IJoFCS (2010) 1, 16-21

e-forensic PRESS

The International Journal of
FORENSIC COMPUTER SCIENCE

www.IJoFCS.org

Performance Analysis of Quality of Service in PMP Mode WiMax Networks

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Abstract - IEEE 802.16 standard supports point-to-multipoint (PMP) and Mesh topologies. This paper proposes a quality of service (QoS) mechanism for IEEE 802.16 in PMP mode and a base station (BS) scheduler for PMP mode. It also describes the QoS over WiMAX networks. The average WiMAX delay, load, and throughput at the BS were analyzed and compared by applying different schedulers at the BS and fixed nodes.

1. Introduction

IEEE 802.16 is a set of telecommunications technology standards aimed at providing wireless access over long distances in various ways, from point-to-point (PTP) to full mobile cell–type access. IEEE 802.16 was developed to serve fixed subscriber stations (SSs) through a central base station (BS) using a point-to-multipoint (PMP) topology. In PMP mode, every subscriber station (SS) directly communicates with the central BS. The PMP mode in WiMAX easily provides more types of services than wired networks, and does so at lower cost.

The IEEE 802.16 standards were developed with *quality of service* (*QoS*) in mind. In PMP mode, 5 different service classes are introduced for different applications, and packets from different service classes are handled based on their QoS constraints. In this paper, we compared the QoS mechanism obtained using the weighted fair queuing (WFQ) or deficit weighted round robin (DWRR) queue in PMP mode in WiMAX.

2. PMP Mode of IEEE 802.16

IEEE 802.16 -2004 (defined in 2004) operates at both 2-11 GHz and the original 10-66 GHz band. The standards provide medium data rates and support PTP and PMP operation modes for fixed subscribers only. Only ***line-of-sight (LOS)*** and ***non line-of-sight (NLOS)*** communication are supported. In LOS communication, receiver(s) are placed on high rise towers such that all physical obstacles between the transmitter and receiver are avoided. When LOS communication is not possible (e.g., when transmitter/receivers are located inside a home), the communication is said to be NLOS. In this case, signals transmitted from the receiver undergo attenuation and multipath distortion (e.g., after bouncing off trees and buildings).

In PMP mode, the physical and medium access control (MAC) layers mediate communications between the BS and SSs. WiMAX defines the concept of *service flow*, which is the unidirectional flow of packets with a particular set of QoS parameters. A service flow is identified by a 32-bit service flow identifier (SFID). WiMAX is a connection-oriented protocol [1] that provides a means for handling bandwidth requests, allocation traffic, and QoS parameters with service flow, etc. A connection is identified by a 16-bit connection identifier (CID).

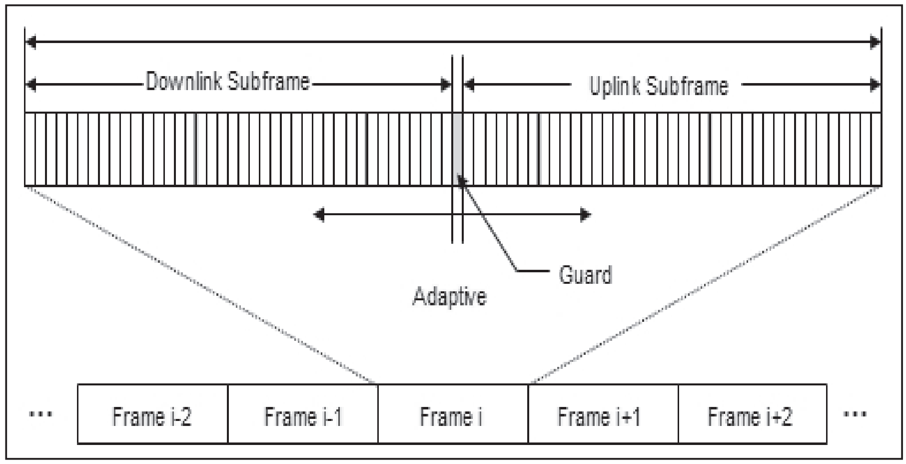

Figure 1. TDMA-frame structure

The MAC layer is divided into 3 sublayers. The *service-specific convergence sublayer (CS)* defines the interface with higher layers, and converts higher-layer packets into MAC-level service flow and parameters. The *common part sublayer (CPS)* implements common MAC functionalities, such as link initialization, admission control, controlling channel access, transmission scheduling, QoS, fragmentation, error control, and retransmission. Finally, the *security sublayer* provides security through authentication, key management, and encryption.

