

E2E QOS TESTBED FOR 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.

Keywords: beyond 3G, end-to-end QoS, DiffServ, heterogeneous access network, policy-based service negotiation..

1. 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). The reference architecture is aligned with the work carried out in 3GPP and IEEE 802.11, and the EVEREST project vision encompasses users with multimode mobile terminals in the time frame of 2008-2012. Furthermore, the selected scenarios and the corresponding evaluation procedures are compliant with 3GPP specifications in order to facilitate the impact of the project result in 3GPP.

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. Then, such scenarios should consider different radio networks capabilities, traffic load conditions, propagation

characteristics, user mobility patterns, service configurations for the all mobile users, as well as different deployments, and network configurations where several radio access networks (RANs) can give access through a common core network (CN) to offered services.

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.

In fact, the EVEREST testbed aims to provide a number of features that are not easily achievable by means of conceptual studies or system level simulations. Among such 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.

2. CONCEPTUAL REFERENCE ARQUITECTURE

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. To this end, several extensions of the 3GPP architecture are envisaged to fulfil B3G QoS requirements:

- **Introduce E2E resource based admission control mechanisms.** Within the current 3GPP solution, the Policy Decision Function (PDF) will authorize all

resource requests if a session at application level can be established. Therefore any resource limitation or congestion in neighbour domains is not taken into account.

- **Extend the policy-based framework to cope with resource management in the radio access part as well as in the CN.** Actually this management is hidden to the policy framework. Common radio resource management is also envisaged in this framework.
- **Use policy technologies to manage the derivation of UMTS QoS parameters.** This function is currently restricted to the GGSN (and UE) and there are not standardised mechanisms to manage the QoS provisioning over the different bearer services within the UMTS network (RAB BS and CN BS).

From the previous considerations, Figure 1 illustrates the proposed architecture over a B3G network where different RANs can be offered to access at the same Core Network. The key aspects of this QoS management architecture are the following:

- 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. A clear parallelism can be done between the WQB and the BB. These two entities share the same functionalities, both acts as policy decision points: the admission control and the handover decision (respectively at radio and IP level) are based on the network operator policy.
- 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.
- The relationship between the PDF entity from IMS and the new entities WQB and BB is envisaged in terms of QoS negotiation. Furthermore this QoS negotiation is extended from the PDF, which really acts as a master PDP of the domain, towards external neighbouring domains.
- The proposed architecture is valid for any degree of coupling among the heterogeneous RANs. Thus, from the radio resource management perspective, the functions envisaged for the WQB entities are the same either in a tight coupling scenario with integrated CRRM functions or in the case of independent RAN, although the commitment of these functions would effectively depend on the degree of coupling.
- SGSN control functions are separated from its routing functions. This approach is intended to introduce native IP transport down to the RNC and its equivalents.

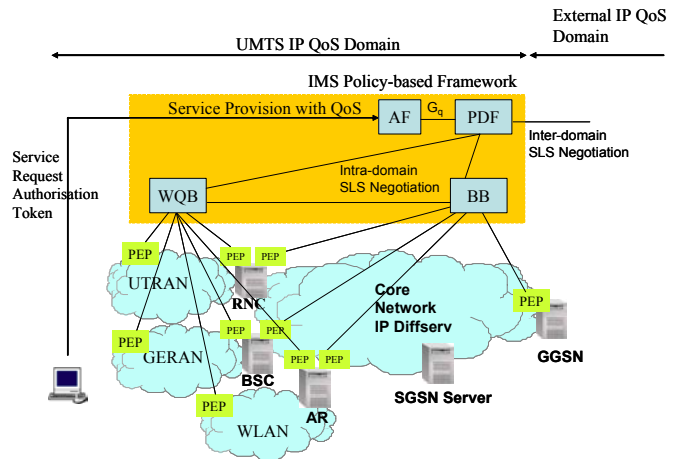


Figure 1. EVEREST proposal for QoS architecture in a heterogeneous radio access network.

