Power Efficient Radio Bearer Selection in MBMS Multicast Mode

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ABSTRACT
Multimedia Broadcast Multicast Services (MBMS) was introduced in Third Generation Partnership Project (3GPP) Release 6 in order to address the need for the efficient usage of the expensive radio resources. The goal of this effort is to support downlink streaming and download-and-play type services to large groups of users. From the radio perspective, MBMS includes point-to-point (PtP) and point-to-multipoint (PtM) modes. 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. Consequently, the analysis of the transmitted power plays a fundamental role in the planning and optimization process of Universal Mobile Telecommunications System (UMTS) radio access networks. In this paper we investigate the factors that affect the Node B's transmission power levels during an MBMS session, such as, cell deployment, propagation models, users' distributions and mobility issues. To this direction, the transport channels in the downlink, currently existing in UMTS which could be used to transmit the multicast data over the UMTS Terrestrial Radio-Access Network (UTRAN) interfaces are examined.

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
Radio Bearer Selection, Power Control, Switching Point, MBMS, FACH, DCH, HS-DSCH.

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1. INTRODUCTION
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 PtP 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 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 PtM service in which data is transmitted from a single source entity to multiple destinations [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. Consequently, the analysis of the transmitted power plays a fundamental role in the planning and optimization process of UMTS radio access networks. This paper investigates several factors affecting Node B's transmission power levels such as, cell deployment, propagation models, QoS requirements, users' distributions and mobility issues.

Furthermore, 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). In this paper, all these transport channels will be examined and a power based scheme for the selection of the most efficient channel will be proposed. The selection of the most efficient transport channel in terms of power consumption is a key point for the MBMS, since a wrong channel selection could result to a significant decrease in the total capacity of the system.

Several studies and simulations have been carried out focusing on the threshold for switching between dedicated and common resources in terms of transmission power. In [5] 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, while in [6] the threshold is 5 UEs. However, only the information about the number of users in a cell may not be sufficient so as to select the appropriate radio bearer (PtP or PtM) for the specific cell. 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 [7] where the authors propose a switching point (based on power consumption) of 5 UEs between dedicated and common resources. Finally, in [8] 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. However, the switching point between PtP and PtM is expected to increase with the introduction of High Speed Downlink Packet Access (HSDPA) technology.

The paper is structured as follows. Section 2 provides an overview of the UMTS and MBMS architecture. In Section 3, we present an analysis of the power control in MBMS, while Section 4 presents the results of the analysis. Finally, some concluding remarks and planned next steps are briefly described.

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.

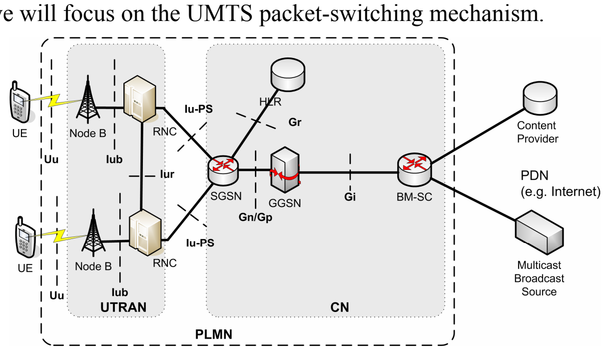

Figure 1. UMTS and MBMS Architecture

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], [9].

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 [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 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. However, in the multicast mode the receivers have to signal their interest in order to receive the data.

Regarding the transmission of the packets over the Iub and Uu interfaces, it may be performed on common (i.e. FACH), dedicated (i.e. DCH) or shared (i.e. HS-DSCH) transport channels. As presented in [10], 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. The HS-DSCH was introduced as the primary radio bearer in Release 5 of UMTS. The HS-DSCH resources can be shared between users in a particular sector and can offer higher bit rates.

3. POWER PLANNING OF MBMS IN UTRAN

As already mentioned, this paper investigates several factors that affect the Node B's transmission power levels. The first factor examined is the cell deployment. To this direction, power planning of MBMS is investigated separately for macro and micro cell environments.

