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LULEÅ TEKNISKA UNIVERSITET

Department of Computer Science, Electrical and Space Engineering

D7030E: Advanced Wireless Networks

Lab 4: LTE Module

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The following topology should be implemented in your scenario

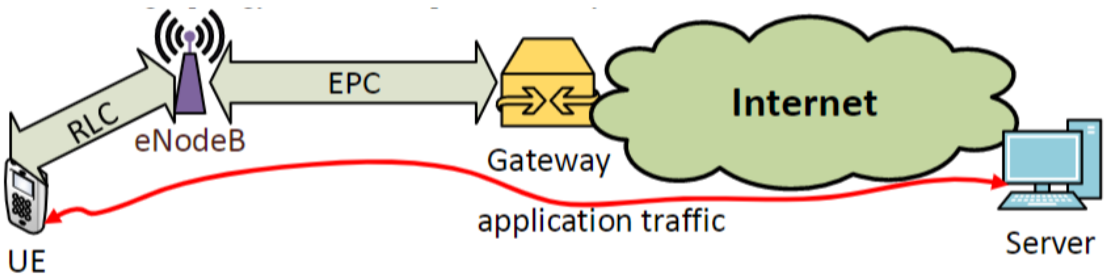

Figure 1. Scenario for the lab

Specification for Scenario:

1. "ns3::LteAmc::AmcModel": LteAmc::PiroEW2010
2. Attributes for LteHelper
   - Pathloss model: TwoRayGroundPropagationLossModel
   - SchedulerType: PfFfMacScheduler
   - DlEarfcn: 100
   - UlEarfcn: 18100
   - DlBandwidth= UlBandwidth: 50
3. Study different antenna configurations (parabolic, cosine and isotropic)
4. Enable routing between the Server and the UE
5. For application use OnOffHelper with "UdpSocketFactory" deployed on a server (Try simulations with 3 different DataRates for the socket).
6. Record PCAP trace from the server's side
7. Record traces from LteHelper

Tasks:

1. Write simulation scenario
2. Be able to describe the content of traces from LTE system

The protocol stack for LTE air interface is composed of the control plane and the user plane as shown in the following figure. The control plane is associated with the signalling between different LTE components while the user plane represents the actual application data.

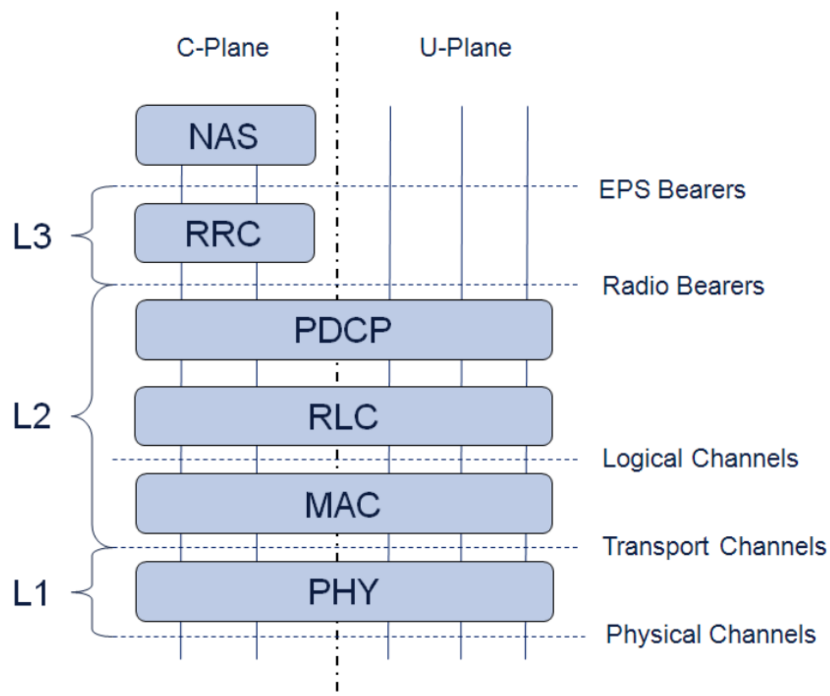

Figure 2. Protocol stack for LTE air interface

LTE simulation generated traces for L1 & L2 as follows:

PDCP traces for UL/DL contains:

- Start and end time of simulation in seconds
- Cell Info
- Unique UE ID (IMSI)
- Logical Channel ID
- No. of transmitted and Received PDCP PDUs & bytes
- Minimum & maximum PDCP PDU size
- Average PDCP PDU delay in seconds.

