Testbed for CRRM and E2E QoS Management Evaluation in B3G Networks

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***Abstract*— This paper describes the motivation, methodology and implementation approach of the testbed to be developed in the framework of the EVEREST project. Such testbed will be used for demonstrating some of the main concepts addressed within the project, concerning both: Common Radio Resource Management strategies and end-to-end QoS architectures and mechanisms for B3G systems based on the UMTS architecture. The complexity of the interaction between B3G systems and the user applications, while dealing with the QoS concept, pushes to develop this kind of emulation platforms, where algorithms and applications can/must be tested in realistic conditions, not achievable by means of off-line simulations.**

***Index Terms*— beyond 3G, end-to-end QoS, DiffServ, heterogeneous access network, policy-based service negotiation.**

I. Introduction

THE main objective of the EVEREST project is to investigate and propose mechanisms and algorithms that can handle the expected traffic growth and the more demanding QoS services in a heterogeneous network structure which comprises 2G and 3G cellular systems as well as wireless local area networks (WLANs).

Due to the complexity of such heterogeneous systems, an appropriate definition of the envisaged scenarios is crucial in order to determine the performance of algorithms and strategies, especially when a manifold of users, services and radio access technologies are involved. The considered scenarios are mainly based on the requirements and visions of the four Mobile Operators that participate in the project, which are interested in analyse the impact that resource management algorithms have on the system performance.

In such context, the main objective of the EVEREST testbed is to demonstrate the benefits of the developed Common Radio Resource Management (CRRM) algorithms and proposed QoS management techniques. Basically this demonstration framework will consist of the emulation, in real time, of the conditions that the wireless heterogeneous network behaviour, including the effect of the other users, produces over the user under test (UUT), when making use of real applications (i.e. videoconference). Then, the EVEREST testbed aims to build a GERAN/UMTS/WLAN stand-alone real time emulator platform, including all the relevant QoS entities in both the radio access part and the CN, to show and analyse the end-to-end QoS performance. Such approach will allow testing multimedia IP-based applications (videoconference, streaming services, web browsing, etc.) on an end-to end basis and over an emulated access network with enhanced RRM features. Among EVEREST testbed features, it should be emphasised the possibility to test the end-to-end Quality-of-Service (QoS) performance and to assess, in real time, the effects that RRM/CRRM/BB algorithms have on the user's perceived QoS.

Manuscript received February 6, 2005. This work has been performed in the framework of the project IST-EVEREST (www.everest-ist.upc.es), which partially funded by the European Commission under the IST framework and the Spanish Research Council under TIC2003-08609 grant.

II. CONCEPTUAL REFERENCE ARQUITECTURE

A. Review Stage

The main research topics in EVEREST are addressed within a proposed end-to-end QoS management framework aligned as much as possible with the QoS architecture envisaged in 3GPP Release 5 and 6 [6][7] for the Internet Multimedia Subsystem (IMS) and other relevant IETF proposals. In particular, a QoS management architecture extending the 3GPP policy-based framework is considered in order to address the QoS issue within B3G networks. The proposed architecture over a B3G network where different RANs can be offered to access at the same Core Network, incorporating several extensions of the 3GPP architecture to fulfil B3G QoS requirements, is illustrated in Figure 1.

The key aspects of this QoS management architecture is that the a the PDF function already introduced in 3GPP R5/R6 policy framework is maintained and two new entities are introduced in the B3G QoS architecture, namely: the Bandwidth Broker (BB) and the wireless QoS broker (WQB). The BB, [1][2], is in charge of the control plane of the DiffServ domain, while the WQB [8][9] is the counterpart of the BB for the radio part of the access network. Both BB and WQB could act as policy managers and their policies are enforced in the core network routers as well as in the radio equipment respectively. Common RRM strategies are managed by the WQB.

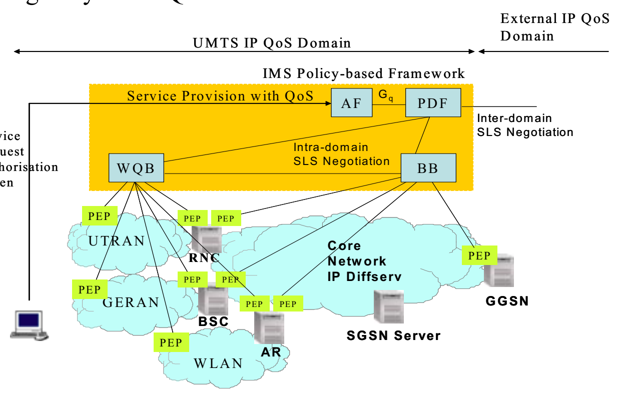

Figure 1. EVEREST QoS architecture in a heterogeneous radio access network.

