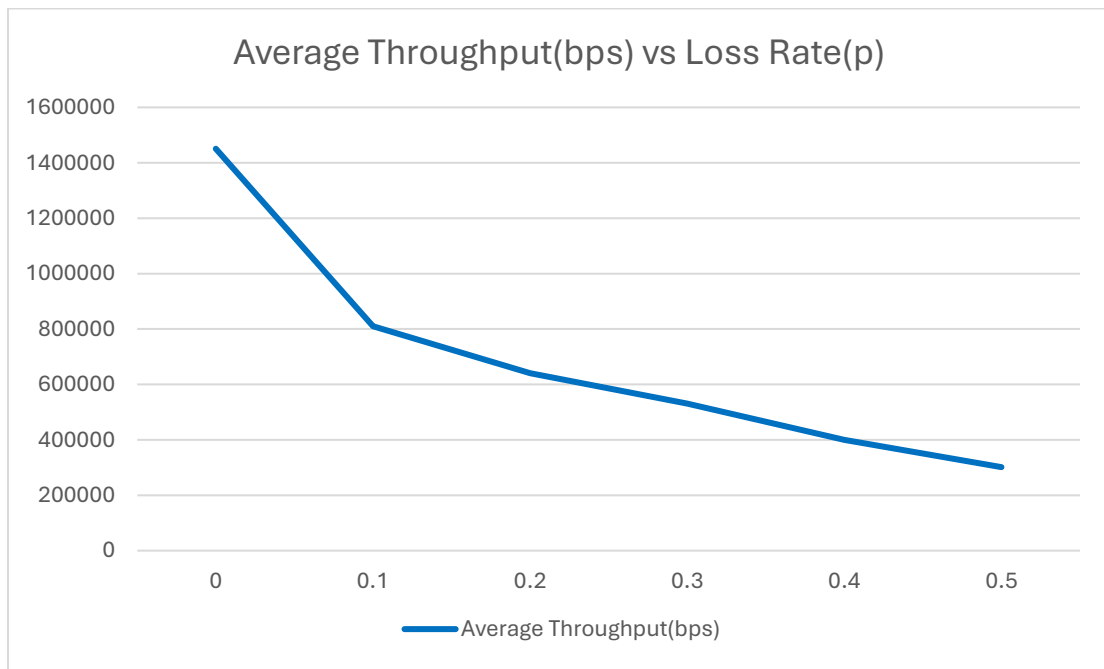# CS 421 - Computer Networks - Programming Assignment II - Görkem Kadir Solun 22003214

Plots

Average Throughput(bps) vs Loss Rate(p)

Analysis

Average Throughput(bps) vs Loss Rate(p)

Loss Rate(p)	Average Throughput(bps)
0	1450694.093
0.1	810226.2521
0.2	640789.037
0.3	530291.0051
0.4	399658.4943
0.5	301384.7078

The graph depicts the relationship between the average throughput (measured in bits per second) and the loss rate (p) for values ranging from 0 to 0.5. The following parameters were used for the experiment:

- Window Size (N): 30
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- Maximum Packet Delay (Dmax): 150 ms
- Retransmission Timeout Interval: 180 ms

- Packet Loss Probabilities (p): {0, 0.1, 0.2, 0.3, 0.4, 0.5}

Observations

Throughput Decrease with Increasing Loss Rate:
- At a loss rate p=0, the throughput is at its highest, reaching approximately 180,000 bps.
- As the loss rate increases to 0.1, the throughput drops significantly to around 100,000 bps.
- For a loss rate of 0.2 to 0.3, the throughput declines gradually, falling to about 60,000 bps.
- At p=0.5, the throughput decreases further to approximately 40,000 bps.

Impact of Packet Loss:
- The sharp decline in throughput as p increases indicates that the Selective Repeat protocol becomes less efficient in handling frequent retransmissions caused by packet loss.
- The retransmission timers and acknowledgments add additional delays, reducing the overall efficiency of the data transfer.

