Performance Enhancement of WiMAX using Adaptive Modulation Scheme

Anjali Koranga, Koushik Barman

Abstract— This paper studied different aspects of WiMAX system in detail. In this paper WiMAX architecture, comparison between WiMAX and WiFi networks, different modulation schemes for performance enhancement of existing WiMAX system has been reviewed. A novel approach of Adaptive Modulation and Coding (AMC) has been proposed.

Index Terms— Adaptive Modulation and Coding (AMC), IEEE802.16, OFDMA, QoS, WiMAX.

1 INTRODUCTION

World Wide Interoperability for Microwave Access (WiMAX) is the most promising technique for upcoming wireless network. It is highly appreciable in terms of spectral efficiency, coverage area, transmission bandwidth and Quality of service (QoS).

WiMAX is approved by IEEE 802.16 group, which is intended for point to multipoint wireless networking. WiMAX forum has been established in April 2001[2].Initially, It has been implemented for the line of sight communication in the frequency band of 10-66GHz. IEEE 802.16a and IEEE 802.16d made it possible to deploy WiMAX in the licensed and unlicensed frequency band of 2-11GHz for Non Line of Sight communication. Further, IEEE 802.16 came up with the IEEE 802.16e standard to enable the mobility. Fixed WiMAX, based on IEEE 802.16 Air Interface Standard, is a cost effective fixed wireless alternative to cable and DSL service [1]. In addition, Mobile WiMAX is an attractive solution to provide high bit rate over a broader range of coverage. Furthermore, Implementation of some techniques like Adaptive modulation and coding at PHY layer of the base station can improve the performance of a WiMAX system in terms of BER and spectral efficiency for different applications.

2 WIMAX PROTOCOL ARCHITECTURE

IEEE 802.16, WiMAX protocol architecture covers only two layers, Physical (PHY) layer and Media access control (MAC) layer. MAC layer is connection oriented. It was designed for point to multipoint wireless applications. MAC layer is composed of three sublayers: Convergence sublayer (CS), Common part sublayer (CPS) and security sublayer (SSL).The CS sublayer is to converse with higher layers and transform upper layer data services to lower layers.MAC CS has two types of sublayers: one is ATM convergence sublayer for ATM networks and services and second one is packet convergence sublayer for packet data services.

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So this layer classifies the data as ATM cell or Packet and forward frames to CPS layer [3]. CPS is the main part of MAC layer, which defines all method for connection management, bandwidth distribution, request & grant, connection control and Automatic repeat request (ARQ). Next, the SS layer is for encryption and decryption of data that is coming and leaving the Physical layer. It is also used for authentication and secure key exchange. Physical layer is for data transmission between BS and SS. It relies on the resource allocation of data burst through the OFDMA (Orthogonal Frequency Division Multiple Access) scheme.

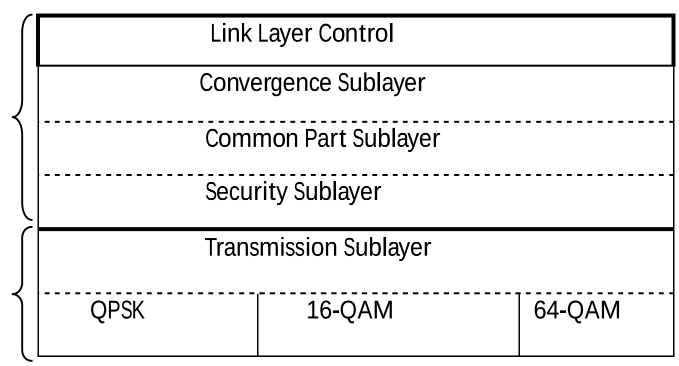

Fig. 1. IEEE 802.16 Protocol Architecture

A BS can transmit to multiple SS concurrently in downlink (DL) direction in separate subchannel; similarly multiple SS can transmit to the same BS concurrently in the uplink (UL) direction in separate subchannel. The modulation method in downlink and uplink are binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-Quadrature amplitude modulation (QAM) and 64-QAM.

