CSE 489/589
Programming Assignment 2 Report
Reliable Transport Protocols

Notes: (IMPORTANT)

- ➔ One of your group members select <File> - <Make a copy> to make a copy of this report for your group, and share that Google Doc copy with your teammates so that they can also edit it.
- ➔ Report your work in each section. Describe the method you used, the obstacles you met, how you solved them, and the results. You can take screenshots at key points. There are NO hard requirements for your description.
- ➔ For a certain test, if you successfully implemented it, **take a screenshot of the result from the grader as required in section 5 (required).** You can just provide the overall result for each test.
- ➔ For a certain test, if you tried but failed to implement it, properly describe your work. We will partially grade it based on the work you did.
- ➔ Do **NOT** claim anything you didn't implement. If you didn't try on a certain protocol or test, leave that section blank. We will run your code, and if it does not match the work you claimed, you and your group won't get any partial grade score for this WHOLE assignment.
- ➔ There will be **15.0** points for this report. These are NOT bonus points and will be given based on the completion of the analysis part (section 6.1).
- ➔ If you decide not to attempt the analysis part (section 6.1) of the assignment, you will still NEED to submit this report with the requirements stated in section 6.
- ➔ Under **NO** circumstances may you rely on the work of your peers, including but not limited to GitHub repositories or code submissions from previous academic terms.
- ➔ All the analysis results in section 6 should come from one of the provided hosts, NOT on your local machine (see section 3.1 in the handout).
- ➔ The maximum score for PA 2: 85 + 15 = 100

1 - Academic Integrity Policy Statement

I have read and understood the course's academic integrity policy .

2 - Group and Contributions

- Name of member 1:
  - UBITName: anurimav
  - Contributions: ABT, Report, Experiment 1 and 2
- Name of member 2:
  - UBITName: madhavia
  - Contributions: SR and GBN

3 - SANITY Tests

[2.0] ABT

```
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./sanity_tests -p ./../madhavia/abt -r ./run_experiments
Testing with MESSAGES:1000, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:50, WINDOW:0 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
```

```
Testing with MESSAGES:20, LOSS:0.0, CORRUPTION:1.0, ARRIVAL:1000, WINDOW:0 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
SANITY TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
ones.cse.buffalo.edu  ⊗ 0 ⚠ 0  0
```

[5.0] GBN

```
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./sanity_tests -p ./../madhavia/gbn -r ./run_experiments
Testing with MESSAGES:1000, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:50, WINDOW:10 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
Testing with MESSAGES:1000, LOSS:0.2, CORRUPTION:0.0, ARRIVAL:50, WINDOW:10 ...
```

```
Testing with MESSAGES:20, LOSS:0.0, CORRUPTION:1.0, ARRIVAL:50, WINDOW:50 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
SANITY TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
```

tones.cse.buffalo.edu ⊗ 0 ⚠ 0 0

[8.0] SR

```
Run#10 [seed=9999] ...  Done!
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./sanity_tests -p ./../madhavia/sr -r ./run_experiments
Testing with MESSAGES:1000, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:50, WINDOW:10 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
Testing with MESSAGES:1000, LOSS:0.2, CORRUPTION:0.0, ARRIVAL:50, WINDOW:10 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
```

```
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
Testing with MESSAGES:20, LOSS:0.0, CORRUPTION:1.0, ARRIVAL:50, WINDOW:50 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
SANITY TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
```

4 - BASIC Tests

[5.0] ABT

```
SANITY TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./basic_tests -p ./../madhavia/abt -r ./run_experiments
Testing with MESSAGES:20, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:1000, WINDOW:0 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
Testing with MESSAGES:20, LOSS:0.4, CORRUPTION:0.0, ARRIVAL:1000, WINDOW:0 ...
```

```
Testing with MESSAGES:20, LOSS:0.0, CORRUPTION:0.8, ARRIVAL:1000, WINDOW:0 .
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
BASIC TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
```