2.1 IEEE 802.16 MAC Protocol

The PMP architecture consists of 1 BS that manages multiple SSs. Transmissions between the BS and SSs are realized in fixed-sized frames by means of time division multiple access (TDMA)/ time division duplexing (TDD) modes of operation. According to Vinel et al. [2], the frame structure consists of a downlink subframe for transmissions from the BS to SSs and an uplink subframe for transmissions in the reverse direction (Fig. 1). The Tx/Rx transition gap (TTG) and Rx/Tx transition gap (RTG) are inserted between the subframes to allow terminals to turn around from reception to transmission and vice versa. In the downlink subframe, the BS transmits the downlink map (DL-MAP) and uplink map (UL-MAP) messages, which comprise bandwidth allocations for data transmission in the downlink and uplink direction, respectively.

2.2 IEEE802.16 QoS Classes and Scheduling

IEEE 802.16 standard supports multiple communication services (data, voice, and video) with different QoS requirements. The MAC layer defines QoS signaling mechanisms and functions that control BS and SS data transmissions.

Downlink transmission is relatively simple, because the BS is the only station that can transmit during a downlink subframe. Data packets are broadcast to all SSs, but a SS can listen only to the packets that are destined for it. On the uplink, the BS determines the number of time slots for which each SS will be allowed to transmit in an uplink subframe. This information is broadcast by the BS through the UL-MAP at the beginning of each frame. The UL-MAP contains 1 information element (IE) per SS, which includes the transmission opportunities for each SS (i.e., the time slots in which a SS can transmit during the uplink subframe). The BS uplink-scheduling module determines the IEs from the bandwidth request message sent from the SSs to the BS.

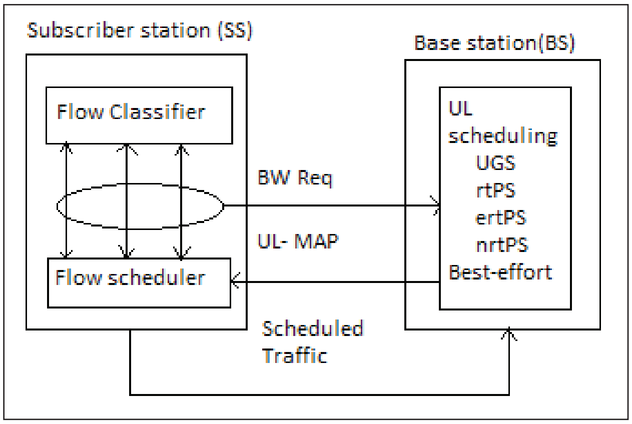

Figure 2. QoS Architecture of IEEE802.16

In IEEE 802.16, bandwidth requests normally are transmitted in *contention* and *contention-free* (polling) *modes* [3]. In the contention mode, the SSs send bandwidth requests during a contention period, and contention is resolved by the BS using an exponential back-off strategy. In the contention-free mode, the BS polls each SS, and each SS in reply sends its bandwidth request.

There are 5 types of basic services described in IEEE 802.16: unsolicited grant (UGS), real-time polling (rtPS), non–real-time polling (nrtPS), extended real-time polling (ertPS), and best-effort (BE) services. Variable bandwidth assignments are possible in rtPS, nrtPS, ertPS, and BE services, while the UGS service needs a fixed and dedicated bandwidth assignment. Figure 2 shows the QoS architecture of IEEE 802.16-based services.

