

Network Term Project Part 2

Group 29

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I. INTRODUCTION

In this assignment, we have designed and implemented a network which consists of a source node, a broker (B), routers and a destination node. We are sending a large file (exactly 5.000.000 bytes) from source to destination. The Source sends packets to Broker via TCP. Between Broker and Destination, our RDT protocol is working on top of UDP.

II. PURPOSE OF THE PROJECT

The purpose of this project is to learn reliable data transfer protocol basics like timeout, retransmission, and packet order. We have learned to implement reliable data transfer protocol in python and we reinforce our TCP, UDP socket programming knowledge along with the GENI platform, SSH, SCP, and TMP protocols.

III. DESIGN PROCESS

In our project, we have three nodes that will run scripts and two routers that will route the packets to the next hop.

We have designed our routers so that they forward the packets directly to the next hop as it is stated in the homework text. Forwarding tables and configuration commands are in the readme file.

Since the communication between the Source and Broker is TCP, we are sure that packets that we send from the Source to the Broker will receive correctly and in order. The Source node first sends the whole file to the Broker. While Broker gets the packets from the Source, it does not start to send, but first stores the whole packets. Then, the broker can guarantee to send the packets to the destination correctly and in order by using our RDT protocol.

We design our protocol to be a UDP-based "Reliable Data Transfer" (RDT) protocol that supports pipelining and multi-homing. To support pipelining functionality, we preferred "go back-n" protocol since we think it meets the homework's requirements about pipelining. We have explained how the "go back-n" protocol provides pipelining functionality under the "Algorithms and Strategies" section.

Similarly, to make our project support multi-homing, we design our Broker and Destination working algorithm to use both r1 and r2. Therefore, we split the traffic between r1 and r2 equally. This approach also explained under the "Algorithms and Strategies" section in more detail.

We have used the timeout mechanism to detect lost packets and retransmit those packets as it is in the "go back-time", and sequence numbers to ensure the correct order of packets while designing the RDT protocol functionality of our project.

IV. IMPLEMENTATION PROCESS

We choose python3 as a programming language for the implementation process.

We continue from our previous part 1 implementation. The first minor change was to read and send a file over the network in the source implementation and write the result to an output file in the destination side. The headstones of the implementation of our protocol for each script is explained in subsections.

A. Source (*source.py*)

TABLE I
GLOBAL AND/OR IMPORTANT VARIABLES OF SOURCE

Name	Description
file_object	The file object that will be send to the destination.
payload_size	The size of packets that are send to the broker.

We opened the file that will be sent to the destination. Then we set the Broker's host address and the port. We created a TCP socket and an address object with the host address and port number of Broker. Then, connection is established between source and broker with tcp socket. After the connection, in a while loop, we read and send the file with the payload size until the whole file is sent in.

B. Broker (*broker.py*)

When Brokers receives TCP request from the Source, the "handle" method of "ThreadingTCPRequestHandler" class starts to execute. First, it gets the whole file in payload size chunks, prepares the packets that will be sent and stores them into snd_pkt array. This made the retransmission process easy.

TABLE II
GLOBAL AND/OR IMPORTANT VARIABLES OF BROKER

Name	Description
nextseqnum	Sequence number of the next packet that will be sent.
base	The oldest sent but not ACKed packet.
wnd_size	The number indicating how many not ACKed packet can be send consecutively.
snd_pkt	The array that contains all of the packets that will be sent.
sample_rtt	The sample round trip time value.
estimated_rtt	The estimated round trip time value
dev_rtt	The deviation value of round trip time.
total_packet_count	Total number of packets that will be sent.
sent_time	Start time of RTT.
is_acked	Flag indicating that this measurement of RTT finished or not.
received_time	End time of RTT.
payload_size	The size of packets payload.
timeout_interval	The interval of timeout.
lock	The lock object that provides concurrency.
timer	"threading.Timer" object that initiates timeout function after "timeout_interval" amount of time has passed after it started

When packets are ready, we start to send them to the Destination over r1 and r2 in a while loop. Here the problem was that broker sends the packets too fast and destination could not handle incoming packets in the correct order because too many threads are working at the same time. As a result, too many timeout and retransmission happened. We solve this problem by putting a sleep statement in the while loop that sends packets. This made the scenario more realistic and worked more compatible. Inside the while loop, we implemented "go back-n" protocol.

