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Quality of Service (QoS) in Wi-Max (IEEE 802.16)

Meenakshi Rani[1], Hemant Dalal[2] and Amit Dalal[3]

[1]**M. Tech. Student, ECE Department, CBS, Fatehpuri, Jhajjar, Haryana (India)**
meenakshi.dalal5@gmail.com

[2]**Assistant Professor, ECE Department, CBS, Fatehpuri, Jhajjar, Haryana (India)**
hemantdalal87@gmail.com

[3]**Assistant Professor, ECE Department, GITAM Kablana, Jhajjar, Haryana (India)**
amitdalal1988@gmail.com

Abstract

In last few years there has been significant growth in the area of wireless communication. Quality of Service (QoS) has become an important consideration for supporting variety of applications that utilize the network resources. These applications include voice over IP, multimedia services like video streaming, video conferencing etc. IEEE 802.16/WiMAX is a advanced network over Wi-Fi which is designed with quality of services. This paper aims on quality of service as implemented by the Wi-MAX networks. In real life we use voice call, video streaming which are set up through Wi-Max. We use many parameters for quality of service and these are: throughput, packet loss, average jitter and average delay. Wi-Max is the advanced version of Wi-Fi in which we get the better quality of resources.

Keywords: *Improvement over Wi-Fi, IEEE 802.16, QoS, Wi-MAX.*

1. Introduction

Wi-Max is advanced version over Wi-Fi in which we get high speed and good range in connectivity for internet. WIMAX stands for Worldwide Interoperability for Microwave Access. It is the technology aimed to provide broadband wireless data access over long distances. This technology provides basic Internet Protocol (IP) connectivity to the user. The variety of applications used in IP networks has increased tremendously in the recent years. Various multimedia applications along with the common email, file transfer and web browsing applications are becoming increasingly popular. These applications send large audio and video streams with variable bandwidth and delay requirements. On the other hand, remote monitoring of critical services such as E-commerce and banking applications which do not need strict bandwidth guarantees due to the good nature of the data transfer. Instead, these applications require reliable and prompt packet routing. The presence of different kinds of applications in a network, results in heterogeneous traffic load. The traffic from different applications may require certain type of quality of service. In this paper, the Quality of Service (QoS) as prescribed in the Wi-MAX networks is studied.

As packets travel within a wireless network such as Wi-MAX, they experience the following problems: Delay, jitter, out-of-order delivery, packet loss or error.

Quality of Service refers to the probability of the telecommunication network meeting a given traffic contract. In the field of packet-switched networks and computer networking it is used informally to refer to the probability of a packet succeeding in passing between two points in the network. Although the name suggests that it is a qualitative measure of how reliable and consistent a network is, there are a number of parameters that can be used to measure it quantitatively. These include throughput, transmission delay or packet delay, delay jitter, percentage of packets lost etc.

Quality of service enables end-to-end IP based QoS. Among other things, the MAC layer is responsible for scheduling of bandwidth for different users. The MAC layer performs bandwidth allocation based on user requirements as well as their QoS profiles. The standard is designed to support a wide range of applications. These applications may require different levels of QoS. To accommodate these applications, the Wi-Max has defined many service flow classes.

These service flows can be created, changed, or deleted by the issuing Dynamic Service Addition (DSA), Dynamic Service Change (DSC), and Dynamic Service Deletion (DSD) messages. Each of these actions can be initiated by the Subscriber Station (SS) or the Base Station (BS) and are carried out through a two or three-way-handshake.

Wi-Max is advanced version over Wi-Fi in which we get high speed and good range in connectivity for internet. These applications send large audio and video streams with variable bandwidth.

