Quantitative analyses and evaluation of various modulation techniques in effect of varying SNR and cyclic prefix over WiMAX environment

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Abstract— Wireless networks are generally less efficient and unpredictable compared to wired networks, which make quality of service (QoS) provisioning a bigger challenge for wireless communications. The evergreen demand for fast delivery of large volumes of data is one of the challenging task for wireless communication technology. WiMAX (Worldwide Interoperability for Microwave Access) is a wireless broadband solution that offers a rich set of features with a lot of flexibility in terms of deployment options and potential service offerings. Its main objective is to provide quality with cost effectiveness. But Delivering QoS is more challenging for mobile broadband than for fixed. The time variability and unpredictability of the channel become more acute, and complication arises from the need to hand over sessions from one cell to another as the user moves across their coverage boundaries. The wireless medium has limited bandwidth, higher packet error rate, and higher packet overheads that altogether limit the capacity of the network to offer guaranteed QoS.in this paper, we provide an overview of the cyclic prefixes (Conventional/ Turbo) and service classes that are the key functions in the MAC common part sub layer. In this thesis work, the effect of varying SNR and channel encoding is examined on to analyze and evaluate the performance of different digital modulation schemes namely BPSK, QPSK and QAM under different coging rates [1/2, 2/3, 3/4]. The impact of SNR [5, 10, 15, 20, 25] and cyclic prefixes [1/4, 1/8, 1/16, 1/32] on the performance of these said OFDMA's digital modulation schemes under coding rate [1/2, 2/3, ¾] is observed under NS2 simulator.
Keywords : WiMAX, IEEE 802.16, SNR, BPSK, QPSK,QAM

I. INTRODUCTION

The IEEE 802.16 group has started to produce recommendations for a relatively long period. The evolution of the wireless physical layers is seen in the different versions, the same way it can be noticed in IEEE 802.11 standard. That is why we can see a first physical layer implementing plesiochronous digital hierarchy (PDH) like data rates with a line of sight restrictive condition. Few years later, with the familiarization to OFDM, a new version has come up with “line of sight” restriction removed but with lower throughput. We did not see any IEEE 802.16 equipment in the first editions of the standard, not because the lack of products, but because of the unclear legislation in that area together with the wide deployment of fixed asymmetric digital subscriber line (ADSL) wired lines.

A. WiMAX

WiMAX will boost today's fragmented broadband wireless access market and mobile WiMAX promises to offer a solution to closing the existing digital divide. WiMAX can address the fixed wireless access and portable Internet market, complementing other broadband wireless technologies. Government initiatives to reduce the digital divide are making gains for broadband wireless countries such as Australia, South Korea, Taiwan, and the United States have programs in place today, and there has been a push by the European Commission for more flexible spectrum policies. WiMAX access can be easily integrated within both fixed and mobile architectures, enabling operators to integrate it within a single converged core network, thereby providing new capabilities for a user-centric broadband world. WiMAX addresses the following needs which may answer the question of closing the digital divide :

- Cost effective
- Offers high data rates
- Supports fixed, nomadic, and mobile applications thereby converging the fixed and mobile networks
- Easy to deploy and has flexible network architectures
- Supports interoperability with other networks
- Aimed at being the first truly a global wireless broadband network

WiMAX is a standard that is championed by the WiMAX forum which was formed in June 2001 to promote conformance to IEEE 802.16 standard. The WiMAX forum currently has more than 470 members comprising the majority of operators, component, and equipment companies in the communications ecosystem. The WiMAX forum promotes interoperability by working closely with IEEE and other standards groups such as the European Telecommunications Standards Institute (ETSI) which have their own versions of broadband wireless. Along these lines, the WiMAX forum works closely with service providers and regulators to ensure that WiMAX forum certified systems meet customer and government requirements.