More details about this E2E proposal can be found in [3][4][10].

III. SCENARIOS

In case of evaluation of RRM/CRRM strategies within cellular heterogeneous networks, the items considered relevant for the scenario definition includes the Network architecture and corresponding entities, the Services (including mix and traffic load), the Environment (suburban, urban and indoor) and the Radio access technologies, capabilities and functionalities. Both theoretical and realistic target scenarios have been chosen which consider situations where we foresee an important impact of the heterogeneous networks concept and of the selected common RRM strategies. Both types of scenarios include a mix of GSM, EDGE, UMTS and WLAN deployments.

IV. TESTBED DESIGN CRITERIA

A. Proof of concepts

The testbed is aimed at demonstrating most of the concepts addressed within the EVEREST project and analyse them under the set of scenarios identified [4]. Hence, the design of the testbed must be implemented taking into account the need to execute a set of suitable procedures to validate such concepts. The envisaged ones are includes the initial RAT selection mechanism and the connection establishment with E2E QoS negotiation, the E2E QoS Re-negotiation, the evaluation of the CN Mobility Management and QoS interactions, the Common Radio Resource Management operation and the test of the impact of CRRM and QoS management on applications.

B. Testbed facilities: Centralised Management

The tool developed, AGMT (Advanced Graphical Management Tool) to centrally manage the whole EVEREST testbed is based on the management tool developed within the ARROWS project [11] and will incorporate the procedures to configure and set-up the whole testbed, to control and monitor the execution process, to obtain valuable data in real-time, to demonstrate the selected procedures as well as to gather signalling traces and data statistics to be processed off-line.

V. TESTBED IMPLEMENTATION DETAILS

The architecture proposed for the EVEREST testbed reproduces the reference architecture depicted in section II and has been built in base of using cluster of Linux OS PC's. We divided the testbed between the emulation of the RAN side and the CN side.

A. RAN side

The functional architecture of the RAN side is the depicted in the Figure 2. The main components are the following:

User Equipment Emulation. This node will hold applications and a QoS client to manage connections through the heterogeneous access network.

RAN Emulators. A set of emulation platforms to cope with the main characteristics of the UTRAN, GERAN and WLAN technologies is considered.

Wireless QoS Broker. This node will handle QoS management in the heterogeneous RAN as well as CRRM functions.

Switching Node. It is mainly used to be able to establish different configurations of coupling between RANs and the correspondent routers in the CN.

Master PDP. Policy Decision Point, which acts as the master of the overall heterogeneous access network (RANs plus CN).

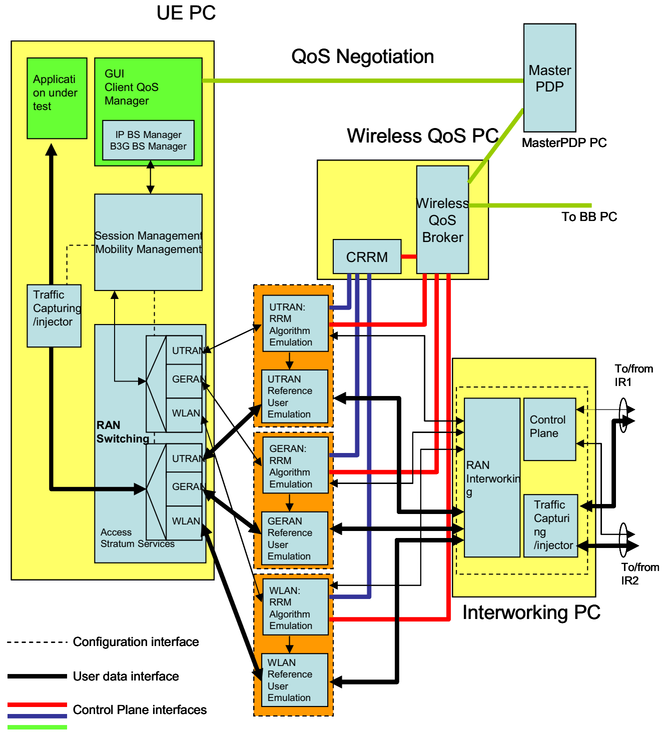

Figure 2. Emulation of the Radio Access part.

Considering the scenarios defined in the EVEREST project, we assume that the UUT shall behave as any of the other users allocated in the scenario and, thus, it will run a set of specific applications (according to services supported) while it follows a given trajectory within the scenario. This general assumption is illustrated in Figure 4 where the hotspot within urban area scenario is taken as an example.

