Department of Computer Science, Electrical and Space Engineering

Advanced Wireless Networks

Lab 2 - LTE module

Ameer Hamza, Otabek Sobirov

27th September 2021

Tasks

1. Write simulation scenario

Simulation scenario code is already provided for the isotropic antenna. For other antennas, relevant changes were made to the code to generate and analyze the trace files.

2. Be able to describe the content of traces from the LTE system.

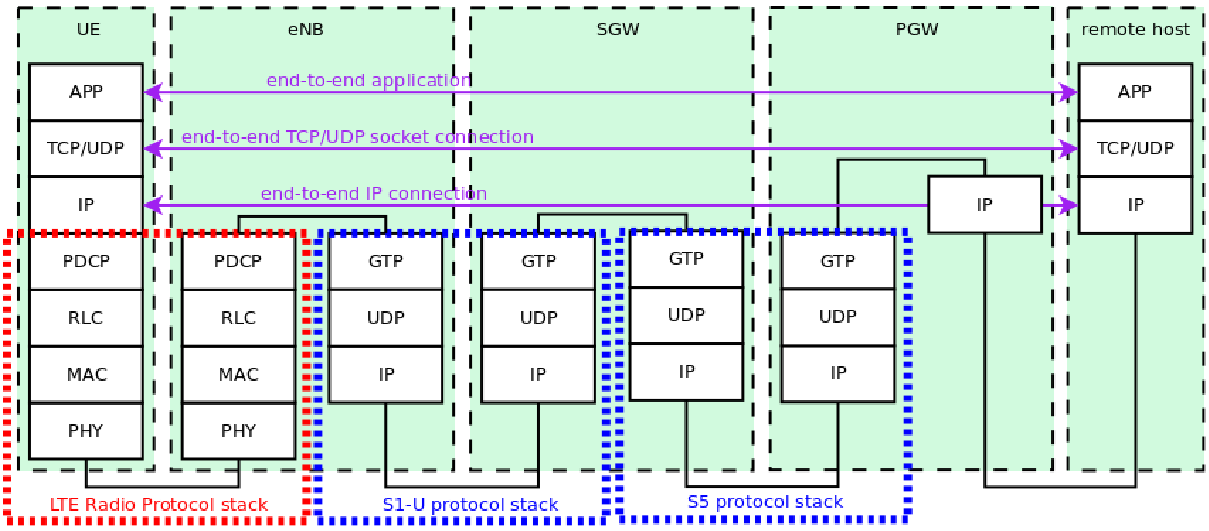

Figure 1

NS3 simulation generates a total of 14 files. Trace files are generated separately for the uplink and downlink of each layer of the LTE data stack, namely: **PDCP, RLC, MAC, PHY**.

PDCP and **RLC** have the same column names. These trace files contain information regarding:

1. Simulation time
2. Cell / UE identity
3. Bytes sent and received
4. PDU delay

MAC trace contains information regarding:

1. Cell / UE identity
2. Frames
3. Modulation and coding scheme

For the **PHY** layer a total of 7 trace files are generated with the following information:

1. Cell / UE identity
2. Reference Signal Received Power (RSRP)
3. Signal-to-noise ratio (SNR)
4. Interference values
5. Other parameters related to radio communication

A **pcap** file is also generated showing downlink communication between the remote server and UE. The remote server sends data to UE using UDP.

3. Describe which differences in traces you have observed for different antenna configurations (parabolic, cosine, and isotropic). Especially, observe cases, when UE is not aligned with the antenna's direction (possible only for parabolic and cosine antennas). Do not be surprised you do not see a large difference in results for parabolic and cosine antennas.

