Network Protocols and Algorithms
ISSN 1943-3581
2011, Vol. 3, No. 3

QoS Traffic Mapping between WiMAX and DiffServ Networks

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Received: November 11, 2011 Accepted: November 30, 2011 Published: December 18, 2011

DOI: 10.5296/npa.v3i3.1063 URL: http://dx.doi.org/10.5296/ npa.v3i3.1063

Abstract

Even when data communications are made inside an all-IP domain, in a hybrid network different mechanisms and policies for the management of Quality of Service (QoS) could coexist in the different access networks and nodes involved. Specifically, in the scenario considered along this work, a WiMAX segment is included inside an IP network using the DiffServ protocol for QoS management. The conflict arises due to the different ways to handle and label traffic flows provided by the DiffServ protocol and the native Medium Access Control (MAC) layer QoS mechanism implemented, and the lack of a one-to-one correspondence between the different classes of traffic defined in both domains. Along this work, a solution to this problem in the form of a traffic mapping system for QoS purposes is presented.

Keywords: DiffServ, Hybrid Networks, Quality of Service, WiMAX

1. Introduction

One of the most prominent consequences of the Internet's evolution has been the birth of innovative communication services, such as videoconferences, VoIP (Voice over IP) or multimedia streaming. These services usually require specific QoS (Quality of Service) conditions in order to exhibit a proper and fluent behavior, conditions that old networks, lacking specific QoS management techniques, where unable to guarantee. Because of this, QoS mechanisms such as DiffServ (Differentiated Services) [1] have appeared, in order to provide QoS-support for network operations.

Newly developed access networks, such as WiMAX (Worldwide Interoperability for Microwave Access), defined in the IEEE 802.16 standard and offering wireless ADSL-like speeds with ranges of up to 50-60 km, have been already designed with QoS in mind, and as such they implement their own native QoS management methods. And even more, innovative technology-specific strategies and solutions for improving QoS are being introduced and proposed constantly [2]-[4]. This means that when operating in the context of a bigger IP based network, there is a 'mismatching' between the QoS management techniques used internally in the access network and the IP-level QoS management techniques (like the previously mentioned DiffServ) of the external network. Therefore, in order to transfer the guaranteed QoS parameters from one domain to the other and guarantee service level QoS [5]-[7], it is necessary to perform a translation at the boundary nodes [8]-[10]. In the specific case of a WiMAX domain inserted into a DiffServ-enabled IP network, as both technologies implement QoS management through a traffic classification strategy (assigning different priorities -resource sharing- to different traffic classes), one possible way of performing the QoS domain translation is to use a traffic mapping, i.e. assigning equivalences between the different traffic classes considered by each of the QoS domains.

WIMSAT [11]-[13] (*Convergencia de WiMAX, IMS y Satélite* – WiMAX, IMS and Satellite Convergence) is a Spanish Project, co-funded by the Spanish *Ministerio de Industria, Turismo y Comercio*. In the network scenario defined inside WIMSAT two domains coexist: TCP/IP and WiMAX. Inside the purely IP segment, the DiffServ QoS architecture (defined in IETF RFC 2475) is considered as one of the most relevant solutions for QoS provision due to its simplicity and scalability. It is because of this that one of the aims of WIMSAT is to study traffic models to properly define a correlation between the different traffic classes in WiMAX and DiffServ, and identify the impact of that mapping in the QoS experience of the hybrid network.

After this introduction, Section 2 of this work presents an overview of the management mechanisms implemented by DiffServ to provide end-to-end QoS, while Section 3 outlines an equivalent summary for WiMAX networks. A solution for inter-domain traffic mapping is described in Section 4, together with its lab implementation in Section 5 and the simulation results in Section 6. Finally, Section 7 collects the conclusions of the work.