So, the traffic generated by the real application of the UUT must be processed by a given RAN emulation module, which will provide the requested QoS parameters. The processing of the UUT data will be different along the time depending on what RAN the user is attached on as well as the QoS is provided at each instant of the demonstration.

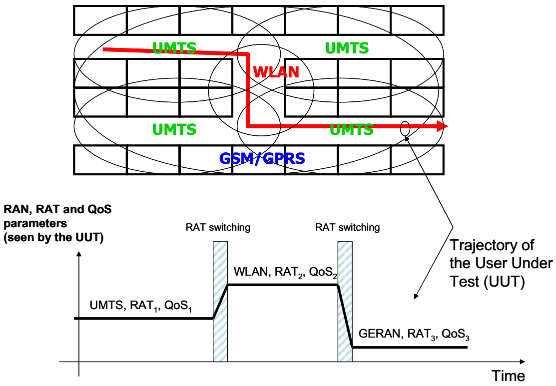

Figure 3. The reference user follows trajectory within one of the scenarios.

As the testbed is envisaged to manage mechanisms for QoS selection, including negotiation, the behavior, in terms of QoS, observed by the UUT can not be "replayed" from a previous situation assessed by off-line simulation. The degrees of freedom that we want to give to the UUT force the RAN modules to be able to adapt its behaviour according to several external inputs as The selected RAT and its related QoS parameters, the user location, dynamic inputs coming from the decision modules (e.g. CRRM functions) and static inputs (e.g. scenario selection)

Moreover, the RAN modules generate a set of parameters (e.g. load factor in the case of UTRAN) that may be used in the decision modules (e.g. CRRM module), such as it is also illustrated in the Figure 5, This fact is denoted in the figure as a dynamic output of the RAN module.

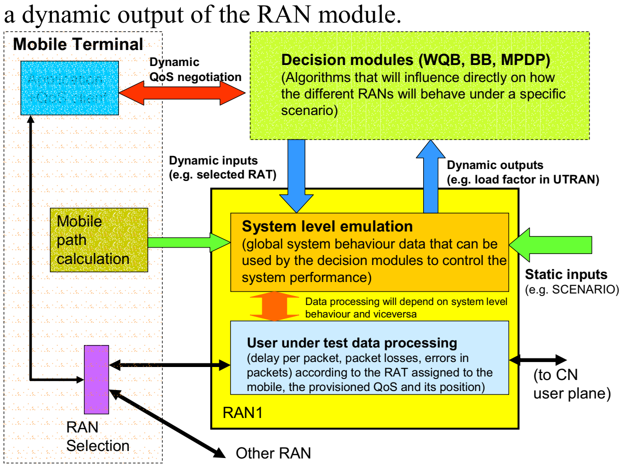

Figure 4. RAN emulation modules within the testbed.

At this point, the problematic behind the RAN emulation has been identified. Now these ideas should be translated in a specific internal RAN implementation mixing both statistic data from off-line simulations but also implementing part of the algorithms to trade-off the degrees of freedom and the size of statistical information considered.

UTRAN Emulation

Within UTRAN, several Node-Bs (or base stations) are connected to a RNC (Radio Network Controller) element which is really the responsible of most radio resource management mechanisms [15]. Node-B is mainly in charge of air interface processing and Iub interface extends the transport capabilities up to RNC where layer 2 functions and above are implemented. The emulation of the UTRAN part in the testbed has been carried out with the implementation of the following main modules:

- Emulation of the lower layers of the Uu interface in accordance to 3GPP specifications (release 5): Packet Data Convergence Protocol (PDCP), Radio Link Control (RLC) and Medium Access Control (MAC). Physical layer emulation performed by means of histograms obtained from off-line simulations [16]. Different histograms are used for the different environments (outdoor 120 km/h, outdoor 50 km/h or pedestrian 3 km/h), for each RAB configuration and associated TFC (Transport Format Combination) and for different values of Eb/N0 (bit energy over noise energy).
- A RRM module to carry out all the relevant RRM algorithms. Due to the impact that the RRM has over the QoS, such module has been implemented in detail.

