On Coverage Analysis for LTE-A Cellular Networks

Jaafar A. Aldhaibani[1], A.Yahya[2], R.B.Ahmab[3], A.S. Md Zain[4], M.K.Salman[5], Riad Edan[6]

[1,2,3,4,5]School of Computer & Communication Engineering
University Malaysia Perlis (UniMAP)
Kangar, Perlis, Malaysia
[6]Ministry of Science & Technology, Iraq, Baghdad
[1]Jaffar_athab@yahoo.com

***Abstract*— In this paper we analyze the coverage area for LTE-A cellular network by taking into account the interference of first tier and frequency reuse planning. We considered the numerical calculations and simulation results to measure the received signal strength at the users for downlink and uplink performances. It has been shown from results that there is degradation in the received signal strength at cell boundaries from-34dBm at the center to -91dBm at the boundaries with spectral efficiency from (4.3 to 0.5) bps/Hz at cell edge. We verify the mathematical model by using the ATDI simulator for the LTE radio planning that deals with a real digital cartographic and contains standard formats for propagation loss.**

Keyword- LTE-A, RSSI, Coverage, UE

I. INTRODUCTION

With the growing application for of wireless services, and the capacity of 2G networks and 3G is reaching saturation point. Long Term Evolution-Advanced (LTE-A) is a technological advancement proposed by the Third Generation Partnership Project (3GPP) to meet the requirements of Fourth Generation (4G) mobile broadband system with a powerful service carrying capacity and the efficiency of resource use, and lower cost of network construction and operation, and flexible network deployment[1].

The LTE is the latest standard in the mobile network technology tree. It inherits and develops the GSM/EDGE and UMTS/HSPA network technologies and is a step toward the 4th generation (4G) of radio technologies designed to optimize the capacity and speed of 3G mobile communication network.

From the view point of LTE network design, these technologies and algorithms recover network performance but enhance system difficulty as well. To work out an efficient, reliable network coverage planning design for LTE, it is required to study the system's technical features expansively using system theories, simulations, and tests [2, 3].

The main aim of coverage planning is to estimate the coverage distance of a BS with parameter settings derived from actual cell boundary coverage requirements sequentially to meet network size requirements. Planning strategies for LTE system coverage can be classified into uplink edge and downlink edge, uplink edge is essentially applied in coverage. The uplink coverage radius is calculated using the received power from users to base station and link budget parameters, then the downlink edge is based on the received power at the users from donor and the interferences power from neighbors cell as shown in Figure 2.

It is well known that the coverage of the cell has an inversely proportional with the user capacity of the same cell. An increasing in the number of users in the cell causes the total interference seen at the receiver to increase. This causes an increase in the power required to be received from each user [4, 5]. This is due to the fact that each user has to retention of a certain Signal-to-Interference plus noise Ratio (SINR) at the receiver for satisfactory performance. For a set maximum acceptable transmission power, an increase in the required power reception will result in a decrease in the maximum distance a mobile can be from the BS thereby reducing the coverage.

The analysis in this paper proposed to the downlink performance in terms of the SINR at the user equipment (UE), where the UE associates itself with the BS which has the maximum SINR at the UE. The signal strength at the UE is an important metric that decides the outage probability, capacity and spectral efficiency of a cellular network in the downlink. The description of SINR distribution is helps in the complete understanding of the SINR metric.

The structure of the paper is organized as follows: Section II describes the proposed mathematical system model of the analysis the LTE coverage performance. The link budget describes that used to approve the mathematical model for received signals strength at the users over cell is explained in Section III. The discussion of results and conclusion are explained in Section IV and Section V respectively.

