



## **PERFORMANCE INVESTIGATION OF DIFFERENT SIGNALING AND CODING RATES IN WIMAX NETWORK**

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**Abstract:** WiMAX (Worldwide Interoperability for Microwave Access) is a promising technology which can offer high speed voice, video and data service up to the customer end. The IEEE 802.16 technology is a better alternative to 3G or wireless LAN networks for providing last mile connectivity by radio link due to its high data rates, low cost of deployment and large coverage area. In this paper, QoS performance of WiMAX network is analyzed in terms of QoS parameters i.e. delay, load, throughput, packet delay variation and packet end to end delay by using OPNET 14.5 simulator. Performance is carried out with different modulation techniques and coding rates like QPSK  $\frac{1}{2}$ , QPSK  $\frac{3}{4}$ , 16 QAM  $\frac{1}{2}$ , 16 QAM  $\frac{3}{4}$ , 64 QAM  $\frac{1}{2}$  and 64 QAM  $\frac{3}{4}$ . This paper concludes that coding rate  $\frac{3}{4}$  and QAM techniques perform best.

**Keywords:** WiMAX, OPNET, QPSK, 16 QAM, 64 QAM, OFDM.

### **I. Introduction**

The demand for broadband mobile services is continuously growing. Conventional high-speed broadband solutions are based on wired-access technologies such as digital subscriber line (DSL). This type of solution is difficult to deploy in remote rural areas because it lacks support for terminal mobility. Mobile Broadband Wireless Access (MBWA) provides flexible and cost-effective solution to these problems [1]. The IEEE WiMax/802.16 is a promising technology for broadband wireless metropolitan area networks (WMANs). WiMax technology ensures broadband access for the last mile. It provides a wireless backhaul network which enables high speed Internet access to small and medium business customers, residential and also Internet access for WiFi hot spots and cellular base stations. WiMAX becomes a promising standard nowadays because it becomes an excellent solution for the places where the cost of deployment and maintenance of technologies like DSL is not profitable. WiMAX offers a good solution for these challenges because it provides a cost-effective, rapidly deployable solution. Additionally, WiMAX will represent a serious competitor to 3G (Third Generation) cellular systems as high speed mobile data applications can be achieved with the 802.16e standard. The original WiMAX standard was only catered for fixed and Nomadic services. It was then enhanced to full mobility applications, hence the mobile WiMAX defined under the IEEE 802.16e standard. Mobile WiMAX supports full mobility, nomadic and fixed systems [2].

In wireless communication, parallel transmission of symbols concept is applied to achieve high throughput and better transmission quality. Many methods are proposed to combat the multipath effects in wireless communication. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques used for parallel transmission. The idea of OFDM is to split the total transmission bandwidth into a number of orthogonal sub carriers so that to transmit the symbols using these sub carriers in parallel [4]. Each smaller data stream is then mapped to individual data sub-carrier and modulated using one of the Modulation techniques such as QPSK, 16-QAM, 64-QAM. OFDM needs less bandwidth than Frequency Division Multiplexing (FDM) to carry the same amount of information which converts to higher spectral efficiency. Besides a high spectral efficiency, an OFDM system such as WiMAX is more suitable in NLOS environment. It can easily overcome issues caused by multipath like interference and frequency-selective fading because equalizing is done on a subset of sub-carriers instead of a single broader carrier [5]. WiMAX uses a special type of modulation technique which is a mixture of ASK and PSK with a new name called Quadrature Amplitude Modulation (QAM). In QAM, amplitude and phase changes at the same time. Different types of QAM are available for WiMAX networks depending on throughput and range. 64 QAM has higher throughput but the lower range whereas 16 QAM has lower throughput but higher range to cover from the BS. WiMAX has the freedom to select Quadrature Phase Shift Keying (QPSK) and QAM as its modulation techniques depending on the situation [4].

To accommodate the Wireless medium 802.16 basically employ PHY (physical) and a MAC (media access control) layer.

