Overview of the EVEREST Project

F. Casadevall*; P. Karlsson**; O. Sallent*; H. Gonzalez+; A. Barbaresi++; M.Dohler♦; M.Dinis♦♦

* *Universitat Politecnica Catalunya, Jordi Girona 1-3, 08034-Barcelona (Spain); e-mail: [ferranc, oriol]@tsc.upc.es*

** *TELIASONERA; Hjälmaregatan 3 SE201-20 Malmö (Sweden)* e-mail: Peter.C.Karlsson@teliasonera.com

+ *Telefónica I+D; Emilio Vargas 6, 28043-Madrid (Spain) ; e-mail: hector@tid.es*

++ *Telecom Italia; Via Reis Romoli 274, 10148-Torino (Italy) ; e-mail: Andrea.Barbaresi@TILAB.COM*

♦ *King's College London; Centre for Telecommunications Research , Dept. of Electrical Engineering , STRAND,WC2R 2LS London (United Kingdom)e-mail: michael.dohler@kcl.ac.uk*

♦♦ *Portugal Telecom Inovaçao; Rua Eng. Jose Ferreira Pinto Basto 3810-106 Aveiro (Portugal); e-mail: MDinis@ptinovacao.pt*

ABSTRACT

The provision of beyond 3G heterogeneous network topologies is conceptually a very attractive notion; however, it is a challenge to accomplish an efficient network design. In this context, Radio Resource Management (RRM) strategies are responsible for an utmost efficient utilization of the air interface resources in the available Radio Access Networks (RANs). Certainly, any stand-alone wireless systems or heterogeneous hybrids thereof, rely on RRM strategies to provide enough capacity and guarantee a certain prior agreed QoS.

The objective of the EVEREST project[1] is to devise and assess a set of specific strategies and algorithms for access and core networks, leading to an optimal utilization of scarcely available resources for the support of mixed services with end-to-end QoS mechanisms within heterogeneous networks beyond 3G.

In order to accomplish the above objectives, the project evolves around two main activities: (1) algorithmic development and simulation by means of advanced simulation tools, and (2) demonstration of the technology by means of implementing real time testbeds to prove the concepts developed in the project.

I. INTRODUCTION

Technological advances and market developments in the wireless communications area have been astonishing during the last decade; they were mainly driven by the successful deployment of GSM networks and similar voice service networks. The last year's uptake of mobile data services in 2.5G/3G systems and wireless local area networks (WLAN) has further increased this development.

Very few will disagree that the mobile and wireless communications sector will continue to be one of the most dynamic technological drivers within comparative industries. This is mainly to be attributed to our inherent needs for independence and flexibility. The 'connected everywhere, anytime, anyhow' philosophy, however, will have to be corroborated with sophisticated business models, available technologies, network roll-out alternatives, etc.

It is thus generally acknowledged today that beyond 3G systems encompasses network heterogeneity. That is, a plethora of different network technologies and topologies will have to co-exist or be inter-connected. These networks need to be inter-connected in an optimum manner with the ultimate objective to provide the end-user with the requested services and corresponding Quality of Service (QoS) requirements.

The provision of services across heterogeneous networks is conceptually a very attractive notion; however, it is certainly a challenge to the network designer. Certainly, the available radio resources of inter-working networks will have to be managed jointly, up to the degree allowed by the coupling mechanism. Targeted is an optimum solution in terms of throughput, cost per packet, development and deployment cost, etc.

In any wireless system the scarce resource is the available bandwidth. In addition to that, 3G and beyond systems intend to provide to the end user a variety of services also with high bit rates while assuring the desired QoS and supporting high capacity. The only way to harmonize these contradictory points (scarce bandwidth and high capacity of a variety of services with stringent QoS) is to be able to develop and exploit an intelligent management of the available radio resources. Then, the Radio Resource Management (RRM) strategies are responsible for an utmost efficient utilization of the air interface resources in the Radio Access Network (RAN).

In addition to the Access Network, a typical mobile operator domain also includes a Core Network (CN) part. Then, to provide end-to-end QoS some mechanisms ought to be placed within the Core Network to allow an optimum routing of IP traffic.