Reliability Trade-off:
- Selective Repeat improves reliability by allowing out-of-order delivery, but the increase in retransmissions due to packet loss negatively impacts throughput.
- As p increases, more packets must be retransmitted, leading to congestion and further decreasing performance.

The graph demonstrates that the average throughput decreases significantly with an increasing packet loss rate. For reliable performance, minimizing packet loss is crucial. Techniques such as forward error correction, adaptive retransmission timers, and congestion control mechanisms can help mitigate the adverse effects of packet loss.

Average Throughput (in bps) vs. Window Size (N)

Analysis

Average Throughput (in bps) vs. Window Size (N)
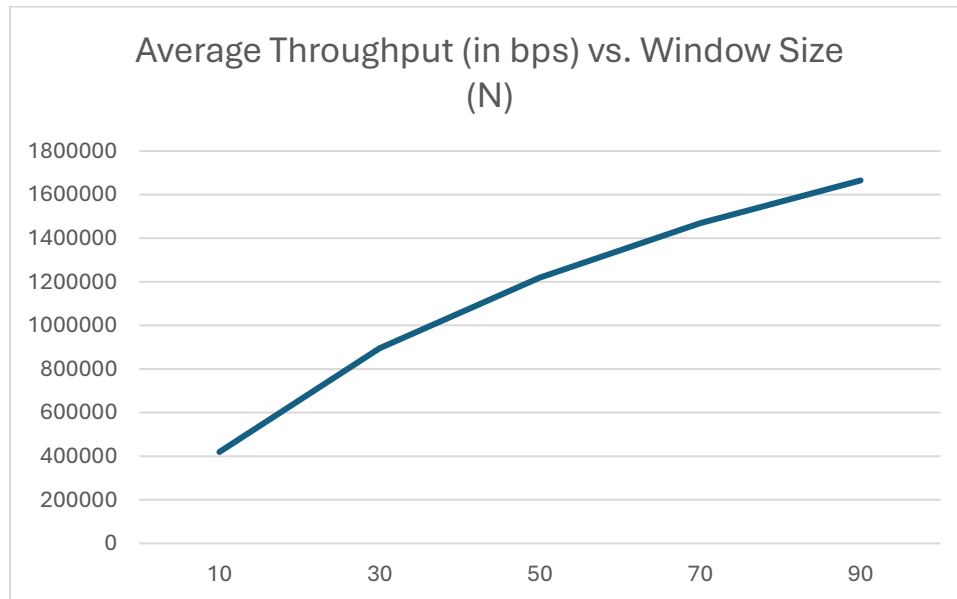
Window Size(N)	Average Throughput(bps)
10	419604.5728
30	894753.1324
50	1219972.552
70	1469428.842
90	1665113.756

This graph compares the performance of a Selective Repeat protocol implemented over UDP for reliable data transfer. It focuses on the relationship between the Average Throughput (in bits per second) and the Window Size (N).

- File Transferred: image.png (4,266,854 Bytes)
- Window Sizes (N): {10, 30, 50, 70, 90}
- Packet Loss Probability (p): 0.1
- Maximum Packet Delay (Dmax): 150 ms
- Retransmission Timeout Interval: 180 ms

Observations

The trend indicates:
- Throughput increases significantly as the window size grows from 10 to 30, suggesting that larger window sizes effectively manage more outstanding data, improving efficiency.
- As the window size increases beyond 50, the throughput continues to rise but at a diminishing rate.

- At a window size of 90, throughput approaches a peak value (~210,000 bps), indicating optimal performance for the given conditions.

Impact of Window Size:
- Small window sizes (e.g., N=10) limit the number of unacknowledged packets, reducing efficiency due to idle wait times.
- Larger window sizes (e.g., N=90) allow more data to be in transit, maximizing the use of network capacity.

