

# Vertical Handover Support in Coordinated Heterogeneous Radio Access Networks

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**Abstract.-** Beyond 3G wireless networks must be able to coordinate services within a diverse network environment. One of the most challenging problems for coordination is vertical handover (VHO), which is the decision for a mobile node to change the point of attachment between different types of networks. While traditional handover is based on received signal strength comparisons, VHO must evaluate additional factors, such as type of service, network conditions, operator policies and user preferences. This paper describes how VHO is supported within the QoS framework developed within the EVEREST project for a B3G network architecture where multiple heterogeneous radio access technologies are connected to a diffserv-enabled UMTS core network. The addressed VHO encompasses common radio resource management (CRRM) mechanisms deployed in the B3G network.

## I. INTRODUCTION

A significant challenge for beyond third generation (B3G) wireless networks is to coordinate the many different types of networks being used for wireless communications. A plethora of different radio access networks (e.g. cellular networks as GPRS and UMTS as well as wireless LAN hostspots) will have to co-exist. These different networks ought to be inter-connected in an optimum manner with the ultimate objective to provide the end-user with the requested services and corresponding QoS (Quality of Service) requirements. One of the most challenging problems for coordination is vertical handover (VHO), which is the decision for a mobile node to hand over between different types of networks [1].

In this paper we describe how VHO can be supported in B3G network architecture considered within EVEREST project [2] where multiple heterogeneous radio access technologies (RATs) are connected to a diffserv-enabled IP-based UMTS core network. In particular we assume a future mobile network scenario where different RANs may co-exist in the same area and multi-mode mobiles can be connected to them. Furthermore, common radio resource management (CRRM) mechanisms are expected to be deployed within the different RATs of the B3G network as well as QoS control mechanisms in IP core network.

In a general sense, it can be stated that the RAT selection problem within the VHO decision function should be managed by the mobile user when available candidate networks are not coordinated (i.e. a user must decide which

is the “best” network by himself, and of course, in this decision operator and network constraints are implicitly considered –cost, subscription profile and so on--). However, when some degree of coordination exists in the available candidate networks (e.g. CRRM), the user may want to delegate “part of the decision” to the coordinated network where a better decision is expected to be done in terms of both a better user satisfaction and effective usage of network resources. The meaning here of “part of the decision” is that although RAT selection decision would be taken in the network, user preferences would be considered in the decision process (i.e. from its user profile). Thus, in the composite network environment described above a RAT selection function controlled by the network although based on user preferences is envisaged.

The paper is organised as follows. Section II describes a reference network architecture for the envisaged B3G scenarios. Then, a QoS framework deployed over the B3G scenario encompassing CRRM and QoS mechanisms in the UMTS core network is addressed in Section III. Vertical handover considerations and requirements over the proposed QoS framework are described in Section IV and Section V shows how the VHO procedure can be supported in a composite radio access network scenario. Finally Section VI concludes the paper.

## II. B3G NETWORK REFERENCE ARCHITECTURE

The considered reference architecture for the B3G network consists of a set of heterogeneous radio access networks (UTRAN, GERAN and WLAN) interfacing a common core network (UMTS CN). Each Radio Access Network (RAN) is built around a specific radio access technology and an extended UMTS core network is used to interconnect all the RANs. Figure 1 illustrates the main concepts of the envisaged B3G network interconnection architecture where GERAN, UTRAN and WLAN technologies would be deployed in RANs connected to a common IP core network. The figure also illustrates the main elements of the framework proposed to manage QoS over such a B3G network approach. This QoS framework is discussed later on in section III.

From release 5 of UMTS, an IP transport can be used for signalling and traffic in the UMTS access network, which encompasses the RAN (Iub and Iur interfaces), the Iu interface and the CN (Gn interfaces). At the layer 2 any suitable technology can be used, including the already

deployed ATM technology. Moreover 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. For the control management of the IP QoS data plane, the bandwidth broker (BB) entity is envisaged [3]. And the BB is in charge of the IP QoS in the IP domain confined between RNCs and GGSNs. The QoS control of the BB does not extend to the Node B (or AP), as it is supposed that RNC and Node B are connected through a point-to-point link, which is over-provisioned. The IP domain confined between the RNC and GGSN has a partially mesh based topology. Thus, RNCs can be connected to multiple CN nodes, as specified in the technical specification TS23.236-v5.2.0.

