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Performance Enhancement of Wi-Max Mobile Network using OFDM and Trellis Encoder

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Abstract - Wi-Max is the communication network used widely over almost all the wireless and mobile devices to connect with internet and sharing, videos, photos, information and music etc. The performance of Wi-Max Mobile network should be significant enough to exploit the available wireless media against the noises and interferences. The impacts of the interferences and noises can be minimized using detection techniques, encodings, error detection with correction etc. In this paper the Wi-Max Mobile network is implemented with the help of most efficient technology i.e. Orthogonal Frequency Division Multiplexing(OFDM) with BPSK, QPSK and 4-QAM modulation techniques and the performance of the system i.e. BER is improved by adopting Trellis Encoder. The system is simulated for the high volumes of data and achieved better results.

Keywords- Wi-Max, OFDM, Trellis Encoder(TE), BPSK, QPSK and 4-QAM.

I. INTRODUCTION

Some decades ago, we were purely dependent on analog method. Equally the sources and communication system were on analog format but the advancement of technology made it possible to transmit data in digital structure. Beside with those, the processor was getting faster to the fastest, the data payload capability and transmission time increased from kilobit to megabit and megabit to gigabit. As of wire to wireless concept emerged and after researching and investing so large amount money, engineers became successful to invent wireless transmitter to transmit data. Applications like Internet contact, voice, instant messaging, SMS, file transferring, paging, gaming, video conferencing and entertainment etc became a part of life. Cellular mobile phone systems, WLAN, wide-area wireless data systems, satellite communication systems and ad-hoc wireless networks etc are wireless communication. Every emerged based on wireless technology to provide maximum throughput, enormous mobility, longer range, vigorous backbone to thereat. The vision extended a bit more by the engineers to provide smooth transmission of multimedia anywhere on the globe through variety of applications and devices leading a new concept of wireless communication which is cheap and flexible to implement even in odd environment.

Wi-MAX is called the next generation broadband wireless technology which offers high speed, sophisticate secure, and last mile broadband services along with a cellular back haul and Wi-Fi hotspots. The evolution of Wi-MAX began a few years ago when scientists and engineers felt the need of having a wireless Internet access and other broadband services which works well everywhere especially the rural areas or in those areas where it is hard to establish wired infrastructure and economically not feasible. IEEE 802.16, also called as IEEE Wireless-MAN, enhanced both licensed and unlicensed band of 2-66 GHz which is standard of fixed wireless broadband and included mobile broadband application. Wi-MAX forum, a private organization was formed in June 2001 to coordinate the components and develop the equipment those will be compatible and inter operable. After several years, in 2007, Mobile Wi-MAX equipment developed with the IEEE 802.16e standard got the certification and they announced to release the product in 2008, provided mobility and nomadic access.

Fixed Vs Mobile Wi-MAX:

There are certain differences between Fixed Wi-MAX and Mobile Wi-MAX. 802.16d (Rev 2004) is known as Fixed Wi-MAX and 802.16e standard is fondly referred as Mobile-Wi-MAX. The 802.16d standard supports fixed and nomadic applications such as 802.16e standard supports fixed, mobile, nomadic and portable uses. The 802.16e standard carries all the features of 802.16d along with new specifications that enables full mobility at vehicular speed, better QoS and power control but 802.16e stander devices are not compatible with 802.16d standard base stations as 802.16e based on TDD where 802.16d is on top of FDD. Due to other compatibility issue with offered networks, 802.16e adopted S-OFDMA and 2048-FFT size.

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II. BASIE ARCHITECTURE OF OFDM

With OFDM the used bandwidth is divided into several frequency sub-carriers so that they are orthogonal to each other. The input data stream is separated into multiple. Parallel sub- data streams with reduced data rate. Then the sub-data streams are modulated individually and sent on separate sub-carriers. As result of this is the increase in symbol duration. As the long signal duration decreases Inter Symbol Interference (1ST) caused by multipath propagation. It is proficient to transmit the low-rate streams in parallel, as a substitute of one high-rate data stream. The signal duration is long. Thus by using a proper guard interval, the 1ST can be avoided totally, assume the guard interval is longer than the difference between the first and last multipath echo. The Figure 2. 1 below shows the principle of several sub-streams combined at the transmitter and separated again at the receiver.

