Overview of Implementation

For the implementation of the Project, I changed the original lte_project_template.cc file so that based on the parameters passed in during compilation, the simulation would adjust based on that. In addition, I added a bash script that passes in the parameters for each simulation variant. Rather than having all the different variants in the cc file, I use the bash script to execute each simulation variant. I also added in the cc the to capture the tcp packets using the enablepcap() function. This information allows us to calculate the TCP Throughput and the TCP Round-Trip-Time. For extracting the handovers, I used the notification function used to notify when a handover occurs to add every timestamp that gets added into a vector array. Then at the end of each simulation, the data from the vector gets added to a txt file. After executing the cc file, I used the python scripts to format all the data into graphs. After the simulation executes the TCP packet capture gets added into a txt file using the command. Then the python script will read the data and manipulate it so that it returns the Round-Trip-Time and the Throughput. To calculate the throughput, I used the Throughput function given in the lab manual and for the Round-Trip-Time, I used the formula ack=(A.seq+A.len).

How to Run the Simulation

In order to run the entire simulation, the command needed to be typed in the terminal is “bash script.bash” where the bash script already has all the commands necessary to run all needed files. Just make sure, before executing the program, the directory is in the ns-3.43.

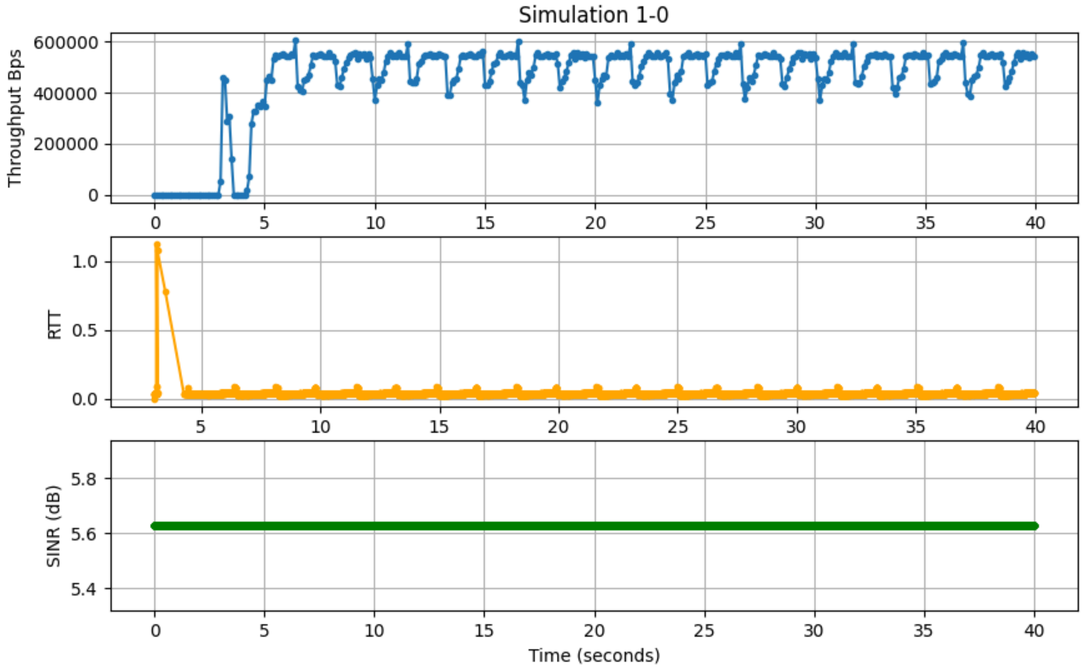
How I process the Traces

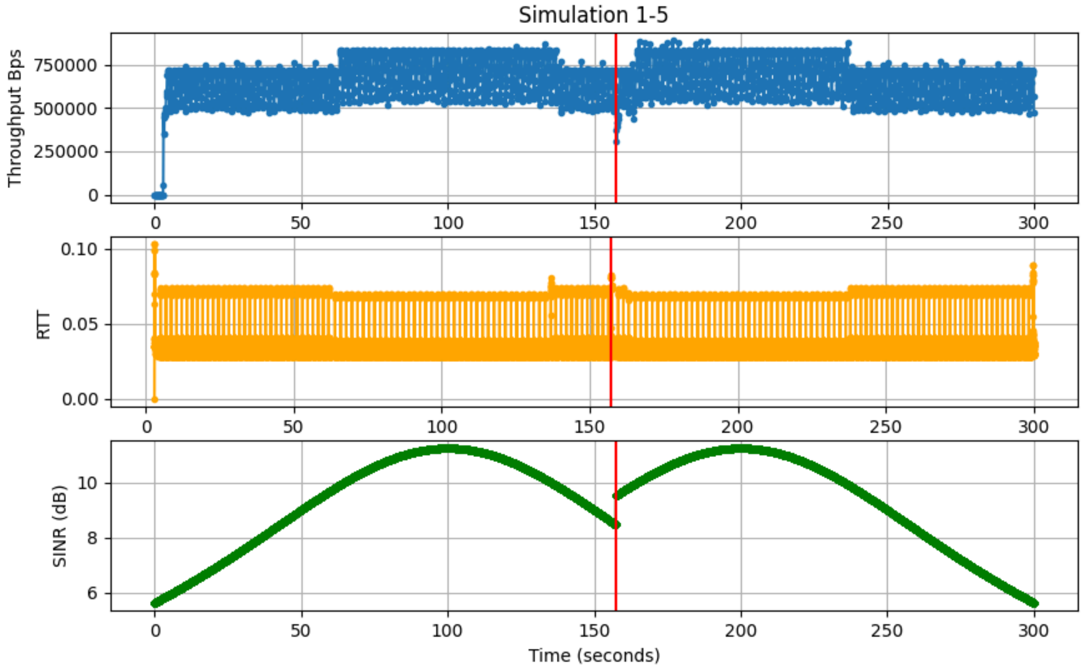
As described above, I processed the simulation using the python script that formats the data and also processes it. In terms of retrieving, I added all the handovers into a txt file whenever the callback function for the handover is executed. When reading the capture file and turning it into the tcp_packets.csv file, the python file would read the data using certain libraries, and format it so that it calculates the Round-Trip-Time and the Throughput. It will then output the information in three graphs for each of the simulations.