[12.0] GBN

```
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./basic_tests -p ./../madhavia/gbn -r ./run_experiments
Testing with MESSAGES:20, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:50, WINDOW:50 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
Testing with MESSAGES:20, LOSS:0.4, CORRUPTION:0.0, ARRIVAL:50, WINDOW:50 ...
```

```
PASS!
Testing with MESSAGES:20, LOSS:0.0, CORRUPTION:0.8, ARRIVAL:50, WINDOW:50 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
BASIC TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
```

[18.0] SR

```
Run#10 [seed=9999] ...  Done!
PASS!
SANITY TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./basic_tests -p ./../madhavia/sr -r ./run_experiments
Testing with MESSAGES:20, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:50, WINDOW:50 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
Testing with MESSAGES:20, LOSS:0.4, CORRUPTION:0.0, ARRIVAL:50, WINDOW:50 ...
```

```
PASS!
Testing with MESSAGES:20, LOSS:0.0, CORRUPTION:0.8, ARRIVAL:50, WINDOW:50 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
BASIC TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
```


5 - ADVANCED Tests

[5.0] ABT

```
BASIC TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./advanced_tests -p ./../madhavia/abt -r ./run_experiments
Testing with MESSAGES:1000, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:50, WINDOW:0 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
```

```
Testing with MESSAGES:1000, LOSS:0.0, CORRUPTION:0.8, ARRIVAL:50, WINDOW:0 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
ADVANCED TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
```

[10.0] GBN

```
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./advanced_tests -p ./../madhavia/gbn -r ./run_experiments
Testing with MESSAGES:1000, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:50, WINDOW:10 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
Testing with MESSAGES:1000, LOSS:0.0, CORRUPTION:0.8, ARRIVAL:50, WINDOW:
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
ADVANCED TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
ones.cse.buffalo.edu  ⊗ 0 ⚠ 0  0
```

[20.0] SR

```
BASIC TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} > ./advanced_tests -p ./../madhavia/sr -r ./run_experiments
Testing with MESSAGES:1000, LOSS:0.1, CORRUPTION:0.0, ARRIVAL:50, WINDOW:10 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
Testing with MESSAGES:1000, LOSS:0.2, CORRUPTION:0.0, ARRIVAL:50, WINDOW:10 ...
Testing with MESSAGES:1000, LOSS:0.0, CORRUPTION:0.8, ARRIVAL:50, WINDOW:10 ...
Running simulator [10 Runs] ...
Run#1 [seed=1234] ...  Done!
Run#2 [seed=1111] ...  Done!
Run#3 [seed=2222] ...  Done!
Run#4 [seed=3333] ...  Done!
Run#5 [seed=4444] ...  Done!
Run#6 [seed=5555] ...  Done!
Run#7 [seed=6666] ...  Done!
Run#8 [seed=7777] ...  Done!
Run#9 [seed=8888] ...  Done!
Run#10 [seed=9999] ...  Done!
PASS!
ADVANCED TESTS:  PASS
stones {/local/Spring_2023/madhavia/cse489589_assignment2/grader} >
```

6 - ANALYSIS & REPORT [15.0]

Timeout Scheme

Alternating Bit

In ABT, there is one single standard hardware timer set for retransmission. Hence different values were tested and finally set it to 10.0 for optimal throughhput.

Go Back N

In GBN, during timeout, we need to retransmit all the previous packets in the current active window. If we put a very low timer, retransmissions might increase aggressively and decrease the overall throughput. Hence after analysising results for various timers, 300.0 was set to give best results.

Selective Repeat

In SR, we need to implement timer for each packet. But as there is only one hardware timer, we used get_sim_time() to get the current simulator time and added timeout interval to it to set a

logical timer for each packet. These details were stored in a new structure. This timeout interval was fixed to 30.0 for retransmitting each packet.

