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"Evaluation of WIMAX 802.16 Technology Performance by Evaluating the Bit-Error Rate (BER) of OFDM Physical Layer under Different Modulation Schemes and Channel Conditions"

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Abstract: WiMAX stands for Worldwide Interoperability for Microwave Access. WiMAX technology enables ubiquitous delivery of wireless broadband service for fixed and/or mobile users. Routing is the key issue of WiMAX. Various modulation techniques have been studied. It was mandatory to evaluate the performance of WIMAX 802.16 technology by evaluating the Bit-Error Rate (BER) of OFDM physical layer under different modulation schemes and channel conditions. In this work, with the performance investigation of the WIMAX system under different applications generating high load data traffic, various modulation schemes like BPSK, QPSK, QAM 64 etc. were introduced. The performance of WIMAX physical layer is analysed based on the simulation results of Bit-Error Rate (BER) and Signal-to-Noise Ratio (SNR) and the results are represented in the form of tables and graphs. Creating the simulation scenario that is equivalent to real world is the first step of simulation. In this work, various modulation techniques used by OFDM physical layer of WIMAX 802.16 are implemented. To generate data in the network, applications generating high load data traffic at VBR will be designed. A discrete event simulator called OPNET (Optimized Network Engineering Tool) Modeller version 14.0 is used to implement all the mechanisms by using the process models provided by the library of the simulator. In the last various performances evaluation metrics are used to gather the results of Bit Error Rate (BER) and Signal to Noise Ratio (SNR) in tabular and graphical form and conclusion is drawn based on the gathered results.

Keywords: IEEE 802.16 WiMAX, Physical layer, OPNET, Modulation techniques, Bit Error Rate.

I. INTRODUCTION

WiMAX (Worldwide Interoperability for Microwave Access) technology enables ubiquitous delivery of wireless broadband service for fixed and/or mobile users, and became a reality in 2006 when Korea Telecom started the deployment of a 2.3 GHz version of mobile WiMAX service called WiBRO. The fixed wireless versions of WiMAX (IEEE 802.16-2004) have mostly been applied to broadband wireless backbone applications. Because this technology was developed for commercial licensed applications, the quality of service feature was well established, thus, it can support differentiated service levels. The fixed version of WiMAX operates with a TDM (Time Division Multiplexing) data stream on the downlink and TDMA (Time Division Multiple Access) on the uplink communications with a centralized scheduler controlling access. Mobile WiMAX on the other hand utilizes Scalable Orthogonal Frequency Division Multiple Access (S-OFDMA) with a scheduler controlling frequency selective access both on the uplink and downlink depending on five different service categories.

II. IEEE 802.16 WiMAX

The IEEE 802.16 specifications were designed with the focus on flexibility, thus leaving several parts as optional and allowing various BS and MS implementations. Moreover, the standard only deals with the MAC and physical layers, without defining the over-the-air upper layer signaling nor the overall network architecture and protocols. These two factors were the main catalyst for the establishment, in 2001, of the WiMAX. Since its birth, the goal of the WiMAX Forum has been to enable conformity and inter-operability of SSs and BSs based on IEEE 802.16. Since June 2008, the WiMAX Forum has been working on a new version of the Mobile WiMAX, called Release 1.5, based on the latest IEEE 802.16-2009 standard. This release is aimed at enabling mobile WiMAX in new spectrum bands, including those for FDD operation, addressing the most recent MAC improvements, and introducing advanced network capabilities.

III. WiMAX RF PHYSICAL LAYER AND MODULATIONTECHNIQUES

The use of WiMAX is starting to grow rapidly, and many manufacturers are producing WiMAX equipment. One of the areas of particular interest is the WiMAX RF physical layer or air interface as this governs the radio signal that is transmitted and received. The WiMAX, 802.16-2004 standards describes four different RF or air interfaces dependent upon the application envisaged. Of these the one that is intended for non-line of sight applications up to 30 km and for frequencies below 11 GHz is the most widely implemented at the moment. As a result it is often thought of as the WiMAX air interface. The WiMAX RF signal uses OFDM (orthogonal frequency division multiplex) techniques and the signal incorporates multiples of 128 carriers in a total signal bandwidth that may range from 1.25 to 20 MHz. A summary of the different modulation access / modulation technologies and oversampling rates is given in the table below:

Table 1: Channel bandwidth

ATTRIBUTE/ CHANNEL BANDWIDTH (MHZ)	1.25	3.5	5	10
Physical layer modulation / access mode	128 OFDMA	256 OFDMA	512 OFDMA	1024 OFDMA
Oversampling	28/25	8/7	28/25	28/25

In digital modulation techniques a set of basic functions are chosen for a particular modulation scheme. Generally the basic functions are orthogonal to each other. Basis functions can be derived using ‘Gram Schmidt orthogonalization procedure. Once the basis function are chosen, any vector in the signal space can be represented as a linear combination of the basic functions.

a) BPSK (Binary Phase Shift Keying)

In Binary Phase Shift Keying (BPSK) only one sinusoid is taken as basis function modulation. Modulation is achieved by varying the phase of the basis function depending on the message bits. The constellation diagram of BPSK will show the constellation points lying entirely on the x axis. It has no projection on the y axis. This means that the BPSK modulated signal will have an in-phase component but no quadrature component. This is because it has only one basis function. A BPSK modulator can be implemented by NRZ coding the message bits (1 represented by +ve voltage and 0 represented by -ve voltage) and multiplying the output by a reference oscillator running at carrier frequency.

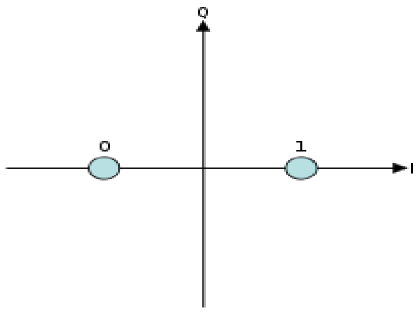

Fig. 1 Constellation map of BPSK Modulator

b) DPSK (Differential phase shift keying)

Differential phase shift keying isa common form of phase modulation conveys data by changing the phase of carrier wave. In Phase shift keying, High state contains only one cycle but DPSK contains one and half cycle. Figure illustrates PSK and DPSK Modulated signal by 10101110 pulse sequence High state is represented by a M in modulated signal and low state is represented by a wave

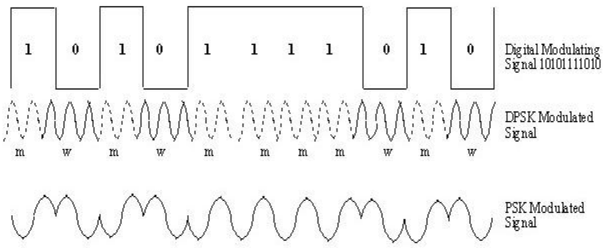

Fig. 2DPSK and PSK modulated signals

which appears like W in modulated signal DPSK encodes two distinct signals of same frequency with 180 degree phase difference between the two.

c) GMSK (Gaussian Minimum Shift Keying)

GMSK modulation is based on MSK, which is itself a form of continuous-phase frequency-shift keying. One of the problems with standard forms of PSK is that sidebands extend out from the carrier. To overcome this, MSK and its derivative GMSK can be used.

MSK and also GMSK modulation are what is known as a continuous phase scheme. Here there are no phase discontinuities because the frequency changes occur at the carrier zero crossing points. This arises as a result of the unique factor of MSK that the frequency difference between the logical one and logical zero states is always equal to half the data rate. This can be expressed in terms of the modulation index, and it is always equal to 0.5.

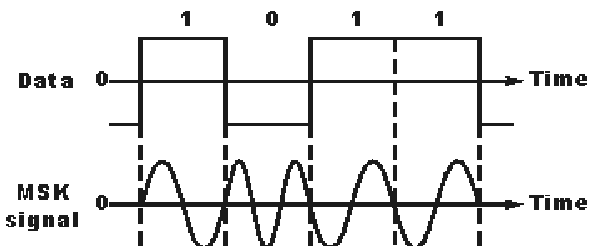

Fig 3GMSK Signal using MSK modulation

d) QAM (Quadrature Amplitude Modulation)

Quadrature Amplitude Modulation, QAM is a form of modulation that is a combination of phase modulation and amplitude modulation. The QAM scheme represents bits as points in quadrant grid know as constellation map.

