34 Ack=277 Win=2160896 Len=29
884	42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
1060	47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
1061	47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
1062	47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
1063	47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
1064	47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
1065	47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
1066	47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
1067	47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
1736	87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
1737	87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
1738	87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=121 Ack=1112 Win=2160128 Len=29
1739	87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
1800	02.020477	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0

0101 = Header Length: 20 bytes (5)

- Flags: 0x018 (PSH, ACK)
 - 000 = Reserved: Not set
 - ...0 = Accurate ECN: Not set
 - 0.... = Congestion Window Reduced: Not set
 -0.... = ECN-Echo: Not set
 -0.... = Urgent: Not set
 -1.... = Acknowledgment: Set
 -1.... = Push: Set
 -0.... = Reset: Not set
 -0.... = Syn: Not set
 -0.... = Fin: Not set

[TCP Flags:AP...]

Window: 8442

[Calculated window size: 2161152]

[Window size scaling factor: 256]

Checksum: 0x362c [unverified]

[Checksum Status: Unverified]

Urgent Pointer: 0

► [Timestamps]

► [SEQ/ACK analysis]

TCP payload (277 bytes)

► Data (277 bytes)

Data: [REDACTED]

No.	Time	Source	Destination	Protocol	Length	Info
	883 42.830856	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=34 Ack=277 Win=2160896 Len=29
	884 42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
	1060 47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
	1061 47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
	1062 47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
	1063 47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
	1064 47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
	1065 47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
	1066 47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
	1067 47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
	1736 87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
	1737 87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
	1738 87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=121 Ack=1112 Win=2160128 Len=29
	1739 87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1809 92.092667	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1810 92.092697	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1811 92.093070	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1812 92.093091	127.0.0.1	127.0.0.1	TCP	44	5000 → 5000 [ACK] Seq=1112 Ack=151 Win=2161152 Len=0

```
0101 .... = Header Length: 20 bytes (5)
Flags: 0x018 (PSH, ACK)
 000. .... = Reserved: Not set
  ...0 .... = Accurate ECN: Not set
  ....0 .... = Congestion Window Reduced: Not set
  ....0.... = ECN-Echo: Not set
  ....0.... = Urgent: Not set
  ....1.... = Acknowledgment: Set
  ....1.... = Push: Set
  ....0.... = Reset: Not set
  ....0.... = Syn: Not set
  ....0.... = Fin: Not set
[TCP Flags: .....AP...]
Window: 8440
[Calculated window size: 2160640]
[Window size scaling factor: 256]
Checksum: 0xcbbe8 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
  [Timestamps]
  [SEQ/ACK analysis]
  TCP payload (29 bytes)
```

Data (29 bytes)
Data: 7b22535441545553223a20224f4b222c202241434b223a20224d30227d

```
0000 02 00 00 00 45 00 00 45 5f 3d 40 00 80 06 00 00 ... E .. _=0 ...
0010 7f 00 00 01 7f 00 00 01 13 88 d3 2c c8 72 db 20 ... ,r
0020 00 dc 6a 9e 50 18 20 f8 cb e8 00 00 7b 22 53 54 ... j P {"ST
0030 41 54 55 53 22 3a 20 22 4f 4b 22 2c 20 22 41 43 ATUS": "OK", "AC
0040 4b 22 3a 20 22 4d 30 22 7d K": "MO" }
```

No.	Time	Source	Destination	Protocol	Length	Info
	883 42.830856	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=34 Ack=277 Win=2160896 Len=29
	884 42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
	1060 47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
	1061 47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
	1062 47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
	1063 47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
	1064 47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
	1065 47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
	1066 47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
	1067 47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
	1736 87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
	1737 87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
	1738 87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=121 Ack=1112 Win=2160128 Len=29
	1739 87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1809 92.092667	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1810 92.092697	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1811 92.093070	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1812 92.093091	127.0.0.1	127.0.0.1	TCP	44	5000 → 5000 [ACK] Seq=1112 Ack=151 Win=2161152 Len=0

```
0101 .... = Header Length: 20 bytes (5)
Flags: 0x018 (PSH, ACK)
 000. .... = Reserved: Not set
  ...0 .... = Accurate ECN: Not set
  ....0 .... = Congestion Window Reduced: Not set
  ....0.... = ECN-Echo: Not set
  ....0.... = Urgent: Not set
  ....1.... = Acknowledgment: Set
  ....1.... = Push: Set
  ....0.... = Reset: Not set
  ....0.... = Syn: Not set
  ....0.... = Fin: Not set
[TCP Flags: .....AP...]
Window: 8442
[Calculated window size: 2160640]
[Window size scaling factor: 256]
Checksum: 0x56b5 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
  [Timestamps]
  [SEQ/ACK analysis]
  TCP payload (248 bytes)
```

Data (248 bytes)
Data [...]: 7b226d65746164617461223a207b22736571223a20312c2022636865636b73756d223a202261333965643639343

```
0000 02 00 00 00 45 00 01 20 5f 3f 40 00 80 06 00 00 ... E .. _?0 ...
0010 7f 00 00 01 7f 00 00 01 d3 2c 13 88 00 dc 6a 9e ... ,j
0020 c8 72 db 3d 50 18 20 fa 56 b5 00 00 7b 22 6d 65 ... P . V {"me
0030 74 61 64 61 74 61 22 3a 20 7b 22 73 65 71 22 3a tadata": {"seq": 1, "che cksum": "a39ed69 402fff62
0040 20 31 2c 20 22 63 68 65 63 6b 73 75 6d 22 3a 20
0050 22 61 33 39 64 36 39 34 30 32 66 66 36 32
0060 62 39 62 33 30 38 34 39 63 65 30 35 34 34 64 33
0070 35 37 35 61 61 33 35 33 31 31 36 36 63 39 30 37
0080 39 61 63 35 35 64 33 35 33 62 39 33 62 65 30 38
0090 37 22 2c 20 22 74 6f 74 61 6c 5f 73 65 67 6d 65 7", "tot al_segm
00a0 6e 74 73 22 3a 20 32 2c 20 22 6d 65 73 73 61 67 ents": 2, "messag
00b0 65 5f 69 64 22 3a 20 22 32 2d 66 33 34 64 65 e_id": "2-f342de
00c0 39 65 22 2c 20 22 69 73 5f 6c 61 73 74 22 3a 20 9e", "is _last": true, "o_ig_nal...
00d0 74 72 75 65 2c 20 22 6f 72 69 67 69 6e 61 6c 5f length": 112, "data": "d du et
00e0 6c 65 6e 67 74 68 22 3a 20 31 32 7d 2c 20 22 erat co nvallis
00f0 64 61 74 61 22 3a 20 22 64 20 64 75 69 20 65 74 feugiat ac in du
0100 20 65 72 61 74 20 63 6f 6e 76 61 6c 69 73 20 1."}
```

No.	Time	Source	Destination	Protocol	Length	Info
	883 42.830856	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=34 Ack=277 Win=2160896 Len=29
	884 42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
	1060 47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
	1061 47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
	1062 47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
	1063 47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
	1064 47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
	1065 47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
	1066 47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
	1067 47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
	1736 87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
	1737 87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
	1738 87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=121 Ack=1112 Win=2160128 Len=29
	1739 87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1809 92.092667	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1810 92.092697	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1811 92.093070	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1812 92.093091	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1113 Ack=151 Win=2161152 Len=0

In the above screenshots highlighting packets number 1060 , 1062 , 1064 and 1066 , observe that the client has sent another message

"Lorem ipsum dolor sit amet, consectetur adipiscing elit. Donec eleifend dui et erat convallis feugiat ac in dui .",

similar to the previous case. However, in this scenario, the message's data size has **exceeded** the server's **max_msg_size** , which **obligated** the client to split the message into two segments M0 and M1 , respecting the boundary set by the server. This confirms that the segmentation process has been executed successfully.

No.	Time	Source	Destination	Protocol	Length	Info
	884 42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
	1060 47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
	1061 47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
	1062 47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
	1063 47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
	1064 47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
	1065 47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
	1066 47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
	1067 47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
	1736 87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
	1737 87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
	1738 87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=121 Ack=1112 Win=2160128 Len=29
	1739 87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1809 92.092667	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1810 92.092697	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1811 92.093070	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1812 92.093091	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1113 Ack=151 Win=2161152 Len=0

```
0101 .... = Header Length: 20 bytes (5)
Flags: 0x018 (PSH, ACK)
 000.... .... = Reserved: Not set
  ...0.... .... = Accurate ECN: Not set
  ...0.... .... = Congestion Window Reduced: Not set
  ...0.... .... = ECN-Echo: Not set
  ...0.... .... = Urgent: Not set
  ...1.... .... = Acknowledgment: Set
  ...1.... .... = Push: Set
  ...0.... .... = Reset: Not set
  ...0.... .... = Syn: Not set
  ...0.... .... = Fin: Not set
[TCP Flags: .....AP...]
Window: 8442
[Calculated window size: 2161152]
[Window size scaling factor: 256]
Checksum: 0x5672 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
[Timestamps]
[SEQ/ACK analysis]
TCP payload (310 bytes)
Data (310 bytes)
Data [...]: 7b226d65746164617461223a207b22736571223a20302c2022636865636b73756d223a202232306237663532363
```

```
0000 02 00 00 00 45 00 00 45 5f 41 40 00 80 06 00 00
0010 7f 00 00 01 7f 00 00 01 13 88 d3 2c c8 72 db 3d
0020 00 dc 6b 96 50 18 20 f7 c9 d4 00 00 7b 22 53 54
0030 41 54 55 53 22 3a 20 22 4f 4b 22 2c 20 22 41 43
0040 4b 22 3a 20 22 4d 31 22 7d
```