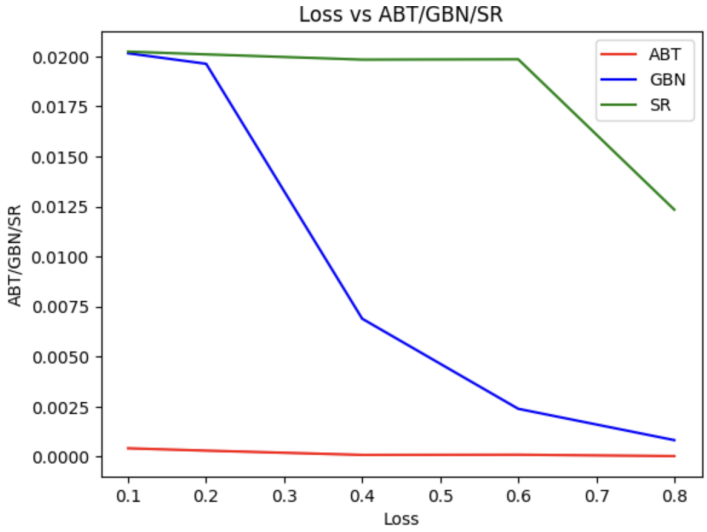
```
struct SRpacket {
  struct pkt packet;
  float timer;
  int acked;
};
```

Experiment 1 : Window size : 10 X - axis : Loss probability Y - axis : Throughput

With loss probabilities : { 0.1, 0.2, 0.4, 0.6, 0.8 } , compare the 3 protocol throughputs at application layer of receiver B. Use 2 window sizes : { 10, 50 } for the Go Back N version and the Selective Repeat version.

Loss	ABT	GBN	SR
0.1	0.000422	**0.019861**	**0.020188**
0.2	0.00030	**0.015021**	**0.020100**
0.4	0.000092	**0.00301**	**0.020044**
0.6	0.000101	**0.001640**	**0.014969**
0.8	0.000034	**0.000534**	**0.003750**

The above values are obtained after taking the average of all the throughput values obtained for window size 10 for different loss values.



Analysis

ABT : When the loss rate is low, the impact on the throughput may be negligible. However, if the loss rate is high, the sender may need to retransmit many packets, resulting in a significant reduction in the throughput.

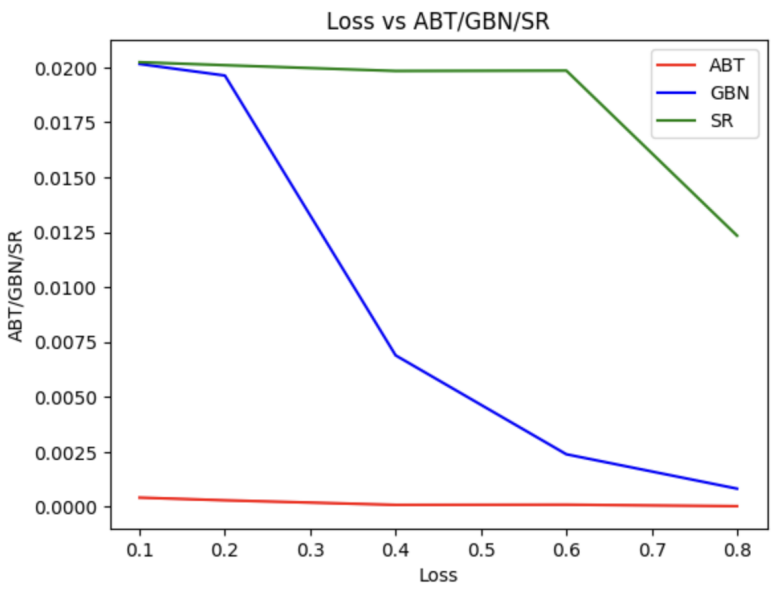
Go Back N : As the loss increases, the throughput gradually decreases because the sender has to spend more time retransmitting packets rather than sending new packets. In other words, the sender's efficiency decreases, and the overall time taken to transmit a set of packets increases.

Selective Repeat : SR has better throughput than the other 2 as it uses buffer and retransmits only those messages that are lost. This decreases the retransmission and increases throughput.

