Buletinul Ştiinţific al Universităţii "Politehnica" din Timişoara

Seria ELECTRONICĂ şi TELECOMUNICAŢII
TRANSACTIONS on ELECTRONICS and COMMUNICATIONS

Tom 53(67), Fascicola 2, 2008

Quality-of-Service Implementation and Validation on a WiMAX-Based Testbed

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Abstract – In this paper we will present a part of the activity we carried within the framework of the IST WEIRD project, which aims to enhance the WiMAX-based architectures specifically for convergence layer and upper layers (for resource management and control), in order to support real-time applications.
Our part in the project included: implementation of a testbed interconnected internationally with the other partners' testbeds, writing and testing software which allowed Quality of Service (QoS) enforcement over WiMAX, and validation of the setup.
Keywords: WiMAX, testbed, QoS, validation

I. INTRODUCTION

This paper presents the work performed by the authors in the framework of the European IST WEIRD project (WiMAX Extensions to Isolated Research Data networks, IST-034622-IP), focusing on the QoS reservations based on WiMAX, of an end to end multi-domain IP based system.
Section II contains a general overview of the WiMAX (802.16) wireless standard. Section III introduces the WEIRD project. In section IV we describe the Bucharest testbed of the project. In section V the qualitative and quantitative measurements made on this testbed are shown. Section VI concludes this paper.

II. THE WIMAX 802.16 STANDARD

WiMAX (Worldwide Interoperability for Microwave Access, based on IEEE 802.16 link layer technology) is a wireless standard superior to 802.11 WiFi in matters of speeds, distances, number of users and non Line-of-Sight (NLOS) availability. It can be seen as a wireless technology optimized for the delivery of IP centric services over a wide area, and a scalable wireless platform for constructing alternative and complementary broadband networks.
WiMAX is frequently seen as a wireless version of xDSL, intended primarily as an alternative to wire technologies (Cable Modems, xDSL and T1/E1 links), to provide wireless broadband access to customer premises (the "last mile" paradigm).
The main characteristics of WiMAX are:

- Range – theoretically- 30-mile (50-km) from base station (BS) to Subscriber Station (SS). Typically, a base station can cover up to 10 km radius, either LOS and NLOS
- Data rate - Up to 70 megabits per second
- Frequency bands - 2 to 11 GHz and 10 to 66 GHz (licensed and unlicensed bands)
- Defines both the MAC and PHY layers and allows multiple PHY-layer specifications.

The current standards are IEEE 802.16d for fixed access and IEEE 802.16e for mobile access [1], [2].
An important feature of IEEE 802.16/WiMAX is its controlled QoS capability. It can offer QoS guarantees based on its *connection oriented* approach and special MAC layer request-grant and scheduling mechanisms (collision-free). Each packet belongs to a service flow (SF) that defines the transmission ordering and scheduling on the air interface and some QoS parameters, like throughput, jitter and latency. Service flows exist in both uplink and downlink direction and they are identified by a 32-bit SFID (Service Flow identifier). SFID is unique between a BS and a SS/MS.
A set of QoS parameters forms a Class of Service (CoS). Table 1 summarises the WiMAX classes:

CoS	Name	Description
UGS	Unsolicited Grant Service	Used for VoIP with fixed packet size
rtPS	Real-time Polling Service	Real-time, variable bitrate, guaranteed minimum bandwidth, guaranteed delay, used for some VoIP codecs, MPEG, etc.
nrtPS	Non real-time Polling Service	Used for FTP, guaranteed bit rate, not guaranteed delay
BE	Best Effort	Used for web access and other non real time applications

Table 1 – WiMAX Classes of Service

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Typically, a BS serves more than one SS. The BS is usually located outdoor, while the SS can either be indoor or outdoor.

III. THE WEIRD PROJECT

The WEIRD project [3], funded by the European Community (ended June 2008), is a 24 month integrated project aiming at implementing research testbeds using the WiMAX technology in order to allow isolated or impervious areas to get connection to national research networks (NRENs).

