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A Study of Wireless Channel and Channel Capacity Estimation

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Abstract: *In this paper we study about wireless channel model, Wimax technology, multi user switched diversity in Wimax, challenges in multiuser switched diversity, the factors influencing system bandwidth capacity in IEEE 802.16e networks. The opportunity for WiMAX to serve those people who want to switch to broadband service is huge in many parts of the world where wired technologies may not be practicable. An analytical study of the WiMAX propagation channel by using Cost-231 Hata Model is proposed. This model performed in different frequency bands; the Signal to Noise Ratio (SNR) is achieved under different frequency band as well. The proposed methodology would help those operators that plan to implement a wide coverage network in a city. Using the introduced methodology, service providers will be able to estimate the number of base stations and hence the network investment and profitability.*

Keywords: *WiMAX capacity,IEEE 802.16, mobile WiMAX, SNR, Cost-231 Hata*

1. INTRODUCTION

There are multiple physical-layer choices, within IEEE 802-16 standard. Similarly, there are multiple choices for MAC architecture, duplexing, frequency band of operation, etc. In fact, one could say that IEEE 802.16 is a collection of standards, not one single interoperable standard. To grant interoperability the WiMAX Forum defines a limited number of system profiles and certification profiles. A S*ystem Profile* defines the subset of mandatory and optional physical and MAC-layer features selected by the WiMAX Forum from the IEEE 802.16-2004 or IEEE 802.16e-2005 standard. By now two different system profiles are defined: one based on IEEE 802.16-2004, OFDM PHY, called the fixed system profile; the other one based on IEEE 802.16e-2005 scalable OFDMA PHY, called the mobility system profile. The Mobile WiMAX standard has been developed to be the best wireless broadband standard for portable devices enabling a new era of high throughput and high delivered bandwidth together with exceptional spectral efficiency when compared to other 3G+ mobile wireless technologies. The transmitter receives packets of bits from a higher protocol layer and sends those bits as electromagnetic waves toward the receiver. The key steps in the digital domain are encoding and modulation. The encoder generally adds redundancy that will allow error correction at the receiver. The modulator prepares the digital signal for the wireless channel and may comprise a number of operations. The modulated digital signal is converted into a representative analog waveform by a digital-to-analog convertor (DAC) and then up converted to one of the desired WiMAX radio frequency (RF) bands. This RF signal is then radiated as electromagnetic waves by a suitable antenna. The receiver performs essentially the reverse of these operations. There are 3 major factors affecting wireless channels that cannot be found in wired networks. These are *Pathloss, shadowing* and *fading*. Each of these phenomena impact the received signal in a especial manner.

Pathloss refers to the reduction of the energy between transmitter and receiver that are located at a distance *d* away from each other. This concept is dependent on the propagation environment. There are different formulas suggested for path loss calculation in different urban, suburban and rural environments. Path loss is the base of cellular network designs.

Shadowing can be caused by obstacles that are located between transmitter and receiver that affect the received power. On the other words, any abnormal changes in the amount of received power in both degrading or increasing way, for example absorption or diffraction caused by a building or a temporary line-of-sight transmission path, is referred to as shadowing.

Fading is caused by the reception of multiple versions of the same signal. These multiple versions referred as *multipath* between Tx and Rx can arrive at the receiver at nearly the same time. In this case, depending on their phase difference, the interferences can be constructive or destructive when being combined.

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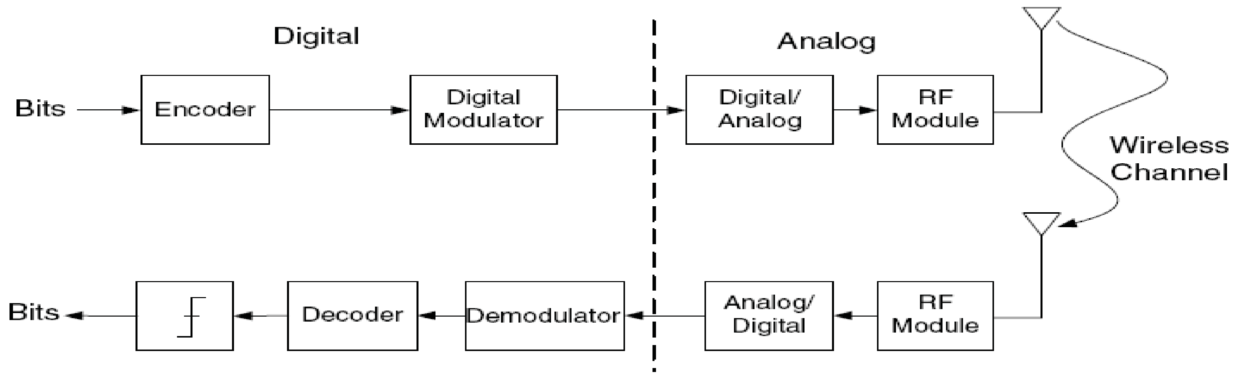