2. QoS Management in DiffServ

The main idea behind the DiffServ QoS mechanism is that nodes in the network handle the packets according to the traffic class they belong to [14], prioritizing resources so the most critical packets experience better network conditions. In order to implement this behaviour, boundary nodes of the DiffServ-enabled network have first to classify traffic into the different supported classes, tagging the packets using the IP header field Differentiated Services Code Point (DSCP) with the appropriate traffic class. The inner nodes in the network then are able to read this tag and apply a different treatment accordingly, called Per Hop Behaviour (PHB). For each traffic class a PHB is defined. While in principle the specification is flexible to allow personalized PHBs, in practice most implementations agree to a common set: Expedited Forwarding (EF), Assured Forwarding (AF) and Best Effort (BE).

2.1 EF PHB: Expedited Forwarding PHB

Traffic treated under the EF PHB (IETF RFC 3246) is high priority traffic which requires low levels of delay, jitter and losses, normally generated by multimedia real-time applications (voice, video, etc.). Packets subject to this PHB will normally face empty or very short queues, and their operation will be independent from the load present under other PHBs. EF packets will experience a quality of service equivalent to a configurable guaranteed transmission data.

2.2 AF PHB: Assured Forwarding PHB

Traffic tagged with this PHB is subdivided in four classes and three drop precedence levels, for a total of 12 sub-groups. The main objective of this PHB is to guarantee delivery as long as a given rate is not surpassed. For each class, different levels of service are guaranteed, and drop precedence is used inside a class to determine the relative importance of the packet in case of congestion. AF traffic is not associated to quantifiable temporal requirements, such as delay or jitter.

2.3 BE PHB: Best Effort PHB

BE traffic is served without any kind of guarantee. Packets will be relayed as soon as possible, using the resources not employed by the rest of the classes. Usual implementations however include a minimum amount of resources reserved for this PHB in order not to completely block this kind of traffic under heavy load circumstances in other PHBs.

3. QoS Management in WiMAX

The WiMAX specification includes several features to handle QoS requirements [15] for a variety of services and applications, including for instance asymmetric upload/download traffic and flexible resource allocation. WiMAX provides QoS management at the Media Access Control (MAC) level using the concept of unidirectional connections [16]: before a service is started, the Base Station (BS) and the user terminal establish a unidirectional connection, and all the packets generated by the service are associated to this connection.

The QoS parameters given to the connection define how the traffic flow is classified and how access to the medium (which often represents the bottleneck of the system) is scheduled [17]. Additionally, the QoS parameters of the connection can be dynamically allocated using MAC-layer signalling in order to adapt the reserved resource to service requirements changing over time.

WiMAX supports four different scheduling services to cover different kinds of traffic:

3.1 UGS: Unsolicited Grant Service

This scheduling service is designed to support services with strong real-time requirements which employ data packets with a fixed size at a fixed rate [18]. This scheduling service therefore offers fixed-size, fixed-rate resource reservation, avoiding the need to continuously perform resource requests by the Subscriber Station (SS), the entity providing connectivity between user terminals and a BS. This reservation is available for the entire lifetime of the connection.

3.2 rtPS: Real Time Polling Service

This scheduling service aims at supporting services with strong real-time requirements, but using variable size packets at variable rates, like for instance MPEG (Moving Picture Experts Group) encoded video. The rtPS service periodically offers opportunities for the stations to renegotiate the reserved resources, therefore requiring the SS to continuously send resource requests. In turn, resource reservation is optimized and more efficient, since the resources reserved are always adapted to the requirements of the service.

3.3 nrtPS: Not Real time Polling Service

This scheduling service periodically polls the SSs to ensure that everyone of them has a chance to send request reservations, even under network congestion situations. Basically, the BS sequentially asks all the stations with active nrtPS connections.

3.4 BE: Best Effort

This scheduling service is assigned resources when they are left available by the other ones.

4. Interdomain Traffic Mapping

For a proper QoS transfer between the DiffServ and WiMAX domains it is necessary to map the traffic classes defined by DiffServ over the appropriate MAC 802.16 scheduling service [19]. For that, the convergence sublayer (presented in Fig. 1 along its two main elements, classifier and processor) will be in charge of performing the adaptation of DiffServ flows over the WiMAX network.