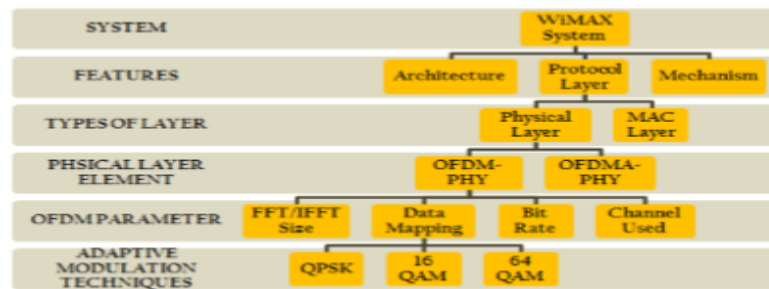


Figure 1 Specification of WiMAX system

These are the two layers of WiMAX which are very important. PHY layer plays a very important role in WiMAX network. PHY is the actually physical transport of data itself. A variety of technologies like OFDM, TDD, FDD, QAM and Adaptive Antenna Systems (AAS) are utilized to achieve maximum performance from the PHY itself. Modulation technique is one of the technologies used by PHY layer so it motivates to compare different modulation techniques with different coding rates to achieve best performance. In this paper different modulation techniques with different coding rates are compared with QoS parameters and concluded which gives best QoS.

This paper is organized as follows. Simulation model of network using OPNET modeler is described in section II. Simulation environment is also in section III then Results are discussed in section IV, before we finally conclude in Section V. References are given in section V.

## II. Simulation Model

In this study, we used OPNET to develop a simulation model. OPNET Modeler simulation tool was selected as the tool of choice given its widespread adoption in both commercial and military domains. Moreover, the OPNET Modeler included native support for WiMAX component technologies. A network topology shown in Figure 2, consisting of geographically separated video client and video services subnets, was employed to simulate a more realistic real world scenario [6].

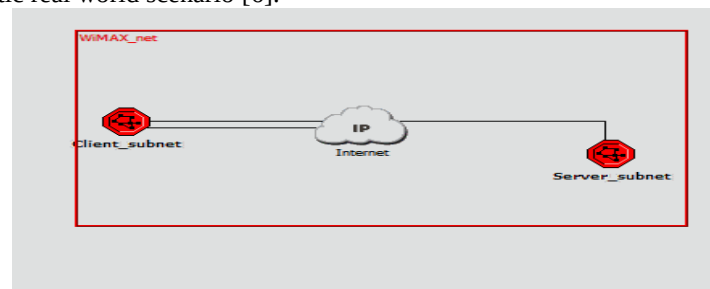


Figure 2 Network topology

The server subnet, shown in Figure 2 provisions a VoD server capable of streaming stored video content to video clients on request and client subnet encompass various video client stations that will access the same VoD services. Client subnet and server subnet shown in network topology are connected through IP backbone.

In the client subnet shown in figure 3, six fixed wireless WiMAX stations are located. The base station is connected wirelessly to all the client stations [7].

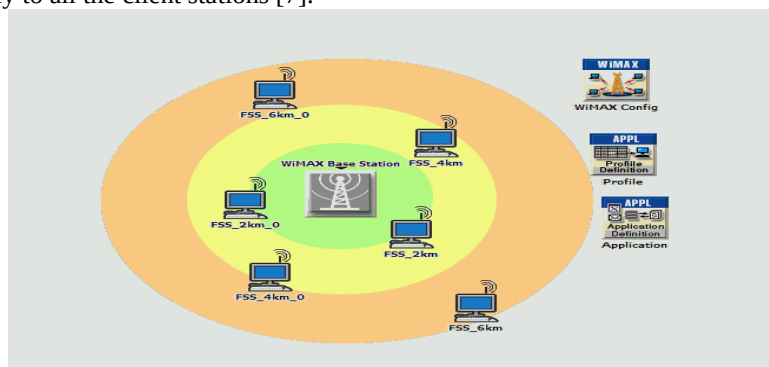


Figure 3 Simulation Model

## II. Simulation Environment

WiMAX service classes appropriate the QoS requirements of service flows, where service flows represent traffic flow between the base station and the subscriber stations. Service flows from the base station to the subscriber station are called downlink flow whereas service flows from the subscriber station to base station are called uplink flows. For a given service class, the key parameters are minimum sustainable traffic rate and the scheduler type, which enables WiMAX to provide QoS capabilities, thereby supports delay sensitive traffic such as audio and video services. There are four scheduler types: UGS (ungranted service), rtPS (real time polling service), nrtPS (non-real time polling service) and BE (best effort). The available bandwidth resources are first allocated to UGS then to rtPS and nrtPS flows. Lastly, any remaining resources are then assigned to BE flows. For the purpose of this study, we created one service class for the downlink using BE scheduling and 3.0 Mbps minimum sustainable data rate. Another service class was created using BE scheduling and 640 kbps minimum sustainable data rate as shown in Figure 4.