Now that the IP QoS framework, which follows 3GPP specifications, has been described, some specific issues regarding IP mobility management in UMTS are highlighted. The mobility management in UMTS is assured by the GPRS tunnelling protocol (GTP), in a similar way as an IP tunnel-based micromobility management protocol [4]. GTP is in charge of the mobility inside the operator domain. For the roaming with other domain, i.e. between the GGSNs a macromobility protocol like mobile IP has to be used. In Figure 1, it can be seen that the GTP protocol as a tunnel-based micromobility protocol manages mobility

between RNCs and that mobile IP as a macromobility handles inter-GGSN handover. Furthermore in the considered scheme the BB does admission control based on the information provided by the intra-domain QoS routing. Thus, QoS routing is used in the following way in the IP domain: first QoS routing is used in the area between the RNC and the SGSN below the GPRS mobility overlay, and secondly in the area between the SGSN and the GGSN as shown in Figure 1. In summary, the IP architecture described here follows the 3GPP R5 specifications and is based on the use of an IP tunnel-based mobility management protocol (GTP) and also on DiffServ and the BB.

Regarding the integration of the WLAN, Figure 1 shows a tight coupling solution where the WLAN functionality is seen as a UTRAN/GERAN network and as such an interface similar to Iu-PS/Gb interface would be used to connect it to a SGSN. In such case, in order to support RRM and CRRM functionalities, a new element is required in the WLAN with equivalent functions like the RNC or the BSC for the UTRAN and GERAN respectively. In particular the APC architecture design could follow the Generic Access Network (GAN) approach described in 3GPP TR 43.901.

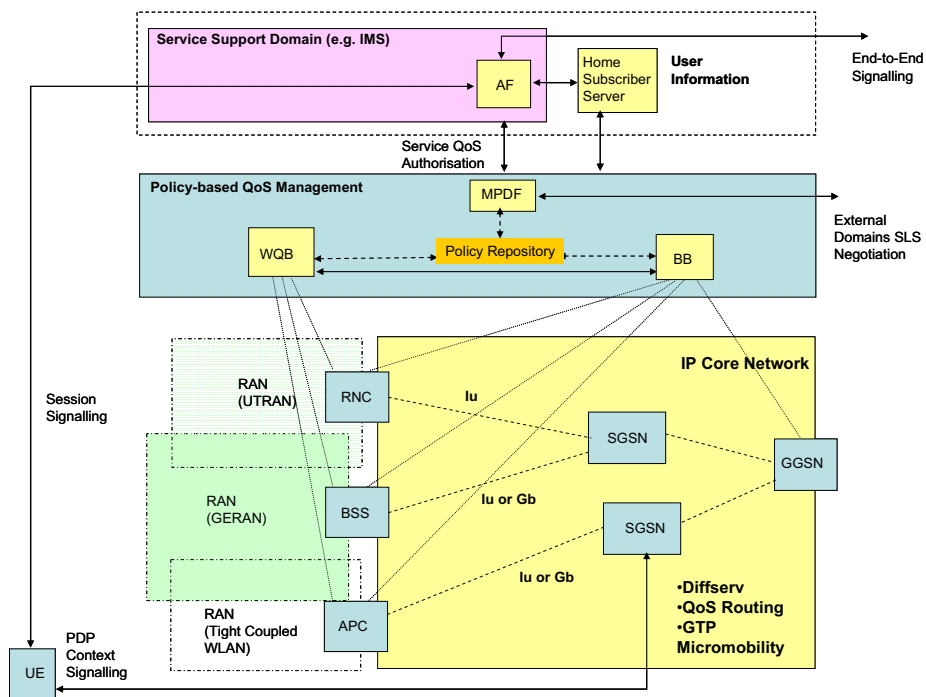


Figure 1. Reference B3G network UMTS-based architecture

### III. EVEREST QOS FRAMEWORK

The Everest QoS management framework addresses the QoS provisioning problem of multimedia services (e.g. IMS services) in B3G systems. The proposed framework is based on the UMTS QoS architecture introduced in 3GPP release 5 for IMS services [5]. Under such 3GPP framework, a Policy Decision Function (PDF) is used to authorise IP QoS parameters for multimedia services. This

authorisation takes place during the session establishment phase (e.g. by means of the application function, AF, that serves as a proxy for SIP/SDP signalling) and as a result a media authorisation token is generated and sent to the mobile terminal. Then, this token is used within the PDP Context activation procedures to ask for authorised network resources. A Policy Enforcement Point (PEP) allocated in the GGSN and connected to the PDF through a COPS-based interface is used to check whether requested

resources are compliant to those previously authorised. Once valid IP QoS parameters are known, a translation function is used to obtain the QoS parameters of the overall UMTS Bearer Service (BS). This 3GPP QoS framework can be seen as a first step to introduce policy-based mechanism in UMTS networks. Over such a basis, several extensions are proposed in EVEREST so as to fulfil B3G scenarios requirements. In particular, a policy-based RAT selection decision function is considered mandatory within the QoS management framework as well as the introduction of dynamic QoS negotiation mechanisms among all the potential RATs and the CN.

