Coverage and Capacity Analysis of LTE Radio Network Planning considering Dhaka City

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ABSTRACT
Long Term Evolution (LTE) is the latest and most enhanced broadband wireless access (BWA) technology. LTE is the latest standard in the mobile network technology tree that previously realized the GSM/EDGE and UMTS/HSxPA technologies. LTE is expected to ensure 3GPP's competitive edge over other cellular technologies. The standardization process of LTE is almost at its end. With industrial attachment very few radio planning works of LTE are going on. But because of certain commercial issues those works aren't widely available. Radio network planning is a very vital step for wireless communication technology. As standardization work of LTE is approaching the end line, it's high time to go for efficient radio network planning guideline for LTE. In LTE just like other cellular technologies, initial planning is normally guided by various industries and vendors at their own discretion. They aren't likely to disclose their advancements and findings. That makes the job even more challenging. As a result, going on with LTE radio network planning perspective is a well-chosen challenge and a certain hot topic in the current research arena. In this work, a detailed LTE radio network dimensioning procedure i.e. capacity and coverage analysis has been performed in order to prepare a radio planning guideline considering possible network implementation in the densely populated South-Asian city-Dhaka.

General Terms
Telecommunications, Wireless Networks.

Keywords
LTE, Dimensioning, Link Budget, Coverage, Capacity, Radio Network Planning

1. INTRODUCTION
LTE is a set of enhancements to the Universal Mobile Telecommunications System (UMTS) which was introduced in 3rd Generation Partnership Project (3GPP) Release 8. The main advantages with LTE are high throughput, low latency, plug and play, FDD and TDD in the same platform, an improved end-user experience and a simple architecture resulting in low operating costs.LTE downlink transmission scheme is based on Orthogonal Frequency Division Multiple Access (OFDMA) which converts the wide-band frequency selective channel into a set of many at fading subchannels. The LTE specification provides downlink peak rates of at least 100 Mbps, an uplink of at least 50 Mbps and RAN round-trip times of less than 10 ms. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time division duplexing (TDD) [1] [2] [3]. LTE will also support seamless passing to cell towers with older network technology such as GSM, CDMAOne, W-CDMA (UMTS), and CDMA2000. The next step for LTE evolution is LTE Advanced and is currently being standardized in 3GPP Release 10 [1, 2] [4, 5].

Radio network planning is a very vital step for a wireless communication technology. As standardization work of LTE is approaching the end line, it's high time to go for efficient radio network planning guideline for LTE. For the same reason, along with the fact that LTE radio network planning work just like other cellular technologies, initial stage planning is normally guided by various industries and vendors at their own discretion. They aren't likely to disclose their advancements and findings. That makes the job even more challenging.

Whenever new cellular technology is considered for mass deployment hundreds of its RF parameters go through tuning process with a view to find out optimum value. But this phase is time consuming and very costly. So, before commercial deployment if extensive simulation can be run this tuning phase can be facilitated in numerous ways. Cost can also be greatly minimized. That is the benefit of running simulation before mass commercial deployment. In this sub-continent LTE is expected to be commercially launched in Q4 of 2012. All these aim at proper radio network planning of LTE. So, looking for optimizing the vital parameters in the least possible time is a very challenging issue which will obviously help network operators in a greater extent.

The ultimate objective of this work is to come up with the detailed radio network planning guideline with respect to Dhaka city. With this mission ahead, in this paper a step by step method was followed starting from gathering preplanning information which went up to coverage and capacity analysis. For this link and system level simulation had to be performed and link budget had to be prepared. All these have been presented here. Prior to that, a brief description of radio network planning methodology has been given.

2. RELATED WORKS
In [6] coverage and capacity estimation is carried out in radio network dimensioning. Radio link budget is investigated for coverage planning. Theoretical work is later put into the development of an Excel based dimensioning tool which is designed to keep the interface simple and to set the functional parts clearly distinguishable. The final product gives the number of sites (cells) needed in order to support a certain

subscriber population with a given capacity. In [7] an attempt to provide analysis of LTE system performance from radio network planning aspects has been made. Determination of the number of resources to be allocated to the PDCCH and how UEs should be efficiently signaled over the PDCCH is addressed in [8]. Resource allocation in LTE downlink and LTE PHY layer simulation aspects have been featured respectively in [8] and [9]. [10-16] are the 3GPP Technical Specifications related to this work. Link and system level simulations have been performed using [17] and [18] respectively. Effect of change in number of transmitting antennas has been shown in [19].