For every incoming request from the destination, the "handle" method of "ThreadingUDPRequestHandler" class is executed. When an ack packet received, the "time_out_interval" variable is updated. For the not corrupted incoming ack packets, the receiver side of the "go back-n" protocol is implemented

While implementing the broker.py, we faced with concurrency problems because a new thread handles every incoming packet, meaning more than one thread runs and access to the same variables at the same time. We solved this problem using "threading.Lock" objects. Before accessing the common object, we hold the lock and prevent other threads to access the same variables.

We implement the approach that is stated in the course's textbook under section 3.5.3 while calculating the timeout interval. The approach is the following. The sampleRTT, denoted by sample_rtt in our code, for a segment is the amount of time between when the segment is sent (that is, passed to IP) and when an acknowledgment for the segment is received. Instead of measuring a SampleRTT for every transmitted segment, we take only one sampleRTT at a time. Therefore, we measured time sampleRTT at every round trip time. The estimatedRTT,

denoted by an estimatedRTT in our code, is the weighted average of the previous value of estimatedRTT and the new sampleRTT. [RFC 6298] defines the RTT variation, denoted by devRTT in our code, as an estimate of how much SampleRTT typically deviates from EstimatedRTT. Now we can determine the TimeoutIntervaltime, denoted by time_out_interval in our code. Clearly, the interval should be greater than or equal to EstimatedRTT, or unnecessary retransmissions would be sent. But the timeout interval should not be too much larger than EstimatedRTT; otherwise, when a segment is lost, our protocol would not quickly retransmit the segment, leading to large data transfer delays. It is therefore desirable to set the timeout equal to the EstimatedRTT plus some margin. The margin should be large when there is a lot of fluctuation in the SampleRTT values; it should be small when there is little fluctuation. The value of DevRTT should thus come into play here. All of these considerations are taken into account in our protocol's method for determining the retransmission timeout interval:

$$\text{TimeoutInterval} = \text{EstimatedRTT} + 4 \cdot \text{DevRTT}$$

An initial TimeoutInterval value of 1 second is recommended [RFC 6298].

C. Destination (destination.py)

TABLE III
GLOBAL AND/OR IMPORTANT VARIABLES OF BROKER

Name	Description
exp_seq_number	Sequence number of the packet that we expect to receive next.
sndpkt	The last Ack packet that we send.
result	The variable that we store file before writing the output file.
lock	The lock object that provides concurrency.

Destination listens both its own interfaces and opens a new thread for every incoming request. For every incoming request "handle" method of "ThreadingUDPRequestHandler" class is executed. When a packet arrives, we first check if it is corrupted or not. If the packet is not corrupted and has sequence number equal to the expected sequence number, we implemented the "go back-n" protocol of receiver side. However, if the packet is corrupted or not have the sequence number equal to the expected sequence number, we send the "sndpkt" which is the last Ack packet.

Here, we have faced with the concurrency issue as we had in the broker implementation. We solved the problem as we did in the broker, that is, we declared a lock object and acquired the lock before accessing the common elements.

Another problem was to understand when the whole file is received and it is time to write the result to the output file. We have overcome this problem by putting a finish flag to the header, indicating that no any other packet left and the whole packet is finished. We check this flag for incoming packets and understand if the file is received. If the flag is set, we write the result to the output file.

Algorithms and Strategies

V. ALGORITHMS AND STRATEGIES

In this project, we used "Go Back-N" protocol to support pipelining and RDT mechanisms (checksum, retransmission, ack mechanism, sequence number, timeout mechanism etc) to provide reliable data transfer.