The applications deployed on the testbeds are various: video surveillance, fire and volcanic monitoring, and telemedicine. All of these have QoS constraints.

The project consortium comprises 16 partners, from 6 countries (Italy, Portugal, Finland, Spain, Iceland and Romania); the partners are universities, telecommunications providers and research organizations. The Romanian partners are UPB (University "Politehnica" of Bucharest) and ORO (Orange Romania).

The WEIRD architecture is based on the WiMAX Forum model [2]. Besides the SS/MS (Subscriber/Mobile Station), its main components are shown in fig. 1:

- The ASN (Access Service Network) is a network infrastructure having a complete set of functions needed to provide radio access to WiMAX subscriber SS.
- The CSN (Connectivity Service Network) is a network infrastructure having a set of network functions that provide IP connectivity services to the WiMAX subscriber(s).

The NSPs are Network Service Providers; the *Rn* reference points are interconnection points according to the model.

While WEIRD is focused on WiMAX and ASN networks, its architecture is open and it can cooperate with CSN core IP networks in end to end chains.

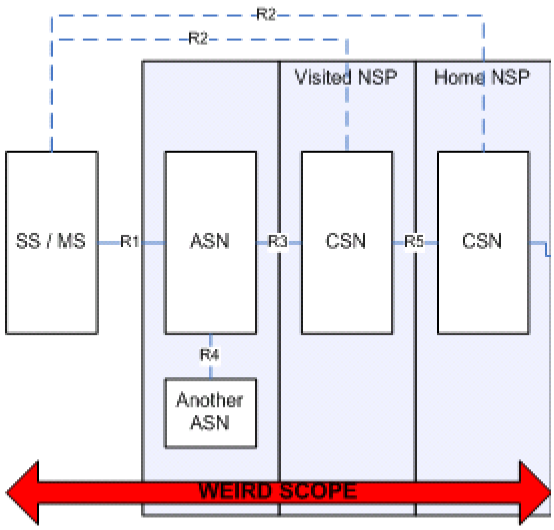

Fig. 1 the WEIRD architecture

While the 16 partners implemented 4 testbeds, we will further discuss the structure and interconnections of the testbeds in Bucharest and University of Coimbra (UoC - Portugal), shown in fig. 2.