3. RADIO NETWORK PLANNING PROCESS

Radio Network Planning contains number of phases: 1) Initial phase-which includes collection of pre-planning information and starting network dimensioning i.e. Link Budget preparation, coverage and capacity calculation by running simulations 2) Nominal and detailed planning- which includes selection and use of radio planning tool. This step involves propagation model tuning, defining thresholds from Link budget, creating detailed radio plan based on the thresholds, checking network capacity against more detailed traffic estimates, Configuration planning, Site surveys, Site pre-validation and Site validation, eNodeB parameter planning. 3) Defining KPIs and Parameter Planning- using eNodeB system parameters and counters, defining performance KPIs and its target values based on vendor's promise, verification of the KPIs and target values using planning and dimensioning tools nominally along with pre and post-launch optimization.

In this particular work, radio planning stage has gone up to the selection or use of tool.

3.1 Initial Phase

A detailed survey is conducted in order to garner necessary information prior to radio planning. The necessary information can be as follows:

- User Related: User density in different areas. User profile in different areas, in terms of their demand of data rate, use rate, data traffic class of the users, quality requirement, tolerance to unexpected quality, payment capacity and demographic trends etc.
- Terrain and Structure: Location and heights of buildings, foliage, and highway overpasses. Clutter information (Morphology) that generally characterizes the land cover at the particular location. Terrain elevations or topography. Rain and other atmospheric absorption.
- eNodeB/UE Related: eNodeB/UE transmit power, antenna type and gain, feeder loss and body loss.
- Available Spectrum
- Build-out Methodology
- Market Setup
- Data Resolution, Datasets and Cost of data

3.2 Network Dimensioning

Network Dimensioning means determining the areas that need to be covered and computation of number of sites required to serve the target areas while fulfilling the coverage and capacity requirements. Thus, it basically includes the following analyses.

- **Coverage Analysis:** Coverage or cell range is determined for coverage-limited scenario or for interference-limited scenario. This depends on fading margin, cell edge target throughput, average network load, etc.
- **Capacity Analysis:** The capacity analysis involves assessment of demanded and available traffic considering activity factor, Overbooking Factor (OBF), UL/DL frame ratio, etc.

In brief the network dimensioning process goes like that:

- ✓ The pre-planning information is taken as input for network dimensioning. Besides, the probable height of Base Stations at the sites and few other parameters are determined in order to use as input. Once the design requirements are defined, the network dimensioning is performed.
- ✓ A spreadsheet based tool should be developed for the particular requirement. The tool makes use of Link Budget for cell coverage estimation. A system level simulator may be used for the best estimation of capacity which is an input for the tool.
- ✓ The spreadsheet based tool basically determines the cell range using coverage analysis. If the capacity in the range can be handled, then the final number of cells and their locations are determined. On the other hand, if the number of cells required for capacity exceeds the number of cells required for coverage, then an iterative process is required which involves squeezing the cells to handle the capacity.
- ✓ The coverage calculation requires the selection of an appropriate propagation model. Empirical models (e.g. Modified Cost231-Hata, SUI) may better suit than physical models.
- ✓ Customized Continuous Wave (CW) measurements may be performed to tailor an accurate propagation model. A link level simulator may be used for the best calculation using propagation model.

Network dimensioning provides the following results.

- Site count and location of sites
- Cell ranges and cell areas
- Site throughput and sector throughput

Also, it provides expected variation of these results with time. Decision is made about few parameters in dimensioning phase. For example, target MCS, BLER, BS configuration, e.g. 3-sector/omni, antenna types, MIMO type etc. The results of dimensioning assists in estimation of core network and backhaul requirement and initial implementation cost. Thus, it helps in calculation of probable return, planning the tariff strategy, overall business planning, etc.

