Overview of the AROMA Project

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ABSTRACT

The provision of beyond 3G (B3G) heterogeneous network topologies is conceptually a very attractive notion; however, it is a challenge to accomplish an efficient network design.

A typical heterogeneous scenario is constituted by several Radio Access Technologies (RATs) each having a Radio Access Network (RANs) interfacing a common Core Network (CN). Thus, interworking among heterogeneous RANs leads to a better overall performance than the accumulated performances of the stand-alone systems. This challenge calls for the introduction of new radio resource management (RRM) algorithms operating from a common perspective that take into account the overall amount of resources offered by the available RANs, and therefore are referred as Common Radio Resource Management (CRRM) algorithms.

The objective of the AROMA[1] project is to devise and assess a set of specific resource management strategies and algorithms for both the access and core network part that guarantee the end-to-end QoS in the context of an all-IP heterogeneous network.

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 testbed for proof of 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. 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 first release of Universal Mobile Telecommunication System (UMTS) is a reality in today's mobile networks. At the moment, the cellular business is mainly focused on deploying and evolving this system: major effort has been spent on improving the performance of UMTS, with 3GPP (3rd Generation Partnership Project) Release 5 and Release 6 containing very important features like High Speed Downlink Packet Access (HSDPA), High Speed Uplink Packet Access (HSUPA) and Multimedia Broadcast Multicast Service (MBMS). On the other hand, recently IP-based wireless technology has received a strong technological and economical boost. This has been fostered by industry standards (e.g. Bluetooth) as well as "Internet oriented" standards (e.g. IEEE 802.11x, 802.16x, 802.20x). These technologies are currently evolving towards higher – broadband – data rates and/or support of continuous mobility in wide service areas, even though these systems generally provide only part of the functionality of full-blown mobile networks.

In that context, the need to provide evolved 3G interworking with these technologies and networks becomes mandatory, such as underpinned by the recent 3GPP Rel-6 with the work item for 3GPP-WLAN interworking.

The evolution of RAN beyond Release 6 is expected to be a bigger step in the 3GPP system performance. With respect to the envisaged evolution, the RAN architecture should also be evolved to accommodate future IP-based networks, which allow a common transport even in different access networks, simple resource management, and easy heterogeneous inter-working. For this architecture, current network nodes such as the Radio Network Controller (RNC), Node B, and core nodes are simplified in order to achieve a high quality seamless connection with intra and inter networks where users can conveniently access with high quality service continuity. Additional interfaces and a re-ordering of the functionalities should be considered in order to support the evolution towards higher bit rates on the air interface.

Then, in this evolved architecture, the available radio resources of coupled access networks will have to be managed jointly, up to the degree allowed by the coupling mechanism (loose, tight or very tight). An optimum solution is targeted in terms of throughput, cost per packet, development and deployment cost, etc. RRM and CRRM strategies are responsible for an utmost efficient utilisation of the air interface resources in the RAN and pool of RANs

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[1] Acronym of the FP6 IST STREP project entitled "Advanced Resource Management Solutions for Future all IP Heterogeneous Mobile radio environments", started in January 2006.

respectively. Any stand-alone wireless systems or heterogeneous hybrids thereof, rely on RRM strategies to guarantee a certain prior agreed QoS, to maintain the planned coverage area, to offer high capacity, etc. Without them, the most efficient physical transmission system coupled into the most sophisticated IP core network would fail or, at least, will not operate at its best.

On the other hand, within the CN mechanisms ought to be in place, which allow an optimum routing of incoming traffic to the appropriate RAN. Then, from the IP Core Network viewpoint, there are two main topics to be addressed: mobility management and QoS. In this sense, two alternatives for the architecture of the CN could be:
1. DiffServ managed by bandwidth brokers (in conjunction with QoS routing) and a tunnel-based micro-mobility management.
2. MPLS (MultiProtocol Label Switching) used as a complementary technology to the proposed QoS architecture.

In summary, the evolved heterogeneous networks will pose new demands for assuring end-to-end QoS. Therefore, efforts should hence be directed to fulfil the requirement to uniformly and seamlessly integrate users, services, heterogeneous technologies, operators/providers via Mobile IP(v6).

Then, the paper is organized as follows. In Section II the main project goals are introduced. Next, in Section III, the technical approach used to achieve the project objectives is described. Finally, a summary of the expected project results is addressed in Section IV.

II. PROJECT MAIN GOALS

The objective of the AROMA project is to devise and assess a set of specific resource management strategies and algorithms for both the access and core network parts that guarantee the end-to-end QoS in the context of an all-IP heterogeneous network.

