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Mobile WiMAX and 3rd Generation Cellular Technology (3G) Link Budget Calculation

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Abstract- In this paper cell range for different region and modulation schemes has been calculated for WiMAX and 3G mobile technologies, considering both as a cellular mobile technology. While resolving the cell range using different propagation models, effect of various parameters like frequency, base station antenna height, transmitting power, maximum allowable path loss and SNR over cell range have also been studied. Analysis has been done for both uplink and downlink. From the study it reveals that for downlink, cell range increases with increasing transmitting power and decreases with frequency and SNR. For uplink, cell range decreases with SNR. When adaptive modulation advances, it affects cell range significantly for parameters such as frequency, base antenna height and SNR.

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I. INTRODUCTION

WiMAX, based on the IEEE 802.16 standard, offers full mobility of cellular networks with high broadband speeds. Both fixed and mobile versions of WiMAX are there to provide broadband wireless services. All these technologies of cellular mobile networks are evolving to meet different user requirements [1].

3G mobile technologies support high bandwidth communications in addition to voice. It is based on one of the several standards included under the ITU's IMT-2000. ETSI developed two standards for IMT-2000, one of them is UMTS and other is CDMA2000 [2].

This paper calculates the link budget incorporating the various system parameters which leads to evaluate the cell range of mobile WiMAX and 3G network. In calculations system parameters are taken in the allowable range.

ii. Erceg-Greenstein (E-G) Model (Suburban Areas):

$$\text{Path loss} = A + 10\gamma \log\left(\frac{d}{d_0}\right) + (\Delta PL_f + \Delta PL_h) + s \text{ (dB)} \quad [1] \quad [5] \quad [6] \quad (2)$$

Here,

A = free space path loss, γ = path loss exponent, ΔPL_f = frequency correction term, ΔPL_h = receiver antenna height correction term, s = log normal fading, d = BS to MS distance (Km), d_0 = 0.1Km (Chooses as reference distance).

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II. LINK BUDGET & PATH LOSS MODELS

a) Link Budget

A link budget is the accounting of all of the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system. It accounts for the attenuation of the transmitted signal due to propagation, as well as the antenna gains, feed-line and miscellaneous losses. A simple link budget equation looks like this:

$$\text{Received Power (dBm)} = \text{Transmitted Power (dBm)} + \text{Gains (dB)} - \text{Losses (dB)}. \quad [3]$$

The calculation of link budget of mobile WiMAX and 3rd Generation Cellular Technology incorporates different types of modulation schemes like QPSK, 16QAM, 64QAM etc. Each modulation scheme offers different data rate and as the modulation scheme advances the data rate usually increases. Support for QPSK, 16QAM and 64QAM are mandatory in the DL with Mobile WiMAX. In the UL, 64QAM is optional [4].

The Link Budget as well as the cell range that we have calculated here is based on propagation models such as Free Space Path Loss model, COST-231 model (Modified Hata model), Walfish-Ikegami model, Erceg-Greenstein model.

b) Path Loss Models

i. Free Space Model

The free space loss (FSL) equation-

$$FSL = 32.45 + 20\log(f_c) + 20\log(d) \text{ dB} \quad (1)$$

Here, d = distance between Base Station (BS) and Mobile Station (MS), f_c = carrier frequency.

These parameters can be calculated as –

$$A = 20\log(4\pi d_0/\lambda) \quad (3)$$

$$\gamma = a - bh_b + c/h \quad (4)$$

$$\Delta PL_f = 6\log(f/2000) \quad (5)$$

$$\Delta PL_h = -10.8\log(h_m/2) ; \text{ For terrain A and B} \quad (6)$$

$$= -20.0\log(h_m/2) ; \text{ For terrain C} \quad [6] \quad (7)$$

We Assume, λ = carrier wavelength (m), h_b = base station (BS) height (m), h_m = mobile station (MS) height (m), f = carrier frequency

The maximum path loss category is hilly terrain with moderate-to-heavy tree densities (Category A). The minimum path loss category is mostly flat terrain with light tree densities (Category C). Intermediate path loss condition is captured in Category B. [6]

a, b, c are constants dependent on the terrain category: [5] [6]

