WiMAXmeter: Test & Measurement bench for WiMAX systems

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***Abstract*—Wireless access networks are today the most important revolutionary technology in the data network area. Bringing wireless communications, special at local area levels (WLANs), to a development stage never imagined just a few years ago. WiMAX technology (IEEE 802.16) was developed having in mind the concept of wireless access in metropolitan areas with bit rates equivalent to those achieved by wired technologies, with the flexibility of WLANs.**

The work described herewith concerns an integrated tool to analyze, test, monitor and help the planning of a WiMAX network. The WiMAXmeter tool integrates most of the requirements that separated tools have to fulfill individually, following an "all-in-one" approach. Results obtained with this tool, have shown that important issues such as flexibility, usability and platform independence were successfully achieved.

I. INTRODUCTION

The final decades of the twentieth century brought an increasing installation of better fixed access to communication networks worldwide, in order to cope with users' demand for better and faster accesses. On the other hand, the flexibility required for accessing information "*anywhere, anytime"* led to the development of wireless technologies capable of coping with installation costs, coverage and scalability issues.

Until now however, there wasn't a single wireless technology that really represents an alternative to wired fixed access technologies (e.g. ADSL, HFC) in wide areas. Cellular technologies have improved a lot, since the old days of 2G systems, but still lacking important characteristics for being considered as a credible concurrent to wired technologies, at least as to what concerns data communications. WiMAX Forum founders claim that WiMAX was indeed the first wireless technology to fill this gap.

However, in order to evolve to a mature state, capable of being used as *the* wireless technology for the *last mile*, WiMAX has to undergo several development steps. As happened with other technologies, like WiFi (802.11) an effort has to be made by software companies, in the development of tests and measurement tools for WiMAX system.

The contribution of this work is therefore to provide an integrated tool capable of merging the different needs of test and measurement platforms tailored to the specific characteristics of such technology, like access to transmission parameters, management of radio resources, QoS parameters, analyses of MAC messages and aid the radio planning of a WiMAX network. The architecture followed a platform independent philosophy, so that it can work with any WiMAX system.

With this architecture, it was developed a software package, called WiMAXmeter. This prototype was then tested with the WiMAX system installed at IST-Taguspark to validate its main functionalities and to assess its main benefits.

The remainder of this paper is organized as follows: section II describes some work done in Tests&Meausurements for WiMAX systems. Section III explores the requirements and defines an architecture capable of fulfilling such requirements and shows the choices made over the architecture defined to the implementation of the prototype. Section IV shows some results of the tests made with the tool and finally section V draws some conclusions and lays out the future work.

II. RELATED WORK

Since ITU announced WiMAX as a 3G standard technology, the process of adoption of this standard may become easier. Although, there are still few WiMAX facilities worldwide, many efforts have been developed with the purpose to make an accurate characterization of this new standard.

Being a very recent standard, it is necessary to carry out many tests, in different scenarios, in order to be able to understand how this technology behaves when it is deployed. Some measurements campaigns have been conducted to capture the real behavior of this technology in non-urban and urban environments [2].

There are no tools (or very few) that allow an easy and effective way to collect the main parameters to measure and to test already installed infrastructures along with future WiMAX networks. Another factor is the distance that the system can theoretically reach, being much larger than the one achieved by WiFi. In order to achieve a measurements campaign that characterizes this system, it is necessary to take into account both measures at the physical layer, as well as at the higher layers. An example of works with this purpose were made in Oslo-Norway for the characterization of a WiMAX system[10], and in Portugal by ISEL [9]. In bothworks, the need to create "home-made" solutions for tests and measurements on this technology, was present due to the lack of tools available for this purpose. In this way, these works give an idea about some of the procedures that a software should implement.

Aside from a few shortcomings, some measurement tools are beginning to appear allowing to perform tests on WiMAX systems. An example of these tools are:ViewMAX 0, Wireshark (both for taking MAC traces) and for planning we have, for example the work presented in [4].For the MAC analysers software, these solutions

don't work with every equipment and it is possible to point out that these tools are still in a pre-development stage. For the planning, the scenario is today a bit different. We are now starting to have professional applications for planning a WiMAX network, since much work done in previous technologies, can be reused. But most of this tools follow a proprietary philosophy and thus cannot be used freely.

III. System Design & Implementation

A. *WiMAXmeter Architecture:*

The WiMAXmeter tool should be used in an environment where a WiMAX system is already installed. In Fig 1, the physical architecture is shown.

