Research Article

QoS Performance for Monitoring and Optimization of Data and VoIP traffic in WiMAX Network Mac Layer
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Abstract
In this paper we are providing a concept of Worldwide Interoperability for Microwave Access (WiMAX) network performance for QoS monitoring and optimization solution for Base Station (BS) with multimedia application to equate quality and cost. The Physical and MAC layer of WiMAX Technology refer to the IEEE 802.16 standard defines five 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. We have developed six scenarios to compares the performance obtained using two different types of MAC layer delivery service class used to transport VoIP traffic the Unwanted Grant Service (UGS) and real-time polling service (rtPS). In each scenario the number of fixed BS and SS has been increased from one to six in the BS and four to twenty four in the SS to cover more required users. All the simulation results are optimized based on networks and area, and the results indicate that the delay sensitive traffic fluctuates beyond its nominal rate, having the possibility to give back some of its reserved bandwidth; rtPS has the advantage to permit the transmission of Best effort (BE) traffic than UGS and also the traffic priority for UGS is high as compared to rtPS.

1. Introduction

Due to its large coverage area, low cost of deployment and high speed data rates, WiMAX is a promising technology for providing wireless last-mile connectivity. Worldwide Interoperability for Microwave Access (WiMAX) is one of the most important broadband wireless technologies and is anticipated to be a viable alternative to traditional wired broadband techniques due to its cost efficiency. Being an emerging technology, WiMAX
supports multimedia applications such as voice over IP (VoIP), voice conference and online gaming since it is necessary to provide Quality of Service (QoS) guaranteed with different characteristics. Therefore, an effective scheduling is critical for the WiMAX system. Many traffic scheduling algorithms are available for wireless networks, e.g. Round Robin, Proportional Fairness (PF) scheme and Integrated Cross-layer scheme (ICL). Among these conventional schemes, some cannot differentiate services, while some can fulfil the service differentiation with high-complexity implementation (Xiaodong and Georgious, 2004).

WiMAX has undoubtedly emerged as the most promising leading technology for broadband connection in wide area networks. Its light infrastructure makes it very cheap and easy to deploy and thus WiMAX becomes an effective solution to the last mile wireless connection problem which include multipath fading, environmental factors (such as heavy rains), interference and varying SLA demands amongst a host of other problems. It is especially effective in rural areas where wired infrastructures are difficult to install (Jha et al, 2010).

WiMAX quality of service (QOS) depends generally on the 802.16 Layers 1 and 2, as these provide all important base station with an inherently difficult environment compared to, say, a wire line broadband network. In particular, 802.16d used Orthogonal Frequency Division Multiplexing. The capabilities of these technologies have a direct impact on end-user services and QOS (Vinit and Ajay 2010). Generally speaking, OFDM provides a simple, relatively straightforward scheduler design, giving best performance for larger packet sizes, as the overhead/padding problem isn’t so important. This makes it better for the needs of certain data services, such as legacy TDM (Vinit and Ajay 2010).

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1.1 WIMAX QoS and Scheduling Services

The organizing service plays a huge role in determining the QoS in WiMAX. It determines the information-handling systems using the MAC scheduler for data transport around the connection. Each connection is indicated an association identifier (CID) and several QoS parameters. The organizing service determines the quantity of the UL and DL transmission options, in addition to BW allocation systems. Initially, four different service types were supported in the 802.16 standard: Unsolicited Grant Service (UGS), real-time polling service (rtPS), non-real-time polling service (nrtPS) and Best Effort (BE) (Lee et al, 2006 and Jha et al, 2010).

1. The UGS (Unwanted Grant Service) resembles the CBR (Constant Bit Rate) service at (Asynchronous Transfer Mode) ATM, which produces a collection size burst periods. A reverse lookup might be accustomed to replacing T1/E1 wired line or possibly a continuing rate service. Furthermore, it might be accustomed to support real-time programs for instance Voice over IP or streaming programs. Even though the UGS, may possibly not function as the finest choice for the Voice over IP because it might waste bandwidth through the off amount of voice calls Lee et al, 2006 and Jha et al, 2010).

2. The rtPS (real-time polling service) is ideal for an adaptable bit rate real-time service for instance Voice over IP. Every polling interval, BS polls as well as they asked to transmit between requests (bandwidth request) whether or not this has data to provide. The BS grants or loans or financial loans the data burst using UL-MAP-IE upon its reception.
3. The nrtPS (non-real-time polling service) is much like the rtPS with the exception that it enables contention based polling.

