Power Saving Techniques in MBMS Multicast Mode

Antonios Alexiou, Christos Bouras, Vasileios Kokkinos
Research Academic Computer Technology Institute, Greece and
Computer Engineering and Informatics Dept., Univ. of Patras, Greece
University of Patras, Rio Campus, 26500 Rio, Patras, Greece
+302610996951, +302610996954
alexiua@cti.gr, bouras@cti.gr, kokkinos@cti.gr

ABSTRACT
Multimedia Broadcast Multicast Services (MBMS) was introduced in Third Generation Partnership Project (3GPP) Release 6 in order to more efficiently use network and radio resources for the transmission of multimedia services both in the core network and, most importantly, in the air interface of UTRAN (UMTS Terrestrial Radio Access Network). From the radio perspective, MBMS includes point-to-point (PtP) and point-to-multipoint (PtM) modes. The latter aims to overcome network congestion when a large number of users request the same content. One of the most important aspects in MBMS is power control. The fact that Node B's transmission power is a limited resource and must be shared among all MBMS users in a cell indicates the need for power control during an MBMS service. Techniques, such us rate splitting and mixed usage of transport channels can be used to reduce the power requirement of delivering multicast traffic for MBMS users. To this direction, this paper presents simulation results that will reinforce the need for the usage of such techniques and will reveal the amount of power that is saved.

Categories and Subject Descriptors
C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design – *Wireless communication*; C.2.3 [**Computer-Communication Networks**]: Network Operations – *Network Management, Public networks*; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems – *Evaluation/methodology*.

General Terms
Design, Management, Performance, Verification.

Keywords
UMTS, Power Control, Power Saving Techniques, Switching Point, MBMS, FACH, DCH.

WMuNeP'07, October 26, 2007, Chania, Crete Island, Greece.

1. INTRODUCTION
Universal Mobile Telecommunications System (UMTS) constitutes the third generation (3G) of cellular wireless networks which aims to provide high-speed data access along with real time voice and video calls. Wireless data is one of the major boosters of wireless communications and one of the main motivations of the next generation standards [1].

At first, UMTS offered tele-services (e.g voice and SMS) and Bearer Services for point-to-point transmission using the Unicast technology. Later, with the introduction of new services, such as IP Video Conferencing, Streaming Video and others, there was an increasing need for communication between one sender and many receivers, leading to the need of point-to-multipoint (PtM) transmission. One efficient way to implement this type of transmission is the use of broadcast and multicast technologies [2]. The 3rd Generation Partnership Project realized the need for broadcasting and multicasting in UMTS and proposed some enhancements on the UMTS Release 6 architecture that led to the definition of the MBMS framework. MBMS is a point-to-multipoint service in which data is transmitted from a single source entity to multiple destinations, allowing the networks resources to be shared [3], [4].

Power control is one of the most important aspects in MBMS due to the fact that Node B's transmission power is a limited resource and must be shared among all MBMS users in a cell. The main purpose of power control is to minimize the transmitted power, thus avoiding unnecessary high power levels and eliminating intercell interference. As transmission power plays a fundamental role in the process of planning and optimization of UMTS radio access networks, its analysis is supposed to be of great importance. This analysis is the main objective of this paper. Several techniques have been proposed for the reduction of Node B's transmission power. Succinctly, some of these techniques are: Dynamic Power Setting, Usage of longer Transmission Time Interval (TTI) and Space Diversity, Macro Diversity Combining, Rate Splitting and mixed Usage of Multiple DCH channels and FACH [5].

Moreover, the benefits of using different transport channels for the transmission of the multicast data over the UTRAN interfaces are investigated. The transport channels, in the downlink, currently existing in UMTS which could be used to serve MBMS are the Dedicated Channel (DCH), the Forward Access Channel (FACH) and the High Speed Downlink Shared Channel (HS-DSCH). Each channel has different characteristics in terms of power control. In this paper, FACH and DCH channels will be examined, while the benefits of the mixed usage of these two channels will be investigated. Based on this analysis we will propose a power based scheme for the selection of the most efficient channel. The importance of the selection of the most efficient transport channel in terms of power consumption is a key point for the MBMS, since a wrong transport channel selection for the transmission of the MBMS data could result to a significant decrease in the total capacity of the system. The main problem is that the Radio Network Controllers (RNC) do not have the information about the instantaneous transmitted power of each user, and need to know what the exact number of PtP connections that are "equivalent" to a single PtM connection is. In other words, the determination of the "ideal" switching point between multiple DCHs and FACH is essential for the reduction of the transmission power.