Constant	Terrain A	Terrain B	Terrain C
a	4.6	4.0	3.6
b	.0075	.0065	.005
c	12.6	17.1	20.0

The result is provided by the equation:

$$Path\ loss = 46.3 + 33.9\log(f_c) - 13.82\log(h_b) - a(h_m) + (44.9 - 6.55\log(h_b))\log(d) + C_M \text{ (dB)} \quad [7] \quad (8)$$

Where, $C_M = 0$ (dB) for medium sized city and sub-urban areas and 3 (dB) for metropolitan centers. $a(h_m)$ = correction factor for effective mobile antenna height, f_c = carrier frequency

$$a(h_m) = (1.1\log f_c - 0.7)h_m - (1.56\log f_c - 0.8)\text{dB}; \text{ For small to medium sized city} \quad (9a)$$

$$= 8.29[\log(1.5h_m)]^2 - 1.1 \text{ dB}; \text{ For large city and for } f_c \leq 300 \text{ MHz} \quad (9b)$$

$$= 3.20[\log(11.75h_m)]^2 - 4.97 \text{ dB}; \text{ For large city and for } f_c > 300\text{MHz} \quad [8] \quad (9c)$$

According to different locations the path loss (PL) equations are as follows:

$$PL(\text{Sub} - \text{Urban}) = PL(\text{Urban}) - 2[\log(f_c/28)]^2 - 5.4 \text{ (dB)} \quad (10a)$$

$$PL(\text{Rural}) = PL(\text{Urban}) - 4.78[\log(f_c)]^2 + 18.33\log(f_c - 35.94) \text{ (dB)} \quad (10b)$$

$$PL(\text{Open}) = PL(\text{Urban}) - 4.78[\log(f_c)]^2 + 18.33\log(f_c - 40.94) \text{ (dB)} \quad (10c)$$

iv. Walfish-Ikegami (W-I) Model

The Walfish-Ikegami model (street canyon model) that includes ground reflections is more realistic than the others as it is based on measurements [7].

$$Path\ loss = 42.64 + 20\log(f_c) + 26\log(d); d \leq d_{break} \quad (11a)$$

$$Path\ loss = 42.64 + 20\log(f_c) + 26\log(d_{break}) + 40\log(d/d_{break}); d > d_{break} \quad (11b)$$

Where, $d_{break} = \frac{4h_b h_m}{\lambda}$ [7] and λ is the carrier wavelength.

Although climate impacts such as rain and fog can result in extra attenuation, they are considered negligible in our calculations for frequencies between 2 and 6 GHz [7].

III. SIMULATION AND RESULTS

Four kinds of regions are selected for link budget calculations and they are open, rural, sub-urban and urban. But in this paper our emphasis is on the large cities.

For downlink frequency range is taken 1900-3500 MHz (WiMAX) and 1800-2100 MHz (3G), base station height range is taken 10-50 m, power per antenna

iii. Cost-231 Model (Modified Hata Model)

We have used Cost 231 propagation model for Mobile WiMAX and 3G coverage area calculations allowing for urban, rural and open areas.

The Hata formula is being used for many applications but its main disadvantage is that it is developed for frequencies below 2 GHz. In order to use it for the envisioned frequencies of the non line-of-sight systems beyond 3G, the original formula has to be extrapolated to frequencies up to 6 GHz. [7].

range is taken 5-30 Watts, SNR range is taken from -9 to 9 dB and maximum allowable path loss range is taken from 100 to 200 dB. All these parameters are considered for QPSK 1/8, QPSK 1/2. For uplink frequency, maximum allowable path loss and SNR have the same ranges as downlink. And the modulation schemes are also same.

Figure 1 through Figure 6 demonstrate that the cell range varies with varying different system parameters like power per antenna, carrier frequency, SNR etc both for WiMAX and 3G network.