3 FEATURES OF WIMAX

WiMAX technology has been emerged as a key solution for data as well as voice networks. Due to some improvements in original fixed WiMAX standard, it offers cost-effective broadband services to the end user with increased performance in NLOS environment for mobile and fixed indoor applications. Features of WiMAX are [2][7]:

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3.1 Mobility

It is the measure feature of mobile WiMAX. It allows a SS to maintain a connection even when moving from one BS to other thus provides optimized handover which support full mobility application. Mobile WiMAX is designed to support mobility applications up to 160km/h.

3.2 NLOS performance

New technologies like intelligent antenna technology which includes adaptive antenna system (AAS), Multiple-Input-Multiple-Output(MIMO),high performance coding ,such as turbo coding and a Hybrid Automatic Repeat Request(HARQ) has been introduced for increasing NLOS performance.

3.3 Security

WiMAX support best security features by adopting best technologies available today. It supports device and user authentication, flexible key management protocol, strong traffic encryption and security protocol optimization for fast handovers. In addition a 3-way handshaking scheme is supported by mobile WiMAX.

3.4 Fractional frequency reuse

Mobile WiMAX supports frequency reuse of one, i.e. all cell/sectors operate on the same frequency channel to maximize the spectral efficiency.

3.5 QoS

WiMAX supports two QoS mechanisms to support two-way traffic in order to manage both UL (uplink) & DL (downlink) direction, such as VoIP. Those are connection based and service-type-based QoS.

3.6 Flexibility

The flexibility of the physical layer enables the system designers to change their system according to requirement. Some of adaptations in WiMAX PHY layer are the use of OFDM (Orthogonal frequency Division Multiple) and OFDMA (Orthogonal frequency Division Multiple Access) for fixed and mobile communication [5].

4 WiMAX VS. Wi-Fi

If we compare both the existing technologies, both works on the same principles of data transfer between/among devices. But if we look in terms of data transfer rate there is difference. The fastest Wi-Fi connection can transmit 54 megabits per second while WiMAX is able to handle 70 megabits per second. Even if there is difference in data transfer rate but the biggest difference is of their coverage range. WiFi range is about 100 feet (30m) while WiMAX can cover a radius of 30 miles (50km) with wireless access. This increased range is due to frequencies used and power of the transmitter. WiMAX provides coordinated QoS control while WiFi provides decentralized QoS control. There is full duplex communication in WiMAX but other one supports half duplex.

Although WiMAX has the better performance than Wi-Fi yet it cannot replace Wi-Fi in some cases. The cost and complexity of equipment and the high cost of frequency license, can make difficult the replacement of Wi-Fi by WiMAX for some applications.

TABLE 1
COMPARISON OF WIMAX AND WIFI

Parameter	WiMAX(802.16)	WiFi(802.11)
Frequency band	2-11GHz	2.4GHz ISM
Data transfer rate	70Mbps	55Mbps
Range	50 km	30 m
QoS	Coordinated	decentralized
Duplexing	TDD &FDD	TDD
Access protocol	Request/Grant	CSMA/CA

WiMAX is a technology not to replace WiFi but to coexist with it. Integrated WiMAX/WiFi architecture can be the best example to show it. In this kind of architecture a new wireless access point (AP) is there named as WiMAX/WiFi AP (W2-AP) is developed to manage the WiMAX/WiFi interface.