UGS is designed for constant bit-rate (CBR)-like flows, which require constant bandwidth allocation (e.g., voice over IP, VoIP). The rtPS service is designed for variable bit-rate (VBR) flows, which have specific bandwidth requirements and latencies (e.g., MPEG video). The ertPS service builds on the efficiency of both UGS and rtPS, and is designed to support real-time service flows that generate variable-size data packets on a periodic basis (e.g., VoIP services with silence suppression). According to Le and Wu [4], the nrtPS and BE services are for VBR non–real-time applications (e.g., bandwidth intensive file transfer) and best-effort applications (e.g. HTTP), respectively.

Haider and Harris [5] previously classified packets schedulers into *work* and *nonwork conserving* types. Examples of work conserving scheduling algorithms include generalized processor sharing (GPS), weighted round robin (WRR), DWRR, WFQ, and self-clocked fair queuing (SCFQ). Hierarchical round robin (HRR), stop-and-go, and jitter earliest due date are some examples of nonwork conserving schedulers.

Our proposed QoS mechanism uses the DWRR and WFQ schedulers. DWRR is a modified weight round robin scheduling discipline that can handle packets of variable sizes without knowing their mean size. A maximum packet size number is subtracted from the packet length, and packets that exceed that number are held back until the next visit of the scheduler. WRR serves every non-empty queue. DWRR serves packets at the head of every non-empty queue whose deficit counter is greater than the packet size at the head of queue (HoQ). If the deficit counter is lower than the packet size at HoQ, then the queue is skipped (the HoQ packet is not served) and its credit is increased by some given value (called a quantum). The increased value is used to calculate the deficit counter the next time around when the scheduler examines this queue for serving its head-of-line. If the queue is served, then the credit is determined by the size of the packet being served. Haider described DWRR as simply O(1), and indicated that it can be employed for scheduling at the BS of a WiMAX network [5].

The WFQ data-packet scheduling technique, which is a generalization of fair queuing (FQ), allows the prioritization of statistically multiplexed data flows. In WFQ and FQ, each data flow has a separate FIFO queue. In FQ with a link data rate of R, at any given time the N active data flows (i.e., those with nonempty queues) are serviced simultaneously, each at an average data rate of R/N. Since each data flow has its own queue, an ill-behaved flow (i.e., 1 that has sent larger packets or more packets per second than the others since it became active) will only punish itself and not other sessions. Unlike FQ, WFQ allows different sessions to have different service shares. If N data flows currently are active, with weights $w_1, w_2 \ldots w_N$, then the data flow number i will achieve an average data rate of

$$\frac{R w_i}{(w_1+w_2+w_3+\ldots\ldots+w_N)}$$

A network with WFQ switches and a leaky bucket-constrained data flow can guarantee an end-to-end delay bound. By regulating the WFQ weights dynamically, we can utilize WFQ to control the QoS.

3. Proposed QoS Mechanism

The network topology of the simulation scenarios is illustrated in Figure 3. We applied the DWRR and WFQ schedulers for 5 different traffic classes (e.g., UGS, rtPS, nrtPS, BE, and ertPS) at each of 5 fixed nodes and at the 1 BS. Note that we could have used DWRR at the BS for scheduling in the WiMAX network and WFQ at the fixed stations for scheduling the traffic belonging to the nrtPS class.

We assigned different interfaces with different IP addresses to the BS and 5 fixed nodes (SSs). We then applied the DWRR and WFQ schedulers at the BS and SSs and used BE type of service (TOS).

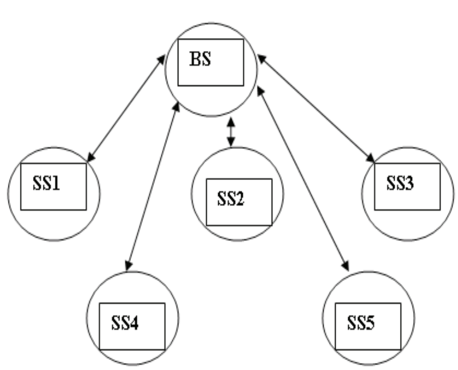

Figure 3. Network topology

4. Simulation Scenario

In the simulation, SS1 sends ftp traffic to SS2; SS2 sends video traffic to SS3; SS3 sends http traffic to SS4; SS4 sends VoIP with silence suppression; and SS4 sends voice traffic to the SS1 fixed node. Error-free link conditions were assumed. The wireless OFDMA PHY layer of IEEE 802.16 was used with a channel bandwidth of 20 MHz and frame duration of 12.5 ms. ARQ and packing mechanisms were not used. Other simulation parameters are provided in Table 1.