Constellation map

It is a graph of the phase and amplitude modulation points in a given modulation scheme.

A) Shown below is the constellation map of 16-QAM

16-QAM Symbol = 4 bits

2 ^ 4 bits = 16

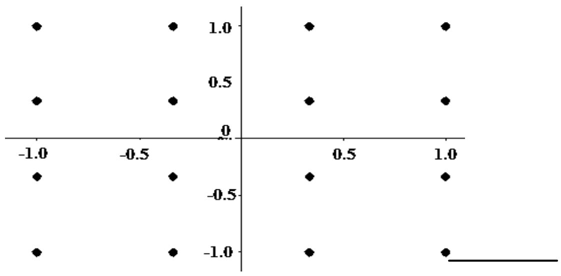

Fig. 4 Constellation map of 16-QAM

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B) Shown below is the constellation map of 64-QAM
64-QAM
Symbol = 6 bits
2 ^ 6 bits = 64

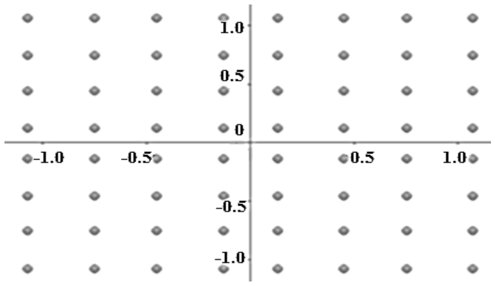

Fig. 5 Constellation map of 64-QAM

IV. CONFIGURATION PARAMETERS

a) OFDM physical layer configuration

Table 2: OFDM physical layer

Attributes	Values
Frame duration (milliseconds)	5
Symbol duration (microseconds)	102.86
Number of Subcarriers	2048
Duplexing Technique	TDD
Base Frequency (GHz)	5 GHz
Bandwidth (MHz)	5.0 MHz

b)General Configuration Parameters:

Table 3: General configuration Parameters

Attributes	Values
Maximum Sustained Traffic Rate (bps)	5 Mbps
Minimum Reserved Traffic Rate (bps)	384
Maximum Latency (milliseconds)	30.0
Number of Retries	Distribution Name (uniform_int) Minimum Outcome (1) Maximum Outcome (10)
Number of Nodes	40
Simulation Duration	30 minutes
Simulation Kernel Type	Optimize
Trajectory	Vector

V. SIMULATION ENVIRONMENT AND PARAMETERS

Creating the simulation scenario that is equivalent to real world is the first step of simulation. In this work, various modulation techniques used by OFDM physical layer of WIMAX 802.16 are implemented. To generate data in the network, applications generating high load data traffic at VBR will be designed. A discrete event simulator called OPNET(Optimized Network Engineering Tool) Modeller version 14.0is used to implement all the mechanisms by using the process models provided by the library of the simulator. In the last various performances evaluation metrics are used to gather the results of Bit Error Rate (BER) and Signal to Noise Ratio (SNR) in tabular and graphical form and conclusion is drawn based on the gathered results.

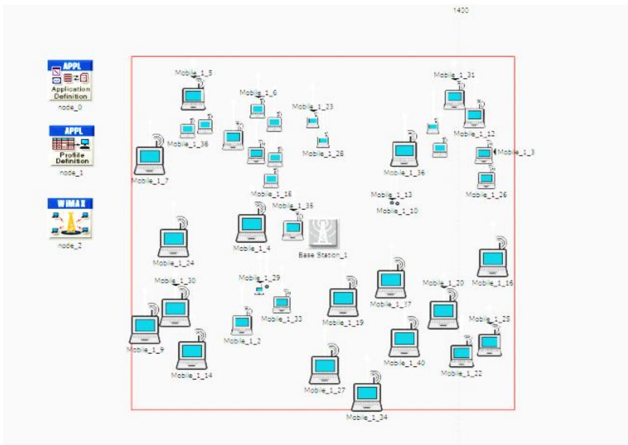

Fig 6: WiMAX Network Model

5.1 PERFORMANCE METRICS

Metrics is a property of a route in computer networking, consisting of any value used by routing algorithms to determine whether one route should perform better than another. The routing table stores only the best possible routes, while link-state or topological databases may store all other information as well. For the comparison of protocols under the applications generating heavy traffic, four different metrics can be chosen.