3.3 Link Budget

The link budget calculations estimate the maximum allowed signal attenuation, called path loss, between the mobile and the base station antenna. The maximum path loss allows the maximum cell range to be estimated with a suitable propagation model, such as Okumura–Hata. The cell range gives the number of base station sites required to cover the target geographical area. The link budget calculation can also be used to compare the relative coverage of the different systems.

The Link Budget calculation uses various parameters as follows.

I. Transmitting End

- BS/CPE transmit power per antenna.
- BS antenna height.
- Transmit power increase with MIMO
- Feeder loss
- Antenna Gain (Typically, around 18 dBi for directional antenna and 8 dBi for omni-directional antenna at BS. CPE has 0 dBi)
- Tower Mounted Amplifier (TMA) Insertion losses
- Body Loss

II. Receiving End

- Antenna Gain
- Noise Figure
- Gain against shadowing
- Receiver sensitivity

4. RADIO PLANNING FOR DHAKA CITY

Dhaka is the capital of Bangladesh and it is an overpopulated city in the South-Asian region. Efficient radio network planning is obviously a big challenge here with the optimal utilization of limited resources. In this part of the work, coverage analysis-link level simulation result along with link budget preparation and capacity analysis-system level simulation have been performed .Calculations have been made Dhaka city specific. As a result, it can be included for the complete Dhaka city radio planning performing the simulations with planning tool like Atoll. But this part is here now considered to be the potential future work.

4.1 Coverage Analysis

For coverage analysis, along with link budget link level simulation result is required.

4.1.1 Link level simulations and results

For the simulation purpose and CQI to SNR mapping, transmission mode 2(Transmit diversity) has been considered in this portion with 2 transmitting and 2 receiving antennas.

Flat Rayleigh channel is used with fast fading for 0 and 3 HARQ retransmissions. Simulation has been performed over significant number of subframes which is here 5000. Simulation has been performed using [17].

The Figure 1 shows Block Error Rate (BLER) vs. SNR (dB) plots for CQI value 7 (out of values from 1 to 15) in transmission mode 2.From the BLER vs. SNR plot, SNR value for acceptable 10% BLER is taken for CQI value.

The result obtained in Figure 2 helps us get an idea of the required SNR level for the cell average throughput for the required transmission mode 2 for 2x2 along with other modes. For TxD 2x2 the required DL SNR level for the average cell throughput is found as around 6 dB.

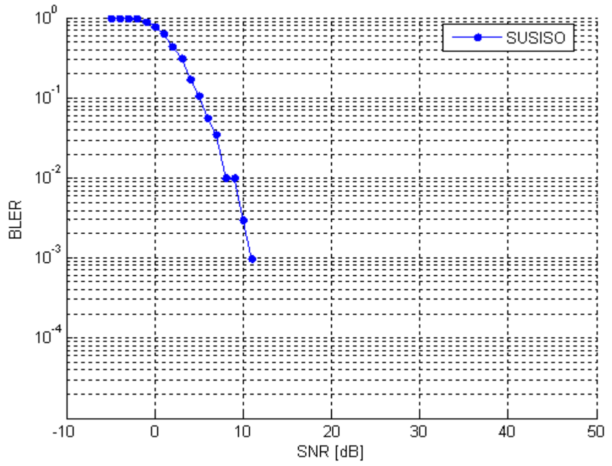

Fig 1: BLER vs SNR for Transmission Mode 2 (2×2)