Several studies and simulations have been carried out focusing on the reduction of the Node B's transmission power and on the threshold for switching between dedicated and common resources in terms of transmission power during an MBMS session. In [6] is claimed that for a FACH with transmission power set to 4 Watt, the threshold for switching from dedicated to common resources is around 7 UEs per cell/sector, while in [7] the threshold is 5 UEs. However, only the information about the number of users in a cell/sector may not be sufficient so as to select the appropriate radio bearer (PtP or PtM) for the specific cell/sector. The decision has to take into account the total power required for the transmission of the multicast data in the PtP and PtM cases. An interesting study under this assumption is presented in [8] where the authors propose a switching point (based on power consumption) of 5 UEs between dedicated and common resources. In [9] the authors have presented an analysis of the factors that affect the switching point (based on power consumption) between multiple DCHs and FACH in micro and macro cell environments. On the other hand, in [5] and [10] the authors have investigated several techniques in order to reduce the FACH transmission power, thus decreasing the switching thresholds.

The paper is structured as follows. Section 2 provides an overview of the UMTS and MBMS architecture. In Section 3, we present the problems in terms of power consumption during a MBMS session and we provide an overview of the proposed solutions. Section 4 constitutes an introduction in the analysis of the power control in MBMS; Section 5 presents the topology deployment and the main simulation assumptions, while the results of the analysis are presented in Section 6. Finally, some concluding remarks and planned next steps are briefly described in Section 7.

2. UMTS AND MBMS ARCHITECTURE

UMTS network is split in two main domains: the User Equipment (UE) domain and the Public Land Mobile Network (PLMN) domain. The UE domain consists of the equipment employed by the user to access the UMTS services. The PLMN domain consists of two land-based infrastructures: the Core Network (CN) and the UTRAN (Figure 1). The CN is responsible for switching/routing voice and data connections, while the UTRAN handles all radio-related functionalities. The CN is logically divided into two service domains: the Circuit-Switched (CS) service domain and the Packet-Switched (PS) service domain [1]. The CS domain handles the voice-related traffic, while the PS domain handles the packet transfer. In the remainder of this paper, we will focus on the UMTS packet-switching mechanism.

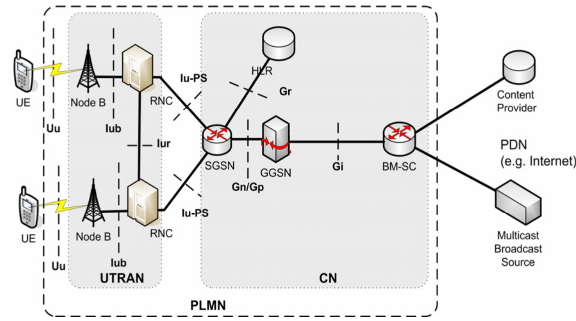

Figure 1. UMTS and MBMS Architecture

The PS portion of the CN in UMTS consists of two kinds of General Packet Radio Service (GPRS) Support Nodes (GSNs), namely Gateway GSN (GGSN) and Serving GSN (SGSN) (Figure 1). SGSN is the centerpiece of the PS domain. It provides routing functionality interacts with databases (like Home Location Register (HLR)) and manages many Radio Network Controllers (RNCs). SGSN is connected to GGSN via the Gn interface and to RNCs via the Iu interface. GGSN provides the interconnection of UMTS network (through the Broadcast Multicast–Service Center) with other Packet Data Networks (PDNs) like the Internet [1], [11].

UTRAN consists of two kinds of nodes: the first is the RNC and the second is the Node B. Node B constitutes the base station and provides radio coverage to one or more cells (Figure 1). Node B is connected to the User Equipment (UE) via the Uu interface (based on the Wideband Code Division Multiple Access, WCDMA technology) and to the RNC via the Iub interface. One RNC with all the connected to it Node Bs is called Radio Network Subsystem (RNS) [1].

3GPP is currently standardizing the MBMS framework. Actually, the MBMS is an IP datacast (IPDC) type of service, which can be offered via existing GSM and UMTS cellular networks. It consists of a MBMS bearer service and a MBMS user service. The latter represents applications, which offer for example multimedia content to the users, while the MBMS bearer service provides methods for user authorization, charging and Quality of Service (QoS) improvement to prevent unauthorized reception [3]. The major modification in the existing GPRS platform is the addition of a new entity called BM-SC. As Figure 1 depicts, BM-SC communicates with both the existing UMTS network and external PDNs [3].

As the term MBMS indicates, there are two types of service mode: the broadcast and the multicast mode. In broadcast mode, data is delivered to a specified area without knowing the receivers and whether there is any receiver at all in this area. On the other hand, in the multicast mode the receivers have to signal their interest for the data reception to the network and then the network decides whether the user may receive the data or not.

Regarding the transmission of the packets over the Iub and Uu interfaces, it may be performed on common or dedicated transport channels. As presented in [12], the transport channel that the 3GPP decided to use as the main transport channel for PtM MBMS data transmission is the FACH with turbo coding and

QPSK modulation at a constant transmission power. DCH is a PtP channel and hence, it suffers from the inefficiencies of requiring multiple DCHs to carry the data to a group of users. However, DCH can employ fast closed-loop power control and soft handover mechanisms and generally is a highly reliable channel.