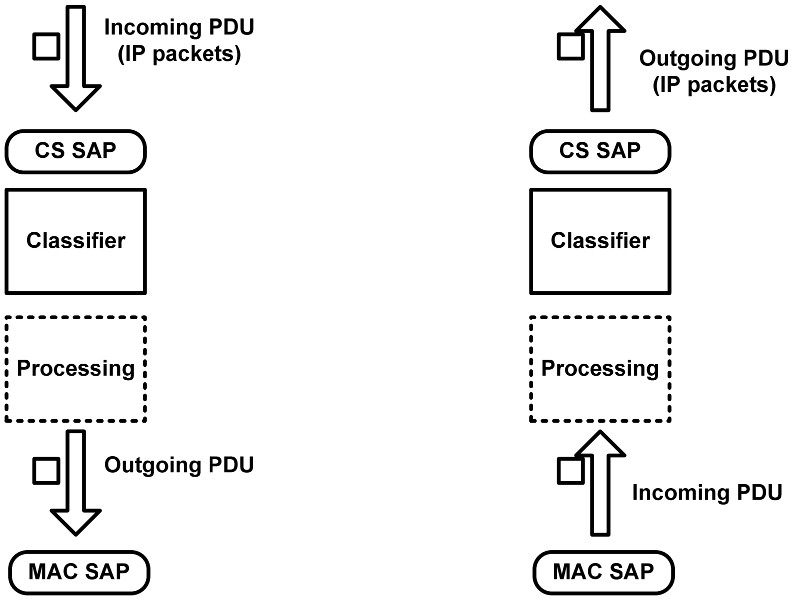

Figure 1. Convergence sub-layer operation.

The WiMAX technology supports the service provision according to DiffServ classes. [19] [20] include descriptions of alternative architectures for multiple service class support over WiMAX and proposals for the traffic mapping of DiffServ classes over WiMAX classes, but the solution given in [20] is focused on the QoS problem in MAC Layer. Based on the different features of the traffic classes, the traffic mapping proposed is depicted in Table 1. [19] and [21] for instance present other similar mapping options for their respective domains. However, it is necessary to mention that this classification could be adapted to the specific requirements of different scenarios, traffic profiles, and applications.

Table 1. Basic traffic classification according to QoS requirements

Traffic	DiffServ PHB	WiMAX Service	Example Application
Real time, highly intolerant to delay and jitter. Fixed packet size and rate.	EF	UGS	VoIP
Real time, highly intolerant to delay and jitter. Variable packet size and rate.	EF	UGS	Videoconference
Signaling, small bandwidth, highly intolerant to delay and losses.	EF	UGS	
No real time restrictions, high bandwidth, medium tolerance to delay, highly tolerant to jitter.	AF4	rtPS	On-demand HD Video
No real time restrictions, medium bandwidth, medium tolerance to delay, highly tolerant to jitter.	AF3	rtPS	Video Streaming, Web browsing
Signaling, small bandwidth, highly intolerant to losses, highly tolerant to delay.	AF2	nrtPS	
No real time restrictions, small bandwidth, medium tolerance to delay, highly tolerance to jitter, medium tolerance to losses.	AF1	nrtPS	Instant Messaging
No real time restrictions, high tolerance to both losses and delay.	BE	BE	E-mail FTP

In order to validate the traffic mapping concept, an experimental test bed, depicted in Fig. 2, has been developed and implemented. It includes the following modules:

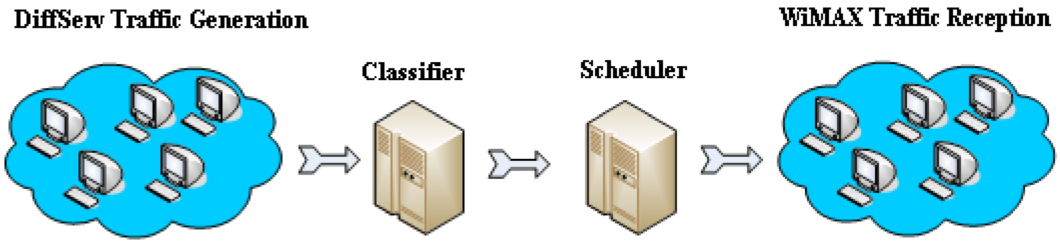

Figure 2. Network scheme for the experimental test bed.