RLC traces for UL/DL contains:

- Start and end time of simulation in seconds

- Cell Info
- Logical Channel ID
- Unique UE ID (IMSI)
- No. of transmitted and Received RLC PDUs & bytes
- Minimum & maximum RLC PDU size
- Average RLC PDU delay in seconds.

MAC traces for UL/DL contains:

- Start and end time of simulation in seconds
- Cell Info
- Unique UE ID (IMSI)
- Frame & subframe number.
- MCS & size for TBs.

PHY traces for UL/DL contains:

- Simulation time in seconds
- Cell ID
- IMSI
- RSRP & SINR
- Interference values per RB
- Transmission layer
- MCS
- Size of the TB

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 antenna's direction (possible only for parabolic and cosine antennas).

Total of 9 LTE simulations were conducted for this section as follows:

- The antenna position in x,y,z coordinates was configured at (0.0.1)
- We configured three antenna models (parabolic, cosine, and isotropic) without changing their default parameters. For parabolic & cosine antennas, the orientation of the antenna on the x-y plane relative to the x axis is 0 degree.
- For each antenna model, three simulations were conducted for three different UE positions to check LTE traces in different alignment scenarios.
- The UE positions were as follows:
  (500.0.1): 500 meters away from the antenna along the x axis & facing the main lobe with 0-degree orientation.
  (0.500.1): 500 meters away from the antenna along the y-axis & deviating 90 degrees from antenna main lobe.
  (-500.0.1): 500 meters away at the back of the antenna & deviating 180 degrees form the antenna main lobe.

The following levels for uplink and downlink signal to interference and noise ratio (SINR) & reference signal received power were obtained:

Table 1. RSRP & SINR for different antenna models

Antenna Model	eNB position (x,y,z)	UE position (x,y,z)	DL RSRP	DL SINR	UL SINR
Isotropic	(0,0,1)	(500,0,1)	2.67E-14	56.2183	28.1759
		(0,500,1)	2.67E-14	56.2183	28.1759
		(-500,0,1)	2.67E-14	56.2183	28.1759
Cosine		(500,0,1)	2.67E-14	56.2183	28.1759
		(0,500,1)	2.67E-17	0.0563402	0.028237
		(-500,0,1)	0	0	0
Parabolic		(500,0,1)	2.67E-14	56.2183	28.1759
		(0,500,1)	2.67E-16	0.562183	0.281759
		(-500,0,1)	2.67E-16	0.562183	0.281759

As demonstrated in table 1, isotropic antenna that radiates the same intensity of radio waves in all directions has fixed values for RSRP & SINR regardless UE location.

The cosine antenna with vertical beamwidth of 360 degrees and horizontal beamwidth of 120 degrees shows a different response. Along the x-axis (500.0.1) we obtained high SINR & RSRP levels, however, as we are moving away from the axis of antenna directivity, the received signal power decreases until we lose it at (-500.0.1 – outside antenna coverage area).

The same behavior is observed for the parabolic antenna model which has a beamwidth of 60 degrees. The highest SINR levels along the x-axis, & much less power levels when moving away from its directivity.

Antenna misalignment results in LTE service interruption, UE won't be able to receive or send data as shown in the following table.

