INVESTIGATIVE ANALYSIS OF IMPROVED QOS SUPPORT FOR WIMAX NETWORKS

A. Ahmed and A. F. Salami
Department of Computer Engineering
Federal University of Technology Minna
P.M.B 65, Minna, Niger state, Nigeria
aliyu.ahmed@futminna.edu.ng and kermkerm1@gmail.com

ABSTRACT
Quality of Service (QoS) is considered as the backbone of any Broadband media access network of which Worldwide Interoperability for Microwave Access (WiMAX) is not an exception. Consequently, this area has gathered a lot of interest from academic researchers and industrialists with the goal of coming up with improved QoS service to support different traffics in WiMAX network. This research work is an investigation of the various state of the art QoS schemes that have been proffered as solutions to this challenge. It presents an investigative analysis of three approaches - the hierarchical scheduling approach for improving QoS Service in WiMAX which divides the scheduling scheme into three different tiers, cross-layer optimization approach for improving QoS in WiMAX and on demand bandwidth allocation approach for improving QoS in WiMAX. The performance evaluation of each of the approaches are investigated using the same metrics and then presented for making trade-offs decisions.

KEY WORDS
WiMAX, QoS (Quality of Service), Scheduling, Broadband Access Network, Bandwidth Allocation, Throughput, Performance.

1. Introduction
WiMAX (Worldwide Interoperability for Microwave Access) network is a form of broadband wireless access networks. It is becoming very popular in the world of communications and computer networks both in the industries and academia. It has potential to provide broadband wireless access, better and cheaper solution for communication services when compared with the existing standards and technologies [1]. However, Quality of Service (QoS) remains one of the major factors that are hindering the design of WiMAX network to support different types of traffic [2]. This research surveys the various research works done in this area. This research paper also provides recommendations regarding the top three approaches of improving the quality of service (QoS) to support different traffics in the WiMAX network with the best performances. These approaches are based on the IEEE 802.16 standards which defines the MAC (Media Access Control) layer of the WiMAX [1] network. Subsection 2 gives the overview of some related works that serve as the underlying technology for the approaches surveyed in this work. Subsections 3, 4 and 5 describe state of the art approaches surveyed and presented in this work. The approaches are hierarchical scheduling approach for QoS Service in WiMAX, cross-layer optimization approach for QoS in WiMAX and on demand bandwidth allocation approach for QoS in WiMAX. Lastly, performance evaluation of investigated techniques is presented in subsection 6 while the conclusion is given in subsection 7.

2. Background Review
Many scheduling schemes and algorithm for fine-tuning the QoS service for WiMAX network have been proposed and implemented in the past. A single layer approach was proposed in [3], while, [4] introduces hierarchical approach for QoS support in WiMAX networks. Token bank fair queuing (TBFQ) was proposed by [5]. This makes use of the priority index and then tracks the normalised service that is received by the excess flows. In a protocol called UBAR (uplink Bandwidth Allocation and Recovery), a proportional fair scheme is engaged to utilize the bandwidth efficiency [6]. Half-duplex allocation (HDA) is a grant allocation algorithm proposed to certify a constant and feasible grant allocation while meeting up with the sufficient conditions [7]. Hence, the user will have on board an adaptive bandwidth allocation scheme (ABAS) to adjust the bandwidth ratio according to the current traffic profile. In this scheme, the overall throughput is higher but lack fairness to the service flow priority. Certainly, using this scheme will bring up the cost for service flow [3]. However, the proposed pre-emptive deficit priority fair priority queue (PDFPQ) in [3] promise to optimize the QoS requirement of real time polling service (nrPS) flow category, providing reduction in the delay time and at the same time improve the throughput. Then, the proposal of highest urgency first (HUF) algorithm emerged. This is a modulation aware algorithm that guarantees service differentiation and fairness without compromising latency.

3. Hierarchical Scheduling Approach for improving QoS Service in WIMAX

Scheduling algorithm is important in the provisioning of guaranteed quality of service parameters such as delay, packet loss rate and throughput. In this subsection, Hierarchical scheduling framework for improving the QoS (Quality of Service) in WiMAX point-to-point is reviewed. This approach provides three-tier QoS service architecture while scheduling schemes are used to provide the needed support for the improvement of QoS supports in WiMAX networks with point-to-point topology [8]. The major principle is that, the QoS provisioning is distributed dynamically to three tiers and each of the tiers is implemented independently in a separate BS (Base Station) and SSs (Subscriber Station). It is expected of this approach to improve the performance of WiMAX point-to-point network in terms of QoS such as packet delay, packet loss rate and throughput [8]. This approach is deployed with real-time and non-real-time traffic integration.