- DiffServ Traffic Generator: this block acts as a source of DiffServ traffic with a variety of priorities and requirements, modelled after the corresponding applications. The different traffic profiles generated account for the different services that fall under the set of service classes defined by DiffServ, so it is possible to independently analyze their behaviour.
- Classifier: this block receives the input traffic and determines in which of the different input queues it should be received, according to the different priorities and PHBs assigned by the Traffic Generator.
- Scheduler: this module is in charge of implementing the traffic class mapping and relaying the packets according to the established politics, in a way that critical applications with priority traffic are transmitted faster than applications with softer QoS requirements.
- WiMAX Traffic Receiver: this module receives the traffic and collects statistics to perform the analysis of the system.

5. Test bed implementation and scenarios

5.1 OPNET Modeler

In order to implement this test bed, the OPNET Modeler [22] software has been chosen as one of the most widely extended tools in the modelling and simulation of communications system, due to its flexibility and multi-level architecture that is able to operate at all layers and components of a system: device, protocol, application, etc.

OPNET modelling is based in discrete-event simulation and comprises three different layers: network model, node model, and process model, the last one completely configurable and programmable in C++.

One of the main advantages of the OPNET modeler is that it natively includes a vast array of libraries containing implementations of applications, protocols, devices, nodes, links, networks, etc. Even more, these models are completely configurable and modifiable, so they can be adapted to the specific purpose of the simulation.

5.2 Configuration

Fig. 3 presents the network topology designed to implement the traffic mapping test bed, including an IP DiffServ network, a WiMAX network and an intermediate node.

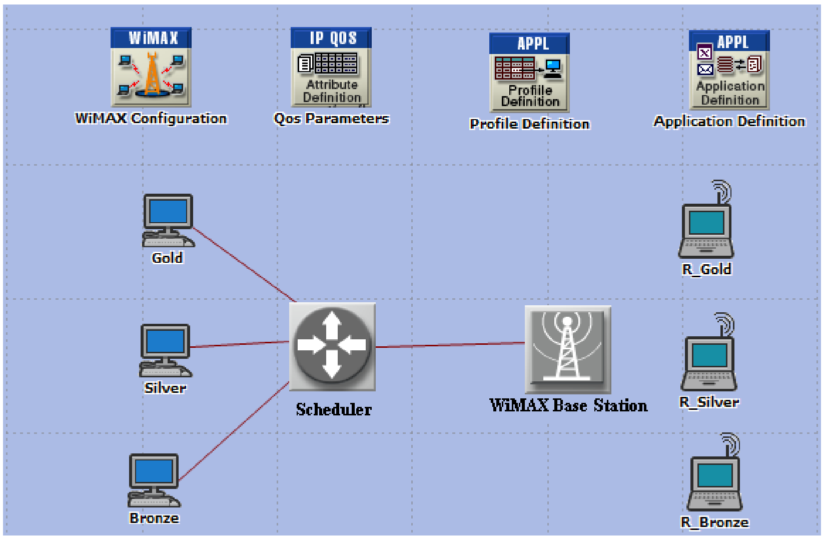

Figure 3. Hybrid DiffServ, WiMAX network topology.

The three IP sender workstations have been labelled Gold, Silver and Bronze respectively, accounting for the different priority of the data flows they are going to transmit. Accordingly, the Gold station will send high priority traffic, while Bronze will send data with low QoS requirements. Specifically, in this scenario, the Bronze station sends low priority Web browsing traffic (labelled as BE), the Silver station sends multimedia streaming data (labelled as AF, should be mapped to rtPS in WiMAX), and Gold sends interactive voice traffic (labelled as EF, should be mapped to UGS in WiMAX). The respective receiving stations in the WiMAX network have also been labelled Gold, Silver and Bronze, depending on the traffic they are handling.