The services classes defined by Wi-Max are given below:

Table 1: Service Classes Defined by Wi-Max

	Description	**Applications**
Unsolicited Grant Service	For Constant Bit Rate (CBR) and delay- dependent applications	VOIP
Real-Time Polling Service	For Variable Rate and delay dependent applications	Streaming audio, Streaming video
Extended Real-Time Polling Service	For Variable Rate and delay dependent applications	VOIP with silence suppression
Non-real-time Polling Service	Variable rate and non-real time applications	FTP
Best Effort	Best Effort	E-mail, web traffic

This paper focuses on the QoS in WiMAX networks. The details of the implementation of QoS in the WiMAX network architecture will be presented. It includes the definition of various service flows defined by the IEEE 802.16 standard. The details of the network's MAC layer QoS implementation are presented. To analyze the QoS parameters simulation based on the popular network simulator ns-2 is used. Various parameters that determine QoS of real life usage scenarios and traffic flows of applications is analyzed. The goal is to compare different types of service flows with respect to the QoS parameters, such as, throughput, average jitter, average delay and packet loss.

A Wi-MAX module written for ns-2 is used to simulate real life situations and analyze the effect of various network conditions and load on QoS parameters. We have many Qos Parameters like Throughput, Average delay, Average Jitter etc.

The VOIP traffic is set up using five different VOIP codecs which have different packet size and data rates. The effect of number of nodes in the network requesting VOIP traffic is analyzed The VOIP traffic is set up using the three supported service flows that are supported namely, best effort, real-time polling service and unsolicited grant service. The effect of the service flow on the quality of service parameters such as throughput, average jitter and packet loss is studied.

Next, the use case of streaming video is case is studied. The effect of number of nodes on the multimedia traffic is analyzed for different service flows. Similar to the case of VOIP traffic, the analysis is done based on the four QoS parameters namely, throughput, average jitter, average delay and packet loss.

2. Network Architecture and Layers

A. WiMAX Network Architecture and MAC layer details

The WiMAX End-to-End Network Systems Architecture document defines the WiMAX Network Reference Model. It is a logical representation of the network architecture. The Network Reference Model identifies functional entities and reference points over which interoperability is achieved. The architecture has been developed with the objective of providing unified support of functionality needed in a range of network deployment models and usage scenarios.

Figure shows basic components of a WiMAX network. The SS are connected over the air interface to the BS. The base station is part of the Access Service Network (ASN) and connects to the Connectivity Service Network (CSN) through the ASN Gateway. In generic telecommunication terminology, ASN is equivalent to RAN (Radio Access Network) and CSN is equivalent to Core.

B. MAC layer details in IEEE 802.16/WiMAX network

The IEEE 802.16 MAC layer performs the standard Medium Access Control (MAC) layer function of providing a medium-independent interface to the physical (PHY) layer. WiMAX systems are based on Orthogonal Frequency Division Multiple Access (OFDMA). It provides improved multi-path performance and operation in non-line-of-sight environments. Scalable OFDMA (SOFDMA) is introduced in the IEEE 802.16e amendment to support scalable channel bandwidths. Some of the key features supported by WiMAX include the following.

i) High Data Rates: Data rates of up to 65 Mbps in downlink and up to 40 Mbps in uplink can be achieved in WiMAX in a 15MHz channel. This is possible because of inclusion of MIMO (Multiple Input Multiple Output) antenna techniques along with flexible sub-channelization schemes, larger MAC frames, Advanced Coding and Modulation.

ii) Scalability: WiMAX technology is designed to be able to scale to work in different channelization from 1.25 to 20 MHz. This also deployment of WiMAX network in different geographical regions based on varying needs.

iii) Security: Another key feature of WiMAX networks is that the security layer is built into the protocol stack instead of being added on later. The security layer is sandwiched between PHY and MAC layers. The messages for authentication and key exchange are defined as part of the MAC layer. The MAC layer performs encryption based on the keys negotiated during the key exchange phase.

iv) Mobility: WiMAX supports optimized handover schemes with latencies less than 50 milliseconds to ensure real-time applications such as VoIP perform without service degradation. Flexible key management schemes assure that security is maintained during handover.

v) QoS: Finally the fundamental premise of the IEEE 802.16 MAC architecture is QoS. The QoS architecture will be discussed in detail shortly.

