1. Introduction & Author

This project implements a basic UDP client-server file transfer system with error handling using Reliable Data Transfer (RDT) 2.2. It is built over an unreliable UDP channel that can introduce bit errors in packets and ACKs.

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2. Phase 2

This project implements **Reliable Data Transfer (RDT) 2.2** using **UDP** in an unreliable network environment that introduces **bit errors in packets and ACKs**. The implementation includes:

- **Checksum-based error detection**
- **ACK validation and retransmissions**
- **Handling ACK corruption**
- **Timeout-based packet retransmission**
- **Performance measurement of transfer times under different error rates**

3. Phase 2 (Extra Credit)

The extra credit phase enhances the Reliable Data Transfer (RDT 2.2) protocol by incorporating advanced networking features, improved error detection, and a high-quality GUI for real-time monitoring. A graphical interface was implemented to visualize the file transfer process, including FSM (Finite State Machine) state transitions for both sender and receiver, live progress tracking, and real-time image preview as packets arrive. To simulate real-world network conditions, random transmission delays (0-500ms) and an adaptive timeout mechanism were introduced to dynamically adjust retransmission timing based on observed delays. Additionally, CRC-16 was implemented as an alternative to XOR checksum, improving error detection and reducing packet corruption. A multi-threaded approach was used to optimize data transmission, ensuring concurrent packet sending and acknowledgment processing, leading to reduced latency and improved performance. Finally, a comparative analysis was conducted to evaluate the impact of these enhancements on transmission time, error rates, and retransmissions under varying loss conditions (0% to 60%).

4. System Overview

4.1 Components

The system consists of two main components:

1. **Client (Sender)**
    - Reads and splits the **JPEG image file** into **1024-byte packets**.
    - Appends a **4-byte sequence number** and **1-byte checksum** to each packet.
    - Sends packets via UDP **one at a time**, waiting for an ACK before sending the next packet.
    - Retransmits packets if **ACKs are missing or corrupted**.
2. **Server (Receiver)**
    - Receives and validates packets using **checksum verification**.
    - Sends **ACKs** for valid packets.
    - Detects **corrupt or duplicate packets** and requests retransmissions.
    - Reassembles and saves the received **JPEG image** file.

5. Implementation Details

5.1 Reliable Data Transfer (RDT) 2.2

Client-Side Functionality:

1. **Read BMP file and split into packets** (1024 bytes each).
2. **Calculate checksum** for each packet.
3. **Send the packet with a sequence number** over UDP.
4. **Wait for an ACK**:
    - If ACK is correct, send the next packet.
    - If ACK is missing/corrupted, retransmit the packet.
5. **Continue until all packets are sent**.

Server-Side Functionality:

1. **Receive incoming packets and extract data.**
2. **Validate checksum**:
    - If correct, send an **ACK** and store the packet.
    - If incorrect, discard the packet and do not ACK.
3. **Send ACK with sequence number** to acknowledge successful receipt.
4. **Reassemble packets into an output BMP file** once all packets are received.