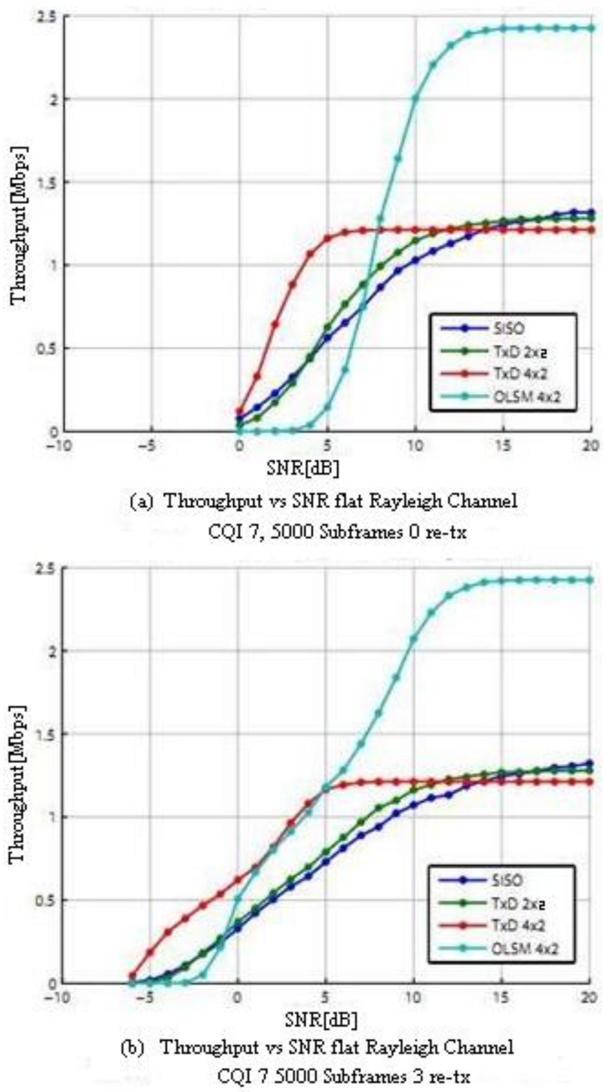

Fig 2- (a), (b): Throughput vs SNR for 0 & 3 re-tx

4.1.2 Link Budget Calculation

The screenshots shown in Figure 3 below provide an example LTE link budget prepared for the uplink assuming a 64 kbps data rate and two resource block allocation (giving a 360 kHz transmission bandwidth). The UE terminal power is assumed to be 24 dBm (without any bodyloss for a data connection). It is assumed that the eNodeB receiver has a noise figure of 2.0 dB, and the required Signal to Noise and Interference Ratio (SINR) has been taken from link level simulations performed earlier which for UL is 7 dB. An interference margin of 2.0 dB is assumed. A cable loss of 2 dB is considered, which is compensated by assuming a masthead amplifier (MHA) that introduces a gain of 2.0 dB. An RX antenna gain of 18.0 is assumed considering a 3-sector macro-cell (with 65-degree antennas). In conclusion the maximum allowed path loss becomes 158.4 dB.

Again, the screenshot in Figure 4 shows LTE link budget for the downlink assuming a 1 Mbps data rate (antenna diversity) and 10 MHz bandwidth. The eNodeB power is assumed to be 46 dBm, a value typical among most manufacturers. Again the SINR value is taken from link level simulations [17] performed earlier and the value found as 6 dB. A 3dB interference margin and a 1 dB control channel overhead are assumed, and the maximum allowed path loss becomes 160.5 dB [2].

4.1.3 Target Coverage Calculation

For target coverage calculation along with link level simulation results and link budget preplanning Information is also required. Related pre-planning information of Dhaka:

- Dhaka Population: 15 million
- Assumed Overbooking factor: 50
- Area: 1463.6 km2

Considered propagation model for this study project was COST-Hata. The COST-Hata-Model is formulated as,

$$L = 46.3 + 33.9\log f - 13.82\log h_B - a(h_R) + [44.9 - 6.55\log h_B]\log d + C$$

For suburban and rural environments:

$$a(h_R) = (1.1\log f - 0.7)h_R - (1.56\log f - 0.8)$$

Where, C= $\begin{cases} 0 \text{ dB for medium cities and suburban areas} \\ 3 \text{ dB for metropolitan areas} \end{cases}$

L = Median path loss. Unit: Decibel (dB)
f = Frequency of Transmission. Unit: Megahertz (MHz)
h_B = Base Station Antenna effective height. Unit: Meter (m)
d = Link distance. Unit: Kilometer (km)
h_R = Mobile Station Antenna effective height. Unit: Meter (m)
$a(h_R)$ = Mobile station Antenna height correction factor as described in the Hata Model for Urban Areas.