5.1.1 DELAY

The packet end to end delay is the average time that packets take to transverse the network. This is the time from the generation of the packet by the sender up to their reception at the destination application layer and is expressed in seconds. It therefore includes all the delays in the network such as transmission delay, processing delay and the propagation delay. Mathematically

$D_{end\text{-}end} = D_{trans} + D_{prop} + D_{proc}$

Where,

$D_{end\text{-}end}$ = End to end delay
D_{trans} = Transmission delay
D_{prop} = Propagation delay
D_{proc} = Processing delay

5.1.2 THROUGHPUT

Throughput is the measurement of number of packets passing through the network in a unit of time. This metric show the total number of packets that have been successfully delivered to the destination nodes. The throughput is defined as the total amount of data a receiver receives from the sender divided by the time it takes for the receiver to get the last packet. It is expressed in bits per second or packets per second. Factors that affect throughput include frequent topology changes, unreliable communication, limited bandwidth and limited energy. A high throughput network is desirable.

5.1.3 TRAFFIC RECEIVED (BITS/SEC)

Data traffic successfully received by the WiMAX MAC from the physical layer in bits/sec. While computing the size of the received packets for this statistic, the physical layer and MAC headers of the packet are also included.

5.1.4 TRAFFIC SENT (BITS/SEC)

Data traffic transmitted by the WiMAX MAC in bits/sec. While computing the size of the transmitted packets for this statistic, the physical layer and MAC headers of the packet are also included.

VI. SIMULATION RESULTS AND ANALYSIS

After designing the network scenario, the simulation is done for modulation schemes like BPSK, QPSK, QAM 16 and QAM 64. Various results obtained are present and discussed in the subsequent subsections.

a) DELAY

It has been observed that QAM16 has the lowest delay out of the all modulations. It was followed by QAM whose value is initially increased, then decreased. BPSK has higher value of delay. This is because as end to end delay is less, packets takes less time to transverse the network. Therefore QAM16 performance is better than other modulations in case of end to end delay.