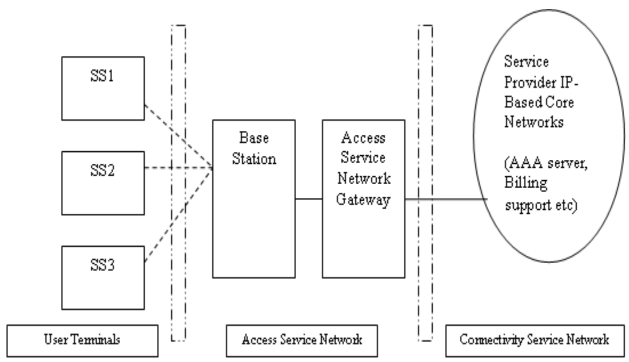

Figure 1: Network Architecture of Wi-Max

The main focus of the MAC layer is to manage the resources of the air-link in an efficient manner. MAC layer is responsible for overall connection and session processing. The MAC layers at BS and SS communicate to set up an RF connection, and to set up, add and delete services on an as needed basis. As mentioned earlier, the IEEE 802.16 standard has defined five service flow classes which have different QoS requirements: Unsolicited Grant Service (UGS), Real- Time Polling Service (rtPS), non-Real-Time Polling Service (nrtPS), Enhanced-Real-Time Polling Service (ertPS), and best effort (BE).

Each scheduling service is characterized by a mandatory set of QoS parameters, which is tailored to best describe the guarantees required by the applications that the scheduling service is designed for. Furthermore, for uplink connections, it also specifies which mechanisms to use in order to request bandwidth.

UGS is designed to support real-time applications (with strict delay requirements) that generate fixed-size data packets at periodic intervals, such as T1/E1 and VoIP without silence suppression.

The guaranteed service is defined so as to closely follow the packet arrival pattern. Uplink grants are granted by the BS regardless of the current estimation of backlog; hence, UGS connections use the unsolicited granting bandwidth-request mechanism. Thus UGS connections never request bandwidth. It is given periodic bandwidth without any polling or contention. The grant size is computed by the BS based on the minimum reserved traffic rate, which is defined as the minimum amount of data transported on the connection when averaged over time. If additional bandwidth is required, the SS may request the BS to poll it to allocated bandwidth. rtPS is designed to support real-time applications (with less stringent delay requirements) that generate variable-size data packets at periodic intervals, such as Moving Pictures Expert Group (MPEG) video and VoIP with silence suppression. The key QoS parameters for rtPS connections are the minimum reserved traffic rate, which has the same meaning as with UGS, and the maximum latency, which upper bounds the waiting time of a packet at the MAC layer. Since the size of arriving packets with rtPS is not fixed, as it is with UGS-tailored applications, rtPS connections are required to notify the BS of their current bandwidth requirements. The BS periodically grants unicast polls to rtPS connections. The polling period may be explicitly specified as an optional QoS parameter, namely, the unsolicited polling interval.

Unlike UGS and rtPS scheduling services, nrtPS and BE are designed for applications that do not have any specific delay requirement. The main difference between the two is that nrtPS connections are reserved a minimum amount of bandwidth (by means of the minimum reserved traffic rate parameter), which can boost performance of bandwidth- intensive applications, such as File Transfer Protocol (FTP). Both nrtPS and BE uplink connections request bandwidth by either responding to broadcast polls from the BS or piggybacking a bandwidth request on an outgoing Packet Data Unit (PDU). These requests are contention based.

C. Analysis Strategy

To analyze QoS in a network it is necessary to study real life scenarios. The simulation set up would reflect the actual deployment of the WiMAX network. Based on the network reference model described earlier, Fig. shows the setup that will be used. There are multiple SS's in the range of a base station. The base station is connected to the core network.

The focus of analysis will be the connection between the subscriber and the base station. Various types of traffic can be set up from the subscriber station to mimic real life scenarios.