Figure 1.1- Wireless channel model

The basic principle in MUSwiD scheduling schemes is to find *any acceptable user* (i.e. having good channel condition) instead of finding *the best user* among all. The term "multiuser switched diversity" was suggested in [1], because the proposed scheduling scheme has a similar principle of operation to the "switch-based" antenna selection scheme used long-time ago in multiple-antenna receivers [2]. It was suggested in [1] to use a scheduling strategy based on *examining the CSI of the users sequentially instead of jointly*. Once a "good-channel" user is found, the process of examining the channel conditions terminates, and that user is scheduled. The decision whether the channel condition of a specific user is acceptable or not is assessed by a predefined threshold. MUSwiD schemes, there are some fundamental technical challenges that should be addressed adequately before MUSwiD schemes can lend themselves for practical implementation. In our opinion, there are mainly three technical challenges:

• **Fairness:** Maximizing the sum capacity is not always an appropriate optimization criterion for realistic network scenarios since users usually have asymmetric channel statistics. Furthermore, in MUSwiD schemes, the users' ordering strategy gives an advantage to the users who are placed in the first positions in the feedback sequence. It becomes likely that users placed in the latter positions of the sequence may not get channel access despite having very strong channel. So, is it possible to achieve fairness in MUSwiD schemes? And how? The current proposals in the topic (e.g. [5], [3]) suggest keeping changing the feedback sequence continuously in order to achieve fairness.

We demonstrate in this paper that we can maintain fairness without this requirement.

• **Centralized optimization:** As discussed in [4], the optimization of the feedback thresholds in MUSwiD systems is done at the central scheduler and it requires the knowledge of the statistics (i.e. probability density functions (PDF)) of all users' channels. However, due to the CSI feedback reduction, the central scheduler will not be able to have accurate estimates of the PDFs of the users' channels. This will affect the optimality of the assigned per-user thresholds and will consequently degrade the system performance.

• **Capacity-feedback tradeoff:** A comparison of MUSwiD schemes with full-feedback (MUSelD) opportunistic scheduling schemes is needed to evaluate how much rate we lose due to the feedback savings.

2. RELATED WORKS

In this paper [6], a generalized binary communication channel with memory based on a finite queue, referred to as WQBC, is introduced. It is shown that, the WQBC can be described by similar modeling complexity as the traditional QBC. The channel properties are analyzed and several of its statistical and information theoretical quantities (e.g., block transition distribution, auto correlation function, and capacity are derived in closed forms. Analytical results indicate that the WQBC requires a much smaller Markovian memory than the QBC to achieve the same channel capacity.

In this paper [7] , a scaling compatible, mismatch, and PVT insensitive6-bit TDC is presented. The TDC effectively reuses a delay cell and sampling flip-flop to achieve a fine resolution (3.1–3.8 ps)with high linearity DNL LSB , low power consumption(3 mW), and small area (0.004 mm). A DFLL continuously corrects the TDC resolution for PVT insensitive operation. The proposed TDC is demonstrated in a digital fractional-nPLL targeting WiFi/WiMax applications. The DPLL incorporating the proposed TDC shows –51.9 dBc worst case fractional spur which is the lowest number reported without mismatch calibrations.

In this paper [8], the authors study the theoretical data transmission limits in terms of outage throughput capacity for hybrid wireless networks. The impact of fading on such hybrid networks is examined and close-form solutions for outage throughput capacity at high SNIR are derived. Under intra-cell transmission mode, the authors introduce opportunistic sources to cooperate with the scheduled source and all these sources share the entire bandwidth. A SIC decoder is then designed at the receiver to limit the intra-cell interference and achieve the maximum capacity. The authors showed that, in the intra-cell transmission scenario, the per-node outage throughput capacity over Rayleigh fading. Clearly, with the introduction of opportunistic sources, intra-cell mode could effectively combatfading and significantly improves the throughput capacity as wireless nodes increases. However, the infrastructure mode will be bottlenecked by the downlink transmission, since base station is the only transmitter during the downlink phase. The related outage throughput capacity under infrastructure transmission mode is derived.

