Reliable Data Transfer (RDT)

Kanav Meena(2023266), Aditya Dixit(2022030), Pranjal Bharti(2021080)

2. Objective

Implement a reliable data transport (RDT) protocol over an unreliable channel capable of dropping packets.
The goal was to design sender and receiver modules that ensure reliable, ordered, non-duplicated delivery similar to TCP but without flow or congestion control.

3. Implementation Overview

Sender (`sender_helper.c`)

- Maintains two pointers:

    - `send_base` – the first unacknowledged byte.

    - `next_seqno` – the sequence number for the next byte to send.

- Stores unacknowledged packets in a linked list buffer.

- **rdt_send()**:

    - Embeds 63-bit sequence number using `make_pkt`.

    - Sends via `udt_send`.

    - Starts timer if not already running.

- **rdt_recv_ack()**:

    - Updates `send_base` on cumulative ACKs.

○　Removes acknowledged packets from the buffer.

　　　○　Stops or restarts timer appropriately.

- **timeout()**:

　　　○　Retransmits only the earliest unacknowledged segment (`send_base`).

Receiver (`receiver_helper.c`)

- Maintains `recv_base` (next expected byte).

- Stores out-of-order packets in a sorted linked list.

- **rdt_recv()**:

　　　○　Extracts sequence number and data.

　　　○　Buffers out-of-order packets.

　　　○　Moves contiguous data into reassembly buffer and sends cumulative ACK.

　　　○　Calls `notify_app()` when new in-order data becomes available.

- **app_recv()**:

　　　○　Copies available data to the application buffer.

　　　○　Removes delivered data and advances internal pointers.

Both modules only use APIs provided in the skeleton (`udt_send`, `send_ack`, `start_timer`, etc.), and no custom networking syscalls.

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4. Test Case Results

Test Case 1

Command: `./sender`
 Result: `test PASSED`

Runtime: 0 m 6.77 s
Maximum resident set size: 1920 KB

Test Case 2

Command: `./sender 1`
Result: `test PASSED`
Runtime: 0 m 22.38 s
Maximum resident set size: 2648 KB

Both tests completed within 60 seconds, earning full marks.

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5. Detailed `/usr/bin/time -v` Summary

Metric	Test 1 (sender)	Test 2 (sender 1)
User time (s)	0.34	0.86
System time (s)	0.11	0.28
Elapsed (wall clock)	0:06.77	0:22.38
CPU %	6 %	5 %
Max RSS (kB)	1920	2648
Minor page faults	210	668
Voluntary context switches	3603	4787
Involuntary context switches	11	32
Exit status	0	0

Receiver showed comparable times and memory when run in parallel.

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6. Observations

- Both tests passed consistently on multiple runs.

- Packet loss and retransmission are correctly handled (confirmed via checkpoints).

- Memory usage is minimal (< 3 MB).

- No unnecessary retransmissions observed; cumulative ACKs function properly.

7. Conclusion

The implemented RDT protocol ensures reliable byte-stream delivery over an unreliable channel with dropped packets.
 Both sender and receiver conform strictly to the assignment's APIs, and performance results are well within the evaluation thresholds.

8. Print Statements:

Test case 1(sender):
[0] checkpoint successful ao: 0
[1] checkpoint successful ao: 0
[2] checkpoint successful ao: 0
[3] checkpoint successful ao: 0
[4] checkpoint successful ao: 0
[5] checkpoint successful ao: 0
[6] checkpoint successful ao: 0
[7] checkpoint successful ao: 0
[8] checkpoint successful ao: 0
[9] checkpoint successful ao: 0
[10] checkpoint successful ao: 0
[11] checkpoint successful ao: 0
[12] checkpoint successful ao: 0
[13] checkpoint successful ao: 0
[14] checkpoint successful ao: 0
[15] checkpoint successful ao: 0
[16] checkpoint successful ao: 0
[17] checkpoint successful ao: 0
[18] checkpoint successful ao: 0
[19] checkpoint successful ao: 0

[20] checkpoint successful ao: 0
[21] checkpoint successful ao: 0
[22] checkpoint successful ao: 0
[23] checkpoint successful ao: 0
[24] checkpoint successful ao: 0
[25] checkpoint successful ao: 0
[26] checkpoint successful ao: 0
[27] checkpoint successful ao: 0
[28] checkpoint successful ao: 0
[29] checkpoint successful ao: 0
[30] checkpoint successful ao: 0
[31] checkpoint successful ao: 0
test PASSED

Test Case 2(Sender 1):
[0] checkpoint successful ao: 16
[1] checkpoint successful ao: 17
[2] checkpoint successful ao: 20
[3] checkpoint successful ao: 17
[4] checkpoint successful ao: 15
[5] checkpoint successful ao: 13
[6] checkpoint successful ao: 13
[7] checkpoint successful ao: 12
[8] checkpoint successful ao: 14
[9] checkpoint successful ao: 13
[10] checkpoint successful ao: 14
[11] checkpoint successful ao: 14
[12] checkpoint successful ao: 14
[13] checkpoint successful ao: 14
[14] checkpoint successful ao: 15
[15] checkpoint successful ao: 15
[16] checkpoint successful ao: 15
[17] checkpoint successful ao: 14
[18] checkpoint successful ao: 13
[19] checkpoint successful ao: 13
[20] checkpoint successful ao: 12
[21] checkpoint successful ao: 13
[22] checkpoint successful ao: 13
[23] checkpoint successful ao: 14
[24] checkpoint successful ao: 14
[25] checkpoint successful ao: 15
[26] checkpoint successful ao: 14
[27] checkpoint successful ao: 14