ATUS": "OK", "AC
K": "M1" }

No.	Time	Source	Destination	Protocol	Length	Info
	884 42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
	1060 47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
	1061 47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
	1062 47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
	1063 47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
	1064 47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
	1065 47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
	1066 47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
	1067 47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
	1736 87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
	1737 87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
	1738 87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=1112 Ack=1112 Win=2160128 Len=29
	1739 87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1809 92.092667	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1810 92.092697	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1811 92.093070	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1812 92.093091	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1113 Ack=151 Win=2161152 Len=0

```

0101 .... = Header Length: 20 bytes (5)
Flags: 0x018 (PSH, ACK)
 000. .... = Reserved: Not set
...0 .... .... = Accurate ECN: Not set
....0.... .... = Congestion Window Reduced: Not set
....0.... .... = ECN-Echo: Not set
....0.... .... = Urgent: Not set
....1.... .... = Acknowledgment: Set
....1.... .... = Push: Set
....0.... .... = Reset: Not set
....0.... .... = Syn: Not set
....0.... .... = Fin: Not set
[TCP Flags: .....AP...]
Window: 8438
[Calculated window size: 2160128]
[Window size scaling factor: 256]
Checksum: 0xc982 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
[Timestamps]
[SEQ/ACK analysis]
TCP payload (29 bytes)
Data (29 bytes)
Data: 7b22535441545553223a20224f4b222c202241434b223a20224d30227d

```

In packets [1736](#) and [1738](#), we observe another example of the client sending data to the server, in a process similar to the previous messages demonstrated. The message sent in this case is in the Amharic language:

| አማርኛ እያታረኩ ገንዘብ እያከናዣ::

Which explains why instead of the characters seen above, the content of the message has been encoded in [UTF-8](#) format, and decoded back into presentable text when received at the server's side, confirming the functionality of the [UTF-8](#) encoding component implemented in the project.

In all of the screenshots above, we may also observe that the window sliding mechanism is also functional, as the window slides only after receiving the full data's segments, and in [correct sequential order](#), and then and only then would the window slide, allowing for more data to be sent by the client, which confirms intended behaviour.

No.	Time	Source	Destination	Protocol	Length	Info
	884 42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
	1060 47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
	1061 47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
	1062 47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
	1063 47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
	1064 47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
	1065 47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
	1066 47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
	1067 47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
	1736 87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
	1737 87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
	1738 87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=1112 Ack=1112 Win=2160128 Len=29
	1739 87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1809 92.092667	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1810 92.092697	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1811 92.093070	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1812 92.093091	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1113 Ack=151 Win=2161152 Len=0

```

Transmission Control Protocol, Src Port: 54060, Dst Port: 5000, Seq: 1112, Ack: 150, Len: 0
Source Port: 54060
Destination Port: 5000
[Stream index: 27]
[Conversation completeness: Complete, WITH_DATA (31)]
[TCP Segment Len: 0]
Sequence Number: 1112 (relative sequence number)
Sequence Number (raw): 14445772
[Next Sequence Number: 1113 (relative sequence number)]
Acknowledgment Number: 150 (relative ack number)
Acknowledgment number (raw): 3362970487
0101 .... = Header Length: 20 bytes (5)
Flags: 0x011 (FIN, ACK)
 000. .... = Reserved: Not set
...0 .... .... = Accurate ECN: Not set
....0.... .... = Congestion Window Reduced: Not set
....0.... .... = ECN-Echo: Not set
....0.... .... = Urgent: Not set
....1.... .... = Acknowledgment: Set
....0.... .... = Push: Not set
....0.... .... = Reset: Not set
....0.... .... = Syn: Not set
....1.... .... = Fin: Set
[TCP Flags: .....A-F]

```

No.	Time	Source	Destination	Protocol	Length	Info
	884 42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
	1060 47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
	1061 47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
	1062 47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
	1063 47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
	1064 47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
	1065 47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
	1066 47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
	1067 47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
	1736 87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
	1737 87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
	1738 87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=121 Ack=1112 Win=2160128 Len=29
	1739 87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1809 92.092667	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0
	1810 92.092697	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1811 92.093070	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=150 Ack=1113 Win=2160128 Len=0
	1812 92.093091	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1113 Ack=151 Win=2161152 Len=0

Transmission Control Protocol, Src Port: 5000, Dst Port: 54060, Seq: 150, Ack: 1113, Len: 0	0000 02 00 00 00 45 00 00 28 5f d2 40 00 80 06 00 00 ... E ..(_ -0 ...
Source Port: 5000	0010 7f 00 00 01 7f 00 00 01 13 88 d3 2c c8 72 db 77 , r -w
Destination Port: 54060	0020 00 dc 6c cd 50 10 20 f6 98 93 00 00 .l P . . .
[Stream index: 27]	
► [Conversation completeness: Complete, WITH_DATA (31)]	
[TCP Segment Len: 0]	
Sequence Number: 150 (relative sequence number)	
Sequence Number (raw): 3362970487	
[Next Sequence Number: 150 (relative sequence number)]	
Acknowledgment Number: 1113 (relative ack number)	
Acknowledgment number (raw): 14445773	
0101 = Header Length: 20 bytes (5)	
▼ Flags: 0x010 (ACK)	
000. = Reserved: Not set	
...0 = Accurate ECN: Not set	
.... 0.... = Congestion Window Reduced: Not set	
.... .0.... = ECN-Echo: Not set	
.... ..0.... = Urgent: Not set	
.... ...1.... = Acknowledgment: Set	
.... 0.... = Push: Not set	
....0.... = Reset: Not set	
....0.... = Syn: Not set	
....0.... = Fin: Not set	
[TCP Flags:A....]	

No.	Time	Source	Destination	Protocol	Length	Info
884	42.830877	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=277 Ack=63 Win=2161152 Len=0
1060	47.762440	127.0.0.1	127.0.0.1	TCP	321	54060 → 5000 [PSH, ACK] Seq=277 Ack=63 Win=2161152 Len=277
1061	47.762463	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=63 Ack=554 Win=2160640 Len=0
1062	47.763437	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=63 Ack=554 Win=2160640 Len=29
1063	47.763451	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=554 Ack=92 Win=2161152 Len=0
1064	47.764003	127.0.0.1	127.0.0.1	TCP	292	54060 → 5000 [PSH, ACK] Seq=554 Ack=92 Win=2161152 Len=248
1065	47.764020	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=92 Ack=802 Win=2160384 Len=0
1066	47.764560	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=92 Ack=802 Win=2160384 Len=29
1067	47.764576	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=802 Ack=121 Win=2161152 Len=0
1736	87.371211	127.0.0.1	127.0.0.1	TCP	354	54060 → 5000 [PSH, ACK] Seq=802 Ack=121 Win=2161152 Len=310
1737	87.371241	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=121 Ack=1112 Win=2160128 Len=0
1738	87.372291	127.0.0.1	127.0.0.1	TCP	73	5000 → 54060 [PSH, ACK] Seq=121 Ack=1112 Win=2160128 Len=29
1739	87.372312	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1112 Ack=150 Win=2161152 Len=0
1809	92.092667	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [FIN, ACK] Seq=1112 Ack=150 Win=2161152 Len=0
1810	92.092697	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [ACK] Seq=150 Ack=1113 Win=2160128 Len=0
1811	92.093070	127.0.0.1	127.0.0.1	TCP	44	5000 → 54060 [FIN, ACK] Seq=150 Ack=1113 Win=2160128 Len=0
1812	92.093091	127.0.0.1	127.0.0.1	TCP	44	54060 → 5000 [ACK] Seq=1113 Ack=151 Win=2161152 Len=0

```

Sequence Number (raw): 14445773
[Next Sequence Number: 1113 (relative sequence number)]
Acknowledgment Number: 151 (relative ack number)
Acknowledgment number (raw): 3362970488
0101 .... = Header Length: 20 bytes (5)
Flags: 0x010 (ACK)
 000. .... .... = Reserved: Not set
 ...0 .... .... = Accurate ECN: Not set
 .... 0.... .... = Congestion Window Reduced: Not set
 .... .0.... .... = ECN-Echo: Not set
 .... ..0.... .... = Urgent: Not set
 .... ...1.... .... = Acknowledgment: Set
 .... ...0.... .... = Push: Not set
 .... ...0.... .... = Reset: Not set
 .... ...0.... .... = Syn: Not set
 .... ...0....0 = Fin: Not set
[TCP Flags: .....A....]
Window: 8442
[Calculated window size: 2161152]
[Window size scaling factor: 256]
Checksum: 0x988e [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
▶ [Timestamps]

```

In packets [1809-1812](#), we can observe the client initializing the process of terminating the ongoing connection between the client and the server. The client begins by sending a **FIN** packet, signaling to the server the intent of terminating the connection. The server replies with an **ACK** packet, and then shortly after, a **FIN** packet, to which the client replies with an **ACK** packet. This process is called the **four-way handshake**, and is used to terminate TCP connections gracefully and securely between a server and a client.