As seen in the Figure 2.1 the information is coded and modulated across the sub-carriers before performing an Inverse Fast Fourier Transform (IFFT). The IFFT takes advantage of the frequency diversity of the multipath channel. To finish, before transmitting the data, the data streams are combined to a single signal and sent to the air interface. At the receiver side the procedure is same except in reversed order. The 802. 16e specification defines the Fast Fourier Transform (FFT) size to be 128, 512. 1024 and may be 2048 with respective channel bandwidths 1.25, 5, 10, and 20 MI-Iz. However, the Mobile Wi-MAX allows other bandwidth profiles to be used as well, but the sub-carrier frequency cannot be kept constant anymore (more in the next sub- subsection)

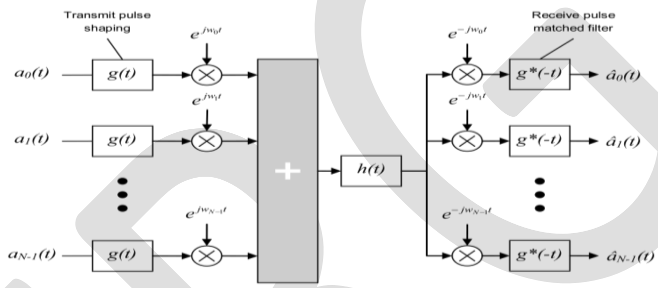

Fig. 2.1 Basic System Architecture of an OFDM System

III. TRELLIS ENCODER/DECODER

The name trellis was coined because a state diagram of the method, when drawn on document, closely resembles the trellis network used in rose gardens. The method is mainly a convolutional code of rates (r,r+1). Ungerboeck's unique contribution is to apply the parity check on a per symbol basis instead of the older technique of applying it to the bit stream then modulating the bits. The key system he termed Mapping by locate Partitions. This scheme was to set the symbols in a tree like fashion then separate them into two limbs of the same size. At each branch of the tree, the symbols were further apart. Although hard to visualize in multi-dimensions, a easy one measurement example illustrates the basic procedure.

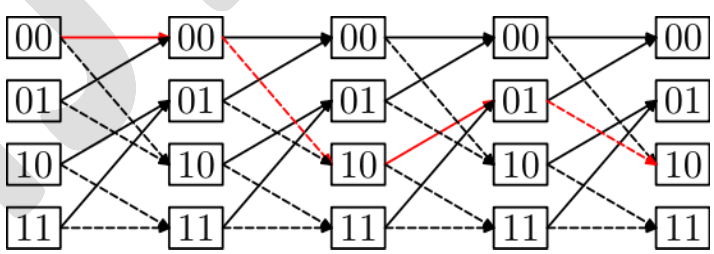

Fig. 3.1 Trellis Encoding

Then take all odd symbols and place them in one set and the even symbols in the second set. It is not quite correct because Ungerboeck was looking at the two dimensional problem, but the principle is the unaffected, take every other one for every group and repeat the procedure for every one of tree limb. He after that explained a method of assigning the encoded bit stream onto the symbols in a very systematic procedure.

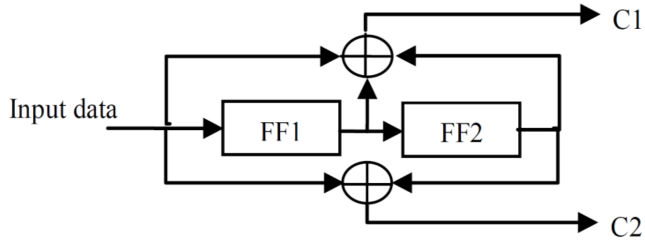

Fig. 3.2 Trellis Encoder

Once this procedure was fully explained, after that next step was to program the algorithms into a computer and let the computer search for the best codes. The results were astonishing. Even the most simple code (4 state) produced error rates nearly one one-thousandth of an equivalent uncoded system.

