Cross Layer Scheduling in WiMAX QoS for Disaster Management

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***Abstract*— How a base station assigns free resource slots to BE service class is depending on the available channel bandwidth after all the other classes have been served. Generally, it is known that the performance of BE is always the worst and provides the lowest level of quality compared to all other classes. However, if somewhat unexpected natural disaster strikes or an environmental catastrophe occurs, when the major communication infrastructure has been destroyed, it is possible that the only available Quality of Service (QoS) service is BE. Under this condition, users or, particularly, a rescue team will not have any other options but to use the only available service class for any types of applications including voice communications or even video communications. Based on that scenario, we have performed simulations using OPNET modeler simulation tool to evaluate the rtPS and BE performance with particular focus on video conferencing/streaming and also data transfer applications. Simulation results show that in certain situations, a user with BE QoS could provide better throughput compared to a user with rtPS. In addition, we also propose a cross layer scheduling mechanism by assigning the video conferencing/streaming application to BE service class and file transfer application to the rtPS service class. The results obtained indicate that for certain combinations of users and QoS, BE service class demonstrates a higher throughput than rtPS. This scenario can be practically applied by a rescue team in any disaster management operations apart from normal teleconference services.**

***Index Terms*—BE, QoS, rtPS, throughput.**

I. Introduction

In an emergency situation, planning a relatively fast and robust communication system is vital particularly during times of calamity such as earthquakes, tsunamis, flooding or forest fires when the entire incumbent communications infrastructure has been destroyed or damaged. In order to support the operation of the emergency response personnel and rescue agencies, a reliable communication link plays a predominant role to circulate the current situations with the outside world. Therefore, a secure and reliable communication link is needed particularly with the consideration of accessing the incident areas; Worldwide Interoperability for Microwave Access (WiMAX) seems to be the ideal solutions [1].

WiMAX is an attractive and promising broadband wireless solution that can be deployed in urban and rural areas as well as in the risk and inaccessible areas and even in the proximity of a possible hazard such as volcanoes and nuclear power stations. The selection of WiMAX based communication architecture is the best solution due to its capabilities in terms of coverage; may reach 15 km in Non-Line- Of-Sight (NLOS) conditions and up to 50 km in Line-Of-Sight (LOS) environments, data rates; excess of 10 Mbps, user mobility; supporting high mobility nodes and with velocities exceeding 60km/hour, and even enables meeting different QoS constraints in relation to different types of applications and traffic; voices, videos, text and other types of data transmission [2][3].

To fulfil the user's satisfaction, the WiMAX standard has defined five types of QoS that are classified within WiMAX architecture; Unsolicited Grant Service Service (UGS), real-time Polling Service (rtPS), non-real time Polling Service (nrtPS), extended real-time Polling Service (ertPS) and Best Effort (BE) [4]. The five QoS classes are depending deeply on the physical (PHY) and medium access control layers (MAC) as the MAC layer is a connection-oriented architecture that is designed to support a variety of applications, including voice and multimedia services. In each QoS, the standard does provide the parameter requirements for the service classes; however it leaves the MAC scheduler algorithm undefined [5][6].

Allocation of network resources according to the desired applications is one of the constraint possibilities that might happened in an emergency situation. It is even worse if the major communication infrastructure has been destroyed and also if the incident area is too large to be covered by a limited number of base stations. Occasionally, the only available type of class of service during the critical situation is BE.

During search and rescue operations in any emergency situation, any type of information such as voices, videos or even texts would really be useful to be transferred by the responders to the monitoring center. However, if the only available QoS service class is BE, therefore there is no other choice except to communicate using the video communication medium with any available channel which is of another concern that needs to be considered in that particular scenario.

In this paper, we assign the 5 QoS classes into 2 fragments; the real time application types which consist of UGS, rtPS and ertPS services and non-real type applications; nrtPS and BE services classes. Therefore, in this paper, we investigate the possibilities of BE service class producing a better performance than the rtPS service class. We also evaluate a cross layer (MAC layer and Physical layers) approach to be applied in WiMAX as a private network. With this structure, the bandwidth can be shared among a greater number of users and also the cost of implementing the system can be reduced without having the need to deploy another base station.