Terminal Screenshots

Client-Side

```

Starting Reliable Transfer Client...
Welcome to the Reliable Transfer Client!

Load configuration from (F)ile or (U)ser input? f
Load (D)efault configuration or custom (P)ath? d

Loaded default configuration successfully!

Current Configuration:
Message: Lorem ipsum dolor sit amet, consectetur adipiscing elit. Donec eleifend dui et erat convallis feugiat ac in dui.
Message Size: 112 bytes
Maximum Message Size: 100 bytes
Number of Segments: 2
Window Size: 4
Timeout: 2 seconds

Connecting to server...
[00:44:25] INFO: Connected to server at 127.0.0.1:5000
[00:44:25] INFO: Sending max size request to server
[00:44:25] INFO: Waiting for server response...
[00:44:25] INFO: Received response: {"MAX_SIZE": 100, "STATUS": "OK"}
[00:44:25] INFO: Server maximum message size: 100 bytes
[00:44:25] INFO: Message Segmenter initialized with the following parameters:
max_segment_size = 100,
metadata_overhead = 30,
max_data_size = 70
Connected to server successfully!

Options:
1. Send a message
2. Send message from configuration
3. Exit

Enter your choice (1-3): 1

Enter your message: Hello server! Ariel University student sending message!

Sending message...
[00:44:41] INFO: Sent segment M0
[00:44:41] INFO: Received ACK M0
Message sent successfully!

Options:
1. Send a message
2. Send message from configuration
3. Exit

Enter your choice (1-3): 2

Sending configured message...
[00:44:42] INFO: Segmented message (ID: 2-f342de9e) into 2 parts
[00:44:42] INFO: Sent segment M0
[00:44:42] INFO: Received ACK M0
[00:44:42] INFO: Sent segment M1

```

[00:44:42] INFO: Received ACK M1
Message transmitted successfully!

Options:
1. Send a message
2. Send message from configuration
3. Exit

Enter your choice (1-3): 1

Enter your message: አዲስ አበባ የንግድ አቀፍነት:

Sending message...
[00:44:52] INFO: Sent segment M0
[00:44:52] INFO: Received ACK M0
Message sent successfully!

Options:
1. Send a message
2. Send message from configuration
3. Exit

Enter your choice (1-3): 3

Content

Starting Reliable Transfer Client...

Welcome to the Reliable Transfer Client!

Load configuration **from** (F)ile or (U)ser input? f

Load (D)efault configuration or custom (P)ath? d

Loaded default configuration successfully!

Current Configuration:

Message: Lorem ipsum dolor sit amet, consectetur adipiscing elit. Donec eleifend dui et erat convallis feugiat ac in dui.

Message Size: 112 bytes

Maximum Message Size: 100 bytes

Number of Segments: 2

Window Size: 4

Timeout: 2 seconds

Connecting to server...

[00:44:25] INFO: Connected to server at 127.0.0.1:5000

[00:44:25] INFO: Sending max size request to server

[00:44:25] INFO: Waiting **for** server response...

[00:44:25] INFO: Received response: {"MAX_SIZE": 100, "STATUS": "OK"}

[00:44:25] INFO: Server maximum message size: 100 bytes

[00:44:25] INFO: Message Segmenter initialized with the following parameters:

max_segment_size = 100,

metadata_overhead = 30,

max_data_size = 70

Connected to server successfully!

Options:

1. Send a message
2. Send message **from** configuration
3. **Exit**

Enter your choice (1-3): 1

Enter your message: Hello server! Ariel University student sending message!

Sending message...

[00:44:41] INFO: Sent segment M0

[00:44:41] INFO: Received ACK M0

Message sent successfully!

Options:

1. Send a message
2. Send message **from** configuration
3. **Exit**

Enter your choice (1-3): 2

Sending configured message...

```
[00:44:42] INFO: Segmented message (ID: 2-f342de9e) into 2 parts
[00:44:42] INFO: Sent segment M0
[00:44:42] INFO: Received ACK M0
[00:44:42] INFO: Sent segment M1
[00:44:42] INFO: Received ACK M1
Message transmitted successfully!
```

Options:

1. Send a message
2. Send message **from** configuration
3. **Exit**

Enter your choice (1-3): 1

Enter your message: አማካይ እያችለን ገንዘብ እያከናዣ::

Sending message...

```
[00:44:52] INFO: Sent segment M0
[00:44:52] INFO: Received ACK M0
```

Message sent successfully!

Options:

1. Send a message
2. Send message **from** configuration
3. **Exit**

Enter your choice (1-3): 3

Server-Side

```
Starting Reliable Transfer Server...
Welcome to the Reliable Transfer Server!

Load configuration from (F)ile or (U)ser input? f
Load (D)eafault configuration or custom (P)ath? d

Loaded default configuration successfully!

Server Configuration:
Message: Welcome to our reliable server! Please enjoy your stay!
Message Size: 55 bytes
Maximum Message Size: 100 bytes
Number of Segments: 1
Window Size: 4
Timeout: 2 seconds

Initializing server...
[00:44:23] INFO: Message Segmenter initialized with the following parameters:
max_segment_size = 100,
metadata_overhead = 30,
max_data_size = 70

Server starting...
Press CTRL + C to shutdown the server

[00:44:23] INFO: Server initialized on 127.0.0.1:5000, mode set to 'LISTEN'
[00:44:25] INFO: New connection from ('127.0.0.1', 55018)
[00:44:25] INFO: Waiting for max size request...
[00:44:25] INFO: Received request: REQUEST_MAX_SIZE
[00:44:25] INFO: Sending response: {"MAX_SIZE": 100, "STATUS": "OK"}
[00:44:25] INFO: Sent max message size: 100
[00:44:25] INFO: Waiting for client data...
[00:44:41] INFO: Processing segment M0 of message 1-551bee00
[00:44:41] INFO: Initialized new message 1-551bee00
[00:44:41] INFO: Stored segment M0
[00:44:41] INFO: Updated sequence to M0
[00:44:41] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[00:44:41] INFO: ACK sent successfully
[00:44:41] INFO: Received complete message: Hello server! Ariel University student sending message!
[00:44:41] INFO: Ready for next message
[00:44:41] INFO: Waiting for client data...
[00:44:42] INFO: Processing segment M0 of message 2-f342de9e
[00:44:42] INFO: Initialized new message 2-f342de9e
[00:44:42] INFO: Stored segment M0
[00:44:42] INFO: Updated sequence to M0
[00:44:42] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[00:44:42] INFO: ACK sent successfully
[00:44:42] INFO: Waiting for client data...
[00:44:42] INFO: Processing segment M1 of message 2-f342de9e
[00:44:42] INFO: Stored segment M1
[00:44:42] INFO: Updated sequence to M1
[00:44:42] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M1"}
[00:44:42] INFO: ACK sent successfully
[00:44:42] INFO: Received complete message: Lorem ipsum dolor sit amet, consectetur adipiscing elit. Donec eleifend dui et erat convallis feugiat ac in dui.
```

```
[00:44:42] INFO: Ready for next message
[00:44:42] INFO: Waiting for client data...
[00:44:52] INFO: Processing segment M0 of message 3-67a65157
[00:44:52] INFO: Initialized new message 3-67a65157
[00:44:52] INFO: Stored segment M0
[00:44:52] INFO: Updated sequence to M0
[00:44:52] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[00:44:52] INFO: ACK sent successfully
[00:44:52] INFO: Received complete message: አማካይ እያችለን ገንዘብ እያከናዣ::
```

```
[00:44:52] INFO: Ready for next message
[00:44:52] INFO: Waiting for client data...
[00:46:50] INFO: Client closed connection (no data)
[00:46:50] INFO: Connection from ('127.0.0.1', 55018) closed
```

```
Server shutdown requested.
[00:46:56] INFO: Initiating server shutdown...
[00:46:56] INFO: Server socket closed
```

```
Server shutdown complete.
Terminate batch job (Y/N)? Y
```