Table 2. PDCP & RLC packets for different antenna models and alignments

Antenna Model	eNB position (x,y,z)	UE position (x,y,z)	PDCP				RLC			
			nTxPDUs	TxBytes	nRxPDUs	RxBytes	nTxPDUs	TxBytes	nRxPDUs	RxBytes
Isotropic	(0,0,1)	(500,0,1)	1526	1608404	564	594456	250	596242	250	596242
		(0,500,1)	1526	1608404	565	595510	250	596242	250	596242
		(-500,0,1)	1526	1608404	565	595510	250	596244	250	596244
Cosine		(500,0,1)	1526	1608404	565	595510	250	596244	250	596244
		(0,500,1)	1526	1608404	0	0	5	825	0	0
		(-500,0,1)	1526	1608404	0	0	4	1	165	0
Parabolic		(500,0,1)	1526	1608404	565	595510	250	596242	250	596242
		(0,500,1)	1526	1608404	0	0	5	825	5	825
		(-500,0,1)	1526	1608404	0	0	5	825	5	825

4. Calculate the throughput between the eNodeB and UE for different application's Datarates

Both PDCP & RLC traces contains KPIs for transmitted and received bytes that can be used to calculate the throughput over LTE air interface. However, in our experiments RLC traces were used to calculate the throughput for the following reason:

- Packet data convergence protocol (PDCP) is located on top of the radio link control (RLC) layer in the LTE protocol stack, it provides services to user plane IP layer for header compression, ciphering, & integrity protection functionalities. On the other hand, RLC layer is located on top of MAC layer and its responsible of error detection and correction, it segments and reorders upper layer PDUs into smaller or larger RLC layer PDUs according to the available radio data rate. Therefore, RLC is more aware of the radio conditions & closer to the physical layer.

The following throughput were obtained when varying the application data rates from 10 Mbps to 50 Mbps with isotropic antenna & 30 meters distance between UE and eNB.

Table 3. Air interface throughput vs application data rate

Antenna Model	Distance Between UE & eNB (m)	Application Data Rate (Mbps)	RLC					Air Interface Throughput (Mbps)
			nTxPDUs	TxBytes	nRxPDUs	RxBytes	delay	
Isotropic	30	10	250	322080	250	322080	0.003	10.30656
		20	250	644050	250	645105	0.003	20.64336
		30	250	965990	250	965990	0.003	30.91168
		40	250	1098748	250	1098748	0.003	35.159936
		50	250	1098750	250	1098750	0.003	35.16

$$\text{Throughput} = (\text{RxBytes}*8/0.25)$$

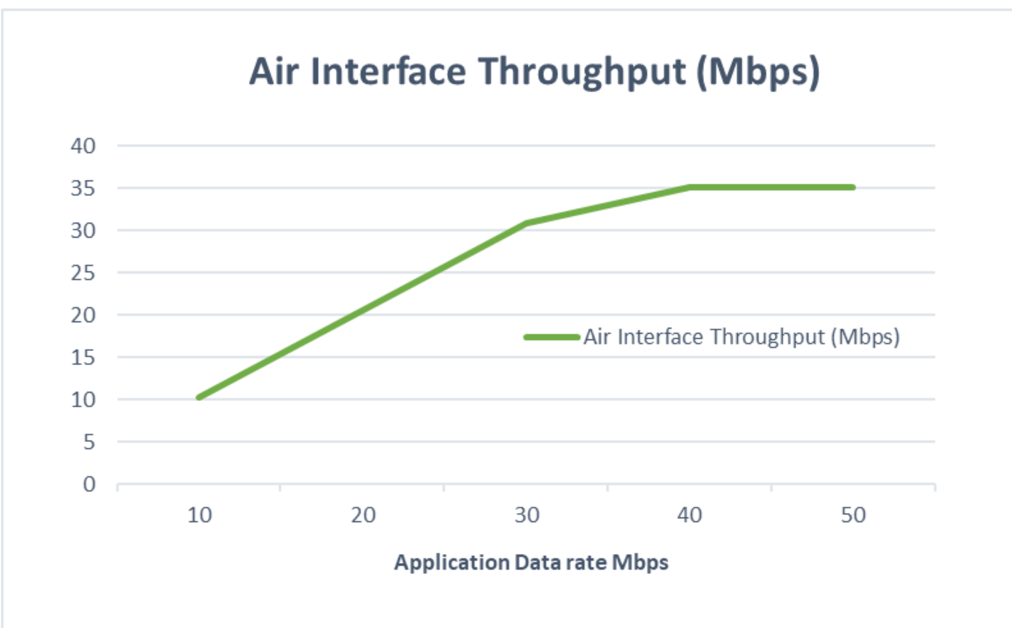

Figure 3. Air Interface throughput vs Application data rate

The previous results show that the air interface throughput increases linearly with the application data rate until the maximum throughput supported by the air interface is reached, any higher application data rates will be bottlenecked by this limit, i.e., 35.16 Mbps in our scenario.

