LTE Cell Covarage Planning Considerations-Case study of Misurata City

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Abstract - Long term evolution (LTE) is a 4G wireless broadband technology developed by Third Generation Partnership Project (3GPP), an industry trade group. There is an increasing interest in technologies that will be define the next generation (5G) telecommunication standard. The aim of the cell planning engineer is to establish the proper radio network in terms of service coverage, QoS, capacity, cost, and performance. In order to launch a new mobile system such as LTE, a pre-planning guidelines for the new network has to be considered. This includes the measurement of the required capacity and the obtained coverage area for the area under study. A geographic information, and the population of this area should be included in the analysis. In this paper a pre-planning procedure case study –for Misurata City- has been established by the assistance of A System Level Simulator tool of LTE Networks. The results show that at least 93 end node basestation (eNodeB) sites with around 4.3 km spacing are required to the fulfil the LTE system given in Table 1.

Index Terms— **LTE, Link Budget, Coverage, Capacity, Radio Network Planning**

I. INTRODUCTION

Long Term Evolution (LTE); as defined by the 3GPP; is supposed to be the next generation and will be the basis on which future mobile telecommunications systems will be built. 3GPP engineers named the technology "Long Term Evolution" because it represents the next step (4G) in a progression from GSM, a 2G standard, to UMTS, the 3G technologies based upon GSM. LTE was required in release 10 to deliver a peak data rate of 100 Mbps in the downlink and 50 Mbps in the uplink. This has been gradually increased to 300 Mbps in Release 13, which will also be upgraded to 1 Gbps in Release 15 and beyond. [1].

LTE supports deployment on different frequency bandwidths. The current specification outlines the following bandwidth blocks: 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz, and 20MHz [1]. Frequency bandwidth blocks are essentially the amount of space a network operator dedicates to a network. Depending on the type of LTE being deployed, these bandwidths have slightly different meaning in terms of capacity.

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 sub-channels. LTE will also support seamless passing to cell towers with older network technology such as GSM, CDMA, W-CDMA (UMTS), and CDMA2000. The next step for LTE evolution is LTE Advanced and is currently being standardized in 3GPP Release 10 and beyond.

Radio network planning is an essential step for a wireless communication technology particularly when lunching new networks. Whenever new cellular technology is considered, many 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. Therefore, before commercial deployment if extensive simulation can be run, this tuning phase can be facilitated in numerous ways. That is the benefit of running simulation before mass commercial deployment. All these aim at proper radio network planning of LTE. Thus, 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.

Nowadays, extensive studies have been conducted by many researchers to enhance the limits of the LTE system capabilities. In [2] a comprehensive study has been made to consider the problem of resource allocation for uplink of Single Carrier Frequency Division Multiple Access (Sc-FDMA) that used in LTE-A networks. In this study, the Machine to Machine (M2M) devices are clustered to fulfil the Quality of Service (QoS) requirements. The results in this study show that the proposed algorithm has very close performance to the optimal solution and it has better throughput compared with the performance of the Greedy algorithm. In another study [3], the performance of the MIMO schemes in LTE system with a bandwidth of 5 MHz in terms of Block Error Rate (BLER) and data throughput is examined. The results of this study show a significant improvement can be achieved using three different MIMO schemes (Space Frequency Block Codes (SFBC), Frequency Switched Transmit Diversity (FSTD) and Open Loop Spatial Multiplexing (OLSM)) over SISO configuration.

Since the radio propagation essentially depends on the site geographic, as well as, the frequency changes, the cell coverage area of the LTE based 1800 MHz system for different scenarios is studied in [4]. This research is very helpful in the preprocess and setup of the LTE network planning. Also, in [5], a LTE radio network planning for densely populated Indian city-Dhaka. The authors in this study demonstrate a procedure to calculate the capacity and the coverage area by means of simulations.

In this paper, the coverage analysis, link budget and capacity calculations are performed for Misurata city-Libya. For the link budget calculations, we make use of the COST-Hata Model as the channel propagation. Measurements such as Channel Quality Indicator (CQI), Block Error Rate (BLER) and Signal to Interference and Noise ratio (SINR) are used to evaluate the proposed system. The system level demonstrator given in [6] is used here to obtain these measurements in which, the required number of base stations and the capacity are obtained.