Here,
L=158.4 dB, f=2100 MHz, h_B =33m, h_R =1.5m, $a(h_R)$=0.049

As Cost-Hata propagation model provides a pathloss of 158.4 dB for, d=3.254 km
Area of the Hexagonal shape for one eNodeB site =$3\sqrt{3}d^2/2$= 27.51 sq km where, d= cell radius
So, No of eNodeBs for coverage=1463.6/27.51≈53

4.2 Capacity Analysis

To get the capacity analysis done system level simulation has to be performed. Using [18] system level simulation was performed with the following environment shown in Table 1 below:

Table 1: System Level Simulation Environment

Environment	Urban
Scheduler	Proportional fair
Bandwidth	10 MHz
Transmitter power	43 dBm
Inter eNodeB distance	500m
Transmit diversity	2×2
UE speed	Pedestrian

The simulation results are shown in Figure 5, 6 & 7. In Figure 5,UE no. 3- is in close region (between 100 m radius of enodeB); in Figure 6, UE no. 5- is in intermediate region (between 175 m radius of enodeB), in Figure 7,UE no. 6- is in far region (between 250 m radius of enodeB).

4.2.1 Throughput Analysis

From the System Level Simulation results obtained, satisfactory throughput was achieved for 15 UE/cell.

- For UE in close region (between 100 m radius of eNodeB) target average throughput is 1.1 Mbps
- For UE positioned in intermediate region (between 175 m radius of eNodeB) target average throughput is 0.9 Mbps
- For UE in far region (between 250 m radius of eNodeB) target average throughput is 0.7 Mbps

4.2.2 Target Capacity Calculation

Let 0.75% of the total population to be covered i.e. 1,12,500
As overbooking factor was assumed as 50; users to be supported simultaneously=112500/50 = 2250
Now, No. of eNodeB for capacity= 2250 /(3*15) = 50

4.3 Summary of Obtained Results

Here, a slight difference is found in the number of eNodeB required in terms of capacity and coverage. In this case, number of cell required for coverage exceeds that of capacity. It means capacity can be effectively handled. The target capacity and coverage values can be attempted in the nominal and detailed radio planning stage with radio planning tools like Atoll for complete radio network planning.

	A	B	C	D	E	F	G	H	I
1	**Uplink Link Budget for 64 kbps with dual-antenna receiver base station**								
2	**Data rate (kbps)**			64		64 kbps data rate and two			resource block allocation (giving a 360 kHz transmission bandwidth)
3	**Transmitter-UE**								
4	A. Max. Tx Power (dBm)			33					
5	B. Tx antenna gain (dBi)			0					
6	C. Body loss (dB)			0					
7	D. EIRP (dBm)=A+B-C			33					
8									
9	**Receiver – eNode B**								
10	E. e Node B noise figure (dB)			2					
11	F. Thermal noise (dBm)			-118.4		k(Boltzmann) * T* B			
12	G. Receiver noise floor (dBm)			-116.4		E+F			
13	H. SINR (dB)			7		From Link Level Simulations performed			
14	I. Receiver sensitivity (dBm)			-109.4		G+H			
15	J. Interference Margin (dB)			2		compensated by assuming a masthead amplifier (MHA) that introduces a gain of 2.0 dB			
16	K. Cable Loss (dB)			2					
17	L. RX antenna gain (dBi)			18		3 sector macro-cell (with 65-degree antennas)			
18	M. MHA gain (dB)			2					
19	**Maximum path loss**			**158.4**		(D+L+M)-(I+J+K)			
20									