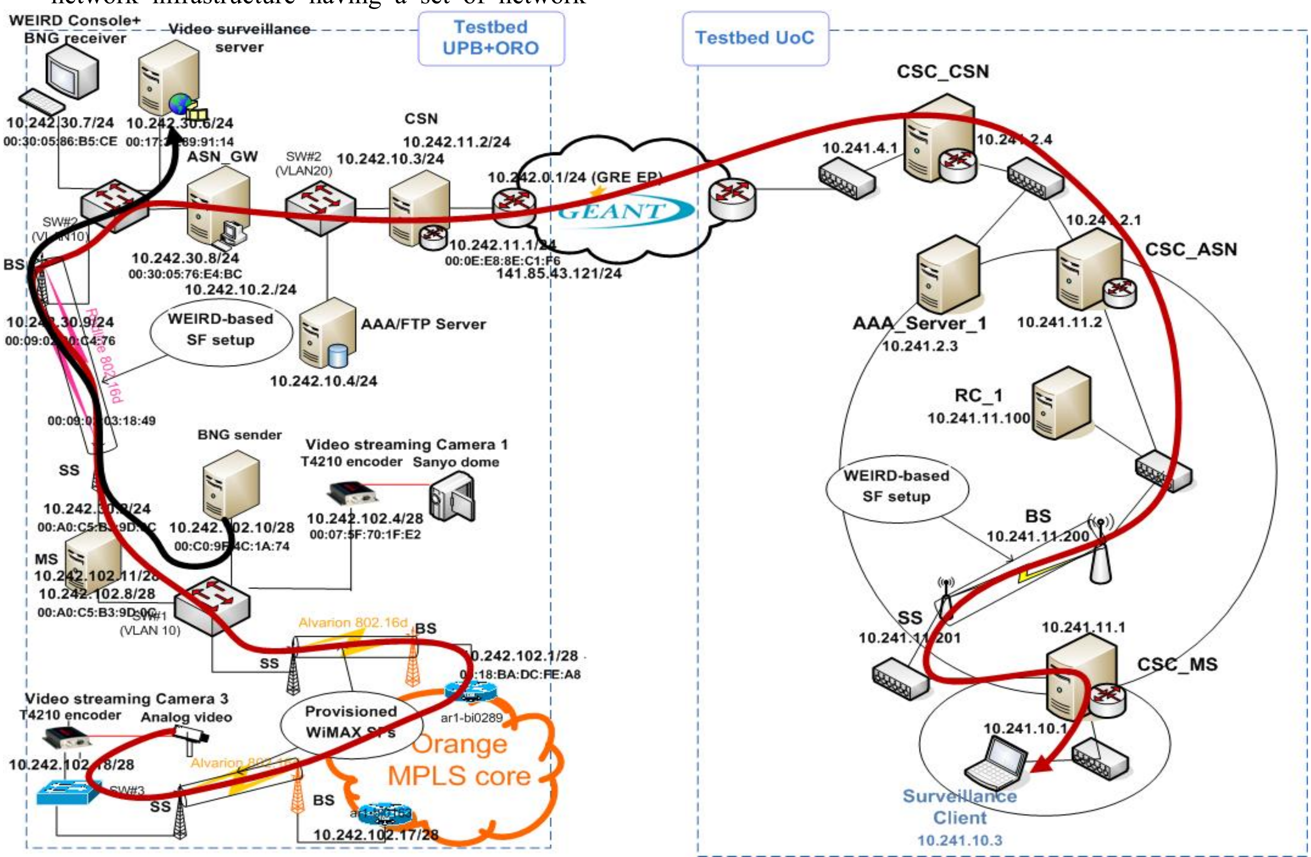

Fig. 2 The Bucharest and Coimbra testbeds

The connection between testbeds through the GEANT2 network is performed via GRE tunnels, and all IPs are from the 10.0.0.0/8 network.

IV. TESTBED DESCRIPTION

The Bucharest testbed is composed of two islands, the UPB Island and the ORO Island, linked through WiMAX to form the actual Romanian test bed. The test bed is interconnected with the Romanian NREN which is the GÉANT2 network, through the Romanian Education Network RoEduNet via a 622Mbps link. Access to the RoEduNet is provided through the UPB Island.

The testing area consists of two sites in the Politehnica University campus, interconnected via WiMAX links and Orange MPLS network. They are located in the UPB ETTI and Rectorat buildings. The two base-stations provided by Orange to link the two sites are located outside the campus and are working over typical urban environment conditions on 1.75MHz channels bandwidth in licensed 3.5GHz band.

At the ETTI location equipments are deployed in two rooms at different floors (3rd and 8th) and the link between them is done by means of a 3rd WiMAX connection, a BS and SS from the Redline manufacturer and working in the licensed 3.5GHz band.

The QoS parameters are set up on the Redline BS. Two modes of operations can be used:

- "native" mode, which uses the Redline-provided Web interface on the AN100U Sector Controller SS
- WEIRD mode, using a specially developed set of software modules within the project (team members from all the testbeds were involved, since it is a fairly complex software chain). This mode will be further described.

In order to perform reservations, a signalling chain is established using the NSIS framework (Next Steps in Signaling [6]).

The NSIS protocols used are:

- GIST (General Internet Signalling Transport)
- QoS-NSLP
- QoS-NSLP-Auth
- QSPEC (QoS Specification)

The data and signalling paths (path-coupled mode) include all NSIS aware nodes. The chain comprises the ASN, CSN, CSC (Connectivity Service Controller), RC (resource Controller) and AAA (Authentication, Authorization and Accounting) nodes and can be followed on fig. 2.