B. WiMAX network architecture

In Figure 1, the overall network architecture of a WiMAX network. The network can be logically partitioned into three components, user terminals, ASN, and CSN. User terminals capture the data origination points, could be using the fixed, mobile, or portable WiMAX technology. All the three variations can be supported using a common air interface. ASN spans the BS and the ASN-GW. BS receives the transmitted signal, processes it, and converts into an IP packet and sends to the GWon the outgoing IP transport link. GWreceives and upon processing determines the destination on the network side and sends the packet. BS and GW are connected to each other using an IP transport. Typical implementations would have BS located in the field/coverage area and the GW will be centrally located in the switch centers. Therefore, the IP link between BS andGW forms the transport backhaul network.

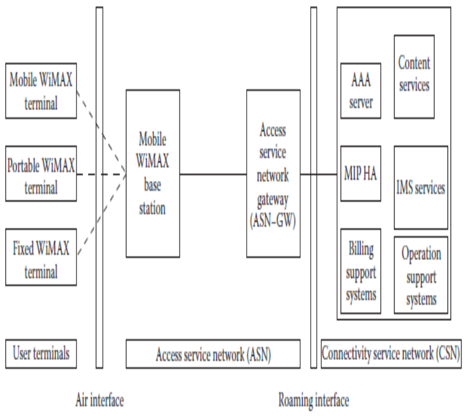

Fig. 1: Logical network architecture of a WiMAX network.

CSN contains many different commercial off-the shelf (COTS) components, which provide connectivity services to the WiMAX subscribers. Addressing, authentication, and availability (AAA) servers, mobile IP home agent (MIP HA), IP multimedia services (IMS), content services, etc. provide support for seamless services to subscribers. AAA servers ensure that a user is uniquely identified and authenticated as legitimate customer. MIP HA ensures that roaming across IP networks is handled and accurate routing of data packets is ensured. Call processing related services is provided by IMS entity. Billing and operational support systems help in managing the overall network.

In Figure 2, typical implementation of a WiMAX network in a market. For example, say a carrier plans to lay down WiMAX network in Washington D.C. market. Typically, we would have more than 100 BSs connecting to a GW location, based on the anticipated traffic, each GW location might require a cluster of servers providing the functions of the GW. Each IP transport link would be leased from the local carrier and provisioned. Based upon the cost points and required capacity, the carrier can choose to directly lease a TDM segment, Ethernet link, fiber connectivity, etc. Components of the CSN located at each switch center might also be implemented using clusters and would have enough capacity to support the entire market. Switch centers could be connected to each other using a high speed IP network running on an OC-192 (or higher) SONET ring leased from local exchange carrier. Actual network would also include connectivity to the other markets, trucking with public switched telephone network (PSTN) via the end office (EO), tandem connections with For most WiMAX networks, it is unlikely that the carriers would provision the IP transport based on the capacity of the WiMAX air interface. According to WiMAX forum, air interface built on 10 MHz channel with 2 × 2 MIMO can support peak downlink rate of 63 Mbps and peak uplink rate of 28 Mbps per sector. Assuming three sectors per BS, this would translate into close to 200 Mbps of backhaul transport for each BS. When we share the symbols 3:1 between DL and UL, it could provide data rates of 46 Mbps DL and 8 Mbps UL per sector. Even then it would require about 150 Mbps of capacity between BS and GW. Such a requirement would lead to an unmanageable backhaul cost, which might become a road block in the large-scale adoption of the WiMAX technology.

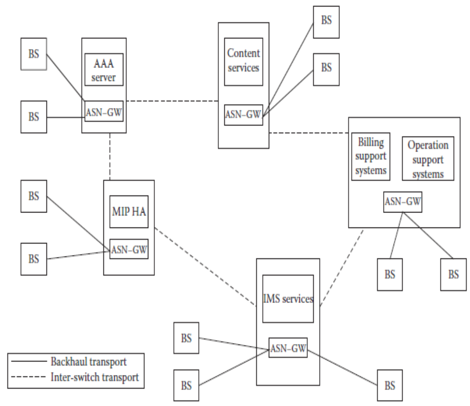

Fig. 2: Physical network architecture of a WiMAX network.