Fig 3: Screenshot of Uplink Link Budget

21	**Downlink Link Budget for 1 Mbps with dual-antenna receiver terminal**				
22	Data rate (Mbps)	1		1 Mbps data rate	(assuming antenna diversity) and 10 MHz bandwidth
23	**Transmitter – eNode B**				
24	A. TX power (dBm)	46			
25	B. TX antenna gain (dBi)	18		3 sector macro-cell (with 65-degree antennas)	
26	C. Cable loss (dB)	2			
27	D. EIRP (dBm)	62			
28	**Receiver – UE**				
29	E. UE noise figure (dB)	4			
30	F. Thermal noise (dBm)	-112.5		k(Boltzmann) * T* B	
31	G. Receiver noise floor (dBm)	-108.5		E+F	
32	H. SINR (dB)	6		Link Simulations performed	
33	I. Receiver sensitivity (dBm)	-102.5		G+H	
34	J. Interference Margin (dB)	3			
35	K. Control Ch. Overhead (dB)	1			
36	L. Rx antenna gain (dBi)	0			
37	M. Body Loss (dB)	0			
38	**Maximum path loss**	**160.5**		(D-I)+(L-J)+(M-K)	

Fig 4: Screenshot of Downlink Link Budget

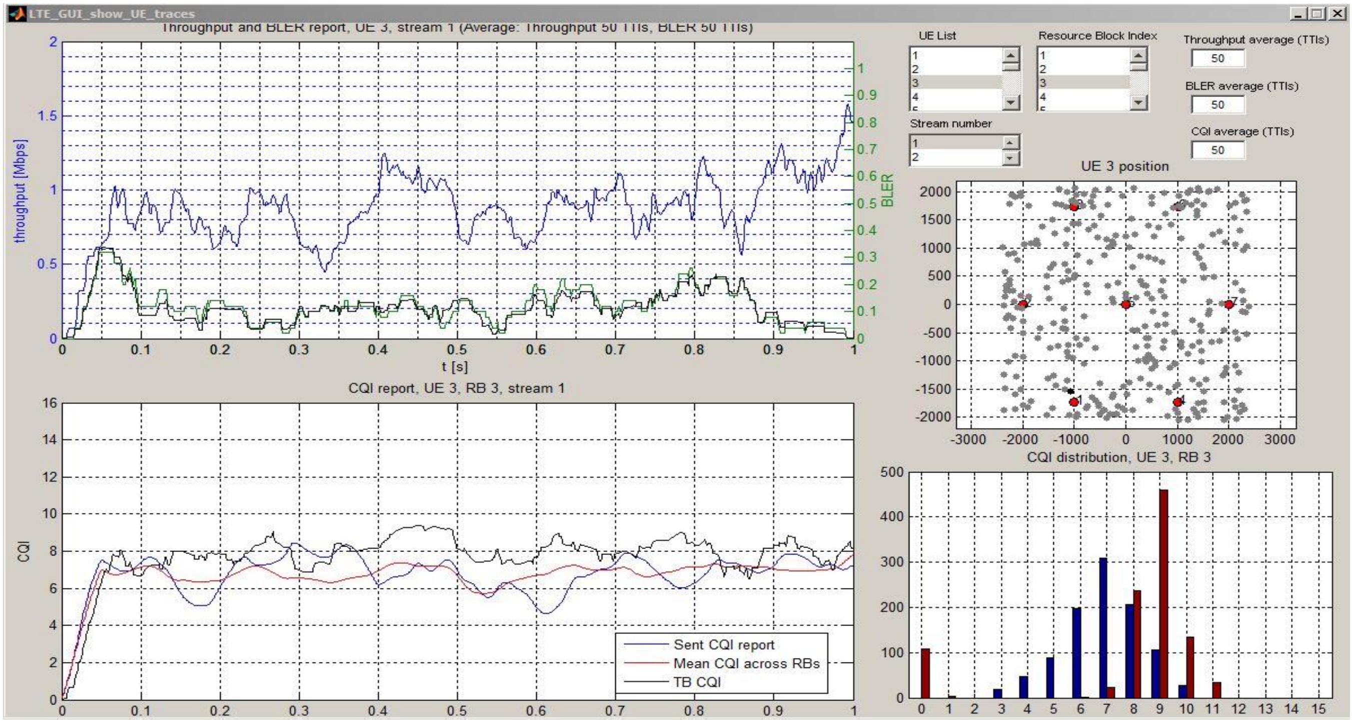

Fig 5: System Level Simulation (UE in close region)