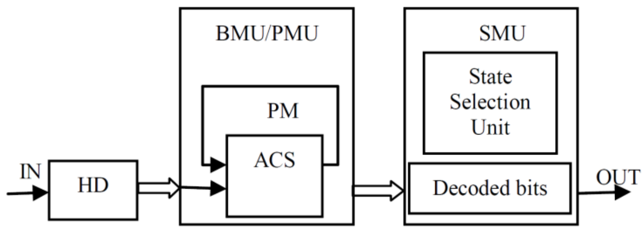

Fig. 3.3 Trellis Decoder

For two years Ungerboeck kept these results private and only conveyed them to close colleagues. Forward Error Correction (FEC) improves the bit error rate (BER) performance of power-limited and/or bandwidth-limited channels by adding structured redundancy to the transmitted data. The type of additive noise experienced on the channel determines the class of FEC used on the channel. Tree codes are used for channels with Additive White Gaussian Noise (AWGN) and block codes are used for channels with additive burst noise. Trellis Encoder is typically used for systems that both power and bandwidth limited. The standard modulation are mainly 8-PSK and 16-PSK.

The Trellis Encoder supports two codes rates: 2⁄3 for 8 PSK and 3⁄4 for 16 PSK. The Trellis Mode also supports built-in phase synchronization for 8-PSK and 16-PSK.

IV. PROPOSED METHODOLOGY

Wi-Max Mobile network has numerous applications in the field of information and media broadcasting, digital video broadcasting, internet, personal area networks (PANs), local area networks (LANs) and wide area networks (WANs).

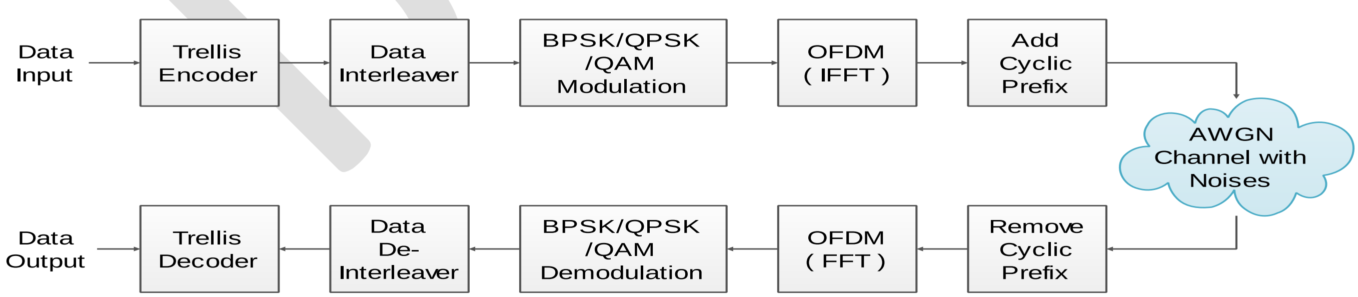

Fig. 4.1 Block Diagram of Proposed Methodology

All these listed application need continuity of link from source to data with high data rates. In this part a proposed approach is explained to facilitates the Wi-Max Mobile networks in terms higher data handling capacity and less noise susceptibility.

In Fig. 4.1 the block diagram of proposed Wi-Max Mobile system with OFDM and Trellis Encoder (TE) is presented. The scheme has major blocks like trellis encoder, data interleaver, modulator, OFDM modulator and AWGN channel having noises etc.

The above mentioned proposes system is implemented for simulation purposes and the implemented algorithm has been described in the Fig. 4.2.