WiMAX standard suggests that the real time applications such as VoIP (Voice over IP), video conferencing/streaming and VoIP with silence suppression should be assigned respectively to UGS, rtPS and ertPS QoS in MAC layers [7] [8]. Meanwhile, for the non-real time application, namely file transfer and web browsing are assigned respectively to ertPS and BE QoS. However, in this paper, we propose a cross layer algorithm where we align the non-real time applications to rtPS QoS and also the real time applications to BE QoS.

The rest of this paper is organized as follows. In Section II, the cross layer and scheduling approach are presented. In Section III, we explained how the proposed cross layer approach applied in disaster situation. A detailed specifications of our simulation parameters are described in Section IV. Finally, the proposed scenario for emergency situation together with simulation results is presented in Section V before concluding our remarks in Section VI.

II. Cross Layer and Scheduling Approach in WiMAX QoS

WiMAX standard has provided QoS by defining five service classes which are described in Table . Also, WiMAX has been designed to have a layered architecture in which each layer would would work autonomously of one another. The MAC layer which gives the essential capacities to getting to the wireless medium and support for QoS has been characterized in the WiMAX standard. However, the specific way or algorithm for scheduling the users based on these classifications has been left undefined [9]. During allocating and scheduling the users, another imperative aspect that needs to be considered is the QoS. QoS is characterized as the capacity of a system to have some level of affirmation that its traffic and service necessities would be fulfilled in terms of packet loss, delay, throughput and jitter [10].

For the above reasons, we proposed cross layer approach, which involves MAC and PHY layers in WiMAX QoS particularly for the rtPS and BE classes. In this paper, we assigned Audio/Video Streaming applications for BE QoS classes, whereas data transfer, web browsing to rtPS classes. Details of the proposed algorithm applied to an emergency situation are explained in the next section.

Table 1
WiMAX QoS [11]

QoS Classes	QoS Specifications	Applications
Unsolicited Grant Service (UGS)	Jitter tolerance Maximum latency tolerance Maximum sustained rate	VoIP
Real-time Polling Service (rtPS)	Traffic priority Maximum latency tolerance Minimum reserved rate Maximum sustained rate	Audio/Video Streaming
Extended Real-time Polling Service (ertPS)	Traffic priority Jitter tolerance Maximum latency tolerance Maximum reserved rate Maximum sustained rate	VoIP (VoIP with Activity Detection)
Non-real-time Polling Service (nrtPS)	Traffic priority Minimum reserved rate Maximum sustained rate	File Transfer Protocol
Best Effort Service (BE)	Traffic priority Maximum sustained rate	Data transfer, web browsing

III. WiMAX in Disaster Situations

As we have mentioned before, based on the special feature of WiMAX, it seems to be the most radical communication architecture beneficial to the emergency communication system scenarios. WiMAX is also being used as a point to multipoint communication link for backhaul connectivity in diverse areas such as in the fire prevention scenario, environmental monitoring of volcanoes, and even applied in the telemedicine area [12].

The key success factor in the fire prevention situation is the implementation of early fire detection system in a potential hazard area such as forest reserves or recreational parks. In the absence of the detection system and especially during summer season, any potential spark ignited in a small area which could then easily burst into flames into a much larger area will go unnoticed by the relevant authorities [13] . This is where video cameras and wireless sensor networks that implement WiMAX special features such as the data rates, bandwidth, potential range and adaptability towards environmental conditions, can be placed at the targeted site to record any untoward incidents [14]. In fact, the networks can be used to link the communication between control centers and surveillance towers.

In an earthquake incident, prediction of any seismic activity may become more efficient depending on the number of recorded seismic signals. Initially, this situation was deemed impossible as the prediction of seismic activity preceding volcanic eruptions can only be observed approximately one hour before the magma reaches the surface [15].