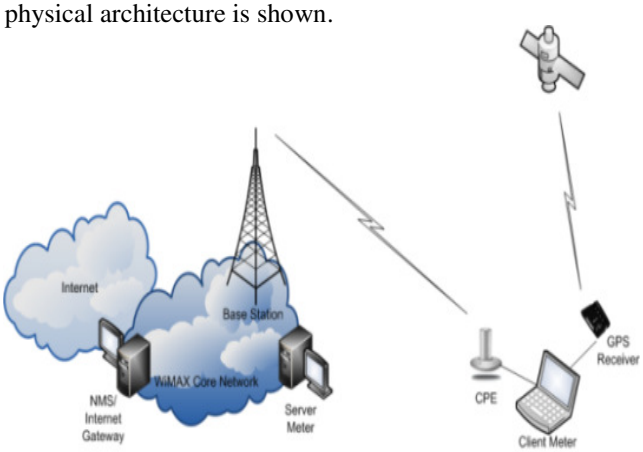

Fig 1. Physical Architecture

The system is composed by 6 entities: NMS/Internet Gateway, WiMAX Base Station, ServerMeter, CPE, ClientMeter, and GPS Receiver. The NMS located in the WiMAX core network is the platform network management system and it belongs to the infrastructure already installed. It also has the job of assuring an Internet-gateway functionality. The ServerMeter, together with the ClientMeter, are responsible for performing the basic steps of the system's analysis. The Base Station and CPE are the equipment under test, responsible for establishing the connection between the user and the network through a 802.16 access. Finally the GPS receiver allows that all measurements made by the entity ClientMeter, to be geo-referenced. Next is presented the implementation architecture as well as the functional description of each of the blocks of the tool.

B. *Functional Description:*

The WiMAXmetertool, can be divided into seven functional blocks. These blocks form the core of the application. Each of these blocks is responsible to meet the requirements already discussed.

Tool implementation followed an approach based on functional blocks. Each of these blocks corresponds to a Java class. Each of these classes works in an independent way of the main application.

There is a main class, WiMAXmeterCore that implements the entire graphical interface and start each of the classes (blocks) that exist in the application. The addition of new features is possible.

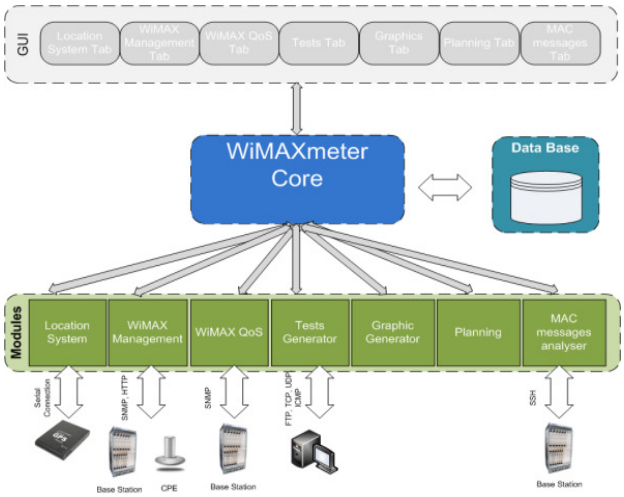

Fig 2. System Architecture

This main class is also responsible for sending the information needed to be stored in the Database. In Fig 2, we can see the architecture of the solution. Next, are presented the possible paths to implement a software package like this as well as the detailed implementation followed for each of these blocks.

1) *Location System:*

The application opens a serial connection with a GPS receiver and gets the NMEA statements that are being sent through that connection (regarding mainly the $GPRMC statement). With those coordinates, the application computes the distance between the user and the Base Station, and shows a map of the location.

2) *WiMAX Management*

The required management information is the following: measurement parameters provided by the CPE in use, RF signal characteristics, such as SNR, RSS, etc. Since one of the requirements of the tool is the interoperability, with WiMAX equipments, all of the management information needs to be collected in a common accessible way by any WiMAX equipment. 802.16f have set a standard management MIB (both for CPEs and base station) and so this is the best way of getting the information. With this approach, regardless of the manufacturer, the tool can access the information. Alternatively, for the CPE, the information can be collected through a HTTP page provided by the CPE for diagnostics propose. This approach however does not allow the interoperability with other equipment, as these pages are organized and implemented by manufacturers in a non-standard way.