[28] checkpoint successful ao: 15
[29] checkpoint successful ao: 15
[30] checkpoint successful ao: 15
[31] checkpoint successful ao: 15
test PASSED

/usr/bin/time -v ./sender 1:
[0] checkpoint successful ao: 1
[1] checkpoint successful ao: 3
[2] checkpoint successful ao: 4
[3] checkpoint successful ao: 3
[4] checkpoint successful ao: 6
[5] checkpoint successful ao: 10
[6] checkpoint successful ao: 11
[7] checkpoint successful ao: 11
[8] checkpoint successful ao: 12
[9] checkpoint successful ao: 12
[10] checkpoint successful ao: 13
[11] checkpoint successful ao: 14
[12] checkpoint successful ao: 13
[13] checkpoint successful ao: 13
[14] checkpoint successful ao: 13
[15] checkpoint successful ao: 12
[16] checkpoint successful ao: 12
[17] checkpoint successful ao: 13
[18] checkpoint successful ao: 13
[19] checkpoint successful ao: 12
[20] checkpoint successful ao: 12
[21] checkpoint successful ao: 12
[22] checkpoint successful ao: 12
[23] checkpoint successful ao: 13
[24] checkpoint successful ao: 12
[25] checkpoint successful ao: 13
[26] checkpoint successful ao: 12
[27] checkpoint successful ao: 12
[28] checkpoint successful ao: 12
[29] checkpoint successful ao: 12
[30] checkpoint successful ao: 11
[31] checkpoint successful ao: 12
test PASSED
        Command being timed: "./sender 1"
        User time (seconds): 0.86
        System time (seconds): 0.28
        Percent of CPU this job got: 5%

Elapsed (wall clock) time (h:mm:ss or m:ss): 0:22.38
Average shared text size (kbytes): 0
Average unshared data size (kbytes): 0
Average stack size (kbytes): 0
Average total size (kbytes): 0
Maximum resident set size (kbytes): 2648
Average resident set size (kbytes): 0
Major (requiring I/O) page faults: 0
Minor (reclaiming a frame) page faults: 668
Voluntary context switches: 4787
Involuntary context switches: 32
Swaps: 0
File system inputs: 0
File system outputs: 0
Socket messages sent: 0
Socket messages received: 0
Signals delivered: 0
Page size (bytes): 4096
Exit status: 0
/usr/bin/time -v ./sender:
[0] checkpoint successful ao: 0
[1] checkpoint successful ao: 0
[2] checkpoint successful ao: 0
[3] checkpoint successful ao: 0
[4] checkpoint successful ao: 0
[5] checkpoint successful ao: 0
[6] checkpoint successful ao: 0
[7] checkpoint successful ao: 0
[8] checkpoint successful ao: 0
[9] checkpoint successful ao: 0
[10] checkpoint successful ao: 0
[11] checkpoint successful ao: 0
[12] checkpoint successful ao: 0
[13] checkpoint successful ao: 0
[14] checkpoint successful ao: 0
[15] checkpoint successful ao: 0
[16] checkpoint successful ao: 0
[17] checkpoint successful ao: 0
[18] checkpoint successful ao: 0
[19] checkpoint successful ao: 0
[20] checkpoint successful ao: 0
[21] checkpoint successful ao: 0
[22] checkpoint successful ao: 0
[23] checkpoint successful ao: 0

[24] checkpoint successful ao: 0
[25] checkpoint successful ao: 0
[26] checkpoint successful ao: 0
[27] checkpoint successful ao: 0
[28] checkpoint successful ao: 0
[29] checkpoint successful ao: 0
[30] checkpoint successful ao: 0
[31] checkpoint successful ao: 0
test PASSED
        Command being timed: "./sender"
        User time (seconds): 0.34
        System time (seconds): 0.11
        Percent of CPU this job got: 6%
        Elapsed (wall clock) time (h:mm:ss or m:ss): 0:06.77
        Average shared text size (kbytes): 0
        Average unshared data size (kbytes): 0
        Average stack size (kbytes): 0
        Average total size (kbytes): 0
        Maximum resident set size (kbytes): 1920
        Average resident set size (kbytes): 0
        Major (requiring I/O) page faults: 0
        Minor (reclaiming a frame) page faults: 210
        Voluntary context switches: 3603
        Involuntary context switches: 11
        Swaps: 0
        File system inputs: 0
        File system outputs: 0
        Socket messages sent: 0
        Socket messages received: 0
        Signals delivered: 0
        Page size (bytes): 4096
        Exit status: 0