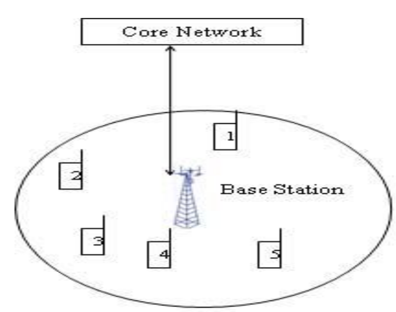

Figure 2: Core Network

D) Network Simulator

The network simulator 2 (ns-2) is a popular tool for the simulation of packet-switched networks. It provides substantial support for simulation of TCP, routing, and MAC protocols over wired and wireless networks. The simulator core is written in C++. It has an OTcl (Object Tool Command Language) interpreter shell as the user interface and allows input models written as Tcl (Tool Command Language) scripts to be executed. Most network elements in ns-2 simulator are developed as classes, in object-oriented fashion. It is freely distributed and all the source code is available.
Figure shows basic structure of ns-2. The network topology and traffic agents etc are specified in the TCL file. It is parsed by the oTCL interpreter. The C++ library has all the implementation details. When ns-2 is run, the resulting data could be obtained in a trace file format. The trace file contains time stamp and information about each packet that is sent, received or dropped. It also has information about the packet size, type of packet etc. A base station and a subscriber station can be set up as a node in ns-2. As the number of nodes in the simulation increase, the packets that are sent and received increases. This makes the trace file very large.

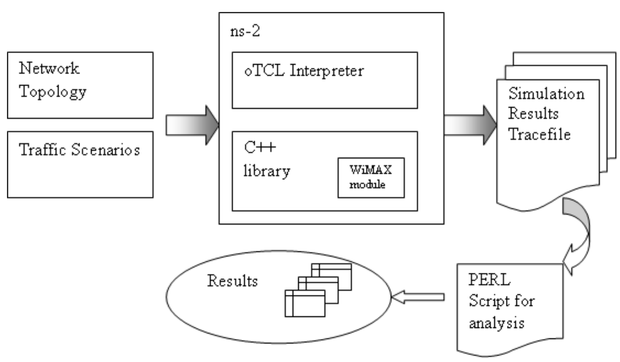

Figure 3: NS-2 Architecture

E) QoS Parameters

QoS provisioning encompasses providing Quality of Service to the end user in terms of several generic parameters. The perceived quality of service can be quantitatively measured in terms of several parameters. In the analysis, the throughput, average delay, average jitter and packet loss were considered

(i) Throughput

Throughput is a measure of the date rate (bits per second) generated by the application. Equation 1 shows the calculation for throughput TP, where PacketSize is the packet size of the ith packet reaching the destination, PacketStart is the time when the first packet left the source and PacketArrival is the time when the last packet arrived.

$$TP = \sum PacketSize / (PacketArrival - PacketStart)$$

From the trace file, based on the packet ID, each data packet was kept track of. The time a packet is sent, the time when the packet was received and the packet size was stored for all packets that reached the destination. To calculate throughput, the size of each packet was added. This gave the total data that was transferred.

The total time was calculated as the difference between the time the first packet started and the time the last packet reached the destination. Thus throughput is equal to the total data transferred divided by the total time it took for the transfer.

(ii) Average Delay

Delay or latency would be time taken by the packets to transverse from the source to the destination. The main sources of delay can be further categorized into: source-processing delay, propagation delay, network delay and destination processing delay. Equation 2 show the calculation for Average Delay, where $PacketArrival_i$ is the time when packet "i" reaches the destination and $PacketStart_i$ is the time when packet "i" leaves the source. "n" is the total number of packets.

Average delay= (Packet Arrival- Packet Start)/n

(iii) Average Jitter

Delay variation is the variation in the delay introduced by the components along the communication path. It is the variation in the time between packets arriving. Jitter is commonly used as an indicator of consistency and stability of a network. Measuring jitter is critical element to determining the performance of network and the QoS the network offers.

Average Jitter= ((Packet Arrival+1)- (Packet Start+1))-((Packet Arrival)-(Packet Start))/n-1

(iv) Packet Loss or Corruption Rate

Packet loss affects the perceived quality of the application. Several causes of packet loss or corruption would be bit errors in an erroneous wireless network or insufficient buffers due to network congestion when the channel becomes overloaded.

Packet Loss= (∑(Lost Packet Size/∑Packet Size)*100

3. Conclusion

In this paper, the general concepts of Quality of service (QoS) in wireless networks were studied. The IEEE 802.16/WiMAX network architecture was presented and the MAC layer features that enable end-to-end QoS mechanism in the network were discussed.

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