II. SYSTEM MODEL

The system model comprises LTE-A cellular network with a reference cell surrounded by the first tier of co-channel cells. R, is the radius of each cell

The received signal at the downlink for each user k can be represented as the following equation

$$Y_{i,k} = \sqrt{P_i} B_{i,k} X_{i,k} + \sum_{j=0}^{N_{cell}} \sqrt{P_j} B_{j,k} X_{j,k} + N_k \tag{1}$$

where the $j = 0 \cdots N_{cell}$, N_{cell} number of neighboring cell and $j \neq i$, the P_i, P_j is the transmit power of donor BS and neighboring BSs, also, the $B_{i,k}$ $B_{j,k}$ is the fading channel gain for donor and neighboring cell respectively and N_k is AWGN for each k- user .

$$\rho_{i,k} = \frac{P_i \,|\, B_{i,k} \,|^2}{N_k + \sum_{j=0}^{N_{cell}} P_j \,|\, B_{j,k} \,|^2} \tag{2}$$

Where the $\rho_{i,k}$ is SINR from the i -th link in each single sub-carrier (k) UEs [4, 6, 7]:

In a severely interference limited, scenario, the background noise N_k can be ignored to simplify the calculations and the above expression can be write as [8, 9].

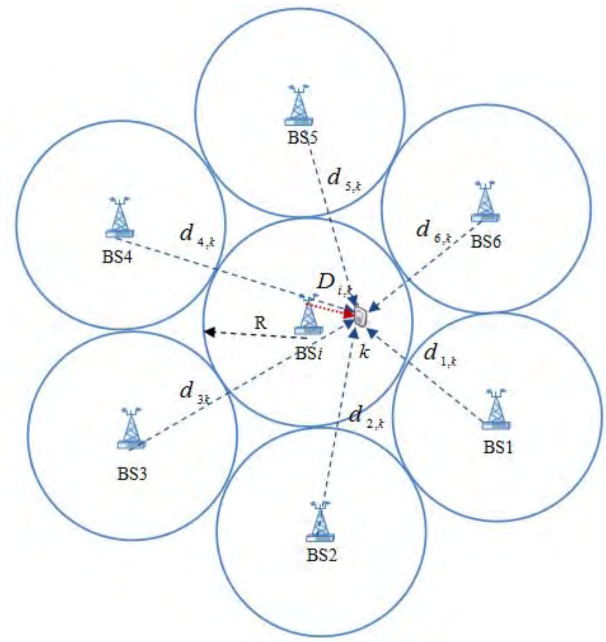


Figure1.First tier of LTE-A cellular Network

$$\rho_{i,k} = \frac{P_i G_{r,k} G_{t,i} \left(\frac{\lambda}{4\pi}\right)^2 D_{i,k}^{-\alpha}}{\sum_{j=1}^{N} P_j G_{r,k} G_{t,j} \left(\frac{\lambda_j}{4\pi}\right)^2 d_{j,k}^{-\alpha}} \tag{3}$$

$$\rho_{i,k} = \frac{P_i L D_{i,k}^{-\alpha}}{\sum_{j=1}^{N} P_j L_j d_{j,k}^{-\alpha}} \tag{4}$$

Where the B is the function of path loss, $|B|^2 = LD^{-\alpha}$, $L = G_r G_t \left(\frac{\lambda}{4\pi}\right)^2$ is constant depend on the infrastructure of sender and receiver, $G_r G_t$ is the antenna gains of transmitter and receiver λ is the wavelength of carrier frequency, $D^{-\alpha}$ and $d_{j,k}$ is the distances between the user and donor BS and neighboring cells BS_j respectively as shown in figure1 , α is path loss exponent [3]. According to [10, 11], the capacity in a Single Input Single Output (SISO) LTE system can be estimated by

$$C_i = \min\left\{BW_{eff} \log 2(1+\rho_i / \rho_{eff}\ ),\ C_{\max}\right\} \tag{5}$$

where C_i is the estimated spectral efficiency in bps/Hz, $C_{\max}$ is upper limited according to the hard spectral efficiency given by 64-Quadrature Amplitude Modulation (QAM) with the coding rate 0.753 equal 4.32 bps/Hz [4,12] . ρ_i is the SINR for each user in cell , BW_{eff} is adjusts for the system bandwidth efficiency and ρ_{eff} is adjusts for the SINR implementation efficiency. { BW_{eff} , ρ_{eff} } has the value of {0.56, 2.0} in the downlink, and {0.52, 2.34} in the uplink [11].