Figure 6 illustrates the internal structure of the RRM module in the testbed where the influence of the rest of the users over the UUT has been taken into account. The RRM module includes a traffic generator for each individual user and the management of its transmission buffer. It is worth noting that RRM strategies applied to these external users are exactly the same as the ones concerning the UUT. So, whenever a new connection is requested, the admission control procedure is checked taking into account the required QoS profile. If the connection is admitted, a RAB (Radio Access Bearer) is properly configured with the TFCS and the SIR (Signal to Interference Ratio) Target. Then, each TTI, the execution of the short term RRM algorithms for all the mobiles leads to the selected TFC that, jointly with the calculated signal to noise ratio (Eb/No) experimented in each connection, is used to manage the transmission buffer of the external users. Instead, for the user under test, these parameters are signalled to the module that emulates UMTS lower layers and real traffic is managed accordingly. Furthermore, taking into account the mobility pattern of each mobile, the position of all the users in the testbed, including the reference one, is updated and measurements are calculated over the time to trigger all the mechanisms associated with handover. Also, in case of network congestion, resolution and recovery policies are applied in the same way for all the users.

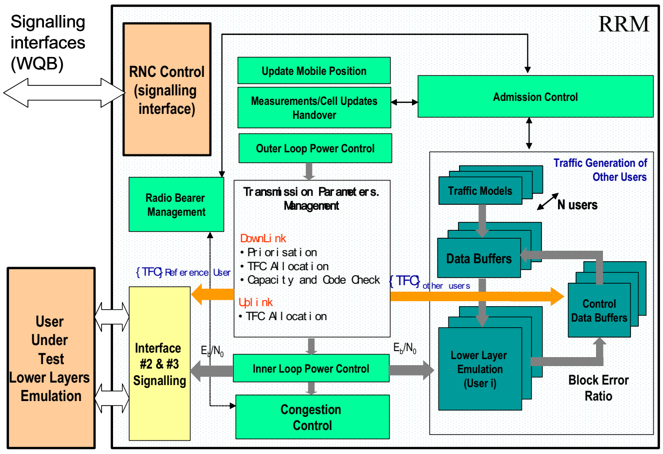

Figure 5. Internal structure of the RRM module.

The number of active users to be included in the demonstrations should be high enough to force specific load conditions where the performance of RRM strategies could be evaluated (Up to 5000 users has been tested in real-time). This condition, jointly with the fact that the currently defined scenarios to be demonstrated consist of 14 tri-sectored sites, imposes serious restrictions in software design in order to cope with real-time.

GERAN/WLAN Emulation

Both, GERAN and WLAN, emulation follow similar emulation approach. Hereafter only the GERAN model is addressed to better describe such approach. In the GERAN model the processing of the UUT data is separated from the global system behaviour. Figure 7 shows the GERAN emulation model (that can be used both in uplink and downlink):

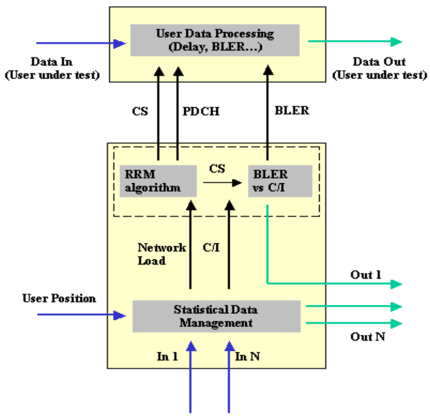

Figure 6. GERAN emulation model.

The functionality of the blocks of the previous figure can be described as following:

- *User Data processing.* This processing is done directly over the IP packets. In these blocks we can identify three types of processes: Segmentation of the user information in RLC blocks taking into account the coding scheme (the RRM algorithm establishes this coding scheme as a function of the measured C/I values), transmission of the blocks taking into account the available resources of the server cell (PDCHs) and computation of the errors in the transmission block based on the observed BLER (derived for the C/I). The transmitted block may be erroneous or not depending of the currently applied BLER obtained from the current C/I.
- *Statistical data management.* This block contains all the scenario information identified in section 3. The next information is required: Network load information; C/I value for each position of the user under test trajectory, for both uplink and downlink; and Available resources (PDCHs per cell for different load situations).
- RRM algorithm. It takes two decisions: Selection of the coding scheme and of the number of resources available for the user (p.e. number of PDCHs) and transmission instant. At this point, to establish the instant in which the mobile can transmit, it has been considered the different medium access modes.
- BLER vs C/I. Having selected the coding scheme used from the C/I measured values, the actual BLER is estimated using the C/I value associated at the new position of the mobile in the transmission instant. Link level results are used to link C/I with BLER values.

B. Core Network

For the core network part, there is no emulation. The tests are carried out using the communication stack of the Linux operating system, which acts as an IP router. In Figure 8, the topology of the IP CN and the IP mobility entities can be seen.