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

3. SCENARIOS

The traffic scenario definition for the envisaged heterogeneous network should be based in the identification of the existing operational environment classes.

In case of evaluation of RRM/CRRM strategies within cellular heterogeneous networks, four main items could be considered relevant for the scenario definition:

- Network architecture and corresponding entities
- Services (including mix and traffic load)
- Environment (suburban, urban and indoor)
- Radio access technologies, capabilities and functionalities

The communications environment and network deployment are important when investigating and evaluating RRM/CRRM strategies. In order to have a complete set of relevant target scenario, we have divided the scenarios into realistic and theoretical ones. In particular, two realistic and two theoretical scenarios have been defined. The reference architecture, service mix and traffic characteristics are common for both realistic and theoretical scenarios, while the detailed description of the environment (mainly the layout) for each category varies.

Both, the theoretical and realistic target scenarios chosen, consider situations where we foresee an important impact of the heterogeneous networks concept and therefore of the selected common RRM strategies. Both types of scenarios include a mix of GSM, EDGE, UMTS and WLAN deployments and they are described as follows:

Realistic target scenarios:

- Urban / Suburban
- Dense urban

Theoretical target scenarios:

- Hot Spot within urban area;
- Hot Spot along main road in suburban area.

A short description of such scenarios is done in the following paragraphs.

Urban / Suburban

From a general point of view, the overall topology scenario must respect the following main characteristics:

- Coverage area dimension: about 8000 per 4000 meters.
- Pixel dimension: about 10 meters.
- Number of sites (considering 3-cells sites): about 20 for UTRAN, 20 for GERAN.
- Cells types: macro.

The suggested scenario's dimension should make feasible to study several aspects of RRM strategies and algorithms (according to the project's goals) and, at the same time, should avoid a too high level of complexity. With regard to this fact, it is important to stress that the propagation information needed to characterize the above scenario consists in a large amount of data. For every pixel, in fact, it is necessary to have the RSCP (Received Signal Code Power) of Common Pilot Channel (CPICH) for all UTRAN cells, and the received signal strength for every GSM/GPRS cell. Both magnitudes can be calculated based in propagation models.

Dense urban

A geographical area corresponding to one of the main cities of Spain has been selected as the reference proposed scenario. This is a business area, characterized by high office buildings, residential blocks and a principal avenue. Two zones have been delimited in the scenario; the inside area (1 km x 1 km) is the zone under study. The outside zone is the border area (1.5 km x 1.5 km) and should be used for restrict the border effect in the inner study zone.

In this scenario GERAN, UMTS and WLAN technologies coexist. GERAN sites and UMTS macrocells positions and their main characteristics are almost real. However, for UMTS microcells and WLAN access points, the selected site allocation is theoretical, because UMTS microcells and WLAN APs are still not deployed.

Hot Spot within urban area

The hotspot within urban area scenario is typically found in hotels, offices, city shopping malls and train stations. Although these kinds of environments have not been sufficiently studied yet, their increasing importance for wireless operators justifies to be considered in the Everest project. This sort of environment is characterised by small

areas isolated by walls/buildings, with a high user density and low mobility (the majority of users can be assumed to be at pedestrian speed).

The total study area in this theoretical indoor hotspot scenario is a building with floor plan of 20 000 m² or 0,02 km². Full WLAN coverage is provided inside the building. Note that the GERAN and UTRAN cells in the study area also carry traffic in the urban area just encompassing the indoor hotspot. This urban area adjacent to the building corresponds to 2 GERAN cells and 4 UTRAN cells and the size of this area is 0,139 km². Users outside the building are only considered for their partial load of the cellular GSM and UMTS systems.

Hot Spot along main road in suburban area

Wireless services on roads and in buildings along the roads will increase in the near future. For that reason, the second theoretic target scenario is constituted by an isolated hotspot along suburban main roads.

This scenario emphasizes that mobile services must be handled with users moving from one position and a given RAT to another location and other RAT. This environment is characterized for having large areas with low density and higher transmits powers. Medium to very high speed is expected. In the suburban area outside the hotspot building we assume 70% consumer users and 30% business users, while the ratio inside the building is 40% consumer and 60% business users.

