WLAN-UMTS INTEGRATION TO OPTIMIZE MBMS PROVISION

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ABSTRACT

Provision of multimedia services with high bandwidth demands is constantly increasing its share in mobile systems. Aiming a more efficient distribution of multicast/broadcast contents in the UMTS networks, 3GPP introduced the Multimedia Broadcast Multicast Service (MBMS). Even though this technology brought significant improvements regarding the network efficiency, the UTRAN (UMTS Terrestrial Radio Access Network) remains the network's most vulnerable area due to its shortage resources. The integration of wireless LAN (WLAN) access technology in cellular data networks to enhance their services coverage and increase data rates, is an extremely interesting solution for operators. In addition, this solution based on WLAN is easily deployed and can provide additional license-free bandwidth. Therefore, this paper addresses a possible WLAN integration, which uses a UMTS Access Point (UAP) that establishes a WLAN tunnel to provide MBMS data services to UEs with both UMTS and WLAN interfaces. Using this simulation environment, we pretend to measure and conclude about the benefits achieved from merging these two access technologies when delivering MBMS services.[1]

I. INTRODUCTION

As the deployment of mobile technology increases and the capabilities of mobile equipment improves, not only services are becoming more demanding when it comes to their contents quality, but also they are being targeted to a much wider amount of users. Multicast and broadcast communications are consequently very suitable for the delivery of these emerging IP-based services.

The main breakthrough of the MBMS is the ability to reduce the allocated resources when providing data with high bandwidth requirements, such as multimedia video streaming, to a group of users. This is achieved not only by reducing to only one the data stream entering the UTRAN (in the Iu interface) from the core network (CN), but also through the introduction of the Point-to-Multipoint (PtM) cell state, in addition to the Point-to-Point (PtP). While the PtP transmission mode uses a Dedicated Channel (DCH) for each MBMS user within the cell, the PtM transmission provides a MBMS service to the whole cell area using a single Forward Access Channel (FACH) shared by all interested users, leading to power savings if the service is broadcasted to a significant number of users.

However, when high bit rate contents are delivered to a large number of users, the ability of cellular networks to accomplish the required service quality as the coverage area increases becomes more problematic. Therefore, a way of overcoming the limited macro cell capacity and improve multimedia service delivery is to install smaller cells, also referred as Personal Cells, to provide a higher data rate per area. Besides 3G cellular networks, personal cells can implement other access technologies and take advantage from their combination to improve radio and network resource efficiency.

Looking at the different available access technologies, WLAN is the most widely spread one to provide high data rate coverage in small areas. Consequently, integrating it with UMTS cellular networks is considered as an appealing solution for enhancing the operator's data services capacity. There are some proposals that envisage this goal [11, 12, 13, 14]. However, concerning the delivery of MBMS services over WLAN extensions from the cellular network, few is know about its success. Alike the MBMS common channel mechanism, WLAN packets are distributed using a medium that is shared by all the intervening users. Although the WLAN shared medium may offer low capacity when numerous users are transmitting and receiving different traffic, if we consider that MBMS is mainly aimed for services consisting of equal contents to several users, this WLAN limitation fades away.

In Section II we justify the development of our WLAN interworking approach by analyzing the involved technology characteristics and different WLAN integration mechanisms. Section III provides technical details related to our implementation. The evaluation approach is presented in Section IV, and the simulation results are presented and analyzed in Section V. Finally, we will draw the overall conclusions from this research in Section VI.

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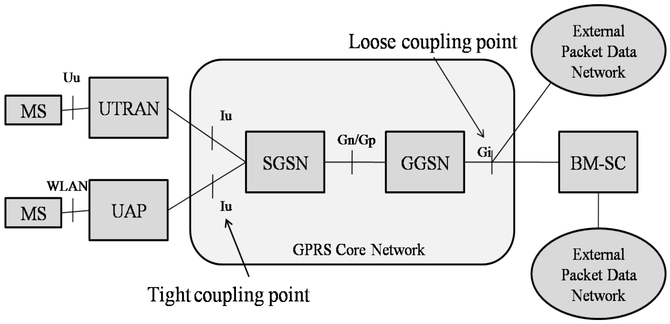

Figure 1 GPRS reference diagram showing the WLAN coupling points

II. RELATED WORK

A. Integration

As far as integration is concerned, the proposed approaches [1][2] can be divided into the IP-based approach or loose coupling, and the UMTS-based or tight coupling (Fig. 1). Loose coupling is carried out in the *Gi* reference point of GPRS (with an architecture that for the purpose of the current paper is similar to the one of UMTS), providing WLAN an independent behavior from UMTS since data traffic access bypasses the UMTS core network, even though they can share the same subscriber database. Tight coupling, on the contrary, connects to the UMTS core network like any other radio access network (RAN), hence making use of the same control protocols and routing traffic through the UMTS core network (CN) [3].