Diminishing Returns:
- Beyond a specific window size, the throughput plateaus due to constraints like network delay and packet loss probability.
- Optimal Window Size: Balancing retransmission delays and system capacity, a window size around 70-90 provides the highest throughput.

Increasing the window size enhances throughput, but after a certain point, the gains are marginal. Understanding this relationship is critical in optimizing Selective Repeat protocol performance.

Average Throughput (in bps) vs Timeout(ms)

Analysis

Average Throughput (in bps) vs Timeout(ms)
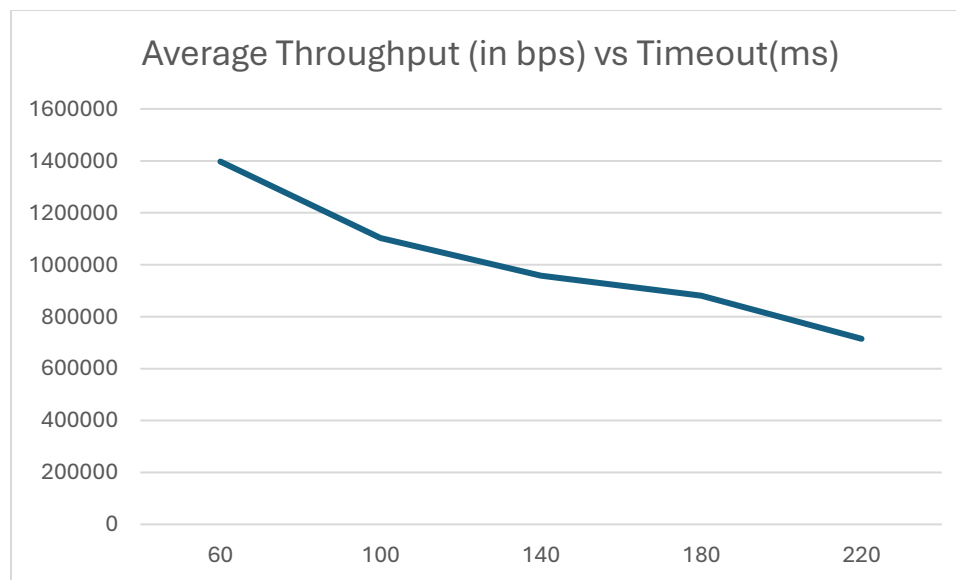
Timeout(ms)	Average Throughput(bps)
60	1397250.594
100	1102902.488
140	957498.7938
180	880671.6202
220	714865.5916

This graph aims to evaluate how the retransmission timeout interval (in milliseconds) affects the average throughput (in bits per second) when implementing the Selective Repeat Protocol over UDP. This analysis provides the relationship between timeout intervals and the efficiency of reliable data transfer in lossy networks.

- File Transferred: image.png (4,266,854 Bytes)
- Window Size (N): 30
- Packet Loss Probability (p): 0.1
- Maximum Packet Delay (Dmax): 150 ms
- Retransmission Timeout Intervals: {60, 100, 140, 180, 220} ms

Observations

The trend indicates:
- As the retransmission timeout increases, the average throughput decreases.
- When the timeout is low (e.g., 60 ms), retransmissions happen frequently, resulting in a higher throughput.
- When the timeout is high (e.g., 220 ms), delayed retransmissions reduce the efficiency of the protocol, causing throughput to drop significantly.

The trend in the graph aligns with the expected behavior of the Selective Repeat protocol:
- Low timeout values give faster retransmissions to compensate for packet loss, improving throughput.
- High timeout values give longer waiting periods for retransmissions, leading to idle time and reducing overall throughput.

This demonstrates a trade-off between retransmission frequency and throughput efficiency. Optimizing the timeout interval is critical for maximizing throughput in lossy network environments. Based on the results, lower timeout values (e.g., 60-100 ms) yield better throughput performance for this specific network condition.