Simulation parameter	Value
Channel Bandwidth	20 MHz
Frame Duration	12.5 ms
TTG	106 ms
RTG	60 ms
Modulation scheme	64 QAM, 16 QAM
Coding rate	3/4
Duplexing Technique	TDD

Table 1. Simulation parameters

5. Simulation Results

We compared the average WiMAX delay at the BS and each SS using the DWRR and WFQ schedulers with different TOSs. In the following simulation results, nnn- and rrr-scenario1-DES-1 refer to the simulations run with the WFQ and DWRR scheduler, respectively.

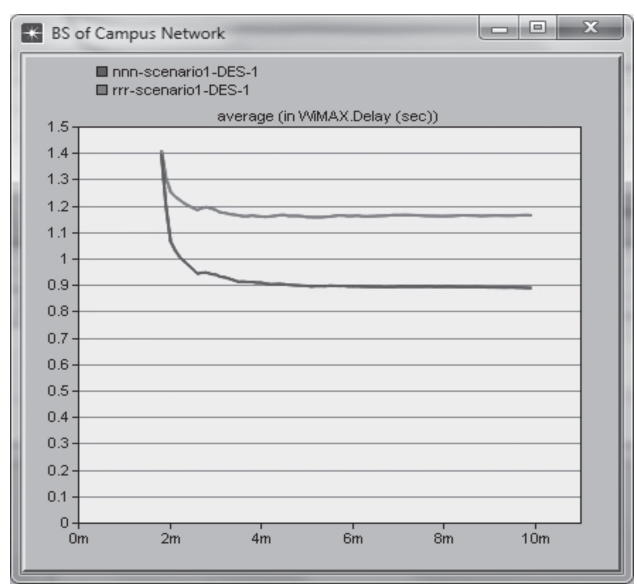

Figure 4. Average delay (s) in WiMAX

The average WiMAX delay obtained with the WFQ scheduler at the BS was less than that obtained with the DWRR scheduler (Fig. 4). The average WiMax throughput obtained with the WFQ scheduler at the BS was higher than that obtained with the DWRR scheduler (Fig. 5).

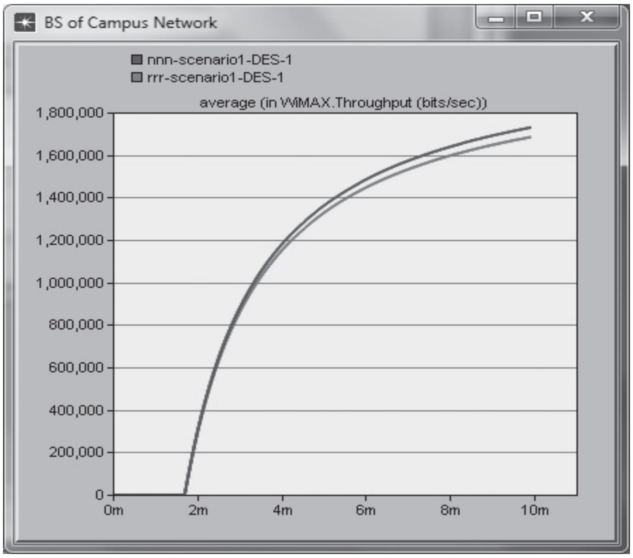

Figure 5. Average throughput (bits/s) in WiMAX

The average load in WiMAX was converted entirely to the average delay in WiMAX at the BS. Therefore, the average load obtained with the WFQ scheduler was higher than that obtained with the DWRR scheduler (Fig. 6).