3.1 The Structure of WiMAX PMP (Point-to-Multipoint) Network and Workability

WiMAX PMP network consists of a base station (BS), subscriber stations (SSs) and mobile or fixed stations (user equipment). All the communications among the base station (BS) and the subscriber stations (SSs) occurring within the radio coverage of a BS are coordinated and regulated by the BS. Time slot is shared between the sub-channels (downlink and uplink) for information transmission. Thus, it is part of BS's regulating activity to allocate these time slots to each SS Uplink map message (UL-MAP) broadcast this information on the bandwidth allocation. This always happen at the beginning of each Downlink sub-frame. Information element (IE) contained in Uplink-map message (UL-MAP) represent the number of time slots that each SS is allowed to transmit within the UL sub frame [8]. Therefore, as seen above, it can be said that BS is responsible for scheduling the contents in the IE based on the bandwidth request protocol data units used from SSs [8].

3.2 The Overview of the Three-Tier Scheduling Scheme

The scheduling scheme is divided into three tiers of hierarchies. Tier 1 scheduling is achieved by using the "priority-based queue length weighted scheduling algorithm" within each class of service at the BS [8]. In the Tier 2 scheduling scheme, the "self-clocked fair queuing" and the "weighted round robin scheduling" scheme is used within each class of service at each SS. While, lastly, the scheduling scheme called, the "earliest deadline first and shortest packet length first" [9] is applied to Tier 3. The purpose of this algorithm is to carry burst traffic on that Tier alone. One of the important features of this approach is that it makes use of "dynamic resource reservation" (DRR) to improve the QoS service in the WiMAX network. Other advantages of this approach are-

- It provides monopoly of QoS service used on four different types of traffic in one system.
- Since the QoS support is distributed over three tiers and are independently performed by both base station and subscriber station, the bandwidth, traffic congestion, delay and throughput are efficiently improved.
- It dynamically allocates bandwidth to both uplink and downlink [8].

3.3 Criteria for the design of Efficient QoS for WiMAX Networks

- The existing WiMAX QoS signalling mechanisms and the downlink/uplink map mechanism should be fully applied.
- Effort should be made to minimize the per-connection scheduling overhead.
- The QoS service parameters for each connection should be guaranteed [8]

This approach provides an architecture which make up for the missing protocols in the QoS architecture specified in the IEEE 802.16d standard, thereby providing the required enhancement and improvement in the performance metrics such as delay, bandwidth, data drop rate and throughput of the WiMAX network.

One of the proposals based on hierarchical Scheduling Scheme is 'a two-stage downlink scheduling and resource allocation mechanism collaborating with application layer forward error correction' proposed in [18] to maximize the system throughput and provide guarantee in QoS to fulfil the requirements of multimedia applications. Results in [18] indicate that the system throughput under different traffic class is significantly improved and suggests that resource consumption could be minimized.

4. Cross-Layer Optimization Approach for improving QoS in WiMAX

The requirements of delivering end-to-end quality of service (QoS) in this new age of computing especially in (WiMAX) considering the limited network resources available involve more efficient use of spectrum. Cross-layer optimization technique should improve high transmission rates with QoS support guarantee for all traffic scenarios and high mobility [17].

To achieve the requirements of high spectral efficiency and QoS provisioning in mobile radio setting entails the integration of several layers in the WiMAX network system which in turn calls for effective optimization scheme that is cross-layer adaptive [11]. According to [10], to attain the QoS requirement service guarantee such as minimum data rate, reliability, jitter-controlled, low latency, and user fairness of next generation wireless network systems, proper and efficient design of cross-layer optimised wireless network is necessary. In this section, cross-layer framework for WiMAX networks is reviewed. This optimises the network performances along with sustaining the end-to-end QoS of individual users. In [10], it is stressed that cross-layer design approaches are very vital for efficiently making the most of the limited radio resources with QoS delivering in the 4G wireless network systems such as WiMAX. In other words, better system performance (QoS requirements) in terms of minimum data rate and low latency can be achieved through information exchanges across different protocol layers which the conventional layered architecture cannot provide.

