Wimax Capacity Estimation Through Different Channel Characterstic

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Abstract
In this paper we study a factors influencing system bandwidth capacity in IEEE 802.16e networks. The system capacity of 802.16j also investigated and evaluated to understanding how the relay architecture can lead to capacity increases in the downlink. An analytical study of the WiMAX propagation channel by using Cost-231 Hata Model is presented. This model performance in different frequency band, and also the SNR achieved under different frequency band. The useful bandwidth for WiMAX in downlink and calculation the maximum numbers of subscriber station (SS) based on traffic modelling also calculated. Numerical results and discussion highlight the effect of factors over WiMAX capacity; also we simulated the modeling for different system parameter and traffic cases to ease the mobile WiMAX planning using MATLAB.

Keywords
WiMAX capacity ; IEEE802.16j ; mobile WiMAX ; SNR ; Cost-231 Hata.

I. INTRODUCTION

In recent years, there has been a considerable growth in demand for high-speed wireless internet access and this has caused the emergence of new long-range wireless technology. In particular IEEE 802.16 offer an alternative to the current wired access networks such as cable modem and digital subscriber line (DSL) link.

The IEEE 802.16 has become an attractive alternative as it can be deployed rapidly even in areas difficulty for wired infrastructures to reach, and also it covers broad geographical area in many economical and time efficient manner than traditional wired system.

The first specification of metropolitan area wireless networks was approved under the IEEE 802.16 standard with product certification name WiMAX. The IEEE 802.16 2004 standard was developed to add NLOS. Applications support to the basic standard. This standard serves fixed and nomadic users in the frequency range of 2-11 GHz. In order to add mobility to wireless access, the WiMAX IEEE 802.16e 2005 specification was defined utilizing frequencies 6 GHz.

Though WiMAX deployment planning has been widely conducted but the explicit planning issue is mostly limited to some practical cases and white papers [2,4].thus, in this paper we study a factors influencing system bandwidth capacity in IEEE 802.16e networks. The system capacity of 802.16j also investigated and evaluated to understanding how the relay architecture can lead to capacity increases in the downlink. An analytical study of the WiMAX propagation channel by using Cost-231 Hata Model is presented.

The rest of paper is organized as follows: in Section II we present mobile WiMAX PHY and MAC layers; in Section III we present the IEEE802.16j mobile wimax relay network; in Section IV we present the simulation results and analysis; in Section V we introduce the conclusion and future work.

II. PHY AND MAC LAYERS IN MOBILE WIMAX

A. OFDM

The WiMAX physical layer is based on orthogonal division multiplexing. OFDM is the transmission scheme of choice to enable high-speed data communication in broadband system. OFDM based on the idea of dividing a given high-bit rate data stream into several parallel lower bit-rate stream and modulation each stream on separate subcarrier. This technique helps us with minimizing the inter-symbol interference (ISI) [6].

In order to completely eliminate the ISI and benefit an ISI free channel cyclic prefix technique is used. The rate of cyclic prefix to useful symbol time is indicated by G and can undertake value of 1/4 1/8 1/16 or 1/32.

B. OFDMA

The total capacity available with a base station is shared among multiple users on a demand basis, using a burst TDM scheme. When using the OFDMA-PHY mode, multiplexing is additionally done in the frequency dimension by allocating different subset of OFDM sub-carrier to different users [7].

There are four different types of sub-carrier in an OFDMA symbol. Data sub-carrier, pilot sub-carrier (used for estimated and synchronization purposes), DC sub-carrier and Guard sub-carrier (used for guard band).Fig. 1 the

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general TDD frame structure for WiMAX, in a 5 ms TDD frame the DL and UL sub-frame are prorated with DL:UL ratio and are separated with 11.4µs transmission Gap.

C. MAC Structure

In the MAC layer, one or more service data unit (SDU) are encapsulated into protocol data unit (PDU) which are appropriately modulated and mapped onto a PHY frame.

DL-MAP and compressed MAP are the broadcasting message, and either of these MAP is the first MAC management message located in the frame. In order to reveal

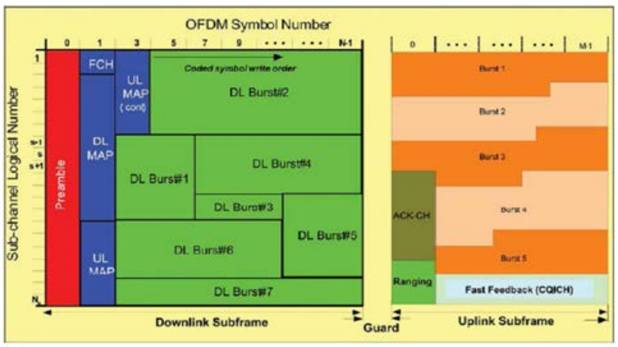

Figure 1. WiMAX OFDMA TDD Frame Structure [1].

the redundant factors of DL-MAP, we will first examine element of the MAC PDU because DL MAP is also a MAC PDU [8]. The MAC PDU format of IEEE 802.16 is illustrated in Fig. 2.