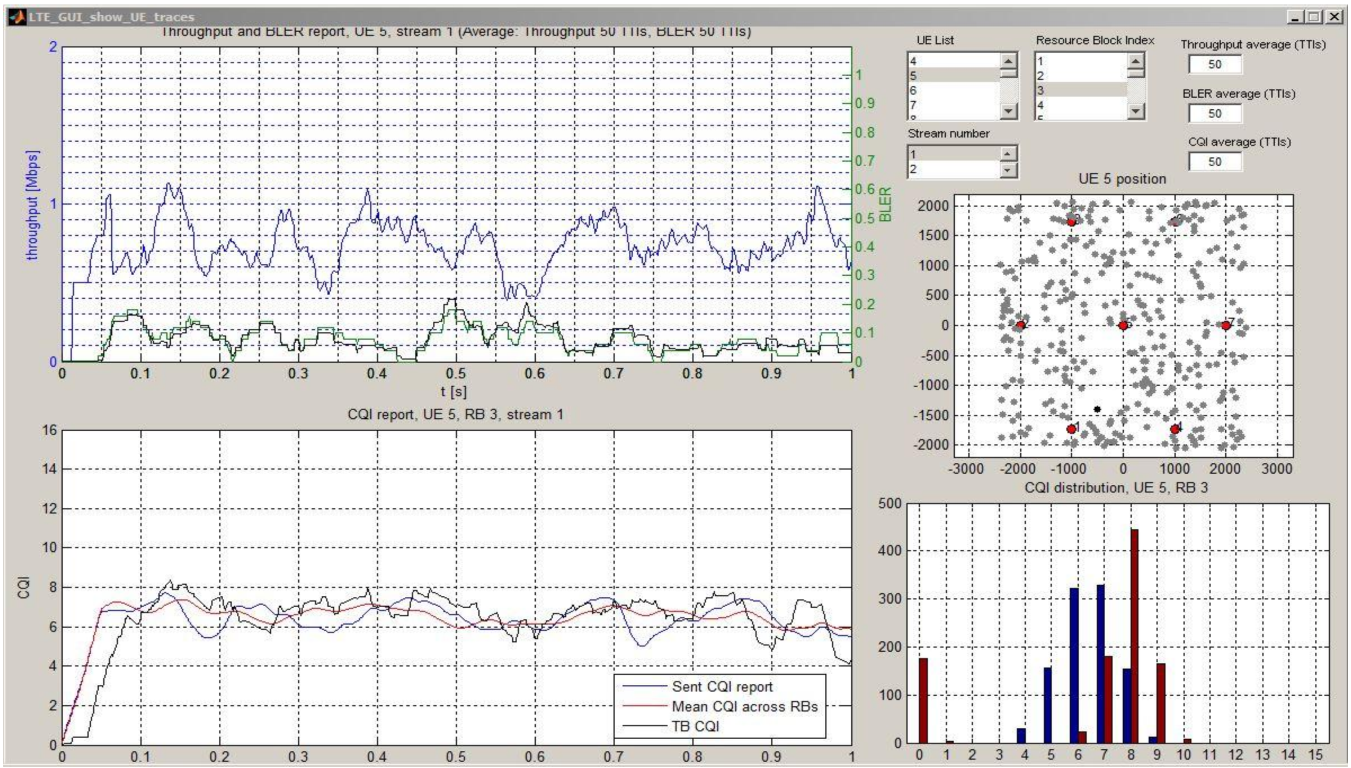

Fig 6: System Level Simulation (UE in intermediate region)