Content

```
Starting Reliable Transfer Server...
Welcome to the Reliable Transfer Server!
```

```
-----
Load configuration from (F)ile or (U)ser input? f
Load (D)efault configuration or custom (P)ath? d
```

```
Loaded default configuration successfully!
```

```
Server Configuration:
```

```
Message: Welcome to our reliable server! Please enjoy your stay!
```

```
Message Size: 55 bytes
```

```
Maximum Message Size: 100 bytes
```

```
Number of Segments: 1
```

```
Window Size: 4
```

```
Timeout: 2 seconds
```

```
Initializing server...
```

```
[00:44:23] INFO: Message Segmenter initialized with the following parameters:
max_segment_size = 100,
metadata_overhead = 30,
max_data_size = 70
```

```
Server starting...
```

```
Press CTRL + C to shutdown the server
```

```
-----
[00:44:23] INFO: Server initialized on 127.0.0.1:5000, mode set to 'LISTEN'
[00:44:25] INFO: New connection from ('127.0.0.1', 55018)
[00:44:25] INFO: Waiting for max size request...
[00:44:25] INFO: Received request: REQUEST_MAX_SIZE
[00:44:25] INFO: Sending response: {"MAX_SIZE": 100, "STATUS": "OK"}
[00:44:25] INFO: Sent max message size: 100
[00:44:25] INFO: Waiting for client data...
[00:44:41] INFO: Processing segment M0 of message 1-551bee00
[00:44:41] INFO: Initialized new message 1-551bee00
[00:44:41] INFO: Stored segment M0
[00:44:41] INFO: Updated sequence to M0
[00:44:41] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[00:44:41] INFO: ACK sent successfully
[00:44:41] INFO: Received complete message: Hello server! Ariel University student sending message!
[00:44:41] INFO: Ready for next message
[00:44:41] INFO: Waiting for client data...
[00:44:42] INFO: Processing segment M0 of message 2-f342de9e
[00:44:42] INFO: Initialized new message 2-f342de9e
[00:44:42] INFO: Stored segment M0
[00:44:42] INFO: Updated sequence to M0
[00:44:42] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[00:44:42] INFO: ACK sent successfully
[00:44:42] INFO: Waiting for client data...
[00:44:42] INFO: Processing segment M1 of message 2-f342de9e
[00:44:42] INFO: Stored segment M1
[00:44:42] INFO: Updated sequence to M1
[00:44:42] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M1"}
[00:44:42] INFO: ACK sent successfully
[00:44:42] INFO: Received complete message: Lorem ipsum dolor sit amet, consectetur adipiscing elit. Donec eleifend dui et erat convallis feugiat ac in dui.
[00:44:42] INFO: Ready for next message
[00:44:42] INFO: Waiting for client data...
[00:44:52] INFO: Processing segment M0 of message 3-67a65157
[00:44:52] INFO: Initialized new message 3-67a65157
[00:44:52] INFO: Stored segment M0
[00:44:52] INFO: Updated sequence to M0
[00:44:52] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[00:44:52] INFO: ACK sent successfully
```

```
[00:44:52] INFO: Received complete message: ከምና አይታረስ ገንዘብ እያከሰለ::  
[00:44:52] INFO: Ready for next message  
[00:44:52] INFO: Waiting for client data...  
[00:46:50] INFO: Client closed connection (no data)  
[00:46:50] INFO: Connection from ('127.0.0.1', 55018) closed
```

Server shutdown requested.

```
[00:46:56] INFO: Initiating server shutdown...  
[00:46:56] INFO: Server socket closed
```

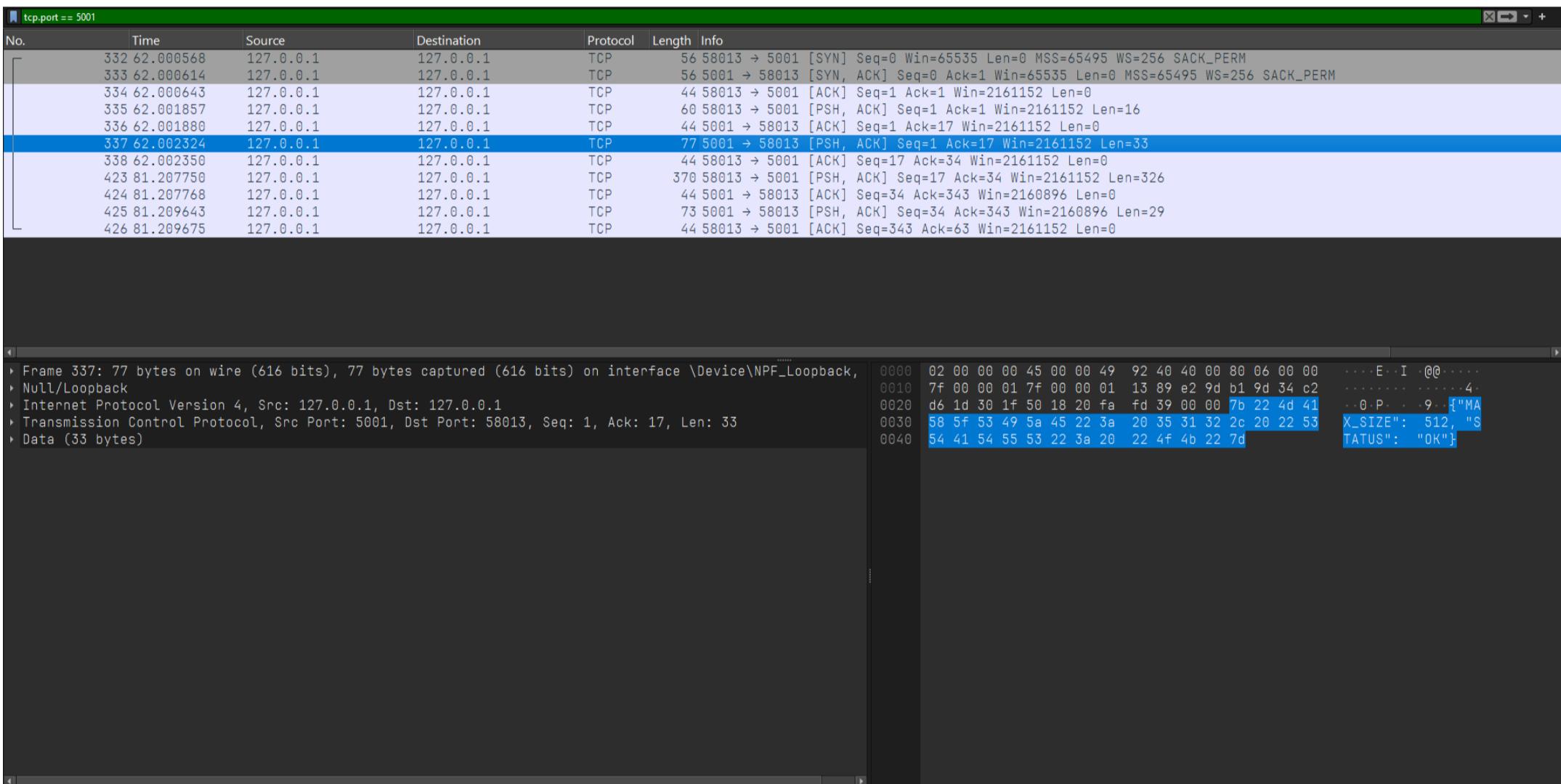
Server shutdown complete.

Terminate batch job (Y/N)? Y

Edge Cases Testing

High Packet Loss Rate

In this scenario, we'll test the high packet loss rate scenario.



At this point, the server has sent an reply containing the `MAX_SIZE` parameter for the client.

```
Enter network simulation conditions (0.0-1.0 for rates):
```

```
Packet loss rate: 0.5
ACK loss rate: 0
Minimum delay (seconds): 0
Maximum delay (seconds): 0
Packet duplication rate: 0
Packet reordering rate: 0
```

```
Initializing server...
```

```
[02:25:27] INFO: Message Segmenter initialized with the following parameters:
 - MAX_SEG_SIZE : 512,
 - HEADER_SIZE : 222,
 - MAX_DATA_SIZE : 290.
```

```
Network Simulator active with conditions:
```

```
packet_loss: 0.5
ack_loss: 0.0
min_delay: 0.0
max_delay: 0.0
duplication: 0.0
reordering: 0.0
```

```
Server starting...
```

```
Press CTRL + C to shutdown the server
```

```
[02:25:27] INFO: Server initialized on 127.0.0.1:5001, mode set to 'LISTEN'
[02:25:32] INFO: New connection from ('127.0.0.1', 58013)
[02:25:32] INFO: Waiting for max size request...
[02:25:32] INFO: Processing handshake packet directly
[02:25:32] INFO: Received request: REQUEST_MAX_SIZE
[02:25:32] INFO: Sending response: {"MAX_SIZE": 512, "STATUS": "OK"}
```

Notice that we have set the packet loss rate at a probability of 0.5, this means that approximately half of sent packets in a large enough number of retransmissions will be dropped and lost.

```
[02:25:32] INFO: Sending max size request to server
[02:25:32] INFO: Waiting for server response...
[02:25:32] INFO: Received response: {"MAX_SIZE": 512, "STATUS": "OK"}
[02:25:32] INFO: Message Segmenter initialized with the following parameters:
 - MAX_SEG_SIZE : 512,
 - HEADER_SIZE : 222,
 - MAX_DATA_SIZE : 290.
```

```
Connected to server successfully!
```

```
Options:
```

1. Send a message
2. Send message from configuration
3. Exit

```
Enter your choice (1-3): 2
```

```
Sending configured message...
```

```
[02:25:40] INFO: Sent segment M0
[02:25:41] WARNING: Timeout waiting for ACK (retry 1/5)
[02:25:42] WARNING: Timeout waiting for ACK (retry 2/5)
[02:25:42] INFO: Retransmitted segment 0
[02:25:43] WARNING: Timeout waiting for ACK (retry 3/5)
[02:25:44] WARNING: Timeout waiting for ACK (retry 4/5)
[02:25:45] WARNING: Timeout waiting for ACK (retry 5/5)
[02:25:46] ERROR: Max retries exceeded for message
```

```
Options:
```

1. Send a message
2. Send message from configuration
3. Exit

```
Enter your choice (1-3): 2
```

```
Sending configured message...
```

```
[02:25:49] INFO: Sent segment M0
[02:25:49] WARNING: Timeout waiting for ACK (retry 1/5)
[02:25:50] WARNING: Timeout waiting for ACK (retry 2/5)
[02:25:51] INFO: Retransmitted segment 0
[02:25:51] INFO: Received ACK M0
Message sent successfully.
```

```
Options:
```

1. Send a message
2. Send message from configuration
3. Exit

```
Enter your choice (1-3):
```

The client logic performs multiple retransmissions in order to mitigate the packet loss, as he has no received any ACKs yet. In the case of a complete timeout, with zero response from the server, we stop retransmitting and move onto another thread to continue operation as normal.

