QoE – Based Scheduling in WiMAX Networks

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Abstract: Worldwide Interoperability for Microwave Access (WiMAX) networks provide wireless broadband internet access, interoperability, while decrease the entrance barrier in mobile communications sector, and offer services comparable to those of the emerging 4G technology. The standard 802.16, upon which WiMAX networks are based, has not designated any particular scheduling algorithm, allowing each provider to develop its own. However, existing scheduling algorithms take into account the Quality of Service (QoS), fairness and other parameters, but do not provide Quality of Experience (QoE). For this reason, in this paper two different approaches are proposed in order to provide QoE, especially for the rtPS WiMAX service. Simulation results show that by applying different policies the QoE provided to the WiMAX users is improved.

1 INTRODUCTION

Current trends and future projections of the traffic patterns show that multimedia traffic will soon represent the largest proportion of wireless bandwidth, replacing voice and data traffic. However, since existing legacy wireless technologies where deployed to support only voice and data, advanced wireless networking technologies are essential for the provision of the multimedia traffic, since its nature differs fundamentally from voice and data.

WiMAX (Worldwide Interoperability for Microwave Access) (IEEE Standard 802.16-2004) is an emerging wireless access technology that provides high data rates and differentiated services based on individual QoS (Quality of Service) requirements (Lee an Song, 2010). In general the IEEE 802.16 standard specifies the Unsolicited Grant Service (UGS) to support real-time service flows that have fixed-size data packets on a periodic basis, the real-time Polling Service (rtPS) to support real-time service flows that generate variable data packets size that are transmitted at fixed intervals, the extended rtPS (ertPS) to support real-time service flows that generate variable data packets size on a periodic basis, the non real-time Polling Service (nrtPS) to support non real-time service flows that require variable size bursts on a regular basis, and the Best Effort (BE) designed for traffic where no throughput or delay guarantees are provided. Table 1 presents the WiMAX Services and their representative examples, as well as, the QoS specifications of each service.

However, since the multimedia applications require interaction with the users, existing QoS requirements and performance metrics such as jitter, packet loss, throughput etc, cannot guarantee the user‘s satisfaction. For that reason the service providers are now switching from QoS to Quality of Experience (QoE), a term that encompasses both QoS and the overall user satisfaction, which is defined subjectively for each application, according to the users’ expectations. This creates the opportunity for users, service providers and network operators to take advantage of the varying bandwidth and delay requirements, in order to improve the aggregate QoE in the system, and at the same time to limit the operating costs.

The contribution of this paper consists of the application of QoE to WiMAX networks, where each user has different subjective requirements of the system in terms of quality of service. For this

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reason, in this paper two different approaches are proposed in order to provide QoE, especially for the rtPS WiMAX service. In the first policy the system reduces the transmission rate of each connection if a packet loss is occured, until each connection‘s minimum allowable transmission rate is achieved. In the second policy the transmission rate of the connection is reduced if its packet loss is greater than a threshold, while in the opposite case the transmission rate is increased. Simulation results show that by applying different policies the QoE provided to the WiMAX users is improved.

Table 1: WiMAX Services –Applications and QoS Specifications.

Service	Applications Examples	QoS Specifications
UGS	Voice (VoIP) without silence suppression	Maximum sustained rate Maximum latency tolerance Jitter tolerance
rtPS	Voice (VoIP) with silence suppression	Maximum sustained rate Minimum reserved rate Maximum latency tolerance Jitter tolerance Traffic priority
nrtPS	File Ttransfer	Maximum sustained rate Minimum reserved rate Traffic priority
ertPS	Streaming audio or video	Maximum sustained rate Minimum reserved rate Maximum latency tolerance Traffic priority
BE	Email, Web browsing	Maximum sustained rate Traffic priority

The paper is organized as follows: Section 2 presents related work concerning scheduling algorithms for WiMAX networks. Section 3 presents the proposed QoE policies while section 4 provides details about the simulation parameters and presents the obtained results from the proposed policies. Finally Section 5 concludes the paper.