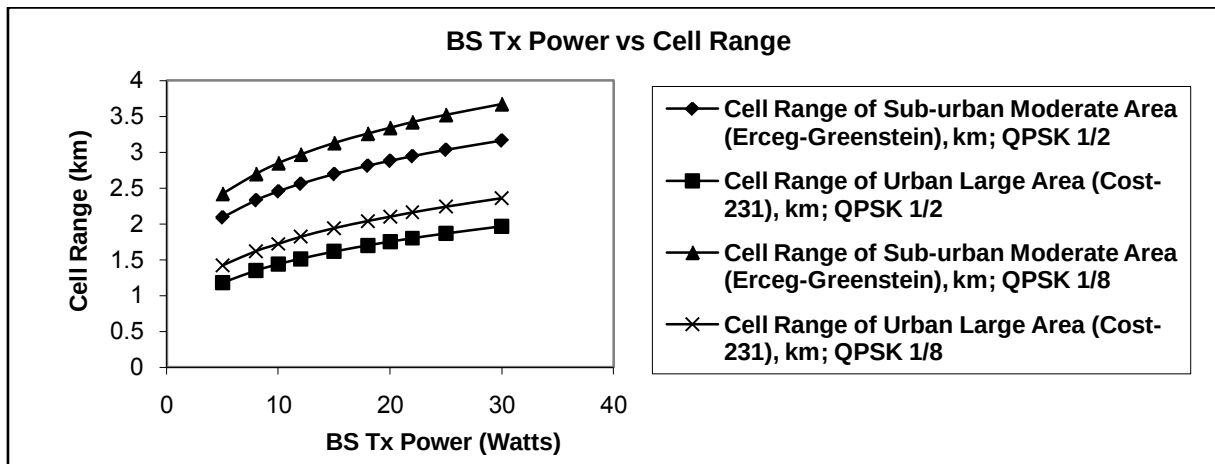


Figure 1 : Graphical representation of BS Tx Power vs Cell Range of WiMAX for downlink

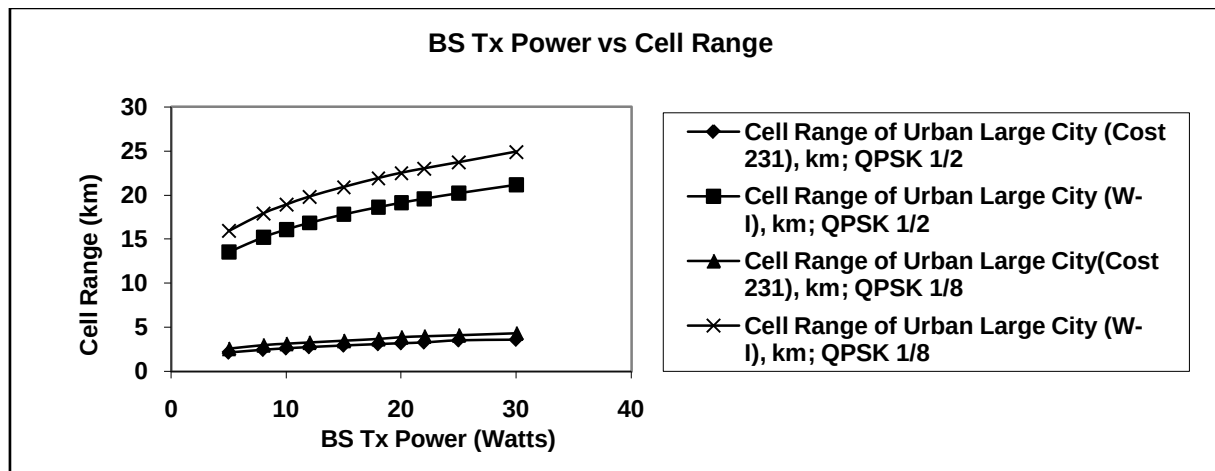


Figure 2 : Graphical representation of BS Tx Power vs Cell Range of 3G for downlink