In the screenshot above, even with the high packet drop loss, (rate of 0.5), the client eventually succeeds in sending the message segments and receiving an ACK.

High ACK Loss Rate

Capturing from Adapter for loopback traffic capture

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Start Stop Restart Options Open Save Close Reload Find Packet... Previous Packet Next Packet Go to Packet... First Packet Last Packet Auto Scroll in Live Capture Colorize Packet List Zoom In Zoom Out Normal Size Resize Columns Reset Layout

tcp.port == 5001

No.	Time	Source	Destination	Protocol	Length	Info
1084	155.259415	127.0.0.1	127.0.0.1	TCP	56	58512 → 5001 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
1085	155.259460	127.0.0.1	127.0.0.1	TCP	56	5001 → 58512 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
1086	155.259488	127.0.0.1	127.0.0.1	TCP	44	58512 → 5001 [ACK] Seq=1 Ack=1 Win=2161152 Len=0
1089	155.283227	127.0.0.1	127.0.0.1	TCP	60	58512 → 5001 [PSH, ACK] Seq=1 Ack=1 Win=2161152 Len=16
1090	155.283259	127.0.0.1	127.0.0.1	TCP	44	5001 → 58512 [ACK] Seq=1 Ack=17 Win=2161152 Len=0
1091	155.284072	127.0.0.1	127.0.0.1	TCP	77	5001 → 58512 [PSH, ACK] Seq=1 Ack=17 Win=2161152 Len=33
1092	155.284102	127.0.0.1	127.0.0.1	TCP	44	58512 → 5001 [ACK] Seq=17 Ack=34 Win=2161152 Len=0
1097	155.287252	127.0.0.1	127.0.0.1	TCP	370	58512 → 5001 [PSH, ACK] Seq=17 Ack=34 Win=2161152 Len=326
1098	155.287276	127.0.0.1	127.0.0.1	TCP	44	5001 → 58512 [ACK] Seq=34 Ack=343 Win=2160896 Len=0
1099	155.288625	127.0.0.1	127.0.0.1	TCP	73	5001 → 58512 [PSH, ACK] Seq=34 Ack=343 Win=2160896 Len=29
1100	155.288658	127.0.0.1	127.0.0.1	TCP	44	58512 → 5001 [ACK] Seq=343 Ack=63 Win=2161152 Len=0
1112	155.392499	127.0.0.1	127.0.0.1	TCP	370	58512 → 5001 [PSH, ACK] Seq=343 Ack=63 Win=2161152 Len=326
1113	155.392555	127.0.0.1	127.0.0.1	TCP	44	5001 → 58512 [ACK] Seq=63 Ack=669 Win=2160640 Len=0
1114	155.396037	127.0.0.1	127.0.0.1	TCP	73	5001 → 58512 [PSH, ACK] Seq=63 Ack=669 Win=2160640 Len=29
1115	155.396096	127.0.0.1	127.0.0.1	TCP	44	58512 → 5001 [ACK] Seq=669 Ack=92 Win=2161152 Len=0
1122	157.403174	127.0.0.1	127.0.0.1	TCP	370	58512 → 5001 [PSH, ACK] Seq=669 Ack=92 Win=2161152 Len=326
1123	157.403192	127.0.0.1	127.0.0.1	TCP	44	5001 → 58512 [ACK] Seq=92 Ack=995 Win=2160128 Len=0
1124	157.405105	127.0.0.1	127.0.0.1	TCP	77	5001 → 58512 [PSH, ACK] Seq=92 Ack=995 Win=2160128 Len=29

Frame 1099: 73 bytes on wire (584 bits), 73 bytes captured (584 bits) on interface \Device\NPF_Loopback, 0000 02 00 00 00 45 00 00 45 9c 75 40 00 80 06 00 00 ... E..E ..u@....
Null/Loopback
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
Transmission Control Protocol, Src Port: 5001, Dst Port: 58512, Seq: 34, Ack: 343, Len: 29
Data (29 bytes)
0000 02 00 00 00 45 00 00 45 9c 75 40 00 80 06 00 00 ... E..E ..u@....
0010 7f 00 00 01 7f 00 00 01 13 89 e4 90 77 64 17 12wd..
0020 b9 a5 00 31 50 18 20 f9 81 43 00 00 7b 22 53 54 ..1P. .C. [UST
0030 41 54 55 53 22 3a 20 22 4f 4b 22 2c 20 22 41 43 ATUS": "OK", "AC
0040 4b 22 3a 20 22 4d 30 22 7d K": "MO"]

_packets: 1563 - Displayed: 31 (2.0%) Profile: Default

Capturing from Adapter for loopback traffic capture

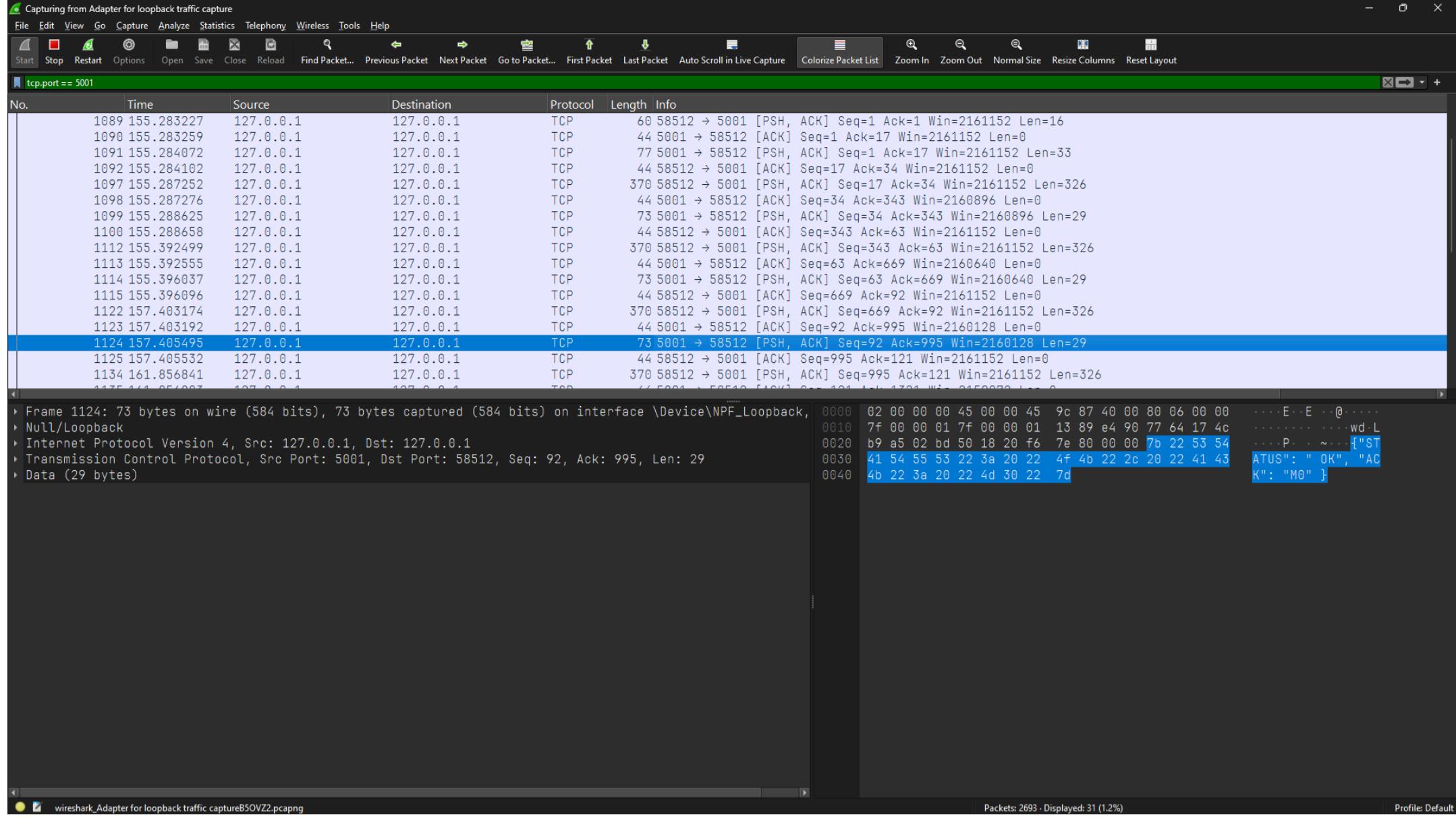
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Start Stop Restart Options Open Save Close Reload Find Packet... Previous Packet Next Packet Go to Packet... First Packet Last Packet Auto Scroll in Live Capture Colorize Packet List Zoom In Zoom Out Normal Size Resize Columns Reset Layout

