Common radio resource management for WLAN-UMTS integration at radio access level

Natasa Vulic, Sonia Heemstra de Groot and Ignas Niemegeers

***Abstract*—Integration of UMTS and WLAN can be performed at different levels. A promising interworking approach embeds the WLAN into the UMTS radio access network. It provides additional license-free capacity to operators and good vertical handover performance. As the WLAN is attached directly to the UMTS radio resource manager, this approach allows possibility of collocation of resource managers of both networks. Common radio resource management allows more efficient use of resources and facilitates vertical handover management. The paper discusses this issue for two architectural options for WLAN-UMTS integration at radio access level.**

***Keywords*—UMTS, WLAN, radio access integration, common radio resource management**

I. INTRODUCTION

The demand for accessing services while on the move, at any place and time, has lead to the current efforts towards integration of heterogeneous wireless networks. In particular, inteoperability of UMTS and WLAN, as complementary systems in providing capacity and coverage, draws a lot of attention.

Interworking of the wireless networks requires different mobility management, security and QoS mechanisms to be harmonized and integrated into a common architecture. Different choices of these mechanisms lead to several interworking approaches that can be organized into two groups: IP-based and UMTS-based. In the IP-based approach, the networks remain independent of each other and potentially belong to different administrative domains. Only the subscriber information management can be common for the networks. In the UMTS-based approach, the WLAN is embedded in the UMTS network. The UMTS control protocols are reused within the WLAN. The WLAN data traffic is routed via the UMTS core network. This solution is suitable for a single, 3G operator.

WLAN-UMTS integration in the UMTS-based approach can be performed either at the UMTS Core Network (CN) or Radio Access Network (UTRAN). Both interworking solutions provide the operator with additional license-free bandwidth and promise good handover performance. Integration at the radio access level has the advantage that the UMTS core network protocols remain unaffected and the interworking architecture deals with radio aspects only.

In addition, when increasing the degree of coupling of the networks, the resources can be utilised in a more efficient way. In the case of integration at radio access level, the WLAN is directly attached to the Radio Network Controller (RNC), which is responsible for the UTRAN Radio Resource Management (RRM). As the information on the networks usage is available locally, the RNC represents a suitable entity to manage the network resources of both networks. Such a Common Radio Resource Management (CRRM) entity for both networks will optimise the resource utilisation in terms of network load, cost, QoS requirements, etc. Besides, due to the global view of the available resources, it can enhance the management of vertical handover.

This paper addresses introduction of the CRRM for the UMTS-WLAN integration at the radio access. It is organised as follows. In section II, WLAN integration at the UMTS radio access level is presented. Two general architectural options are described. In section III, concept of CRRM is provided. Introduction of the CRRM for the both architectural options, benefits and implications are discussed in section IV. It is followed by a conclusion in section V.

II. UMTS-WLAN INTEGRATION AT RADIO ACCESS LEVEL

A. General network architecture

General network architecture for the WLAN-UMTS integration at radio access level is shown in Figure 1. The WLAN IEEE 802.11 is attached at the Iub-like (Iubw) UTRAN interface directly to the RNC. The WLAN network consists of one or more access points (AP), connected by a distribution system (DS). The DS considered here is IEEE 802.3.

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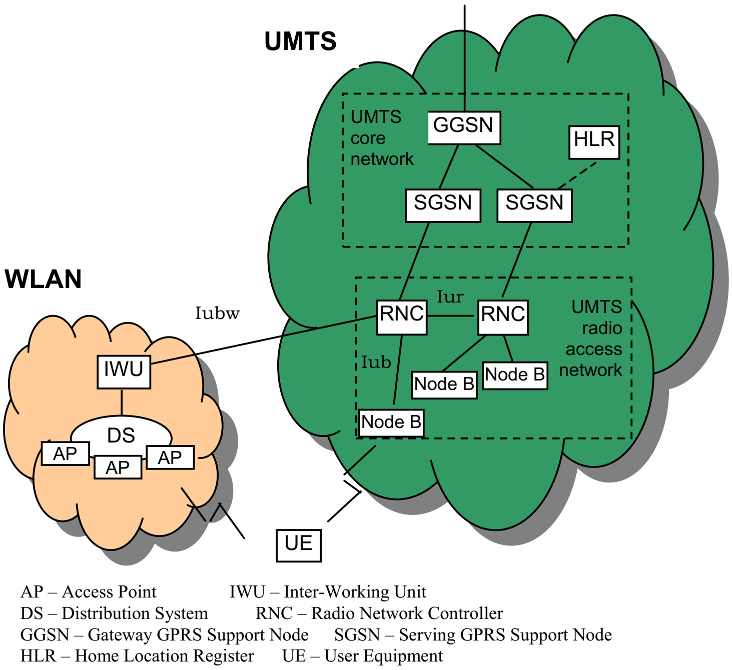