The RNC for radio efficiency reasons, can use either dedicated resources (one DCH for each UE in the cell), common resources (one FACH for all the UEs) or shared resources (one HS-DSCH shared by all UEs in a cell) 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 (close to the Node B or at cell edge) in the cell, the required bit rate of the MBMS session and the experienced signal quality E_b/N_0 for each user. Eqn(1) calculates the Node B's total transmission power required for the transmission of the data to n users in a specific cell [11] and can be applied both in macro and micro cell environments.

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

where P_T is the base station total transmitted power, P_{Ti} is the power devoted to the ith user ,P_P is the power devoted to common control channels $L_{p,i}$ is the path loss, $R_{b,i}$ the ith 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 ith 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 jth cell L_{ij}. More specifically [11]:

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

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 cell. Consequently, the fixed power should be high enough to ensure the requested QoS in the whole coverage area of the cell and independently of UEs location. FACH power efficiency depends on maximizing diversity as power resources are limited. Diversity can be obtained by the use of a longer TTI, e.g. 80ms instead of 20ms, to provide time diversity against fast fading (fortunately, MBMS services are not delay sensitive) and the use of combining transmissions from multiple cells to obtain macro diversity [12]. The bit rate of the MBMS service and the desirable coverage area of the cell are also factors that affect the allocated power for a FACH.

Finally, regarding the HS-DSCH, it has to be mentioned that it is rate controlled and not power controlled. There are mainly two different modes for allocating HSDPA transmission power to each Node B. In the first power allocation mode, the controlling RNC explicitly allocates a fixed amount of HSDPA transmission power per cell and may update HSDPA transmission power allocation any time later, while in the second mode the Node B is allowed to use any unused power in the cell (the remaining power after serving other, power controlled channels) for HS-DSCH transmission [13]. Each mode has a different impact on the obtained data rates and on capacity remaining to serve R99 users. As expected, HSDPA cell throughput increases when more HSDPA power is allocated, while DCH throughput simultaneously decreases. In this paper, we assume a fixed power allocation mode. More specifically, 35% of total Node B power is allocated to HSDPA [13]. With the above mentioned portion, MBMS services with higher bit rates can be supported, depending on the number of the users. These services would require prohibitively high power levels in the case where multiple DCHs or FACH channels were used.

3.1 Macrocell Planning

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. Furthermore, the main simulation assumptions (Table 1) for the case of the macro cell environment are presented [7], [14], [15].

As can be observed from Table 1, 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 Eqn(3):

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

where R represents the distance between the UE and the Node B in Km [14].

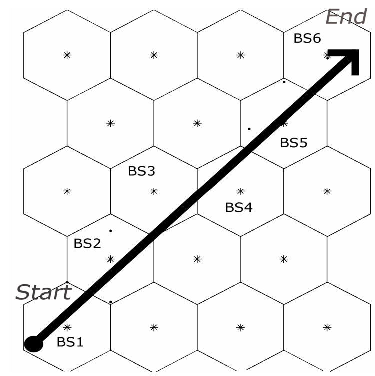

Figure 2. Macrocell Topology

Moreover, it should be mentioned that the fixed FACH transmission power for a 32Kbps MBMS service is set to 4 W (equal to 20.9% of BS total transmission power), for a 64Kbps MBMS service this value is set to 7.6 W (equal to 38% of BS total transmission power), while for a 128Kbps MBMS service FACH Tx power is 15.8 W (equal to 79% of BS total transmission power). These power levels correspond to the case where no Space Time Transmit Diversity (STTD) is assumed. In addition, TTI 80ms, 1% BLER target and geometry G = -6 (for 95% cell coverage) is assumed [7], [15].

Table 1. Macrocell 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
E_b/N_0 target	5 dB
FACH Tx power (no STTD, 95% coverage)	4 W (32Kbps service)
	7.6 W (64Kbps service)
	15.8 W (128Kbps service)
HS-DSCH Tx power	7 W

3.2 Microcell Planning

In the case of a micro cell environment the topology is represented in Figure 3, while the assumed simulation parameters are represented in Table 2 [7], [14], [15], [16]. In the case of micro cell environment the propagation model taken into account is the Walfish-Ikegami model with BS antenna below roof top level. According to this model, the path loss is given by Eqn(4):

$$L = 24 + 45\, Log10\, (d+20) \qquad (4)$$

where d is the shortest physical geographical distance between the BS and the UE (in meters).