| Attribute                                | Value           |
|------------------------------------------|-----------------|
| Maximum Traffic Burst (bytes)            | 0               |
| Traffic Priority                         | Not Used        |
| Unsolicited Poll Interval (milliseconds) | Auto Calculated |
| <b>Row 2</b>                             |                 |
| Service Class Name                       | Silver_DL       |
| Scheduling Type                          | Best Effort     |
| Maximum Sustained Traffic Rate (b...     | 5 Mbps          |
| Minimum Reserved Traffic Rate (bps)      | 3000000         |
| Maximum Latency (milliseconds)           | 30.0            |
| Maximum Traffic Burst (bytes)            | 0               |
| Traffic Priority                         | Not Used        |
| Unsolicited Poll Interval (milliseconds) | Auto Calculated |
| <b>Row 3</b>                             |                 |
| Service Class Name                       | Silver_UL       |
| Scheduling Type                          | Best Effort     |
| Maximum Sustained Traffic Rate (b...     | 1 Mbps          |
| Minimum Reserved Traffic Rate (bps)      | 640000          |
| Maximum Latency (milliseconds)           | 30.0            |
| Maximum Traffic Burst (bytes)            | 0               |
| Traffic Priority                         | Not Used        |
| Unsolicited Poll Interval (milliseconds) | Auto Calculated |

Figure 4 WiMAX Service Class Configurations

PHY layer access was configured to utilize OFDM over a 2.5 GHz base frequency with 5 MHz channel bandwidth that provisions 512 subcarriers. The client station transmit power was configured to use 33 dBm (2 watts) of transmit power using 14 dB gain antennas. The base station transmit power was configured to use 35.8 dBm (3.8 Watts) over the 5MHz channel bandwidth with 15 dB gain antenna. Moreover, a pathloss model fixed suburban (Erceg) was employed with a conservative terrain type that accounted for mostly flat terrain with light tree densities. The 2km FSS modulation and coding rates for both uplink and downlink service flows are shown in Figure 5.

| Attribute                     | Value      |
|-------------------------------|------------|
| <b>Row 0</b>                  |            |
| Service Class Name            | Silver_DL  |
| Modulation and Coding         | 16-QAM 1/2 |
| Average SDU Size (bytes)      | 1500       |
| Activity Idle Timer (seconds) | 60         |
| Buffer Size (bytes)           | 1048576    |
| ARQ Parameters                | Disabled   |
| PDU Dropping Probability      | Disabled   |
| CRC Overhead                  | Disabled   |
| HARQ Enabled                  | Disabled   |
| Uplink Service Flows          | (...)      |
| Number of Rows                | 1          |
| <b>Row 0</b>                  |            |
| Service Class Name            | Silver_UL  |
| Modulation and Coding         | 16-QAM 1/2 |
| Average SDU Size (bytes)      | 1500       |
| Activity Idle Timer (seconds) | 60         |
| Buffer Size (bytes)           | 64 KB      |
| ARQ Parameters                | Disabled   |
| PDU Dropping Probability      | Disabled   |
| CRC Overhead                  | Disabled   |

Figure 5 FSS service flow modulation and coding rates.

#### IV. Results and Discussions

In this section, the simulative investigations of different modulation techniques with different coding rates have been done to find out the optimum behavior of WiMAX network. OPNET provides a Virtual Network Environment that models the behavior of entire network. Performance of different modulation techniques with different coding rates are compared in terms of QoS parameters like delay, load, packet delay variation, traffic received and throughput.

In all figures from 6 to 10, first scenario that is blue line shows 16-QAM  $\frac{1}{2}$ , scenario 2 of red line shows 64-QAM  $\frac{3}{4}$ , and scenario 3 of green line shows 64-QAM  $\frac{3}{4}$ , scenario 4 of sky blue line shows 64-QAM  $\frac{3}{4}$ , scenario 5 of yellow line shows QPSK  $\frac{1}{2}$  and scenario 6 of pink line shows QPSK  $\frac{3}{4}$  adaptive modulation techniques. Simulation is done for 10 min. Initially up to 2m network takes time to establish connection so that packets can be transferred that's why comparison is achieved after 2m.