The communication with the Base Station has also a alternatively approach. Such communication can be made using Web-services. The NMS platforms provided by manufacturers, provide the majority of the communication interfaces and a way to access administration/management mechanisms. For communication with the CPE, the implementation via SNMP could not be achieved, since the equipment available was not 802.16f fully compatible. The communication is done via HTTP. Regarding the communication with the Base Station, the Web Services approach could not be implemented since the Web

Services interface was not yet fully available by the manufacturer [1]. Then the use of SNMP for all kinds of communication with the base station was adopted. After accessing the MIB table, the application retrieves the management items. Once it receives, the information is collected, and then displayed on the GUI. It was also implemented a command to reset the CPEs. This is done by sending set of SNMP messages (to the Base Station) that changes the status of the CPE in the MIB table of the base station to the "restart" state. As soon as the Base Station detects this, it immediately sends an order for the CPE to restart itself (802.16 WiMAX RES-CMD).

3) WiMAXQoSConfigurator

To perform the provisioning from a tool, there are basically two ways to do this. The first and preferred mechanism (QoS Management), would be through the Web-services interface, that most Base Stations have since its only necessary to have the WSDL file from a specific vendor to access its interface. Another approach is to communicate directly with the Base Station with SNMP. This is however a time consuming way, comparing to the Web-Services solution. Due to the limitations found in the implementation of WiMAX Management module, it was not possible to accomplish the original objective of setting up the traffic profiles in any WiMAX equipment. Although the Base Station is 802.16f compliant, the truth is that most of the information needed to set up these profiles, are not on the MIBs defined by the 802.16f taskforce, but on proprietary tables. The application communicates by SNMP with the Base Station and gets all the traffic profiles that exist there. After getting this list, the application allows the user to select a particular profile. The application then sends a set of SNMP SET messages, so that the CPE is provisioned with the desired service flow.

4) Tests Generator

The tests must simulate end-user applications. The simulated scenario for this WiMAX network is a general purpose access network. The ClientMeter would run on a laptop within the range of the WiMAX network, and carry out a battery of tests with the ServerMeter located in the core network.

So the battery of tests is composed by: FTP File Transfer test, VoIP traffic generator (to test in a location to check if a VoIP service can be assured), TCP/UDP Traffic generator (to stress the network) and a Latency Test (to measure the round-trip-time with ICMP packets).

For the FTP test, a FTP client was implemented in Java. The VoIP test consists in generating traffic with the characteristics for VoIP (packages with 160 bytes at a rate of 64 kbps)[6]. To generate this traffic, the application uses the known Iperf tool. The Stress Network test is to generate background traffic that allows testing the network in high traffic conditions. Finally the Connectivity test, is to test mainly the latency between ClientMeter and Server Meter (for example).

5) Graphics Generator

The goal of this block is to aid in parameters monitoring analysis. This is achieved by having a specific block that is responsible for drawing graphics of the main parameters that need to be analyzed.

6) WiMAXPlanning Module

This is the module responsible for the simple preliminary planning of a WiMAX network. The block is used to estimate the coverage and performance of the installed network. To achieve this, we had to identify what are the needed steps. In Fig 3, we can see that the first step is to choose the parameters that define the channel to be used.

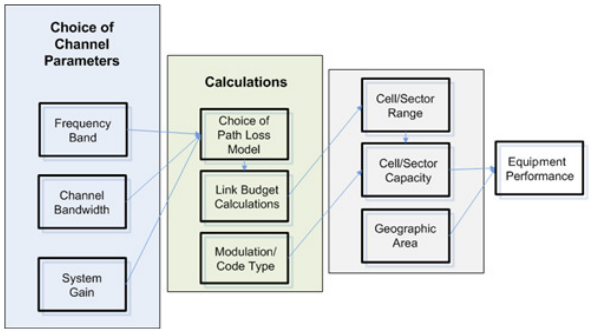

Fig 3– Planning Flow

Putting together this information, and with the modulation and encoding schemes expected to be used, one gets an estimation of the capacity of the WiMAX system under review. Finally, adding some features of the base station surrounding terrain the result is the overall performance of the equipment. Expression 1 represents the *Link Budget* and expression 2 the SUI propagation model.

$$P_{r[dBm]} = P_{e[dBm]} + G_{e[dBi]} + G_{r[dBi]} - PL_{[dB]} \quad (1)$$

$$PL = A + 10\gamma log_{10}\left(\frac{d}{d_0}\right) + X_f + X_h + s \quad (2)$$

7) MAC Messages Analyser

This block of the tool is responsible for the access and decode of the MAC messages that are being transferred on the WiMAX network. It is expected that this block has a behaviour and provide the same type of information that is available from network protocol analysers, that already exist in the market but, in this case, for WiMAX technology. The approach that is followed by such tools is to capture all the information that passes through the network interface that is being analysed. Then with a series of interpreters for each of the existing protocols, the information is dissected and characterized according with the protocol that was detected in this communication. After this, the information is mapped under a protocol stack. Finally the information is filtered to be understood by the user. In the case of WiMAX, the challenges are in the information capture from the 802.16 interface and, as a consequence, making a WiMAX dissector.