III. SIMULATION CALCULATIONS

The signal strength in the service area must be measured to design a more accurate coverage of modern LTE networks. The propagation of a radio wave is a complicated and less predictable process if the transmitter and receiver properties are considered in channel environment calculations. The process is governed by reflection, diffraction, and scattering, the intensities of which vary under different environments at different instances.

The ATDI simulator is used to approve the mathematical model for optimum relay placement. The propagation model for this simulator between the nodes can be expressed as the following equation:

$$P_r = P_t + G_t + G_r - L_{prop} - L_t - L_{re} \ \ [\text{dB}] \tag{6}$$

where P_t indicates the power at the transmitter and P_r is the power at the receiver; G_t and G_r are the transmitter and receiver antenna gains, respectively; L_t and L_{re} express the feeder losses; and L_{prop} is the total propagation loss [9,7], formulated as

$$L_{prop} = L_{fsd} + L_d + L_{sp} + L_{gas} + L_{rain} + L_{clut} \tag{7}$$

L_{fsd} : free space distance loss,

L_d : diffraction loss,

L_{sp} : sub path loss,

L_{gas} : attenuation caused by atmospheric gas,

L_{rain} : attenuation caused by hydrometeor scatter,

L_{clut} : cutter attenuation,

This equation describes the link budget. A link budget describes the extent to which the transmitted signal weakens in the link before it is received by the receiver. The link budget depends on all the gains and losses in the path, which is facing the transmitted signal to reach the receiver. A link is created by three related communication entities: transmitter, receiver, and a channel (medium) between them. The medium introduces losses caused by suction in the received power, as shown in Fig. 2.

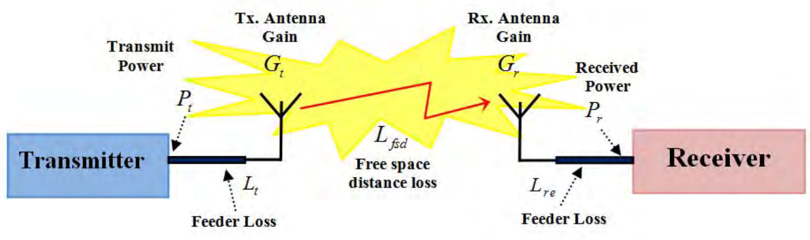


Figure2. Link budget scheme

The SINR at the user equipment over the simulation test can be explained by using the following equation:

$$SINR_{sim} = \frac{P_r}{N_o + \sum_{j=1}^{j=N} P_{rj}} \tag{8}$$

where the $SINR_{sim}$ is the received SINR by the user and calculated by the simulator; P_{rj} is the received signal from the neighbouring cell; and $j = \{1 \cdots N\}$, where N is the number of neighbouring cells. For simplicity, we suggested the use of the first tier (six cells around the centralized cell) in planning for an urban area, with N_o as the background noise at the receiver.

$$P_r = \frac{P_t G_t G_r}{L_{prop} L_t L_{re}} \quad \text{(watt)} \tag{9}$$

$$SINR_{sim} = \frac{\dfrac{P_t G_t G_r}{L_{prop} \ L_t \ L_{re}}}{N_o + \sum_{j=1}^{j=N} \dfrac{P_j G_{t,j} G_r}{L_{prop,j} \ L_j \ L_{re}}} \tag{10}$$

where L_t , L_j , L_{re} are the feeder loss for senders (central BS and the surrounding BS_j) and destination

$$C_{sim} = 0.5 \log_2 \left(1 + SINR_{sim}\right) \tag{11}$$

$$C_{sim} = 0.5 \log_2 \left(1 + \frac{\dfrac{P_t G_t G_r}{L_{prop} \ L_t \ L_{re}}}{N_o + \sum_{j=1}^{j=N} \dfrac{P_j G_{t,j} G_r}{L_{prop,j} \ L_j \ L_{re}}} \right) \tag{12}$$