3. PROBLEM STATEMENT AND PROPOSED TECHNIQUES

In this section, the two main problems during a MBMS session are highlighted and the proposed techniques to overcome these problems are presented. The analysis that follows will constitute the guide for our assumptions and simulation experiments.

The first problem during an MBMS service (in order to be more precise, this is a general problem and not only in the case of MBMS) is that although each Node B knows exactly the instantaneous transmitted power of each user that it serves; the RNC does not have this information and needs to know what the exact number of PtP connections that are "equivalent" to a single PtM connection is. In other words, the appropriate (depending on the used technique) switching points between multiple DCHs and FACH should be determined with precision. The determination will provide the RNC with the possibility of commanding the Node B to switch between these channels, based only on the number of users, with main objective the reduction of the transmission power. The easiest way to overcome this problem is to use only the FACH for the delivery of the MBMS service (DCHs will never be deployed); however, since Node B will have high losses of power (specifically when the number of users is small), this way is immediately rejected. Therefore, the determination of the appropriate switching points seems to be a one way road.

The second problem during an MBMS session, in terms of power consumption, is the exceedingly high fixed power levels when allocating FACH as transport channel. Synoptically, the proposed techniques that partly overcome this problem, thus reducing the Node B's transmission power (not just the FACH transmission power), are stated in the remaining of this section.

3.1 Efficient Channel Selection

We mention this technique first as it is the most obvious and thoroughly studied. It concerns the selection of the most efficient channel during a MBMS session in terms of power consumption. The transport channels which could be used to serve MBMS are the DCH and the FACH; however, each channel has different characteristics in terms of power control. Taking into account the factors that affect the Node B's transmission power levels during an MBMS session (such as, cell deployment, propagation models, QoS requirements, users' distributions and mobility issues) a power based scheme for the selection of the most efficient channel can be extracted. The importance of the selection of the most efficient transport channel is a key point for the MBMS, since a wrong transport channel selection for the transmission of the MBMS data could result to a significant decrease in the total capacity of the system [9]. The decision should be taken after calculating the total cell transmitted power in each case. However, in order to have an efficient switch of channel, the number of users above which the most appropriate channel is FACH should be determined with precision.

Experimental results have shown that for small number of users high sums of power can be saved (compared to the case where only FACH was used). This power gain is increased as the number of users decreases [9]. Therefore this technique will be analyzed alone and in combination with the other two techniques (3.2 and 3.3).

3.2 Rate Splitting

The Rate Splitting technique assumes that the MBMS data stream is scalable, thus it can be split into several streams with different QoS. Only the most important stream is sent to all the users in the cell to provide the basic service. The less important streams are sent with less amount of power or coding protection and only the users who have better channel conditions (i.e. the users close to Node B) can receive those to enhance the quality on top of the basic MBMS. This way, transmission power for the most important MBMS stream can be reduced because the data rate is reduced, and the transmission power for the less important streams can also be reduced because the coverage requirement is relaxed [15].

In our experiments we will consider that a 64 kbps service can be split in two streams of 32 kbps. The first 32 kbps stream (basic stream) is supposed to carry the important information of the MBMS service (therefore it must be provided throughout the whole cell, i.e. a FACH with such power so as to provide 95% coverage must be used). On the other hand, the second 32 kbps stream (less important stream) is sent only to the users who are close to the Node B. To this direction, a FACH with such power so as to provide 50% coverage must be used, providing the users in the particular region with the possibility of receiving the full 64 kbps service.

3.3 Mixed Usage of Multiple DCH channels and FACH

The mixed usage of DCHs and FACH can significantly decrease the Node B's transmission power, depending on the number and the location of the users that receive the MBMS service. In this approach, the FACH channel only covers the inner part of the sector (50% in our experiments) and provides a 64 kbps service to the users that are found in this part. The rest of the users are served using DCH to cover the remaining outer cell area. The total downlink power consumption including FACH and dedicated channels obviously depends on the number of users who are served by DCHs and their location [16].

Several more techniques have been proposed for the reduction of Node B's transmission power. Briefly, some of these techniques are: Dynamic power setting [5], Usage of longer TTI and Space Diversity [13], Macro-diversity [10] and Handover Control [14]. High sums of power can be saved with these techniques; however, the examination of power savings and the determination of the appropriate switching points when these techniques are used will be the subject of research of a future work.

In this paper the power gain from techniques 3.1, 3.2 and 3.3 will be examined. A combination of these techniques will also be examined in order to reveal the additional power gain. Furthermore, the appropriate switching point between multiple DCHs and FACH in each case will be determined.

4. POWER PLANNING OF MBMS IN UTRAN

The RNC for radio efficiency reasons, can use either dedicated resources (one DCH for each UE in the cell), or common resources (one FACH for all the UEs) to distribute the same content in a cell.