The rest of the paper is organized as follows: Section II describes the radio network planning process that used in this study. This follows by Section III which applies Section II on specific area; Misurata/Libya. The results are summarized in Section IV and finally Section V concludes the paper.

II. RADIO NETWORK PLANNING PROCEDURE

Radio network planning should have a number of steps. The important phase includes pre-planning and network dimensioning, *i.e* link budget, Capacity and coverage calculations. After that a detailed survey is conducted in order to garner necessary information prior to radio planning. The required information that used in design and plan of a sophisticated network are [5, 6]:

a) Information that related to the user: number of users that cover the different city areas and their demand of data traffic and the required QoS. Some of these information are listed in Table 1.

TABLE I
VALUES OF THE CONSTANTS USED IN SIMULATION

Environment	Urban
Bandwidth	10MHz
Frequency	2e9 Hz
Inter eNodeB distance	500m
Transmit diversity	2x2
Transmitter power	46 dBm
Channel	AWGN, Flat rayleigh
UE speed	Pedestrian

b) Terrain and Structure such as location and heights of buildings, roads and streets.
c) The bandwidth, transmitter power, antenna type and gain, different types of losses due to antennas and others.
d) Assigned data rates for each user.

Before the calculation of the link budget, we need to know the network dimension, i.e. determining the areas that need to be covered and the calculation of the number of eNodeB required to serve the target areas. This may include [3]:

Coverage analysis: the cell radios has to be obtained for any coverage limit or the limit of interference scenarios. These limits are depending on some parameters such as fading margin, cell edge, target throughput, and average network load. Choosing a suitable propagation model is very important that makes the coverage calculations quit similar to the real case. Other models such as empirical models (e.g. Modified Cost231-Hata) may better suit than physical models.

Capacity analysis: This analysis is mainly depending on the the availability of the traffic.

From the obtained analysis of the coverage and the capacity, we can obtain the following:

- Number and location of each eNodeB.
- The radius, which means, the area of all the cells.
- Throughputs of both eNodeB and sector.

The Link budget is the important phase in radio network planning. It estimates the maximum allowed signal attenuation, called path loss, between the mobile and the base station antenna. Link budget is a wireless survey tool which gives an idea about the signal power levels and receiver sensitivity levels needed to render the good link quality. The link budget equation comprises many parameters [5]:

- Power transmitted by the transmitter.
- Gain of Antenna (both transmitter and receiver).
- Feeder losses of antenna (both transmitter and receiver) as well as the path loss.
- The sensitivity of both the eNodeB and the receiver (user equipment (UE)).

III. RADIO NETWORK PLANNING FOR MISURATA CITY

Fig.1 presents network dimension for Misurata city. Misurata is a city located in Libya in North Africa, with an area of about 400 Km^2 and a population of around 400,000 [4]. As we mentioned in Section II, the calculation and analysis of the coverage and capacity as specified by the parameters given in Table I are calculated as follows:

Fig.1 Misurata city, area 400 km^2, the population is 400,000

A. *Coverage analysis*

Based on the system environment given in Table I, a system level simulation has to be performed. The UE sends CQI feedback as an indication of the data rate which can be supported by the downlink channel. This helps the eNodeB to select appropriate modulation scheme and code rate for downlink transmission.

The UE determines CQI to be reported based on measurements of the downlink reference signals. The UE determines CQI such that it corresponds to the highest Modulation and Coding Scheme (MCS) allowing the UE to decode the transport block with error rate probability not exceeding 10%.

For simulation purpose, the CQI to SNR mapping transmit diversity has been considered in this part with 2 Tx and 2 Rx and it was compared with SISO system. Flat fading channel is also used with fast fading for 0 and 3 Hybrid Automatic Repeat Request (HARQ) retransmission.

For the tow Tx antenna case, the Alamouti Scheme [5] has been used, which can be written as:

$$\begin{bmatrix} y_0 \\ y_1^* \end{bmatrix} = \begin{bmatrix} h^{(0)} & h^{(1)} \\ h^{(1)*} & -h^{(0)*} \end{bmatrix} \cdot \begin{bmatrix} x_0 \\ x_1 \end{bmatrix} + \begin{bmatrix} n_0 \\ n_1 \end{bmatrix} \quad (1)$$

where $\boldsymbol{h}^{(0)}$ and $\boldsymbol{h}^{(1)}$ represent the channel coefficients from the first and second transmit to all receive antennas.