The MAC PDU may be mapped onto data sub-carrier of the PHY frame by the following equation:

$$N_{d\text{-}sub}=BR/MC \tag{1}$$

Where B is the number of bits of the MAC PDU, M is the number of bits for a subcarrier under a byte of modulation, C and R are the coding rate and the number of repetitions respectively.

We define the MAC data rate (MDR) as the transmission rate of the data bursts in the frame. This is represented as:

$$MAC_{data\text{-}rate}= N_{Tbits}\text{-}OH_{bits}/T_f \text{ (bits/s)} \tag{2}$$

Where the total number of bits N_{tbits} represent the total bits which a frame transfers within a frame duration and overhead bits OH_{bits} are the number of bits used for non-data control message such as preamble, FCH, DL-MAP, UL-MAP etc. The number of symbols in the TDD/ OFDMA frame in Fig. 1 is calculated using

$$N_{symbol} = T_f - (TTG + RTG)/T_S \tag{3}$$

Where the symbol time is equal to $T_b + T_g$. Useful symbol time is $1/\Delta_f$ subcarrier spacing and cyclic prefix time T_g is T_b.G The subcarrier spacing can be obtained using the channel bandwidth BW, sampling factor n and FFT size NFFT. According to standard, the sampling frequency F_S is (n.BW/8000) x 8000 and the subcarrier spacing Δ_f is F_S/N_{FFT} therefore, the symbol time is

$$T_s=T_b+T_g=Tb+T_b.G=(1+G)T_b=(1+G/\Delta f)$$
$$=(1+G).N_{FFT}/F_S \tag{4}$$

And thus

$$N_{symbol} = (T_f - (TTG + RTG))/(1+G)N_{FFT} \tag{5}$$

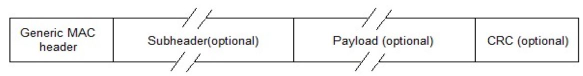

Figure 2. MAC PDU formats [7].

D. AMC and Cell-Range Estimation

Adaptive modulation and coding allows the WiMAX system to adjust to the signal modulation scheme depending on the signal to noise ratio (SNR) condition of the radio link. When the radio link is high in quality, the highest modulation scheme is used and gives the system more capacity. Values of the receiver SNR assumptions are proposed in Table 266 of the IEEE 802.16e amendment of the [3].

In this paper we study different AMC in the presence of path loss with different frequency band without neglecting the overarching concept of BWA technology. These results in the division of the cell into r regions, i = 1...r (see Fig. 3), which we assume to be concentric circles of radius Ri for simplicity. In each region, users have the same modulation scheme. To calculate the area covered by each modulation scheme, we must determine the maximal distance Ri between BS and users (SS) using a corresponding modulation [5]. This distance is determined using the path loss calculation as follows.

The COST-231 Hata model as the path loss model is incorporated. The COST-231 model [6] is an extension to the Hata-Okumura model that also has corrections for rural, suburban, and urban areas. The basic path loss equation for suburban areas is:

$$PL\ dB] = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - ah_m$$
$$+44.9 - 6.55\log_{10}(h_b)\log_{10}(R) + C_m \tag{6}$$

f is the frequency in MHz, h_b is the height of the BS in meters, R is the distance from the BS to the receiver in kilometers, h_m is the receiver height in meters, Cm is a standard deviation constant, 0dB for suburban or rural environments and 3dB for urban environments. For suburban or rural areas, the term a (h_m) is defined as follows:

$$a(h_m) = [1.1\log_{10}(f) - 0.7]h_m - [1.56\log_{10}(f) - 0.8] \quad (7)$$

And for urban areas, the term a(h_m) is defined as follows:

$$a(h_m) = 3.2[\log_{10}(11.75h_m)]^2 - 4.97 \quad (8)$$

$$PL[dB] = PE[dB] - SNR[dB] - N[dB] \quad (9)$$

PE is the emitted power and we consider the case of antennas in BS and user equipment without gain. N is the thermal noise (in units of decibels) which is equal to:

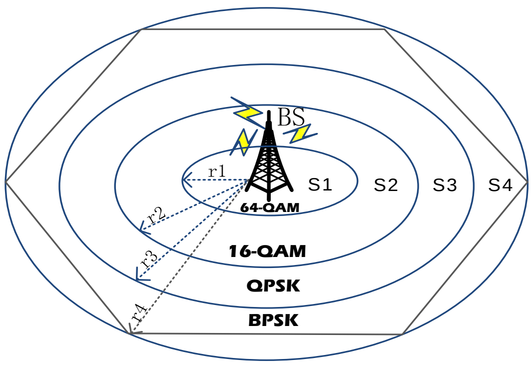

Figure 3. Cell decomposition into regions

Where $\tau = 1.38 \cdot 10^{-23}$ W/K-Hz is the Boltzmann constant, T is the temperature in Kelvin (T = 290) and W is the transmission bandwidth in Hz [5].

Using these equations, we can calculate the relationship between the distance and the SNR as follows:

$$R = 10^{\frac{P[dB]-SNR[dB]-N[dB]-46.3-33.9\log(f)-13.82\log(h_b)+a(h_m)-C_m}{10[44.9-6.55\log(h_b)]}} \quad (11)$$

For the sake of illustration, let us consider the following example based on the licensed band for mobile WiMAX at different frequency band and the system bandwidth equal to 5MHz. At this bandwidth, the thermal noise is equal to (-136.99dB). The transmitted power is fixed and equal to 1W.

The BS antenna is considered to be 35 m above the ground. The SS antennas heights are fixed at 1.5 m above the ground in suburban environment and the RS antenna is considered to be 27 m above the ground. Considering the above mentioned assumptions in (11) for each value of SNR, a certain amount of distance from BS will be obtained. Considering minimum SNR for each MCS according to Table I, the maximum radiuses of each MCS region are obtained (as shown in last 5 column's of the table I). Thus, we can determine the areas of each MCS region for each scenario with specific conditions. Table II defined the system parameter for capacity estimation.

TABLE I. WIMAX CHANNEL BANDWIDTH SPREADSHEET MODEL

Item	Value	Units	Comments
Base Station	1	#	No. of BS
FFT size	512 1024	#	FFT configuration
Channel size	5 10	MHz	Channel size
Cyclic prefix	1/4,1/8,1/16,1/32	#	CP
N	28/27	#	Sampling factor
Fs	11.2	MHz	Sampling frequency
Tb	91.43	µs	Useful symbol time
Tg	11.43	µs	Guard time CP
Ts	102.86	µs	Symbol time (Tb +Tg)
Tf	5	ms	Frame duration
DL:UL	3:1	#	DL:UL ratio
Path loss model PL	Cost-231 Hata	#	Cost-231 Hata Model
Thermal noise No	-136.99dB	#	

III. IEEE802.16J MOBILE WIMAX RELAY NETWORK

As the extension of the standards (IEEE802.16d and IEEE802.16e), IEEE 802.16j aims to defining the multi-hop relay specification including the MAC and the physical (PHY) layers (Fig. 4) [9].

WiMAX uses adaptive modulation and coding AMC, and the optimal modulation is automatically selected depending on the signal quality (Fig. 4). For example, if the relay station (RS) or subscriber station (SS) is far away from the nearest base station (BS) the connection is guaranteed to it, but with low-level modulation, that is the maximum speed is slowing down. It is investigated when signal is modulated with QPSK (Quadrature Phase-Shift Keying) and QAM (Quadrature amplitude modulation) modulation [10].

According to the newest baseline document [9], two modes, non-transparent mode and transparent mode, are specified to support those application scenarios.

IV. SIMULATION RESULTS AND ANALYSIS

As show in Fig. 5, the path loss is increased when distance from base station increased, and due to mobile system design, base station (BS) serve all users in the cell area, and hand off process will occur when the user is located at the cell edge. Highest frequency band 5.8GHz have highest path loss among

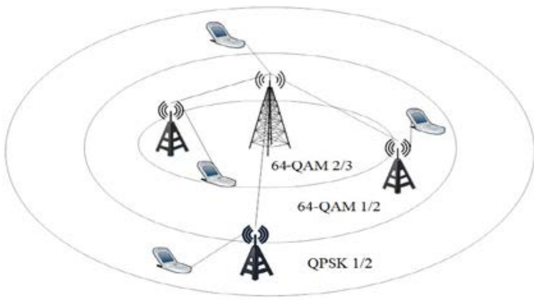

Figure 4. The typical topology of relay network [9, 10]