Resource allocation and scheduling remain crucial concern since efficient use of the scarce network resources is highly needed to achieve the sole aim of high level of cross-layer optimisation for QoS in next generation wireless network. According to [12], resource allocation is associated with medium access control (MAC) and is a cross-layer design issue that is applied in MAC by means of information exchange with other layers. Proper and efficient cross-layer resource allocation remains a challenge that must be considered and addressed as the wireless channel conditions and user requirements of QoS may not be constant. Hence, the need for constant updating of parameters. Cross-layer design based on the order in which QoS optimisation is carried out can be classified in four (4) categories as discussed in [10]:

- **Top-down technique**: In this approach, higher protocols improve their parameters together with the strategies in use at the immediately following lower layer. According to [10], most current systems have employed this cross-layer solution during which the MAC parameters and strategies are dictated by the application, while the MAC selects the most advantageous PHY layer modulation and coding scheme.
- **Bottom-up technique:** In bottom-up technique, lower layer protocols attempt to shield the higher layers from losses and bandwidth variations. This cross-layer solution according to [10] is not the best when it comes to multimedia transmission owing to the unnecessary performance (throughput) reductions and delays experienced during the transmission.
- **MAC centric technique:** In this approach, the application layer forwards its traffic details and requirements to the MAC which in turn comes to a decision as to which application layer packets should be transmitted and the particular QoS level the packets should be transmitted. The MAC as well chooses the PHY layer parameters and strategies [13] depending on the available channel information.
- **Integrated technique:** In the integrated approach, all feasible strategies and their corresponding parameters are tried so as to choose the most appropriate composite strategy that will lead to the best quality or optimal performance (or throughput). In other words, strategies are determined jointly; but this is rather difficult if not impractical as a result of the associated complexity involved. In [10] and [13], this complex cross-layer optimisation problem could be resolved in an integrated manner through the application of learning and classification techniques, which yield the most optimum but complex design.

The MAC centric cross-layer optimisation which is comparatively easier as well as simple to implement, and presents the most suitable approach to solving the current problem of using cross-layer framework for WiMAX networks for the system performance optimisation in addition to maintaining the end-to-end QoS of individual users.

'QoS aware cross-layer optimized resource allocation scheme for WiMAX networks' is one of the proposals based on the cross-layer integration approach to improve the QoS in WiMAX networks [15]. It optimizes the performance of the system and maintains the end-to-end QoS of each user. For any good, service guarantees such as high minimum data rate, low latency, fairness, and design simplicity for such networks are very important [15]. The above proposal is aimed at maximizing the performance of delay-tolerant applications [15].

Medium access control (MAC) centric cross-layer conceptual framework for resource allocation optimisation is as depicted in figure 1. It is made up of source, wireless channel, Application Layer, MAC and PHY layers. Application layer Access the source through the source characteristics Dynamics.

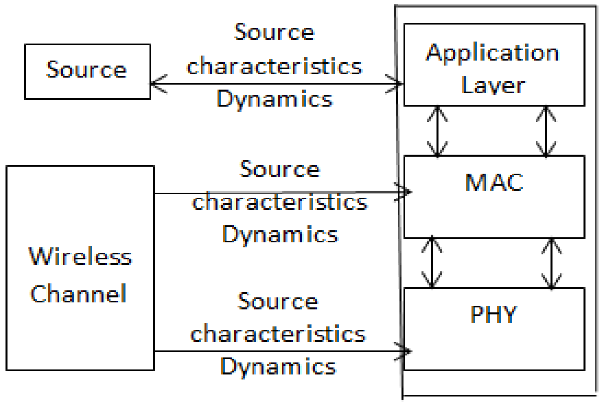


Figure 1: Dynamics of Cross-layer Design [10]

5. On-Demand Bandwidth Allocation Scheme for improving QoS in WiMAX

These techniques are proposed to tackle the problem of bandwidth allocation in WiMAX network based on IEEE 802.16e-2005 standard, by using a mechanism which allocates the bandwidth on demand.

However, it is important to note that the IEEE 802.16e-2005 is an additional expansion of WiMAX standard. IEEE 802.16e-2004 and further expansion of WiMAX in the frequency range up to 6Ghz with the goal of accommodating mobile application and roaming [14]. The size of carriers can vary over a wide range relative to the permutation zones and Fast Fourier Transform (FFT) base (128, 512, 1024 and 2048). The frame control header (FCH) content has been shortened and modified for Fast Fourier Transform (FFT) size 128. This adjustment introduces new feature and attribute to the standard necessary to support mobility [14].

WiMAX key technology can use both OFDMA and OFDM modulation scheme to sufficiently enable Multi-path access in (NLOS) non-line-of –sight situations, it thus, selects appropriate bandwidth at 1.25—20Mhz based on the frequency resources and service flow demand [14]. WiMAX Physical layer Switch to TDD mode, to select proportion frame for uplink and down link direction, based on the service demand. In order to provide efficient channel access control mechanism, the MAC layer is defined by IEEE 802.16e-2005 protocol. the control mechanism mainly includes service, access control, past convergence, ranging, link scheduling and optional automatic retransmission mechanism.