The flow chart of proposed model is having important steps which are as follows:

a) *Creation of simulation environment*
b) *Generate data to transmit over system*
c) *Encode data using Trellis Encoder(TE)*
d) *Pass data through Data Interleaver(DI)*
e) *Modulate with BPSK, QPSK and 4-QAM separately to compare*
f) *Apply OFDM Modulation (IFFT + Add Cyclic Prefix)*
g) *Transmit signal trough AWGN channel*
h) *OFDM Demodulation (eliminate Cyclic Prefix + FFT)*
i) *Demodulate with BPSK, QPSK and 4-QAM*
j) *Pass through Data De-Interleaver*
k) *Decode data with Trellis Decoder*
l) *Calculate Bit Error Rate*
m) *Compare and Display Results for variable data sizes and FFT points*

Bit Error Rate

In the case of QPSK modulation and AWGN channel, the Bit error rate as function of the Eb/N0 is given by:

$$\mathrm{BER} = \frac{1}{2}\mathrm{erfc}(\sqrt{\mathrm{E_B} - \mathrm{N_0}})$$

Signal to Noise Ratio

The signal-to-noise-ratio (SNR), Eb /N0, of unit is in decibels, but we must convert decibels to an standard ratio before we can make further apply of the SNR. If we place the SNR to m dB, then

$$E_b/N_0 = 10m/10.$$

Using Matlab, we get the ratio,of ‘ebn0’, from the SNR in the decibels, ‘snrdb’, as:

$$e_b n_0 = 10\hat{}\ (snrdb/10).$$

The E_b/N_0 is a dimensionless quantity.

E_b Energy-per-bit is the total energy of the signal, divided by the number of bits contained in the signal.

$$E_b = \frac{1}{N.\,fbit}\sum_{n=1}^{N} x^2(n)$$

Here N is the total number of samples in the signal, and f bit is the bit rate in bits-per-second.

Using Matlab, The energy-per-bit, 'e_b', of our broadcast signal, 'x', that has a bit rate 'f_b', as:

$$e_b = sum(x.\hat{}2)/(length(x) * fb).$$

Since our signal, x (n), is in units of volts, the units of are E_bJoules.
N_0

With the SNR and energy-per-bit known, for calculating N_0, the one-sided power spectral density of the noise. Divide E_b by the SNR, providing the SNR from decibels to a ratio. by Matlab, we get the power spectral density of the noise, 'n_0', given energy- per-bit 'e_b', and SNR '$e_b n_0$', as:
$n_0 = e_b/e_b n_0$.