In order to have an efficient real-time of earthquake indications, the seismic sensors would need to be located beyond 30km and again WiMAX is the most suitable choice. It has mobility features which are able to support real-time communication between the incident area and with the emergency services. This particular scenario has been practically used in the 2010 Haitian Earthquake [16].

In this paper, we are analyzing the performance of rtPS and BE QoSs with respect to real-time and non-real-time applications. Currently, in WiMAX, there are 5 different QoSs in which rtPS provides higher quality while BE provides the worst quality. However, in the case of a disaster, there is a need to have any types or any means of communication. Therefore, in this paper, we are demonstrating that with certain combination of some specific scenarios and applications, it is possible to achieve a higher throughput with BE rather than with rtPS. From the WiMAX standard, video conferencing/streaming service is normally assigned with rtPS QoS class. However, there are a number of scenarios where video conferencing can work with BE QoS, for example, in WiFi network. Therefore, in this paper, we propose a cross layer approach where video conferencing/streaming is designed to work with BE class. This outcome will be beneficial for the rescue team when they have to perform live broadcasting communication without the need to deploy extra base station.

IV. SIMULATION ENVIRONMENT

In this work, we analyze the effectiveness of the cross layer approach and scheduling algorithm using a software package: Opnet Modeler 17.5. It provides a comprehensive development environment to model communication networks and distributed systems through Discrete Event Simulations (DES) [17]. The simulation parameters described in Table 2 are used with the downlink to uplink time division duplex (TDD) split ratio of 1:1. Since the admission control mechanism is not a subject of interest here, only adaptive modulation technique is employed in which the coding and modulation are adaptively modified based on the network conditions. The traffic parameters with specific frame size requirements are shown in Table 3. For benchmarking purposes, free space propagation loss is chosen to represent the wireless medium in the simulation.

We start of the simulation with a simple scenario which consists of 10 mobile nodes connected to 1 BS. The video conferencing application is assigned to the rtPS scheduling class and file transfer application is tied to the BE scheduling class. The service flows for both scheduling classes are classified under Silver.

Table 2: Simulation Parameters

WiMAX Parameter	Value
PHY Profile	OFDM
Operating Frequency	2.5 GHz
Bandwidth	10 MHz
No. of Subcarriers	1024
TTG (Transmit-receive Transition Gap)	106 µs
RTG (Received-transmit Transition Gap)	60 µs
Min Reserved Traffic Rate (rtPS)	140 kbps
Max Sustained Reserve Traffic Rate	2.8 Mbps
Poll interval rtPS	5 ms

Table 3: Traffic Parameters

Application	Parameters
Video Conference	Frame size :128x120 resolution Frame inter arrival time : 10 fps
File Transfer Protocol	File size: 50 kbytes

V. RESULTS AND DISCUSSION

We conduct several simulation scenarios to evaluate the proposed algorithm. The first scenario evaluates the condition which BE QoS is perceived to perform better than rtPS QoS in WiMAX. The second scenario evaluates the possibilities for video conferencing application to be used with BE type of scheduling class. For further investigations, we extend the number of users in the network with 15 and 20 mobile nodes connected to 1 BS. To determine whether rtPS and BE service classes have their minimum bandwidth guaranteed and not exceeding the maximum bandwidth level, a throughput graph will be used. For delay requirement, a delay graph is used to determine whether all the data packets are successfully received and forwarded to the higher layers.

A. Scenario 1

In this scenario, the scheduler is evaluated on its effectiveness on ensuring QoS requirements of throughput, and delay for the WiMAX network. For this purpose, we start simulating a simple scenario consisting 1 BS and 10 mobile nodes. Two nodes are assigned with file transfer applications and also hooked to BE scheduling type. The remaining 8 mobile nodes are installed with video conferencing applications and their scheduling types are tied to rtPS.