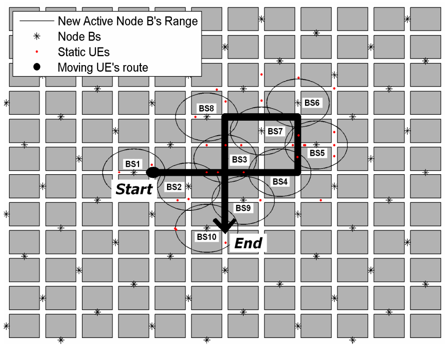

Figure 3. Microcell Topology

Furthermore, in the case of the micro cell environment, the FACH transmission power is assumed to be 0.36 W for a 64Kbps MBMS service (which corresponds to 18% of BS total transmission power). This power level is set so as to provide 95% cell coverage, while TTI is 80ms, BLER target is 1% and when no STTD is assumed [15], [16].

Table 2. Microcell simulation assumptions

Parameter	Value
Cellular layout	Manhattan grid
Number of cells	72
Block width : Road width : Building to building distance	75m : 15m : 90m
Straight line distance between transmitters	360m (4 blocks)
Maximum BS Tx power	2 W (33 dBm)
Other BS Tx power	0.5W (27 dBm)
Common channel power	0.1 W (20 dBm)
Propagation model	Walfish-Ikegami
Multipath channel	Pedestrian A 3Km/h
Orthogonality factor (0 : perfect orthogonality)	0.1
E_b/N_0 target	6 dB
FACH Tx power	0.36 W (64Kbps service)
HS-DSCH Tx power	0.7 W

As far as the HS-DSCH transmission power is concerned, it is constant and equal to 0.7 Watt. This constant value corresponds to 35% of total Node B power [13], which in the micro cell environment equals to 2 Watt.

4. RESULTS

In this section, analytical simulation results, distinctly for the cases of macro and micro cell environments, are presented. Transmission power levels when using DCH, FACH or HS-DSCH channels are depicted in each one of the following figures. The aim for this parallel plotting is to determine the most efficient transport channel, in terms of power consumption, for the transmission of the MBMS data.

4.1 Macro Cell Environment

The main goal of this paper is to investigate all the factors that affect the Node B's transmission power levels. To this direction, analytical simulation results are presented in order to compare the dedicated (DCH) to common or shared resources (FACH or HS-DSCH respectively), in terms of power consumption. The figures presented in this section depict the fluctuation of Node B's transmission power for varying simulation parameters in a macro cell environment. As our main target is to analyze the degree of the impact that several factors have on the Node B's transmission power, we give certain values to each factor separately. These values correspond to certain cases that do not limit the generality.

In Figure 4 the effect of UEs location throughout the cell is presented. When multiple DCHs are used, it is obvious that the further the UE is from the Node B the more power is required for successful delivery of MBMS service in a cell. The results are somewhat expected, meaning that it is quite expected to have increased power for longer distances. However, Figure 4 also depicts how the appropriate switching point between DCHs and FACH or HS-DSCH changes with distance (or cell coverage). For instance, the switching point between DCHs and FACH (for a 64 kbps service) for 95% cell coverage (or 550 m from BS) is 9 UEs. Above this number of UEs, FACH is the most appropriate channel for the transmission of the multicast data in terms of power consumption. On the other hand, the switching point between DCHs and HS-DSCH for the particular distance is 8 UEs. The switching point increases drastically even for a small decrease in the cell coverage. For 75% cell coverage (or 430 m distance from BS) the switching point between multiple DCHs and FACH increases in 14 UEs, while between DCHs and HS-DSCH in 19 UEs.

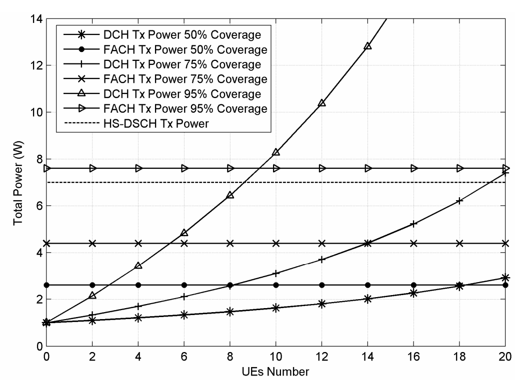

Figure 4. Macrocell - Tx power vs. Cell Coverage

For 50% cell coverage, as depicted in Figure 4, Node B's transmission power is low in the cases when DCH and FACH are used. For such cell coverage, HS-DSCH is inefficient for the transmission of MBMS services and Release 99 channels (DCH and FACH) are the appropriate channels to be deployed. For 50%

cell coverage the switching point between multiple DCHs and FACH is 18 UEs.