The total downlink transmission power allocated for all MBMS users in a cell that are served by multiple DCHs is variable. It mainly depends on the number of UEs, their location in the cell, the required bit rate of the MBMS session and the experienced signal quality E_b/N_0 for each user. Equation (1) calculates the Node B's total transmission power required for the transmission of the data to n users in a specific cell [17].

$$P_T = \frac{P_P + \sum_{i=1}^{n} \frac{\frac{(P_N + x_i)}{W}}{\frac{W}{(E_b/N_0)_i R_{b,i}} + p} L_{p,i}}{1 - \sum_{i=1}^{n} \frac{p}{\frac{W}{(E_b/N_0)_i R_{b,i}} + p}} \qquad (1)$$

where P_T is the base station total transmitted power, P_{Ti} is the power devoted to the *i*th user, P_P is the power devoted to common control channels, $L_{p,i}$ is the path loss, $R_{b,i}$ the *i*th user transmission rate, W the bandwidth, P_N the background noise, p is the orthogonality factor (p = 0 for perfect orthogonality) and x_i is the intercell interference observed by the *i*th user given as a function of the transmitted power by the neighboring cells P_{Tj}, j=1,…K and the path loss from this user to the *j*th cell L_{ij}. More specifically [17]:

$$x_i = \sum_{j=1}^{K} \frac{P_{Tj}}{L_{ij}} \qquad (2)$$

On the other hand, a FACH channel essentially transmits at a fixed power level since fast power control is not supported in this channel. A FACH channel must be received by all UEs throughout the desirable cell part. Consequently, the fixed power should be high enough to ensure the requested QoS in the desired coverage area of the cell and independently of UEs location.

Table 1. FACH Tx Power Levels

% Cell Coverage	Service Bit Rate (kbps)	Required Power (Watt)
50	32	1.8
	64	2.5
95	32	4.0
	64	7.6

The FACH transmission power levels presented in Table 1 correspond to the case where no Space Time Transmit Diversity (STTD) is assumed. In addition, TTI 80ms and 1% BLER target is assumed [5], [8].

5. TOPOLOGY DEPLOYMENT - SIMULATION ASSUMPTIONS

In this section, the topology deployment that was used in our simulation is presented. Figure 2 depicts the macro cell environment, which consists of 18 hexagonal grid cells, while the main simulation assumptions are presented in Table 2 [8], [18] and [19].

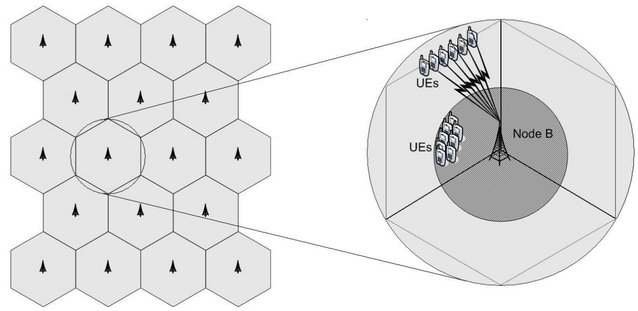

Figure 2. Macrocell Topology

As can be observed from Table 2, in macro cell environment, the Okumura Hata's path loss model is employed which, considering a carrier frequency of 2 GHz and a base station antenna height of 15 meters, is transformed to Equation (3):

$$L = 128.1 + 37.6\, Log10(R) \qquad (3)$$

where R represents the distance between the UE and the Node B in Km [18].

Table 2. Simulation Assumptions

Parameter	Value
Cellular layout	Hexagonal grid
Number of neighboring cells	18
Sectorization	3 sectors/cell
Site to site distance	1 Km
Cell radius	0,577 Km
Maximum BS Tx power	20 W (43 dBm)
Other BS Tx power	5 W (37 dBm)
Common channel power	1 W (30 dBm)
Propagation model	Okumura Hata
Multipath channel	Vehicular A (3km/h)
Orthogonality factor (0 : perfect orthogonality)	0.5
Eb/N0 target	5 dB

6. RESULTS

In this section, analytical simulation results, distinctly for each of the aforementioned techniques, are presented. Moreover, a combination of these techniques is examined in order to reveal the additional power gain. Transmission power levels when using DCH or FACH channels are depicted in the most of the following figures. The aim for this parallel plotting is to determine the most efficient transport channel (i.e. the appropriate switching points) in terms of power consumption, for the transmission of the MBMS data.

6.1 Efficient Channel Selection

As there are many factors that affect the Node B's transmission power levels during an MBMS session, it should be mentioned that the figures in this paragraph correspond to the simulation assumptions presented in Table 2. Consequently, two different cases are examined, depending on the region that is desired to be covered. In the first case the region is the 50% of the cell (Figure 3), while in second the 95% of the cell (Figure 4). Each figure represents the power required for the transmission of a MBMS service (32 or 64 kbps) as a function of the number of users, both in the cases when DCH or FACH channels are used.

