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A Performance Evaluation Of IEEE 802.16e Networks For TCP And UDP Traffics

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Abstract

Evaluation of the performance of a WiMAX network is essential before its deployment. In this paper, we evaluate the performance of IEEE 802.16e which is also called Mobile WiMAX. We focus on the following performance parameters: (i) average delay, (ii) throughput, and (iii) jitter. We evaluate the effects of the number of subscriber stations, the distance between the subscriber station and its base station, modulation schemes combined with coding techniques on the performance parameters.

1. Introduction

WiMAX stands for *Worldwide Interoperability for Microwave Access*. It is based on wireless metropolitan area network standards developed by IEEE 802.16 group. It provides solution to constantly increasing demands for broadband wireless applications. Broadband wireless applications include audio and video streaming, streaming a live sporting event, Voice over IP (VoIP), and IP television (IPTV).

WiMAX operates in both 10-66 GHz (licensed frequency band) as well as 2-11 GHz (unlicensed frequency band) for *line of sight* (LOS) and *non-line of sight* (NLOS) operation, respectively. The WiMAX network technology is an evolutionary one as it uses *Orthogonal Frequency Division Multiplexing* (OFDM) which makes the transmissions to resist to fading and multipath effects. The early WiMAX solution, which is based on IEEE 802.16-2004, is also known as fixed WiMAX. After this, the newer version, IEEE 802.16-2005, which is also called Mobile WiMAX, is capable of supporting nomadic and mobile users. In addition, a WiMAX network can work as a point-to-point backhaul trunk with a transmission capacity of around 72 Mbps for a transmission distance of around 30 miles. With its technological advantages of power, throughput, transmission range, WiMAX might be a strong competitor of other technologies, such as WiFi and 3G. It is the capability of WiMAX networks in providing high bandwidth with QoS deployed over large areas which is seen as key advantage of WiMAX.

In [3], throughput and packet access delays of best-effort service of a saturated IEEE 802.16 network are analyzed using contention based multiple access techniques. Specifically, a simple fixed-point analytical model to approximate the failure probability of a request to allocate bandwidth is developed and expressions for throughput and delays are presented. In [4], the quality of service as implemented by the WiMAX networks is analyzed. Various real life scenarios like voice call, video streaming are setup in the simulation environment. Parameters that indicate quality of service, such as, throughput, packet loss, average jitter and average delay, are analyzed for different types of service flows as defined in WiMAX.

In [5], the performance of WiMAX system in various morphological scenarios, namely, dense urban, urban, and sub-urban is investigated. In [6], an evaluation of the performance of *point-to-multipoint* (PMP) mode of WiMAX is carried out. Therein, the focus is on the evaluation of the effects of using different scheduling algorithms such as Weighted Fair Queuing (WFQ), Round Robin (RR), Weighted Round Robin (WRR) and Strict Priority (SP) and how each scheduling algorithm supports different services such as Unsolicited Grant Service (UGS), Real Time Polling Service (rtPS) and Extended Real Time Polling Service (ertPS).

In [7], the effects of employing scheduling algorithms such as RR, Max *Carrier to Interference Noise Ratio* (CINR) (MC), Fair Throughput (FT) and Proportional Fair (PF) are evaluated for Mobile WiMAX. A discussion of the implementation methodologies and tradeoffs associated with these scheduling algorithms is also provided. In [8], the performance of WiMAX from the viewpoint of an optimal boundary per WiMAX cell under different WiMAX network models is presented. In [9], a comparison of the effects of employing First-In First-Out (FIFO) and Deficit Round Robin (DRR) on the performance of WiMAX is provided.

In [10], a performance comparison of the effects of employing User Datagram Protocol (UDP), Stream Control Transmission Protocol (SCTP) and Datagram Congestion Control Protocol (DCCP) protocol for transporting video traffic over WiMAX is presented. It is observed that DCCP performs better than SCTP which in turn performs better than UDP. However, a comparison of the performance of Mobile WiMAX under UDP and TCP traffic is not available in [10].

In this paper, we evaluate the performance of IEEE 802.16e, which is also called Mobile WiMAX, under TCP and UDP traffics. We focus on the throughput, delay, and jitter as the major performance parameters. We evaluate impacts of the number of subscriber stations, distance of a subscriber station from the base station, and the modulation and encoding techniques.