Figure 1. WLAN integration into the UMTS radio access network

This UMTS-WLAN integration architecture requires introduction of an inter-working unit (IWU) and modifications of the involved networks. The IWU is introduced between the WLAN and the RNC and is responsible for integration-specific and radio-related issues. Modifications of the WLAN may be minor and related mostly to the user access to the network. Major modifications take place in the UTRAN affecting its control protocols and mechanisms, in the first place the Radio Resource Control (RRC) protocol. In addition, the RNC as well as the CN elements have to be upgraded in order to support the WLAN traffic.

The WLAN integrated into UMTS in this manner can be provided with different levels of capabilities. Data traffic can be transferred within the WLAN only in the downlink or bi-directionally. The WLAN-related signalling can be exchanged via the WLAN or WCDMA air interface. Access to the network can be allowed via both air interfaces simultaneously or via a single interface at a time. Combinations of these variants result in different architectural options, which can be divided into two types: WLAN-dependent and WLAN-independent.

B. WLAN- dependent architectural option

This option is attractive because it offers in a relatively simple manner data traffic over the WLAN, while confining signalling over the WCDMA interface. Both air interfaces need to be used simultaneously, since the proper functioning is dependent on the UTRAN support. In addition to control information, the WCDMA interface can optionally carry uplink traffic in case the WLAN traffic is provided only in the downlink. Since both air interfaces are available simultaneously, only the best-effort WLAN 802.11 is considered.

In this architectural option, integration is performed below the UMTS MAC-d layer. Two new transport channels, with related MACwd and MACwu entities, are introduced for the support of WLAN data traffic in the downlink and uplink. These new MAC entities are part of an integration layer that is added in the UE and IWU protocol stack. Functionality of this integration layer involves mapping between the Iubw and WLAN MAC frames, signalling exchange with the RNC, scheduling, etc.

The UE should register first with UMTS, which is done in the usual way. If the UE has a subscription for the WLAN type of access, an association with the WLAN may follow. The WLAN authentication message here additionally includes a one-time identifier (OTI), which is delivered by the RNC in advance. In this way, the RNC can check whether the access to the WLAN is given to a registered subscriber. Choice of the 802.11 Access Point (AP) is still made by the UE, and the network does not have any control.

A request for a session is made via the WCDMA interface, as specified in UMTS. Having information on the air interfaces at disposal, the RNC makes a decision on the most suitable radio interface for a particular session, based on current network load, required QoS properties, user's preference, cost, etc. For example, best-effort traffic could be delivered over the WLAN, while a voice call is still carried over WCDMA interface.

Regarding handover control, new types of handovers are specified. These are handovers between an AP and NodeB as well as the APs themselves, which can be connected to the same or different IWUs. Besides, this architectural option introduces possibility of simultaneous inter-NodeBs and inter-APs handovers.

C. WLAN- independent architectural option

In the WLAN-independent option, both bi-directional data traffic and signalling are provided within the WLAN. This option is based on an assumption that the network is accessed via a single interface at a time. A variant of this approach may allow simultaneous access via both air interfaces when needed, as for example, for load balance or different QoS requirements. Here we consider only the case a single air interface is active at a time. Conversely to the previous architectural option, the use of the QoS-enabled WLAN IEEE 802.11e is here recommended.