5. Calculate the throughput between the eNodeB and UE for one fixed application's DataRate and different distances between eNodeB and UE for the isotropic antenna type.

The following throughput were obtained when changing the distance between UE & eNB from 30 meters to 1500 meters, the application data rate was configured at 50 Mbps to stress the air interface.

Table 4. Air interface throughput at different distances

Antenna Model	Application Data Rate (Mbps)	Distance Between UE & eNB (m)	RLC					Air Interface Throughput (Mbps)
			nTxPDUs	TxBytes	nRxPDUs	RxBytes	delay	
Isotropic	50	30	250	1098750	250	1098750	0.003	35.16
		125	250	1098748	250	1098748	0.003	35.159936
		250	250	1098750	250	1098750	0.003	35.16
		500	250	596242	250	596242	0.003	19.079744
		1000	250	155241	250	155241	0.003	4.967712
		1500	250	41248	249	41083	0.003	1.314656

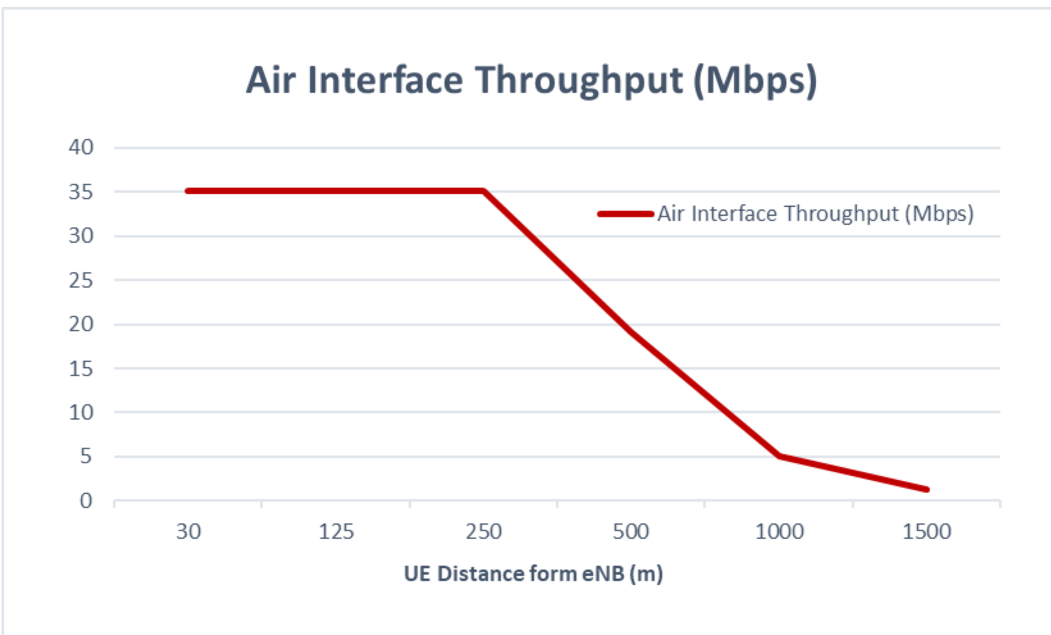

Figure 4. Air Interface throughput at different distances

The previous results shows that the achieved air interface throughput decreases with distance. As the distance increases the radio conditions becomes worse and the received SINR decreases due to the propagation loss, noise, and interference. Therefore, the eNB adjusts physical layer parameters to overcome the bad radio conditions. For example, the MCS Index changed from 28 at 30 meters that provides higher modulation order & throughput to 0 at 1000 meters.