The rest of paper this organized as follows. Section II provides problem formulation. In Section III, we describe an overview of IEEE 802.16e or Mobile WiMAX. Section IV contains results and discussion. The last section is for conclusion.

2. Problem Formulation

There are some applications which can tolerate packet loses, however, those are delay sensitive, e.g. multimedia streaming. Alternatively, if someone is watching a movie over the Internet, the packet losses will degrade the quality. If losses are not too much, the application will run. However, if there are large packet delays, there will be several glitches which are not acceptable. The applications which are delay sensitive require faster transport layer services. Often User Datagram Protocol (UDP) is recommended for these applications instead of Transport Control Protocol (TCP). The reason is that UDP provides a faster transport service as compared to TCP.

On the other hand, there are several applications that require reliable data transmission e.g. HTTP or Web, file transfer protocol (FTP), email, Telnet. In other words, these applications cannot tolerate packet losses, however, these are not so sensitive to delays. TCP is best suited for these kinds of applications.

In this paper, we try to answer following research question: How does a WiMAX network perform under TCP traffic and under UDP traffic. In other words, we evaluate the performance of WiMAX network for applications that use TCP as a transport layer protocol and for applications that use UDP as a transport layer protocol**.**

3. An Overview of Mobile WiMAX, TCP and UDP

3.1. An Overview of Mobile WiMAX

Mobile WiMAX or IEEE 802.16e-2005 offers a true broadband connection that supports multiple usage scenarios, including fixed, portable and mobile access, using the same network infrastructure. Some of the salient features of Mobile WiMAX are as follows.

- *High Data Rates:* WiMAX supports very high peak data rates. The peak PHY data rate can be as high as 74 Mbps when operating at 20 MHz, and 25 Mbps when operating at 10 MHz frequency.
- *Quality of Service:* The support for quality of service is a fundamental component of WiMAX MAC layer design. QoS is achieved using connection oriented MAC architecture where all uplink and downlink traffics are controlled by the serving BSs. The QoS parameters include traffic priority, maximum delay, tolerated jitter, ARQ technique, scheduling algorithm, etc.
- *Adaptive Modulation and Coding:* WiMAX supports a number of modulation and coding schemes. Various modulation schemes supported by WiMAX are: $BPSK_{1/2}$, $QPSK_{1/2}$, $QPSK_{3/4}$, $16QAM_{1/2}$, $16QAM_{3/4}$, $64QAM_{1/2}$, $64QAM_{2/3}$, etc. Here m/n stands for convolution codes where m data bits are coded to generate an n bit code, $m \leq n$. These modulation schemes are allowed to be changed based on channel condition to maximize the throughput.
- *Mobility:* The IEEE 802.16e-2005 standard defines a framework to support mobility. Mobility

management is done with the help of two basic mechanisms. In particular, the standard defines mechanisms for tracking SS as they move from one base station to another. The standard also has protocols to enable a optimized handover which requires less time.

- *Security:* WiMAX supports two encryption schemes which are Advanced Encryption Standard (AES) and Data encryption Standard (triple DES). New high performance coding schemes such as *Low-Density Parity Check (LDPC)* codes are also included. These features enhance the security of the mobile WiMAX air interface.
- *Orthogonal Frequency Division Multiple Access (OFDMA):* It is a multiuser version of OFDM scheme supported by mobile WiMAX. In this scheme, different users are allocated different subset of OFDM tones. It offers frequency diversity by spreading the carriers all over the used spectrum, which significantly increases system capacity.
- *Scalability:* Mobile WiMAX can support a wide range of bandwidths. Scalability is achieved with the help of OFDMA scheme, in which *Fast Fourier Transform (FFT)* size may be scaled based on the available channel bandwidth. It can optionally support channel bandwidths ranging from 1.25 MHz to 20 MHz, and therefore, can be easily deployed.

3.2. An Overview of TCP

The Transmission Control Protocol (TCP) is a connection-oriented, end-to-end reliable protocol designed to fit into a layered hierarchy of protocols which support multi-network applications. TCP is connection-oriented because before one application process can begin to send data to another, the two processes must first “handshake” with each other (that is, they must send some preliminary segments to each other to establish the parameters of the ensuing data transfer [14]). Process-to-Process Communication, Stream delivery services, full duplex communication and reliability are the services offered by TCP to process at application layer. TCP is the protocol used by major Internet applications such as the World Wide Web, email, remote administration and file transfer.