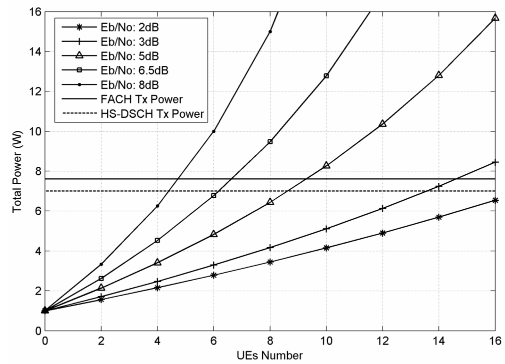

Figure 5. Macrocell - Tx power vs. E_b/N_0

Similarly, Figure 5 and Figure 6 show that as E_b/N_0 and MBMS bit rate increase, transmission power increases too. Simulation results presented in these figures correspond to the worst case scenario where 95% coverage is assumed. Additionally, these figures depict the impact of these parameters on the switching point between DCHs and FACH or HS-DSCH.

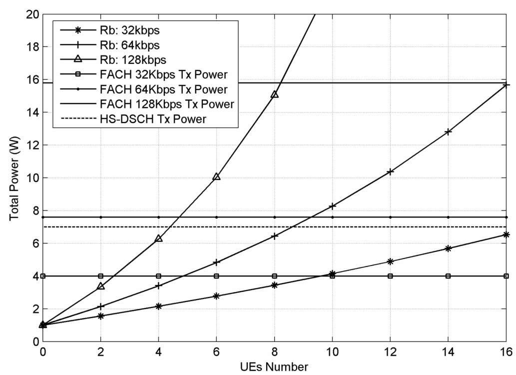

Figure 6. Macrocell - Tx power vs. bit rate

Figure 6 indicates that for a 128 kbps service, even for small number of UEs (more than 4), the power levels of DCHs and FACH channels become prohibitive. Allocating 15.8 Watt of the total Node B's power for a 128 kbps service will reduce dramatically the remaining power, which is necessary for other applications (e.g. voice calls). Taking into account this remark, the most appropriate channel to deliver services with such high bit rates is the HS-DSCH, as it can support about 17 UEs with a 128 kbps service, while the allocated power is 7 Watt (see Figure 14).

Another crucial factor that has to be taken into account is the transmission power of the cells that neighbour with the examined cell, expressed by the parameter P_{Tj} in Eqn(2). Figure 7 depicts the impact of this factor under the assumption that all neighbouring Node Bs transmit at the same power levels. Of course, it is rather impossible that all neighbouring Node Bs transmit at the same power level, but this is assumed here for better understanding of this parameter's significant impact. Higher transmission power of neighbouring Node Bs increases intercell interference, leading in turn the examined Node B to increase its transmission power in order to meet the MBMS service demands.

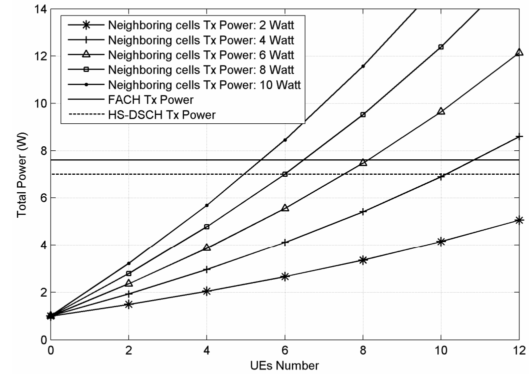

Figure 7. Macrocell - Tx power vs. Neighboring cells Tx power

Furthermore, a real-world scenario which simulates static and non-static UEs is examined. This scenario, for the case of a macro cell environment, is depicted in Figure 2. More specifically, in this scenario we assume a number of static UEs and a moving UE that, at simulation time 0 sec begins moving from the Start point towards the End point as shown in Figure 2. During this route, the moving UE enters and leaves successively the coverage area of 6 different macrocells, served by base stations BS1, BS2, …, BS6. The number of static UEs that each cell serves and their distance from the corresponding Node B are presented in Table 3.