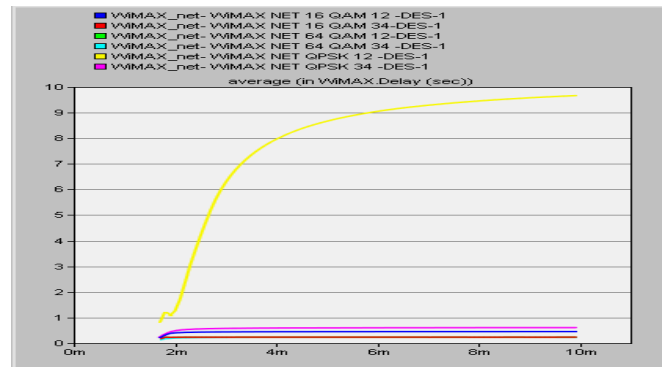


Figure 6 Comparison of average in WiMAX delay (sec)

Figure 6 represents delay which shows QPSK  $\frac{1}{2}$  has maximum delay which means it takes longer time for transmission from source to destination. 64-QAM  $\frac{3}{4}$  and 16-QAM  $\frac{3}{4}$  has minimum delay and 16-QAM  $\frac{1}{2}$  and 64-QAM  $\frac{3}{4}$  has moderate delay. It means 16-QAM  $\frac{3}{4}$  and 64-QAM  $\frac{3}{4}$  performs best.

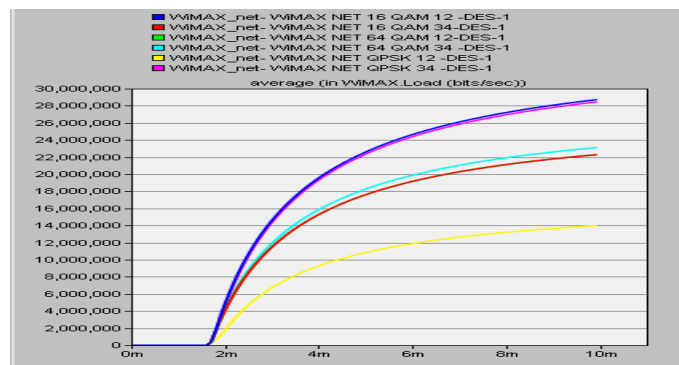


Figure 7 Comparison of average in WiMAX load (bits/sec)

Figure 7 represents load in bits/sec. Initially the load is constant for all techniques afterwards it eventually increases. Load is maximum for 64-QAM  $\frac{1}{2}$  and QPSK  $\frac{3}{4}$ , and minimum for QPSK  $\frac{1}{2}$ . 16-QAM  $\frac{3}{4}$  and 64-QAM  $\frac{3}{4}$  has moderate load.

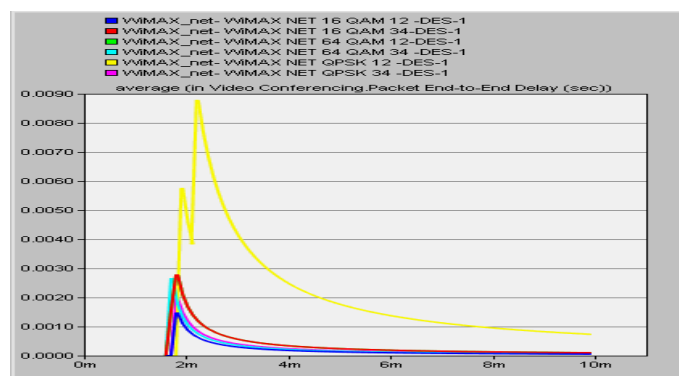


Figure 8 Comparison of Packet End to End delay (sec)

Figure 8 represents Packet End to End delay which shows end to end delay is maximum for QPSK  $\frac{1}{2}$  and  $\frac{3}{4}$  coding rate behaves almost same even though 16 QAM  $\frac{3}{4}$  and 64 QAM  $\frac{3}{4}$  has minimum delay

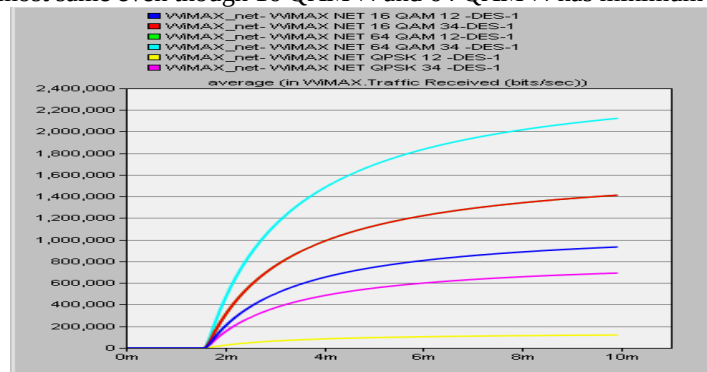


Figure 9 Comparison of Traffic Received (bits/sec)