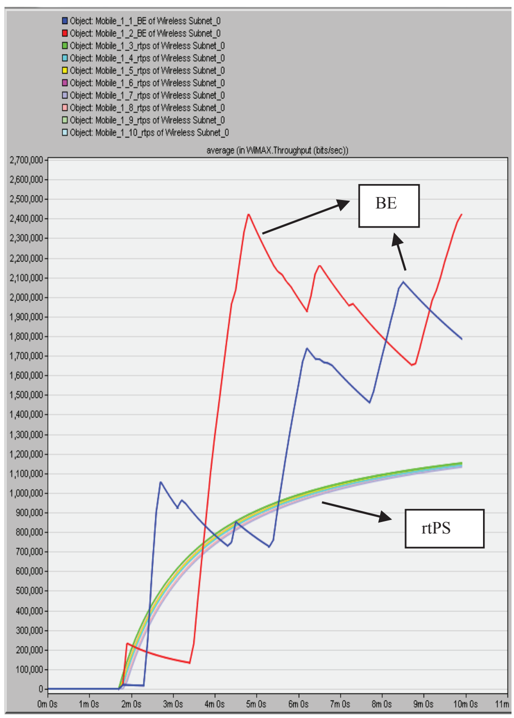

Figure 1: Average throughput of rtPS and BE

Figure 1 presents the average throughput of rtPS and BE connections. It can be seen that the two BE service classes are gaining higher throughput with small fluctuations until the end of the simulation because of the application type assigned to the BE service class. The throughput for all rtPS connections show some exponential increase at the early stage of the simulation before starting to linearise and stabilise at 1.2 Mbps, however, the results are still lower than those for the BE class. This is because the BE service has no minimum bandwidth requirement and is given the remaining resources after the rtPS classes have been served. Another important factor is the total number of rtPS and BE mobile nodes in a network. If the number of BE services is increasing, the throughput will drop since the available bandwidth will be divided among the number of BE nodes.

This scenario can be further investigated based on the delay outcome as shown in Figure 2. As expected, the delays of rtPS services show somewhat constant low values and even with the rtPS load increasing, the delays are still not exceeding their delay requirement [18]. Meanwhile, the delays for the BE connections are slightly higher than those for their rtPS counterparts, however, the delay trends tend to reach constant values as time progresses due to the non-delay requirement of BE services.

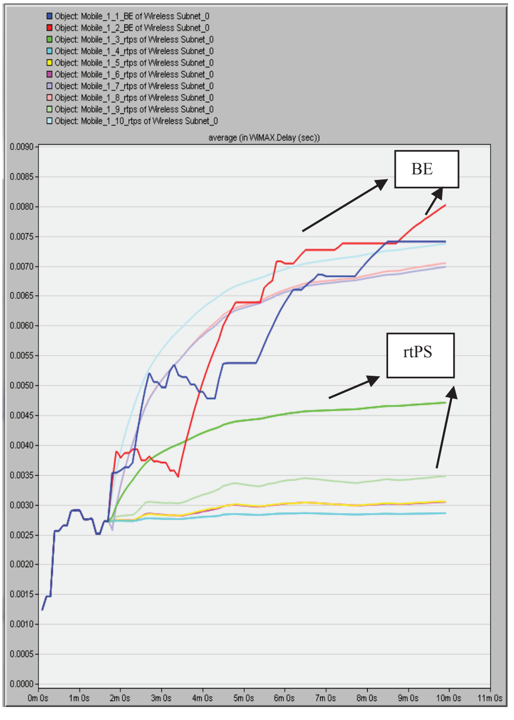

Figure 2: Average delay of rtPS and BE

B. Scenario 2

In the second scenario, the proposed cross-layer approach on the performance of rtPS and BE QoS classes is evaluated. Based on the first scenario, it shows that BE service is justifiable to produce better throughput than rtPS. However, the total number of mobile nodes in the network and the scheduling class combinations are absolutely vital to the network performance outcomes. Therefore, in order to evaluate the cross layer approach, the total number of mobile nodes and BS remains the same. The distributions of the application and service types for the 10 mobile nodes are done as follows. Three mobile nodes are assigned to rtPS connections and data transfer applications, 2 mobile nodes are assigned to BE connections and video conferencing applications, and 5 mobile nodes are assigned to rtPS connections and video conferencing applications.