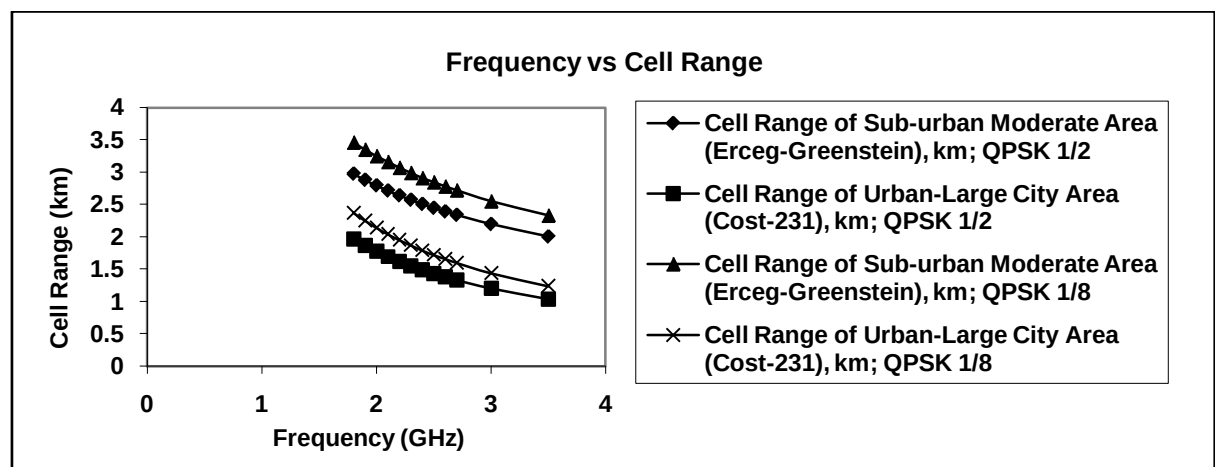


Figure 3 : Graphical representation of Frequency vs Cell Range of WiMAX for downlink

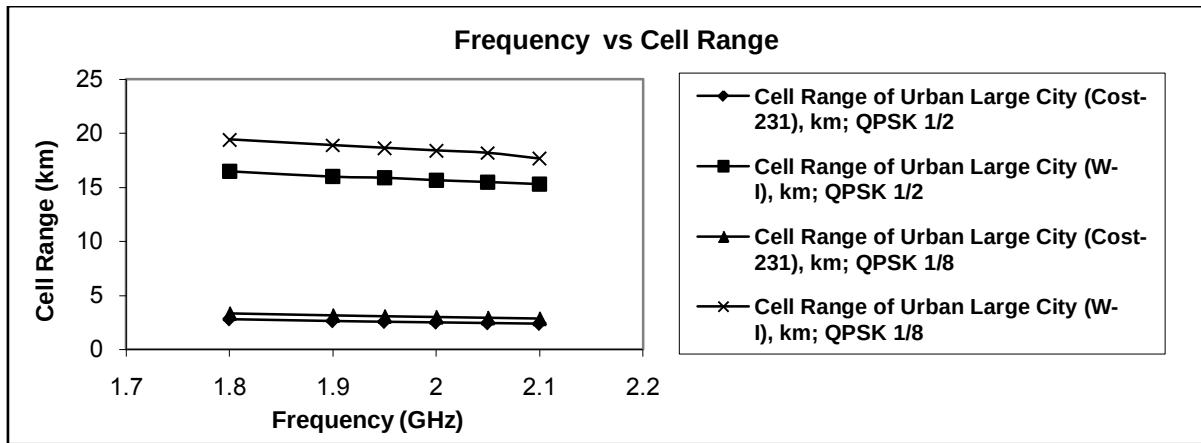


Figure 4 : Graphical representation of Frequency vs Cell Range of of 3G for downlink