Experiment 1 : Window size : 50 X - axis : Loss probability Y - axis : Throughput

Loss	GBN	SR	ABT
0.1	0.020154	0.020235	0.000422

0.2	0.019628	0.020099	0.00030
0.4	0.006895	0.019837	0.000092
0.6	0.002395	0.019853	0.000101
0.8	0.000830	0.012342	0.000034



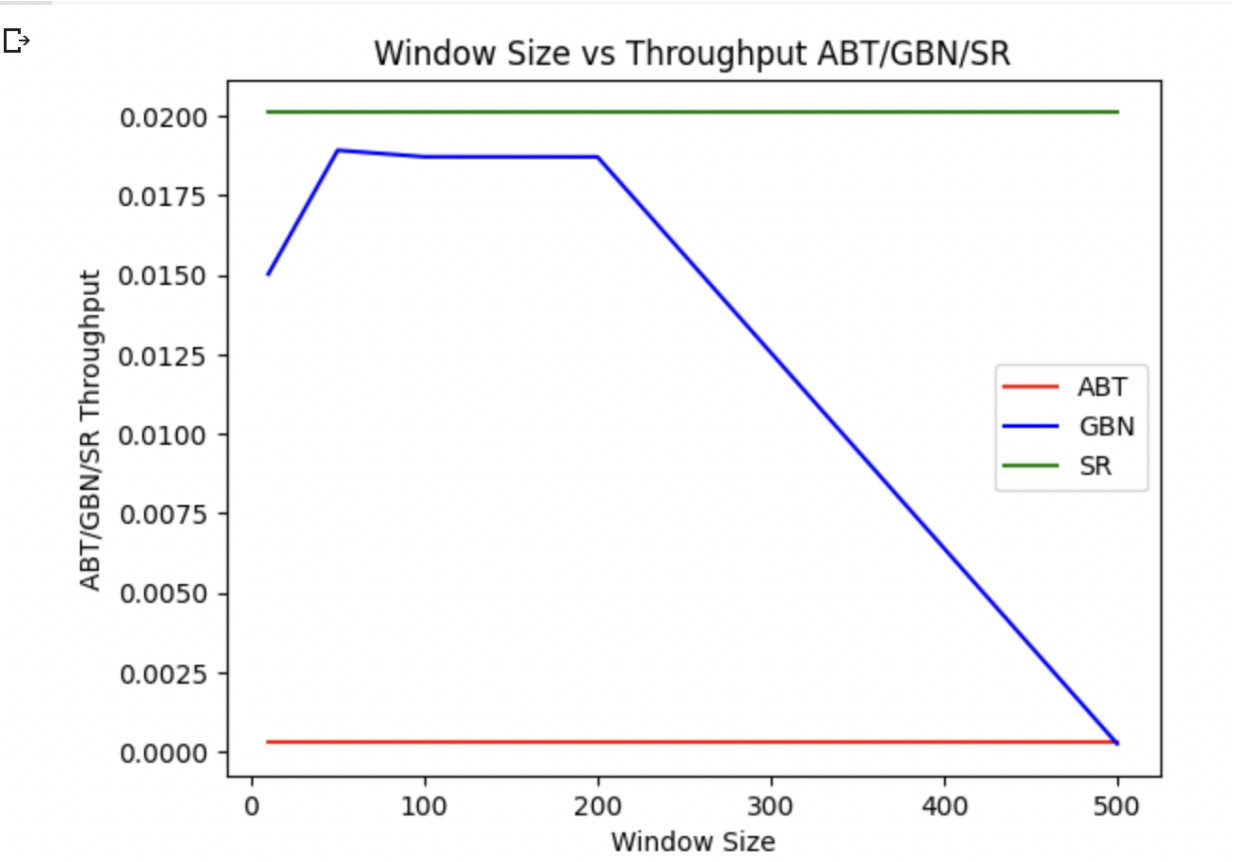
Analysis

ABT : As expected, there is not much change in throughput for ABT with window size
Go Back N : With window size difference, there is slight change in throughput.
Selective Repeat : SR has better throughput than the other 2 as it uses buffer and retransmits only those messages that are lost. This decreases the retransmission and increases throughput.