The study area in this target scenario is 2,8 km² suburban area including a hotspot building of 50000 m² or 0,05 km². We assume full WLAN coverage inside the building with 15 access points. The GERAN and UTRAN cells in the study area carry traffic both in the suburban area as well as inside the indoor hotspot. This suburban area, adjacent to the building, is covered by 1 GERAN cell and 3 UTRAN cells. The border area for evaluations includes 9 GERAN and 12 UTRAN cells. The size of the GERAN and UTRAN border coverage area is 25 km² and 11 km², respectively.

4. TESTBED DESIGN CRITERIA

A. Proof of concepts

The testbed is aimed at demonstrating most of the concepts addressed within the EVEREST project. These concepts should be analysed under the set of scenarios identified in the project [4]. Hence, the design of the testbed must be implemented taking into account the possibility to execute a set of procedures suitable to validate such concepts. At this stage of the project the following procedures has been identified:

Initial RAT Selection. This procedure aims to demonstrate the decision of selecting a specific RAT when several radio access networks are available (heterogeneous environment)

under a specific scenario (load, traffic mix, RRM and CRRM strategies, etc).

RAT Switching. This procedure aims to demonstrate the decision and the effect of switching from one RAT to another under a specific scenario (load, traffic mix, RRM and CRRM strategies, etc).

Connection establishment with E2E QoS negotiation. This feature aims to demonstrate a complete procedure to establish an end-to-end connection with QoS assurances over a multidomain scenario, highlighting the decision process and its dependence with the different scenario configurations (load conditions, policies applied).

E2E QoS Re-negotiation. This feature aims to demonstrate a procedure for re-negotiating the end-to-end connection with QoS assurances over a multidomain scenario, when initial requirements (conditions) cannot be fulfilled anymore. A typical example might when a RAT switching is performed and QoS should be modified accordingly. The procedure also would like to demonstrate the decision process and its effect, depending on different scenario configurations (load conditions, policies applied).

CN Mobility Management and QoS interactions. This aims to demonstrate the interactions between the IP mobility management and the IP QoS entity (i.e. the BB) of the CN. These interactions are needed in order to provision QoS along the new path after a handover.

Common Radio Resource Management operation. This procedure aims to demonstrate the decision process of the CRRM strategies considered in a given scenario. In this sense, different RAN behaviours should be validated and justified in terms of selected CRRM strategies.

Impact of CRRM and QoS Management on Applications. This procedure aims to demonstrate the effects of the developed applied RRM and CRRM algorithms and QoS management strategies over real applications.

B. Testbed facilities: Centralised Management

Among the goals to be fulfilled when designing the testbed, management features are very important. Management features should include 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. All these functions should be supported by the software modules developed within the testbed and should be centrally managed by a tool developed for such purposes.

The tool to centrally manage the whole EVEREST testbed will be based on the management tool developed within the ARROWS project [11]. The functionalities envisaged for this tool are the following:

- Control the execution flow of the test bed (init, run, pause, restart options) and selection of the scenario to be demonstrated.
- Configuration of all the initialisation parameters required in the modules running in the test bed.
- Collect and correlate logged data from the different modules of the demonstrator. This tool is to be used for post-processing purposes. It should allow following the logged events in a dynamic way.
- View statistics during the execution of a demonstration (on-line visualization).
- Change some configuration parameter during the execution of a trial to force a given situation (i.e. increase the number of users dynamically to analyse consequences over radio bearers established by the user under test).

5. TESTBED IMPLEMENTATION DETAILS

The architecture proposed for the EVEREST testbed reproduces the reference architecture depicted in section II. We can notice several differentiated blocks dealing each one of them with a specific set of the testbed functionalities. The first one could be the cluster of PC's required to perform the emulation of the Heterogeneous Radio Access Network, the second one could be the cluster of PC's and other network elements that should deal with the emulation of the UMTS Core Network, the third one envisaged here could be the external IP backbone, and finally the PCs working as user terminal and server of applications.