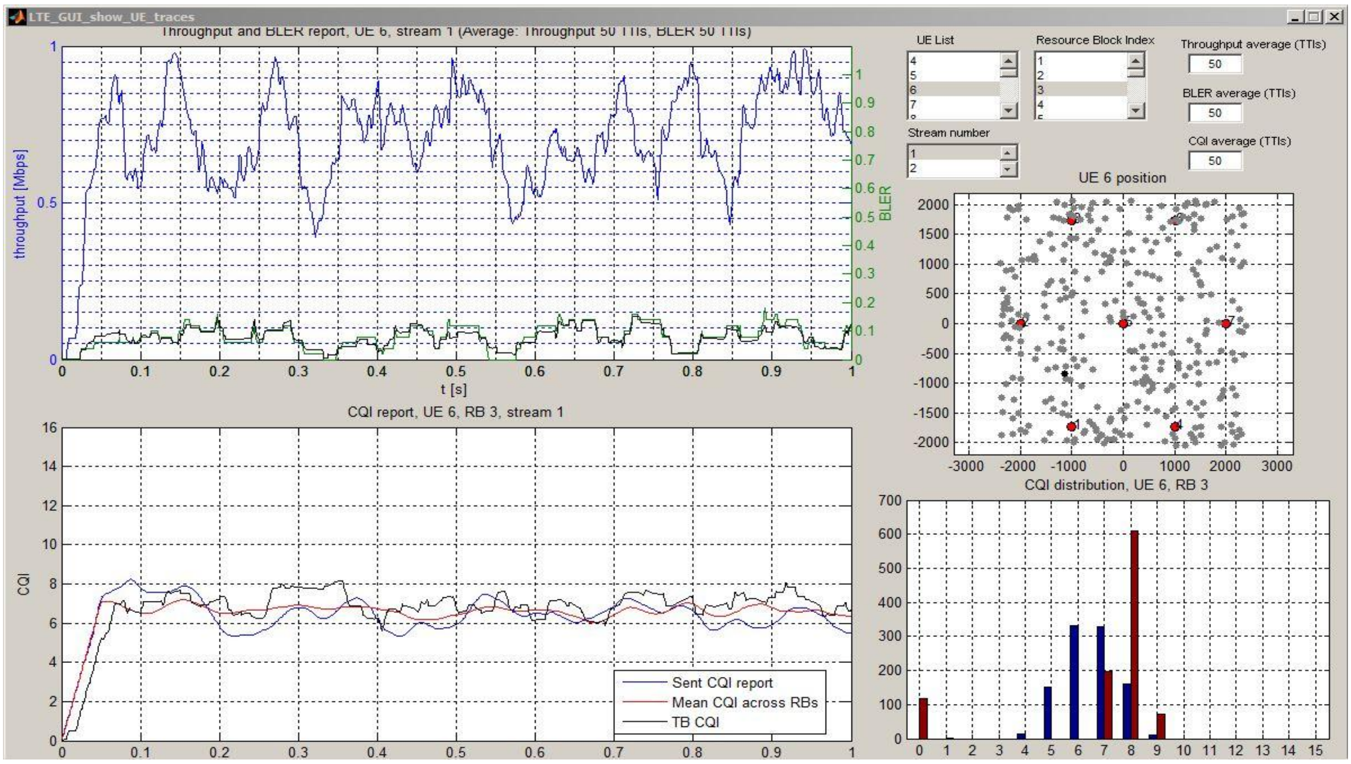

Fig 7: System Level Simulation (UE in far region)

5. CONCLUSION AND FUTURE WORK

The ultimate objectives of the present study of LTE radio network planning guidelines are to introduce the relevant LTE features, to define the basic models for radio propagation planning, to estimate coverage and network element count. The prepared guideline may assist in the development of various tools used in RNP. With this view, following the standard radio network planning procedure link level simulation was performed with certain parameter values. Then link budget was prepared taking some standard or desired value from Link simulator. Thus, in the dimensioning stage coverage analysis was performed. Again, using the system level simulator threshold level capacity analysis was performed. For initial network deployment, at the very beginning only a small number of subscribers are considered for capacity calculation. So, there remains the challenge for future capacity enhancement. Obtained result up to this point are expected to be used in nominal and detailed radio planning stage where Atoll might be used for the radio planning purpose involving Dhaka digital map. In this way, using the obtained coverage and capacity analysis Atoll simulation can provide a detailed traffic map with coverage and capacity solution of well placed eNodeBs.

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