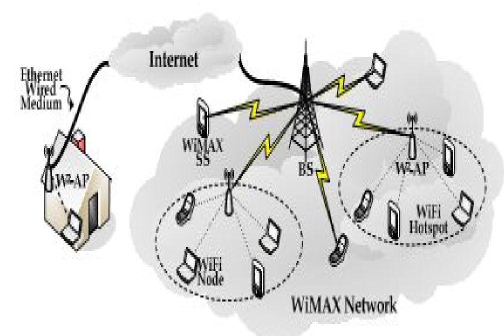

Fig. 2. Integrated WiMAX/WiFi network [4]

There is a WiMAX BS which is connected to every WiMAX SS and multiple W2-APs within its coverage area. WiMAX system provides BWA to multiple W2-AP in a point-to-multipoint (PMP) topology. Every WiFi node is connected to WiMAX BS through W2-AP.The connection between BS and SS is dedicated to single user. However, the connection between BS and each access point (W2-AP) is shared amongst all. As a result this network provides secure communication service while connecting different WiFi nodes to the internet [4].

5 ADAPTIVE MODULATION AND CODING

A communication system must be designed in such a way that it can cope up with the variations and deliver an error rate below a specific limit. Depending on the channel condition,

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WiMAX system can switch to the higher order modulation. Fig. 3. shows the general relationship between distance from the base station (BS) and corresponding channel condition. As the channel condition is good near to BS, i.e. the signal power is high. Signal-to-noise ratio (SNR) is high near to base station, so higher order modulation can be used in order to increase the throughput. As we move away from the base station SNR decreases and modulation scheme switches to the lower order.

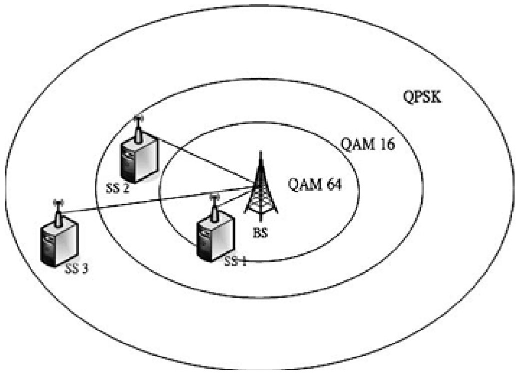

Fig. 3. Scheme for utilization of AMC[8]

5.1 Relation between SNR and Distance from the base station

The path loss for a free space model is given by[8]

$$PL\ [dB] = -10\log\ [G_E G_R(\lambda/4\pi R)^2]$$
$$= -10\log G_E - 10\log G_R + 20\log\ (4\pi R/\lambda) \qquad (1)$$

Where G_E is the gain of emitter antenna, G_R is the gain of receiver antenna, R is the distance between emitter and receiver and λ is the wavelength. Further, path loss is also equal to:

$$PL[dB]=P_E[dBm]-SNR[dB]-N[dBm] \qquad (2)$$

Where P_E is the emitter power and N is thermal noise which is equal to:

$$N[dBm] = 10\log\ (\tau TW) \qquad (3)$$

$\tau = 1.3810^{-23}$ watt / K−Hz is the Boltzmann constant,
T is the temperature in Kelvin (T = 290) and W is the transmission bandwidth in Hz.
Using the above equations there is a relationship between the distance and SNR as below:

R=

$$\frac{\lambda * 10^{\frac{P_E[dBm]+10\log(G_E)[dB]+10\log(G_R)[dB]-SNR[dB]-N[dBm]}{20}}}{4\pi} \qquad (4)$$

5.2 AMC Architecture

AMC scheme can be used for the capacity enhancement of the WiMAX system. Introduction of AMC in PHY layer profile shows improvement in the bit error rate (BER) performance and spectral efficiency and also it provides high throughput with high data rates [7]. A good performance of AMC requires the correct channel estimation at the receiver and a reliable feedback between the estimator and transmitter.