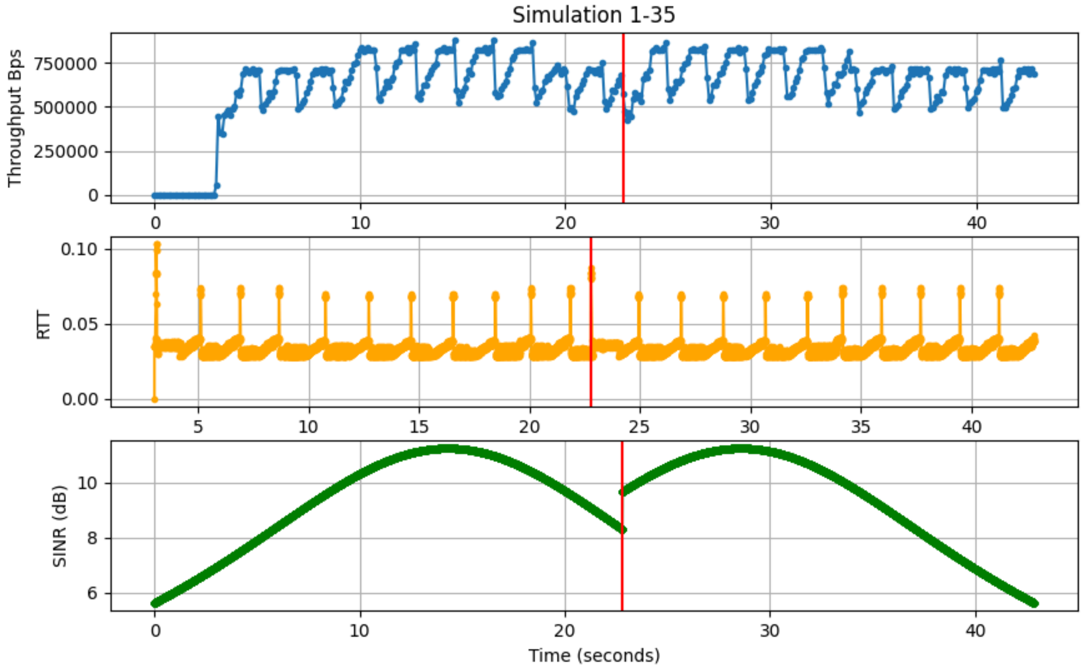
Simulation 1 Analysis

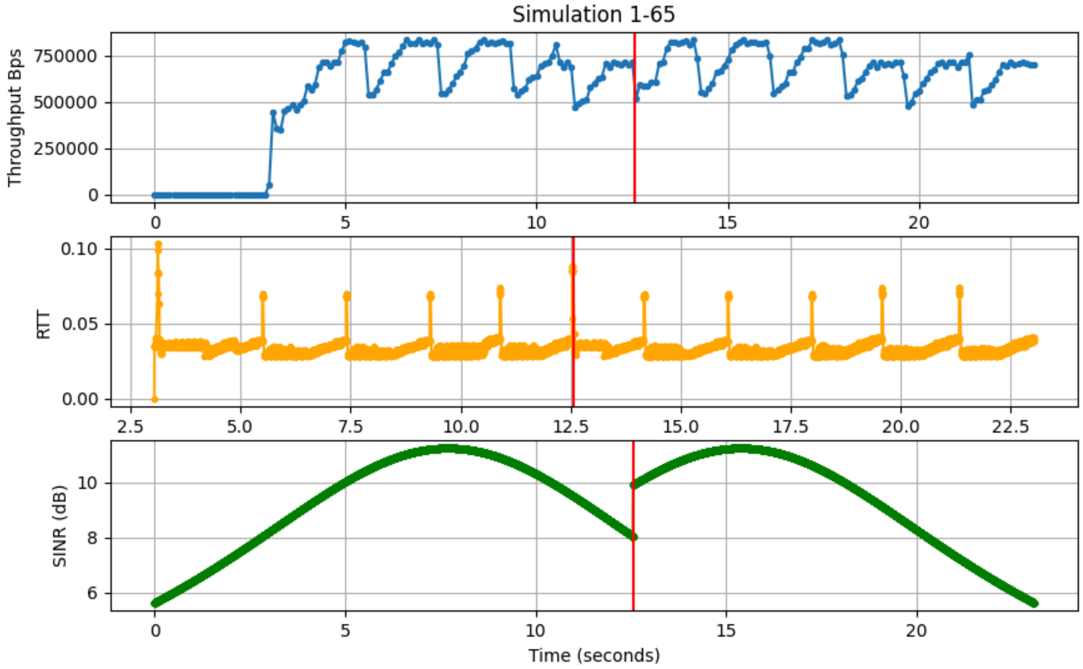
	Throughput	**RTT**	**SINR**
1-0	Since the velocity was 0, there was no handover and the spikes stayed almost in the same pattern throughout the whole simulation	There was an unexpected spike at the beginning but then stayed rather the same in the after.	The SINR stayed the same and didn’t change because the UE isn’t moving.
1-1	Throughput decreased halfway during simulation which caused handover between 20 and 25 seconds then went back to normal.	Latency spiked more than usual at the same time the handover occurred then went back to stable conditions.	For the first half of the simulation there was a normal distribution then handover occurred and created another normal distribution graph. This is due to signal fading from eNBs which caused

			handovers.
1-2	The throughput decreased at its highest when handover occurred then spiked back up.	There was a large spike in latency at the same time that the handover also occurred. Then the spikes stayed about the same as before when switching eNBs	Sinr was about the same as the previous simulation but handover occurred much faster since the velocity is much higher.
1-3	Tcp sent was drastically more than previous simulations due to speed being very slow. It decreased the same as before at handover then went back to normal.	There was a large spike at handover and the beginning and the end of the simulation.	Handover happened much slower than previous simulations due to slow speeds. However, the graph pattern of normal distribution was the same as other simulations.