Figure 9 represents Traffic Received which shows highest traffic is for 64 QAM  $\frac{3}{4}$  and minimum traffic is for QPSK  $\frac{1}{2}$  and all other techniques has moderate traffic received while 16 QAM  $\frac{3}{4}$  and 64 QAM  $\frac{1}{2}$  has more than 16 QAM  $\frac{1}{2}$  and QPSK  $\frac{3}{4}$ .

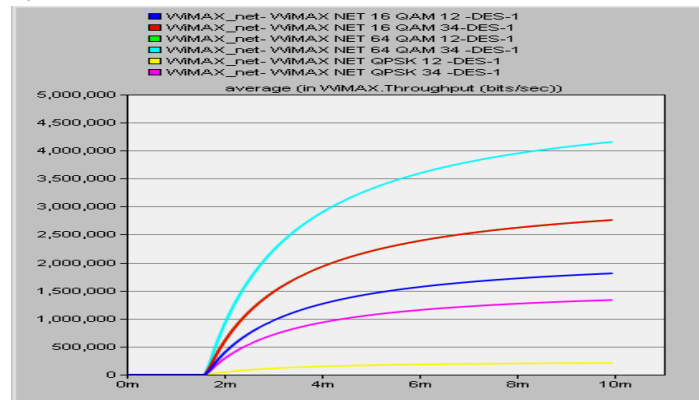


Figure 10 Comparison of average in WiMAX Throughput (bits/sec)

Figure 10 represents throughput in packets/sec. It shows throughput is maximum for 64 QAM  $\frac{3}{4}$  and minimum for QPSK  $\frac{1}{2}$ . 16 QAM  $\frac{3}{4}$  and 64 QAM  $\frac{1}{2}$  has high throughput than QPSK  $\frac{3}{4}$  and 16 QAM  $\frac{1}{2}$ .

| Techniques/<br>Parameters    | Delay    | Throughput      | Packet e2e<br>Delay | Performance                              |
|------------------------------|----------|-----------------|---------------------|------------------------------------------|
| Average Acceptable<br>Values | < 300ms  | 2Mbps-5Mbps     | < 60 ms             | -----                                    |
| 16 QAM 1/2                   | < 100 ms | Around 2Mbps    | < 20 ms             | Acceptable                               |
| 16 QAM 3/4                   | < 50 ms  | Around 3Mbps    | < 30 ms             | Acceptable and better<br>than 16 QAM 1/2 |
| QPSK 1/2                     | 1000 ms  | 1 Kbps          | 90 ms               | Not Acceptable                           |
| QPSK 3/4                     | 100 ms   | Around 1.5 Mbps | 20 ms               | Not Acceptable                           |
| 64 QAM 1/2                   | < 50 ms  | Around 3 Mbps   | < 20 ms             | Acceptable                               |
| 64 QAM 3/4                   | < 50 ms  | Around 4.5 Mbps | < 30 ms             | Acceptable and better<br>than 64 QAM 3/4 |

Table 1 Performance Analysis

According to these values QPSK technique does have any parameter which can be acceptable while QAM techniques have acceptable values which shows that QAM techniques are much better than QPSK. Now all the comparative results shows that coding rate QAM techniques with coding rate  $\frac{3}{4}$  performs much better than QPSK technique and coding rate  $\frac{1}{2}$  in terms of QoS. So QAM techniques with coding rate  $\frac{3}{4}$  are best techniques to achieve best QoS for WiMAX network.

#### IV. Conclusion

This paper presents a comparative performance study of video streaming over WiMAX network with respect to different modulation schemes and coding rates. The performance has been evaluated in terms of average delay, average load, average traffic received, average packet End to End delay and average throughput. It has been demonstrated while using OPNET simulation. We concluded that the coding rate  $\frac{3}{4}$  and higher order modulation namely, 16 QAM and 64 QAM provide much better performance than QPSK and  $\frac{1}{2}$  coding rate.

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