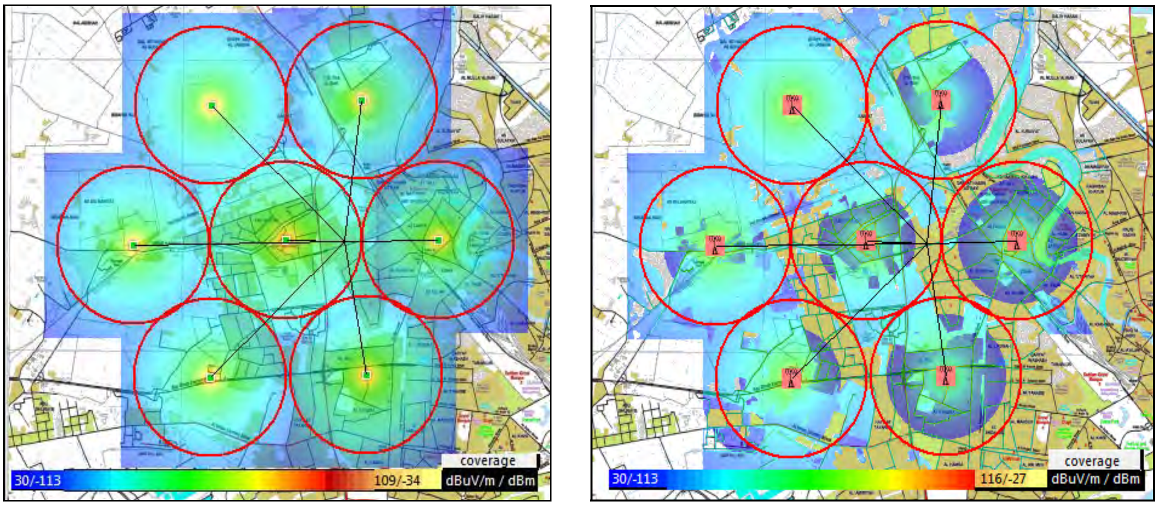
IV. SIMULATIONS RESULTS

In this section, we compared the results of the system capacity and received signal strength for proposed model with simulation. Figure.3(a,b) shows the chromatic scheme of coverage area distribution for LTE-A cellular networks over 7 cells which are choose urban area contains more clutter factors like high building ,trees and terrain which setting over real digital cartography according to Eq.(7) and Table I. Some paths will suffer increased loss; whereas others will be less obstructed and have increased signal strength. In practice the clutter along a path at a given distance will be different for every path, as illustrated in Figure.3b.

The received signal strength at the user is degrading with increase the total propagation loss over cell radius specially the path loss as shown in Figure4a.The interference for first tier (six cells around the main cell) is considered in these results so, the interference is increased at cell edge which leads the to reduce SINR at the boundaries of cell.

TABAL I. SIMULATION PARAMETERS

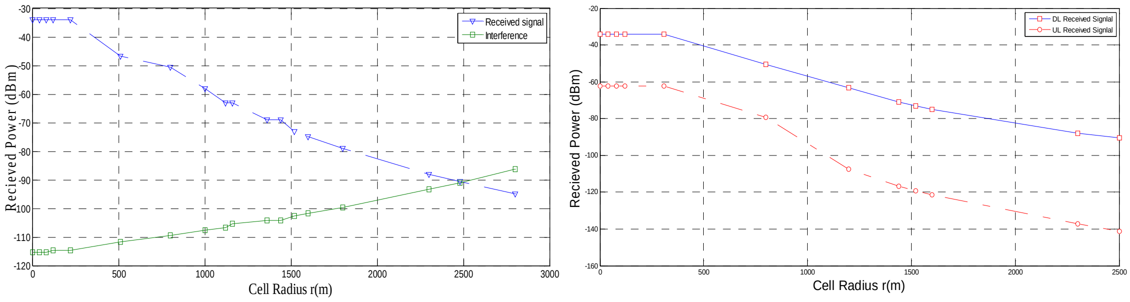
Carrier Frequency	2 GHz
Bandwidth	5 MHz
Number of BS	7
Antenna height of BS	40 (m)
Antenna gain	17 dBi
Type of antenna	Omi directional
Transmitted power of BS	40 Watt
Number of recourse block (RBs)	25
Radius of cell	2500m
Number of UE	1
Antenna height of UE	1.5 m
Antenna gain	0 dBm
Background Noise (N_K)	-175dBm
Coverage threshold	-30dBµv/m