One mechanism to be explored within EVEREST is the Bandwidth Broker (BB) concept, which controls and manages the QoS resources in a given Diffserv domain

---

[1] Acronym of the FP6 IST STREP project entitled "Evolutionary Strategies for Radio Resource Management in Cellular Heterogeneous Networks", started in January 2004.

based on a service level agreement (SLA). The SLA is a contract between a customer and a provider which specifies the forwarding service that should be used by the customer's data flow. The BB will translate the contract terms defined into the SLA in a set of information necessary for provisioning and allocating resources in the Diffserv-enabled routers, particularly at the edge of the domain where the marking of the packets is done. The configuration of the edge Diffserv routers will directly influence the marking of the packets and thus the IP QoS service provided to specific flows coming from the RANs.

In the EVEREST project special attention will be given to the necessary interactions between the BB and common RRM (CRRM), in order to provide the appropriate IP QoS service to flows from different RANs. Moreover, a policy based framework is proposed for managing multiple domains. In particular, EVEREST proposes to identify the involved Radio Access Network technologies as well as the Core Network as separate QoS domains, where specific QoS mechanisms and policies are deployed.

The paper is organized as follows. In Section 2 the main project goals are introduced. Next, in Section 3, the technical approach used to achieve the project objectives is described. In Section 4 the envisaged methodological approach is presented considering both the algorithmc development and the envisaged testbed implementation. Finally, a summary of the expected project results is addressed in Section 5.

II. PROJECT MAIN GOALS

The objective of the EVEREST project is to devise and assess a set of specific strategies and algorithms for access and core networks, leading to an optimized utilization of scarcely available radio resources for the support of mixed services with end-to-end QoS mechanisms within heterogeneous networks beyond 3G.

The provision of beyond 3G heterogeneous network topologies with an efficient network design is certainly challenging. In this context, Radio Resource Management (RRM) strategies are responsible for an efficient use of the air interface resources in the available Radio Access Networks (RANs).

The research challenges, to be tackled by the EVEREST project can thus be summarized as follows:

- To identify, propose, simulate, assess and validate advanced RRM algorithms for GERAN and UMTS as well as novel radio concepts beyond 3G.
- For heterogeneous networks, to develop Common RRM (CRRM) algorithms between access technologies focused on UTRA and GERAN. Both tight and very tight GERAN/UTRAN RRM coupling will be considered.
- To consider other technologies that can be a complement to GPRS/UMTS, such as:
    - WLAN for indoor hotspots
    - Different types of repeaters, acting as coverage extensions
- To support end-to-end QoS in a heterogeneous wired and wireless mobile environment. To this end, the investigation about the relationship between the core network BB and the RRM & CRRM entities for a plethora of RANs (UMTS, GERAN and WLAN) becomes of prime importance. Either loose, tight and very tight WLAN to cellular RRM coupling will be considered.
- To demonstrate the benefits of the developed RRM and CRRM algorithms by means of multimedia IP based applications over a real time testbed.

Moreover, it is a further purpose of the project to contribute actively to the different standardization fora.

In summary, the EVEREST project aims to provide tangible contributions towards a heterogeneous realisation of 2G/2.5/3G (e.g., GERAN and UTRAN) and 3.5G networks (e.g., HSDPA) with the inclusion of newly emerging RANs (e.g., WLAN for hot spot coverage) for the 2007-2010 time frame. In that sense, the results obtained in EVEREST are expected to be of significant momentum, the beneficiaries to which are service-providers, operators, manufacturers and end-users.The potential inclusion of location information in RRM design as well as some forms of RAN sharing will be considered, as additional examples of the medium and long-term research focus of EVEREST. Proposed solutions will be compliant with and aligned to standardisation activities in the field, e.g., 3GPP, IETF, IEEE.

III. TECHNICAL APPROACH

The project is being carried out in the following three main stages:

1. Determination of interest and relevant target scenarios. This takes into account:
    - Communications environment, i.e. macro-cell, micro-cell, indoor, etc., and user mobility.
    - Technologies deployed (GSM, GPRS, EDGE, UMTS, WLAN), their corresponding capabilities and functionalities, as well as their corresponding network architectures and entities.
    - Service mix and service load (conversational, interactive, streaming, etc.)

2. Development of RRM and QoS management algorithms, with evaluation through simulation. Focus is placed on finding commonalities among the different scenarios considered, rather than trying to optimize algorithms and algorithmic parameters for a specific scenario. Thus, the goals of EVEREST extend the mere analysis of different scenarios and will target

the definition of generic RRM criteria, facilitating their applicability in scenarios differing from those studied in detail within the project.