Considering UMTS interworking applications for small coverage areas, we find *femtocell* technology highly relevant to our research. Femtocells are UMTS base-stations designed for use in residential and small business environments, in which the traffic is forwarded to the UMTS CN using a regular broadband Ethernet connection. Although the original *femtocell* proposal required the integration of all the UMTS RAN and CN node functionalities, this architecture was modified by the newly released 3GPP standard that aims to spread the *femtocell* technology deployment through its standardization [4]. Although most of the UMTS based *femtocell's* issues are related to UMTS conflicts driven from the micro-cell integration within the macro-cell [5], their concept can be equally applicable to other air interfaces, such as Wi-Fi.

The new 3GPP *femtocell* concept (Fig. 2) is formed by a Home Node-B (HNB) Access Network composed by two new network elements: the HNB or femtocell, and the HNB Gateway (GW). The main divergence from the original concept is that these two nodes connect through a new interface, known as Iu-h, which serves the same purpose for the HNB as the interface between the RNC and the CN. This tighter interworking approach allows the *femtocell* to use the most of the control plane UMTS functionalities. This is possible through the Iu-h's reliable method of transporting signaling information between the HNB and HNBGW, consisting of the new HNB Application Part (HNBAP) protocol and the RANAP User Adaptation protocol. The HNBAP provides registration both to the HNB and the UE, where the HNB registration allows it to obtain service and CN connectivity from the HNBGW, while the UE registration procedure provides the means for the HNB to carry UE identification data so that the HNBGW may perform access control for the UE. Using the RUA protocol transparent, the CN can transfer to the UE RANAP messages required for RAB management.

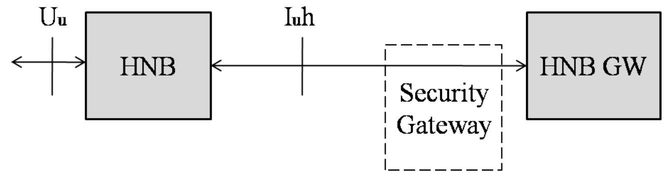

Figure 2 HNB access network elements

Using this architecture, through the HNBAP and RUA protocols implementation, the CN would interface with the *femtocell* and the RNC likewise. Even though this is an interesting option to provide WLAN interworking with UMTS, it introduces complexity due to the need of configuring two new protocols in OPNet. Therefore we choose to follow a simpler tight approach where the node responsible for bridging the two access technologies, the UAP, connects directly to the SGSN. This tight interworking is much more appealing since it allows us to reuse the UMTS and WLAN control protocols, hence, deals with radio aspects only. The UAP node is responsible for establishing a WLAN tunnel to exchange data between the CN and the modified equipments (UW), possessing both UMTS and WLAN interfaces, and so UMTS data services can be provided to the UWs. Likewise, we can achieve integration at the same level as the *femtocell* technology without compromising the accuracy of the results needed for our research. Further integration technical details, regarding the relationship between the UAP and the UMTS CN, are considered in Section III.

B. MBMS

For the UMTS network to support MBMS, not only the Broadcast/Multicast Service Centre (BM-SC) must be added, but also the GGSN, the SGSN, the RAN and the UE are modified [6]. MBMS groups are identified by a standard multicast class D IP address as well as an Access Point Name (APN) specifying the GGSN serving a specific UMTS network. Since MBMS groups are closed, the UE must first subscribe to a service whose data is unidirectional and can only be sent by the GGSN identified with the APN. The IGMP provides a join/leave mechanism in the MBMS group management. When willing to receive a specific multicast service the UE sends a join message to the GGSN, triggering a multicast activation procedure to establish the multicast distribution tree between the BM-SC and the UEs. This activation procedure is required for a node to receive multicast packets from its parent, and to charge the receivers for taking part of the group. Therefore, each node sets a MBMS Bearer Context (MBC) for each multicast group and creates a MBMS UE Context (MUEC) for each UE that is participating in the group.