tcp.port == 5001

No.	Time	Source	Destination	Protocol	Length	Info
1084	155.259415	127.0.0.1	127.0.0.1	TCP	56	58512 → 5001 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
1085	155.259460	127.0.0.1	127.0.0.1	TCP	56	5001 → 58512 [SYN, ACK] Seq=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
1086	155.259488	127.0.0.1	127.0.0.1	TCP	44	58512 → 5001 [ACK] Seq=1 Ack=1 Win=2161152 Len=0
1089	155.283227	127.0.0.1	127.0.0.1	TCP	60	58512 → 5001 [PSH, ACK] Seq=1 Ack=1 Win=2161152 Len=16
1090	155.283259	127.0.0.1	127.0.0.1	TCP	44	5001 → 58512 [ACK] Seq=1 Ack=17 Win=2161152 Len=0
1091	155.284072	127.0.0.1	127.0.0.1	TCP	77	5001 → 58512 [PSH, ACK] Seq=1 Ack=17 Win=2161152 Len=33
1092	155.284102	127.0.0.1	127.0.0.1	TCP	44	58512 → 5001 [ACK] Seq=17 Ack=34 Win=2161152 Len=0
1097	155.287252	127.0.0.1	127.0.0.1	TCP	370	58512 → 5001 [PSH, ACK] Seq=17 Ack=34 Win=2161152 Len=326
1098	155.287276	127.0.0.1	127.0.0.1	TCP	44	5001 → 58512 [ACK] Seq=34 Ack=343 Win=2160896 Len=0
1099	155.288625	127.0.0.1	127.0.0.1	TCP	73	5001 → 58512 [PSH, ACK] Seq=34 Ack=343 Win=2160896 Len=29
1100	155.288658	127.0.0.1	127.0.0.1	TCP	44	58512 → 5001 [ACK] Seq=343 Ack=63 Win=2161152 Len=0
1112	155.392499	127.0.0.1	127.0.0.1	TCP	370	58512 → 5001 [PSH, ACK] Seq=343 Ack=63 Win=2161152 Len=326
1113	155.392555	127.0.0.1	127.0.0.1	TCP	44	5001 → 58512 [ACK] Seq=63 Ack=669 Win=2160640 Len=0
1114	155.396037	127.0.0.1	127.0.0.1	TCP	73	5001 → 58512 [PSH, ACK] Seq=63 Ack=669 Win=2160640 Len=29
1115	155.396096	127.0.0.1	127.0.0.1	TCP	44	58512 → 5001 [ACK] Seq=669 Ack=92 Win=2161152 Len=0
1122	157.403174	127.0.0.1	127.0.0.1	TCP	370	58512 → 5001 [PSH, ACK] Seq=669 Ack=92 Win=2161152 Len=326
1123	157.403192	127.0.0.1	127.0.0.1	TCP	44	5001 → 58512 [ACK] Seq=92 Ack=995 Win=2160128 Len=0
1124	157.405105	127.0.0.1	127.0.0.1	TCP	77	5001 → 58512 [PSH, ACK] Seq=92 Ack=995 Win=2160128 Len=29

Frame 1114: 73 bytes on wire (584 bits), 73 bytes captured (584 bits) on interface \Device\NPF_Loopback, 0000 02 00 00 00 45 00 00 45 9c 7d 40 00 80 06 00 00 ... E-E-}@....
Null/Loopback 0010 7f 00 00 01 7f 00 00 01 13 89 e4 90 77 64 17 2f-.-.wd-/ 0020 b9 a5 01 77 50 18 20 f8 7f e1 00 00 7b 22 53 54 ...WP-...[ST 0030 41 54 55 53 22 3a 20 22 4f 4b 22 2c 20 22 41 43 ATUS": "OK", "AC 0040 4b 22 3a 20 22 4d 30 22 7d K": "M0"]



In ACKS 1099 , 1114 , 1124 , notice that all of them contain the same reply to the same sequence number M0 , this can be seen in many other subsequent ACKS (inspect the attached High ACK Loss Rate.pcapng file) . Let's move onto the terminal view .

```

Enter network simulation conditions (0.0-1.0 for rates):
Packet loss rate: 0
ACK loss rate: 0.4
Minimum delay (seconds): 0
Maximum delay (seconds): 0
Packet duplication rate: 0
Packet reordering rate: 0

Initializing server...
[02:37:56] INFO: Message Segmenter initialized with the following parameters
  - MAX SEG SIZE : 512,
  - HEADER SIZE : 222,
  - MAX DATA SIZE : 290.

Network Simulator active with conditions:
packet_loss: 0.0
ack_loss: 0.4
min_delay: 0.0
max_delay: 0.0
duplication: 0.0
reordering: 0.0

Server starting...
Press CTRL + C to shutdown the server
[02:37:56] INFO: Server initialized on 127.0.0.1:5001, mode set to 'LISTEN'

```

First, set the ACK loss rate to 0.4

Running stress test scenario...

```
Sending message 1/3 (size: 112 bytes)
[02:38:52] INFO: Sent segment M0
[02:38:52] INFO: Received ACK M0
Message sent successfully

Sending message 2/3 (size: 112 bytes)
[02:38:52] INFO: Sent segment M0
[02:38:53] WARNING: Timeout waiting for ACK (retry 1/5)
[02:38:53] WARNING: Timeout waiting for ACK (retry 2/5)
[02:38:54] INFO: Retransmitted segment 0
[02:38:54] WARNING: Timeout waiting for ACK (retry 3/5)
[02:38:55] WARNING: Timeout waiting for ACK (retry 4/5)
[02:38:57] WARNING: Timeout waiting for ACK (retry 5/5)
[02:38:58] ERROR: Max retries exceeded for message
Retrying message... (attempt 2/3)
[02:38:58] INFO: Sent segment M0
[02:38:58] INFO: Received ACK M0
Message sent successfully
```

```
Sending message 3/3 (size: 112 bytes)
[02:38:59] INFO: Sent segment M0
[02:38:59] INFO: Received ACK M0
Message sent successfully
```

Test completed. Success rate: 3/3

```
Connection closed.
Press any key to continue . . .
```

The client awaits an ACK after sending the server segment a message consisting of segment M0. The client does not receive ACKs, and timeouts occur, so we retransmit the segment once more, and eventually, the ACK would finally arrive from the server, showing that even with high ACK loss rate cases, TCP still pushes through and shows its reliability.

```
[02:38:52] INFO: Processing segment M0 of message 1-33a5e2e5186e3e29
[02:38:52] INFO: Initialized new message 1-33a5e2e5186e3e29
[02:38:52] INFO: Stored segment M0
[02:38:52] INFO: Updated sequence to M0
[02:38:52] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[02:38:52] INFO: ACK sent successfully
[02:38:52] INFO: Received complete message: 4zKuSmwAhBtMNmqSVPvBFspUZlZAuS4MQqOXjT9crEfXl7pUIeo1Wi4I5x
v30bjRVG5k63cva3Wap0zXEvFW0YLNvg6sQMnEYVfBRI5I2XUDLy2r
[02:38:52] INFO: Waiting for next message...
[02:38:52] INFO: Processing segment M0 of message 2-b415f80954a1b768
[02:38:52] INFO: Initialized new message 2-b415f80954a1b768
[02:38:52] INFO: Stored segment M0
[02:38:52] INFO: Updated sequence to M0
[02:38:52] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[02:38:52] INFO: ACK sent successfully
[02:38:52] INFO: Received complete message: s800AOeF6InTrTMqaGY4MGkc5f9TSWeuXSJk4EvQHfbZu0oYFxuChnxk59
EUtC58z2T2g1Dv6Xgb1guqI6IF0SoL53hlRq8V7124304PV0DR6lPF
[02:38:52] INFO: Waiting for next message...
[02:38:52] INFO: Dropping ACK
[02:38:54] INFO: Processing segment M0 of message 2-b415f80954a1b768
[02:38:54] INFO: Initialized new message 2-b415f80954a1b768
[02:38:54] INFO: Stored segment M0
[02:38:54] INFO: Updated sequence to M0
[02:38:54] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[02:38:54] INFO: ACK sent successfully
[02:38:54] INFO: Received complete message: s800AOeF6InTrTMqaGY4MGkc5f9TSWeuXSJk4EvQHfbZu0oYFxuChnxk59
EUtC58z2T2g1Dv6Xgb1guqI6IF0SoL53hlRq8V7124304PV0DR6lPF
[02:38:54] INFO: Dropping ACK
[02:38:54] INFO: Waiting for next message...
[02:38:58] INFO: Processing segment M0 of message 3-31ea55994fb6f553
[02:38:58] INFO: Initialized new message 3-31ea55994fb6f553
[02:38:58] INFO: Stored segment M0
[02:38:58] INFO: Updated sequence to M0
[02:38:58] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[02:38:58] INFO: ACK sent successfully
[02:38:58] INFO: Received complete message: s800AOeF6InTrTMqaGY4MGkc5f9TSWeuXSJk4EvQHfbZu0oYFxuChnxk59
EUtC58z2T2g1Dv6Xgb1guqI6IF0SoL53hlRq8V7124304PV0DR6lPF
[02:38:58] INFO: Waiting for next message...
[02:38:59] INFO: Processing segment M0 of message 4-88ddf4f8ae32b582
[02:38:59] INFO: Initialized new message 4-88ddf4f8ae32b582
[02:38:59] INFO: Stored segment M0
[02:38:59] INFO: Updated sequence to M0
[02:38:59] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[02:38:59] INFO: ACK sent successfully
[02:38:59] INFO: Received complete message: MQSA1Sg7IIx66LbiH2etvNbbNpGhWVwGDANjdd64clqlfhrifN5iGUe66w
mhmbBOH9N5UTKj8eIVB6oeKmQedDeugSb5ARryoeyhZe6yhxxkyJaL
```