TCP encapsulates the sender data into TCP segments. The segments are passed down to the network layer, where they are separately encapsulated within network layer IP datagrams. The IP datagrams are then sent into the network. When TCP receives a segment at the other end, the segment's data is placed in the TCP connection's receive buffer. The application reads the stream of data from this buffer. TCP provides reliability by assigning a sequence number to each octet transmitted, and requiring a positive acknowledgment (ACK) from the receiving TCP. It uses checksum to handle corrupted and damage segments.

3.2. An Overview of UDP

The User Datagram Protocol (UDP) is connectionless, unreliable transport layer protocol. It is formally defined in RFC 768. UDP offers minimal transport layer functionalities non-guaranteed data delivery and gives applications a direct access to the network layer. It does not add anything to services of IP except to provide process-to-process communication instead of host-to-host communication. It only performs multiplexing/demultiplexing functions and some light error checking. In other words, UDP protocol is transaction oriented, and delivery and duplicate protection are not guaranteed.

UDP takes messages from an application process, attaches source and destination port for the multiplexing/demultiplexing service, adds two other fields of error checking and length information, and passes the resulting packet to the network layer [14]. The network layer encapsulates the UDP packet into IP datagram and then delivers the encapsulated packet at the receiver. When a UDP packet arrives at the receiving host, it is delivered to the receiving UDP agent identified by the destination port field in the packet header.

4. Results and Discussion

We evaluated the performance of Mobile WiMAX, 802.16e using *network simulator (ns-2).* During our performance analysis, we focus on the following parameters: (i) delay, (ii) jitter, and (iii) throughput. We study the effect of number of subscriber stations, the distance between the subscriber station and base station, and the modulation and encoding techniques.

Figure 3 shows average throughput as a function of number of nodes. We observe that the throughput steadily increases as the number of nodes is increased. This is expected behavior. The reason is that as the number of nodes is increased, the number of packets being transmitted also increases. These include data packets as well as control packets that are exchanged between the SS and BS. So for two nodes, the throughput is around 486 Kbps. For 14 nodes, the value reaches around 4715 Kbps. It is also observed UDP performs better than TCP.

Figure 4 shows average delay as a function of the number of nodes for UDP and TCP traffics. We observe that average delay remains almost constant. The reason is that when the system is underloaded, all queues are almost always empty Thus, when a packet is received by the BS, the scheduler most likely serves it in the subsequent subframe. However, when the system becomes overloaded, the average delay of data traffic increases much more sharply.

Figure 5 shows average jitter as a function of the number of nodes for UDP and TCP traffics. We observe that jitter increases as number of nodes increases. Initially, when a lot of network resources are available, the jitter is the least. However, as the number of nodes increases, the network resources get divided among all nodes.

Figure 6 shows average delay for different modulation and encoding schemes. Let *m* be the number of bits before coding and *n* be the number of bits after coding, then the convolution code is denoted by *m*/*n*. We observe that access delay for modulation technique 64QAM together with encoding technique 3/4 is smaller than those in case of modulation technique 64QAM together with an encoding technique 2/3. The delays incurred by the modulation technique QPSK together with encoding technique 1/2 is much lower than that incurred by the modulation technique BPSK together with an encoding technique 1/2. Let δ be the symbol denoting the average delay. Then, we have,

$$\delta_{64QAM3/4} \leq \delta_{64QAM2/3} \leq \delta_{16QAM2/3} \leq \delta_{16QAM1/2} \leq \delta_{QPSK3/4} \leq \delta_{QPSK1/2} \leq \delta_{BPSK1/2} \quad (1)$$

Figure 7 shows average jitter for different modulation schemes and encoding schemes. Though, there is no specific trend observed for both UDP and TCP traffic. However, we observe that the jitter in case of UDP traffic is smaller than that in case of TCP traffic.

Figure 8 shows average throughput as a function of the distance between base station and subscriber stations. We observe that with the increase in distance, the throughput of 802.16e remains almost constant, however, beyond a distance of 8 Km, the throughput of 802.16e drops drastically. This is also the reason for the fact that Mobile WiMAX or IEEE 802.16e, does not support large distances. As expected, throughput in case of UDP, is higher than that of TCP.