3. Validation and demonstration of the proposed algorithms for the defined scenarios by means of a real time testbed supporting IP-based mobile multimedia applications with end-to-end QoS capabilities. To support this latter service, the IP CN has to be configured in the following way: a mobility management has to be installed, and the QoS framework based on Diffserv, including its control plane, has to be configured. Then, the interactions of the BB with the radio resource entities will be considered.

These main research topics in EVEREST will be 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 and other relevant IETF proposals. In this sense, it is assumed within the project that any end-to-end QoS architecture for converged 3G mobile – wired IP networks should be compliant with 3GPP UMTS QoS general framework [1-2].

A key goal of the QoS architecture taken as a reference within EVEREST should be the support of end-to-end paths in IP multi-networks over various access technologies. It is expected that end-to-end scenarios in future wireless systems can encompass several L2 hops and multiple IP networks. End-to-end QoS-guarantees need to be spread along all domains involved in the communication path. QoS handling in each domain can follow different QoS models as the ones outlined for DiffServ domains and UMTS networks.

This concept has been addressed from different perspectives and different approaches. A first approach of this multi-domain scenario, called Always Best Connected (ABC), has been proposed [3]. Within the ABC vision, an end-to-end path is established though several different IP-based domains according to the following key issues:

- QoS requirements are user-driven and are instantiated by means of wireless hints (Information Elements that are QoS-mechanism-agnostic and access-technology-agnostic).
- Each involved domain contains an IP QoS aware element, named IP QoS Controller in the proposal, which is equivalent to the IP BS Manager element introduced in UMTS.
- There is a need for some QoS information distribution mechanism among the QoS controllers in each domain.
- Each network domain makes a local decision to translate distributed QoS parameters into specific domain QoS provision.

However, the ABC proposal has some open issues that are considered relevant within EVEREST and should be taken into account. Among these open issues we can remark:

- How partitioning of QoS is carried out among the involved domains.
- How other aspects than those related to resource management can be considered in QoS Management decisions.

Another end-to-end approach, which proposes a policy-based QoS management architecture applied to a multi-domain scenario, has also been envisaged [4]. In this work, QoS management in each domain is done according to a set of policy rules that are negotiated and maintained in a consistent way by all the involved domains that can be traversed when establishing a user session.

However, none of the above mentioned solutions offer a complete solution according to EVEREST's goals. For that reason the EVEREST project proposes a new architecture, shown in figure 1, that mixes the advantages of both ABC and policy-based QoS management proposals. Moreover the proposed architecture is well aligned with the IMS (IP Multimedia Subsystem) concept considered in the latest releases of the UMTS specs.

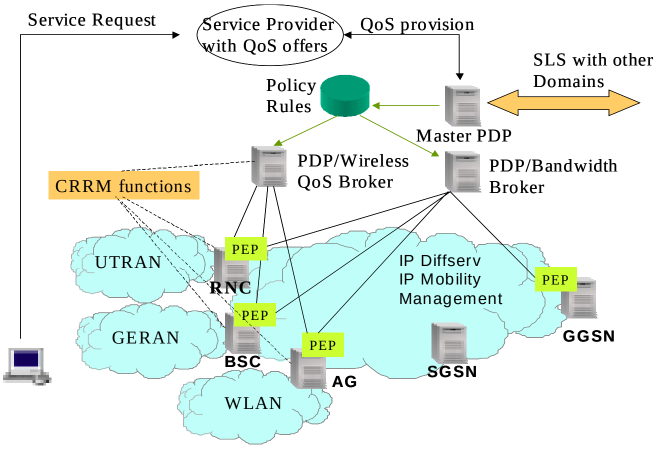

Figure 1. EVEREST proposal for QoS Architecture in a heterogeneous radio access network

Focusing on CRRM issues, two main approaches are envisaged to support CRRM in UTRAN and GERAN: integrated CRRM and loose RRM:

- Loose architectures are based in a CRRM server linked by open interfaces to the RNC (UMTS) and BSC (GERAN). CRRM Server establishes CRRM policies and each RAT executes RRM algorithms according the CRRM server policies. Within this approach, CRRM may contain updated and ordered information from the different RATs.
- Integrated CRRM, also referred to as tight CRRM, incorporates CRRM functions into the existent UTRAN nodes. Hence, proprietary interfaces are needed and non-radio dependent messages get through

indistinctly in each RAT air interface. Notice that, in principle, the two architectures should impact only the performances of CRRM algorithms without introducing any other considerable limitations.