Fig.2 shows the plots of the Block Error Rate (BLER) against SNR (dB) for different CQI values ranging from 1 to 15 for transmission mode 2. From this figure we can notice that the BLER for 2×2 transmit diversity is much less than that for SISO as the SNR values is increased from 0 to more than 15 dB.

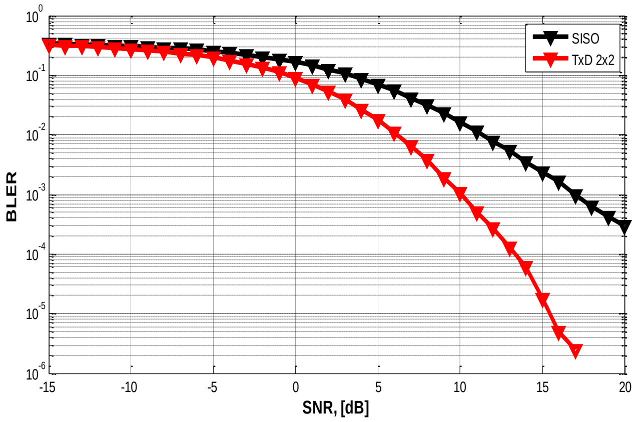

Fig. 2. BLER Curve obtained from 10 MHz , single- user, 5000 subframes long, at CQI=7 for Transmit Diversity 2x2 and SISO .

Fig. 3 shows a generated macroscopic path loss map for different CQI values ranging from 1 to 15 using random positions. In this figure, the users under study are connected to one sector 120°. in a cell of radius of 500 m. In this work, it was chosen the CQI =7 with taking in account that most of users are in this region.

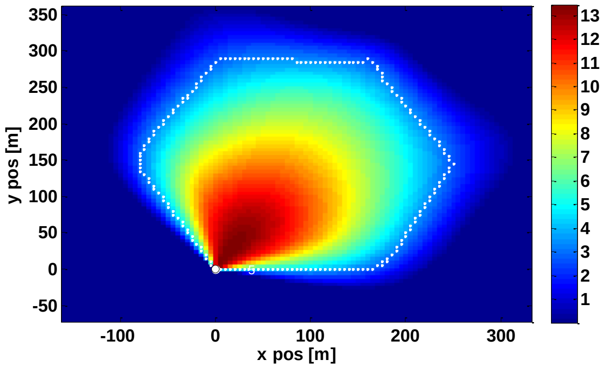

Fig. 3. Macrosopic path loss for different CQI values

Based on the results obtained from Fig. 3, we can calculate SINR for LTE- cluster as shown in Fig. 4 which presents SINR for LTE-cluster and shadow fading.

The path loss between an eNodeB sector and UE is used to jointly model both the propagation path loss due to the distance and the antenna gain. For this case Fig. 5 shows the path loss for 120° sector.

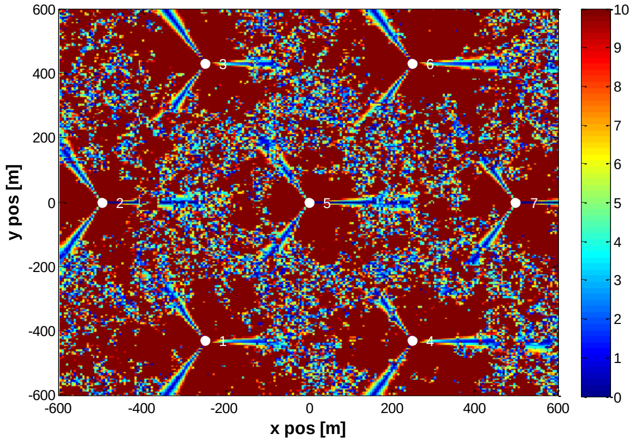

Fig. 4. SINR for LTE-cluster and shadow fading.

Fig. 5 shows the path loss distribution that the users face in terms of the proposed parameters in Table I. For transmit diversity of 2x2. the required DL SNR level for the average cell throughput is found as around 6 dB [7].