As the traffic is already separated at IP level (different priority traffic is generated by different stations, and no station generates more than one type of traffic), the need for the classifier disappears, as traffic is already sent to different queues in the scheduler.

In order to configure the QoS policies in the IP DiffServ network [23], the following queues have been implemented:

- FIFO scheduler in the input queue of the Bronze, low priority traffic: all packets are going to be handled identically.
- PQ (Priority Queuing) scheduler, based on DSCP code, for the medium priority, Silver traffic, allowing different treatment for the data flows depending on their QoS requirements.
- FIFO scheduler in the high priority, Gold traffic, to minimize the processing time

of this kind of packets inside the scheduler.

- WFQ (Weighted Fair Queuing) scheduler, based on DSCP code, in the output of the scheduler module connected to the WiMAX Base Station. This kind of queuing will allow a priority treatment to small size burst traffic, while the rest of the big size burst will share the remaining resources.

6. Results

This Section summarizes the results obtained in the simulation over the described test bed under two different load scenarios.

6.1 Light load scenario

In this scenario, three different traffic flows have been inserted in the network with low transmission rates to allow a normal, non-congestion operation and prove that the traffic is properly received. The three flows are:

- A low priority, Bronze flow, labelled as BE, at a rate of 1.000 packets per second.
- A medium priority, Silver flow, labelled as AF31, at a rate of 2.000 packets per second.
- A high priority, Gold flow, labelled as EF, at a rate of 3.000 packets per second.

Fig. 4 presents the results obtained after 360 seconds of simulation. It is easy to note that the IP DiffServ traffic has been properly received in the other end of the network by the target WiMAX stations. While the simulation shows that there are some differences in the delays of the different types of data (the station starts to receive gold data slightly before silver and bronze data), the main objective of this scenario is to prove that the hybrid network has been properly configured and that, under light load, all the traffic is received at its destination. For instance, the amount of traffic sent and received by the Gold stations (cyan and red lines) coincides.

6.2 Heavy load scenario

In this second scenario, the transmission rates of the inserted traffic flows have been high enough to saturate the network, in order to observe the different treatment received by the packets depending on the priority they have been labelled with inside the WiMAX domain. Specifically, the three traffic flows present the following features:

- A low priority, Bronze flow, labelled as BE, at a rate of 60.000 packets per second.
- A medium priority, Silver flow, labelled as AF31, at a rate of 60.000 packets per second.
- A high priority, Gold flow, labelled as EF, at a rate of 60.000 packets per second.

