# CS 455: Computer Communications and Networking
# PA-2: Mason Transport Protocol



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## Project Description

### Project Overview

In this assignment, you will be implementing TCP's reliable transport protocol to transfer a file from one machine to another. However, instead of using TCP sockets, you will use UDP. This means that your new protocol (let's call it MTP - Mason Transport Protocol) should provide reliable delivery of UDP datagrams in presence of packet loss and corruption.

Your task is to implement a sender and a receiver that connect with each other over UDP. The sender delivers a file to the receiver using MTP. Upon receiving the file, the receiver should be able to verify the integrity of the file.

### MTP specifications

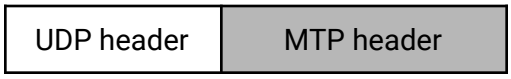
#### Types of packets and packet size

MTP specifies only two types of packets: DATA and ACK. The sender sends the DATA packets and when the receiver receives them, ACK packets are sent back. Since MTP is a reliable delivery protocol, the DATA packets and ACKs should contain a sequence number. The data packet has a header with the following fields

1. type (unsigned integer): data or ack
2. seqNum (unsigned integer): sequence number
3. length (unsigned integer): length of data including the MTP header fields
4. checksum (unsigned integer): 4 bytes CRC

MTP DATA packet looks as shown below. Note that your MTP header + data is encapsulated in the UDP header since the sender and receiver connect over a UDP socket. Of course, the UDP header is already added by the socket and is something that you don't have to implement.
DATA packet:


MTP ACK packet will have the same fields in its header, without any data.
ACK packet:




We will assume the maximum packet size of 1500 bytes. With 8 bytes of the UDP header and 20 bytes of the IP header, the size of (MTP header + data) can be no more than 1472 bytes. Assuming 4 bytes for unsigned int, the MTP header will be 16 bytes for the 4 fields mentioned above. The header size remains the same in all packets.

**MTP reliable delivery policy**
MTP relies on the following rules to ensure reliable delivery:

- Sequence number: Each packet from the sender to the receiver should include a sequence number. The sender reads the input file, splits it into appropriate-sized chunks of data, puts it into an MTP data packet, and assigns a sequence number to it.
    - The sender will use 0 as the initial sequence number.
    - Unlike TCP, we will use sequence numbers of each packet and not for the byte stream.

- Checksum: The integrity of the packet (meaning if it is corrupt or not) is validated using a checksum. After adding the first three fields of the MTP header (type, seqNum, and length) and data, the sender calculates a 32 bits checksum and appends it to the packet. You can use the existing implementation of CRC32 for calculating your checksum.

- Sliding window: The sender uses a sliding window mechanism that we discussed in class. The size of the window will be specified in the command line. The window only depends on the number of unacknowledged packets and does not depend on the receiver's available buffer size (i.e., MTP does not have any flow control).

- Timeout: The sender will use a fixed value of 500ms as the timeout. Similar to TCP, the timer is running for the oldest unacked packet.

- The receiver uses the following rules while ACKing the sender
    - The receiver acknowledges every packet, it does not use cumulative acks or delayed acks.

- The receiver acks the last correctly received in-order packet (not the one it expects next as in TCP).

| **Event at receiver** | **Action taken by receiver** |
|---|---|
| Arrival of an in-order packet with expected sequence # | Send the ACK to sender |
| Arrival of an out-of-order packet with higher-than-expected sequence # or the arrival of a packet that is corrupt | Immediately send a duplicate ACK of the last correctly received in-order packet |

- The sender uses the following rules while sending the DATA packets

| **Event at sender** | **Action taken by sender** |
|---|---|
| Data received from above (i.e., more data to be sent to complete sending the file) | - Create a packet, assign sequence # and checksum.<br>- If the window allows, send out the packet and start a timer.<br>- If not, buffer the packet until the window advances. |
| ACK received for lowest (unacked) sequence # packet in the window | Advance the window and send out more packets if there is more data to send, also start the timer |
| Triple duplicate ACKs received | Retransmit the oldest unacked packet and start the timer |
| Timeout | Retransmit the oldest unacked packet and start the timer |
| Receive a packet (ACK) that is corrupt | Ignore |