The examination of these two figures reveals that in the case of 50% cell coverage (Figure 3), with this technique up to 0.8 Watt can be saved while delivering a 32 kbps service and up to 1.4 Watt while delivering a 64 kbps service. For 95% cell coverage (Figure 4) the gain reaches 2.7 watt for a 32 kbps service and 6.0 Watt for a 64 kbps service (all these values correspond to the case of one UE). The power savings decreases as the number of users increases, in both figures, while from a number of users and above a switch from DCHs to FACH should take place.

As these figures present, when DCHs are used as transport channel, the starting value of the total power is 1 Watt [17]. This is the power devoted to common control channels (term P_p in Equation 1) that is added for the calculation of the power when DCHs are used and has been taken into account in all the simulations. According to Equation 1 this constant term is only added once, regardless of the number of users and their location.

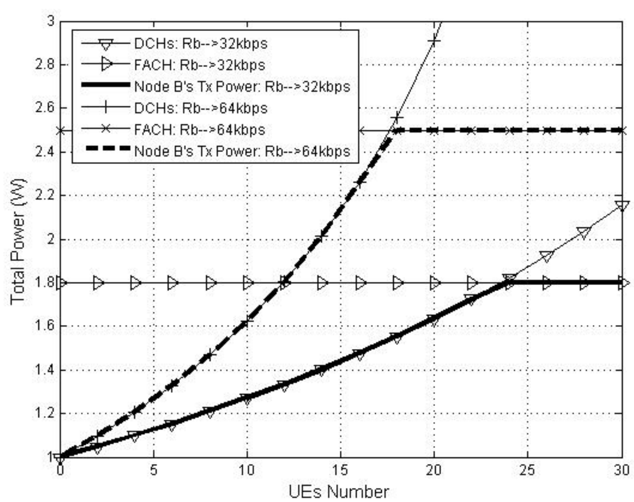

Figure 3. Tx Power for 50% Coverage

The switching points between DCHs and FACH are the following:

For 50% cell coverage

- 23 UEs for a 32 kbps service.
- 17 UEs for a 64 kbps service.

For 95% cell coverage

- 10 UEs both for a 32 kbps and 64 kbps service.

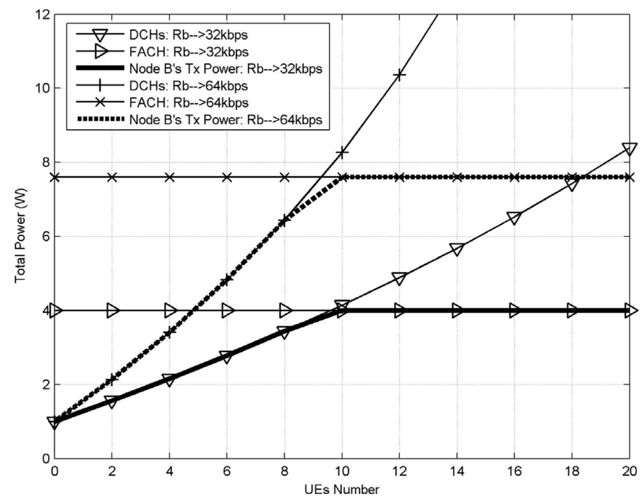

Figure 4. Tx Power for 95% Coverage

Above these numbers of UEs, FACH is the most appropriate channel for the transmission of the multicast data in terms of power consumption. This is the only information that the RNC needs in order to command the Node B to change the transport channel. Many more cases could be distinguished, since there are many factors that influence the transmission power. However, the above two figures are representative of how this technique can considerably decrease the Node B's transmission power.

6.2 Rate Splitting

According to this technique the first 32 kbps stream (basic stream of the 64 kbps service) is provided throughout the whole cell, while the second 32 kbps stream is sent only to the users who are close to the Node B providing the users in the particular region the full 64 kbps service. Figure 5 depicts the way this technique functions, in terms of channel selection and cell coverage.

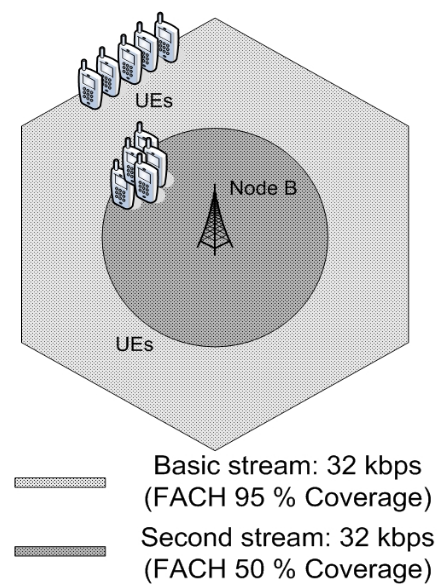

Figure 5. Rate Splitting

From Table 1 it can be seen that this technique requires 5.8 Watt (4.0 for the basic stream and 1.8 for the second). On the other hand, in order to deliver a 64 kbps service using a FACH with 95% coverage the required power would be 7.6 Watt. Thus, 1.8 Watt can be saved using the Rate Splitting technique. However, it is worth mentioning that this power gain involves certain negative results. Some of the users will not be fully satisfied, as they will only receive the 32 kbps of the 64 kbps service, even if these 32 kbps have the important information. As the observed difference will be small, the Node B should weigh between the transmission power and the users' requirements.