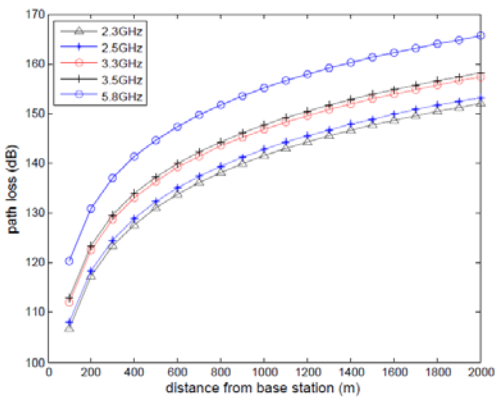

Figure 5. Path loss vs distance

others frequency band. Frequency bands 3.5GHz with 3.3GHz and 2.5GHz with 2.3GHz have closed path loss, that's because this two carrier frequency gap is small. In higher frequency band there is trade-off between reduced cell coverage because highest path loss and high data rates for traffic service.

Fig. 6 shows the relation between the SNR at the receiver and the distance from the transmitter to the receiver. It is worth noting that the optimal RS position is independent of the BS-RS link quality as 64QAM3/4 is maintained on the link independently of the RS position as depicted in Fig. 6.

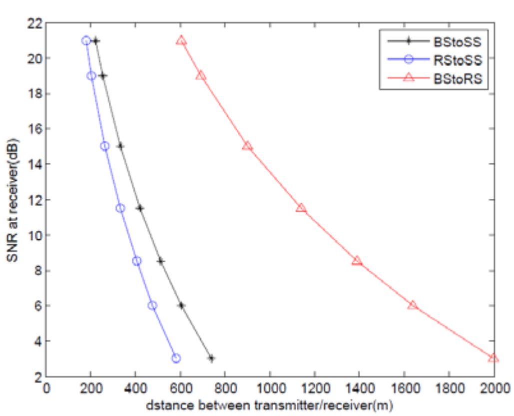

Figure 6. Distance vs. SNR

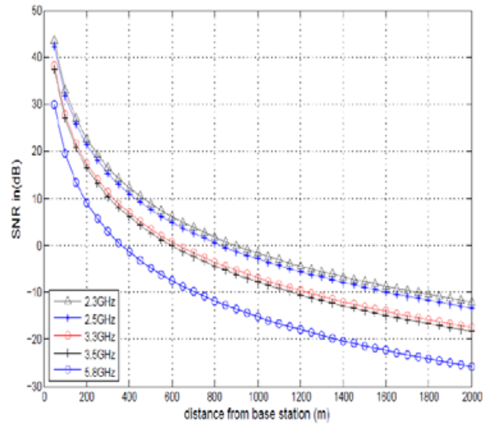

Figure 7. SNR vs distance

Fig. 7 shows the SINR of a subscriber station (SS) with different WiMAX frequency bands at different location from base station (BS). SNR of 2.3GHz is the best among others frequency bands at any distance from base station. Also the SNR of 5.8 GHz drops faster than others bands when the distance from base station increased.

Fig. 8 show the path loss with different wimax frequency bands at different length of base station (BS). Path loss of subcarrier utilizing 2.3GHz frequency band is the best among the others frequency bands. Subcarrier with 5.8GHz experiencing higher level of path loss at any high of base station. We note the path loss is decreased when the higher of base station is increased in all frequency groups.

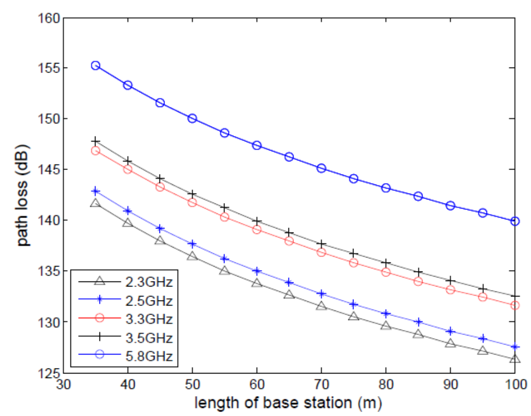

Figure 8. Path loss vs length of base staton

Fig. 9 show the cell radius of the base station (BS) coverage with different WiMAX carrier frequency bands at different modulation and coding scheme (MCS). The result shows that the cell coverage when we utilizing 2.3GHz is the best among the others frequency bands. Subcarrier with 5.8GHz experiencing smaller coverage at any distance from base station (BS).