Experiment 2 : Loss Probability : 0.2 X - axis : Window Size Y - axis : Throughput

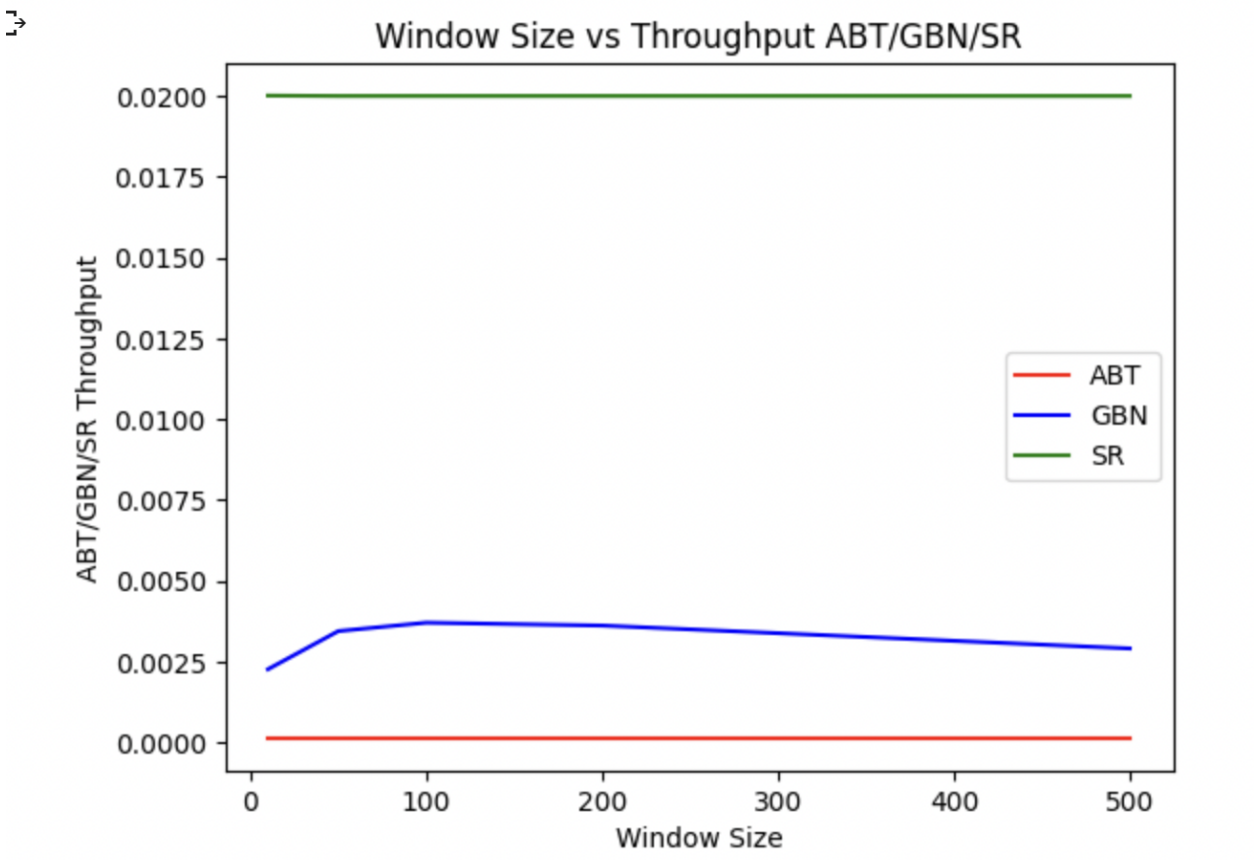
With window sizes : { 10, 50, 100, 200, 500 } for GBN and SR, compare the 3 protocol throughputs at the application layer of receiver B. Use 3 loss probabilities : { 0.2, 0.5, 0.8 } for all 3 protocols.
Loss = 0.2 with varied window sizes

Window size	ABT	GBN	SR
10	0.0003056	0.0150206	0.0201193
50	0.0003056	0.0189098	0.0201193
100	0.0003056	0.0187059	0.0201193
200	0.0003056	0.0187034	0.0201193
500	0.0003056	0.000258868	0.0201193