The CPEs available for the tests had an Ethernet interface with the client so it was not possible to capture the messages directly through this interface, since 802.16 messages are lost in that interface, the alternative way is to get this messages from the Base Station. The Interface Capturer, opens a socket via SSH. From there the entire management information that is exchanged is sent to application. This information is filtered before being sent to the WiMAX dissector. All of the information captured is

formatted with the following structure: (MAC Address, Message Name, Description, Type of Connection, Direction). This solution, however is not platform independent since it rellies on the existing application in the Base Station. For storing all of the test results, a database is implemented.

IV. System Evaluation

This section contains a set of tests that were preformed to validate the full functionality of the tool developed.

A. *MAC Messages analyses*

Both Mac analyser and the *Restart SS* function worked as expected. The MAC Messages Analyser captured all of the know network entry messages sent by the CPE identified by the 00:A0:0A:C2:47:9E MAC Address. As soon as the user selected the *Restart SS* function to this CPE, the application detected the RES-CMD message sent by the Base Station to the CPE.

B. *Planning of a theoretical WiMAX Base Station*

1) *Description:* The scenario consists in a user that has the specifications of a WiMAX system.

2) Results

Modulation	Distance
64 QAM ¾	4,101 km
64 QAM 2/3	4,337 km
64 QAM ½	4,85 km
16 QAM ¾	5,736 km
16 QAM ½	6,895 km
QPSK ¾	8,024 km
QPSK ½	9,49 km
BPSK ¾	10,036 km
BPSK ½	11,224 km

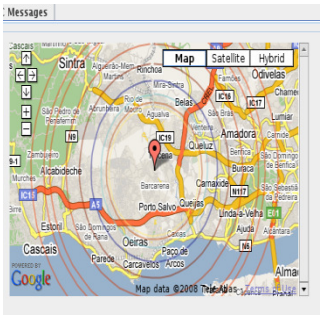

Fig 4 – Results obtained with the Planning Tool

The tests shown that the planning tool module worked as expected. The application with the system given by the user, computed the maximum achievable distances for each modulation (see Fig 4). Then with these values, accessed the Google Maps API and retrieved a map with the location of the Base Station, as well as the coverage predicted.

C. *Measurement campaign in Taguspark*

1) *Description:* Here the test has the objective to make some measurements in the field and test the WiMAX system installed in Taguspark (see Fig 5).

Fig 5 – Tests Location (left), equipment used (right)

2) Results

Tests Name	Núcleo Central	Escadaria	Correios	Porta Principal	Porta Lateral	ISQ
Distance (m)	325	97,5	49,83	167	34	500
Mean SNR (dB)	31,57547	36,73258	36,32791	23,2800	36,07250	4,98809
Mean RSS (dBm)	-68,81226	-45,97528	-46,97441	-81,8000	-59,4600	-95,4452
UL Modulation	QPSK 1/2	64QAM 2/3	64QAM 2/3	BPSK 1/2	16QAM ½	BPSK 1/2
DL Modulation	64QAM 3/4	64QAM ¾	64QAM 3/4	16QAM ¾	64QAM3/4	QPSK 3/4
Sight	NLOS	LOS	LOS	NLOS	NLOS	NLOS

Fig 6 – Mean values of the physical parameters

The campaign results show that the application effectively captured all the information generated during the tests. It stored all the values, that latter in the laboratory enabled to perform a statistical work with Excel (Fig 6).

V. Conclusions

This work aimed to build a tool for test & measurement for IEEE 802.16 equipment, called WiMAXmeter. The main purpose of the tool was to enable testing and analysis of key parameters of a WiMAX network in a single application (integration of various features). It was also proposed an architecture for a tool that would meet specific requirements, namely,access to measurement parameters (physical and logical level), use of simulation applications by a end user, exploitation of QoScapabilities, preliminary planning based on channel parameters and, finally, access and decode of management-level MAC messages. This architecture, being designed to be platform independent allows any type of WiMAX equipment to be used. The tests made with WiMAXmeter have shown that different tests scenarios are attainable and that important issues like usability and flexibility, were achieved.

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