4. In Best Effort (BE) Service can be used as programs for example e-mail or FTP, by which there’s no strict latency requirement. The allocation mechanism is a continuation based while using varying funnel. Another service type known as ertPS (extended rtPS) was brought to support variable rate real-time services for example Voice over internet protocol and video streaming (Poulin, 2006). We have an edge on UGS and rtPS for Voice over internet protocol applications since it carries lower overhead than UGS and rtPS as showed in table 1.

**TABLE 1: WiMAX QoS and Scheduling Services**

<table>
<thead>
<tr>
<th>Service Flow</th>
<th>Definition</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>UGS</td>
<td>Real time data streams with fixed size data packets issued at periodic intervals</td>
<td>T1/E1, VoIP without silence suppression.</td>
</tr>
<tr>
<td>rtPS</td>
<td>Real time data streams with variable size data packets issued at periodic intervals</td>
<td>MPEG video, VoIP with Silence suppression</td>
</tr>
<tr>
<td>nrtPS</td>
<td>Delay Tolerant data streams with variable size data packets issued at periodic intervals</td>
<td>FTP, Telnet</td>
</tr>
<tr>
<td>BE</td>
<td>Delay Tolerant data streams, background traffic or any either application without significant QoS constrains</td>
<td>HTTP, E-mail</td>
</tr>
</tbody>
</table>

**1.2 Voice over IP (VoIP)**

A VoIP application typically works as follows. First, a voice signal is sampled, digitized, and encoded using a given algorithm/coder. The encoded data (called frames) is packetized and transmitted using RTP/UDP/IP. At the receiver’s side, data is de-packetized and forwarded to a play out buffer, which smoothes out the delay incurred in the network. Finally, the data is decoded and the voice signal is reconstructed. The quality of the reconstructed voice signal is subjective and therefore is measured by the mean opinion score (MOS). MOS is a subjective quality score that ranges from 1 (worst) to 5 (best) and is obtained by conducting subjective surveys. Though these methods provide a good assessment technique, they fail to provide an on-line assessment which might be made use for adaptation purpose. The ITU-T E-Model
(Poulin, 2006) has provided a parametric estimation for this purpose. It is an R-factor that combines different aspects of voice quality impairment. It is given by

\[ R = 100 - I_s - I_e - I_d + A \] (1)

Where \( I_d \) is the signal-to-noise impairments associated with typical switched circuit networks paths, \( I_e \) is an equipment impairment factor associated with the losses due to the codecs and network, \( I_d \) represents the impairment caused by the mouth to-ear delay, and A compensates for the above impairments under various user conditions and is known as the expectation factor.

The R-score is related to MOS through the following non-linear mapping (Vinit and Ajay 2010).

\[ MOS = 1 + 0.0345R + 6.5 \times 10^{-6}R(R - 50)(100 - R) \] \( \ldots \ldots \) (2)

For \( 0 \leq R \leq 100 \). If \( R < 0 \), MOS takes the value of 1 and similarly, if \( R > 100 \), MOS takes the value of 4.6.

Among all the factors in the equation (1), only the \( I_d \) and I are typically considered variables in VoIP (Dang, Prasad, and Niemegeers, 2007). Using default values for all other factors, the expression for R-factor given by equation (1) can be reduced to

\[ R = 93.5 - I_e - I_d \] \( \ldots \ldots \) (3)

1.3 Network Dimensioning and Design

WiMAX are operating in a combination of licensed and unlicensed bands. The unlicensed bands are usually both the 2.4 GHz and 5.8 GHz bands. Licensed spectrum provides operators the control of using the band, permitting them to develop a high-quality network. The unlicensed band, however, allows independents to supply backhaul services for hotspots (SRamachandran et al, 2002). Typical area licensed WiMAX spectrum allocations are:

- Lower 700 MHz (US) with 2x6 MHz channels
- GHz Multichannel Multipoint Distribution Service with 15.5 MHz in US and 72 MHz in Canada
- 3.5 GHz Wireless Local Loop with 2 x 2hMHz channel blocks
- 5.8 GHz UNI (license exempt) with 80 MHz allocation (Parsae, Yarali, and Ebrahimzad, 2004)
WiMAX access networks will often be deployed in point to multipoint cellular fashion in which a single base station provides wireless coverage to some set of end user stations in the coverage area. The technology behind WiMAX have been optimized to offer both large coverage distances of up to 30 kilometers under Line of Sight (LOS) situations and a typical cell range of up to 8 kilometers under No LOS (NLOS) (Jha et al, 2010). In a NLOS, a signal reaches the receiver through reflections, scattering, and diffractions. The signals reaching the receiver includes many aspects of indirect and direct paths with various delay spreads, attenuation, polarizations, and stability compared to the direct path.