When the service is about to start, the BM-SC sends a session start message that propagates through all registered nodes within the respective group, namely the SGSN that instructs the RAN to establish the appropriate radio bearers for data transmission, based on the QoS parameters of the service. At this point, each RNC has to decide whether the channel types established for this service are Point-to-point (PtP) or Point-to-multipoint (PtM), but never both at the same time. However there are proposal that advise the opposite [15]. As stated before, when a service has a significant number of users, the PtM channel can be advantageous. However, due to the power control limitations of the physical channel where the PtM FACH transport channel is set, the common channel covering an area is initially configured to cover the whole cell area regardless of the UEs position on the cell [7]. On the contrary, DCH has the capability of adjusting transmission power in accordance with the required strength to reach the UE. As a result, when the number of users participating in a MBMS service is low or when these users tend to locate near the BS, the FACH establishment can result in power wasting.

At first [8], the RNC decided the transmission mode comparing the number of users participating in each service with a predefined threshold, whose value is usually obtained from the number of DCH channels at the cell edge that equal the FACH's power (the worst case). However, this approach does not address the UE position on the cell, hence, Power Counting mechanism was proposed [9] to solve the inaccuracy of the UE counting mechanism for the cases where the users concentrate near the BS. In this method, the downlink transmitted power of the required PtP channels should be estimated and compared with the corresponding PtM's, in order to assess the most advantageous channel type before initiating a service or to decide whether a channel switching should be performed for an ongoing session.

III. Technical Details

The first stage of this work was focused on the UMTS network integration. The UAP (UMTS/WIFI Access Point) registers itself in the UMTS network as a regular RNC possessing just one Node-B cell, providing RANAP functionalities to the SGSN. Also, it behaves like an 802.11 Access Point that establishes a WLAN connection where UMTS traffic for/from the serving UEs is tunneled.

For our tight approach scenario, the integration method of 3GPP services is the following:

--*UMTS association*: the GMM attach process between the UE and the SGSN remains unaffected;

--*Admission control*: In opposing to the resources verification and allocation before establishing radio bearers, the implemented 802.11a/g does not allow channel reservation. Consequently, while the UTRAN assures the delivery of content with a specific QoS, in the UAP the connection is performed on a best-effort basis;

--*Access control and charging*: PDP contexts containing the subscriber's session information are maintained, even though the corresponding RAB set by the UAP is performed over a WLAN connection instead of the UTRAN radio links established in the RNC;

--*Roaming*: The BSS and access technology is manually chosen by the UW. Even though handover between WLAN and UMTS is not implemented, they are considered in our implementation to aid future extensions;

--*Access to PS services*: Due to our options, UE can easily receive UMTS data services.

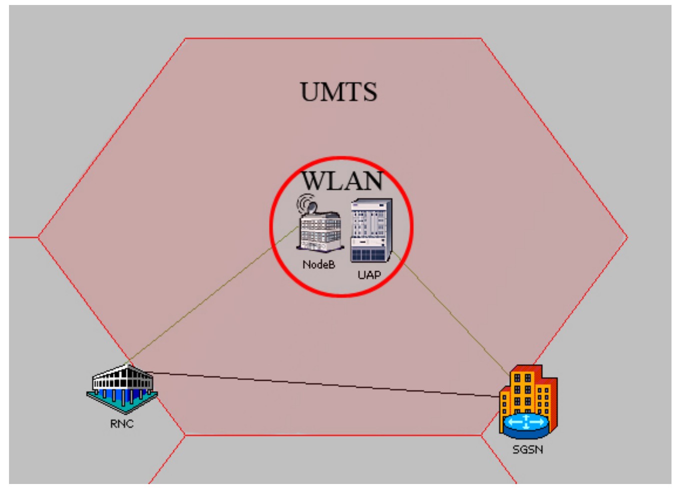

Figure 3. Scenario 1 simulation topology

The B-Bone MBMS Project [10], which developed an MBMS extension for OPNet Modeler 11.0.A UMTS module based on the 3GPP Release 7 MBMS specifications [8], was considered as the starting point to provide MBMS support in the UAP. The main difference from standard MBMS is that we consider PtM as the only transmission mode available, due to the WLAN shared medium approach. Also, when setting the RABs corresponding to an MBMS session, no admission control is performed since RABs are established on top of 802.11a/g without support for resource allocation.

