Performance Assessment of Mobile WiMAX in high Speed Environment

S. K. Malave, A. S. Shirsat, D. M. Yadav

Abstract: ***Currently, there is an increasing demand for high-speed internet access with reliable performance. Mobile WiMAX, IEEE 802.16m is 4G technology employed for broadband internet applications. It incorporates cyclic prefix Orthogonal Frequency Division Multiplexing (CP-OFDM) as a modulation as well as multiplexing technique. In the high-speed scenario, OFDM experiences intercarrier interference, increasing the number of bits in error. In this paper, we provide the performance assessment of Mobile WiMAX for different vehicular speed upto 350km/h. Simulation is carried out for different values of doppler frequencies upto 1200Hz and bit error rate is computed. Result reveals that Bit Error Rate (BER) performance of mobile WiMAX degrades with an increase in vehicular speed. 16QAM gives satisfactory performance in a high-speed environment upto 250km/h.***

Index Terms: ***Mobile WiMAX, OFDM.***

I. INTRODUCTION

Mobile WiMAX, IEEE 802.16m is a 4G technology. It is an enhancement to mobile WiMAX; IEEE 802.16e. IEEE 802.16e offers a data rate of 63Mbps. It supports scalable channel bandwidth from 1.25MHz to 20MHz by adapting the FFT size accordingly from 128 to 2048[1]. Positive attributes of IEEE 802.16m include higher throughput capability alongwith support for voice over IP. It offers a downlink data rate of 300Mbps and uplink data rate of 135Mbps for 20MHz bandwidth. It is capable of providing data transfer rates of 1Gbps for pedestrian mode and 100Mbps in mobile mode with carrier aggregation feature. Additional features are to support multi-carrier operation and extended MIMO [2]. Mobile WiMAX needs to provide the last mile access with good BER performance. It utilizes OFDMA as a multiplexing technique in the downlink (DL) and uplink (UL) for better-quality performance in multipath environment [3]. In OFDMA channel bandwidth is divided into subcarriers which are orthogonal to each other. In the high-speed situation, the channel becomes non-stationary. It responds the transmitted signal differently depending upon the signal frequency and signal duration. OFDM transmits the data symbol by symbol, including a number of subcarriers working orthogonally. Mobile channel disturbs the orthogonality, creating interference among subcarriers. Amount of intercarrier interference (ICI) depends upon the speed of the mobile terminal, which decides doppler shift of carrier frequency. Doppler frequency increases as the velocity of the transmitter or receiver increases [4]-[7]. As OFDM sends the data block by block, when it travels through more than one path, it undergoes the problem of intersymbol interference (ISI). To alleviate the effect of ISI on BER performance, a cyclic prefix called guard band added for every OFDM symbol. Guard interval length is set more than or equal to the channel length to avoid ISI [8].

In this paper bit error rate analysis is carried out as a function of doppler frequency with maximum doppler frequency fd=1200Hz, considering multipath fading channel with carrier frequency of 3.5GHz.System performance is tested for BER performance for SNR variation for 16QAM and 64QAM for vehicular speed of 200km/h. This paper is organized as follows. Section II presents the work related to WiMAX. Overview of Mobile WiMAX, IEEE 802.16m is given in section III. Section IV gives the Simulink model of the Mobile WiMAX. Results are shown in section V. Section VI presents conclusions drawn.