For this task, we have **two scenarios:**

a. ***The default configuration of antennas***

When we ran the script with 3 different antenna types, it generated all the logs on signal level, interference, throughput, etc. There is almost no difference between the log files of the different antenna types. However, in a real environment, there will be considerable differences since the simulator is a mathematical program.

b. ***The change in the alignment of the antenna with EU***

In this scenario, we changed the orientation of two antenna types (cosine and parabolic). The antenna was directed towards X-axis and we changed it to 270 degrees with 3 steps (90, 180, and 270). There is still no change in the throughput values regarding both of the antenna types (at 90 and 270 degrees). The reason for this is that although UE is not aligned with the antenna orientation, the distance between them is too small and enough for good communication.

However, the Reference Signal Received Power (RSRP) level and Signal to Interference Plus Noise Ratio (SINR) changed after adjusting the orientation of the antenna since the UE cannot receive the direct and strong signals from the antenna (at 90 and 270 degrees). The figures below show the difference.

Another big difference is that at 180 degrees, UE could not communicate with the Cosine antenna, but it communicated with the Parabolic antenna.

	A	B	C	D	E	F	
1	Parabolic - 0 degrees						
2	% time	cellId	IMSI	RNTI	rsrp	sinr	Com
3	0.000214285	1	1	0	2.11E-07	4.45E+08	
4	0.00121429	1	1	0	2.11E-07	4.45E+08	
5	0.00221428	1	1	0	2.11E-07	4.45E+08	
6	0.00321428	1	1	0	2.11E-07	4.45E+08	
7	0.00421428	1	1	0	2.11E-07	4.45E+08	
8	0.00521428	1	1	0	2.11E-07	4.45E+08	
9	0.00621428	1	1	0	2.11E-07	4.45E+08	
10	0.00721428	1	1	0	2.11E-07	4.45E+08	
11	0.00821428	1	1	0	2.11E-07	4.45E+08	
12	0.00921428	1	1	0	2.11E-07	4.45E+08	
13	0.0102143	1	1	0	2.11E-07	4.45E+08	
14	0.0112143	1	1	0	2.11E-07	4.45E+08	
15	0.0122143	1	1	0	2.11E-07	4.45E+08	

	A	B	C	D	E	F	G
1	Parabolic - 90 degrees						
2	% time	cellId	IMSI	RNTI	rsrp	sinr	ComponentCarrierId
3	0.000214285	1	1	0	2.11E-09	4.45E+06	0
4	0.00121429	1	1	0	2.11E-09	4.45E+06	0
5	0.00221428	1	1	0	2.11E-09	4.45E+06	0
6	0.00321428	1	1	0	2.11E-09	4.45E+06	0
7	0.00421428	1	1	0	2.11E-09	4.45E+06	0
8	0.00521428	1	1	0	2.11E-09	4.45E+06	0
9	0.00621428	1	1	0	2.11E-09	4.45E+06	0
10	0.00721428	1	1	0	2.11E-09	4.45E+06	0
11	0.00821428	1	1	0	2.11E-09	4.45E+06	0
12	0.00921428	1	1	0	2.11E-09	4.45E+06	0
13	0.0102143	1	1	0	2.11E-09	4.45E+06	0
14	0.0112143	1	1	0	2.11E-09	4.45E+06	0
15	0.0122143	1	1	0	2.11E-09	4.45E+06	0

Figure 2. The Signal and interference levels for Parabolic antenna

	A	B	C	D	E	F	
1	Cosine - 0 degrees						
2	% time	cellId	IMSI	RNTI	rsrp	sinr	Com
3	0.000214285	1	1	0	2.11E-07	4.45E+08	
4	0.00121429	1	1	0	2.11E-07	4.45E+08	
5	0.00221428	1	1	0	2.11E-07	4.45E+08	
6	0.00321428	1	1	0	2.11E-07	4.45E+08	
7	0.00421428	1	1	0	2.11E-07	4.45E+08	
8	0.00521428	1	1	0	2.11E-07	4.45E+08	
9	0.00621428	1	1	0	2.11E-07	4.45E+08	
10	0.00721428	1	1	0	2.11E-07	4.45E+08	
11	0.00821428	1	1	0	2.11E-07	4.45E+08	
12	0.00921428	1	1	0	2.11E-07	4.45E+08	
13	0.0102143	1	1	0	2.11E-07	4.45E+08	
14	0.0112143	1	1	0	2.11E-07	4.45E+08	
15	0.0122143	1	1	0	2.11E-07	4.45E+08	