Table 1. Values of Different Simulation Parameters

Parameter	**Value**
Channel	Wireless
Propagation Model	Two Way Ground
Interface Type	OFDMA
MAC Layer Protocol	802.16
X-dimension	1100 m
Y-dimension	1100 m
Antenna Model	Omni Directional
Traffic Pattern	UDP agent with CBR traffic. TCP agent with Telnet traffic

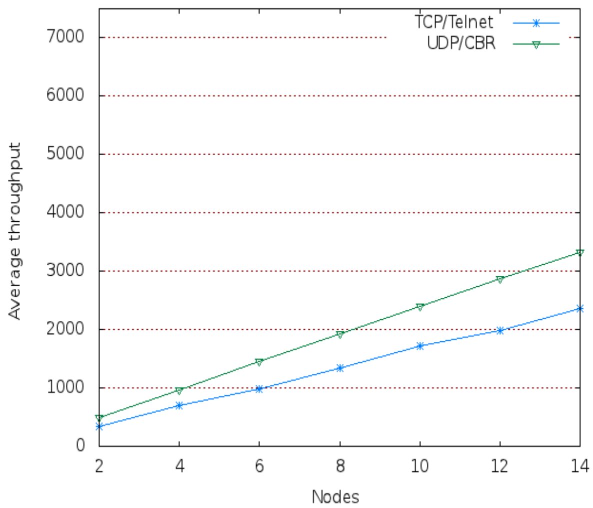

Figure 1. Average throughput (kbps) as a function of the number of subscriber stations.

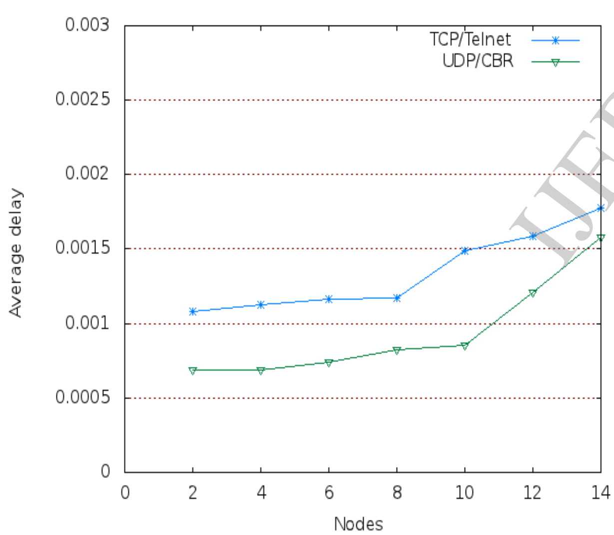

Figure. 2. Average delay (seconds) as a function of the number of subscriber stations.

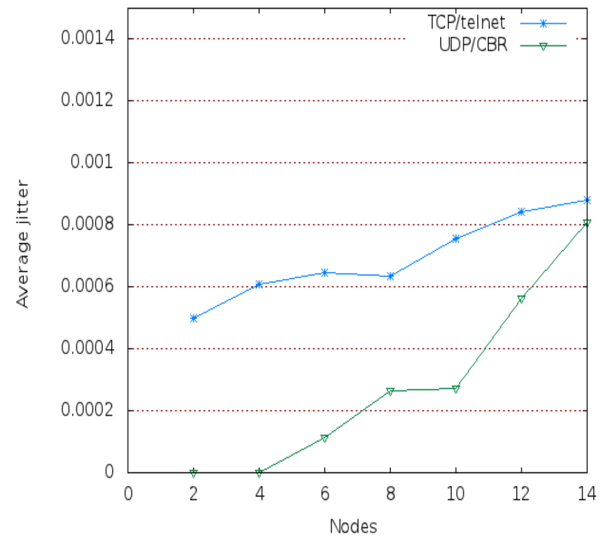

Figure. 3. Average jitter (seconds) as a function of the number of subscriber stations.