In order to achieve the former main objective, the following partial objectives will be addressed in the project:

❖ To identify, propose, simulate, assess and validate advanced RRM algorithms for GERAN and UMTS as well as novel radio concepts B3G.

❖ To develop advanced CRRM, algorithms covering among other: CRRM exploitation of the non-homogeneous system conditions, load-sharing CRRM algorithms using GERAN and UTRA MBMS or CRRM algorithms and Cross layer RRM algorithms based in IP-RAN. Algorithms implementation aspects will be considered too.

❖ To propose, simulate, assess and validate innovative end-to-end QoS strategies considering both radio and

core network aspects under a variety of conditions, at least including: MPLS and lower-layer interaction for end-to-end support, IP-RAN traffic engineering strategies and mobility issues.

❖ To develop mechanisms allowing an automated tuning of the CRRM/RRM algorithms and corresponding parameters via network management software

❖ To carry out economic evaluation on the impacts of the novel solutions considered by the project.

Therefore, the AROMA project aims not only to assess and maximize the potential benefits coming from the medium-term evolution of the considered radio-access technologies (e.g. HSDPA/HSUPA; MBMS) but in parallel also to promote and investigate potential benefits coming from a long-term evolution towards an all IP heterogeneous mobile and wireless network architecture.

On the other hand, in order to support end-to-end QoS in a heterogeneous wired and wireless mobile environment, an appropriate interaction between the QoS management entities of the CN and the CRRM in the radio part is crucial. These kinds of issues are extensively covered in the project.

Last but not least, it is also prime important to carry out economic evaluation on the impacts of the novel architecture solutions considered by the project.

In summary AROMA aims at providing tangible contributions, in terms of resource management, for the future all IP heterogeneous wireless systems, which will take into account 2G/2.5/3G (e.g. GERAN, UTRAN and 3.5G networks (e.g. HSDPA), including the newly emerging RAN technologies (e.g. WLAN) and services, for the 2010-2015 time frame.

In order to accomplish these 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 for proof of concepts.

III. TECHNICAL APPROACH

The project will be carried out in the following main stages:
1. Determination of interest and relevant target scenarios. This includes to consider:
   a. Communications environment, i.e. macrocell, microcell, indoor, etc., and user mobility
   b. Technologies deployed (GSM, GPRS, EDGE, UMTS, WLAN), their corresponding capabilities and functionalities, as well as their corresponding network architectures and entities
   c. Service mix and service load (conversational, interactive, streaming, etc.).

2. Development of advanced resource and QoS management algorithms, with evaluation through simulation. Focus will be placed on finding commonalities among the different scenarios considered, rather than trying to optimise algorithms and algorithmic parameters for a specific scenario. Thus, the goals of AROMA extend the mere analysis of different scenarios and will target the definition of generic end-to-end resource management criteria, facilitating their applicability in scenarios differing from those studied in detail within the project.

3. Techno-economic aspects: economical analyses and evaluation of the technical outputs of the project.
Mobile communications will continue to be one of the most dynamic and profitable market sectors. In such a competitive and standard-centric industrial enviroment, the economical exploitation of the solutions directed towards the optimization of the network performances are of key importance. For this reason, it is considered fundamental for the AROMA project to have the opportunity to also carry out techno-economic analyses and evaluations of the technical issues addressed by the project, investigating also the business impacts of these solutions.

4. 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. .

These main research topics in AROMA 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 (ref. 3GPP TS 23.107, TS 23.207).

Reference architecture
The concept of All-IP in wireless networks is commonly used to refer to those systems which include IP-based multimedia services, IP-based transport, and the integration of IETF protocols for such functions as wide-area mobility support (Mobile IP), signalling (SIP), and Authentication, Authorization and Accounting (RADIUS, Diameter). In a pure All-IP Heterogeneous network, where the IP transport would be present from a network gateway (e.g. Gateway GSN within UMTS) down to an access point (e.g. Node B in UTRAN), two different architectures can be considered:

1. One which is close to the present architecture of 3GPP and which separates the RAN from the CN. In this case, this separation will remain and the IP RAN is connected to the CN through RNCs or equivalents [1]. Thus, IP mechanisms would be used inside the RAN and the CN but mobility and resource management within both parts could be addressed independently.

2. The other architecture is more generic. NodeBs, Access Points (APs) or any other access technology attachment points are simply connected to an IP access network, which deals with resource management (including both radio and IP resource management). This architecture, where different radio access technologies entities are easily plugged into a generic access network, is similar to "IP2 "(IP-based IMT network Platform) [2]. Under the "IP2" approach, no clear separation exists between the RAN and the CN. Instead, a unified IP-based mobility and routing is envisaged from network gateway to Mobile Terminal (MT). Conventional separation of RAN and CN is realized functionally by the boundaries between territories where RRM and Call/Session management are applied.