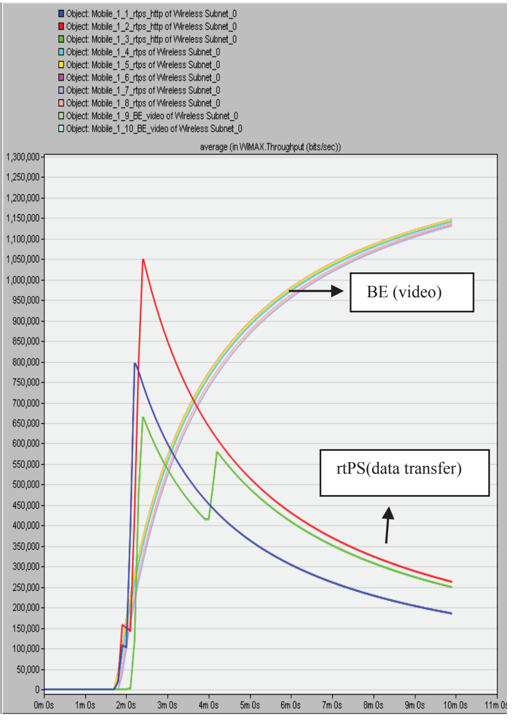

Figure 3: Average throughput of rtPS and BE

The throughput graph of rtPS and BE connections is illustrated in Figure 3 where it shows the throughput increase steadily for mobile nodes with the video conferencing applications. Overall, there are 7 mobile nodes with video conferencing applications which include both the rtPS and BE connections. The remaining 3 mobile nodes that are assigned with rtPS connections and data transfer applications display much lower throughput with respect to time. Based on the results, it shows that BE connection is possible to be assigned with video conferencing applications.

In Figure 4, delays of video conferencing applications with BE connections seem to be significantly lower compared to those with rtPS connections as indicated in Figure 5. Owing to the stringent delay requirements for video communication applications, the scheduler must ensure that the services reach their destinations on time.

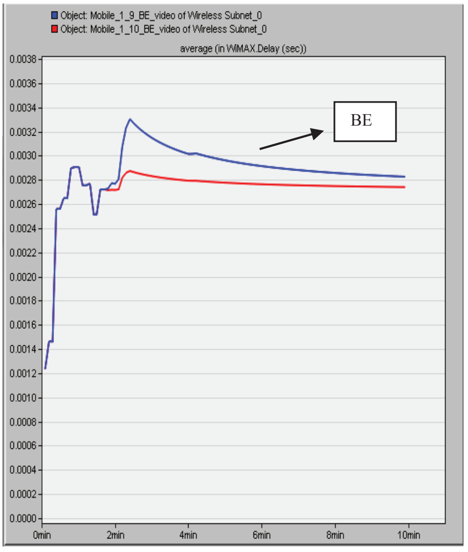

Figure 4: Average delay of BE users

On the contrary, the delays posed by the data transfer applications in Figure 5 are slightly higher even with rtPS connections. This is because data transfer applications are not bound to any delay requirement. However, the delays for both BE and rtPS connections are still lower than the targeted delay requirement [18].

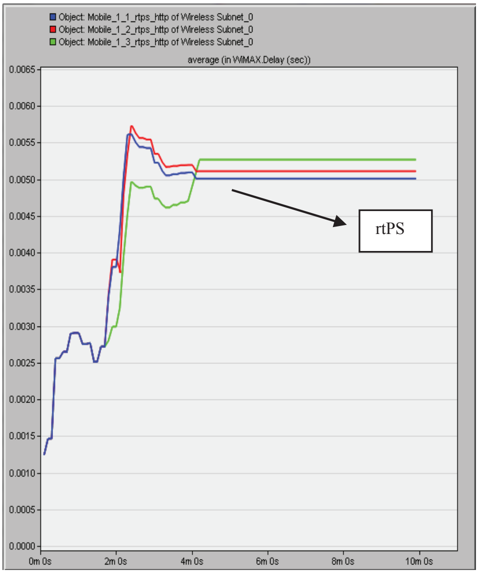

Figure 5. Average delay of rtPS users

C. Scenario 3

The further effects on the performance of rtPS and BE services are further investigated in scenario 3 with the consideration of larger scale of users but with the same amount of bandwidth allocated in the simulation. The simulation includes 15 mobile nodes and 1 BS. The video conferencing application is assigned to rtPS scheduling class and file transfer is assigned to BE scheduling class. In this scenario, we want to investigate whether BE services could have better throughput than rtPS and also satisfy the delay requirements.