The 802.16 standard is designed to offer the ATM like QoS and a key aspect of the design is the polling-based MAC layer that is more deterministic than contention-based MAC used in other similar standards. TheMAC layer employs a single scheduling data service for each connection and each data service is associated with a set of QoS parameters that quantify its behavior. Like ATM, the 802.16MACalso defines different service classes and specifies up to five separate service classes to provide QoS for various types of applications. The service classes include:

1) Unsolicited grant service (UGS):

It is designed to support real-time service flows generated at CBR. The UGS will be granted periodically without a polling-request procedure and thereby reducing the latency.

2) Real-time polling service (rtPS):

It is designed to support real-time service flows where packets are generate at VBR. This service requires more request overheads and latency compared to UGS, but supports variable grant sizes. The rtPS is suitable for connections carrying services like VoIP or video streaming services.

3) Extended real-time polling service (ertPS):

It is designed to support real-time service flows where packets are generated at variable-size rate on a periodic basis, like VoIP services. ertPS is intended to utilize the efficiency of both UGS and rtPS.

4) Nonreal-time polling service (nrtPS):

It is designed to accommodate delay-tolerant data streams that consist of variable-size data packets. These services are capable of tolerating longer delays and are relatively insensitive to delay jitter. The nrtPS is appropriate for Internet services with a minimum guaranteed rate like File Transfer Protocol (FTP) and Hypertext Transfer Protocol (HTTP).

5) Best Effort (BE) service:

The BE service is designed to facilitate data streams that have no minimum service requirement and therefore may be supported on a resource availability basis such as e-mail. For BE, throughput and delay guarantees are not required.

C. Digital Modulations

As for all recent communication systems, WiMAX /802.16 uses digital modulation. The now well-known principle of a digital modulation is to modulate an analogue signal with a digital sequence in order to transport this digital sequence over a given medium: fibre, radio link, etc.. This has great advantages with regard to classical analogue modulation: better resistance to noise, use of high-performance digital communication and coding algorithms, etc.

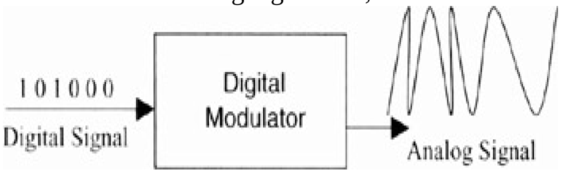

Fig. 3: Digital modulation principle

Four modulations are supported by the IEEE 802.16 standard BPSK, QPSK, 16-QAM and 64-QAM. In this section the modulations used in the OFDM and OFDMA PHYsical layers are introduced with a short explanation for each of these modulations.

1) Binary Phase Shift Keying (BPSK) :

The BPSK is a binary digital modulation; i.e. one modulation symbol is one bit. This gives high immunity against noise and interference and a very robust modulation. A digital phase modulation, which is the case for BPSK modulation, uses phase variation to encode bits: each modulation symbol is equivalent to one phase. The phase of the BPSK modulated signal is π or -¯π according to the value of the data bit.

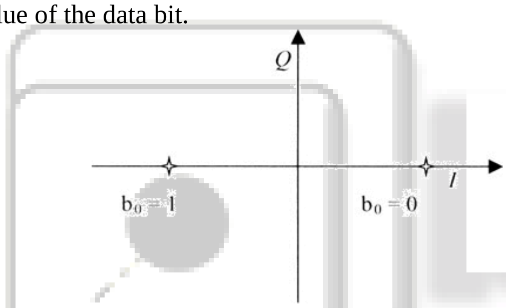

Fig. 4: The BPSK constellation

2) Quadrature Phase Shift Keying (QPSK) :

When a higher spectral efficiency modulation is needed, i.e. more b/s/Hz, greater modulation symbols can be used. For example, QPSK considers two-bit modulation symbols.Many variants of QPSK can be used but QPSK always has a four-point constellation.