(a) (b)

Figure3. Chromatic scheme of coverage area distribution for LTE-A cellular networks over a real digital cartographic of an urban city (a) with no propagation loss (b) with propagation loss

Figure4b is illustrated the received signal strength at the user over two way mode (downlink and uplink) against the cell radius. To obtain to improvement in coverage distribution we must take in account the downlink (DL) and uplink (UP)performance, where the DL and UL transmission are asymmetrical in terms of maximum transmit power according to transmitter characteristics (BS or UE). The received signal in the cell boundaries at user is (-85dBm) while the received signal from user at BS is (-140dBm) as shown in Figure.4b. The sensitivity of base station is very high campier with UE sensitivity therefore this signal is enough to process in base station.

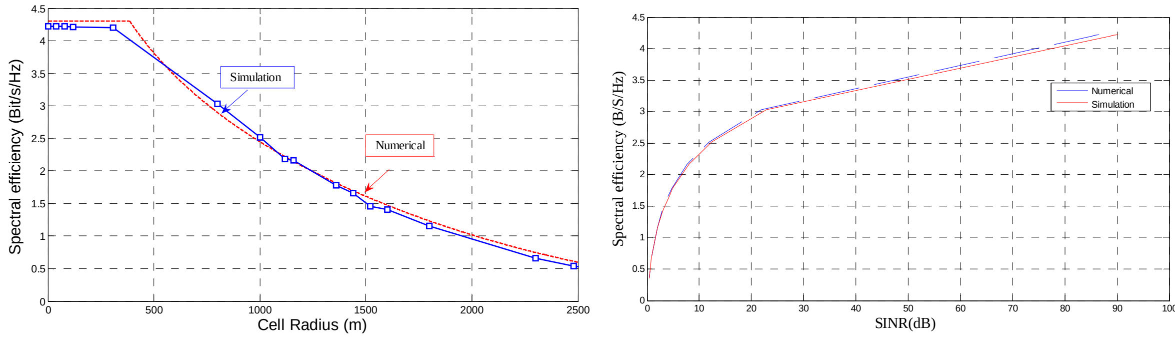


(a) (b)

Figure4. Received signal strength at UE versus the cell radius (a) received signal strength and received interface signal from neighbouring cells (b) received signal strength at UE for downlink and uplink

The maximum spectral efficiency 4.32 bps/Hz is observed for upper limited at the saturation region with 64-QAM with the coding rate of 0.753 according to Eq.(5). The proposed mathematical model is compared with the ATDI simulation considered the interferences for first tier and considered the frequency reuse.

Figure 6 presents the SINR at the user equipment over cell radius with the spectral efficiency for two tests. The spectral efficiency is increased with increasing the SINR that is depending on the link budget between the sender and receiver as mentioned in section III.



(a) (b)

Figure5. Spectral efficiency versus the cell radius.(a) numerical and ATDI simulation results
(b) The SINR versus with spectral efficiency

V. CONCLUSION

In this paper, the performance analyses in coverage and capacity of LTE cellular network have been simulated and evaluated .The numerical analysis of the spectral efficiency and signal strength at users for two way mode transmission (uplink and downlink) has been studied. The first tier interference from neighboring cells is considered. The coverage estimated for dense urban area by using the ATDI RF planning software platform for the LTE Radio Planning that is approved the numerical analysis for proposed scheme.

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