The average throughput of rtPS and BE connections in Figure 6 suggest that BE connections can produce higher throughput with some specific combinations. If the total number of BE connections are lower than the total number of rtPS connections, only then the BE services can produce better throughput. This is because the available bandwidth in the channel is larger than the total bandwidth allocated for the rtPS connections. Based on the results obtained, the specific combination necessary to have a better throughput performance for BE connections is 7 mobile nodes with BE connections and 8 mobile nodes with rtPS. However, if the total combination of BE and rtPS connections is equal, the rtPS connections will give greater throughput since the bandwidth's available balance is now slightly less

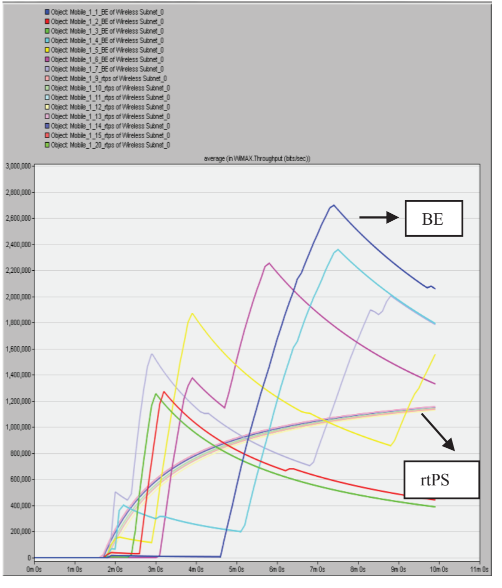

Figure 6: Average throughput of rtPS and BE for 15 mobile nodes

Figure 6 describes that the average throughput for 7 mobile nodes with BE connections are in the range of 1.2 Mbps and 2.5 Mbps Throughput for all the 8 mobile nodes with rtPS connections are increasing at the initial phase and later stabilises at 1.2 Mbps.

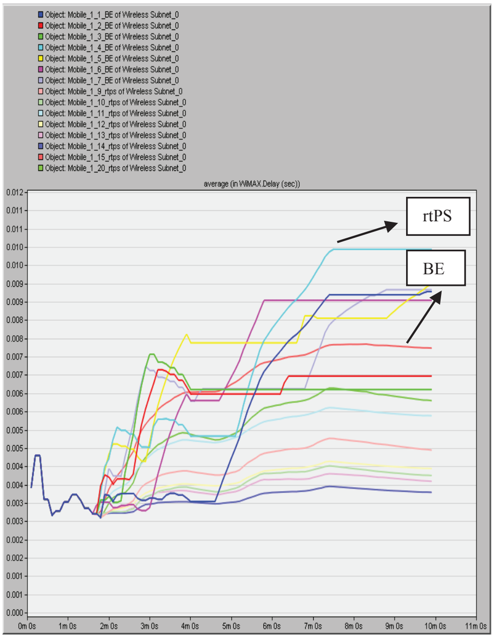

Figure 7: Average delay of rtPS and BE for 15 mobile nodes

The graph shown in Figure 7 explains that the delays of the mobile nodes with rtPS service class are slightly higher than those with BE service class as the load on rtPS increases in the network. However, the delays of rtPS connections are still within the stipulated delay constraint requirement of rtPS QoS.

D. Scenario 4

The effect of increasing the number of connections of rtPS service class towards the QoS level is investigated in this scenario. Therefore, for this purpose, the total number of users is increased to 20 users connected to 1 BS. The connections are simulated for throughput and delay as in previous scenarios.