A. CRRM SERVER

The Common Radio Resource Management server (CRRM Server) is proposed [5] as a new logical node in UTRAN and GERAN. CRRM Server shall provide RRM Decision Support and ask for Reporting Information to the logical entities (i.e. RNC, BSC and other CRRM servers) that are connected to it, so that RATs can be aware of the status in other RATs operating in the same coverage area. For this purpose, Cell Measurement Gathering and Prioritization of the list of candidate cells of a UE for a specific operation (handover, network controlled cell reselection) are identified.

Cell Measurement Gathering

The measurement reporting procedures are based on the UTRAN Iub Common Measurement procedures [6] and/or on the Iur Common Measurement procedures [7]. Both of them support on-demand, periodical or event-triggered reporting methods.

Prioritization of the list of candidate cells

The RNC/BSC sends to the CRMS the list of candidate cells of a UE for a specific operation (handover, cell change order, etc), including (when available) the mobile measurements for these cells and information about the quality of service that the user requires. The CRMS, after applying some algorithms, returns the prioritized list.

B. INTEGRATED CRRM

An alternative approach to achieve CRRM functionality is to integrate it into the existing UTRAN nodes. As a matter of fact, many CRRM functionalities, such as Intra-RAT/Inter-frequency Handover, Directed retry, Service Handover, etc are already supported in the current standard. The Iur and the proposed Iur-g interfaces already include almost all of the required ingredients to support the CRRM functionalities. Therefore, a natural approach is to continue this path and improve the existing CRRM functionalities. To this end, it is proposed to define a new interface between a RNC and a BSC that allows exchanging common measurements and information on cells controlled by distant entities. It is proposed to call this interface Iur-g light and IRNSAP (for Inter Radio Network Subsystem Application Part) the protocol on this interface

The main benefit of the Integrated CRRM is that with limited changes and already existing functionality it is possible to achieve optimal system performance. Most importantly, this is achieved without introducing additional delay that will deteriorate the delay sensitive procedures at call setup, handover and channel switching.

IV. ENVISAGED METHODOLOGY

In order to accomplish the above-mentioned objectives, the EVEREST project evolves around two main activities:

1. Algorithmic development and simulation by means of advanced simulation tools, and
2. Demonstration of the technology by means of implementing real time testbeds to prove the concepts developed in the project.

A. ALGORITHMIC DEVELOPMENT AND EVALUATION

The aim of this activity is to devise suitable RRM solutions for the scenarios and configurations identified. In particular it provides novel algorithms to cope with:

- New challenges derived from the introduction of multi-services, multiple deployed layer structures and new RAT capabilities.
- Network optimisation under the constraints derived from RRM strategies, which are highly interrelated and difficult to identify and isolate from each other. RRM strategies include: Admission Control, Congestion Control, OVSF code management (for UTRA), Packet scheduling, Power Control, Handover, etc.
- Joint network optimisation (i.e. UTRAN, GERAN, WLAN) under the constraints derived from RRM strategies applied at individual RAT level. CRRM strategies to cope with these situations will be derived and assessed.
- End-to-end QoS by proper resource management, both at the CN side and the RANs side. Functionalities will be split between BB and CRRM.

Studies will be accompanied by intensive simulation work. Simulators provided by the different partners, both at link and system level, will be a starting point to initiate the simulation work. Simulators will be upgraded to include new functionalities. Since the simulator core is already available, consistent results are expected by the end of the first year for a limited set of scenarios.

Scenarios considered for algorithm development and evaluation will provide enough perspective according to project research focus. Operators will contribute with real radio network deployment scenarios, thus ensuring that relevant simulation parameter values are considered.

B. EVEREST TESTBED

The project will carry out a set of demonstration activities for selected scenarios by means of the EVEREST testbed. These demonstrations will consist of a real interaction between a user and the wireless heterogeneous network world by means of Internet access, videoconferencing, etc., employing a real user application.