2 RELATED WORK

The IEEE 802.16 standard does not specify the scheduling algorithm to be used. For that reason several scheduling algorithms may be found in the literature. Wu et al. (2012) considers two different categories for scheduling in IEEE 802.16 related research: the serviced-based and the connection-based. In the first-category belong schemes which allocate adaptive and corresponding scheduling mechanism according to different types of services, while the second category concerns adaptive scheduling algorithms for every connection that do not consider the service type of connections. A comprehensive survey concerning MAC based QoS implementations for WiMAX networks can also be found in (Sekercioglu et al., 2009)

In addition several 802.16 modules for ns-2 simulation tools have been deployed (NIST WiMAX Module, LRC WiMAX Module, Borin and Fonseca 2008).

Belghith and Nuaymi (2008) added QoS classes to the ns-2 NIST WiMAX module, in addition to the requirements of QoS management, unicast and contention request opportunities mechanisms, and scheduling algorithms for the UGS, rtPS and BE QoS classes. Simulation results showed that their UGS, rtPS and BE schedulers are in accordance with the specification of QoS classes defined in IEEE 802.16 standard.

3 THE PROPOSED QoE SCHEDULING POLICIES

In this section, the proposed QoE scheduling policies are presented. As mentioned before due the popularity of the video streaming service our interest is focused on the rtPS.

3.1 Policy I

In the first policy a two level QoE is used, where each user has an initial maximum transmission rate and a minimal subjective requirement.

Each node starts to send traffic with the maximum rate. If the per user packet loss over a specified time interval exceeds a threshold, then each user is checked. If the transmission rate of a user is greater than its minimum, then its rate is reduced by a given factor, otherwise it remains the same. In the current simulation setup, the time interval is set at 0.2 seconds, and the rate reduction factor is 10%.

The rate reverts to its original maximum value during the simulation; specifically it is restored every 18 seconds. It was observed that it takes 15 seconds to reach the minimum requirements of all the users.

3.2 Policy II

In the second policy a three level QoE is used, where each user has an initial maximum transmission rate, an average subjective threshold value and a minimal subjective requirement.

Similar to the policy, I the users start to send traffic at their maximum rate. When the per user packet loss exceeds a threshold chosen during the implementation, over a specified interval then each user is checked and if its transmission rate is higher than its minimum rate, then the rate is reduced by a given factor, otherwise it remains stable. However, if the loss rate for a node is less than its threshold, then the user is checked and if its transmission rate is lower than its acceptable rate then its rate is increased by the same factor; otherwise it remains unchanged. In the current simulation setup, the rate increment factor is also set at 10%. The threshold may be selected before running a simulation as a percentage of the data transmission rate of each user, if value 20 is chosen then the threshold for packet loss is 20% of the transmission rate.

4 PERFORMANCE EVALUATION

In this section, we evaluate the performance of the two policies proposed in the previous section.

4.1 Simulation Environment

The WiMAX system operating in Point-to-MultiPoint (PMP) mode was simulated by the well-known ns-2.29 in which the QoS WiMAX module proposed by Belghith and Nuaymi (2007) was embedded that implements UGS, rtPS, and BE schedulers in accordance with the specification of the QoS classes defined in the IEEE 802.16 standard.

The topology of the network consists of one wired node (the sink node) that communicates with 5 wireless nodes through a BS. The nodes are located on a square grid, 250m x 250m. The simulation time was set to 200s.

The PHY settings selected for the simulation are given in Table 2. Moreover, the MAC frame duration was set to 20 ms and the packet size 500 bytes.

Table 2: Simulation Physical Settings.