The noise has units of Watts per Hertz (Hz) of power spectral density

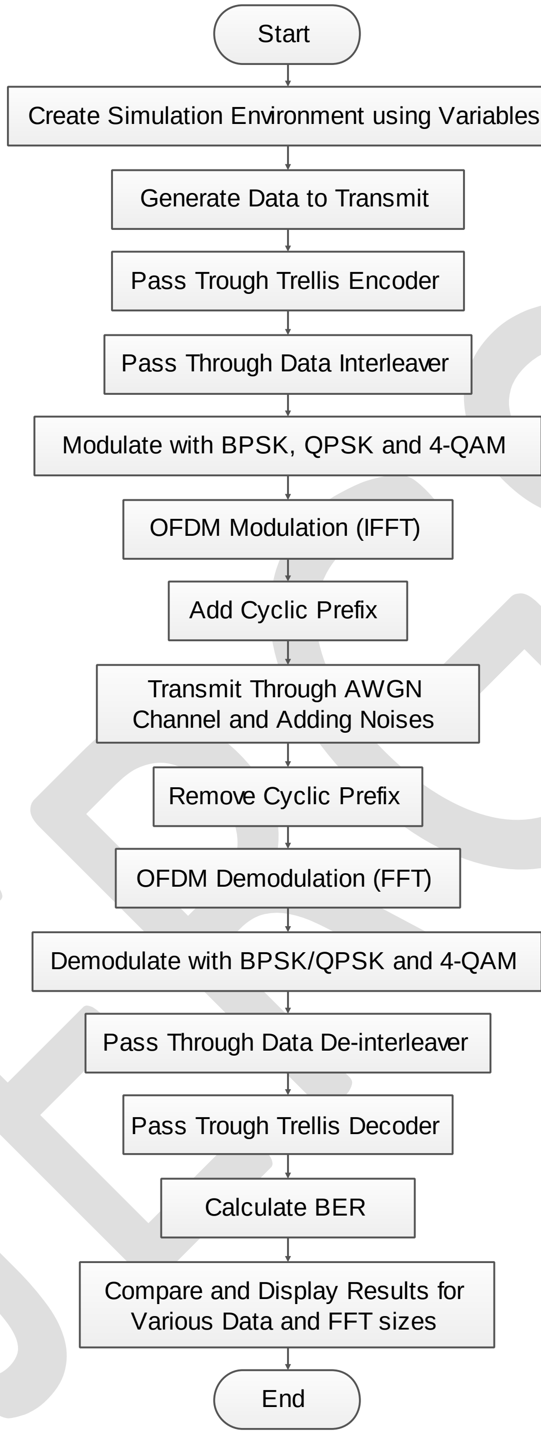

Fig. 4.2 Flow Chart of Proposed Approach

V. SIMULATION RESULTS

The proposed methodology for proposed Wi-Max Mobile system using orthogonal frequency division multiplexing (OFDM) with Trellis Encoder (TE) is explained in the previous sections.

Simulation Parameters:

The simulation of Wi-Max PHY layer model has been carried out using the following system parameters.

a) Digital modulation: BPSK, QPSK, QAM.
b) Encoder: Trellis Encoder
c) Interleaver size: [8 * 16].
d) Channel : AWGN.
e) Packet size : 128 bits (Frame length).
f) Code rate : 171/133.
g) Decoder : Trellis Decoder.

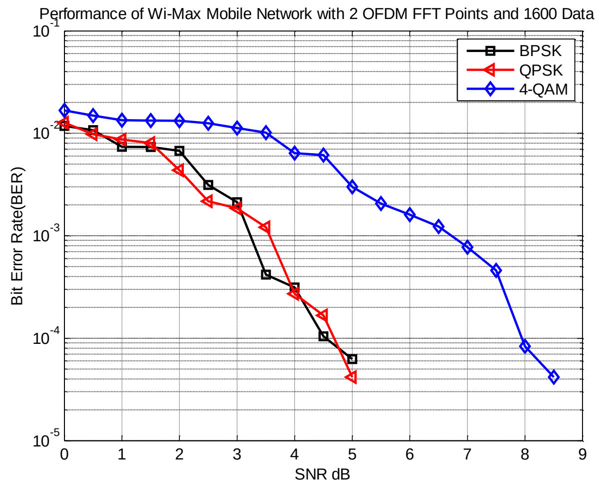

Fig. 5.1 BER performance of Wi-Max Mobile system with Trellis Encoder and 2 FFT points with 1600 bits data

TABLE I: SNR OF DIFFERENT CODING SCHEMES

TYPES OF CODES	SNR AT BER=10^{-2}	SNR AT BER=10^{-3}
Proposed Methodology (Trellis Encoding)	3.2 dB	6.4 db
Convolution Codes	9.2 dB	10.8 db
Turbo Codes (SOVA)	1.0 dB	7.5 dB
Turbo Codes (Log-MAP)	0.5 dB	1.8 db

TABLE II: SNR OF DIFFERENT CODE RATES

TYPES OF CODES	CODE RATES	SNR AT BER=10^{-3}
Proposed Methodology (Trellis Encoding)	177/133	6.4 dB
Turbo Codes (SOVA)	1/2, 1/3	7.5 dB, 5.0 dB
Turbo Codes (Log-MAP)	1/2, 1/3	1.8 dB, 1.5 dB

TABLE III: SNR WITH FRAME RATES

TYPES OF CODES	SNR	FRAME RATE
Proposed Methodology (Trellis Encoding)	6.4 dB	128
Turbo Codes (SOVA)	2.45, 2.3, 2.1 dB	280, 512, 1024
Turbo Codes (Log-MAP)	4.5, 1.6, 1.4 dB	280, 512, 1024