The proposed architecture solution over a B3G network, illustrated in Figure 1, intends to achieve the above requirements and allows for an optimised management, considering both the core network part and the heterogeneous radio access part. As seen in Figure 1, two new functional entities are introduced to support the policy-based approach: the Bandwidth Broker (BB) and the Wireless QoS broker (WQB). The BB [3] 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. The WQB is a new concept developed within the EVEREST project and its functions are briefly summarised hereafter:

- 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.
- 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 in the initial RAT selection problem as well as in the Vertical Handover decision.
- Configuration of RAN elements for QoS provisioning. As each RAN may have specific QoS mechanisms, the WQB might be responsible of the configuration of such mechanisms so as global service requirements are satisfied.

The PDF entity already introduced in 3GPP R5/R6 policy framework is maintained but its functions extended in order to cope with QoS negotiation with external peer domains involved in the provisioning of end-to-end services. So, we refer to this new extension as Master PDF (MPDF) in Figure 1. Relationship between the MPDF and the new entities WQB and BB is envisaged in terms of QoS negotiation so that 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. Negotiation of QoS is achieved by a policy-based service negotiation protocol (e.g. COPS-SLS [6]). What differentiates policy-based negotiation protocols is the flexibility of the signalling and the independence of the signalling from the QoS mechanism used in each domain. Each domain might have a specific set of negotiation parameters (or a set of Service Level Specifications, SLSs) and specific policy for admission control.

#### IV. VERTICAL HANDOVER CONTROL

Handover control in current GERAN/UTRAN networks mostly relies on Radio Resource Management (RRM) algorithms. RRM functions are completely located within the radio access network in both UE and RNC/BSC. In this sense, the main reasons why handover procedures may be activated are basically related either to guarantee radio conditions on user connections (i.e. signal quality reason handover) or to achieve an efficient traffic load distribution (i.e. traffic reason handovers).

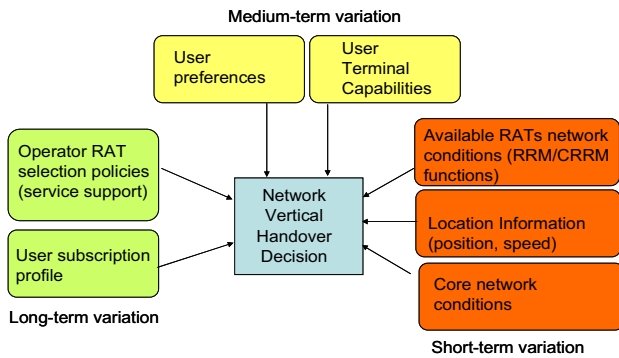
In a scenario where multiple heterogeneous RATs are available, handover decisions should overtake local RRM entities in each network as they do not take into account the current context or the various attachment options for the mobile user. For instance, the reception of good quality UTRAN signal may not impede a mobile user to change to a WLAN network as soon as the signal of a suitable AP is discovered. However, although this specific behaviour may be preferable for non real time services, it might result in quality degradation for a voice session when the selected WLAN AP is heavy loaded. Then, in order to take care of these situations, a Common Radio Resource Management (CRRM) functionality is envisaged in 3GPP TR 25.891 to improve RRM across UTRAN and GERAN networks. According to this approach, a CRRM functional entity is defined as responsible for the coordination of overlapping/neighbour radio resource pools controlled by different RRM entities (A resource pool is defined as the set of resources managed by a single RRM entity). The 3GPP approach for UTRAN/GERAN networks can be easily extended to WLAN when considering a tight coupling approach (e.g. Generic Access Interface).

Furthermore, as long as QoS mechanisms are expected to be deployed in the core network, VHO decision should rely on core network conditions as well. Usually the radio segment is considered as the bottleneck and handover decisions are tightly bind to this fact. However in a heterogeneous access network where the IP CN has to support several types of radio access technologies and is expected to deliver real time services to users, the feasibility of the route establishment across core network routers may be accounted in a VHO decision.