As shown in Figure 8, at the end of 10 minutes simulation time, the throughput of rtPS is levelled at around 0.85 Mbps as opposed to BE connections where the throughput is almost half of the rtPSs'. This is justifiable because rtPS QoS does guarantee the minimum bit-rate requirements while at the same time, it also depends on the types of application used. All possibilities of rtPS and BE connections combination are considered in this scenario, however, the results obtained show that rtPS service class will always provide higher throughput than BE. In contrast, the BE service class shows a lower throughput regardless of the number of rtPS connections in the network.

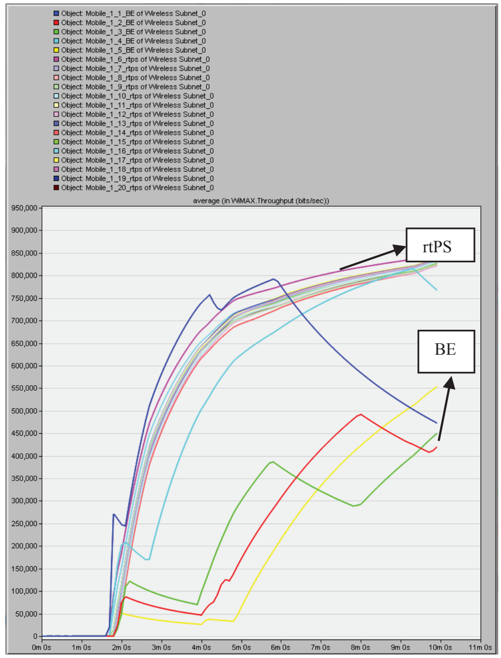

Figure 8: Average throughput of rtPS and BE for 20 mobile nodes

Another important practical implication of this investigation is the average delay of rtPS scheduling class. It can be seen from Figure 9 that the delays of rtPS service class are greater than those of the BE service class as the load increases. Since there is no delay limitation for BE service class, therefore, it is possible for the MAC scheduler to be indifferent in its priority scheduling of rtPS over BE service class. However, this is beyond our main concern of the study.

VI. Conclusion

In this paper, a detail research has been explored on the performance of rtPS and BE QoS service classes in WiMAX network focusing on cross layer interactions between scheduling and service application types and also the number of users in the network. The first part of the research covers the possibilities of BE service class providing better throughput than rtPS. The second part proposes the cross layer scheduling mechanism where the real-time application has been assigned to the BE service class and non-real time application to the rtPS service class. Lastly, investigations on the behavior of rtPS and BE service classes in terms of throughput and latency as the total number of users in the network increases are also studied. The results obtained show that the cross layer approach has fulfilled the QoS requirements of rtPS and BE services classes in WiMAX system in terms of throughput, and delay. Our pending work will focus on hybrid network such as WLAN (Wireless Local Area Network) and LTE (Long Term Evolution).

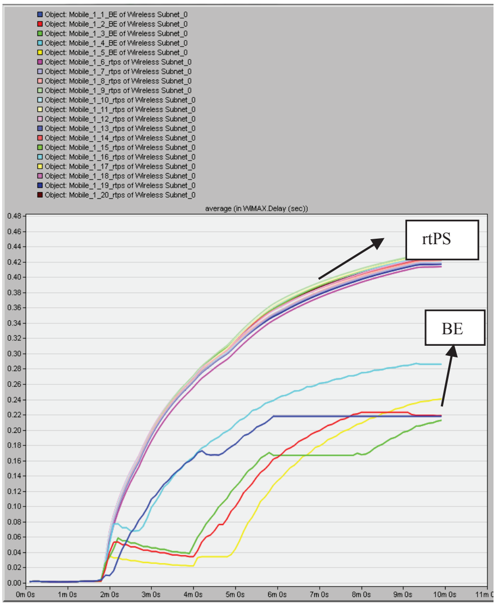

Figure 9: Average delay of rtPS and BE for 20 mobile nodes

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