**Other details**

- MTP does not use a 3-way handshake as TCP. So, you do not need to implement any additional packets or procedures for connection establishment.
- How to indicate the last packet of the file? How does the receiver know that there are no more packets coming? You can use a unique seqNum (of your choice, for example, 2^32-1) to indicate the last packet.
- What if the first packet is lost? We will assume that the first packet (seqNum = 0) is not lost and is always correctly received at the receiver.
- MTP send does not implement any flow control or congestion control.

## Implementation and testing

**Multithreading and locks**

This project will require you to address concurrency. The sender can be sending a DATA packet to the receiver but can receive an ACK from the receiver at the same time for an older packet. Similarly, the

receiver can be sending an ACK to the sender while it receives a new DATA packet from the sender. To handle this, your code should use multiple threads.

One possible design is to implement two threads (one for sending and another for receiving) on both the sender and receiver.

- The send thread on the sender sends the DATA packets.
- The receive thread on the receiver receives the DATA packets.
- The send thread on the receiver sends the ACK packets.
- The receive thread on the sender receives the ACK packets.

Because you are using two threads on each side, you will have to use locks to protect your data structures and ensure concurrency. Updating common data structures such as your packet window will be done through the use of locks.

**Running the MTP sender and receiver**

Your sender should be invoked as follows:

*$> ./MTPSender <receiver-IP> <receiver-port> <window-size> <input-file> <sender-log-file>*

- <receiver-IP> and <receiver-port> are the IP address and port number of MTPReceiver respectively.
- <window-size> size of the window.
- <input-file> will be the file that the sender sends to the receiver.
- <log-file> should log the event occurring at the sender. A sample file can look like

Note that the log files shown below are samples and don't show all events. Please show other necessary events in your implementation.

*$> cat sender-log.txt*

Packet sent; type=DATA; seqNum=0; length=1472; checksum=62c0c6a2
…
Updating window; (show seqNum of 64 packets in the window with one-bit status (0: sent but not acked, 1: not sent)
Window state: [20(0), 21(0), 22(0), 23(0), …, 81(1), 82(1), 83(1)]
…
Packet received; type=ACK; seqNum=0; length=16; checksum_in_packet=a8d38e02; checksum_calculated=a7d2bb01; status=CORRUPT;
…
Timeout for packet seqNum=21
…
Triple dup acks received for packet seqNum=34
…

Your receiver should be invoked as follows:

*$> ./MTPReceiver <receiver-port> <output-file> <receiver-log-file>*

- <receiver-port> is the port number on which the receiver is listening
- <output-file> the received data should be stored in the output file. After completion of your code, the output-file should match exactly with the input-file.
- <receiver-log-file> should log the events occuring at the receiver.

A sample file can look like:

*$> cat receiver-log.txt*

Packet received; type=DATA; seqNum=0; length=1472; checksum_in_packet=62c0c6a2; checksum_calculated=62c0c6a2; status=NOT_CORRUPT

…

Packet received; type=DATA; seqNum=1; length=1472; checksum_in_packet=a8d38e02; checksum_calculated=62c0c6a2; status=CORRUPT

…

Packet sent; type=ACK; seqNum=0; length=16; checksum_in_packet=a8d38e02;

…

Packet received; type=DATA; seqNum=10; length=1472; checksum_in_packet=62c0c6a2; checksum_calculated=62c0c6a2; status=OUT_OF_ORDER_PACKET

...

Note that there can be other events on sender and receiver that are not shown in the example log output above. Please make sure to include them in your implementation.

**Implementation and testing**

You can implement the sender and receiver using

(1) A single machine with localhost IP and different ports for server and client. In this case, you are simply transferring a file from the client's directory to the server's directory. This would be a good place to start developing your code.