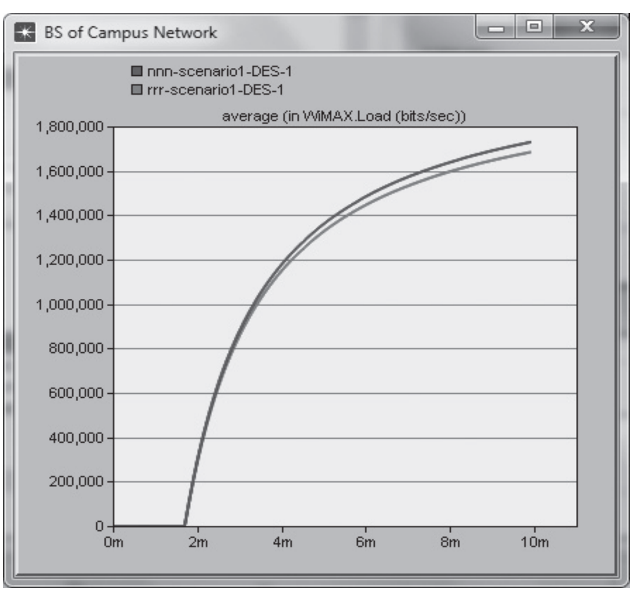

Figure 6. Average load (bits/s) in WiMAX

Next, we determined the interface performance obtained with the DWRR or WFQ scheduler at the BS. A higher traffic received/sent was obtained with the WFQ scheduler than with the DWRR scheduler (Figs. 7 and 8).

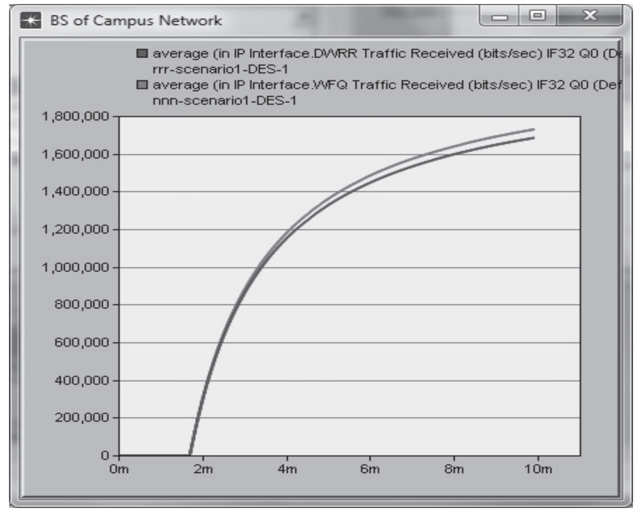

Figure 7. Traffic received (bits/s) through the IP interface

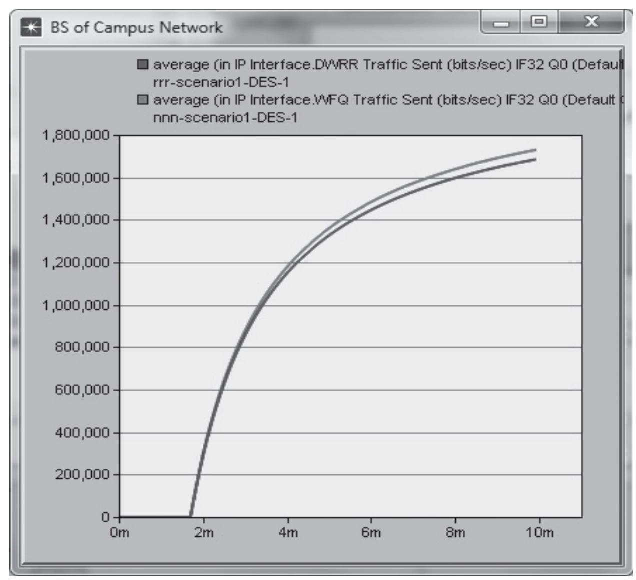

Figure 8. Traffic sent (bits/s) through the IP interface.

6. Conclusion

In this paper, we proposed a QoS mechanism for WiMAX delay in the PMP mode of IEEE 802.16. Using simple scheduling for the BS and fixed nodes, we determined that WFQ performs better than DWRR. Compared to data obtained with the DWRR scheduler, the IP interface gave better outputs for the received and sent traffic, the delay was reduced, and the data transfer rate was increased when the WFQ scheduler was used.

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