In this paper [9], the authors analyze the performance of CDMA system in telecommunication by using cell splitting technique to divide a biggest macro cell into micro, pico and femto cells. The authors have calculated the processing gain, number of subscribers requesting for service within each type of cell, user-transmitted in-band signal power to achieve desired SNR, probability that a call attempt fails and also compared the results by simulating their equations using MATLAB simulation software. From the simulation results, the authors can observe that in CDMA system, parameters such as processing gain of a particular site or cell having a base station to handle the traffic generated by subscriber can be improved or increased by dividing the site or cell into smaller cells with their individual base stations using cell splitting technique. Hence the advantage of Cell splitting technique is to improve the performance and capacity of the system by increasing processing gain, decreasing user-transmitted in-band signal power to achieve desired SNR and decreasing the probability of failure of call attempts.

In [10], Author proposed schemes are based on the concept of multiuser switched diversity that has been recently introduced in the literature. The authors have provided rigorous mathematical treatment to analyze the performance of switched diversity scheduling schemes as well as to optimize their performance. The authors have also characterized the achievable rate region of these scheduling schemes and provided a case study to understand their main attributes and useful design options. The authors proposed a proportional fair scheduler that overcomes major technical challenges of the state-of-the-art proposals in the field. Mainly, our proposed scheduler maintains fairness among users and interestingly enables simpler optimization procedure. The authors have demonstrated that, unlike other schedulers, the optimization procedure of our proposed proportional fair scheduler can be distributed among the users. The authors have shown that the distributed optimization mechanism can be supported by a monitoring mechanism of the base station that enables the detection of ill-behaving users based on real-time performance measurements. Due to their features and performance, multiuser switched diversity scheduling systems are actually attractive options for practical implementation in emerging mobile broadband communication systems.

3. PROPOSED METHODOLOGY

1. Define the service class parameter such as data rates, contention ratio and percentage of residential class subscribers for the different classes like residential and business.
2. Define the value of OVER SUBSCRIPTION RATIO by using the formula

$C_{ref} = FFT_{used} / 2\, T_s$ (1)

where the values for FFT_{used} and T_s depend on the channel bandwidth and the Cyclic Prefix factor respectively. Assume that the residential class occupies 58% of the users under cover of our base station while the business class users are confined to 42%. In this case the total capacity for OSR calculation would be:

$$C_{tot} = N * (58\% * 512 + 42\% * 1000) \quad (2)$$

$$OSR = C_{tot} / C_{ref} \quad (3)$$

Where N refers to the number of users that are connected to the base station.

3. Define value of system parameter- channel bandwidth either it is 5MHz or 10 MHz. In case of bandwidth 5 MHz the number of data sub-carriers is 360 for FFT downlink and 272 for FFT uplink and the number of sub-channels considering PUSC (Partial usage of subcarrier) for downlink is 15 and for the downlink are 17.
4. But in case of bandwidth 10 MHz the number of data sub-carriers is 720 for FFT downlink and 560 for FFT uplink and the number of sub-

channels considering PUSC for downlink is 30 and for the downlink are 35.

5. Further define the value of cyclic prefix rate, DL portion, and UL portion and traffic ratio.

6. The average number of connections per PDU, the average number of PDUs per data burst and (T_b) Fixed Useful OFDM symbols duration (ms) values are taken.

7. Calculate the value for Total symbol duration $T_s = T_g + T_b$
$= (G+1) T_b$ (4)

Where G is the ratio of T_g and T_b. This value can be 1/4, 1/8, 1/16 or 1/32. T_b is $1/\Delta f$, with the sub-carrier spacing Δf given as

$$\Delta f = F_s / N_{FFT} \quad (5)$$

$$F_s = \text{floor}(n\ BW/8000)*8000 \quad (6)$$

Where F_S is the sampling frequency, n is the sampling factor, BW is the nominal channel bandwidth and N_{FFT} is the number of points for FFT or total number of subcarriers.

8. Now calculates the available data-rate in the uplink by removing the overheads originated from the system configuration and additional users.

i. Calculate the bandwidth of the DL and UL channel by using the formula

$$BW = FFT_{used} / Ts * \sum (\%\ p.\ k.\ OCR) \quad (7)$$

Where FFT_{used} is the number of data subcarriers that is dependent on the channel bandwidth, the direction and its permutation scheme.