Simulation 1-0
Throughput Bps
600000
400000
200000
0
0
5
10
15
20
25
30
35
40
RTT
1.0
0.5
0.0
5
10
15
20
25
30
35
40
SINR (dB)
5.8
5.6
5.4
0
5
10
15
20
25
30
35
40
Time (seconds)


Simulation 1-5
Throughput Bps
750000
500000
250000
0
0
50
100
150
200
250
300
RTT
0.10
0.05
0.00
0
50
100
150
200
250
300
SINR (dB)
10
8
6
0
50
100
150
200
250
300
Time (seconds)

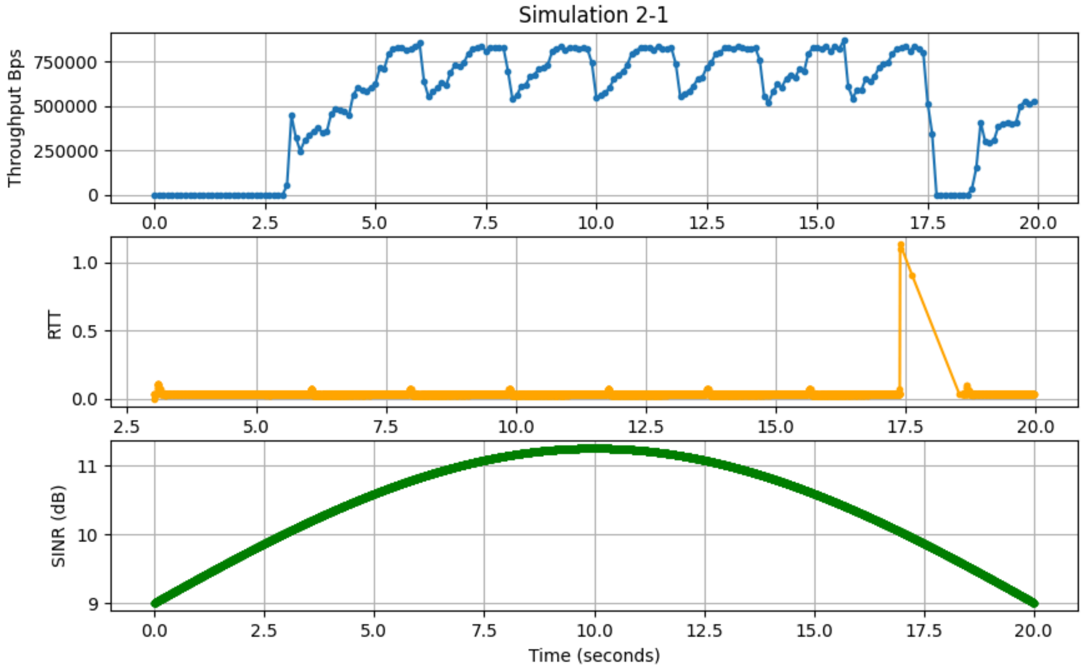


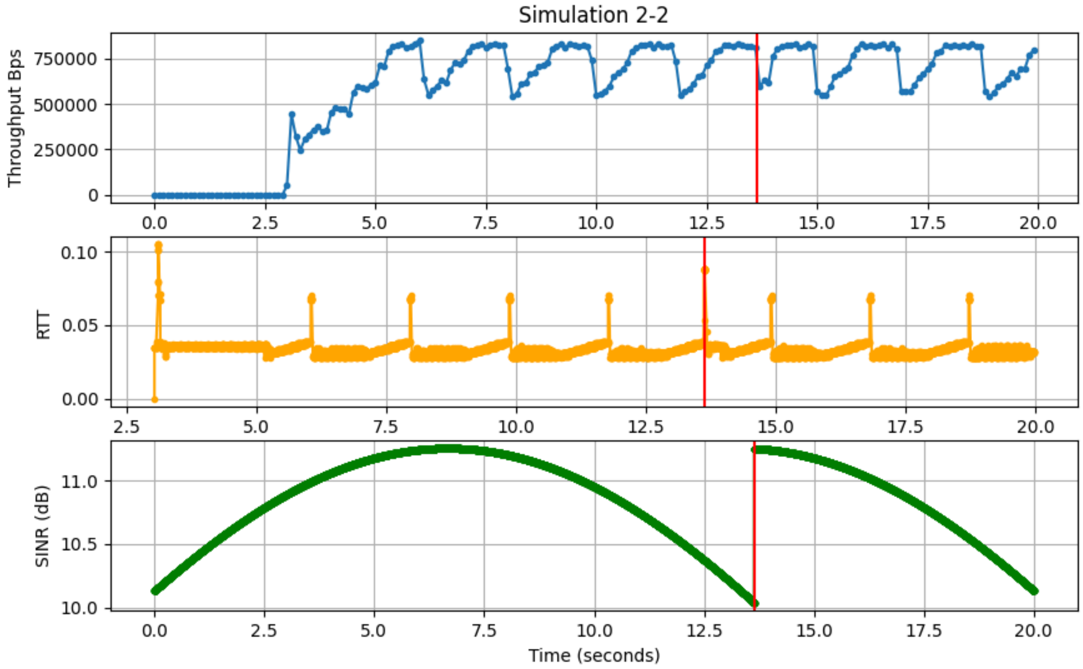


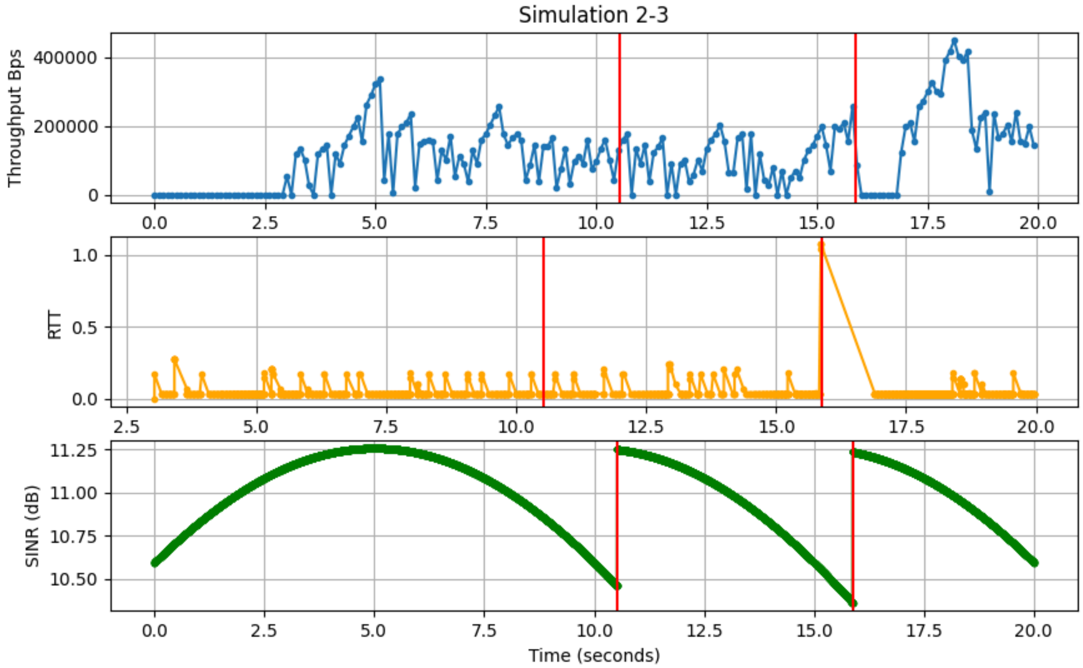
Simulation 2 Analysis

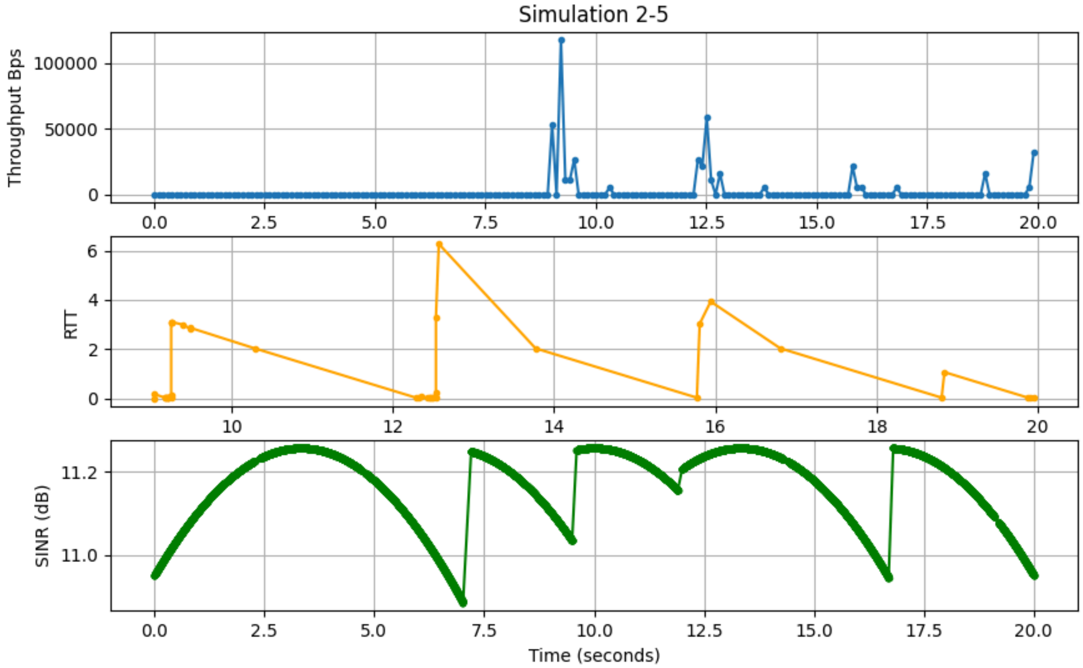
	Observations

2.0	Throughput dropped between 15-20 seconds but raised a little bit. At the same time, there was a spike in latency. For the SINR, it decreased over time
2.1	For two eNBs, there was one handover between 12 and 15 seconds which caused a peak in latency and the SINR to drop.