	A	B	C	D	E	F	G
1	Cosine - 90 degrees						
2	% time	cellId	IMSI	RNTI	rsrp	sinr	ComponentCarrierId
3	0.000214285	1	1	0	2.12E-10	445911	0
4	0.00121429	1	1	0	2.12E-10	445911	0
5	0.00221428	1	1	0	2.12E-10	445911	0
6	0.00321428	1	1	0	2.12E-10	445911	0
7	0.00421428	1	1	0	2.12E-10	445911	0
8	0.00521428	1	1	0	2.12E-10	445911	0
9	0.00621428	1	1	0	2.12E-10	445911	0
10	0.00721428	1	1	0	2.12E-10	445911	0
11	0.00821428	1	1	0	2.12E-10	445911	0
12	0.00921428	1	1	0	2.12E-10	445911	0
13	0.0102143	1	1	0	2.12E-10	445911	0
14	0.0112143	1	1	0	2.12E-10	445911	0
15	0.0122143	1	1	0	2.12E-10	445911	0

Figure 3. The Signal and interference levels for Cosine antenna

4. Calculate the throughput between the eNodeB and UE for 3 different application's Data Rates (determine them on your own) but choose them such that there is a notable difference in the calculated throughput.

	A	B	C	D	E	F	G
1	**Average Tx Byes**						
2		**RLC 1**	**PDCP 1**	**RLC 15**	**PDCP 15**	**RLC 50**	**PDCP 50**
3	**Cosine**	32194.8	32133.8	482863.3	481994.2	1097330.5	1606651.7
4	**Isotropic**	32194.8	32133.8	482863.3	481994.2	1097330.5	1606651.7
5	**Parabolic**	32194.8	32133.8	482863.3	481994.2	1097330.5	1606651.7

Figure 4

Data Rate (Mbps)	Throughput (Mbps)
1	1.03
15	15.45
50	35.11

Figure 5

For this scenario, we ran a total of 9 scenarios. We ran the scenarios for 3 different data rates of the 3 antennas. Figure 4 shows that there is no correlation between the type of antenna and data rate. As for the same data rate, all the 3 types of antennas have the same result.

Throughput was calculated using the RLC trace file instead of PDCP. As shown in Figure 1, RLC is below PDCP in the LTE protocol stack, hence giving us a better measure of throughput. Moreover, if the data rate is increased beyond a certain limit, throughput starts to saturate and PDCP doesn't represent that.

Throughput was calculated using Tx and Rx bytes values. Figure 5 shows that data rate is proportional to throughput but not directly proportional. Beyond a certain data rate, throughput is saturated.

5. Calculate the throughput between the eNodeB and UE for one fixed application's DataRate (choose yourself and motivate your choice) and different distances between eNodeB and UE for the isotropic antenna type.

	A	B	C	D	E
1	**Distance (meters)**	**100**	**1000**	**1500**	**1800**
2	**RLC (TxBytes)**	321921.7	155050	41205	825
3	**PDCDP (TxBytes)**	321325.1	321325	321325	321325

Figure 6

Distance (m)	Throughput (Mbps)
100	10.3
1000	4.96
1500	1.31
1800	0

Figure 7

For this part, the data rate was chosen as 10 Mbps. This rate was chosen as it is sufficient to run most applications and would enable us to analyze the relation between throughput and distance. Throughput was calculated using the RLC trace file for the same reasons as mentioned in part 4.

Figure 7 shows that as the distance increases throughput decreases since UE receives a weak signal because of interference and noise over a distance. And beyond a certain distance of 1800 m in this case, UE and eNodeB lose connection and throughput drops to zero as no data is being sent.