%P stands for the percentage (weight), *k* for number of bits per symbol and *OCR* for the overall coding rate.

ii. Length of the uplink/ downlink frame is calculated by

$$BW_2 = TUL = UL / (UL+DL) * BW1 \quad (8)$$

T_f = 5ms is the frame duration.

Length of the Uplink and Downlink subframe (based on DL/UL ratio)

$$T_{UL} = UL / (UL+DL) * T_f \quad (9)$$

$$T_{DL} = DL / (UL+DL) * T_f \quad (10)$$

iii. Transition gap duration is $T_g = 11.4\mu S$ are fixed values in Mobile WiMAX .

iv. Now the complete symbols ($N_{S\text{-}DL}$ or $N_{S\text{-}UL}$) can be embedded in the downlink or uplink subframe (T_{DL} or T_{UL}) is

$$N_{S\text{-}DL} = [(T_{DL} - T_g) / T_S] \quad \text{and} \quad (11)$$

$$N_{S\text{-}UL} = [(T_{UL} - T_g) / T_S] \quad (12)$$

v. Now remove the subframe overhead by using formula

$$BW_3 = [(N_{S\text{-}DL} * T_S) / T_{DL}] * BW_2 \quad \text{and} \quad (13)$$

$$BW_3 = [(N_{S\text{-}UL} * T_S) / T_{DL}] * BW_2 \quad (14)$$

vi. Now, we need to remove this extra symbol from our useful DL or UL bandwidth

$$BW_4 = (N_{S\text{-}DL} - 1) * BW_3 \quad \text{and} \quad (15)$$

$$BW_4 = (N_{S\text{-}UL} - 1) * BW_3 \quad (16)$$

vii. To reduce the amount of bandwidth wasted in sending small packets, the MAU can be calculated in bytes:

$$MAU = [(N_C * OCR) / N_{Sub\text{-}CH}] \quad (17)$$

Where N_C the coded block size in bytes and *OCR* is the coding rate of the most robust in use modulation scheme, here 64-QAM as the worst case, and $N_{Sub\text{-}CH}$ is the number of sub-channels based on the system's channel bandwidth using PUSC permutation.

viii. The interval between contention allocations is configurable by the operator by

$$N_{contention} = [T_f/100] * [\{(n*100)/ MAU\} + 1] / N_{S\text{-}UL}$$

and

$$N_{contention} = [T_f/100] * [\{(n*100)/ MAU\} + 1] / N_{S\text{-}DL} \quad (18)$$

The contention overhead is removed by

$$BW_5 = BW_4 * (1 - \text{contention}) \quad (19)$$

ix. Number of MAC PDU and number of MAC data burst for the uplink is given by N_PDU= No. of users/ average no. of connections per PDU And the overall overhead bytes imposed by PDUs would be:

$$MAC\_PDU = N_{PDU} * (6+4+3+2) \text{ Bytes.} \quad (20)$$

MAC_PDU overhead (bytes) (6Generic (MH)+3 Fragmentation/Packing(SubH)+2GrantManagement(subH)+4CRC) MAC data burst is given by MAC_BURST= MA_PDU/ average no. of PDU per Data burst

9. Now again calculate the value of OSR.

10. Now compares the available BW (after removing the overheads caused by the system configuration based the number of users) with minimum required data-rate to support users 'demand according to the subscribers classes based on the number of users) in both DL and UL. OSR is calculated as the number of user's raises and is compared with OSR.

11. Plot and compare the result.

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4. CONCLUSION

The opportunity for WiMAX to serve those people who want to switch to broadband service is huge in many parts of the world where wired technologies may not be practicable.The proposed methodology would help those operators that plan to implement a wide coverage network in a city. Using the introduced methodology, service providers will be able to estimate the number of base stations and hence the network investment and profitability.In this paper we study the factors influencing system bandwidth capacity in IEEE 802.16e networks. Additionally, we investigateand evaluate the system capacity of 802.16e in order tounderstand how the relay architecture can lead to capacityincreases in the downlink. An analytical study of the WiMAX propagation channel by using Cost-231 Hata Model is presented. This model performed in different frequency bands; the Signal toNoise Ratio (SNR) is achieved under different frequency band aswell. The useful bandwidth for WiMAX in the downlink helped us to calculate the maximum numbers of subscriber station (SS)based on traffic modeling. Numerical results and discussion highlight the effect of factors over WiMAX capacity.

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