WiMAX technology solves or mitigates the challenge as a result of NLOS conditions by utilizing OFDM, Sub channelization, directional antennas, transceiver diversity, adaptive modulation, error correction and power control (C. Hoymann et al, 2007). The NLOS technology also reduces installation expenses by developing the under-the-eaves Customer Premise Equipment (CPE) installation possible and easing the problem of locating adequate CPE mounting locations. Both LOS and NLOS coverage conditions are controlled by propagation characteristics of the environment, radio link budget and path loss. In each case relays assist to extend the range of the BS footprint coverage permitting a cost-efficient deployment and service (Jha et al, 2010).

This paper discusses about the performance of the MAC Layer by applying different QoS applications using the OPNET Modeler Simulation Tool. The purpose of this study was to examine a case of QoS deployment over a WiMAX network and to examine the capability of a WiMAX network to deliver adequate QoS for voice and data applications. The concept of WiMAX network performance for QoS monitoring and optimization solution for Base Station (BS) with multimedia application to equate quality and cost was discussed. The methodologies taken include creating the WiMAX network, deploying the required applications, deploying QoS configurations within the WiMAX last-mile, adjusting the QoS configurations within a WiMAX network to meet voice requirements, and further adjusting the QoS configurations to improve data application performance, without degrading the performance of voice.

2. Related Literatures
The IEEE 802.16 technology (WiMAX) is a promising alternative to 3G or wireless LAN for providing last-mile connectivity by radio link due to its large coverage area, low cost of
deployment and high speed data rates. The standard specifies the air-interface between a Subscriber Station (SS) and a Base Station (BS). The IEEE 802.16-2004 standard also known as 802.16d, was published in October, 2004 (IEEE Standard 802.16-2004). This was further developed into the mobile WiMAX standard referred to as IEEE 802.16e-2005 or 802.16 (IEEE Standard 802.16e-2005) also according to Ramachandran et al (2002) it is design to support mobile users. IEEE 802.16 can be used not only as xDSL replacement for small business customers but also as a mobile internet access technology. There have been few studies focusing on performance evaluation of IEEE 802.16 WiMAX Networks using OPNET.

Rangel et al (2006) Studied performance evaluation of IEEE 802.16 for Broadband Wireless Access, however, they used OPNET’s DOCSIS models to simulate the IEEE 802.16 MAC.

Dang et al, (2007) Studied performance analysis of QoS scheduling in Broadband IEEE 802.16 Based Networks, Although using OPNET WiMAX models, they focused mainly on implementing their own scheduling algorithms. However, in the IEEE 802.16 standard, the scheduler is left open for implementation, thus creating an avenue for a healthy competition amongst manufacturers. While the standard defines the required procedures and messages for schedulers, it does not offer encouraging means to provide performance, reliability, or Quality of Service (QoS).

Also Dang et al, (2007). Studied performance of scheduling algorithms for WiMAX networks, some of their work is quite related to our works. However they focused mainly on implementing some existing scheduling algorithms.

3. Simulation Setup & Results
Model for Implementation in this experiment, we used OPNET Modeler version 16.0 with WiMAX Module capability (OPNET Modeler). We designed six scenarios to Improve Voice scenario and Improve Data scenario including one scenario with one BS only and rest of five scenarios has two three, four, five and six base stations with four subscribers station around each. The network consist an IP backbone containing one server connected to the IP backbone. Subscriber station Transmission Power is set to 0.5 W. Base Station Transmission Power is set to be 5W. The Path loss and Multipath Model are set to Pedestrian. The parameters of Subscriber Station and Base Station can be seen at Table 1 and Table 2. A
detailed explanation of the simulated network model together with configured traffic that was developed for the Mac Layer QoS Performance of UGS and rtPS are discussed.

Basic parameters associated with WiMAX Configuration attributes, Application Configuration, Application Profile, Task Definition, BSs configuration and Subscribers Station for the proposed Master-Slave model in fixed WiMAX are configured.