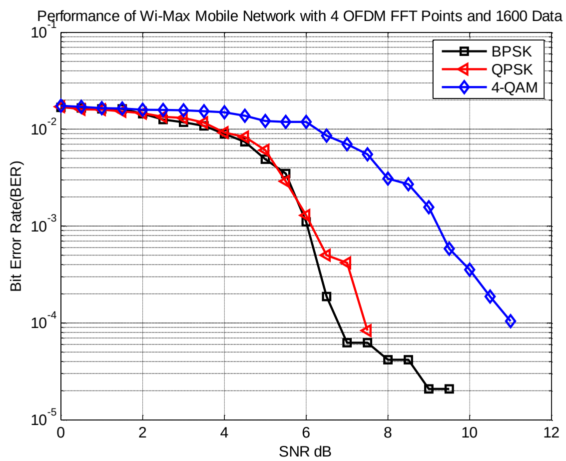

Fig. 5.2 BER performance of Wi-Max Mobile system with Trellis Encoder and 4 FFT points with 1600 bits data

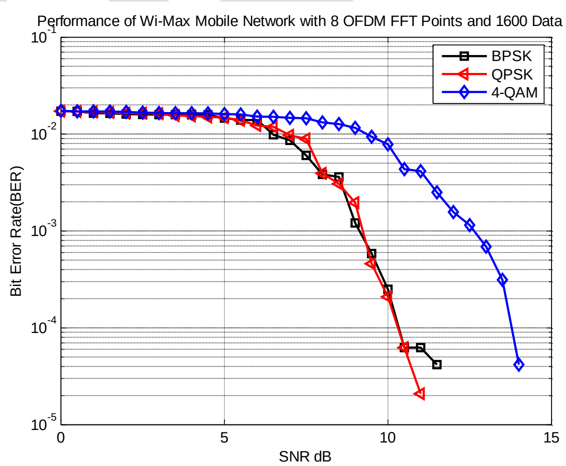

Fig. 5.3 BER performance of Wi-Max Mobile system with Trellis Encoder and 8 FFT points with 1600 bits data

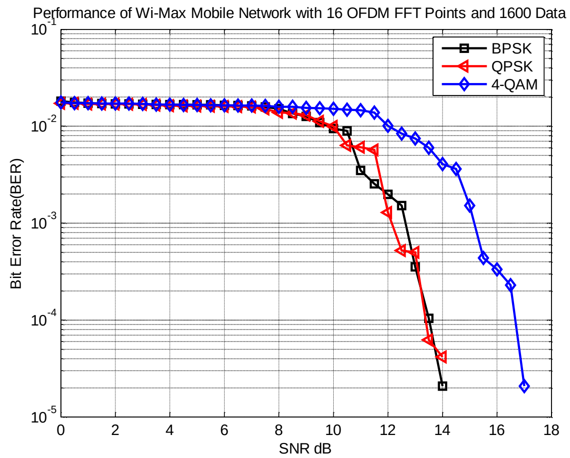

Fig. 5.4 BER performance of Wi-Max Mobile system with Trellis Encoder and 16 FFT points with 1600 bits data

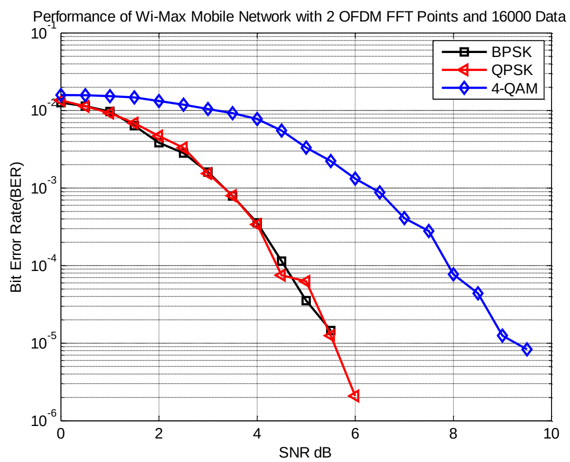

Fig. 5.5 BER performance of Wi-Max Mobile system with Trellis Encoder and 2 FFT points with 16000 bits data