Parameter	Value
Channel	3.486e+9 GHz
Bandwidth frequency	5 MHz
Cyclic prefix	0,25
Propagation Model	Two Ray Ground
Antenna Model	Omni Antenna
Transmit Power	0.025 Watt
Receive Power Threshold	2.025e-12 Watt
Carrier Sense Power Threshold	0.9 * Receive Power Threshold

Each node has different bandwidth requirements. Tables 3 and 4 depict these different requirements.

Table 3: Policy I Node Parameters.

Flow data rate / Nodes	Application rate (KByte/ sec)	Minimum required rate (KByte/ sec)
Node 1	80	40
Node 2	60.6	20
Node 3	80	20
Node 4	80	80
Node 5	60.6	40

Table 4: Policy II Node Parameters.

Flow data rate / Nodes	Application rate (KByte/ sec)	Acceptable rate (KByte/ sec)	Minimum required rate (KByte/ sec)
Node 1	80	60	40
Node 2	60.6	35	20
Node 3	80	40	20
Node 4	80	80	80
Node 5	60.6	50	40

4.2 Simulation Results

In order to evaluate the performance of the proposed algorithm, the following performance metrics are considered:

- The average delay, i.e. the average amount of time needed by each flow for transmitting its data.
- The average throughput per flow
- The packet loss percentage per flow.

In addition, we compared our results with the ones obtained by the scheduler of the Belghith and Nuaymi (2008), denoted as NIST WiMAX scheduler. Figures 1-3 depict the obtained results for the Policy I, labelled as QoE-based-scheduler in the figures in comparison with the NIST WiMAX scheduler while figures 4-6 depict the obtained results for the Policy II for different thresholds, denoted as QoE along with the corresponding threshold, in comparison with the NIST WiMAX scheduler.

As shown in the figure 1, by applying the policy I the transmission delay of each flow is reduced.

Figure 2 depicts the throughput of each flow. As it can been seen from the figure, the data rate of flow 1 for which the minimum user requirement is half of the traffic that it produces, the rate is not reduced tremendously but remains at the same levels as the other flows using the QoE scheduler. However, the rest of the flows alter their transmission rate to approach the minimum requirements of each user in order to reduce delays and packet loss rates.

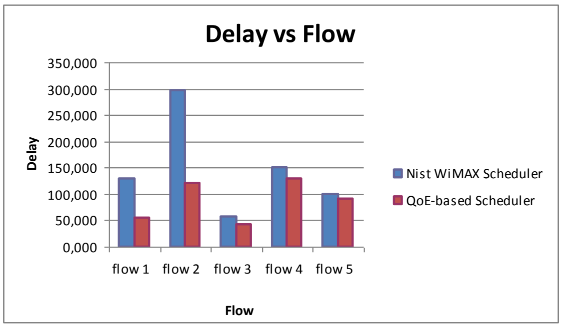

Figure 1: Per flow delay.

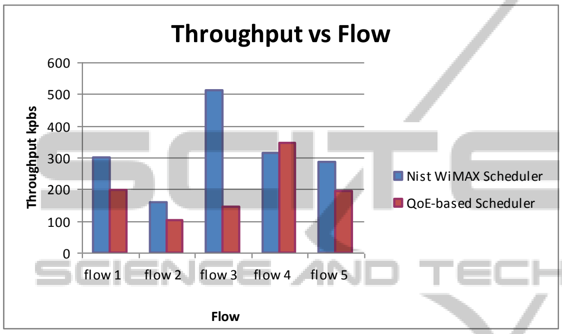

Figure 2: Throughput per flow.

Figure 3 shows the packet loss percentage per flow. In all the flows except of flow 3, which has the biggest flexibility concerning its transmission rate, i.e. its minimum transmission rate is the ¼ of its initial requirement, the packet loss percentage is decreased in comparison with the one obtained from the NIST WiMAX scheduler.