II. RELATED WORK

Various works have been reported to assess the performance of Mobile WiMAX in high-speed environments. Mobile WiMAX IEEE 802.16m downlink physical layer model is tested using a Rayleigh channel and Nakagami-m model for the multipath environment with Non line of sight communication at 2.6GHz carrier frequency. BER performance is analyzed for different vehicular speed with the maximum speed of 200km/h. BER increases with an increase in vehicular speed [9]. Performance of IEEE 802.16e is analyzed for vehicular channels with maximum terminal mobility of 140km/h by computing the number of error bits, and number of frame errors. Mobile WiMAX performs well in urban, suburban and expressway scenario than IEEE 802.11p and IEEE 802.11a [10]. Mobile WiMAX IEEE 802.16e physical layer simulated using MATLAB. BER performance investigated at different vehicular speed with the maximum speed of 120km/h by changing the doppler frequency [11]. Performance of mobile WiMAX 802.16m is assessed considering Downlink (DL) data rate and available throughput as performance metrics for different indoor and outdoor scenarios. Throughput is calculated for different values of the distance between Base Station and Mobile station. Maximum distance from BS to MS is more in case of the suburban area than the urban area for all the propagation models [12]. By combining link adaption techniques, Adaptive Modulation (AM) and Adaptive Modulation and Coding (AMC) scheme with the MIMO technique, the throughput of WiMAX can be enhanced.

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AMC provides better spectral efficiency than the AM [13]. The author tested the performance of IEEE 802.16e with OFDMA technique for two non-stationary vehicular channel conditions. System BER performance analyzed as a function of signal to noise ratio at 100km/h vehicle speed for high traffic density channel and urban channel. Suggested channel estimation, based on average and linear interpolation technique, offers an optimum solution considering estimation accuracy and computational complexity. The system performs better in static channel conditions as compared to dynamic [14]. Performance of IEEE 802.16e investigated for different path loss scenarios. Downlink data rate decreases linearly with path loss, but uplink data rate falls significantly with path loss. The author suggests, ECC33d model for analysis of WiMAX deployment as it has low path loss with maximum throughput [15]. The author proposed a technique of using uneven beamwidths of the sectorized antenna array to achieve better performance of WiMAX system by reducing the doppler spread at high terminal speed [16]. Survey tells that, work done gives insights into the BER performance of Mobile WiMAX in high speed condition, considering maximum vehicular speed upto 200km/h for IEEE 802.16m and 140km/h, IEEE 802.16e respectively. Yet, it is essential to study and assess the performance of IEEE 802.16m in high speed situation upto 350km/h.

III. OVERVIEW OF MOBILE WIMAX, IEEE 802.16M

Mobile WiMAX, IEEE 802.16m is a 4G technology used for mobile broadband internet services upto 100km. Table I gives the specifications for Mobile WiMAX, IEEE 802.16m [3].

Table I. Specifications for mobile WiMAX IEEE 802.16m

Sr.	Feature	IEEE 802.16m
1	Peak Data Rate	DL 300Mbps/20MHz UL 135Mbps/20MHz
2	Channel Bandwidth	5 to 20 MHz per carrier, 100 MHz bandwidths in carrier aggregation mode
3	MIMO/ Antenna Configuration	DL: 2x2 (baseline), 2x4, 4x2, 4x4, 8x8, 4x8 UL:1x2 (baseline), 1x4, 2x4, 4x4
4	Cell Range and Coverage	Satisfactory performance upto 5km. Maximum Range upto 100km with just connectivity
5	VoIP Capacity	>60 Active users /MHz/Sector (DL 2X2 and UL 1x2)
6	Mobility	Optimum performance upto 10km/h (Pedestrian Mode). Performance degradation (Vehicular Speed), Connectivity at 350km/h (high speed)
7	Duplex scheme	TDD, FDD, H-FDD (MS)

WiMAX employs AMC scheme with variable channel encoding rate of 1/2, 2/3 and 3/4. Depending upon the link quality, it changes modulation scheme. If link quality is good, it utilizes a higher level modulation scheme such as 64QAM, increasing throughput. Under bad channel conditions, it adopts a lower level modulation scheme. It selects modulation format based on channel quality indicator (CQI) value provided by the receiver. Channel quality is decided by calculating SNR value at the receiver. Table II enlists modulation scheme and corresponding channel encoding rate.