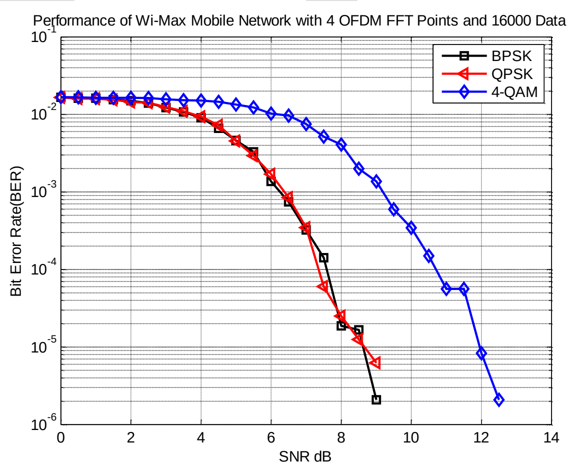

Fig. 5.6 BER performance of Wi-Max Mobile system with Trellis Encoder and 4 FFT points with 16000 bits data

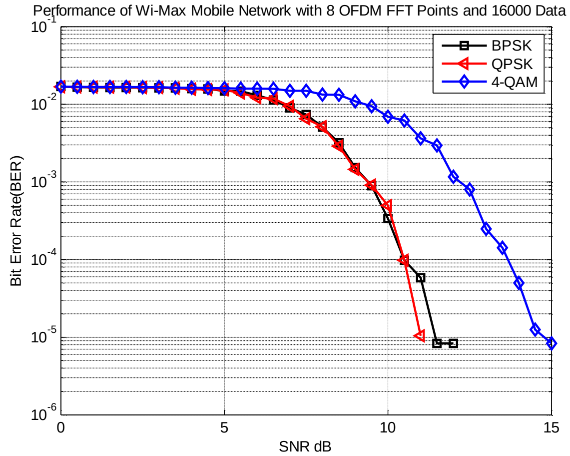

Fig. 5.7 BER performance of Wi-Max Mobile system with Trellis Encoder and 8 FFT points with 16000 bits data

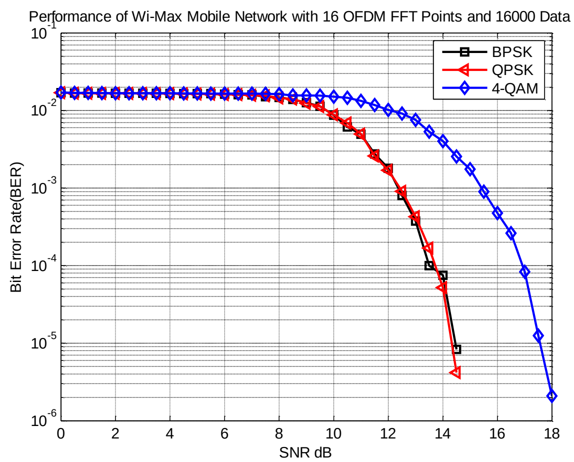

Fig. 5.8 BER performance of Wi-Max Mobile system with Trellis Encoder and 16 FFT points with 16000 bits data

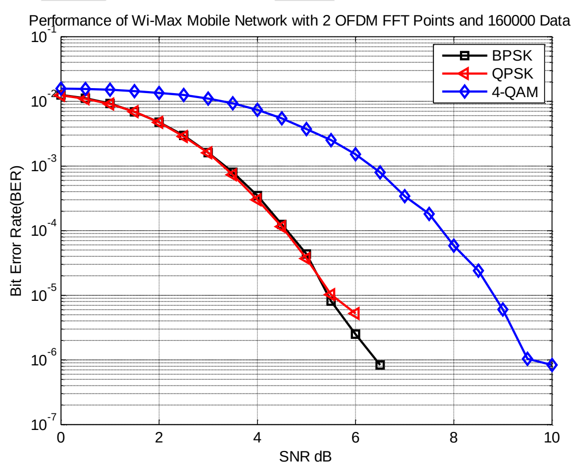

Fig. 5.9 BER performance of Wi-Max Mobile system with Trellis Encoder and 2 FFT points with 160000 bits data