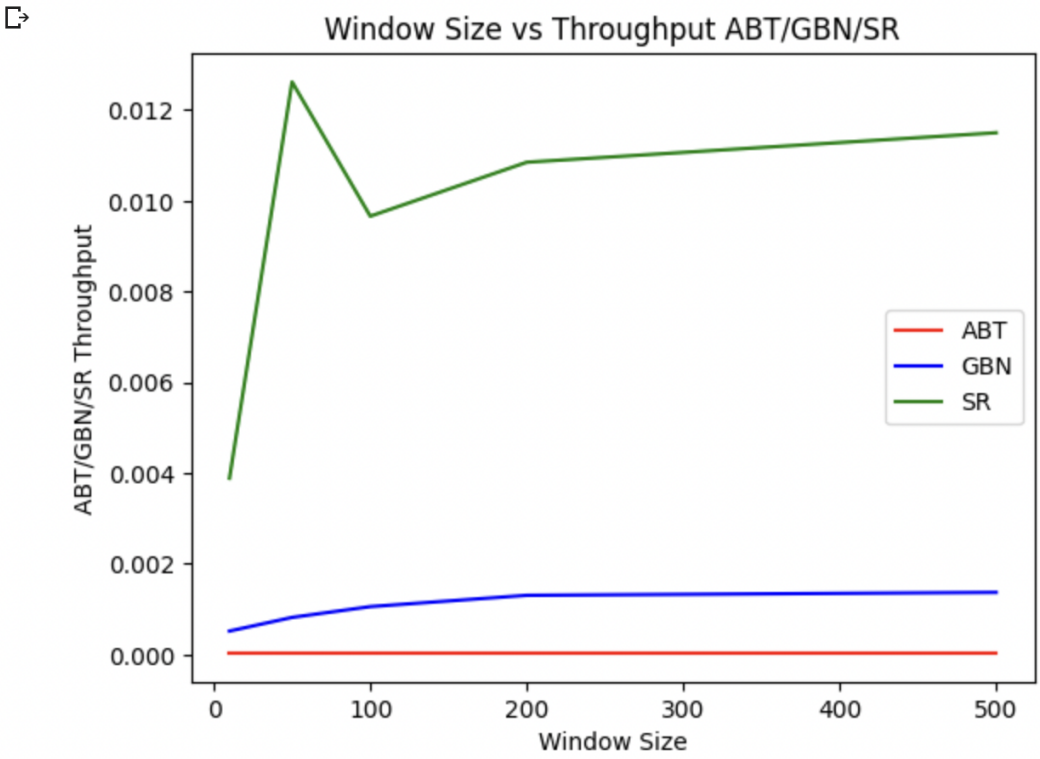
Loss = 0.5 with varied window sizes

Window size	ABT	GBN	SR
10	0.0001391	0.0022695999999999997	0.020010999999999995
50	0.0001391	0.0034498	0.019998699999999997
100	0.0001391	0.0037101	0.019998699999999997
200	0.0001391	0.0036213	0.019998699999999997
500	0.0001391	0.002913	0.019998699999999997



Loss = 0.8 with varied window sizes

Window size	ABT	GBN	SR
10	**0.0000337**	0.000517	0.0038851
50	**0.0000337**	0.000818	0.012620
100	**0.0000337**	0.001056	0.009661
200	**0.0000337**	0.001305	0.010850
500	**0.0000337**	0.001370	0.01150



ABT: There is no change in graphs with increasing window size as ABT doesn't use any concept of window. But with increasing loss, there will be slight change in throughput due to increased retransmissions.

GBN: With increasing window size, throughput decreases with increase loss. While increasing the window size can improve the throughput, increasing it beyond a certain limit can lead to congestion, packet loss, buffer overflow, and an overall decrease in throughput. Therefore, it is crucial to choose an appropriate window size based on the network conditions to achieve the desired throughput.

SR: SR is comparatively unaffected with window size and loss as it uses buffer .The increase is observed in Selective Repeat but not in Go Back N since buffers are used.