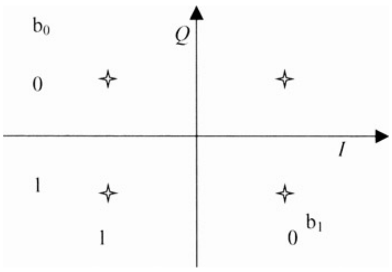

Fig. 5: Example of a QPSK constellation

3) Quadrature Amplitude Modulation (QAM): 16-QAM and 64-QAM :

The QAM changes the amplitudes of two sinusoidal carriers depending on the digital sequence that must be transmitted; the two carriers being out of phase of +π/2, this amplitude modulation is called quadrature. It should be mentioned that according to digital communication theory, QAM-4 and QPSK are the same modulation (considering complex data symbols). Both 16-QAM (4 bits/modulation symbol) and 64-QAM (6 bits/modulation symbol) modulations are included in the IEEE 802.16 standard.

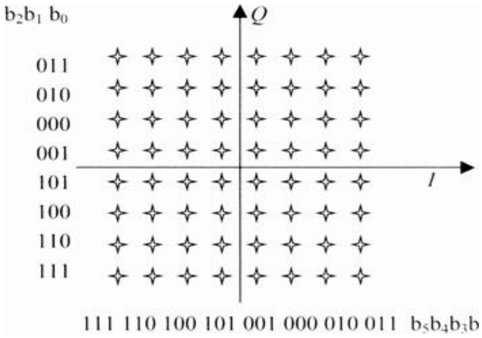

Fig. 6: A 64-QAM constellation

II. RELATED WORK

In [1], Z.M. Elkwash et.al. designed a simulator of WiMAX communication system using Simulink of MATLAB. The authors examine the effect of the cyclic prefix on the bit error rate (BER) with different types of modulation techniques such binary phase shift key,*Quadrature amplitude modulation* that are based on variation in gain vector, delay vector, and signal to noise ratio. In this paper, Performance evaluation is done based on various factors and for different modulation techniques with several code rates. The BER is plotted versus the cyclic prefix, for three cases with different values of delay vector [0 le-6], [0 3e-6], [0 5e-6], and [0 8e-6], gain vector [0-1], [0-3], [0-5], and [0-8], SNR 15, 30, 45, and 60. Different delay vectors, gain vectors, different SNR values were checked against different modulation techniques with several code rates. It was found that WiMax system gave good performance at delay vector of [0 le-6], gain vector of [0-4], cyclic prefix of (1/4), and modulation techniques are 4-QAM, and 16-QAM with coding rate of (2/3).Under BPSK modulation, the best result comes for gain vector [0-5] and CP of (1/\6) with delay gain [0\e-6] and SNR of 60. SNR has a small influence on the BER performance, and the lower BER is presented at SNR of 60. Under 4QAM modulation, the best result comes for gain vector [0-5] and CP of (1/4), but with decrease the CP, the best result comes for gain vectors [0 3], [0 8] and CP of(1/16) and (1/32) and variation of SNR has the small influence on the BER performance, and the lower BER is presented at SNR of 44.Under 4QAM modulation, the best result comes for gain vector [0-3] and CP of(1/32) and the variation of SNR has the small control on the BER performance, and the best BER obtained at SNR of 60 and CP of (1/32). Under 16-QAM modulation, the best result comes for gain vector [0-5] and CP of (1/4), (1/16), and (1/32) and the variation of SNR has the little impact on the BER performance, the lower BER is presented at SNR of 60 and CP of (1/4), (1/16), and (1/32). Under 16-QAM modulation, the best result comes for gain vector [0-1] and CP of(1/32) and SNR which has a small influence on the BER performance but the lower BER is presented at SNR of 60 and CP of (1/32). Under 16-QAM modulation, the best result comes for gain vector [0-3] and CP of(1/16), the variation of SNR has the small influence on the BER performance, and the lower BER is presented at SNR of 60 and CP of (1/16). Under 64-QAM modulation, the best results come for gain vectors [0-3] and [0-5] and CP of (1/4), and (1/16) but there is no major impact of SNR on the BER, and the lower BER is presented at SNR of 60 and CP of (1/16), and the highest BER is occurred at SNR of 15, and 30.Analysis results of RS, CC Encoding with coding rate (2/3), and (5/6), the BER performance has a variable behavior with a CP, but in the coding rate (3/4) gives the lower values of BER. the modulation techniques 4-QAM (2/3), and 16-QAM (2/3) give the lowest values of BER at CP of (1/4), (1/16), and (1/32), but at CP of (1/8) the BPSK technique gives the lowest value of BER. the values of cyclic prefix (1/4), gain vector [0-4] , and delay vector [0 le-6], that give the lowest values of BER are chosen to evaluate the performance the WiMax system. the BER decreases when SNR greater than 25, and the 4-QAM(2/3),and 16-QAM(2/3) give the lowest values of BER when compared with other modulation techniques.