The procedure for accessing the network should be unique and independent on the air interface. Actually, global presence of the UMTS network allows possibility that, while attaching to the network, the UE always gives priority to UMTS. If a WLAN is present, the UE can be automatically transferred there. A new session may be requested over any of the air interfaces, by using the same procedure as defined in UMTS. The network may transfer the data over the currently active interface or request a handover to another air interface.

New types of handovers need to be specified for switching between APs connecting to the same or different IWUs as well as between an AP and NodeB. The major difference to the previous architectural option concerns the fact that simultaneous handovers do not occur here and all ongoing sessions should be handed over to a new point of attachment.

III. CRRM GENERAL CONCEPT

The described architectural options assume that the UE chooses a WLAN AP autonomously and attaches to the AP with the strongest signal. The only modification regarding the IEEE 802.11 was inclusion of an UMTS-related identifier in the authentication message.

An autonomous choice of the AP and triggering the handover by the UE is not optimal, as the UE does not have a view of the use of available resources and the chosen AP may be not suitable for the UE needs. Besides, while moving, association with available WLANs may be undesirable.

All of these imply a need for network control of WLAN resources. A functional model for the common radio resource management is provided in [1], as depicted in Figure 2. It consists of two functional entities:

- RRM entity, responsible for radio resource management of one resource pool, where a resource pool is characterized by having an own RRM functionality [1]
- CRRM entity, responsible for coordination of neighbouring RRMs

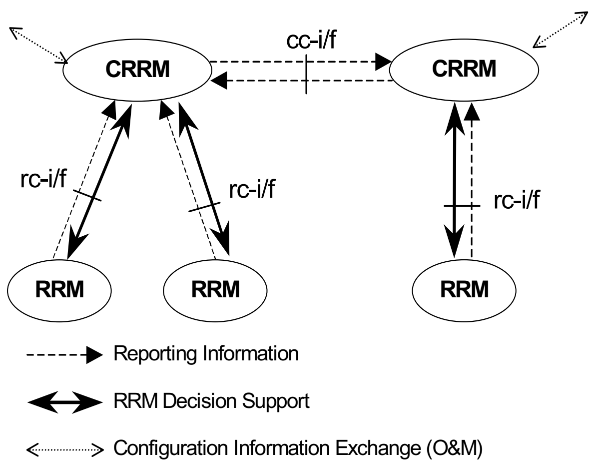

Figure 2. Common radio resource management – functional model [1]

The UTRAN RRM is located at the RNC, while a WLAN RRM needs to be specified. The WLAN RRM is likely to be situated in the IWU.

Generally, for the UMTS-WLAN integration at the radio access, two CRRM models are possible: centralized and distributed. The centralized model denotes that the CRRM is completely situated in the RNC, while in the distributed model the CRRM functionality is located in both RNC and IWUs. How the CRRM functionality is divided between these entities depends on the interworking architectural option and it is discussed more in detail in the following section.

The CRRM functionality can be summed up in the following way:

a) Collecting information on the current network load
b) Obtaining information on base stations visible to the UE
c) Suggesting appropriate target base stations for handover

Information on the current network load is delivered to the CRRM entity by the RRM ones. This communication is performed over the Iubw interface, which requires modification of the related control protocol. Depending on the interworking architectural option, it may include information on WLAN only, or both WLAN and UMTS.

For making a decision on the handover target base station, the CRRM entity needs to know which base stations are visible to the UE. This information is likely to be obtained from the UE, i.e. from the RRM entity with which the UE communicates. The CRRM-RRM communication is either performed locally or over the Iubw interface. The UE-RRM communication requires modification of the related control protocol. It depends on the CRRM model and architectural option, but in most cases, it is the RRC protocol.

The same discussion on affected control protocols is valid for the next CRRM task, which relates to making decisions on suitable base stations for the UE handover. The CRRM entity sends the suggestion to an appropriate RRM entity, which forwards it to the UE. These suggestions may involve only WLAN APs or both types of base stations. In addition, this functionality triggers modifications of the WLAN 802.11 MAC algorithm in order to apply these CRRM suggestions on APs. These WLAN modifications are independent of the applied CRRM model.