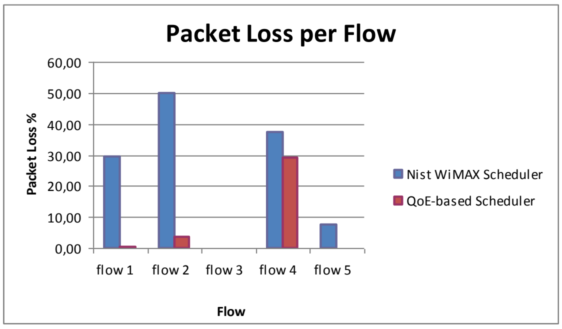

Figure 3: Packet loss percentage per flow.

Figures 4-6 depict the obtained results by applying the policy with different thresholds.

As it can be seen from figure 4, when the threshold is set to 10% the minimum average delay per flow is achieved. For all the other thresholds, the differences between the two schedulers are small. It should be noted that when the threshold is set to 50%, the schedulers produce the same results.

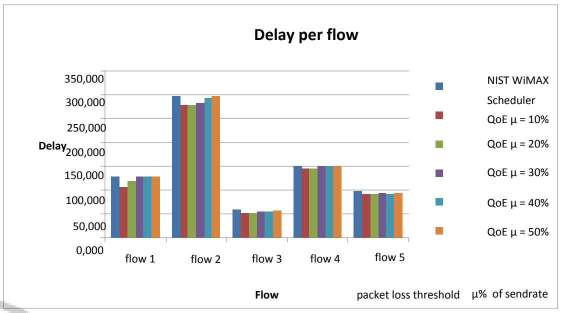

Figure 4: Average delay per flow.

As concerns the throughput per flow, as figure 5 depicts, the selection of the threshold, as well as, the range between maximum and minimum transmission rate, defines the degree of reduction at the throughput in comparison with the results obtained by the NIST scheduler. The throughput for flows 1, 2 and 4 remained at the same levels as with the NIST scheduler. As at policy I, the throughput of flow 5 has the minimum reduction.

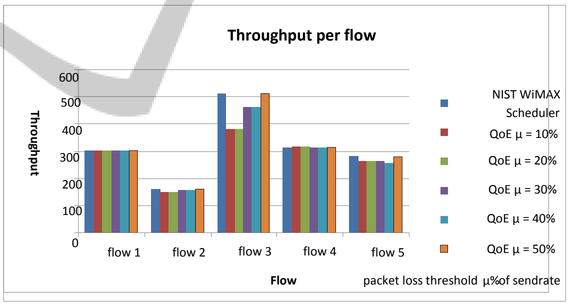

Figure 5: Throughput per flow.

Finally, as Figure 6 depicts the improvement is obvious when using the scheduler based on QoE with a threshold of 10% or 20% regarding the packet loss percentage for all flows except for flows 3 and 5.

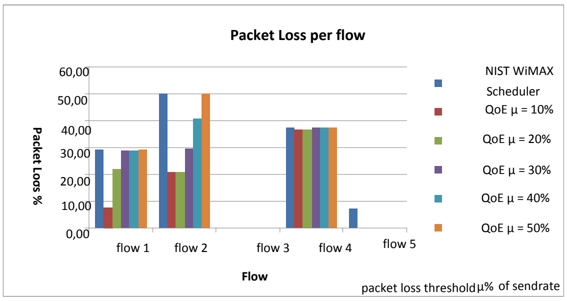

Figure 6: Packet loss percentage per flow.

5 CONCLUSIONS

Multimedia applications require interaction with the users. For that reason the need for QoE provision is imperative. In this paper, two different approaches are proposed in order to provide QoE, especially for the rtPS WiMAX service. Simulations results showed that the use of different levels transmission rate improves the QoE provided to the users. In the first policy, where a two-level QoE is proposed the packet loss and the delay are greatly reduced, but at a slight cost on throughput. When the second policy is applied the packet loss is further decreased without affecting the delay and the throughput of each node. It should be noted that the current results were obtained without human participation, a factor that will be considered in our future research work.

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