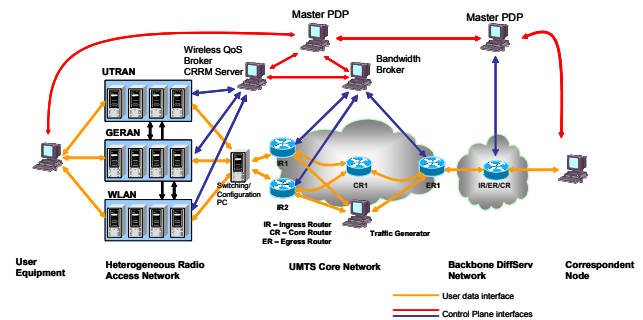


Figure 2. General architecture of the EVEREST Testbed

The main components included in the testbed 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. A detailed view of how these emulators are integrated in the testbed is shown in Figure 2, and the RAN emulation procedures are described in the next subsections.

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

Switching Node. This node is out of the functional concepts to be demonstrated. It is mainly used to be able to establish different configurations of coupling between RANs and the correspondent routers in the CN.

Core Network Routers. The core network will be based on real enhanced IP routers implemented over PCs with Linux. Diffserv mechanisms will be included to provide QoS. QoS will be managed by a bandwidth broker node in charge of QoS provision at CN.

Bandwidth Broker. QoS management entity at CN level.

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

Master PDP. Policy Decision Point, which acts as the master of the overall heterogeneous access network (RANs plus CN). This node is in charge of QoS negotiation with users of the UMTS domain (as the PDF function identified in UMTS) as well as with external domains to allow end-to-end QoS connections to be managed.

Backbone Diffserv Network. Emulates the external network, with QoS management capabilities, where the correspondent node is placed. The QoS functionalities developed in this external network should be enough to demonstrate the End-to-End QoS concepts addressed in EVEREST project.

Correspondent Node. This Node holds applications. These applications are used for testing the QoS perceived by the User Terminal. Envisaged applications are both client/server as well as peer-to-peer type.

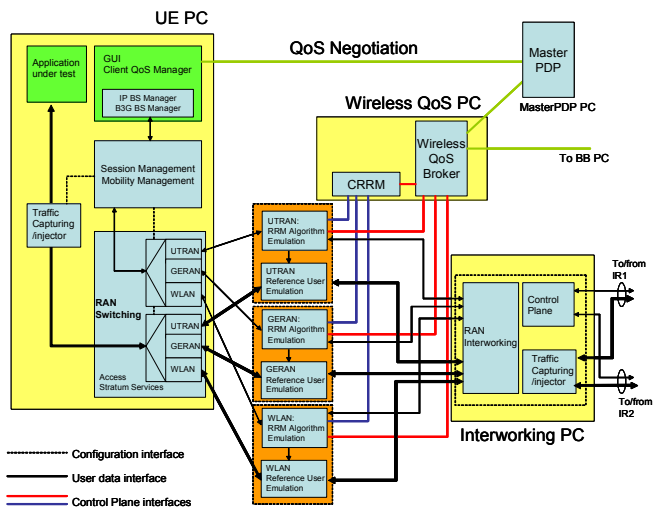


Figure 2. –Detail of the integration of the RAN emulators within the testbed

In the following subsections further details are provided for the emulation approach envisaged in the RAN and in the CN parts.

A. RAN Emulation Model

The required functions to be included in each RAN emulation model can be identified from the type of scenarios that we envisage to test in the demonstrator. Thus, considering the scenarios previously described, 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.