Packet Duplication Scenario

```
Enter network simulation conditions (0.0-1.0 for rates):
```

```
Packet loss rate: 0
ACK loss rate: 0
Minimum delay (seconds): 0
Maximum delay (seconds): 0
Packet duplication rate: 0.5
Packet reordering rate: 0
```

```
Initializing server...
```

```
[03:34:42] INFO: Message Segmenter initialized with the following parameters:
 - MAX_SEG_SIZE : 512,
 - HEADER_SIZE : 222,
 - MAX_DATA_SIZE : 290.
```

```
Network Simulator active with conditions:
```

```
packet_loss: 0.0
ack_loss: 0.0
min_delay: 0.0
max_delay: 0.0
duplication: 0.5
reordering: 0.0
```

In this scenario, we set the packet duplication rate to 0.5. This means that for a high enough number of sent packets, half of them will be duplicated and passed to the server for processing.

```
Connecting to server (attempt 1/3)...
[03:35:00] INFO: Sending max size request to server
[03:35:00] INFO: Waiting for server response...
[03:35:00] INFO: Received response: {"MAX_SIZE": 512, "STATUS": "OK"}
[03:35:00] INFO: Message Segmenter initialized with the following parameters:
 - MAX_SEG_SIZE : 512,
 - HEADER_SIZE : 222,
 - MAX_DATA_SIZE : 290.
```

```
Connected to server successfully!
```

```
Running stress test scenario...
```

```
Sending message 1/5 (size: 112 bytes)
```

```
[03:35:00] INFO: Sent segment M0
[03:35:00] INFO: Received ACK M0
Message sent successfully
```

```
Sending message 2/5 (size: 112 bytes)
```

```
[03:35:00] INFO: Sent segment M0
[03:35:00] INFO: Received ACK M0
Message sent successfully
```

```
Sending message 3/5 (size: 112 bytes)
```

```
[03:35:00] INFO: Sent segment M0
[03:35:00] INFO: Received ACK M0
Message sent successfully
```

```
Sending message 4/5 (size: 112 bytes)
```

```
[03:35:00] INFO: Sent segment M0
[03:35:00] INFO: Received ACK M0
Message sent successfully
```

```
Sending message 5/5 (size: 112 bytes)
```

```
[03:35:00] INFO: Sent segment M0
[03:35:00] INFO: Received ACK M0
Message sent successfully
```

```
Test completed. Success rate: 5/5
```

```
Connection closed.
```

```
Press any key to continue . . . |
```

Observe the client logic transmitting the same packets. Meaning, the headers sent in each segment are approximately identical.

```

[03:35:00] INFO: Received request: REQUEST_MAX_SIZE
[03:35:00] INFO: Sending response: {"MAX_SIZE": 512, "STATUS": "OK"}
[03:35:00] INFO: Sent max message size: 512
[03:35:00] INFO: Processing handshake packet directly
[03:35:00] INFO: Processing new segment M0 of message 1-702f421d6d3efffe
[03:35:00] INFO: Initialized new message 1-702f421d6d3efffe
[03:35:00] INFO: Stored segment M0
[03:35:00] INFO: Updated sequence to M0
[03:35:00] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[03:35:00] INFO: ACK sent successfully
[03:35:00] INFO: Received complete message: LStR5qbCnSo7SMv4eciE01f3RrcMjNnjGWCUj6V6c7Dq5cD6vI5mTNvRhnoBjk3CyB5NuSJBUuOevPeL9EEd05Mriz2mvr04qPk0fUbvCRHcZM
[03:35:00] INFO: Waiting for next message...
[03:35:00] INFO: Processing new segment M0 of message 2-e64b8dbb1b8f8125
[03:35:00] INFO: Initialized new message 2-e64b8dbb1b8f8125
[03:35:00] INFO: Stored segment M0
[03:35:00] INFO: Updated sequence to M0
[03:35:00] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[03:35:00] INFO: ACK sent successfully
[03:35:00] INFO: Received complete message: fnylvYRSWEPNWYgYwlX78IXtzfzzlMWgdAPFKL8gKyMtGLeH4ZirY7J4GtaBazom9asv0SF1t2EzqdGrP0p5WdKFKBIwNGnmn4wBYP0a8sp010s0
[03:35:00] INFO: Waiting for next message...
[03:35:00] INFO: Processing new segment M0 of message 3-b7a456aed02f0caa
[03:35:00] INFO: Initialized new message 3-b7a456aed02f0caa
[03:35:00] INFO: Stored segment M0
[03:35:00] INFO: Updated sequence to M0
[03:35:00] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[03:35:00] INFO: ACK sent successfully
[03:35:00] INFO: Received complete message: B3n5kOR1zKXLDDqnC4cfIkToV9FCXhyBJYE0lMipvuBYkK9zzI6a1eWqgFi13XLZ0i0e9n4WQaKG7WKGZReQfk3bZnplQULMU7Cw7xkIoFwvzMm
[03:35:00] INFO: Waiting for next message...
[03:35:00] INFO: Duplicating packet
[03:35:00] INFO: Processing new segment M0 of message 4-77bda133b1251174
[03:35:00] INFO: Initialized new message 4-77bda133b1251174
[03:35:00] INFO: Stored segment M0
[03:35:00] INFO: Updated sequence to M0
[03:35:00] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[03:35:00] INFO: ACK sent successfully
[03:35:00] INFO: Received complete message: ghwIZBnU2Et0n6aMlP4nqOsLA0NLFSVQPDNZYjmFSW2FTujuLKbxlNCjfDBwbF85hI8ePbqaqgbhv1vp0tG2dKv2IovKcnXHRebkfc2FLZZdKv
[03:35:00] INFO: Waiting for next message...
[03:35:00] WARNING: Duplicate packet detected and discarded - Message: 4-77bda133b1251174, Sequence: M0
[03:35:00] INFO: Processing new segment M0 of message 5-c88a7d67cfef9053
[03:35:00] INFO: Initialized new message 5-c88a7d67cfef9053
[03:35:00] INFO: Stored segment M0
[03:35:00] INFO: Updated sequence to M0
[03:35:00] INFO: Sending ACK message: {"STATUS": "OK", "ACK": "M0"}
[03:35:00] INFO: ACK sent successfully
[03:35:00] INFO: Received complete message: MkQcZBWYJ2ZCsxcxiuW9NhXiYL77JBen0vU0P6qahw3gbtDtkLrSmaGHaVXKUqIqUqCMHO0z14Y3EbWFqjJIwvaX9VyhAbzEreaNqBS30hVx8T8
[03:35:00] INFO: Waiting for next message...

```

Here, observe the server logic detecting duplicate packets and of course, discarding such packets.