In [2] Tarik Anouari et al. investigate the performances of the most common VoIP codecs, which are G.711, G.723.1 and G.729 over a WiMAX network using various service classes and NOAH as a transport protocol. Voice Over Internet Protocol is a promising new technology which provides access to voice communication over internet protocol based network, it becomes an alternative to public switched telephone networks due to its capability of transmission of voice as packets over IP networks. Therefore VoIP is largely intolerant of delay and hence it needs a high priority transmission. protocol . To analyze the QoS parameters, the popular network simulator ns-2 was used. Various parameters that determine QoS of real life usage scenarios and traffic flows of applications is analyzed. The objective is to compare different types of service classes with respect to the QoS parameters, such as, throughput, average jitter and average delay.

C. Chiang et al. [3], propose an Adaptive Split Ratio (ASR) scheme which adjusts the bandwidth ratio of DL to UL adaptively according to the current traffic profile, wireless interference, and transport layer parameters, so as to maximize the aggregate throughput of TCP based traffic. The authors study adaptive channel split ratio of uplink to downlink capacities in TDD-based IEEE 802.16 (WiMAX) wireless networks. ASR can also cooperate with the BS scheduler to throttle the TCP source when acknowledgements are transmitted infrequently, thus preventing either direction (i.e., downlink or uplink) from becoming the bottleneck. The simulation results show that our adaptive scheme outperforms static allocations in terms of higher aggregate throughput and better adaptivity to network dynamics.

In [4], Rakesh Kumar Jha et al. present a concept of our WiMAX (Worldwide Interoperability for Microwave Access) network per-formance for QoS monitoring and optimization solution for BS (Base Station) with multimedia application. In the com-munication sector, the optimal objective is to equate quality and cost. Due to its large coverage area, low cost of de-ployment and high speed data rates. WiMAX is a promising technology for providing wireless last-mile connectivity. Physical and MAC layer of this technology refer to the IEEE 802.16e standard, which defines 5 different data delivery service classes that can be used in order to satisfy Quality of Service (QoS) requirements of different applications, such as VoIP, videoconference, FTP, Web, etc. In this paper we have made six scenarios. Here two types of MAC layer QoS are used and they are UGS and rtPS having application of Voice over IP (VoIP) and MPEG respectively. Also the traf-fic priority for UGS is high as compared to rtPS. In each scenario the number of fixed nodes (Fixed Subscriber Stations) and Mobile nodes (Mobile Subscriber Stations) are different. To cover more nodes or if nodes are outside the coverage area more than one BS are required.

In [5], L.D.Malviya et.al present an Adaptive modulation enables a WiMAX system to optimize the throughput based on propagation conditions. IEEE802.16 (WiMAX) system support BPSK, QPSK, 16-QAM and 64-QAM and the access scheme is OFDM. This paper presents the performance of different variants of transmission control protocols with different modulation schemes when density of mobile nodes changes.

