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Cell Coverage Evaluation for LTE and WiMAX in Wireless Communication System

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Abstract: In this paper, we have evaluated the cell coverage area for LTE and WiMAX technology theoretically for different frequencies and environments in wireless communication systems. The evaluation was done based on the propagation model-COST HATA231 model, which is suitable for LTE in various environments. Based on this model, we have determined the cell radius and coverage area under some real world application for different continents of the World as per licensed spectrum. We have then compared the cell radius obtained in the case of LTE and WiMAX under different environments and frequencies. The comparison results reveled that the LTE technology not only covers grater area than WiMAX for similar frequencies but also provides high-speed, better Q_oS and "all-IP" mode of communications. As the results, it is highly expected to be the best candidate for future wireless communication system.

Key words: LTE · WiMAX · Cell radius · Cell design parameters · Path loss

INTRODUCTION

In the recent years, WiMAX (3G) technology is widely used for wireless communication systems in many countries because it has rich set of features with promising broadband wireless access networks [1]. However, WiMAX technology has some drawbacks such as low bit rate for long distance, low speed of connectivity, low coverage area, security problem and so forth. Among these limitations, network coverage for WiMAX technology is mainly considered in this study.

In order to overcome network coverage limitation of WiMAX and problem of connectivity, we search for new technology. According to the International Telecommunication Union (ITU), the future of mobile phone connectivity now lies in the hands of 4G technologies. The fourth generation (4G) will provide access to wide range of telecommunication services including advanced mobile services, supported by mobile and fixed networks, which are increasingly packet based, along with a support for low to high mobility applications and wide range of data rates [2]. Long Term Evolution (LTE) technology is one of the most promising representatives of 4G wireless systems. LTE can operate in new and more complex spectrum arrangements [2-3]. Orthogonal Frequency Division Multiple Access (OFDMA) is very much useful for LTE (4G) technology to overcome WiMAX limitation [4]. LTE with OFDMA is expected to provide improved systems, like enhanced capacity and coverage, improved end-user throughputs, sector capacity, reduced user plane latency, improved user experience with full mobility, reduced operating costs, multi-antenna support, flexible bandwidth operation and seamless integration with existing systems [5]. With the emergence of Internet Protocol (IP), LTE is scheduled to provide support for IP-based traffic with end-to-end Quality of service (QoS). LTE system is designed to provide the peak data rate of 100 Mbps in downlink and 50 Mbps in the uplink [5-6].

In cellular communication system, the coverage planning of a cell is of great importance and necessary to find the optimal locations for the base stations in order to build continuous coverage according to the planning requirements. Generally, a cell area is designed to provide

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coverage to an area with the expectation of possible increase in population in the near future [7]. That's why we are very much interested in determining the cell radius and coverage area for LTE technology.

In order to determine the cell radius, we consider the COST-231 Hata model, because this model is widely used as the radio frequency propagation model in wireless communication systems. The COST 231 HATA model is just an extension of HATA model. The COST 231 HATA model is very much useful to calculate path loss in three different environments like urban, suburban and rural (flat) [8]. This model provides very simple and easy ways to calculate the path loss. Its simplicity and correction factors still allowed to predict the path loss in this higher frequency range.

Using this model, we have calculated the cell radius for WiMAX and LTE technology for different environments and frequencies. Then the calculated results as obtained for LTE technology have been compared with the calculated results as obtained for WiMAX technology for different environments and frequencies. The comparison results show that the LTE technology has greater cell coverage than WiMAX technology for similar frequencies in both the cases of uplink and downlink transmission.

Cell Design and Coverage Analysis for LTE: A cellular radio system provides a wireless connection to the public telephone network using a system of base stations (sometimes known as "cell sites") for any user location within the radio range of the system [9]. In mobile cellular communication system, a number of factors affect the commencement or completion of a call from a wireless phone, like coverage area, topography, capacity and network architecture. It is necessary for wireless service to determine the extent of their coverage in the areas [10].

The cell coverage area in a cellular system is defined as the percentage of area within a cell that has received power above a given minimum. Assuming some reasonable noise and interference model, the SNR requirement translates to a minimum received power throughout the cell. Cell coverage primarily depends upon user defined parameters such as transmitting power, random shadowing and antenna configuration. The transmit power at the base station is designed for an average received power at the cell boundary where the average is computed based on path loss alone. Several other parameters such as propagation environment, hills, tunnels, foliage and buildings that are not user defined greatly affect the overall coverage [11].