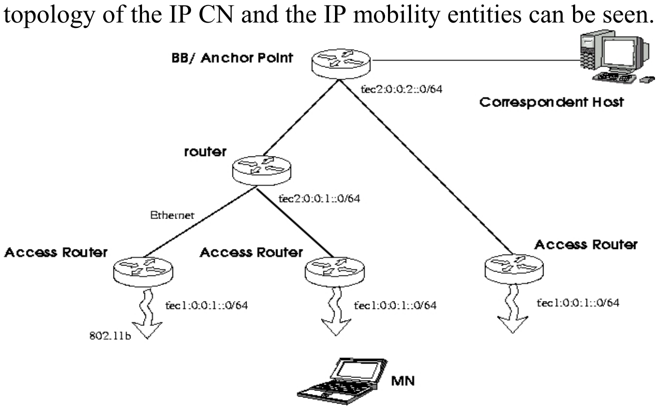

Figure 7. CN testbed layout.

It includes:

Core Network Routers. The core network will be based on real enhanced IP routers implemented over PCs with Linux.

Bandwidth Broker. QoS management entity at CN level.

Traffic Generator. Node in charge of generating controlled traffic to load core network.

Backbone Diffserv Network. Emulates the external network, with QoS management capabilities, where the correspondent node is placed.

Correspondent Node. This Node holds applications. These applications are used for testing the QoS perceived by the User Terminal.

On all the nodes the Linux kernel 2.6 is used. The routers are configured statically; no dynamic routing daemon is used. In order to implement the DiffServ data-plane, the Linux traffic control is used [12]. The Queueing discipline chosen is the Hierarchical Token Buckets with three DiffServ code-points: AF, EF, BE. All routers have a default DiffServ setup, which is configured manually before tests thanks to the traffic control command line "tc" and the IP filtering tool "iptables". Only the edge routers, which here correspond to the Access Router (AR) and gateway, are configured dynamically by the BB entity. The testbed platform is composed of two programs: one which implements the BCMP micromobility management [13] and the other which implements the functionalities of a policy-based BB [14].

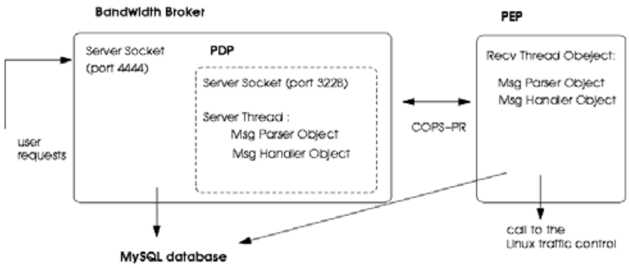

Figure 8. Bandwidth Broker implementation

The BCMP protocol is a C program implementing the MN, the Anchor Point (ANP) and the AR functionalities. The program uses POSIX threads for client/server signalling between MN, AR and between AR, ANP. Then, an IP-in-IP tunnelling for the data packets from the ANP to an AR, is implemented in user-space. Finally, the IP handover is triggered manually by a command line at the MN, instead of a trigger mechanism based on a set of ARs' signal quality values. The policy-based BB implementation is a Java program, which implements part of the Qbone WG BB functionalities. The functionalities implemented include the COPS based communication between the BB/PDP (Policy Decision Point) and the DiffServ edge routers/PEPs (Policy Enforcement Point), a simple request/reply communication between the user and the BB. The implementation of the signalling between BB, PEPs and BB, user relies on the use of Thread and Socket Java classes. Figure 9 shows the interactions between the entities of the BB implementation.

For the interaction between the QoS and the mobility management programs, the approach chosen is the use of AF_UNIX domain socket, which enables inter-process communication with the socket API. Hence, for instance before a handover execution the BCMP program running on the AR node can communicate with the PEP program on the same node in order to trigger QoS reservation request to the BB. The BCMP protocol can be separated into several functions: initial login, handover preparation, handover execution, anchor point change and logout. The first three functions are relevant in that case.

VI. Conclusion

In this paper the main features of the testbed to be implemented in the EVEREST project has been described. Starting from an overview of the architecture model, the main functions and procedures to be deployed in the testbed are identified, especially those related with the common radio resource management strategies and end-to-end QoS issues, which are the main concepts that the EVEREST project is focused in. Details of the EVEREST testbed architecture have been provided, including the different modules and interfaces and the methodology envisaged for their implementation. Special emphasis has been done in the approaches considered for the RAN and CN parts for taking into account all the relevant aspects of the end-to-end QoS concept.

Acknowledgment

This work is part of the EVEREST project, partially funded by the European Commission under the IST framework and the Spanish Research Council under TIC2003-08609 grant.

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