Shraddha Bansal et al. [6], investigate the performance of mobile Wi-Max, its physical layer is simulated using Matlab and bit error rate (BER) performance is observed. Further performance improvement is achieved using forward error correction codes (FEC). Two codes, convolution code (CC) and low density parity check code (LDPC) are considered for this purpose. BER performance is evaluated for these codes under different conditions.

In [7], Tarik Anouari et al. investigate the performances of the most common VoIP codecs, which are G.711, G.723.1 and G.729 over a WiMAX network using various service classes and NOAH as a transport protocol. Voice Over Internet Protocol is a promising new technology which provides access to voice communication over internet protocol based network, it becomes an alternative to public switched telephone networks due to its capability of transmission of voice as packets over IP networks. Therefore VoIP is largely intolerant of delay and hence it needs a high priority transmission. protocol . To analyze the QoS parameters, the popular network simulator ns-2 was used. Various parameters that determine QoS of real life usage scenarios and traffic flows of applications is analyzed. The objective is to compare different types of service classes with respect to the QoS parameters, such as, throughput, average jitter and average delay.

Chenn-Jung Huanget al. in [8] proposed a routing protocol which utilizes the characteristics of Bluetooth technology for Bluetooth based MANET. They maintained routing tables in the master devices and adjusted routing zone radius for each table dynamically by using evolving fuzzy neural networks.

Laxmi Shrivastava et. al. [9], a new algorithm named as load balancedcongestion adaptive routing (LBCAR) algorithm hasbeen proposed for randomly distributed networks in which two metrics - traffic load density and life timeassociated with a routing path, have been used todetermine the congestion status and weakest node of theroute and the route with low traffic load density andmaximum life time is selected for packet transmission.This algorithm combines the idea of load balancing and congestion adaptiveness effectively in AODV and limits the idealized maximum number of packets transmittable through the route having weakest node with minimum life time. It can adaptively adjust the forwarding probability of RREQ messages according to the distribution and load status of nodes and link cost in route discovery phase. Simulation results indicate that, compared with original AODV and DSR, LBCAR can significantly reduce the packet loss balancing the load in the network and increasing the network life time with varying pause time.

In [10], J. B. Othman et.al. present a new admission control (AC) for IEEE 802.16. The AC aims to accept new connections according to the negotiated service class (UGS, rtPS, nrTPS, and BE).

III. PROPOSED METHODOLOGY

These are specific implementations, selections of options within the 802.16e standard, to suit particular ensembles of service offerings and subscriber populations. Although the resource allocation for OFDM-based networks has been well studied in the literature, few modulation schemes have been specifically designed for WiMAX. These schemes should be modified or new schemes should be defined for OFDM-based WiMAX to effectively utilize the network resources and improve the network performance for integrated voice, video, and data services over fixed, nomadic, portable, and fully mobile users. An appropriate resource allocation scheme for OFDM based WiMAX should consider diverse QoS requirement of heterogeneous traffic and mobility issues simultaneously, because a scheme that guarantees QoS for one type of traffic in a fixed network may not perform well for a different type of traffic in a fully mobile network. Moreover, the scheme should balance between users requirements and service providers revenue.

A. Simulation And Results

In this paper, the effect of cyclic prefix (conventional/turbo) on the bit error rate with different type of Signal to Noise Ratio (SNR) under various available modulation techniques. UDP has been considered as transport protocol and CBR as traffic generator. Performance evaluations are based on the simulation using ns2

B. Research Methodology

Ns-2 is an open source discrete event simulator used by the research community for research in networking. It has support for both wired and wireless networks and can simulate several network protocols such as TCP, UDP, multicast routing, etc. More recently, support has been added for simulation of large satellite and ad hoc wireless networks. The ns-2 simulation software was developed at the University of Berkeley. It is constantly under development by an active community of researchers.

The standard ns-2 distribution runs on Linux. However, a package for running ns-2 on Cygwin (Linux Emulation for Windows) is available. In this mode, ns-2 runs in the Windows environment on top of Cygwin as shown in the figure 7.