The inner working of the software modules can be summarized as following:

The MS computer hosts the WEIRD Agent (WA) by which downlink and uplink reservations are performed. The actual configuration of the Redline BS is done via SNMP.

The RC is the WiMAX link management module. It has a northbound interface with the upper modules of the architecture (CSC_ASN) that are unaware of the WiMAX technology specific details, and a southbound interface with the Adapter. The RC has been implemented in C++, using a set of hash tables to store the service classes, service flows and classifiers for the WiMAX link, as well as a state machine to control the status of the SFs.

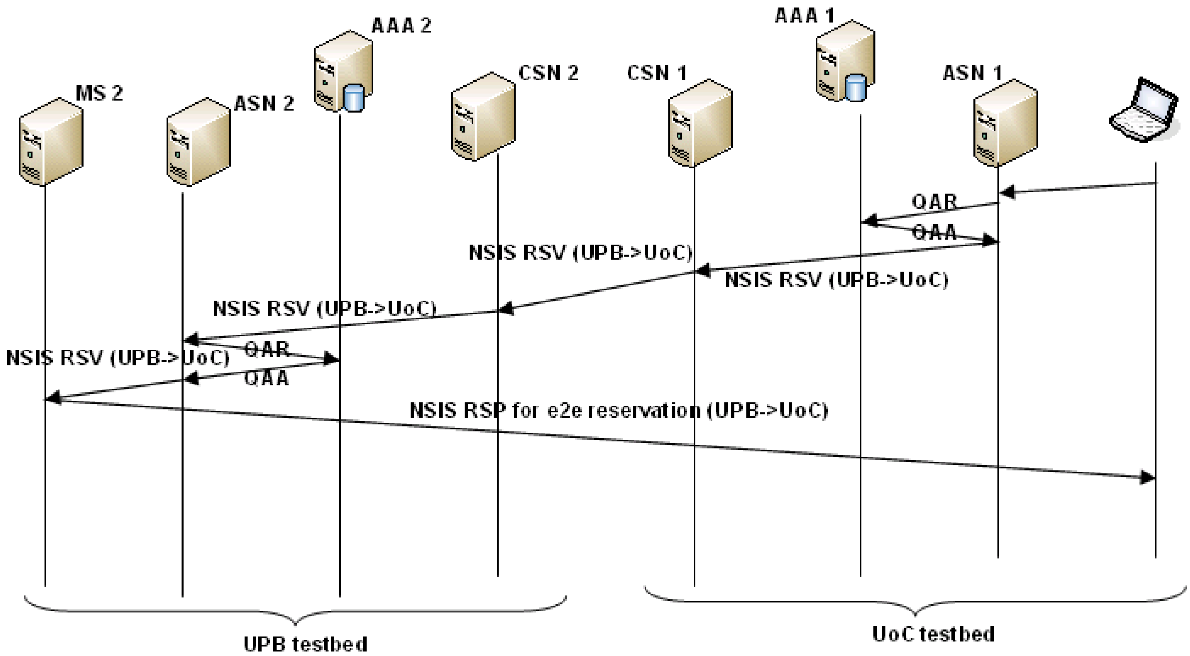

Fig. 3 NSIS Signalling Chain

After the RC processes the QoS request, it sends the reservation information towards the Adapter. The main role of the Adapter is to enforce the reservation requests in the WiMAX system. Particularly, the Adapter shall translate the received QoS parameters to the correspondent MIB (Management Information Base) objects and send the SF establishment request to the BS using an SNMP message. Thereafter, the BS will trigger the SF activation in the WiMAX system using the 802.16d DSA (Dynamic Service Addition) MAC Management messages. The Adapter module has been implemented using C and the Net-SNMP API [7] has been chosen to establish the SNMP interface with the WiMAX BS.

The CSC is implemented in JAVA; before sending messages to the QoS-NSLP (also implemented in JAVA) it maps WEIRD message types to NSIS messages types.

A simplified message sequence chart (MSC) of the NSIS signalling in order to perform a reservation between a WA and MS is depicted in fig. 3.