(2) (optional) Two laptops connected over the Internet. You and your partner can remotely connect to each other over the Internet and test your code in real-world settings. Here the file will be transferred from one machine to the other.

You can generate a file of arbitrary size using the following command. For example,

*$> base64 /dev/urandom | head -c 1000000 > input-file.txt*

will generate a text file of 1MB. You can start by first transferring a small file and then gradually testing your code for larger files. *Your code will only be tested on text files.*

You can verify that your file has been correctly received by calculating sha1sum of your file on sender and receiver.

*$ sha1sum input-file.txt*
381e08efd0d8182d2a559321b2b60234010f74bc input-file.txt

*$ sha1sum output-file.txt*
381e08efd0d8182d2a559321b2b60234010f74bc output-file.txt

**Starter files**

You have been provided with 4 files to get started:

1. MTPSender.py which provides a high-level code structure for client
2. MTPReceiver.py which provides a high-level code structure for server
3. unreliable_channel.py: It is possible that when you are running the client and server on the same machine, you are likely to see no packet loss or corruption. To address this, we have provided you with two sample functions (recv_packet and send_packet) that cause packet loss and corruption to simulate an unreliable channel. Use of these functions is shown in client.py and server.py
4. 1MB.txt: a sample text file which you can use as the file to transfer from client to server

**Grading rubric**

| | |
|---|---|
| Handling the input arguments on both sides | 5 points |
| Sender:<br>Read the input file and create packets<br>Send the packets (window implementation)<br>Receive the ack and check for corruption<br>Timer implementation<br>3 dup acks implementation | <br>10 points<br>15 points<br>10 points<br>15 points<br>5 points |
| Receiver:<br>Receive and parse the packets and check them for corruption<br>Timer implementation<br>Ack and dup ACK implementation | <br>10 points<br>15 points<br>5 points |
| File:<br>File sha1sum matches | <br>10 points |

Your code will be tested for 3 file transfers and randomly selected drop and corruption ratios.

## Policies and submission

### Programming language

You can implement your client in C or Python.

### Working with a partner

You are required to do this project with your project partner of PA1. You can choose to do it alone but cannot change the partner from PA1 without my permission.

### Note on plagiarism

In this class, it is absolutely mandatory that you adhere to GMU and Computer Science Department honor code rules. This also means (1) do not copy code from online resources and (2) your implementation should be purely based on your own thought process and conceived design, and not inspired by any other students or online resources, (3) you can copy your code or design from other students in the class. We reserve the right to check your assignment with other existing assignments (from other students or online resources) for cheating using code matching programs. Any violation of the honor code will be reported to the GMU honor committee, with a failing grade (F) in this course.
*** Do not put your code online on Github or other public repositories ***
Violation of this policy would be considered an honor code violation.

### Grading, submission, and late policy

- The standard late policy applies - The late penalty for this lab will be 15% for each day. Submissions that are late by 3 days or more will not be accepted
- This lab accounts for **11%** of your final grade
- You will submit your solution via Blackboard

### What to submit?

Submit the following

1. Your code in a zip archive file. The code should contain two files MTPSender and MTPReceiver which we will compile and execute to test your implementation. If you simply include a pre-compiled executable binary and do not include your code files in the archive, no points will be given.
2. A README.txt that explains how to compile your program. Once compiled, your sender and receiver will be run using the command line arguments described above. Your code should not accept any more or less command-line arguments than what is asked for.
3. A sender-log-file.txt and receiver-log-file.txt that you got by running your code on your machines while transferring the provided 1MB.txt file.
4. A PARTNERS.txt file mentioning the name and GMU IDs of two students who worked on the project as a team. Both team members should submit these four pieces separately on Blackboard before the deadline.

### Acknowledgments

This programming assignment is based on UC Berkeley's Project 2 from EE 122: Introduction to Communication Networks and UMich's EECS 489 Computer Networks Assignment 3.