Table 3. Static UEs in the scenario

Node B	Static MBMS Users	Distance (m)
BS1	6	425.7
BS2	12	540.7
BS3	4	453.7
BS4	8	493.2
BS5	13	527.2
BS6	3	304.6

Figure 8 presents the total transmission power (power required for the static UEs that it serves and the moving UE) of every Node B that serves the moving UE during its route. For instance, at time period t1 to t2 the moving UE is served by BS2. Specifically, at time t1, the moving UE enters the coverage area of the BS2, while at time t2 leaves this area.

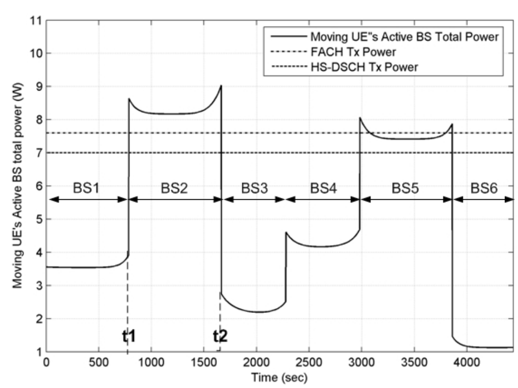

Figure 8. Macrocell - Moving UE's Active BS Tx power

Some important conclusions regarding the selection of the most efficient transport channel, in terms of power consumption, can be extracted from Figure 8. As mentioned above, the channel that requires less power resources, thus minimizing Node B's transmission power, is selected. In general, three different cases can be distinguished regarding the Node B's transmission power, since FACH and HS-DSCH transmission power is constant.

In the first case, the Node B's power consumed when using multiple DCHs is lower compared to the power consumed when using common or shared channels. In our simulation this scenario corresponds to the cases when the moving UE is served by BS1, BS3, BS4 and BS6. In these cases the most efficient channel for the transmission of the multicast data is the DCH.

In the second case, the Node B's power consumed when using multiple DCHs is higher compared to the power consumed when using FACH or HS-DSCH. In our simulation this scenario corresponds to the case when the moving UE is served by BS2. In this case the most efficient channel should be the FACH or the HS-DSCH, depending on the bit rate of the service and the number of the UEs that desire the MBMS service (see Figure 14).

In the third case, depending on the moving UE's position in the cell, the Node B's power consumed when using multiple DCHs is higher (when the moving UE is at the edge of the cell served by BS5) or lower (when the UE is close to the BS5) compared to the power consumed when using FACH or HS-DSCH. In this case the obvious solution would be to deploy FACH or HS-DSCH (when the moving UE enters the specific cell), multiple DCHs (while the UE is near the BS) and FACH or HS-DSCH (when the moving UE leaves the specific cell) respectively. However, the efficiency of switching transport channels at very short time periods, as in the case where the moving UE is at the edge and leaves the coverage area of BS5 (Figure 8), should be further examined in order to minimise ping-pong phenomena.

4.2 Micro Cell Environment

All the factors that were investigated for the macro cell environments will be also investigated for the case of the micro cell environments. In microcells, where street corners isolate the cells more strictly, the amount of intercell interference is lower than in macrocells. Moreover, in microcells there is less multipath propagation, and thus a better orthogonality of the downlink codes. On the other hand, less multipath propagation gives less multipath diversity, and therefore a higher E_b/N_0 requirement in the downlink in microcells than in macrocells is assumed.