6.3 Mixed Usage of Multiple DCH channels and FACH

Figure 6 represents the way of provisioning a 64 kbps service in the "Mixed Usage of Multiple DCH channels and FACH" case. According to Figure 6, FACH channel covers the inner part (50%) of the sector and provides a 64 kbps service to the users that are found in this part (called "inner part" users from now on). The users that reside at the outer part are served using DCH (called "outer part" users from now on).

The main goal is to examine how the transmission power is affected by the number of users. To this direction Figure 7 represents the Node B's total transmission power as a function of the number of the "outer part" users. The total power in Figure 7 includes the power that is required in order to cover the 50% of the cell with FACH (i.e. 2.5 Watt). The number of the "inner part" users is assumed to be greater than 17, so as to justify the choice of FACH as the transport channel in the inner part (see Figure 3).

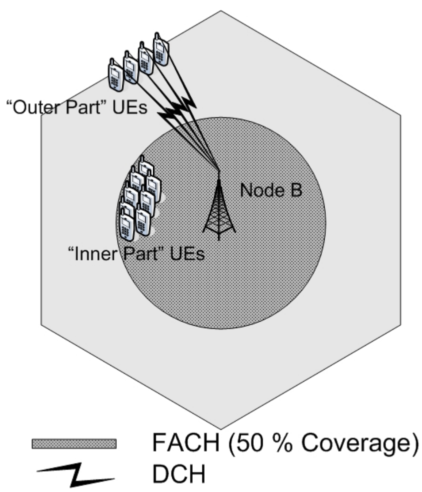

Figure 6. Mixed DCHs and FACH

Figure 7 also depicts the power level that is required in order to deliver a 64 kbps service using FACH with 95% coverage. This addition aims at the determination of the appropriate switching point between multiple DCHs and FACH. When the "outer part" users are more than six, the total power (the power to cover the inner part with FACH plus the power to cover the outer part with DCHs) exceeds the power that is required in order to cover the whole cell with FACH. Thereby, it is more "power efficient" to use a FACH with 95% coverage. Thus, the appropriate switching point (which is independent of the number of "inner part" users) is 6 "outer part" UEs. At this point it is worth mentioning that this switching point refers to the worst case, where all the "outer part" users are found at the cell edge. There would be an increase in the switching point if the distance of the "outer part" users from the Node B decreased.

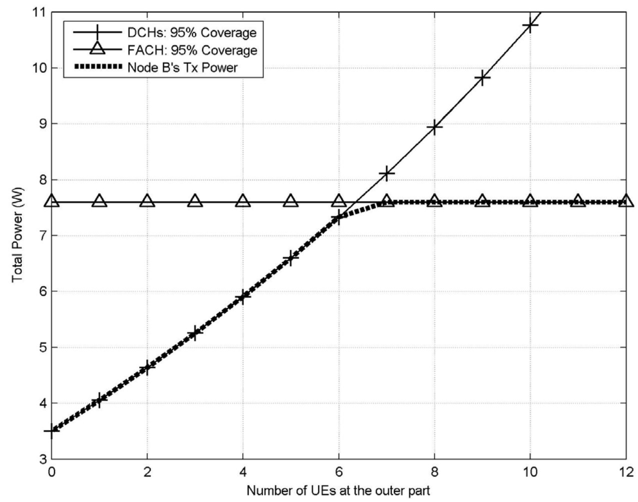

Figure 7. Tx Power for the "Mixed Usage of Multiple DCH channels and FACH" case

Apart from the power gain, this technique has one more advantage which does not become immediately perceptible. This advantage has to do with the fact that DCHs can support soft handover, while FACH cannot. Since with this technique the users that are found near the cell edge are served with DCHs, their transition to another cell will be much smoother, as the service will be provided uninterruptedly.

6.4 Combination of techniques 3.1, 3.2 and 3.3

The combination of these techniques presents special interest as additional power gain can be saved. In order to reveal this additional power gain a scenario will be examined, in which it is more efficient to use a combination of the techniques 3.1, 3.2 and 3.3. Figure 8 presents the way that the users appear, according to the scenario and the most efficient channel in each step.

The results of the simulation are presented in Figure 9. The bold line presents the Node B's total transmission power while combining the three techniques. In Figure 9, the action of "Efficient Channel Selection" technique is appeared for number of users up to 17, the action of "Mixed Usage of Multiple DCH channels and FACH" technique for 18 up to 31 users, while the action of "Rate Splitting" technique for 32 users and above. The results can be distinguished in three categories. Power gain when the combination is used, compared to the case of using:

- None of the techniques.
- Only "Rate Splitting" technique.
- Only "Mixed Usage of Multiple DCH channels and FACH" technique.