IV. Evaluation Approach

This study tries to evaluate the gains obtained by combining WLAN and UMTS technologies when delivering MBMS services in personal cells. For this purpose, differences between two scenarios will be analyzed when considering a typical MBMS CBR video content with a throughput of 64 Kbit/s delivered to a constantly increasing number of MBMS users.

Scenario 1 (Fig. 3), combines both UMTS and the proposed WLAN interworking mechanism. WLAN access is always available in the first 90 meters. It is assumed that all users within the 90m range only use WiFi. However, the cell diameter will vary from 90 up to 380 meters, increasing in 10 and 20 meter steps depending on the radius (Table 1), implying that UMTS is used for distances above 90 meters, competing with WiFi. The FACH channel coverage distance will be equally increased to keep up with the cell. Several tests were then performed, for different cell radius, so that it would be possible to determine until which point the WLAN coverage can be significantly advantageous.

Scenario 2 conditions are similar to the first scenario, however, for this case only UMTS will be considered, so that we can compare the proposed cell configuration with the standard 3GPP's.

As aforementioned, PtM mode is chosen when it is assumed as the most efficient method. By introducing WiFi, the UMTS network can postpone the PtP to PtM transition for a higher number of served UEs. In order to estimate the amount of radio resources saved from combining both access technologies, the average number of users that will justify the FACH is compared for both scenarios.

For scenario 2, a simple approach adopted in [7] points an estimate of 8 DCH channels needed to exceed the power of the FACH channel.

With a random distribution of UEs, some will fall under the influence of WiFi with the probability,

$$(\pi 90^2/\pi r^2) \quad (1)$$

Figure 4 shows the total number of UEs needed to achieve the power threshold for different cell radius in both scenarios.

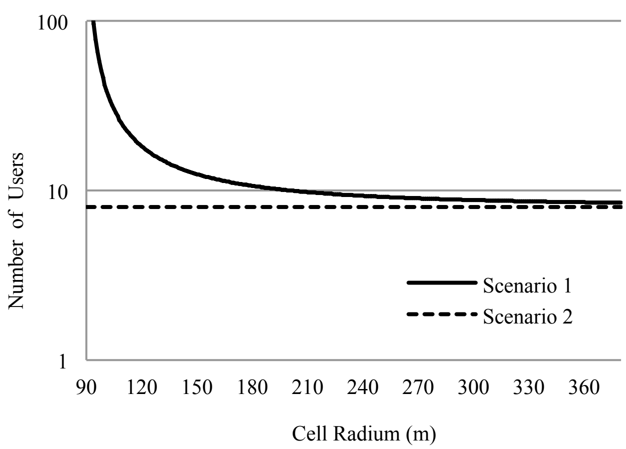

Figure 4. Number of UEs that trigger the PtM establishment assuming 8 DCHs as the switching threshold

As shown in Figure 4, initially most UEs are within the WLAN range. As the cell increases, so does the probability of a user establishing a UMTS connection. For /110 meters cells the WLAN influence remains very strong, since 24 users are required to trigger switching for the PtM mode. At 160 meters the WLAN delays the need of channel transition by 3 UEs (total of 11 UES). Only at 285 meters WiFi remains almost irrelevant, serving only 10% of the UEs.

However this UE Counting approach considers the worst possible case, i.e., assuming that all UEs are requiring maximum power (as if they were located at the cell edge). Since we assume a random UE distribution in the cell, it is expected that the DCH/FACH ratio to remains well below 8. It is important to use a more accurate approach, such as the counting of the DCH power consumption. In the next section we will present and comment the results obtained from the simulation of a power counting approach [9] in OPNet Modeler 11.0.A.

V. SIMULATION RESULTS

The power counting method measures the overall DCH power consumption considering UEs distances to the cell center, and compares it with the FACH power, that is fixed for each cell size.

The session starts with one associated user, and then a new user joins the MBMS session every 20 seconds. Every new user joins the service at a random position in the cell, and in case it falls under the UMTS coverage area the corresponding DCH connection shall be established. Each simulation ends when the total DCH consumed power equals or exceeds the amount of power required by the FACH channel.

Table I - Simulation Parameters

Parameter	Value
Video	CBR 64 Kbit/s
WiFi radius	90 m
Cell radius	90-380 m
Increasing steps (meters)	10 (90-160)
	20(160-380)

Analyzing the obtained results, first of all, for scenario 2, we can verify that by considering the DCH power counting of randomly distributed users for channel switching purposes, the number of UEs required to reach the FACH's consumed power almost duplicates (16 DCHs) in comparison with the equivalent worst case (i.e. scenario 2) discussed in section IV. In addition, for the scenario1, the number of UEs needed to reach the FACH's power is the same as discussed before (i.e. 8), regardless of the cell size.