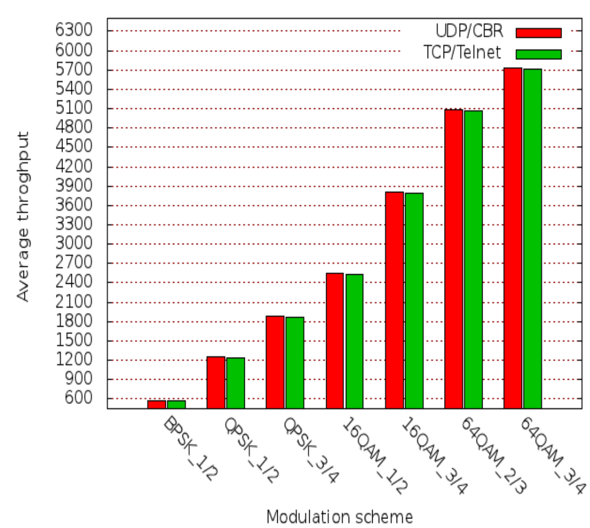

Figure. 4. Average throughput (in Kbps) for different modulation scheme and encoding schemes.

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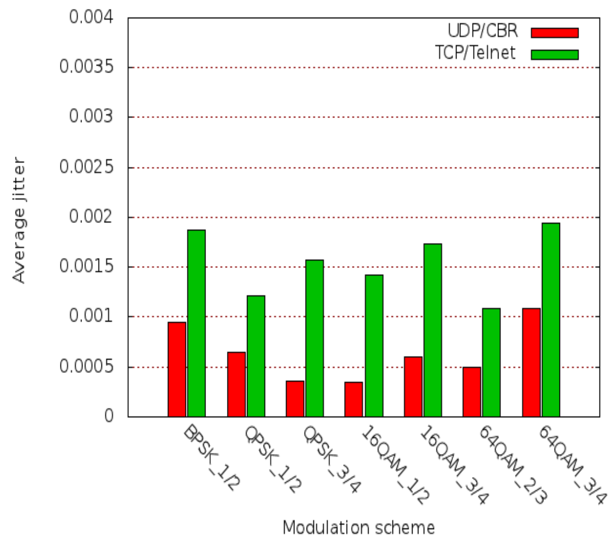

Figure. 5. Average delay (seconds) for different modulation scheme and encoding schemes.

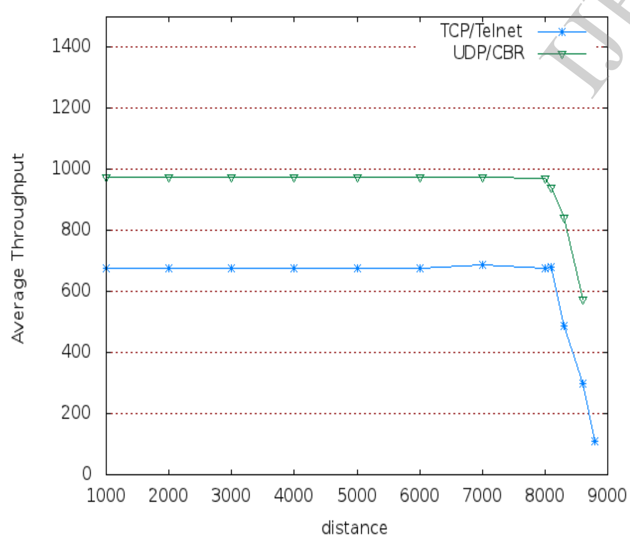

Figure 6. Average throughput (Kbps) as a function of distance (meters) between base station and subscriber stations.

5. Conclusion

The In this paper, we evaluated the performance of IEEE 802.16e or Mobile WiMAX. The contributions made in the paper are as follows. We focused on the following performance metrics: throughput, delay, and jitter. We investigated the effect of the number of nodes, modulation schemes, distance between BS and SS.

We observed that for both TCP and UDP connections, an increase in the number of subscriber stations increases the throughput, however, it also increases the delay and jitter.

The effect of different modulation scheme was evaluated and it is observed that 64QAM is the most efficient modulation scheme and performs better than QPSK which in turn performs better than BPSK.

We observed that Mobile WiMAX provides access to a large distance, which is the biggest feature of this technology as compared to WiFi. Specifically, for the set of simulations presented in this paper, it supports up to 9 Km which can further be increased by increasing the antenna height.

Other factors that may affect the performance of a WiMAX network and can be addressed in future are antenna gain, Multiple Input Multiple Output with Beam Formation (MIMO/BF), output power of BS, Time Division Duplexing (TDD) ratio, Customer Premises Equipment (CPE) antenna gain and receiver antenna gain of BS. Therefore, by choosing appropriate values of different factors/parameters according to channel conditions and other available resources, the performance of WiMAX can be optimized.

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