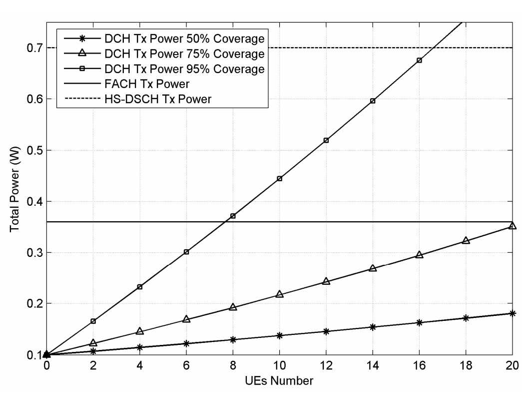

Figure 9. Microcell - Tx power vs. Cell Coverage

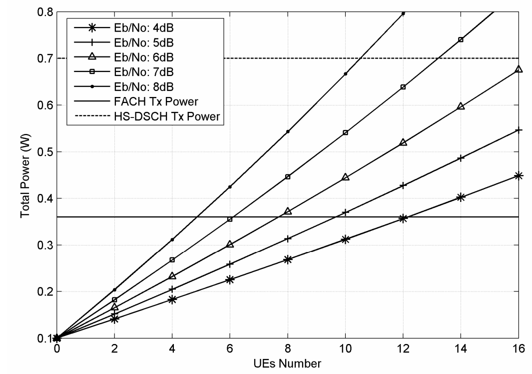

Figure 10. Microcell - Tx power vs. E_b/N_0

As in the macro cell environment, the impact of cell coverage, E_b/N_0, R_b and transmission power of neighbouring cells on the total Node B transmission power, in the case when DCH is used is depicted in Figure 9 - Figure 12. Moreover, in these figures the FACH and HS-DSCH fixed power levels are presented.

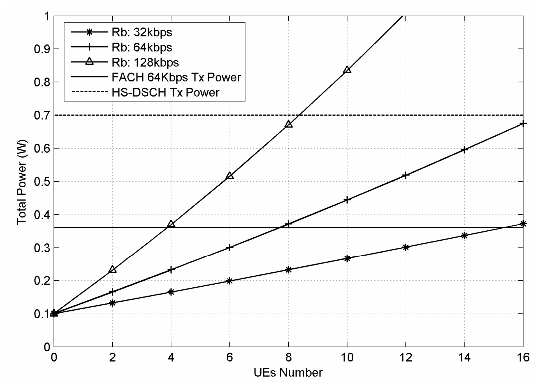

Figure 11. Microcell - TX power vs. bit rate

These figures also represent the impact that the above mentioned parameters have, on the selection of the most efficient transport channel. In general, an increase in the value of each parameter causes a decrease in the number of UEs that can efficiently be served by multiple DCHs.

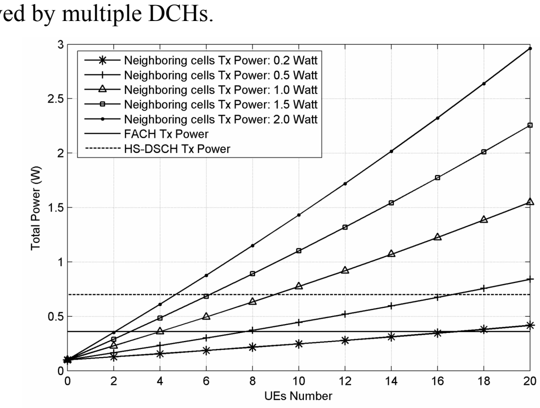

Figure 12. Microcell - Tx power vs. Neighboring cells Tx power

The examination of these figures reveals that for a small number of UEs, the most appropriate channel to deliver the multicast data is the DCH. However, the switching point between multiple DCHs and common or shared channels (FACH or HS-DSCH) varies depending on the environment conditions and the users' requirements. Each of the figures represents the degree of effect that the corresponding factor has on the switching point.

A scenario that consists of both static and non-static UEs, as in the case of the macro cell environment, is also examined. The route of the moving UE is shown in Figure 3, while Figure 13 presents the transmission power (when using DCH, FACH or HS-DSCH transport channels) of every Node B that serves the moving UE during its route.