Table 1 shows the simulation setup parameters used in the scenario by including additional BS, SS, and number of master BS and simulation time.

### TABLE 2: Service flows supported in WiMAX

<table>
<thead>
<tr>
<th>Service-Flow Designation</th>
<th>Defining QoS Parameters</th>
<th>Application Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsolicited-Grant Service (UGS)</td>
<td>Maximum sustained rate, Maximum latency tolerance, Jitter latency tolerance</td>
<td>Voice over IP (VoIP) without silence suppression</td>
</tr>
<tr>
<td>Real-Time Polling Service (rtPS)</td>
<td>Minimum reserved rate, Maximum sustained rate, Maximum latency tolerance, Traffic priority</td>
<td>Streaming audio and video, MPEG (Motion Picture Experts Group) encoded</td>
</tr>
<tr>
<td>Non-Real-Time Polling Service (nrtPS)</td>
<td>Minimum reserved rate, Maximum sustained rate, Traffic priority</td>
<td>File Transfer Protocol (FTP)</td>
</tr>
<tr>
<td>Best-Effort Service (BE)</td>
<td>Maximum-sustained rate, Traffic priority</td>
<td>Web-browsing, Data transfer</td>
</tr>
<tr>
<td>Extended Real-Time Polling Service (ErtPS)</td>
<td>Minimum reserved rate, Maximum sustained rate, Maxi-mum latency tolerance, Jitter tolerance, Traffic priority</td>
<td>VoIP with silence suppression</td>
</tr>
</tbody>
</table>

### TABLE 3. Simulation Parameters

<table>
<thead>
<tr>
<th>Efficiency Mode</th>
<th>Mobility and Ranging Enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC Service Class Definition (QoS)</td>
<td>1) UGS e.g. VoIP (IP Telephony)</td>
</tr>
<tr>
<td></td>
<td>2) rtPS e.g. MPEG (High Resolution Video)</td>
</tr>
<tr>
<td>Modulation Technique</td>
<td>Wireless OFDM</td>
</tr>
<tr>
<td>Number of Subcarriers</td>
<td>2048</td>
</tr>
</tbody>
</table>
Figure 2(a) and 2(b) below shows the Configuration of WiMAX Networks supporting Data and VoIP traffic and The WiMAX subscriber station parameters respectively.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>20 MHz</td>
</tr>
<tr>
<td>Duplexing Technique</td>
<td>TDD</td>
</tr>
<tr>
<td>Frame Duration</td>
<td>1 ms</td>
</tr>
<tr>
<td>Symbol Duration</td>
<td>0.05 us</td>
</tr>
</tbody>
</table>

Figure _2(a) Configuration of WiMAX Networks  Figure_2(b) WiMAX subscriber station Supports Data and VoIP traffic parameters

The WiMAX Base station parameters were shown in Figure 3.

Figure_3 WiMAX Base station parameters
3.1 Scenarios of WiMAX Mac Layer QoS Performance for UGS and rtPS Model

3.1.1 Scenario_1

In this scenario, one WiMAX BSs were developed with four SSs around each BS as shows in Figure 4. All the BSs are connected to the IP backbone (Internet) using point-to-point protocol (ppp). Basic parameters associated with WiMAX Configuration attributes, Application Configuration, Application Profile, BS configuration and SS for the model are configured.

Figure 4_ Mac Layer QoS Performance of UGS and rtPS (scenario_1)

3.1.2 Scenario_2

In this scenario, two WiMAX BSs were developed with eight SSs around each BS as shows in Figure 5. All the BSs are connected with IP backbone (Internet) using point-to-point protocol (ppp). Basic parameters associated with WiMAX Configuration attributes, Application Configuration, Application Profile, BS configuration and SS for the model are configured. All parameters are same as scenario 1
3.1.3 Scenario_3

In this scenario, three WiMAX BSs were developed with eight SSs around each BS as shows in Figure 6. All the BSs are connected to the IP backbone (Internet) using point-to-point protocol (ppp). Basic parameters associated with WiMAX Configuration attributes, Application Configuration, Application Profile, BS configuration and SS for the model are configured. All parameters are same as scenario 1.