In the following section, introduction of the CRRM functionality into the WLAN-UMTS interworking architecture at radio access level and its implications are discussed for both architectural options.

IV. CRRM FOR UMTS-WLAN INTEGRATION AT THE RADIO ACCESS

A. *CRRM for WLAN-dependent architectural option*

Due to the fact that control information is always carried over the WCDMA interface, difference between the centralized and distributed CRRM model is minor. An important feature of the CRRM for WLAN-dependent architectural option is that the CRRM entity considers only APs.

In the centralized CRRM model, all the CRRM functionality is located in the RNC. The IWU is responsible for collecting information on the WLAN current load and its delivery to the RNC on a regular basis or a request. This is also the case for distributed CRRM model, except that the algorithm for decisions on suitable APs is shifted to the IWU.

In this case, the WLAN load reports are not sent to the RNC anymore. Instead, the RNC asks the IWU for a suitable AP when a decision on a handover should be made. In both cases, the RNC is the entity that makes the final decision on handover.

Introduction of the CRRM affects the control protocol at the Iubw interface and the RRC protocol and requires introduction of a new one for AP-IWU communication.

A basic assumption for this architectural option is that all the control communication between the UE and network is carried over the RRC protocol. Its further modification is required in order to support part of the CRRM functionality. It includes upgrade of standard NodeB measurement reports with the information on the signal level of neighbouring APs as well as provision of the CRRM command for attaching to a particular AP.

The RNC-IWU communication on the current network load affects the control protocol at the Iubw interface. Modifications of this protocol and the amount of exchanged information differ for centralized and distributed CRRM. Collecting information on the WLAN load needs a new WLAN-AP control protocol to be specified, which is independent of the CRRM model.

In order to take into account the CRRM decisions on suitable APs, modifications of the IEEE 802.11 MAC algorithm are necessary. These modifications are needed to give priority to a recent CRRM suggestion on the AP over the standard procedure. In case the suggestion is missing, the association request is sent to the AP with the strongest signal, as usual.

B. *CRRM for WLAN-independent architectural option*

The major difference to the WLAN-dependent option relates to the fact that control information may be carried over any of the air interfaces and the decision algorithm on suitable base stations should consider here both NodeBs and APs.

Centralized CRRM model resembles the one described for previous architectural option and requires similar modifications to the affected control protocols. All the CRRM functionality is located in the RNC. Delivery of information on neighbouring base stations and the CRRM suggestions are carried over the RRC protocol, when the WCDMA interface is active, as depicted in Figure 3a). In the case the UE is attached to WLAN, the same protocol can be used, since in the WLAN-independent architecture, the RRC is provided within the WLAN. The centralized CRRM model for the case the WLAN interface is active is shown in Figure 3b).

For distributed CRRM model and the active WCDMA interface, amount of the UE-RNC signalling is the same as for centralized CRRM. It is carried over the RRC protocol, as shown in Figure 4a). Only the communication at the Iubw interface is different and resembles the one in the distributed CRRM model for the WLAN-dependent option. It allows the RNC to require suggestions on APs for a UE handover, but here is the IWU additionally allowed to ask the RNC for information on NodeBs. Having information on all types of base stations, the IWU and RNC are both able to provide suggestions on suitable base stations for handover.

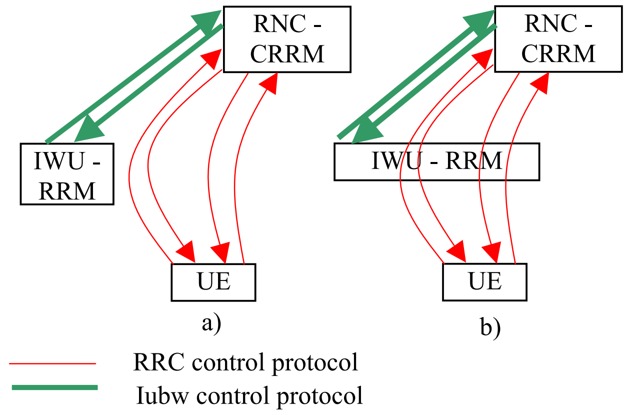

Figure 3. Centralized CRRM model for the case a) WCDMA interface is active b) WLAN interface is active