tcp.port == 5001						
No.	Time	Source	Destination	Protocol	Length	Info
421	16.207247	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=34 Ack=343 Win=2160896 Len=29
422	16.207283	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=343 Ack=63 Win=2161152 Len=0
427	16.310278	127.0.0.1	127.0.0.1	TCP	370	60078 → 5001 [PSH, ACK] Seq=343 Ack=63 Win=2161152 Len=326
428	16.310296	127.0.0.1	127.0.0.1	TCP	44	5001 → 60078 [ACK] Seq=63 Ack=669 Win=2160640 Len=0
429	16.311353	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=63 Ack=669 Win=2160640 Len=29
430	16.311371	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=669 Ack=92 Win=2161152 Len=0
435	16.413560	127.0.0.1	127.0.0.1	TCP	370	60078 → 5001 [PSH, ACK] Seq=669 Ack=92 Win=2161152 Len=326
436	16.413579	127.0.0.1	127.0.0.1	TCP	44	5001 → 60078 [ACK] Seq=92 Ack=995 Win=2160128 Len=0
437	16.415203	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=92 Ack=995 Win=2160128 Len=29
438	16.415243	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=995 Ack=121 Win=2161152 Len=0
439	16.463897	127.0.0.1	127.0.0.1	TCP	370	60078 → 5001 [PSH, ACK] Seq=995 Ack=121 Win=2161152 Len=326
440	16.463948	127.0.0.1	127.0.0.1	TCP	44	5001 → 60078 [ACK] Seq=121 Ack=1321 Win=2159872 Len=0
443	16.468877	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=121 Ack=1321 Win=2159872 Len=29
444	16.468913	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=1321 Ack=150 Win=2161152 Len=0
449	16.576607	127.0.0.1	127.0.0.1	TCP	370	60078 → 5001 [PSH, ACK] Seq=1321 Ack=150 Win=2161152 Len=326
450	16.576624	127.0.0.1	127.0.0.1	TCP	44	5001 → 60078 [ACK] Seq=150 Ack=1647 Win=2159616 Len=0
451	16.577834	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=150 Ack=1647 Win=2159616 Len=29
452	16.577839	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=1647 Ack=170 Win=2159616 Len=0
Frame 435: 370 bytes on wire (2960 bits), 370 bytes captured (2960 bits) on interface \Device\NPF_Loopback						
Null/Loopback						
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1						
Transmission Control Protocol, Src Port: 60078, Dst Port: 5001, Seq: 669, Ack: 92, Len: 326						
Data (326 bytes)						
Data [...] : 7b226d65746164617461223a207b22736571223a20302c2022636865636b73756d223a2022323236356563656663 [Length: 326]						
0000 02 00 00 00 45 00 01 6e c2 bf 40 00 80 06 00 00 ... E-n @...						
0010 7f 00 00 01 7f 00 00 01 ea ae 13 89 fa 54 a3 1d T...						
0020 bf c9 4e fc 50 18 20 fa e9 b5 00 00 7b 22 6d 65 ..N.P. .{me						
0030 74 61 64 61 74 61 22 3a 20 7b 22 73 65 71 22 3a tadata": {"seq":						
0040 20 30 2c 20 22 63 68 65 63 6b 73 75 6d 22 3a 20 0, "che cksum":						
0050 22 32 32 36 35 65 65 66 63 64 35 32 33 33 36 "2265ece fcd52336						
0060 66 64 61 38 64 64 61 63 33 35 31 36 63 62 66 66 fda8ddac 3516cbff						
0070 31 65 38 37 35 39 63 33 37 33 65 31 61 37 37 65 1e8759c3 73e1a77e						
0080 64 61 63 36 31 65 37 61 65 39 63 65 64 66 30 39 dacc1e7a e9cedf09						
0090 39 22 2c 20 22 74 6f 74 61 6c 5f 73 65 67 6d 65 9", "tot al_segm						
00a0 6e 74 73 22 3a 20 31 2c 20 22 6d 65 73 73 61 67 nts": 1, "messag						
00b0 65 5f 69 64 22 3a 20 22 33 2d 61 30 65 30 64 31 e_id": "3-a0e0d1						
00c0 35 34 36 30 35 63 63 39 38 36 22 2c 20 22 69 73 54605cc9 86", "is _last": true, "o						
00d0 5f 6c 61 73 74 22 3a 20 74 72 75 65 2c 20 22 6f riginal_length":						
00e0 72 69 67 69 6e 61 6c 5f 6c 65 6e 67 74 68 22 3a 112}, "data": "						
00f0 20 31 31 32 7d 2c 20 22 64 61 74 61 22 3a 20 22 l0d9JYDB bU0Ep7cM						
0100 6c 4f 64 39 4a 59 44 42 62 55 4f 45 70 37 63 4d xlarAXFW rShRbo5C						
0110 78 6c 61 72 41 58 46 57 72 53 68 52 62 6f 35 43 2ig9dI7x 7h5FF8PQ						
0120 32 69 67 39 64 49 37 78 37 68 35 66 46 38 50 51 y0dp6dqX NdVJ7KAE						
0130 79 4f 64 70 47 64 71 58 4e 64 56 4a 37 4b 41 45 ZWhdFqXY K8eqf32n						
0140 5a 57 68 64 46 71 58 59 4b 38 65 71 66 33 32 6e i6JPh0mT a4blLoxA						
0150 69 36 4a 50 68 4f 6d 54 61 34 62 4c 78 6f 78 41 eCWjcq8I aQkAY5Pa						
0160 65 43 57 6a 63 71 38 49 61 51 6b 41 59 35 50 61 "						
0170 22 7d						

wireshark_Adapter for loopback traffic capture5VRKZ2.pcapng

Packets: 5216 - Displayed: 86 (1.6%) - Dropped: 0 (0.0%)

Profile: Default

No.	Time	Source	Destination	Protocol	Length	Info
421	16.207247	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=34 Ack=343 Win=2160896 Len=29
422	16.207283	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=343 Ack=63 Win=2161152 Len=0
427	16.310278	127.0.0.1	127.0.0.1	TCP	370	60078 → 5001 [PSH, ACK] Seq=343 Ack=63 Win=2161152 Len=326
428	16.310296	127.0.0.1	127.0.0.1	TCP	44	5001 → 60078 [ACK] Seq=63 Ack=669 Win=2160640 Len=0
429	16.311353	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=63 Ack=669 Win=2160640 Len=29
430	16.311371	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=669 Ack=92 Win=2161152 Len=0
435	16.413560	127.0.0.1	127.0.0.1	TCP	370	60078 → 5001 [PSH, ACK] Seq=669 Ack=92 Win=2161152 Len=326
436	16.413579	127.0.0.1	127.0.0.1	TCP	44	5001 → 60078 [ACK] Seq=92 Ack=995 Win=2160128 Len=0
437	16.415203	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=92 Ack=995 Win=2160128 Len=29
438	16.415243	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=995 Ack=121 Win=2161152 Len=0
439	16.463897	127.0.0.1	127.0.0.1	TCP	370	60078 → 5001 [PSH, ACK] Seq=995 Ack=121 Win=2161152 Len=326
440	16.463948	127.0.0.1	127.0.0.1	TCP	44	5001 → 60078 [ACK] Seq=121 Ack=1321 Win=2159872 Len=0
443	16.468877	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=121 Ack=1321 Win=2159872 Len=29
444	16.468913	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=1321 Ack=150 Win=2161152 Len=0
449	16.576607	127.0.0.1	127.0.0.1	TCP	370	60078 → 5001 [PSH, ACK] Seq=1321 Ack=150 Win=2161152 Len=326
450	16.576624	127.0.0.1	127.0.0.1	TCP	44	5001 → 60078 [ACK] Seq=150 Ack=1647 Win=2159616 Len=0
451	16.577834	127.0.0.1	127.0.0.1	TCP	73	5001 → 60078 [PSH, ACK] Seq=150 Ack=1647 Win=2159616 Len=29
452	16.577876	127.0.0.1	127.0.0.1	TCP	44	60078 → 5001 [ACK] Seq=150 Ack=1647 Win=2159616 Len=0

Frame 439: 370 bytes on wire (2960 bits), 370 bytes captured (2960 bits) on interface \Device\NPF_Loopback
 Null/Loopback
 Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 Transmission Control Protocol, Src Port: 60078, Dst Port: 5001, Seq: 995, Ack: 121, Len: 326
 Data (326 bytes): 7b226d65746164617461223a207b22736571223a20302c2022636865636b73756d223a2022323236356563656663 [Length: 326]

```

0000  02 00 00 00 45 00 01 6e c2 c3 40 00 80 06 00 00
0010  7f 00 00 01 7f 00 00 01 ea ae 13 89 fa 54 a4 63
0020  bf c9 4f 19 50 18 20 fa e8 52 00 00 7b 22 6d 65
0030  74 61 64 61 74 61 22 3a 20 7b 22 73 65 71 22 3a
0040  20 30 2c 20 22 63 68 65 63 6b 73 75 6d 22 3a 20
0050  22 32 32 36 35 65 63 65 66 63 64 35 32 33 33 36
0060  66 64 61 38 64 64 61 63 33 35 31 36 63 62 66 66
0070  31 65 38 37 35 39 63 33 37 33 65 31 61 37 37 65
0080  64 61 63 36 31 65 37 61 65 39 63 65 64 66 30 39
0090  39 22 2c 20 22 74 6f 74 61 6c 5f 73 65 67 6d 65
00a0  6e 74 73 22 3a 20 31 2c 20 22 6d 65 73 73 61 67
00b0  65 5f 69 64 22 3a 20 22 33 2d 61 30 65 30 64 31
00c0  35 34 36 30 35 63 63 39 38 36 22 2c 20 22 69 73
00d0  5f 6c 61 73 74 22 3a 20 74 72 75 65 2c 20 22 6f
00e0  72 69 67 69 6e 61 6c 5f 6c 65 6e 67 74 68 22 3a
00f0  20 31 31 32 7d 2c 20 22 64 61 74 61 22 3a 20 22
0100  6c 4f 64 39 4a 59 44 42 62 55 4f 45 70 37 63 4d
0110  78 6c 61 72 41 58 46 57 72 53 68 52 62 6f 35 43
0120  32 69 67 39 64 49 37 78 37 68 35 66 46 38 50 51
0130  79 4f 64 70 47 64 71 58 4e 64 56 4a 37 4b 41 45
0140  5a 57 68 64 46 71 58 59 4b 38 65 71 66 33 32 6e
0150  69 36 4a 50 68 4f 6d 54 61 34 62 4c 78 6f 78 41
0160  65 43 57 6a 63 71 38 49 61 51 6b 41 59 35 50 61
0170  22 7d

```

... E-n @....
 T-c
 ... O P - R - F "me
 tadata": {"seq":
 0, "che cksum":
 "2265ece fcd52336
 fda8ddac 3516cbff
 1e8759c3 73e1a77e
 dac61e7a e9cedf09
 91, "tot al_segm
 ents": 1, "messag
 e_id": "3-a0e0d1
 54605cc9 86", "is
 _last": true, "o
 riginal_length":
 112}, "data": "
 l0d9JYDB bU0Ep7cM
 xlarAXFW rShRbo5C
 2ig9dI7x 7h5f8PQ
 y0dpGdqX NdVJ7KAE
 ZWhdFqXY K8eqf32n
 i6JPh0mT a4bLxoxA
 eCWjcq8I aQkAY5Pa
 "j

Observe packets number 435 and 439. These screenshots confirm the fact that the client truly did send duplicate packets, as their message_id content is identical.

Testing other scenarios

The Network Simulator implemented in the project is flexible and can simulate with a multitude of edge cases and scenarios, there are countless possibilities and combinations of parameters that could be input both in the server and client side of the simulator.

Our tests show that TCP is indeed a reliable, robust protocol for message exchange, and can deal with a large number of network challenges such as the aforementioned edge cases.