When none of the techniques is used, a FACH with fixed power level should be used in order to serve the whole cell. This fixed power level appears in Figure 9 with bold dashed line (for 64 kbps service and 95% coverage). With the combination of techniques, the required power never reaches this power level, as presented in Figure 9. The power gain reaches 6.6 Watt for the case of one user and 1.8 Watt when the number of users forces the Node B to transmit at the power level that is required for the Rate Splitting technique (for more than 31 users). Consequently, about 9% to 33% of maximum Node B's transmission power can be saved, leaving this power for other applications (e.g. voice calls, web browsing, etc.).

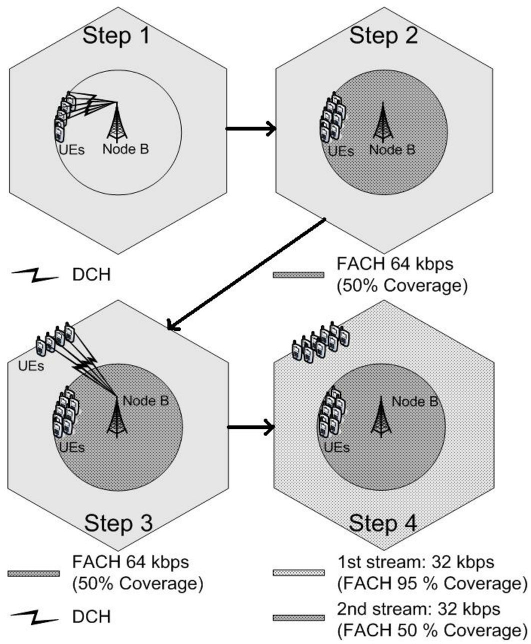

Figure 8. Scenario Steps

The importance of the combination compared to the case of using only the Rate Splitting technique, appears in Figure 9 for UEs' number up to 31 (this number may changes depending on the scenario, or more precisely depending on number of users that are served by the FACH with 50% coverage). As the power that is required for Rate Splitting technique is constant, the power gain with the combination can reach 4.8 Watt (24% of maximum Node B's transmission power).

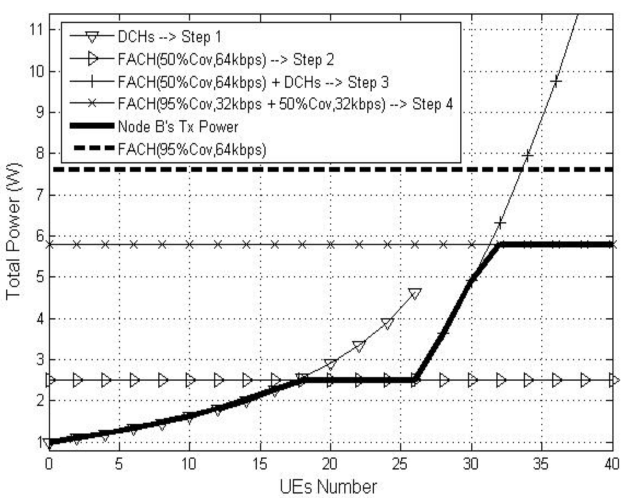

Figure 9. Tx Power for the Combination of the Techniques

Finally, the combination can produce power gain compared to the case of using only the "Mixed Usage of Multiple DCH channels and FACH" technique. In our scenario this gain is presented for UE population smaller than 17. Substantially, this is the switching point between DCHs and FACH when 50% coverage is required (see Figure 3). Up to 1.4 Watt (or 7% of maximum Node B's transmission power) can be saved through the combination.

Summarizing, the usage of the combination in the particular scenario is the optimal solution. According to Figure 9, for any UE population the required Node B's power is decreased compared to the case when none or only one of the technique was used. There are many other scenarios that can verify that the usage of combination outperforms compared to the usage of each technique separately.

However, the goal is to define a scheme that will efficiently cover all the possible scenarios. For the determination of this scheme we will consider the number of "inner part" users as the main parameter. We will define which is the most efficient technique (depending on the number of the "outer part" users), while the number of "inner part" users changes. After taking into consideration the previous analysis Table 3 can be extracted.

The number of "inner part" users and the switching points (or the number of "outer part" users) that are presented in Table 3 refer to the worst case, where the "outer part" users are found at the cell edge and "inner part" users at the half distance. Having covered the worst case it is obvious that any other case is covered having small losses of power. This is a convention that should be made in order to keep the scheme simple and constant.

Table 3. Switching Points and Most Efficient Technique as a Function of the "Inner Part" Users

"Inner Part" Users	"Outer Part" Users	Efficient Channel or Technique
1 to 4	≤ 7	Multiple DCHs
	> 7	Rate Splitting
5 to 17	≤ 6	Multiple DCHs
	> 6	Rate Splitting
17 +	≤ 5	Mixed DCHs and FACH
	> 5	Rate Splitting

The RNC knows the distance of each user via its path loss. When FACH is used for the transmission of the MBMS service, the information about the path loss is sent to the RNC through the Random Access Channel (RACH). On the other hand, when DCH is used there is no need for utilizing another channel, as DCH is bidirectional. Thereby, the RNC is always aware of the number of "inner" and "outer part" users and may command the Node B to select the most efficient channel (or technique) according to Table 3.