But coordination of radio resource pools of overlapping areas as well as core network conditions still does not fulfil vertical handover requirements in B3G network scenarios: important criteria such as monetary cost, operator market strategies, user preferences and so on should be considered. Thus, being able to be connected seamlessly anytime anywhere to the “best” network is a challenging task where policy-based handover decision mechanisms taking care of aforementioned criteria might play an outstanding role.

In a general sense, it can be stated that the RAT selection problem within the VHO decision function should be managed by the mobile user when available candidate networks are not coordinated (i.e. a user must decide which is the “best” network by himself, and of course, in this decision operator and network constraints are implicitly considered –cost, subscription profile and so on--). However, when some degree of coordination exists in the

available candidate networks (e.g. CRRM), the user may want to delegate “part of the decision” to the coordinated network where a better decision is expected to be done in terms of both a better user satisfaction and effective usage of network resources. Thus, in a coordinated heterogeneous radio access network there is considered mandatory to allocate a function devoted to handle the RAT selection problem on behalf of the user. Figure 2 illustrates the envisaged criteria to be considered in a network vertical handover decision.



**Figure 2. Decision criteria in a Vertical Handover Decision function supported in the network**

In next section a VHO handover mechanism that encompasses all the issues pointed in this section is proposed for the reference B3G network scenario under consideration.

## V. DEPLOYMENT OF VHO STRATEGIES

Any handover is a three-stage process: first a decision is done, then link transfer mechanisms are triggered and finally a channel is assigned to the mobile in the new point of attachment. This section is mainly focused in the description of the decision process of a VHO function in the B3G network scenario introduced in Section 2. In particular, the role of proposed QoS management entities (WQB and BB) as well as the RRM and CRRM entities within the decision process is analysed. Link transfer mechanisms and channel assignment are assumed to be the ones specified in 3GPP for UTRAN/GERAN networks. In the case of WLAN, this last assumption is still valid when considering a tight coupling approach (e.g. Generic Access Interface).

The WQB is envisaged to hold most of the logic to make a decision about the best cell to hand over. As pointed in section 2, CRRM functions can play a key role in the vertical handover decision so as the proposed WQB approach is highly dependent on the way CRRM functions are deployed in the system. In this sense, a specific CRRM deployment should be first stated in order to serve as the basic building block of the vertical handover functionality of the WQB. We have found the CRRM policy-based approach is proposed in 3GPP 25.891 as a feasible approach over which the WQB concept can be developed. The basic idea behind the “CRRM policy-based approach” in 25.891 is the standardisation of parameters and information exchange over an open interface between RRM and CRRM entities. This would enable the CRRM entity to

provide CRRM policies to the RRM entities, thus allowing the traffic situation in the network to be dynamically adjusted on the basis of a common strategy. In particular, the local RRM entities act as master of the decisions but decision criteria is determined by the set of installed CRRM policies. A reporting information interface is proposed to achieve a twofold objective: CRRM is aware of network conditions from measurements received from local RRM entities at the same time as local RRM entities can receive information of external cells from the CRRM. Upon such a basis, the CRRM approach considered here extends the CRRM policy-based in 25.891 by adding a decision support mechanism.

According to previous CRRM approach, Figure 3 illustrates how a VHO mechanism would be decided and executed in the considered B3G network scenario (for the sake of simplicity only two radio network controllers RNC1 and RNC2 belonging to any of the considered RATs are illustrated in the figure). In this case, CRRM entity can be thought to be collocated within the WQB functions. Thus, in this case, initial vertical handover decisions would be triggered at local RRM entities according to installed policies. According to Figure 3, the source RRM entity decides that a VHO may be needed and a list of candidate cells is passed to the CRRM entity in the WQB. The CRRM entity there might use measurements gathered from other RNCs to prioritise the provided list in terms of radio resource usage. However, the decision of moving to a target cell of a different RAT should consider criteria other than merely radio specific. In particular, service type, network operator and user preferences must be included in the decision process. So, the WQB might directly retrieve operator policies from a global repository (that can be the same used by the MPDF when evaluates session establishment, i.e. when the AF asks the MPDF about QoS authorisation) and specific information from the user databases (e.g. HSS) so as a decision can be taken locally at the WQB. After that, if the handover decision implies a change in the point of attachment to the core network (i.e. a RNC change according to the proposed architecture), the BB should be checked to guarantee that QoS would be maintained at the new path. Concerning the admission control at the IP level, the BB centralizes all the information regarding the current network utilization. As it has been noticed in section 2, QoS routing is used in the IP domain for the determination of the new IP path after handover. Thus, the QoS routing determines the new path along which the required service is available and this information is transmitted to the BB.