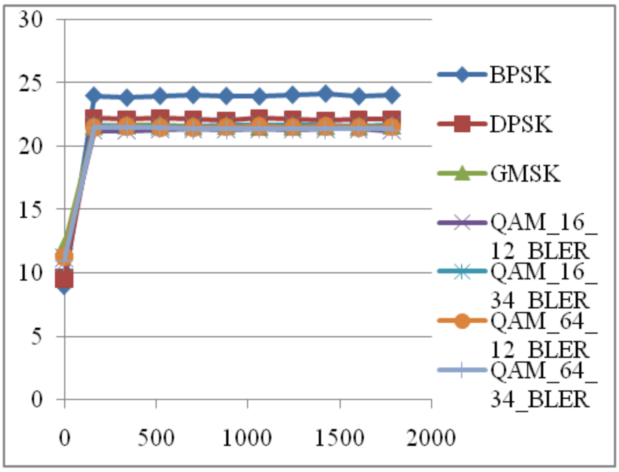

Fig 7: Delay for WiMAX

B)THROUGHPUT

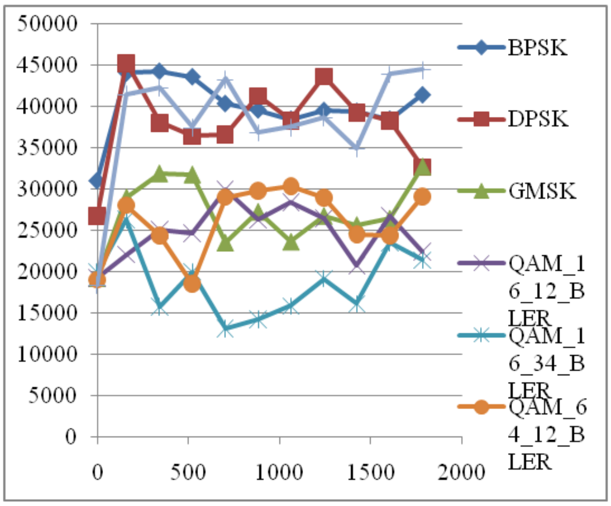

Fig. 8: Throughput for WiMAX

Initially the throughput of all modulations increases and attains peak value and after that gradually degrades with increase in time. The peak point of BPSK is 44311.11 bps, DPSK is 45349.33, GMSK is 31907.56, QAM_16_12_BLER is 29969.78, QAM_16_34_BLER is 26403.56, QAM_64_12_BLER is 24357.33 and that of QAM_64_34_BLER is 42357.33 bps and then both the values exponentially decreased. Since throughput is the ratio of the total amount of data that a receiver receives from the sender to the time it takes for the receiver to get the last packet. Comparing the performance of all modulations, the throughput of BPSK performs better.

c) TRAFFIC RECEIVED

It has been concluded that the Traffic received inQAM16 is lower. In all modulations, Traffic received increases and then decreases.

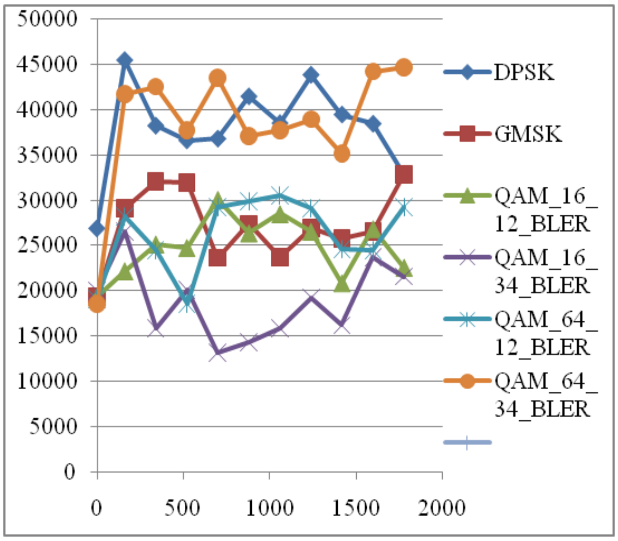

Fig. 9: Traffic received for WiMAX

d) TRAFFIC SENT

It has been concluded that the Traffic sent in BPSK is lower and QAM16 is higher. In all modulations, Traffic sent decreases increases and then increases.

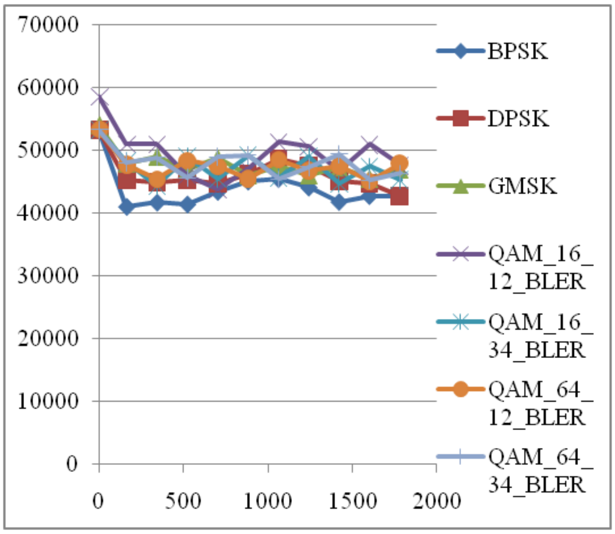

Fig.10: Traffic sent for WiMAX

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VII. CONCLUSIONS

In this work, a simulation based analysis of different modulation schemes such as BPSK, DPSK, GMSK, QAM 16 and QAM 64 has done under the different bit error rates and signals to noise ratio. IEEE 802.16 (WiMAX) has been used as the MAC layer technology for the deployment of networks. All the networks are deployed using ad hoc network based deployment. To evaluate the performance of different modulation techniques using certain conditions, discrete event based simulator 'OPNET' has used. After the intensive simulations, it has seen that in all the given conditions, BPSK modulation technique gives a very stable performance than the other used modulation techniques. As throughput has considered as a primary performance evaluation metrics in the literature, it can be seen that BPSK, DPSK and QAM 64 outperforms all other modulation techniques. But on the bases of the results of other performance evaluation metrics, use of BPSK has been recommended over the DPSK and QAM 64 under the given conditions.

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