Actual delivery of these suggestions to the UE when the WLAN interface is active is performed in a different way for the distributed CRRM. Although the RRC protocol is still accessible in the WLAN, it is not used in order to avoid unnecessary signalling at the Iubw interface. Instead, a new IWU-UE control protocol is introduced, as shown in Figure 4b). The new WLAN control protocol should carry information on signal strength of neighbouring base stations from UEs and suggestions from the CRRM entity that is here the IWU.

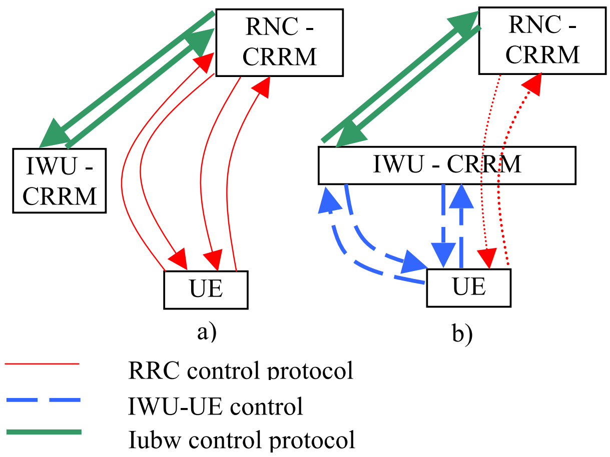

Figure 4. Distributed CRRM model for the case a) WCDMA interface is active b) WLAN interface is active

In order to apply suggestions received by the CRRM, similar modifications to the 802.11 MAC algorithm for choosing target base stations are needed as for the WLAN-dependent option, with a difference that here all types of base stations are taken into account. A suggestion on a suitable base station may come from the RNC or IWU, depending on the CRRM model and active air interface. If there is no timely received decision, the UE will attach to a default base station. Otherwise, type of the suggested base station triggers running of the related algorithm, which should obey to the network decision.

Taking this into account, it can be concluded that, although both centralized and distributed CRRM can be applied to the WLAN-independent architectural option, distributed CRRM model is more favourable, due to sharing of the CRRM functionality between the RNC and IWU and reducing signalling at the Iubw interface. However, this approach requires specification of an additional control protocol.

V. CONCLUSION

This paper discussed the introduction of a common radio resource management entity for the management of resources in UMTS-WLAN integration at the UMTS radio access. We concentrated on two architectures that differ in the degree of WLAN dependency on the UMTS support for signalling. For both of them, two CRRM models, centralized and distributed, were considered. Effects of the CRRM functionality on the control protocols and existing standards were also discussed.

For the dependent WLAN option, the difference between the centralized and distributed CRRM approach is minor, as most CRRM functionality must be located at the RNC. For the independent WLAN architectural option, the distributed approach seems as a more suitable solution.

Introduction of the CRRM affects the control protocols in the integrated network. Which protocols require modifications and to what degree depends on the interworking architectural option and the applied CRRM model. No matter how the CRRM is implemented, modifications of the IEEE 802.11 standard are needed in order to apply the network command to associate with a particular AP.

Introduction of the CRRM in the WLAN-UMTS integrated architecture at the radio access offers several advantages. Due to the high degree of coupling of the networks, it allows for facilitating network load balance and utilisation of the available networks resources in a more efficient manner. Having control over networks of different capabilities, better services can be offered and the desired QoS level can be provided at a lower cost. Common radio resource management also promises to enhance vertical handover procedure, as the current state of all types of neighbouring base stations can be considered during the handover decision phase. Network control over all the available resources can improve vertical handover performance, as part of the handover activities can be performed in advance.

ACKNOWLEDGMENT

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