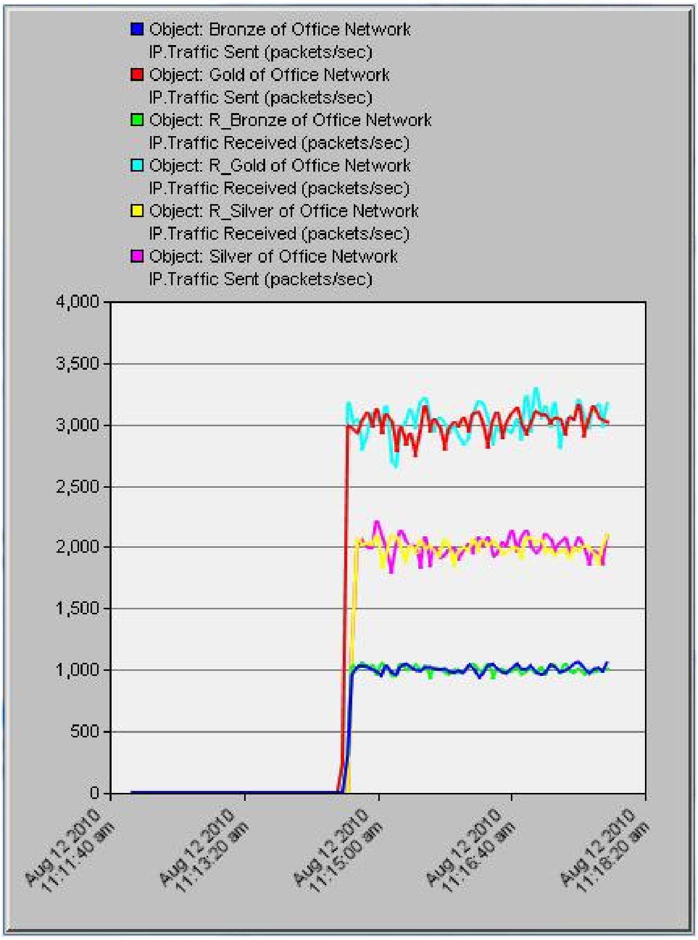

Figure 4. Traffic received in the WiMAX domain under light load.

Fig. 5 presents the results obtained after 360 seconds of simulation. It is easy to realize that Gold traffic (red line) arrives properly and with very little delay while Bronze traffic has suffered heavy losses, with only a mean of 45.000 packets per second arriving at their destination from the 60.000 sent. Silver traffic on the other hand arrives properly (also a mean of 60.000 packets per second arrive), but with a bigger mean delay than Gold traffic. While spuriously there are moments with a slightly higher number of packets received for the Silver traffic compared to the Gold one, this punctual behavior is due to the statistical nature of the simulation, and the averaged packet loss is higher for the Silver traffic.

Table 2 presents the mean values for the delay introduced in each of the traffic streams. The smallest one is the introduced for the highest priority traffic, Gold, and the biggest one is accordingly the experienced by Bronze traffic.

Fig. 6 and Table 3 present the behaviour of the scheduler and the WiMAX Base Station. The scheduler receives all the packets sent but it must discard some of them, in the end relaying 150.000 packets per second instead of the 180.000 received. The WiMAX Base Station discards just a small amount of packets (the red line is just slightly under the dark blue one).

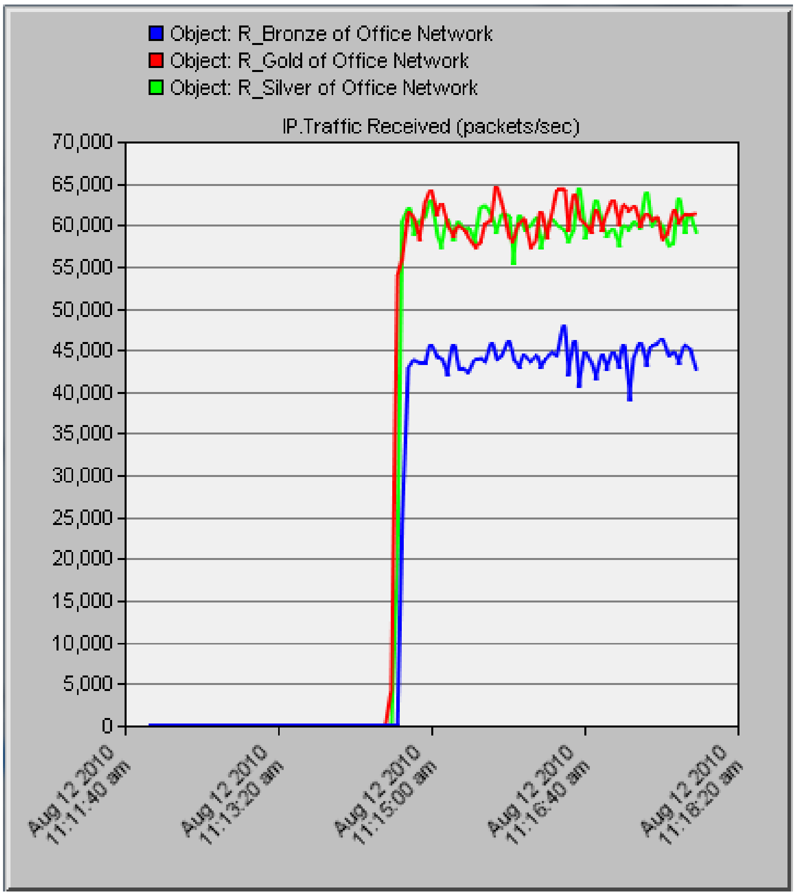

Figure 5. Traffic received in the WiMAX domain under heavy load.