Table II Modulation scheme and coding rate

Modulation Scheme Index	Modulation Scheme	Coding Rate
0	QPSK	1/2
1	QPSK	3/4
2	16 QAM	1/2
3	16 QAM	3/4
4	16 QAM	1/2
5	64 QAM	2/3
6	64 QAM	3/4

WiMAX employs the OFDMA scheme. It consists of data subcarriers to carry data symbols, pilot subcarriers to predict channel behaviour. Null subcarriers used for guard subcarriers and DC subcarriers. OFDMA uses scalable orthogonal frequency division multiple access to support scalable channel bandwidth. As the channel bandwidth varies from 5MHz to 20MHz, it changes FFT size from 512 to 2048[17]. OFDMA assigns a different subset of subcarriers to individual users [18]. Dynamic approach of subcarrier allocation provides better trunking efficiency. Table III shows the scalability of OFDMA technique with channel bandwidth.

Table III. Scalable OFDMA parameters

Sr.	Channel Bandwidth (MHz)	FFT Size
1	5.0	512
2	7.0	1024
3	8.75	1024
2	10	1024
3	20	2048

OFDMA is a high data rate transmission scheme in which a wideband signal is divided into parallel narrowband signals. This converts the fast fading frequency selective channel into a bank of the fast flat fading channel. The delay spread of many fading channels is much smaller, due to which it acts as flat fading channel for each subcarrier. In an open-air environment the coherence bandwidth Bc < B, the entire OFDM signal bandwidth. Hence, the channel becomes frequency selective over the entire OFDM bandwidth. Presently, WiMAX is deployed in the licensed and unlicensed band of 2.3GHz, 2.5GHz, 3.5GHz and 5.7GHz. When transmitted signal propagates through the multipath channel, as a impact of fading and doppler spread, the system performs poor. For Mobile WiMAX, velocity of the mobile node, decides the doppler frequency which can be obtained by (1) [19].

$$fd = fc*v/c*\cos(Ø) \quad (1)$$

where

fd : Doppler shift.

fc : Transmitter carrier frequency.

v : Mobility of receiver (m/s).

c: speed of light ($3X10^8$ m/s).

Ø: Angle of arrival with horizontal plane.

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WiMAX employs space-time block encoding (STBC) technique of advanced antenna technology, which includes enhanced Multiple Input Multiple Output (MIMO) scheme and directional antenna with diversity technique. It can have maximum 8x8 antenna configuration for downlink mode and 4X4 for the uplink mode. This feature helps to gain more throughput of the system and also the reliability of the link. It provides data, voice and video services with different quality of service (QoS) [20].

IV. SYSTEM DIAGRAM AND DESCRIPTION

Fig.1. presents the block diagram of Mobile WiMAX IEEE 802.16m for downlink mode with one base station and two mobile stations (MS). The base station transmits data for two mobile stations (users) in one OFDMA symbol by logically assigning the subcarriers to MS. Data for two users are encoded using convolution encoder and modulated using 16QAM or 64QAM. Modulated signal from both users is assigned different subcarriers by the logical subchannelization. Signal gets converted to the time domain by applying IFFT operation forming OFDMA signal. Pilots are interleaved in OFDMA signal in the frequency domain for channel estimation purpose. Eq. (2) presents OFDM symbol in the time domain.

$$x[n] = \begin{cases} \frac{1}{N} \sum_{k=0}^{N-1} X[k] e^{j(2\pi kn/N)} & 0 \le k \le N-1 \\ 0 & else \end{cases} \quad (2)$$

Where

$x[n]$ = OFDMA symbol in time domain.

$X[k]$ = Complex data symbols from constellation mapper

N=Total No. of Subcarriers in one OFDMA Symbol.

P =No. of Pilot Subcarriers in one OFDMA Symbol.

S= N/P (Spacing between adjacent pilot subcarriers).

Then a cyclic prefix is added as a guard band in the time domain.

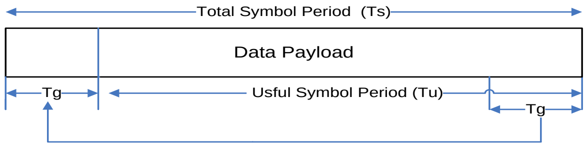

Fig. 2. Signal structure of CP-OFDM

Fig. 2 shows the signal structure of cyclic prefix OFDM. The cyclic prefix or guard interval obtained from the end portion of the OFDM data symbol and attached to the start of the symbol at the place of the guard interval. It's length is 1/4, 1/8, 1/16 or 1/32 of the OFDM data symbol.