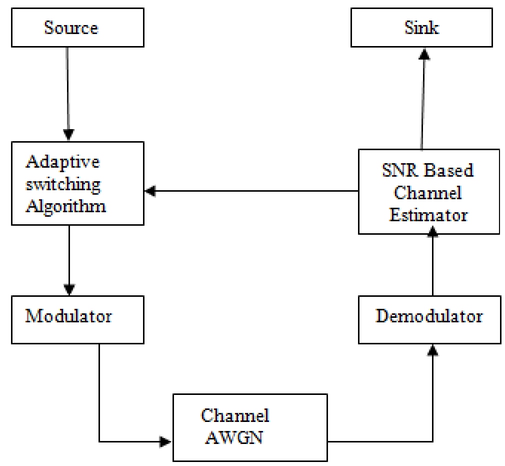

Fig. 4. Adaptive System Architecture

Adaptive modulation switching block is here for selecting the appropriate modulation scheme depends upon the information or SNR received from the feedback. SNR is split into different ranges based upon our desired level of BER. A particular modulation scheme is assigned to operate within a particular region. In Channel estimator SNR are compared with the threshold SNR values to choose the mode and based on a desired BER, select the mode that yields the largest throughput and feed back the selected mode to the transmitter in order that the adaption can be performed.

The adaptive system can only operate efficiently when channel conditions are slowly-varying. Thus in this system feedback of the channel information becomes a limiting factor. So the assumption of a reliable as well as slowly varying channel is necessary to obtain the accurate result.

6 Simulation Results

6.1 BER vs.SNR

Bit Error Rate (BER) is defined as the ratio of erroneous bit to the total number of received bit.

BER= (Erroneous bit) / (Total bits received)

In a communication channel, the erroneous bits are those received bit that has been altered due to noise, interference or bit synchronization errors. BER is the number of bit errors divided by the total number of received bit in a particular given time interval. It is a unit less performance measure, which is often expressed as a percentage. BER can also be defined in terms of probability of error (P_e).

$$P_e = \frac{1}{2}(1-\text{erfc})\sqrt{\frac{Eb}{No}} \qquad (5)$$

Where erf is the error function, E_b is the energy in one bit and N_o is the noise power spectral density. For each modulation technique the error function is different. P_e is proportional to the E_b/N_o, which is signal-to-noise ratio. it is also dimensionless term. This term is useful when comparing the bit error rate (BER) performance of different digital modulation scheme.

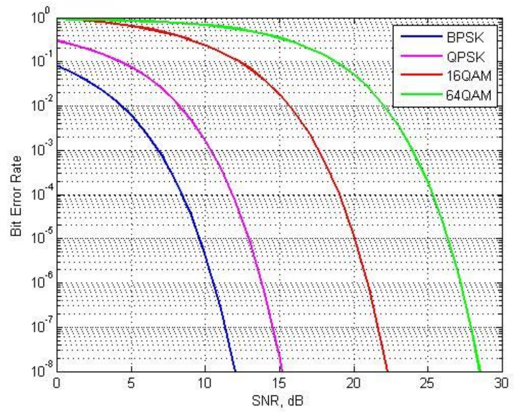

Fig. 5. BER vs.SNR of different modulation scheme

At an operating BER of 10^{-3}, there is BPSK that gives us our desired performance at an SNR below 11dB. Between 11dB and 15dB, there is only one scheme that gives us performance below 10^{-3}, and that is QPSK. Between 17 and 23 dB, 16QAM gives us our desired BER at a better spectral efficiency than QPSK. And at SNR higher than23dB, 64 QAM gives us the best spectral efficiency while providing the desired BER performance.

TABLE 2
Different Switching Thresholds Levels

SNR(dB)	Modulation
SNR<11	BPSK
11<SNR<15	QPSK
17<SNR<23	16QAM
SNR>23dB	64QAM

7 Conclusion

WiMAX offers benefits for the wire line operators who want to provide last mile access to residences as well as businesses in terms of reducing the cost. In this paper AMC scheme has been used for performance enhancement of a WiMAX system. This technique dynamically adopts different modulation scheme based on the information received from the feedback and thus increases the spectral efficiency. In future performance of a WiMAX network can be enhanced by MCCDMA which is nothing but a combination of OFDM and CDMA. This scheme performs well even in a mobile environment. This scheme provides high BER, high throughput and high bandwidth efficiency even in the fading environment.

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