Looking at Figure 5 and the respective values (Table II), it is visible that the WLAN has a greater impact when the size is very small. When the cell has 100 meter of radius, the number of UEs required for triggering the FACH establishment more than doubles (226%). At 110 meters, 68% of the UEs are served by WiFi, which avoids setting a FACH channel until 25 UEs join the same session.

Table II - Simulation Values

Cell Size (m)	Number of UEs Scenario 1	Number of UEs Scenario 2
90	*	15
100	34	15
110	25	15
120	21	16
140	18	15
160	17	15
180	17	15
200	16	14
300	17	16
380	17	15

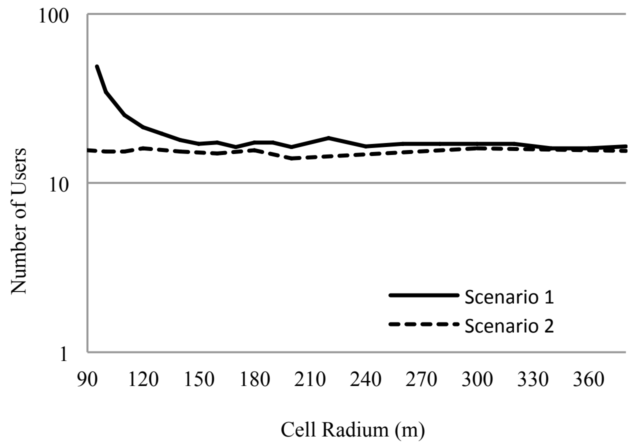

Figure 5. Number of UEs that trigger the PtM establishment considering power counting

As the cell size increases, so does the UMTS coverage area. At 140 meters, while the average number of DCHs needed to equal the FACH's power is increased to 11, the probability of a UE being served by the WiFi reduces to around 38%. As a result, the overall DCH consumed power justifies switching to the PtM mode when at least 18 UEs join the session.

When the radius reaches 240 meters, the use of both access technologies results in a gain of at most 2 UEs, as the probability of a UE falling under a WiFi area is only 18%. From this point on, the difference on the number of UEs needed to establish a FACH channel between the two scenarios gets narrower.

As the cell continues to increase, the share of the WiFi on the overall coverage area loses significance, and so it is the average DCH power consumption that sets the channel transition threshold value. As a result both scenarios will behave equally, since the number of DCHs needed to reach the FACH consumed power in scenario 1 tends to be the same as in scenario 2.

VI. CONCLUSIONS

In this paper, we assess the combination of UMTS with a WLAN interworking mechanism, in order to enhance the delivery of MBMS services.

We start by concluding that the use of power counting over a simpler UE Counting approach improves the efficiency of the network resources allocation.

For small cell areas, the WiFi has such a great influence that, even though the established DCHs have high power comsuption, it results on a significant increase of the UEs number required to establish the FACH channel, when compared with a UMTS exclusive coverage. From the performed simulations we verifiy that, until a radius of 120 meters the inclusion of WiFi technology is able to deviate enough UEs from the UMTS network, postponing the need for establishing a FACH channel to compensante possible DCH power wasting. Also, we can verify that for a range of 140 meters the WLAN is still considerably advantageous. Therefore, we can conclude that the combination of WLAN and UMTS is a suitable mechanism for enhancing multimedia service delivery in personall or micro cells scenarios.

As the cell size increases, the WiFi positive contribution is significantly reduced to a point that it can disregarded. In section IV, it is extimated that the neglictibe effect of WiFi would happen around 280 meters onwards. However in the simulation results obtained in section V, it is hard to accuretly determine at which point the WiFi influence becomes irrelevant.

In future works, we will focus on the WLAN coverage area capabilities, namely the adaptation of the WiFi range in accordance with different MBMS bit-rate requirements. For this reason, we shall attempt to optimize the WLAN interworking mechanim by considering other features, such as: 802.11E, to assure the WLAN users QoS requirements similar to the existent in UMTS networks; admission control capabilities on the UAP; assymetric transmission mode to provide more importance to downlik traffic, which is the predominant transmission for this type of services.

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