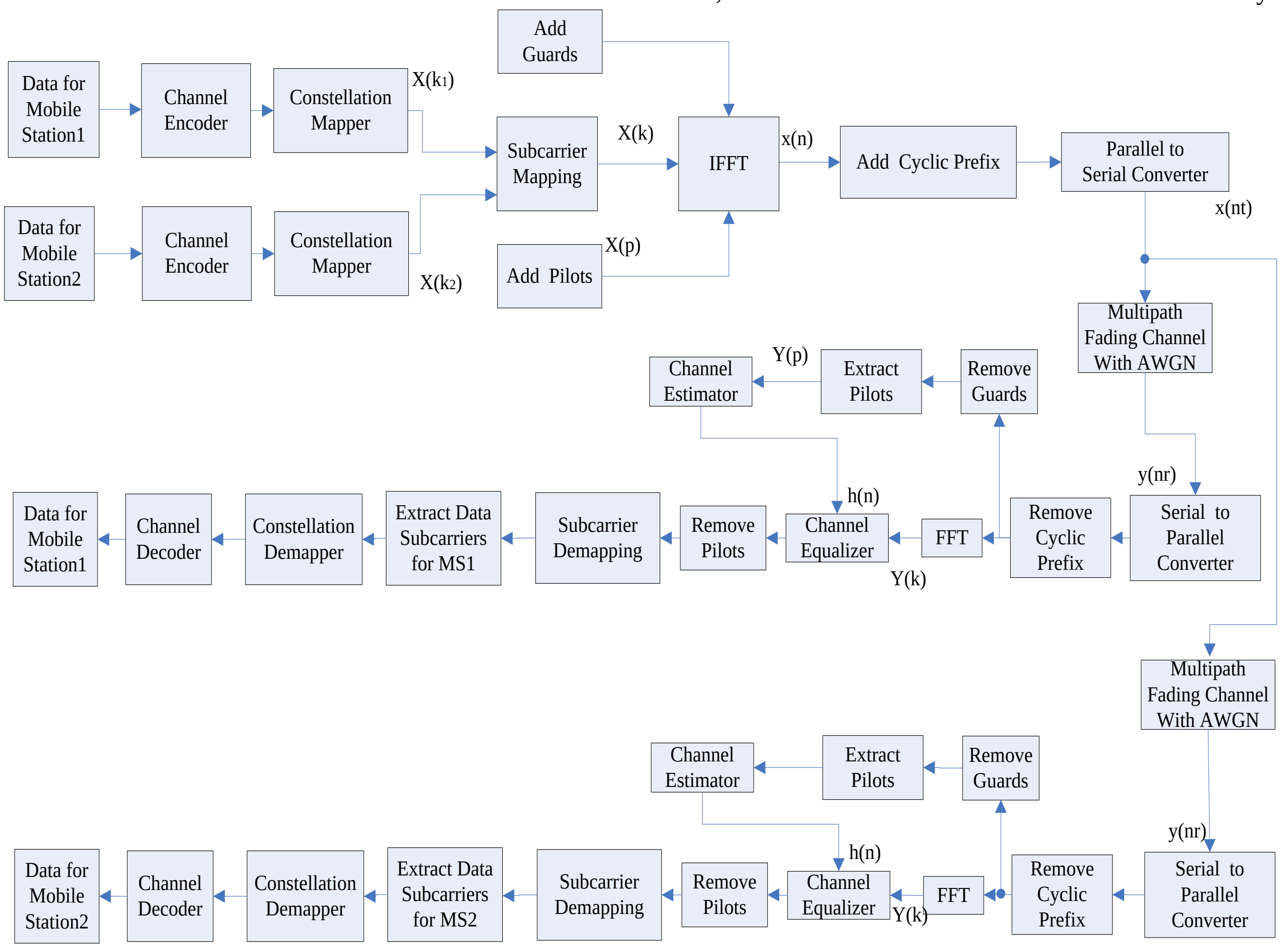

Fig.1. Block diagram of mobile WiMAX IEEE 802.16m transmitter and receiver.