Table 2. Mean delay values for each traffic stream.

	Mean Delay (s)
Gold Traffic	0.001523
Silver Traffic	0.004624
Bronze Traffic	0.012206

Table 3. Mean values for sent and received traffic.

	Sent IP traffic (packets/s)	Received IP traffic (packets/s)
Bronze/R_Bronze	32,785	17,493
Silver/R_Silver	32,183	32,160
Gold/R_Gold	33,106	33,048
Scheduler	84,031	97,994
Base Station	82,493	84,117

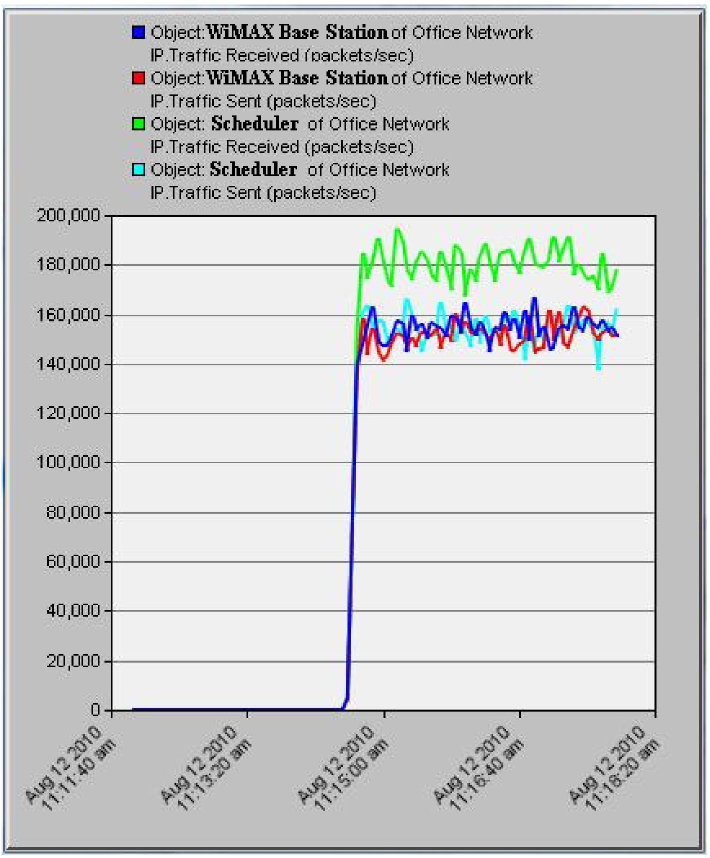

Figure 6. Traffic sent by the scheduler and received by the WiMAX Base Station.

7. Conclusions

The rise of multimedia services with heavy QoS requirements has triggered an evolution in the operation of communication networks, which have moved away from the old Best Effort mechanisms towards implementing more sophisticated algorithms to handle network conditions and traffic management. Various protocols have been designed with the aim of providing better Quality of Service in the networks, and the user Quality of Experience in turn. DiffServ for instance employs a PHB-based mechanism to allow a different treatment of the traffic streams depending on their requirements.

Additionally, technological evolution in the access networks domain has given birth to new kinds of networks, which may implement their own QoS mechanisms, and therefore in order to allow proper interoperation of QoS management in hybrid networks, it is necessary to perform an interdomain mapping. Along this work a mapping system between DiffServ and WiMAX has been proposed, modelled and simulated using the OPNET Modeler tool. The obtained results demonstrate that the mapping conserves the QoS conditions of the external network inside the WiMAX domain.

The result is that the proposed architecture allows the implementation of QoS-enabled hybrid networks which include one or several WiMAX segments. An operator owning this kind of network could offer its customers advanced QoS features that would be unavailable without a mapping of the kind proposed in this work.

Acknowledgement

This work has been partially funded by the Ministerio de Industria, Turismo y Comercio del Gobierno de España inside project WIMSAT (TSI-020100-2010-103).

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