Key metrics to specify for the geographic area are population density, number of households, terrain types and number of small and medium businesses. The next step is to determine the spectrum and bandwidth to be used from the available frequency bands. Parameters of interest include link budget, spectral efficiency, antenna configurations (SISO, SIMO and MIMO), frequency reuse factor, sectorization, frequency reuse plan and type of cell (Pico, micro or macro cells) which altogether control the coverage area per cell site. Then the total number of cell sites or base stations needed to cover the desired geography. In order to achieve end-to-end connectivity, the next step is to dimension and plan the elements that form the core service network [12].

In order for calculating the cell radius, some basic parameters are considered as shown in Table 1. Then the following steps are followed to determine the cell radius:

A. *Determination of SINR*
B. *Determination of Path Loss, L*
C. *Determination of Cell radius, d*
D. *Determination of Coverage area,* A_{cell}

Determination of SINR: To determine SINR the thermal noise N_T is firstly calculated by using the Eq. (1) [13].

$$N_T = 10 \log_{10} (kT\,\Delta f) \qquad (1)$$

where k (Boltzmann constant) $=1.38 \times 10^{-23}$ J/K, T is the temperature (300 K) and Δf is the bandwidth of the channel. We put the values of the parameters as mentioned in the Eq.(1) we get,

$$N_T = -104.28 \text{ dBm} = 3.72 \times 10^{-14} \text{ W} \qquad (2)$$

The SINR is calculated by using the Eq. (3) [14].

$$SINR = \frac{MHA Gain \times Tx Power}{Thermal Noise + Interference} = \frac{Am \times Pt}{Nt + Nj} \qquad (3)$$

Here let us assume that interference, N_j = 4 dB and MHA (Masthead amplifier) Gain, A_m = 2 dB. Using the parameters as given in Table 1 and Eq. (2), we get SINR for both uplink and downlink given in Eqs. (4) and (5).

$$SINR\ (UL) = -8\ (dB) \qquad (4)$$

$$SINR\ (DL) = 13.98\ (dB) \qquad (5)$$

Table 1: Parameter values for uplink and downlink

Uplink		Downlink	
Parameter	Value	Parameter	Value
P_t, Transmitter Power	24 dBm / 0.251 W	P_t, Transmitter Power	46 dBm / 39.81 W
G_t, Transmitter Antenna Gain (dBi)	0	G_t, Transmitter Antenna Gain (dBi)	18
L_b, Body Loss (dB)	4	L_b, Body Loss (dB)	2
h_b, Base Station antenna Height (m)	40	h_b, Base Station antenna Height (m)	40
Mobile Height (m)	2	Mobile Height (m)	2
A_m, MHA Gain (dB)	2 dB / 1.58	A_m, MHA Gain (dB)	2 dB / 1.58
Noise Figure(dB)	2	Noise Figure(dB)	2
G_r, Receiver Antenna Gain (dBi)	18	G_r, Receiver Antenna Gain (dBi)	0
L_r, Receiver Loss (dB)	4	L_r, Receiver Loss (dB)	0.5
N_r, Receiver Noise (dBm)	-102.28	N_r, Receiver Noise (dBm)	-102.28
Propagation Model	COST		
231 HATA	Propagation Model	COST	
231 HATA			
Δf, Bandwidth (MHz)	9	Δf, Bandwidth (MHz)	9

Table 2: Cell radius for LTE in different terrain

	Area	Cell Radius, d (km)
Uplink (2000 MHz)	Urban	1.58
	Suburban	1.93
Downlink (2000 MHz)	Urban	2.28
	Suburban	2.79

Determination of Path Loss: The basic equation for path loss, L for LTE is expressed as [15],

$$L = P_t + G_t - L_b - SINR + G_r - L_r - N_r \text{ (dB)} \quad (6)$$

Using Table 1 and substituting the value of SINR into Eq. (6) the path loss for uplink and downlink are calculated.

$$\text{Path loss (uplink), } L_{UL} = 144.28 \text{ dB} \quad (7)$$

$$\text{Path loss (downlink), } L_{DL} = 149.8 \text{ dB} \quad (8)$$

Determination of Cell Radius, d: Using Cost 231 HATA model, we determine the cell radius of LTE. The cell radius is related to the path loss, L as

$$L = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - ah_m + \{44.9 - 6.55\log_{10}(h_b)\}\log_{10}(d) + C_m \quad (9)$$

Where d is the cell radius in km and f is the frequency in MHz. The parameter C_m has different values for different environments. C_m = 3 dB and 0 dB for urban and for suburban and rural areas respectively. The parameter ah_m is defined

$$ah_m = (1.11\log_{10} f - 0.7)\, h_m - (1.56\log_{10} f - 0.8) \quad (10)$$

Using the Eqs. (7), (8), (9) and (10), the cell radius, d is determined for both urban and suburban area in case of uplink as well as downlink transmission at f = 2000 MHz. Here the frequency of 2000MHz is chosen as this is available in Asia. The calculated cell radii are arranged in Table 2.