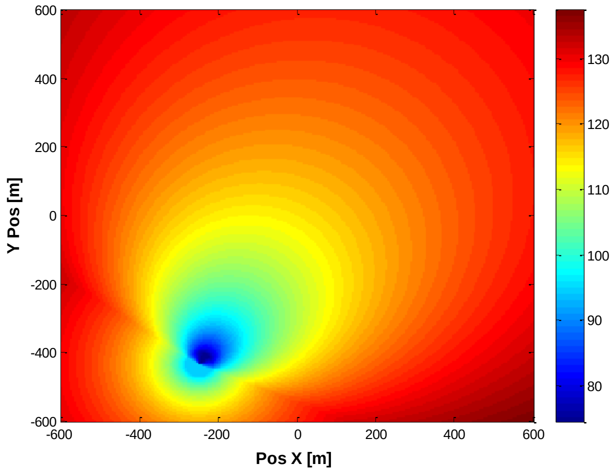

Fig. 5. Path loss for eNodeB1, sector 1, when the transmitted power is 43 dBm

B. *Link budget Calculation*

In this Section the LTE link budget of the downlink (DL) channel has been calculated when a 64 kbps data rate, two resource block allocation that gives a 360 kHz transmission bandwidth, and 24dBm are used neglecting any body loss that may occur for the data connection. It is assumed that eNodeB receiver has a noise figure of 2.0 dB and the SINR values for UL has taken from Fig. 4. 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 120-degree antennas). In conclusion the maximum allowed path loss becomes 141.25 dB.

IV. RESULTS

LTE link budget for the downlink assuming a $1\,Mbps$ data rate (antenna diversity) and $10\,MHz$ bandwidth has been calculated in Section IV. The used eNodeB transmitted power is assumed to be $46\ dBm$ as Tabulated in Table I, a value typical among most manufacturers. Again, the SINR value of 6 dB which is obtained from Fig. 4. A $3\ dB$ interference margin and a $1\ dB$ control channel overhead are assumed, and the maximum allowed path loss becomes $112.5\ dB$ [4].

For calculations of both target coverage and link budget, the following parameters are used:

- Misurata Population: 400 000
- Assumed Overbooking factor: 50
- Area: 400 km^2

Now, the COST-Hata propagation model has been used which is formulated as,

$$L = 46.3 + 33.9 \log(f) - 13.82 \log(h_B) - a(h_R) + [44.9 - 6.55 \log(h_B)] \log(d) + C \quad (3)$$

For suburban and rural environments $a(h_R)$ can be calculated from:

$$a(h_R) = (1.1 \log(f) - 0.7) h_R - (1.56 \log(f) - 0.8) \quad (4)$$

where $C = 0$ for medium cities and suburban areas and $3\ dB$ for metropolitan areas, L = median path loss (dB), f =transmission frequency (MHz), h_B = base station antenna effective height (m), d=Link distance (km), h_R = mobile Station Antenna effective height (m), $a(h_R) =$ mobile antenna height correction factor as described in the Hata model for urban Areas.

Applying (3) and (4) for the case under study, assuming $d = 1.29\ km$, h_B as $33\ m$ and h_R as $1.5\ m$, we obtain L as $141.25\ dB$.

If we assume that the cell is of hexagonal shape, then we can calculate the area of the cell as:

$$area\ of\ the\ cell\ = \frac{3}{2}\sqrt{3}\, d^2 = 4.323\ km^2 \quad (5)$$

Based on this area, and since the area of the city is $\sim 400\ km^2$, the required number of eNodeBs (N_{eNodeB}) which can be covered by the transmitted power is:

$$N_{eNodeB} = \frac{400}{4.323} \approx 93\ eNode \quad (6)$$

V. CONCLUSION

In this paper, the LTE system radio network planning guidelines is performed with certain parameter values. In addition to this, the link budget calculations for Misurata City have been introduced by employing some desired values from the simulator. In this study, we make use of the LTE system level simulator presented in [6] as tool to measure the optimum SINR for CQI=7 for transmit diversity of 2×2.

COST-Hata propagation model has been used to estimate the coverage area as well as the number of eNodeBs that can be offered by the parameters of the LTE system. These obtained information could be used to assist in development of new LTE mobile system.

The obtained results from this study are expected to be a nominal, and in case of more accurate results are preferred, the used model has to be applied with different parameters for different sub-city areas.

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