A. Go Back-N

Go-Back-N (GBN) protocol is a sliding window protocol. In a Go-Back-N protocol, the sender is allowed to transmit multiple packets (when available) without waiting for an acknowledgment but is constrained to have no more than some maximum allowable number, window size, of unacknowledged packets in the pipeline.

Sender

- Before sending a new packet, the sender first checks to see if the window is full, that is, whether there are N outstanding, unacknowledged packets. If the window is not full, a packet is created and sent, and variables are appropriately updated. If the window is full, the sender simply tries to send the packet later.
- Receipt of an ACK. In our GBN protocol, an acknowledgment for a packet with sequence number n will be taken to be a cumulative acknowledgment, indicating that all packets with a sequence number up to and including n have been correctly received at the receiver.
- A timeout event. The protocol's name, "Go-Back-N," is derived from the sender's behavior in the presence of lost or overly delayed packets. A timer will be used to recover from lost data or acknowledgment packets. If a timeout occurs, the sender resends all packets that have been previously sent but that have not yet been acknowledged. Our sender uses only a single timer, which can be thought of as a timer for the oldest transmitted but not yet acknowledged packet. If an ACK is received but there are still additional transmitted but not yet acknowledged packets, the timer is restarted. If there are no outstanding, unacknowledged packets, the timer is stopped.

Receiver

The receiver's actions in GBN are also simple. If a packet with sequence number n is received correctly and is in order (that is, the data last saved came from a packet with sequence number $n - 1$), the receiver sends an ACK for packet n and saves the data portion of the packet. In all other cases, the receiver discards the packet and resends an ACK for the most recently received in-order packet. Note that since packets are saved one at a time, if packet k has been received and saved, then all packets with a sequence number lower than n have also been delivered. Thus, the use of cumulative acknowledgments is a natural choice for GBN.

B. RDT Mechanisms

We have used known various reliable data transfer mechanisms in our project. We manage lost, corrupted, and out of order packet with those mechanisms.

Lost Packets

We handle lost packets by using a timeout mechanism. We have a timer in sender-side which is the Broker. We started this timer as it is explained in the GBN protocol and determined the timeout interval as we explained in the Broker's implementation part.

Corrupted Packets

We handle corrupted packets by using the md5 hashing algorithm. We take the md5 of the whole packet and add this md5 to the end of the packet. Then we control this md5 when we receive the packet on the other side. If they are not equal, we conclude that the packet is corrupted.

Out of Order Packets

We handle out of order packets by using sequence number strategy. We applied the sequence number strategy as it is explained in the GBN protocol. We count packets as the sequence number in our project.

VI. PACKET STRUCTURES

TABLE IV
BROKER TO DESTINATION PACKET STRUCTURE

Sequence Number 4 Bytes	FIN Flag 4 Bytes	Payload	md5 check sum 32 Bytes
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TABLE V
ACKNOWLEDGMENT PACKET STRUCTURE

Sequence Number 4 Bytes	md5 check sum 32 Bytes
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VII. METHODOLOGY

We began our research by looking an example of TCP client and server implementation in python. We then look at to UDP client and server implementation in python. The project includes "socketserver" library.

We search the tc and netem commands from the provided homework text.

VIII. MOTIVATION

This project brings us the knowledge of python socket programming and tc & netem concepts. We experienced to add header to a packet and decompose at the server side. We gain familiarity with the GENI platform and some network concepts like delay, packet lost.

IX. EXPERIMENT RESULTS

A. Netem

Netem provides Network Emulation functionality for testing protocols by emulating the properties of wide area networks. It emulates variable delay, loss, duplication and re-ordering. Netem is used for the virtual machines in GENI.

B. NTP

The Network Time Protocol (NTP) is a networking protocol for clock synchronization between computer systems over packet-switched, variable-latency data networks.

C. Experiment

First we synchronized all of the virtual machine's clocks. Then we add delays to 4 links between broker and destination. We performed three experiment that is stated in homework text. The results are in the following figure:

X. WORKLOAD

We have performed pair work, we were side by side while developing the project. Hence, the workload was fair.