2.2	For 3 eNBs, there were three handovers that occurred. Looking at the throughput graph, the throughput would be high then it would decrease slightly and result in handover. There was also a noticeable spike in between 15 and 20 seconds for the RTT. There were three decreasing patterns for the SINR graph just before handover occurred and went back up again.
2.3	For 5 eNBs, there seemed to be no handovers but the SINR would still decrease but would fix itself back to its normal state without any handovers. In addition, the RTT would have the same pattern where it would have spikes then go back to its normal state. There would also be spikes in the throughput past 7 seconds where the highest spike would be between 7 and 10 seconds.


Simulation 2-1
Throughput Bps
750000
500000
250000
0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
RTT
1.0
0.5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
SINR (dB)
11
10
9
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (seconds)


Simulation 2-2
Throughput Bps
750000
500000
250000
0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
RTT
0.10
0.05
0.00
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
SINR (dB)
11.0
10.5
10.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Time (seconds)





Conclusion for both simulations: For simulation 1, the faster the velocity, the faster the handover occurs and the slower the velocity, there are more tcp packets being sent and more spikes for throughput and RTT and vice versa. For Simulation 2, the more eNBs doesn’t always mean good performance in terms of latency as the 5 eNB simulation caused decreased latency. This means that for good performance, there is a certain limit on how much eNBs can be used.

The simulation that had decent performance was the simulation with 2 eNBs in comparison to the rest as it gave higher throughput and its SINR stayed overall high. . The throughput stayed about the same and there were less latency spikes than the rest.