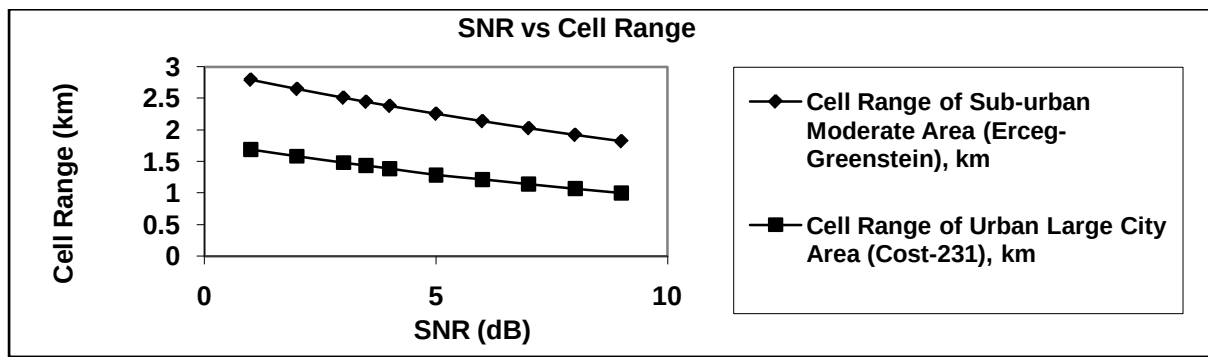


Figure 5 : Graphical representation of SNR vs Cell Range of of WiMAX for downlink

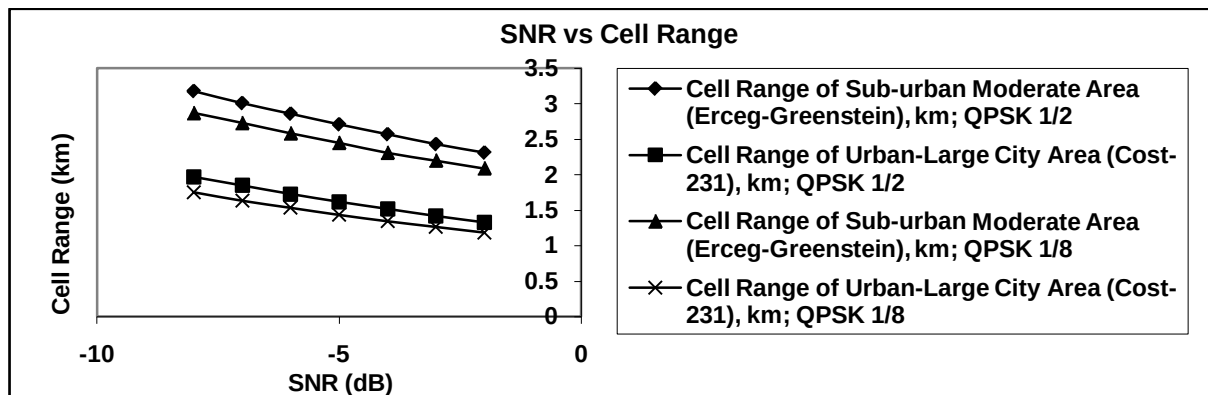


Figure 6 : Grapgical representaion of SNR vs Cell range of WiMAX for uplink

IV. CONCLUSIONS

This research work provides numerical facts regarding the WiMAX and 3G cellular network comparison issues, which are only theoretically discussed in literature.

The figure-1, 2 shows that the cell range increases with increasing base station transmitter power for both WiMAX and 3G respectively. Figure-3, 4 shows that cell range decreases with increasing carrier frequency both for WiMAX and 3G respectively. Figure-5

and 6 are both for WiMAX, but for uplink and downlink respectively, and those shows that the cell range decreases with increasing SNR.

The data transfer rate of WiMAX is mostly depends on the channel bandwidth used. The use of the selectable channel bandwidth by WiMAX ranging from 1.25MHz to 20MHz makes the system very flexible. On the other side 3G uses fixed channel bandwidth.

OFDM also makes it easier to exploit frequency diversity and multiuser diversity to improve capacity. Therefore, when compared to 3G, WiMAX offers higher

peak data rates, greater flexibility, and higher average throughput and system capacity and number of user served by WiMAX is four times greater than the 3G cellular networks [1]. Another advantage of WiMAX is its ability to efficiently support more symmetric links. Typically, 3G systems have a fixed asymmetric data rate ratio between downlink and uplink [9].

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