3.1.4 Scenario_4

In this scenario, four WiMAX BSs were developed with eight SSs around each BS as shows in Figure 7. All the BSs are connected to the IP backbone (Internet) using point-to-point protocol (ppp). Basic parameters associated with WiMAX Configuration attributes,
Application Configuration, Application Profile, BS configuration and SS for the model are configured. All parameters are same as scenario 1.

3.1.5 Scenario_5
In this scenario, three WiMAX BSs were developed with eight SSs around each BS as shows in Figure 8. All the BSs are connected to the IP backbone (Internet) using point-to-point protocol (ppp). Basic parameters associated with WiMAX Configuration attributes, Application Configuration, Application Profile, BS configuration and SS for the model are configured. All parameters are same as scenario1.

3.1.6 Scenario_6
In this scenario, five WiMAX BSs were developed with eight SSs around each BS as shows in Figure 9. All the BSs are connected to the IP backbone (Internet) using point-to-point protocol (ppp). Basic parameters associated with WiMAX Configuration attributes,
Application Configuration, Application Profile, BS configuration and SS for the model are configured. All parameters are same as scenario 1.

![Figure 9: Mac Layer QoS Performance of UGS and rtPS (scenario_2)](image)

### 3.2 Results & Analysis

This section shows the results and analysis obtained through simulation in OPNET Modeler for average WiMAX, average WiMAX Delay and average WiMAX Load.

#### 3.2.1 Average WiMAX Throughput Results

Figure 10 shows the result obtained in the design of scenario 6 of the average Throughput graph.

![Figure 10: WiMAX average Throughput graph](image)

#### 3.2.2 Average WiMAX T Delay Results

The following Figure shows the result obtained from scenario 1 to 6 for the average Load.
3.2.3 Average WiMAX T Delay Results

The following Figure 12 shows the result obtained from scenario 1 to 6 for the WiMAX average delay.

3.3 Analysis of the Results

In this research, we have divided our work into six different scenarios with the help of OPNET Modeler. 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 traffic priority for UGS is high as compared to rtPS. In each scenario the number of Base Stations and Subscriber Stations are increased to enhance the performance. Through different scenario we
have compare the throughput, delay and load with respect to time. The simulation parameters used in this model are listed in Table 2.

Here the global analyses of all the scenarios are done and the comparison of average throughput (packets/sec), average load (packets/sec) and average delay (sec) are given.

Figure 10 indicates the comparison between Through-pu (packets/sec) Vs Simulation Time of all six scenarios. In all scenarios every SS can communicate simultaneously with each other through base station. Simulation time is taken as 60 seconds, after simulation we have observed that throughput of scenario 1 is nearly about 0.6 packets/sec, scenario 2 have 0.89 packets/sec, scenario 3 have 1.1 packets/sec, scenario 4 have 1.4 packets/sec, scenario 5 have 1.89 packets/sec and scenario 6 have 2.45 packets/sec. Figure 11 indicates the comparison between Loads (packets/sec) Vs Simulation Time in each scenario. Scenario 1 have 0.139 packets/sec, scenarios 2 have 0.219 packets/sec, scenario 3 have 0.21 packets/sec, scenario 4 have 0.168 packets/sec, scenario 5 have 0.242 packets/sec, and scenario 6 have the highest load of about 0.239 packets/sec.

Figure 12 indicates the result between Delays (sec) Vs. Simulation Time. We have seen that delay of scenario 1 has 0.00319 sec throughout the simulation time (constant delay). Similarly scenario 2 have 0.00168 sec initially and remains constant at 0.00148 sec, scenario 3 delay is vary from 0.0048 to 0.00379 sec, scenario 4 varies from 0.0015 to 0.0034 sec, scenario 5 varies between 0.00579 to 0.00538 sec and scenario 6 varies from 0.00392 to 0.00164 sec.

4. Conclusions

In this research we have discussed the concept of WiMAX network performance for QoS monitoring and optimization solution for Base Station with multimedia application to equate quality and cost. Six scenarios was developed to compares the performance obtained using two different types of MAC layer delivery service class used to transport VoIP traffic the UGS and rtPS. In each scenario the number of fixed BS and SS has been increased from one to six in the BS and four to twenty four in the SS to cover more required users. All the simulation results are based on optimized networks and area. The results indicate that the delay sensitive traffic fluctuates beyond its nominal rate, having the possibility to give back some of its reserved bandwidth; ertPS has the advantage to permit the transmission of Best effort (BE) traffic than UGS and also the traffic priority for UGS is high as compared to rtPS.
References


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