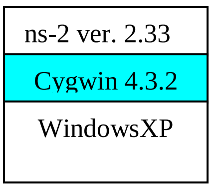

Fig.7: ns-2 over Cygwin

NS-2 provides a split-programming model; the simulation kernel is implemented using C++, while the Tcl scripting language is used to express the definition, configuration and the control of the simulation. This split-programming approach has proven benefits over conventional programming methods. Also, NS-2 can produce a detailed trace file and an animation file for each ad hoc network simulation that is very convenient for analyzing the routing behavior.

Parameter	Value
Simulation time	200 Sec
Simulation area	1500m x 1500m
Antenna	Omni antenna
No. of subscriber	50
Traffic	CBR
Routing protocol	NOAH
Mobilty Model	Random Waypoint Model
Cyclic Prefix	1/4,1/8, 1/16, 1/32
Modulation technique	BPSK , QPSK , 16 QAM, 64 QAM
Transmission range	1200m
Modulation Coding Rates	1/2, 3/4, 2/3
Scheduling scheme	rtPS

. Table. 1: Salient Simulation Parameters

There are many parameters which can be used to evaluate the performance of routing protocols. Performance metrics are considered as follows**:**

1) Throughput

Number of bits delivered successfully per second to the destination. It is the measure of effectiveness. The figure 8 and figure 9 shows the impact of SNR and conventional/turbo codes on the throughput for three different modulation schemes. It is observed from simuation graphs that the throughput of QPSK is better than QAM and BPSK under different coding rates.

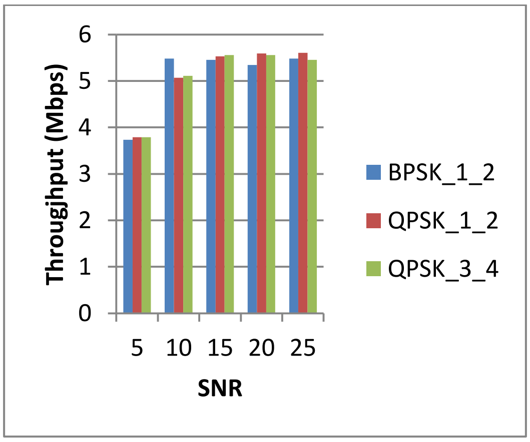

Fig. 8: Throughput versus SNR

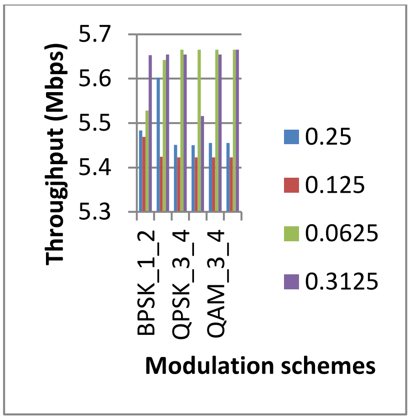

Fig. 9: Throughput versus Cyclic prefixes

2) Packet Delivery Ratio

The ratio of data packets delivered to the destinations to those generated by the sources. Figure 10, shows the packet delivery ratio when the SNR is varied. Simulation results shows all modulation scheme namely BPSK, QPSK and QAM gives higher performace when SNR is highers. Comparsion of simulation results depicts that modulation scheme QPSK gives better performance than other two schemes.

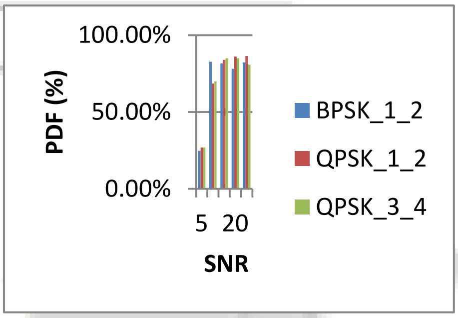

Fig. 10: PDR versus SNR.