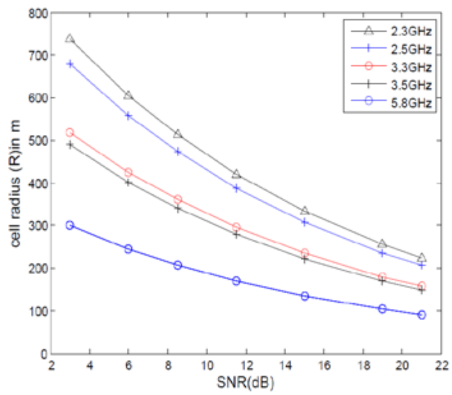

Figure 9. Cell radius vs SNR

Fig. 10 shows capacity per subcarrier with distance from base station. The capacity decreased as the distance increased, 2.3GHz frequency band support highest capacity among others frequency bands.

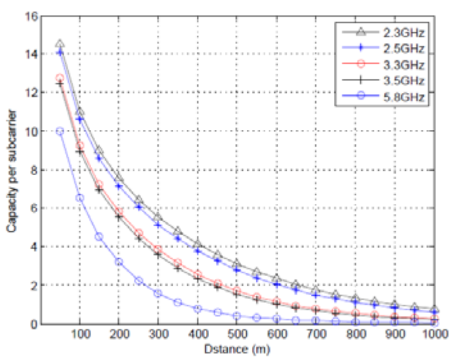

Figure 10. Capacity per subcarrier vs distance

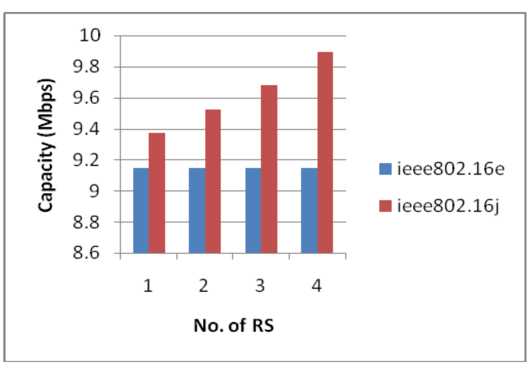

Figure 11. Capacity vs. number of RS

Fig.11 show the capacity of mobile wimax with number of relay station (RS), the result shows when the number of RS deployed in the coverage of base station (BS) increased the system capacity increased.

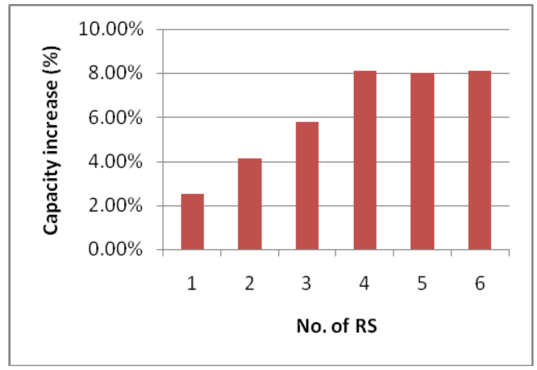

Figure 12. Capacity increase vs. number of RS

Fig.12 show the percentage of mobile wimax capacity increased with number of relay station (RS) , the result shows when the number of RS deployed in the coverage of base station (BS) increased, the overall system capacity is o increased on the DL by approximately 8% compared to a traditional 802.16e system. If the number of RS more than 4 the result shows there is no capacity increased. Thus, the BS cell is properly covered by this amount of relay station and additional relays do not have a significant impact on the system capacity.

V. CONCLUSIONS AND FUTURE WORK

Efficient and optimal utilization of available bandwidth resources has always been a matter of deep concern for engineers designing and implementing Wimax networks. In this paper, we introduce the analytical study over wimax channel characteristic for different frequency band and different modulation coding scheme .the results shows that the wimax channel with lower frequency better performs compared to higher frequency band in aspects of SNR, path loss, cell radius and system capacity estimation .

Instant capacity increased when deploying relay station (RS) in the base station (BS) area coverage. This specific location of RS was chosen as it ensures the highest signal strength possible on the RS-SS link and thus maximizes the reachable capacity increase.

Deploying 4 relay station (RS) to one base station has the most impact over network capacity, this happens because the BS cell is properly covered by this amount of relay station and additional relays do not have a significant impact on the system capacity.

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