7. CONCLUSIONS AND FUTURE WORK

In this paper, we presented an overview of the MBMS multicast mode of UMTS. We underlined the importance of the analysis of transmission power, when delivering MBMS data in the downlink, for the optimization of UMTS networks. We investigated three techniques that could substantially decrease the Node B's transmission power and we determined the power gain that each technique has. Moreover, we examined a scenario with the combination of these techniques, which revealed the additional power gain that could be saved. Finally, the appropriate switching points between DCHs and FACH for each technique were determined.

The step that follows this work is to examine the power gain through other techniques, such as Dynamic power setting, Usage of longer TTI and Space Diversity, Macro-diversity and Handover Control. Having examined all these techniques, an ambitious future step will be the determination of the most suitable technique, or the most suitable combination for the transmission of MBMS of service.

8. REFERENCES

[1] H. Holma, and A. Toskala, “WCDMA for UMTS: Radio Access for Third Generation Mobile Communications”, John Wiley & Sons, 2004. ISBN 0-470-87096-6.

[2] C. Christophorou, A. Pitsillides, “An Efficient Handover Algorithm for MBMS Enabled 3G Mobile Cellular Networks”, 11th IEEE Symposium on Computers and Communications (ISCC'06), Sardinia, Italy, 2006, pp. 187-193.

[3] 3GPP, TR 22.146 v6.5.0, Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service; Stage 1 (Release 6).

[4] 3GPP, TR 23.846 v6.1.0, Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service; Architecture and functional description (Release 6).

[5] P. Chuah, T. Hu, W. Luo, “UMTS Release 99/4 Airlink Enhancement for supporting MBMS Services”, 2004 IEEE Conference on Communications, Paris, France, 2004, vol. 6, 20-24, pp. 3231-3235.

[6] IST-2001-35125 (OverDRiVE), Deliverable of the project (D08), “Spectrum Efficient Multicast and Asymmetric Services in UMTS”, Available at: http://www.comnets.rwthaachen.de/~o_drive/publications/OverDRiVE_wp1d08_v100.pdf.

[7] J. de Vriendt, I. Gomez Vinagre, A. Van Ewijk, “Multimedia Broadcast and Multicast Services in 3G Mobile Networks”, Alcatel Telecommunication Review, 4th Quarter 2003/1st Quarter 2004.

[8] IST-2003-507607 (B-BONE), Deliverable of the project (D2.5), “Final Results with combined enhancements of the Air Interface”, Available at: http://b-bone.ptinovacao.pt.

[9] A. Alexiou, C. Bouras, V. Kokkinos, E. Rekkas, “MBMS Power Planning in Macro and Micro Cell Environments”, Second IEEE Workshop on multimedia Applications over Wireless Networks (MediaWiN 2007), Aveiro, Portugal, 2007, (to appear).

[10] A. Soares, A. Correia, J. Silva, N. Souto, “UE Counting Mechanism for MBMS Considering PtM Macro Diversity Combining Support in UMTS Networks”, IEEE Ninth International Symposium, Manaus-Amazon, Brazil, 2006 , pp. 361-365.

[11] 3GPP TS 23.060 V7.0.0. Technical Specification Group Services and System Aspects; General Packet Radio Service (GPRS); Service description; Stage 2 (Release 7).

[12] 3GPP TS 25.346 v7.1.0, Technical Specification Group Radio Access Network; Introduction of the Multimedia Broadcast Multicast Service (MBMS) in the Radio Access Network (RAN), (Release 7).

[13] 3GPP TSG-RAN WG1#28, Evaluation of combining gains for MBMS (incl. STTD), Qualcomm, R1-021234, October, 2002.

[14] C. Christophorou, A. Pitsillides, “MBMS Handover Control for Efficient Multicasting in IP-Based 3G Mobile Networks”, 2006 IEEE International Conference on Communications (ICC 2006), Istanbul, Turkey, 2006, pp. 2112-2117.

[15] 3GPP TSG-RAN WG1#28, MBMS Power Usage, Lucent Technologies, R1-021239, October, 2002.

[16] 3GPP TSG-RAN WG1#28, Power Usage for Mixed FACH and DCH for MBMS, Lucent Technologies, R1-021240, October, 2002.

[17] J. Perez-Romero, O. Sallent, R. Agusti, M. Diaz-Guerra, “Radio Resource Management Strategies in UMTS”, John Wiley & Sons, 2005. ISBN-10 0-470-02277-9.

[18] 3GPP TR 101.102 V3.2.0. Universal Mobile Telecommunications System (UMTS); Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.2.0).

[19] 3GPP TS 25.803 v6.0.0, Technical Specification Group Radio Access Network; S-CCPCH performance for MBMS, (Release 6).