Figure 11 shows the packet delivery ratio when the Cyclic prefix is varied. Simulation results shows modulation scheme QPSK under coding rate 1/2 gives higher performace when cyclic prefixis is 1/32 and SNR is 25. It is observed that the packet delivery ratio of QPSK under higher turbo code 1/32 and SNR 25, gives better reslts than BPSK and QAM.

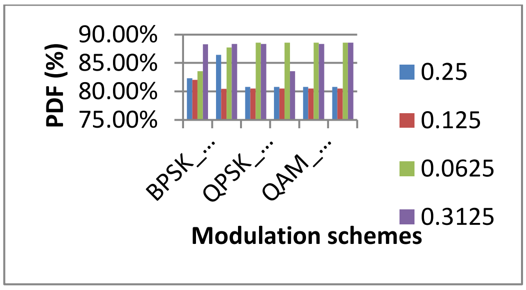

Fig. 11: PDR versus Cyclic prefixes

3) Average Delay

The average delay a data packet takes to travel from the source to the destination node. The figure 12 and figure 13 shows the impact of SNR and conventional/turbo codes on the average end to end delay for three different modulation schemes under different coding rates.

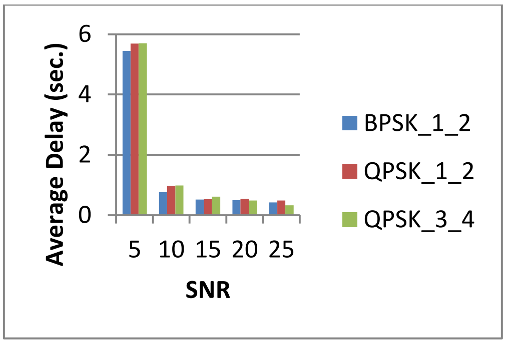

Fig. 12: Average delay versus SNR

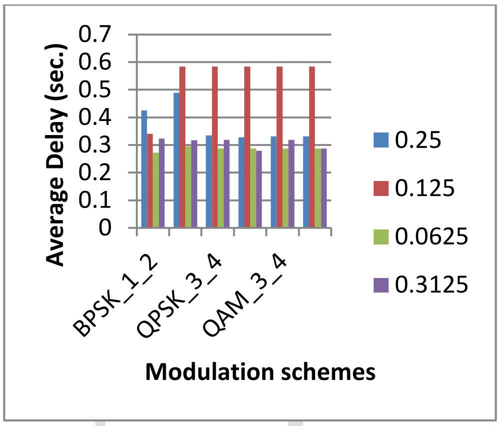

Figure 13: Average delay versus Cyclic prefixes

It is observed from simulation graphs that the throughput of BPSK is better than QAM and QPSK under different coding rates. Comparsion of the graphs (figure 4.8 and 4.9) depicts that BPSK under ½ coding rate performance better as compare to QPSK and QAM when SNR is higer and encoding scheme is 1/16.

IV. CONCLUSION AND FUTURE WORK

In this paper, the effect of SNR and Convention/Turbo codes is examined on to compare the performance of three QoS service classes namely BPSK, QPSK and QAM under different coging rates. WiMAX networks promise to offer an easy deployable and relatively low cost solution for the wireless broadband access. In usual operating conditions, WiMAX will likely support traffic belonging to a wide range of broadband applications, and it is claimed to provide differentiation among heterogeneous demanding flows. Channel encoding and QoS services classes are the key components to provide QoS capability and proportional fairness in the bandwidth sharing over a changing radio environment. The simulation results were presented for SNR 5, 10, 15, 20, and 60, for different modulation techniques with several code rates. From the simulation results it is observed that QPSK under coding rate ½, has best all-round performance under both SNR and channel encoding scenarios considered. BPSK in terms of average end to end delay performs almost similar to QPSK but for packet delivery ratio and throughput QPSK performs better than both BPSK and QAM . Based on our simulation results, we conclude that, suitable parameters that give a good performance of a WiMAX system are SNR of 25, cyclic prefix of (1/32), and modulation techniques are QPSK with coding rate of (1/2).

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