V. PERFORMED TESTS AND MEASUREMENTS

V.1 Visual scenario

On the Bucharest-Coimbra testbeds we performed the following scenario in order to validate the reservation software and to evaluate the end-to-end QoS:
A legacy video streaming client running on the fixed WEIRD enabled terminal at the UoC site, will start a video streaming session with QoS reservation, with the streaming server located within UPB site. The video flow is marked with a thick line on fig. 2 and traverses four WiMAX links, two of them having their QoS parameters controllable via the WEIRD software (on the Redline links; the Orange Alvarion links have fixed parameters).

The scenario comprises 3 phases:

Phase 1:

- No reservation activated in the network (despite all signaling interactions and QoS enabled infrastructure exist).

Video flow: MPEG-4, rate 1.836 Mbps;
WiMAX SF: BE with MSR (Maximum Sustained Rate) 8Mbps, classifier 802.1Q

- Maintain a lightly loaded network (it is actually BE) and sufficient overall bandwidth on all segments
- The perceived quality (PQoS) of the image received in UoC is good (subjective test)

Phase 2:

- The WiMAX link within UPB is loaded with background noise traffic generated from BNG (Background Noise Generator) sender toward BNG receiver (upstream), so that:

WiMAX UL link capacity < BNG sender throughput + video stream throughput

Video flow: the same parameters;
Noise traffic: UDP, rate 8Mbps (upstream); generated between MS and ASN (see fig. 2);
WiMAX SF (Service Flow): BE with MSR 8Mbps, classifier 802.1Q, shared by video and noise traffic

- The image quality is severely degraded

Phase 3:

- While keeping the same network conditions pointed out in the second scenario, the user from UoC site triggers the resource reservation process on WEIRD system using the WEIRD Agent;

Video and noise flow: the same parameters as in previous phase;
WiMAX SF for noise traffic: BE with MSR 8Mbps, MRR rate 0 kbps, classifier 802.1Q;
WiMAX SF for video stream: rtPS, MSR 2.5Mbps, MRR rate 2.5Mbps, classifier IPv4 (higher priority than 802.1Q classifier)

- WEIRD Agent shows that the resource reservation process has been successfully completed end to end;
- The video stream PQoS is as good as in the first scenario.

V.2 Measurements

The PQoS of the received images in V.1 was evaluated visually since no tool for video image quality measurement was available. In order to obtain quantitative results, a second scenario was developed, in which we used the Iperf tool [8]. This software suite allows us to generate traffic according to specifications and to measure QoS parameters of the same traffic at an arbitrary reception point.
Since the main purpose of the test was to evaluate the reservation on the Redline WiMAX link, the tests were performed between the “SS” and “ASN-GW” computers on the left side of fig. 1, effectively taking out of the loop the other two WiMAX links and the UoC side of the testbed. The background noise was, this time, generated by the video camera and the image quality was not monitored. Instead, the data traffic between SS and ASN-GW was monitored.

The WiMAX link was loaded with the following two simultaneous traffic types:

1) video traffic between camera and PC, used as background traffic. Average bandwidth: 2200Mbps, max 5Mbps, BE only
2) Iperf generated traffic between PCs, UDP packets, lengths: 64B, 300B, 1470B; generated bandwidth: 500kbps, 2500kbps, 4000kbps; the following reservations were tested:

- BE
- rtPS, MSR: 5Mbps, min. res. 4.2Mbps, latency 100ms
- nrtPS, MSR: 5Mbps, min. res. 4.2Mbps
- UGS, min. reserved: 2500kbps, max sustained rate: 5000kbps, latency 100ms

The tested parameter was loss rate (measured by Iperf). Results:

- for 500kbps, loss rates were 0% in all cases
- for 2500kbps the results for 4000kbps are presented in graphical form in fig. 4:

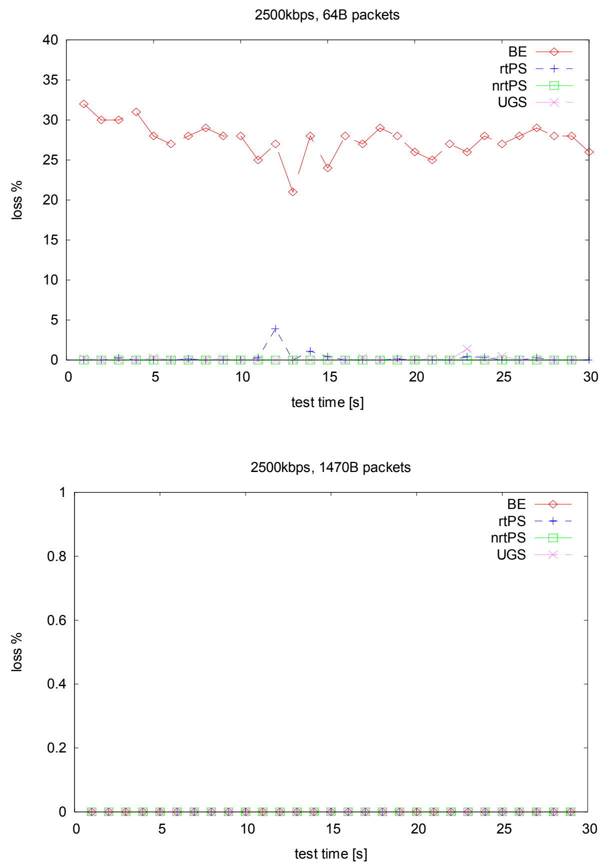

Fig. 4 Measured test results for 2.5Mbps, 4 styles of reservations

- for 4000kbps the results are presented in graphical form in fig. 5:

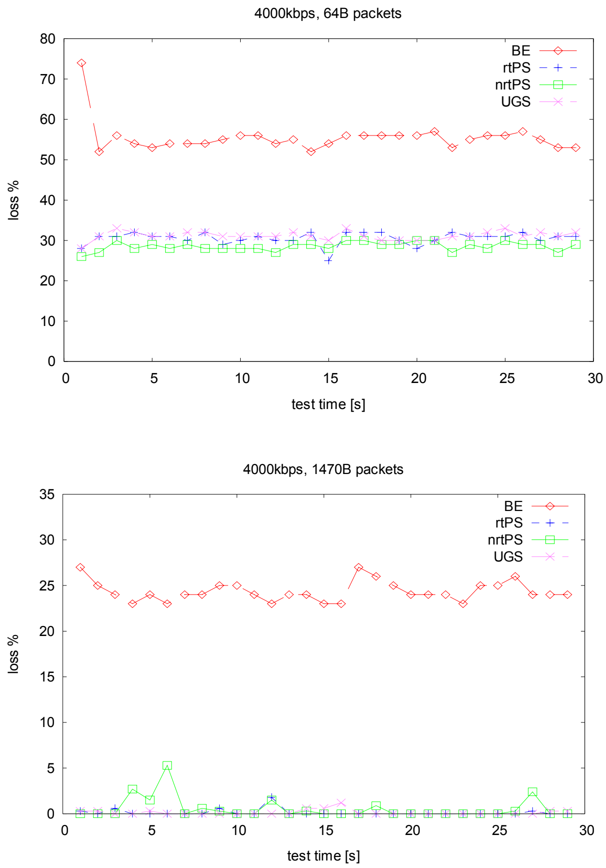

Fig. 5 Measured test results for 4Mbps, 4 styles of reservations

VI. CONCLUSIONS

The results of scenario V.I (visually interpreted) are consistent with the WiMAX QoS classes and also validate the proper functioning of the WEIRD testbed and software. The numerical results are also consistent, showing that the loss is zero or very reduced in all but the BE reservation style. One notable exception is the case with very short packets (64B) which show a loss rate of 30% even with the „strongest" reservation style (rtPS), compared to roughly double with BE; this is a limitation of the Redline's scheduler and not of the WEIRD software.

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