6. Error Handling

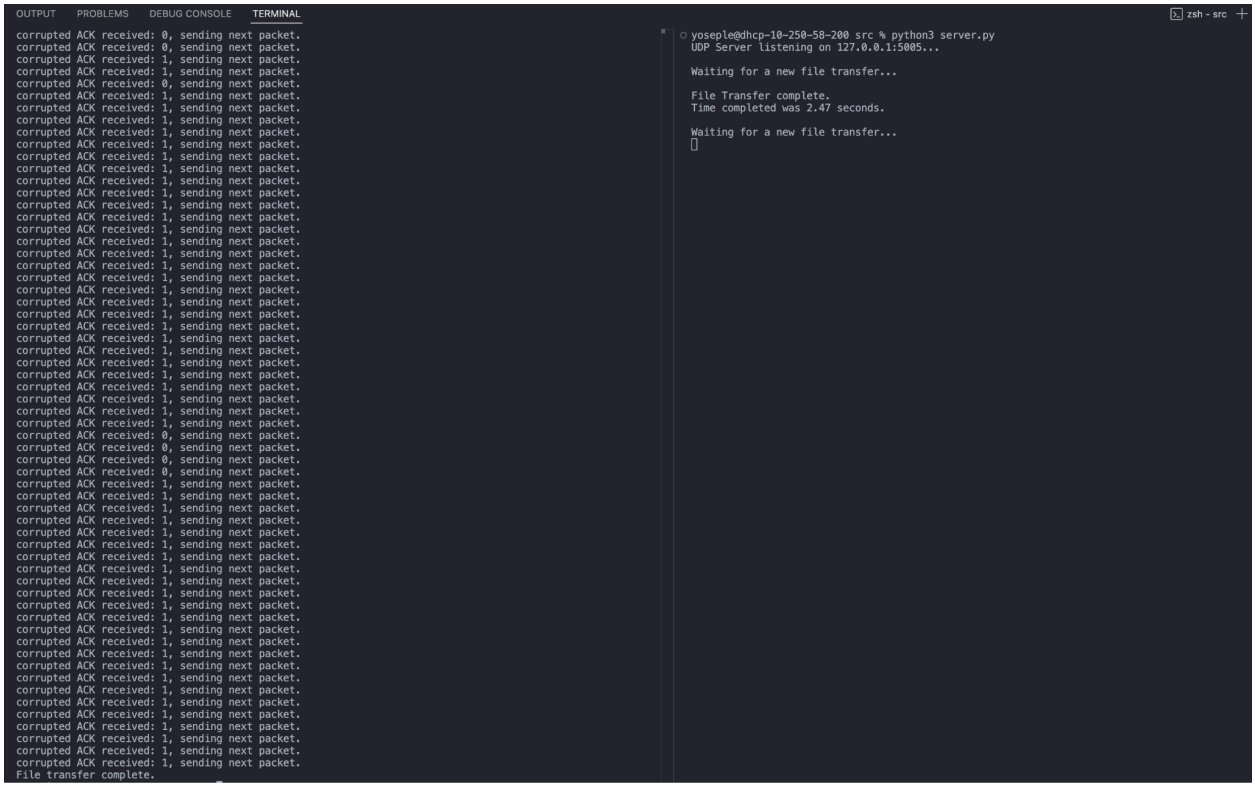
6.1 Checksum-Based Error Detection

- Uses **XOR checksum** to verify packet integrity.
- If checksum validation fails, the packet is **discarded**.

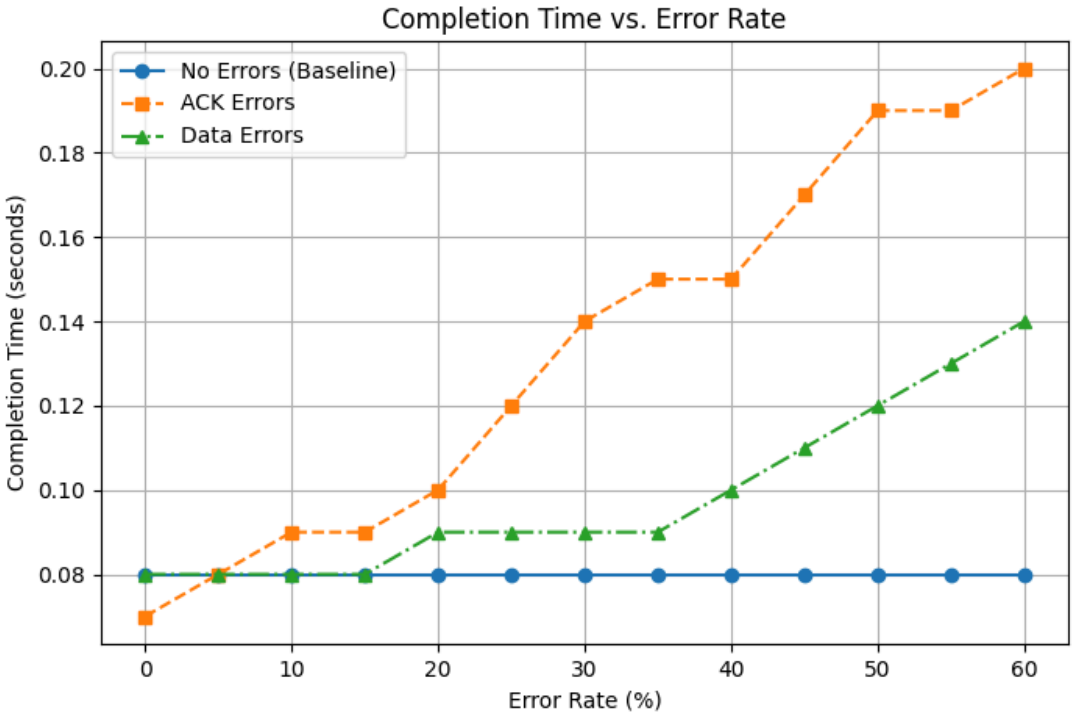
6.2 Handling ACK Corruption

- **Depending on the probability of ACK corruption**.
- If the client receives a **corrupted ACK**, it **retransmits the last packet**.

6.3 Timeout-Based Packet Retransmission

- If timeout occurs, the **last packet is retransmitted**.
- 

7. Performance Evaluation



8. Steps to Execute Program

6.1 Running the Client and Server

1. **Start the server** (First Terminal):
   python3 server.py
2. **Start the client** (Second Terminal):
   python3 client.py
3. The client **transmits the BMP file**, and the **server receives and reassembles it**.
4. The **client simulates packet corruption at increasing error rates**.
5. The **server prints "File Transfer Complete" and logs the completion time**.

6.2 Generating the Performance Graph

1. After running `server.py` and `client.py`,
2. Manually get data by inputting the corruption % in increments of 5
3. Execute: After getting the data from step 2
   python3 plot.py
4. The script generates `performance_plot.png`, showing **how error rates impact completion time**