From Table 2 it is clearly seen that the cell radius for suburban area is greater than that of urban area for uplink and downlink frequency of 2000 MHz. Similarly, the cell radii are calculated for frequencies of 1900, 1950, 2000, 2300, 2500 and 2600 MHz used in different countries of the worlds [16]. The obtained results are shown in Table 3, from which we can see that the cell radius for downlink transmission is always greater than that of the uplink transmission.

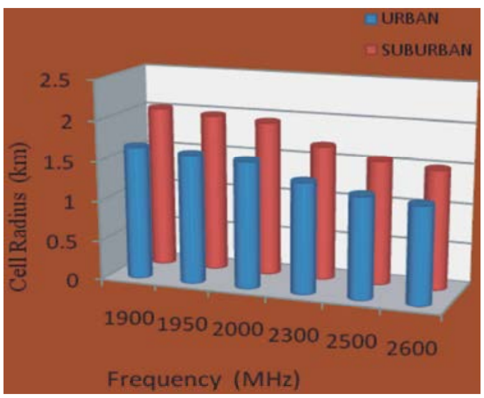
The data from Table 3 are also plotted in Fig. 1(a) and Fig. 1(b) for uplink and downlink transmission, respectively. Fig. 1 clearly indicates that the cell radius d is dependent on terrain type and frequency. For comparatively lower frequencies and for suburban areas the coverage range is greater which agrees well with the theoretical concept.

Table 3: Cell radius for LTE in different frequencies

Frequency (MHz)	Region	Cell Radius for Uplink (km)		Cell Radius for Downlink (km)	
		Urban	Sub-urban	Urban	Sub urban
1900	China	1.66	2.02	2.40	2.93
1950	USA	1.61	1.97	2.34	2.86
2000	Asia	1.58	1.93	2.28	2.79
2300	Asia, Europe	1.38	1.68	1.99	2.43
2500	Europe	1.27	1.55	1.84	2.25
2600	Europe	1.22	1.49	1.77	2.16

Table 4: Cell Coverage in Urban and Suburban Area

Frequency	Cell Radius in Urban (Km)	Cell Coverage in Urban Area (Km^2)	Cell Radius in Suburban (Km)	Cell Coverage in Suburban Area (Km^2)
1900	1.66	7.16	2.02	10.60
1950	1.61	6.73	1.97	10.08
2000	1.58	6.49	1.93	9.68
2300	1.38	4.95	1.68	7.33
2500	1.27	4.19	1.55	6.24
2600	1.22	3.87	1.49	5.78

(a) 

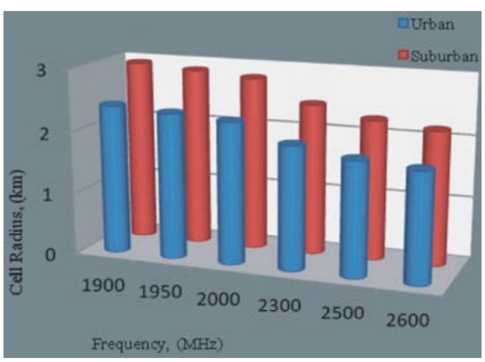
(b) 

Fig. 1: Cell radius for different frequencies in different continents of the World in case of LTE for (a) Uplink (b) Down link.

Determination of Coverage Area, A_{cell}: The coverage area A_{cell} of a base station is expressed by the following formula [14]:

$$A_{cell} = (3\sqrt{3})\, d^2/2 \quad (11)$$

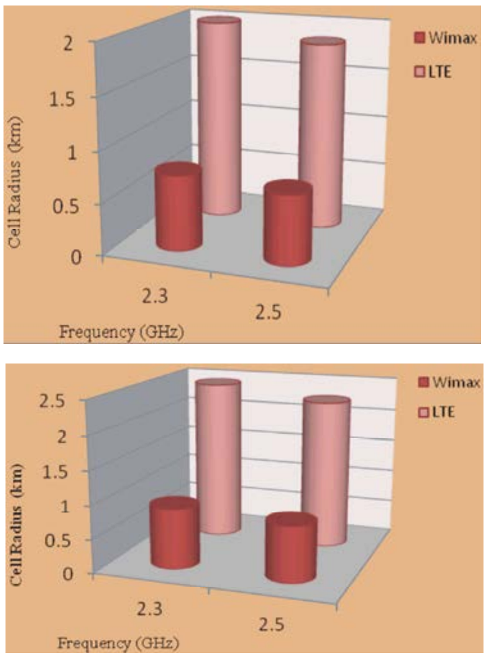
Generally, the cell coverage area is designed considering the uplink cell radius. The coverage area of a cell is determined from Eq. (11) for the frequencies as mentioned in Table 3. The calculated coverage areas for different frequencies are tabulated in Table 4 for uplink cell radii. Here we can see that the cell coverage area is greater in case of lower frequencies and suburban areas.