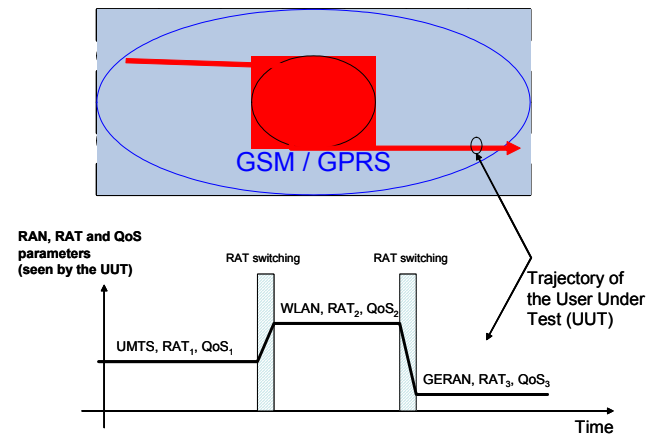


Figure 4. The reference user of the testbed should follow a given trajectory within one of the proposed scenarios.

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.. As illustrated in Figure 4, 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.

As the testbed is envisaged to manage mechanisms for QoS selection, including negotiation¹, the behaviour, in terms of QoS, observed by the UUT can not be “replayed” from a previous situation assessed by off-line simulation. Thus, it is very important to identify which part of a RAN emulation model can be built based on statistical data collected from off-line simulations and which part must be developed in detail for providing the realistic dynamic behaviour at the user under test².

¹ For instance, what is happening at the CN can influence the RAT selection and the QoS parameters assigned to the UUT

² Dynamic in the sense that the processing performed on the UUT traffic can not be previously “recorded” since it depends on decisions performed during the demonstration process.

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 QoS client in the UUT will establish a session and negotiate certain QoS parameters with the decision modules (e.g. Master PDP). The result of this negotiation will be a specific RAT and QoS assignment over a given RAN for this user. Thus, the selected RAN module must be able to process the user data according to this decision.
- The user location. It should be desirable for the trajectory of the UUT not to be coupled with a specific simulation case³ Thus, this condition forces that each RAN module should consider the location of the UUT mobile when processing the traffic data.

Furthermore the RAN emulation modules should also have the following additional inputs that would influence in its processing:

- Dynamic inputs coming from the decision modules (e.g. CRRM functions). For example, if we want to include certain CRRM algorithm that can balance traffic between RANs, the RAN emulation modules must be able to produce different outputs depending on these decisions.
- Static inputs (e.g. scenario selection)

Figure 5 illustrates all the previously mentioned ideas.

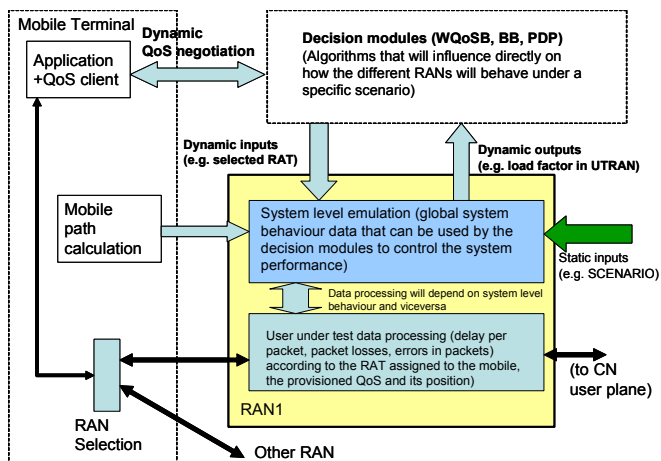


Figure 5. Requirements for the RAN emulation modules within the testbed.

Moreover, apart from the parameters needed to reproduce the behaviour of the UUT under the specific conditions, 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

³ That means, the trajectory could be freely defined over the testbed.

in the Figure 5, This fact is denoted in the figure as a dynamic output of the RAN module.

