



collected monitoring data from both the network and the service level in order to identify faults or optimization opportunities (e.g., high packet loss) according to the specified rules or QoS requirements. Then the appropriate re-configuration action either at the service part or at the WiMAX BS side (wireless access network) is selected and executed. For instance, if there is an increase of the average packet loss due to an increase of the VoIP flows then the NDCM should select between a service reconfiguration at the service provider side (i.e. VoIP codec change) or an on the fly service class change of a group of the existing service flows at the WiMAX BS side (e.g., from low priority service class to high priority service class).

Through this use case the end-to-end performance improvement in a large scale network environment is assessed, while the required interfaces from proprietary or not network devices are identified. The success and eventually the adoption of the tested mechanisms could benefit both the network operators (optimized utilization of resources, automatic planning and reduction of management time, easy adaptation of networks) and the end users (improved quality of service and experience).

#### A. Technical environment

Overview to the developed test environment is shown in Figure 1. Airspan MicroMAX WiMAX base station [3] and subscriber station is located on the Octopus testbed [4] at Oulu. WiMAX operates in FDD mode using 3.5 MHz bandwidth for the DL and UL at 3.5GHz. The user traffic from remote site is tunneled using two IP tunnels over the Internet and rerouted over the WiMAX air interface at the Octopus testbed. For the test environment provisioning, the IP tunneling (IPIP) and routing was setup at both ends, which requires two routers at the user premises – one for sending data to uplink and receiving downlink flows and one for sending downlink and receiving uplink flows.

Two routers are also dedicated on the Octopus testbed for tunneling and routing IP traffic and one computer for hosting control software for QoS service class setup and QoS monitoring of the WiMAX base station. Control software changes QoS service classes on the WiMAX base station dynamically by setting a new configuration to the base station using SNMP. Control software realizes an HTTP interface for the remote use (also a web page for user interface). In addition, the software also provides a remote access to monitor the base station statistics real-time returning timely parameter values retrieved directly from the BS encoded either in XML or YAML format.

#### B. Results

The following two tables depict the improvement on specific QoS features after the re-configuration actions due to an increase of the packet loss rate of VoIP traffic. Table 1 presents the reduction of the packet loss rate after the change of the prioritization (from low priority to high priority service class) at the WiMAX BS of the seventeen (17) VoIP flows that use G711.2 codec.

	G711.2 – Low Priority	G711.2 – High Priority
Number of flows	17	17
Total packets	13095	13066
Average delay	0.374 s	<b>0.348 s</b>
Average jitter	0.017 s	<b>0.016 s</b>
Bytes received	4788948	4754662
Average bitrate	3396.42 Kbit/s	3340.74 Kbit/s
Average packet rate	1160.907 pkt/s	1147.562 pkt/s
Packets dropped	17 (0.13 %)	<b>12 (0.09 %)</b>

Table 1 QoS features improvement using high priority service class

Table 2 depicts the QoS features improvement after a service level adaption of the thirty two (32) VoIP flows that traverse the WiMAX BS and face high packet error rate. As it is depicted in table 2 the modification of the service class prioritization at the BS side (from low priority to high priority class) is not effective, thus an alternative configuration actions has been deduced. Specifically, the change of the VoIP codec between the service provider and the end user, selecting the G729.3 codec, reduces the number of the dropped packets.

	G711.1 – Low Priority	G711.1 – High Priority	G729.3 – Low Priority
Number of flows	32	32	32
Total packets	30565	30602	16118
Average delay	0.514 s	0.761 s	<b>0.382 s</b>
Average jitter	0.012 s	0.012 s	<b>0.020 s</b>
Bytes received	4286549	4151657	4675350
Average bitrate	2789.06Kbit/s	2717.74Kbit/s	3046.94Kbit/s
Average packet rate	2485.90pkt/s	2504.07 pkt/s	1313.02 pkt/s
Packets dropped	3442 (10.12 %)	7929 (20.58 %)	<b>12 (0.07 %)</b>

Table 2 QoS features improvement after VoIP codec change (in the case that service class prioritization change is not effective)

## II. TEST BED AVAILABILITY

The WiMAX air interface is currently operating using a manual setup between University of Athens and Octopus. PII testbed software has been installed on the Octopus testbed and resource adaptor development has been started for provisioning WiMAX base station and subscriber station and the IP tunnels and routing. Service is expected to complete during October 2010 and be available from the Teagle VCT design tool [6] as one of the testing resources.

- [1] Self-NET Project, <http://www.ict-selfnet.eu>
- [2] Apostolos Kousaridas, Gérard Nguengang, Julien Boite, Vania Conan, Vangelis Gazis, Tilemachos Raptis, Nancy Alonistioti, "An experimental path towards Self-Management for Future Internet Environments", Book Chapter In: "Towards the Future Internet - Emerging Trends from European Research" [ISBN 978-1- 60750-539-6], Edited by Georgios Tselentis, Alex Galis, Anastasius Gavras, Srdjan Krco, Volkmar Lotz, Elena Simperl, Burkhard Stiller pp. 95 - 104, 2010.
- [3] Airspan MicroMAX WiMAX and ProST CPE <http://www.airspan.com/>
- [4] Octopus Network testbed <http://www.octofl.net>
- [5] PII project <http://www.panlab.net>
- [6] Teagle VCT design tool <http://www.fire-teagle.org>