Superiority of LTE Over WIMAX: The next generation networks like WiMAX and LTE promise to bring better transfer rates, better coverage area, lower latency, better availability and more to fulfill the needs of the customers [17-18]. From the point of coverage issue, WiMAX signals can reach up to 50 km but with much deterioration in signal quality. WiMAX is much optimized for shorter distances like 1.5 to 5 km. In contrast, LTE can cover up to 100 km, which is twice as much as of WiMAX' coverage. LTE also offers connectivity with speeds up to 350 km/h. So, it is even possible to provide LTE connectivity in a high speed vehicle. On the other hand, WiMAX supports speed up to 120 km/h, because of its optimization for nomadic speeds.

LTE's promise of high-speed, two-way wireless data promises an "all-IP" mode of communications in which voice calls are handled via VoIP. The Speed of LTE would give an edge for bandwidth-hungry applications such as live TV and video downloads in compare to that of WiMAX. The cell capacity of WiMAX is a maximum of 200 users whereas the LTE supports more than 400 users. This is possible because of the greater cell radius of LTE than that of WiMAX.

Table 5: Comparison of Cell Radius for WiMAX and LTE

		Cell radius (km)	
Frequency	Terrain Type	WiMAX	LTE
2300 (MHz)	Urban	0.74	1.99
	Suburban	0.90	2.43
2500 (MHz)	Urban	0.68	1.84
	Suburban	0.83	2.25



(a)

(b)

Fig. 2: Comparisons between cell radiuses of WiMAX and LTE for (a) Urban area (b) Suburban area

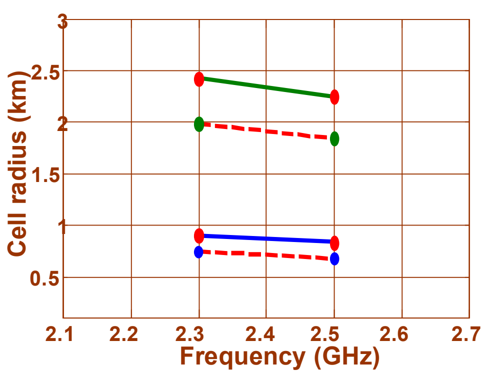


Fig. 3: Comparison between cell radius of WiMAX and LTE

To prove the above theoretical concepts, we have calculated the cell radius for frequency 2300 and 2500 GHz in case of WiMAX and LTE using the COST231HATA model. These frequencies are chosen because they are awarded for WiMAX in Bangladesh according to national license agreement. Using COST231HATA model for 2300 and 2500 MHz, we got cell radii (0.74 km and 0.68 km) for urban and (0.90 km and 0.83 km) for suburban area in case of WiMAX [10].

Similar calculation is also done for LTE for the same frequencies (2300 and 2500 MHz). Then the cell radii for downlink of both WiMAX and LTE are tabulated in Table 5. From Table 5 we can see that the cell radius of LTE is much greater than WiMAX.

The graphical representation of the difference in cell radius found in Table 5 has shown in Fig. 2(a) for urban and in Fig. 2(b) for suburban. Fig. 2 shows that the cell radius of LTE is greater than that of WiMAX for 2300 and 2500 MHz.

The cell radii obtained in Table 5 are used to plot Fig. 3 using MATLAB simulator. In this figure the superiority of LTE over WiMAX in terms of cell radius is shown clearly. Here the dotted and solid lines represent the cell radii of WiMAX and LTE, respectively. The upper two lines are for suburban areas and the lower two lines are for urban areas. So from the simulation we can see that the cell radii for both urban and suburban areas are greater for LTE than WiMAX.

CONCLUSIONS

We have determined the cell radius and coverage area for LTE technology and compared those with WiMAX technology in wireless communication system for different environments. The comparison results ascertained that for both areas (urban and suburban) the cell radius for LTE is greater than that of WiMAX, i.e. LTE (4G) provides better coverage area than WiMAX (3G). Since LTE has rich set of features then many vendors like Ericsson, ZTE, Alvarion, Qualcomm, Verizon, Vodafone and so forth have already launched the LTE technology in China, Japan, Western Europe and North America. This technology is gradually growing up and becoming more popular due to its high speed, quality of service, flexibility and interoperability with other access system. We expect that LTE (4G) technology will play a great role in future wireless communication system.

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