t is chosen greater than the delay spread to avoid intersymbol interference.

$$Ts=Tg+Tu \qquad (3)$$

Where

Tg=Cyclic Prefix interval serving as guard interval.
Tu=OFDM data symbol duration (useful symbol period)
Ts=Total Symbol Period

Transmitted OFDM symbol is given by

$$x[nt] = M + x[n] \qquad (4)$$

Where

$x[nt]$=Transmitted OFDM Symbol,

M = Cyclic Prefix (Guard Band).

The signal passes through the time-varying channel. Discrete-time channel is denoted as a tapped delay line finite impulse response filter. Signal passed through a Rayleigh fading channel with AWGN which is multipath fading channel with a strong line of sight component present. Receiver removes the cyclic prefix and converts the time domain OFDM signal into frequency domain using FFT operation. Left and right guard subcarriers are removed.

Pilot based channel estimation is done in frequency domain by least square channel estimation. It gives channel impulse response at pilot locations.

$$h(p) = Y(p) / X(p) \qquad (5)$$

Where

$h(p)$ = Channel response at pilot positions

$X(p)$ = Pilot subcarriers embedded at transmitter.

$Y(p)$ = Pilot subcarriers extracted at receiver.

Channel frequency response for data subcarriers is achieved by applying a linear interpolation method to pilot subcarriers. Then frequency domain channel equalization is performed to nullify the effect of the channel on the transmitted signal. Data subcarriers are extracted by removing the pilot subcarriers. Data subcarriers for user1 and user2 are separated and demodulated. Channel decoding is applied to demodulated signal and information is recovered. In Mobile WiMAX, IEEE 802.16m with 1024 subcarriers, symbol duration (Ts) is 114.286µs with cyclic prefix 1/4.

IV. METHODOLOGY

Simulation is carried out in MATLAB Simulink. Table IV enlists simulation parameters for Mobile WiMAX; IEEE 802.16m. For simulation purpose, 3.5 GHz is set as a carrier frequency with a channel bandwidth of 10 MHz and 1024 FFT size. 86 subcarriers are used as a left guard interval, and 85 subcarriers are used as right guard interval whereas one subcarrier is considered as DC or null. 720 subcarriers are used as data subcarriers and 120 subcarriers as a pilot. 720 subcarriers are organized into 30 subchannels. Each subchannel contains 24 subcarriers. It employs Partial Usage Subchannels (PUSC) permutation mode. System is simulated to evaluate BER performance as a function of vehicular speed cosidering, doppler frequency variation from 0Hz to1200Hz.

Table V gives the details about the channel parameters. Simulation is carried out for Rayleigh channel and for suburban area. Rayleigh fading channel simulates the non-line of sight (NLOS) environment. Guard interval (CP) is set to 22.46µs which is greater than the maximum path delay.

Table IV. Simulation parameters of mobile WiMAX IEEE 802.16m

Channel Bandwidth	10MHz
Modulation Scheme	16QAM,64QAM
Receiver Velocity	0-350km/h
Taps(S)	3
Carrier Frequency(GHz)	3.5
FFT Length (N)	1024
Data Subcarriers used	720
Pilot Subcarriers used	120
Useful Symbol Duration	91.429µs
Guard interval	1/4
Carrier Spacing (Δf)	10.94KHz
Guard Time(Tg)	22.857 µs
OFDM Symbol Duration	114.286 µs
OFDM Symbols (5ms frame)	43
Number of Users per OFDMA Symbol	2

Table V. Channel parameters

Parameters	Tap1	Tap2	Tap2
Delay (µs)	0	12	0.5
Power (dB)	0	-5	-10

V. RESULT AND DISCUSSION

Fig. 3 shows a simulation of Mobile WiMAX, IEEE 802.16m physical layer with 16QAM and 64QAM modulation scheme for SNR=30dB. Simulation is carried out for Rayleigh channel frequency selective fading mode.