These two architectures differ in the physical location of the RRM functionalities in the access network.

Both All-IP approaches could be applied to B3G and wireless networks, and as according to several comments in UTRAN evolution workshop [3], there is not a general consensus about the reference architecture for All-IP wireless networks. For that reason, and taking into account the more focalised orientation of the STREP instruments, the AROMA project will assume an end-to-end reference architecture close to the 3GPP orientation. An illustration of the reference architecture for investigating performances and requirements of innovative radio resource management algorithms could be the one depicted in Figure 1.

As initial selection, Figure 1 shows the chosen approach for "All-IP" access network, where the IP transport is present from the gateway of the access network up to specific access points within each different RAN. Access Router (AR) functions are shown in the figure co-located to the RNC (or equivalent entity depending on access technology). Moreover, the assumed architecture should be compatible with 3GPP architecture, then the hierarchy of GGSN, SGSN and RNC is kept. Within the RAN, IP would be used as a transport technology to connect access routers/RNCs with access point devices (i.e., Node-B, BTS, and 802.11 AP). The AP is seen as the layer 2 device that offers the wireless link connection to the mobile node.

In these All-IP wireless networks, IP can be deployed in two modes: the transport mode and the native mode. In transport mode, IP is merely used as a transport technology so as IP routing is done according to network components' addresses (RNC, SGSN, GGSN) and user IP packets are encapsulated and transferred over this overlay network. On the contrary, IP native makes use of user IP addresses to route packets within the network. This means that no encapsulation is needed and consequently transport

overhead is reduced. Thus, IP native may lead to significant improvements in terms of network efficiency and performance. It is believed that extended native use of IP in the terrestrial segment of a wireless operator's domain that more readily allows for building a converged network with multiple access technologies.
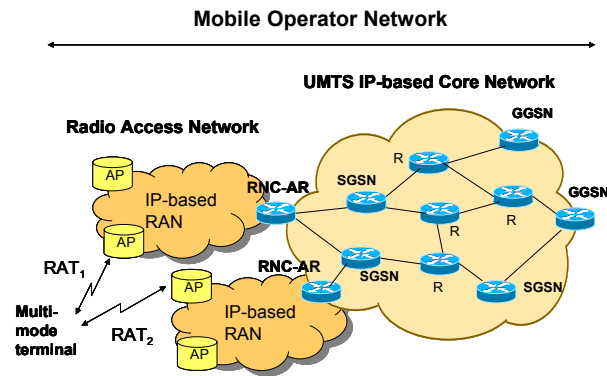

Figure 1.- All-IP mobile network architecture (All-IP UTRAN evolution for UMTS)

Furthermore it can be noticed that in the "all-IP" architecture of UMTS R5, it is specified that DiffServ architecture should be supported in the different interfaces: Iur, Iub (TS24.434, TS25.426), Iu (TS25.414) and Gn. However the IP QoS control management of the access network is left open. Then in the following section issues such as IP QoS control management for a B3G system, or the interaction between the IP QoS and the RRM entities in order to provide an optimal end-to-end QoS are examined.

End-to-end QoS Framework
The AROMA framework is based on the QoS framework developed in IST-EVEREST [4] but important extensions are envisaged to cover the introduction of IP RANs as well as other mechanisms to support QoS in the IP-based core network (e.g. MPLS). In the same way, different inter-working approaches among RANs are going to be further developed so as their impact on the QoS framework is assessed.

More specific, the reference QoS framework is actually based on the UMTS QoS architecture introduced in 3GPP releases 5 for IMS services and extended to other services in release 6 [2]. Therefore, following the Policy-Based Networking (PBN) approach developed in the legacy IST-EVEREST project [5], the reference QoS architecture for this project will be that of a heterogeneous All-IP Network, composed mainly by two different segments: the radio access technologies (GERAN, UTRAN, WLAN, etc..) and the Core network part composed by a pure IP network, where the IP transport is present from a gateway (GGSN) down to the RNC or even at the NodeB or access point. Notice that the proposed reference QoS architecture, shown in Figure 2, extends the

3GPP model so as to fulfil the heterogeneous All-IP Network QoS requirements. That is:

- Policy-based mechanisms are deployed to cope with resource management in the radio access part as well as in the CN. In this sense, resource usage in the entire B3G network elements is expected to operate under a set of policies that guide the system behaviour. In the current 3GPP solution policy-based management is limited to IP QoS resource authorisation at the GGSN.
- Dynamic QoS negotiation among all the potential RATs over which a connection may be served and the CN should be possible. In this sense, it is expected that the way QoS is offered over the overall B3G network domain and can be dynamically adapted to the radio access and core network conditions.
- QoS management should encompass CRRM in coordinated RANs connected to the same CN. So, CRRM mechanism should be made available to the QoS management framework.
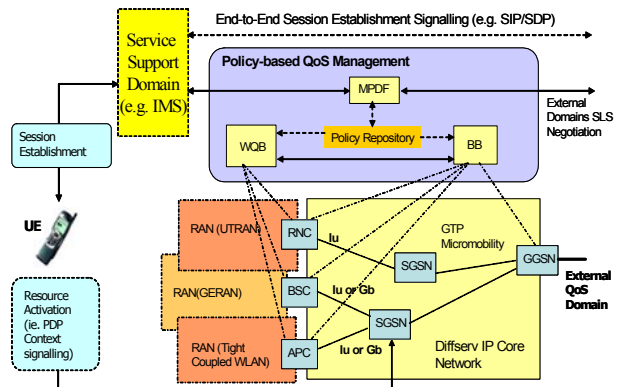

Figure 2. Proposed reference architecture for a heterogeneous All-IP Wireless Network

The key aspects of this QoS management architecture are the following:

o Two new functional entities are introduced to support the policy-based approach: the Bandwidth Broker (BB) and the Wireless QoS broker (WQB). The BB [6] is in charge of the control plane of the DiffServ domain while the WQB is the counterpart of the BB for the radio part of the access network.

o Relationships between the master PDF (M-PDF) and the new entities WQB and BB is envisaged in terms of QoS negotiation. Then, session's QoS-requirements for the whole B3G network domain are provisioned accordingly in the radio access and in the core network as a result of this negotiation. Furthermore, the M-PDF is in charge of QoS negotiation with external peer domains involved in the provisioning of end-to-end services. Inter-domain QoS negotiation can follow different approaches, [4], [7]. For instance in [4] network wide policies are established among peer domains through the exchange of updated Service Level Agreement (SLA) information.

o Negotiation of QoS between the user (or a proxy in the Service Support Domain) and the MPDF is achieved by a policy-based service negotiation protocol (e.g. COPS-SLS [8]). After a session has been negotiated and authorised, resource activation can be committed through the usage of the PDP Context signalling as specified in UMTS although an enforcement solution from QoS entities can be also envisaged (e.g. resources in the edge DiffServ routers of the CN through the COPS-PR protocol).

o The proposed architecture is valid for any degree of coupling among the heterogeneous RANs.

As stated above, the Wireless QoS Broker entity can be seen as the counterpart of the BB for the radio part of the access network, each entity considering the specific characteristics of the corresponding responsibility segment. The envisaged functions for the Wireless QoS Broker entity are briefly summarised hereafter:

o Dynamic QoS negotiation among CN and RATs. Coordination is needed between the WQB and the BB, as the admission control and handover decision are submitted to different constraints in the radio part and the IP CN of the mobile access network. In the first case these constraints are related to the radio resource usage, and in the latter case to the network topology and the traffic distribution in the network.

o Common Radio Resource Management. CRRM functions play a crucial role within the WQB. In particular, the WQB will hold the RAT selection decision function needed for the Vertical Handover decision as well as the initial RAT selection.

o Configuration of RAN elements for QoS provisioning. As each RAN may have specific QoS mechanisms, the WQB might be responsible for the configuration of such mechanisms in order to achieve the expected behaviour. Thus, the WQB would configure QoS mechanisms in RATs elements according to a set of common policies. In the same way, CRRM functions can be configured from the WQB.

IV. EXPECTED RESULTS

The expected research results from the AROMA project can be summarised as follows:

- Further progress on the definition of advanced RRM/CRRM mechanisms leading to an optimized usage of the different Radio Access technologies.
- Providing innovative end-to-end QoS strategies for an All-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 All-IP access network.

- To develop mechanisms allowing an automated tuning of the CRRM/RRM algorithms and corresponding parameters via network management software.
- To carry out economic evaluation on the impacts of the novel solutions considered by the project.

The commercial impact of the studies to be carried out within the project is expected to be viable in the years 2010-2015; from the much hoped-for commercial success of 3G networks until their full maturity. It is anticipated that the progression towards an evolved 3G All-IP Network (AIPN) may enable leverage of information technology (IT) hardware and software with general-purpose, and mobile network specific software that should provide cost reduction (CAPEX and OPEX) for infrastructure equipment and applications of 3GPP based mobile networks.

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