The testbed aims to build a GERAN/UMTS/WLAN stand-alone emulator platform including all the RRM functionalities and QoS entities relevant to show the RRM and QoS end-to-end effects. This emulator ought to be able to interact with applications in real-time. However, the testbed would not attempt to check signalling-oriented behaviours derived from the interconnection between the different Radio Access Technologies.

The 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, emphasised will be the possibility to test end-to-end QoS performance and to assess, in real-time, the effects that RRM/CRRM/BB algorithms have on the user's perceived QoS. Moreover, the impact that resource management algorithms have on the system performance will be demonstrated under different scenarios. Such scenarios include:

- Different scenarios and radio networks capabilities
- Different traffic load conditions
- Different propagation characteristics
- Different user mobility patterns
- Several service configurations for the all mobile users
- Different deployments and traffic models
- Different core networks (CN) connected to the same physical RAN.

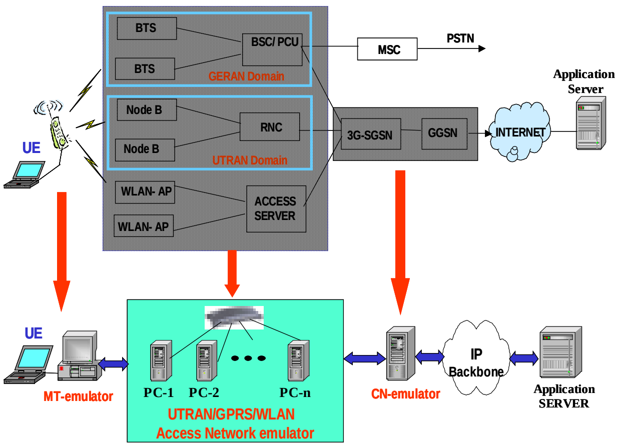

Figure 2. Mapping functional architecture into the testbed architecture

The testbed is built on a network of personal computers (PCs) running Linux ;see Figure 2 for the reference case of tight coupling. The selection of this OS was based on flexibility and the possibility to modify the OS kernel in order to accurately tune its performance, basically to manage the real time requirement.

The basic architecture of the testbed can be summarised as follows:

- There is one PC devoted to emulate the main functionalities associated to the User Equipment, including multimedia capabilities.
- A cluster of several PCs (four or more interconnected through a switch) are devoted to emulate the radio protocols of UTRAN, GERAN and WLAN segments.
- An IP network emulator, used to implement the main functionalities associated to the Core Network. This IP network emulator also includes the Bandwidth Broker Server, which provides connection admission control and manages the QoS resources in the Diffserv IP domain domain and specifies the forwarding service that should be used by the customer's data flow in the Core Network.
- Finally, a multimedia PC is accessible through the IP backbone network. It is used as the fixed partner to test symmetric services (i.e. videoconference) but also to act as a multimedia server (Web, Streaming and Mail server).

IV. EXPECTED RESULTS

The expected research results from the EVERST project can be summarized as follows:

- Further progress on the definition of advanced RRM mechanisms leading to an optimized usage of the different Radio Access technologies.
- Acknowledge and contribute to the definition of useful Common RRM strategies, where a pool of resources belonging to different technologies are commonly considered and commonly optimized.
- Providing end-to-end QoS in an IP mobile access network. Define the interactions between a BB and the radio entities in order to provide the adapted QoS to the service and to use in an optimal way the heterogeneity of the IP access network.

REFERENCES

[1] 3GPP TS 23.107 "Quality of Service (QoS) concept and architecture"
[2] 3GPP TS 23.207. "End-to-end Quality of Service (QoS) concept and architecture"
[3] G. Fodor et al. "Providing Quality of Service in Always Best Connected Networks", IEEE Communications Magazine, July 2003
[4] Wei Zhuang, et al."Policy-Based QoS Management Architecture in an Integrated UMTS and WLAN Environment" IEEE Communication Magazine, November 2003.
[5] 3GPP TR 25.881 "Improvement of Radio Resource Management (RRM) across RNS and RNS/BSS"
[6] 3GPP TS 25.433, "NBAP Specification"
[7] 3GPP TS 25.423, "RNSAP Specification"

ACKNOWLEDGEMENTS

This work has been performed in the framework of the project IST-EVEREST (www.everest-ist.upc.es), which is partly funded by the European Community. The Authors would like to acknowledge the contributions of their colleagues from the EVEREST project