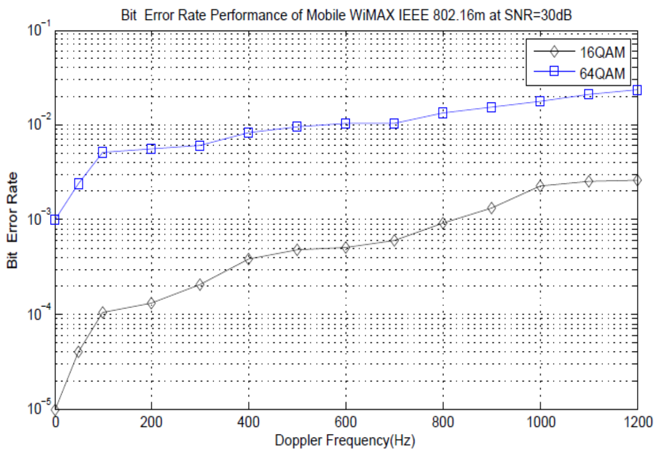

Fig. 3. BER performance of mobile WiMAX IEEE 802.16m with doppler frequency.

Simulation results reveal that coded BER performance of system degrades with an increase in the doppler frequency. As the mobility of the node increases, it increases intercarrier interference, increasing the number of bits in error. It is clear from the results that the lower level modulation scheme; 16QAM outperforms the higher level modulation scheme, 64QAM in a high-speed environment. For a target BER of 10^{-3}, 16QAM works satisfactory upto doppler shift fd=800Hz which corresponds to a vehicular speed of 250km/h.

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Fig. 4 illustrates the coded BER performance of IEEE 802.16m as a function of SNR for 16QAM and 64QAM for different vehicular speed. In this simulation fd=324Hz corresponds to 100Km/h and fd=1134Hz corresponds 350km/h respectively.

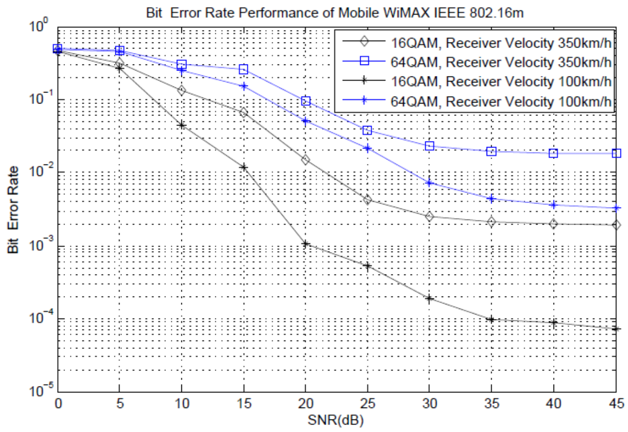

Fig. 4. BER performance of mobile WiMAX IEEE 802.16m at different SNR.

It is observed from the results that at low vehicular speed of 100km/h, an increase in SNR value shows significant improvement in BER performance as compared to high speed at 350km/h. For 100km/h receiver velocity, 16QAM achieves a BER of 10^{-2} at 16 dB SNR whereas 64QAM obtains it at 24dB. For terminal speed of 350km/h, an increase in SNR value has a negligible effect on BER performance above 35dB whereas it shows little improvement in performance for 100km/h. Performance degrades severely as the speed of the vehicle increases. As the speed of vehicle increases, doppler shift increases, generating more intercarrier interference in OFDM subcarriers.

VI. CONCLUSION

In this paper, the performance of Mobile WiMAX, IEEE 802.16m is evaluated in terms of bit error rate for different values of vehicular speed. Simulation results demonstrate that, coded BER performance of Mobile WiMAX, IEEE 802.16m at low terminal mobility is superior to high terminal mobility. Boosting SNR value shows significant improvement in BER performance at low vehicular speed. Lower level modulation scheme, 16QAM can be a suitable choice for vehicular speed upto 250km/h. The system performs better for guard interval greater than maximum path delay as it reduces the intersymbol interference.

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