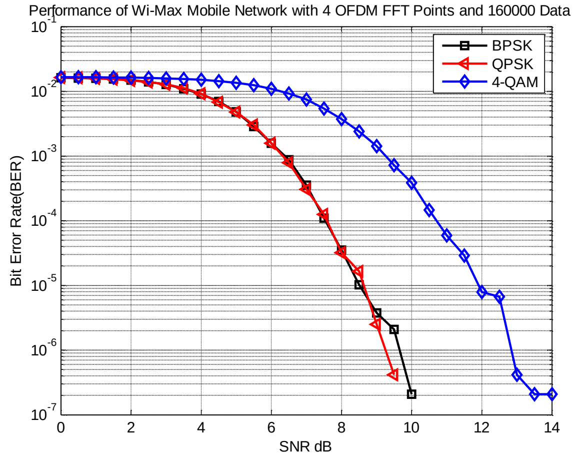

Fig. 5.10 BER performance of Wi-Max Mobile system with Trellis Encoder and 4 FFT points with 160000 bits data

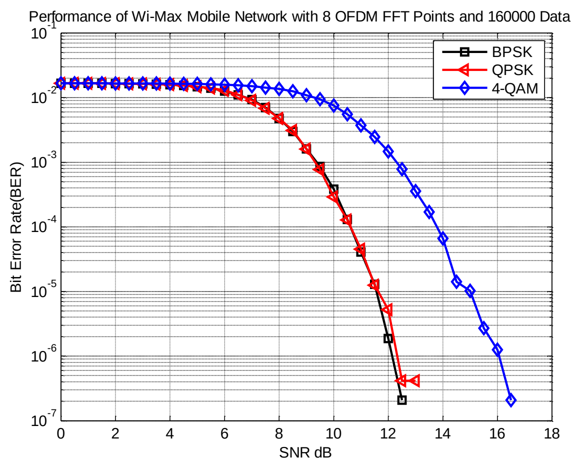

Fig. 5.11 BER performance of Wi-Max Mobile system with Trellis Encoder and 8 FFT points with 160000 bits data

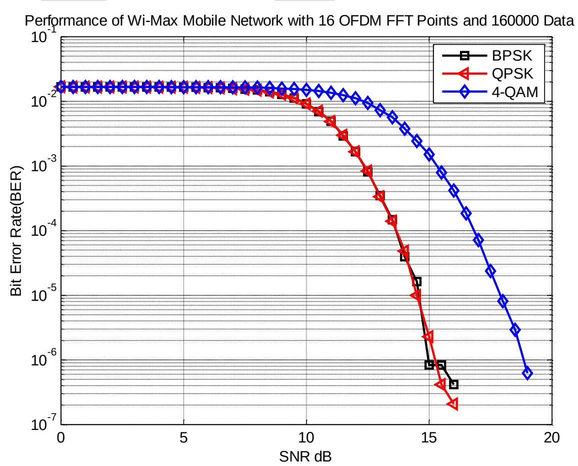

Fig. 5.12 BER performance of Wi-Max Mobile system with Trellis Encoder and 16 FFT points with 160000 bits data

In this the simulation results of the proposed approach are given. The simulations are performed on various data sizes. The changes in system performance seen when the FFT sizes of the OFDM are changed.

VI. CONCLUSION AND FUTURE WORK

From the system implementation and its results it is clear that the Trellis Encoder(TE) is making best out of Wi-Max Mobile Network System. The use of OFDM technology significantly enhances the data handling capacity of the system as seen in the results i.e. when the FFT sizes is reduces the error probability significantly go down and the makes system better. The optimum value of BER is achieved between 10^{-6} and 10^{-7} for 16 FFT points and BPSK modulation on 160000 bits data. The significance of encoder making system robust against noise and interference. In future if the system adopting better modulation technique with applications of some filters will make system better for wireless channels having noises, multipath fading, and interferences.

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