Finally if a VHO is authorised, RNC1 is allowed to execute the decision as a response to the *list of candidate cells* request and the BB is alerted of the handover initiation (at this point, not considered in the current case shown in the figure, the BB may allocate resources in the new path). Notice that in this approach the CRRM does not decide which user should be handed over. Instead, it is the RRM entity who decides it according to some triggering rules. Regarding the preparation and execution phase after a decision is done, either inter-system handover mechanisms or network controlled cell reselection can be triggered. As example, if the UE is initially connected to UTRAN, the

source RNC may initiate an inter-system relocation procedure to an Iu-mode GERAN BSC [25.413]. Serving RNS relocation procedures move the RAN to CN connection point at the RAN side of the source RNC to the target Iu-mode RNC/BSC. In the same way, if the UE is currently connected to GERAN, BSC may initiate a change

cell order procedure [44.060]. For a multi-RAT mobile station, the signalling message sent to the mobile to initiate the change may contain information on a UTRAN target cell. In case of WLAN, an equivalent function to cell change order might be supported in the APC.

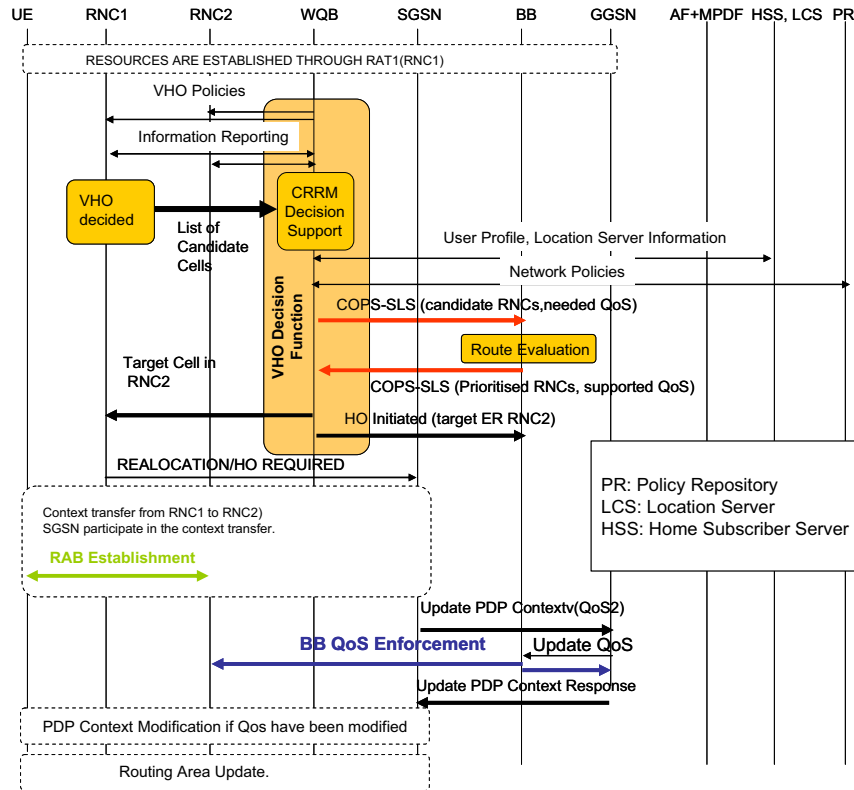


Figure 3. VHO decision procedure

Once RABs are activated in the new radio controller, a PDP context update is required to move the GTP tunnel between the new RNC and the GGSN. This PDP context update may only involve a signalling SGSN and GGSN (The SGSN is involved at control plane although the tunnel is enforced at the RNC user data plane). However, in case those QoS guarantees of the established PDP contexts are not longer guaranteed because of network change, a modification of the PDP Context might be triggered by the network. In this case, the mobile must accept the proposed PDP changes or just release the connection if new conditions are not satisfactory. The BB is kept informed of the network status through its interface to the QoS routing. Finally, a routing area update procedure can be performed to update mobility management information at the SGSN.

### VI. CONCLUSIONS

Effective policy-based VHO decision function is definitively necessary in a composite radio access network scenario. In this paper it is described how this function can be supported in B3G network architecture where multiple RATs technologies (RATs) encompassing CRRM functions are connected to a diffserv-enabled IP-based UMTS core network. The VHO decision is hold by a WQB entity proposed within EVEREST QoS framework and takes into account network conditions on the radio part from RRM/CRRM entities as well as in the core network from

the BB entity. Besides, operator policies, subscriber profile and user preferences are envisaged to be used within the WQB to perform the VHO decision.

### ACKNOWLEDGEMENTS

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