At this point, the problematic behind the RAN emulation has been identified from the point of view of how a RAN module should interact in front of the dynamic inputs in order to achieve the expected degrees of freedom in the testbed. Now these ideas should be translated in a specific internal RAN implementation. The three main approaches are envisaged for developing the emulation RAN modules:

- Detailed implementation. The modules contain a “replica” of the software of the network simulators. This means that each RAN module should reproduce in “real time” the outputs obtained by the off-line simulators. Although this approach is the most flexible in terms of managing “dynamic inputs” (e.g. if the scheduling algorithm in a downlink channel can be modified according to an external control parameter, the RAN module can handle this behaviour because the algorithm really is implemented into the module), this approach is not useful because to the important efforts required for developing such a software in real time.
- Statistical Approach. This approach is just the opposite of the previous one. In this case, the RAN emulation module only contains a set of statistics that cover all the possible situations. For example, if in a given scenario we allow the UUT to choose among N different combinations of RAN and QoS parameters, the RAN module will apply one of the N stored statistics data to produce its outputs. That is, all the required statistics should be obtained off-line and loaded in the testbed. So, the complexity of this approach relies exclusively on the amount of data to be collected, which will depend on the degrees of freedom we want to give to the testbed. In such approach the RAN module will reproduce the delay and losses of the packets send/received from/to the UUT, as well as the value of a set of output parameters (op1,...,opM) required for describing the system level behaviour. This data will be generated on-line from statistics data collected considering the specific RAT, QoS values and UUT location as well as other input parameters (ip1,...,ipN) that should be accessible by the decision modules. Thus, this approach is again not practical if the degrees of freedom are excessive. Otherwise, this approach could be very useful if we decide to analyse only a restricted set of situations over the testbed.
- Mixed approach. Given the important limitations of the previous approaches, the proper solution seems to be a mixed approach, where statistic data from off-line simulations will be required but also part of the algorithms to trade-off the degrees of freedom and the size of statistical information considered.

B. Core Network

For the core network part of the mobile access network, 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 6, the topology of the IP CN and the IP mobility entities can be seen.

Most of the complexity of the IP CN resides at the edge of the IP domain. The functionalities in charge of the edge routers are twofold: QoS and mobility management. Regarding QoS, the edge router has to classify and give different forwarding treatment to incoming packets. In order to achieve this, the traffic control functionalities of Linux (TC), which provides queuing disciplines, classes, filters and policing functions, will be used. Moreover the Linux TC, which is mainly implemented in the kernel space, provides an API to the user-space. Thus, the TC API can be used by other modules to configure dynamically the DiffServ functions of the edge routers. Regarding IP mobility management, the micromobility chosen is: BCMP (Brain Candidate Mobility Protocol) [5]. BCMP is a tunnel-based protocol, i.e. the incoming packets are read at the anchor point, then a lookup of the mobile host is done in the visitor list, and finally the packet is tunnelled toward the appropriate router. The end of tunnel is the access router, corresponding to the RNC, where encapsulation/decapsulation is taking place, as it is the case with the GTP tunnelling protocol. Furthermore the anchor point functionalities can be located in the gateway, which correspond to the GGSN. A core router has only the functionalities of an IP router, enhanced by DiffServ forwarding functions. It does not have any interface with control management (BB, anchor point).

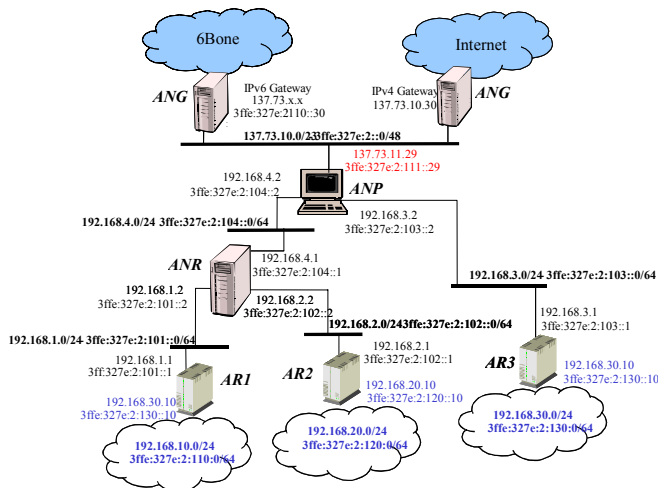


Figure 6 - Physical layout of the CN testbed

6. 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.

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