One of the proposals that are based on on-demand bandwidth allocation scheme is 'Joint Dynamic Bandwidth Allocation. Scheme for IEEE 802.16 single-hop self-backhaul Network using 3-sector base station' [16]. From the results of the implementation in [16], it is indicated that there is a significant improvement in QoS of the MiMAX network by providing higher bandwidth efficiency and better fairness compared to the conventional schemes. Throughput of about 33.3Mbs is recorded [16].

5.1 Brief Description of the Model Design

Bandwidth Allocation Requirement:

- **Ranging:** WiMAX ranging process includes four types of ranging as shown in table 1.

Table 1: WiMAX Ranging process [14]

Code	Function
Initial ranging code	Establish connection between BS & CS
Period ranging code	BS and SS keep contact
HO ranging code	Establish connection between SS and new BS
BR ranging code	SS send to BS for bandwidth allocation

- **Service flow Management of WiMAX System:** WiMAX IEEE 802.16e define five types of service flow, namely; Unsolicited Grant Service (UGS), Extended real time polling service (ertPS), Real time polling service (rtPS), non-real time polling service (nrtPS) and Best effort (BE) [14].
- **QoS parameters Class:** This is a parameter group which describe the service flow such as maximum delay, tolerant jitter, and minimum reserved traffic rate etc. it has 3 levels of class, preparative QoS parameters Class, admitted QoS parameters Class and Activated QoS parameters class [14].

5.2 Brief Description of the Approach

Two new modules are introduced in SS. They are service flow management (SFM) and Uplink (UL) Bandwidth Management (ULBM) modules [14]. The terminal is not responsible for sending the bandwidth request message based on every service flow connection, rather the UBLM will compute the total amount bandwidth of all of the service flow necessary and then forward the bandwidth request message to BS after receiving the granted UL bandwidth by SS from BS. The SS will then distribute the UL bandwidth according to the different service flow QoS demand and requirement. The SFM handles the dynamic service flow management. It sends DAS/DCS/DSD request messages to ULBM which sends feedback response message to SFM according to the UL bandwidth size. Eventually, the UL scheduler will schedule the activated service flow, and the scheduler will adjust the AMC state dynamically according to the granted UL bandwidth size and Hybrid Automatic Request (HRGQ) [14].

6. Performance Evaluation of Investigated Techniques

A summary of the performance evaluation of the investigated techniques is given in Table 2 below:

Table 2: Summary of Performance Evaluation

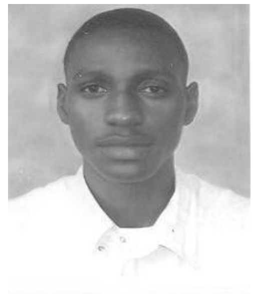
	QoS Parameters											
	TR	PLR	THR	RTD	RLB	SE	M	L	F	J	CLA	MP
HS	N	Y	Y	Y	N	N	N	Y	Y	N	N	N
CLORA	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N
OBA	Y	Y	Y	N	N	N	Y	Y	N	Y	N	Y

The definitions for the acronyms adopted in Table 2 (Summary of Performance Evaluation) are, namely; HS – Hierarchical Scheduling Framework, CLORA – Cross-Layer Optimization and Resource Allocation Framework, OBA – On-demand Bandwidth Allocation Framework, TR – Traffic Rate, PLR – Packet Loss Rate, THR – Throughput, RTD – Real-Time Deployment, RLB – Reliability, SE – Spectrum Efficiency, M – Mobility, L – Latency, F – Fairness, J – Jitter Control, CLA – Cross-Layer Adaptability, MP – Multipath Accessibility, Y – Yes, N – No.

7. Conclusions

This research work investigated three improved approaches to QoS service for enhancing the performance of scheduling scheme in WiMAX networks to support different traffics. Each of the three approaches focuses on a major entity of QoS, (Delay, throughput and bandwidth utilization) for different applications. By comparing the three approaches, it can be seen that each of them tremendously improve the performance of QoS service support in WiMAX networks. Although more work is still required to provide balance and fairness to the QoS performance metrics under different traffics to fully extract the potentials in WiMAX networks.

8. Biographies of Authors



A. Ahmed holds a B.Eng. in Electrical and Computer Engineering of Federal University of Technology, Minna and MSc in Computer Networking of University of Bedfordshire, England, UK. He is currently a Lecturer in the Department of Computer Engineering, Federal University of Technology, Minna.

A. F. Salami holds a B.Eng. in Electronic-Computer and Information Engineering from the International Islamic University Malaysia and MSc in Computer and Information Engineering from the same university. He is currently a Lecturer in the Department of Computer Engineering, School of ICT, Federal University of Technology, Minna.

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