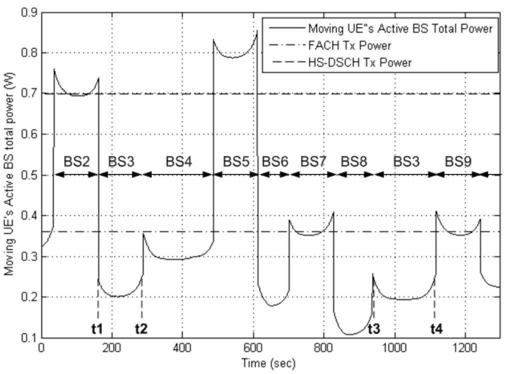

Figure 13. Microcell - Moving UE's Active BS Tx power

Similar to the analysis described in the macro cell case, the transport channel that requires less power resources is preferred to serve the MBMS users. For instance, when the moving UE is served by BS3 (during periods t2-t1 and t4-t3) the most efficient channel should be the DCH.

4.3 HS-DSCH and FACH Comparison

This section constitutes an additional explanation of the previous analysis. From Table 1 and Figure 4 to Figure 8, it can be noticed that the fixed transmission power of the FACH transport channel is always higher than the transmission power of HS-DSCH. This remark arise a reasonable question. What is the point in using the FACH to deliver the multicast data since HS-DSCH is more "power efficient"?

In the case of micro cell environments we notice the exact opposite (Table 2 and Figure 9 to Figure 13). The fixed transmission power of the FACH transport channel is always lower than the transmission power of HS-DSCH. However, the analysis that follows in the rest of this section attempts to make a comparison between FACH and HS-DSCH, thus it is independent of the cell deployment. The main difference, compared to macro cell environments, is that the micro cellular setup is characterized by higher isolation between neighboring cells which results in less other-cell interference as well as less multipath propagation. The average HSDPA cell throughput is therefore found to increase for micro cell environments. The larger HSDPA cell throughput in microcells is achievable because the HS-DSCH SINR at many of the users is sufficiently high to allow frequent transmission using 16QAM modulation [13].

As the HS-DSCH is not power controlled but rate controlled the best way to compare the HS-DSCH and FACH, would be by examining the *per user throughput* of each channel, while their fixed power remain in relatively similar levels. Figure 14 represents the *per user throughput* in the case of a macro cell environment. The transmission power for HS-DSCH is set to 7 Watt and for FACH to 7.6 Watt. By allocating 7.6 Watt of the Node B's power to a FACH, a 64 kbps service can be supported regardless of the UEs' number. The bit rate of the service is the main factor that affects the allocated power for a FACH (for a 128 kbps service 15.8 Watt should be allocated). At this point, it should be mentioned that a FACH can only support services with bit rates up to 128 kbps. More advanced solutions such as macro diversity combining are needed for higher bite rates such as 256 kbps [7]. On the other hand, by allocating 7 Watt to HS-DSCH, depending on the number of UEs, MBMS services with various bit rates can be supported. For a 64 kbps service about 35 users can receive the MBMS service (Figure 14). If the number of the users that desire the service increases, the rest of them will be kept unsatisfied.

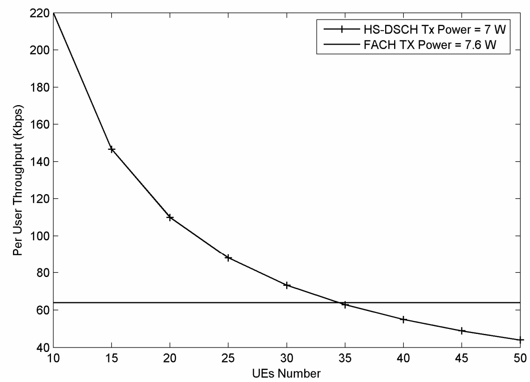

Figure 14. Macrocell - HS-DSCH vs. FACH

Figure 14 indicates that for a small number of UEs the HS-DSCH outperforms compared to the FACH. Although their fixed power remains in relatively similar levels, the first can support services with higher bit rates (depending on the number of UEs). However, for large UEs population, FACH is the most appropriate channel for the transmission of the multicast data, as it can support all the UEs, leaving none of them unsatisfied. In other words, the Node B should weigh the allocated power and the *per user throughput* so as to decide which is the most appropriate channel for the delivery of the MBMS data.

4.4 Switching Point Determination

Until now, we have considered several factors that affect the Node B's transmission power levels and we have analyzed whether is more economic to unicast (point-to-point) to group members rather than multicast (point-to-multipoint).

The decision was based taking as cost function the total cell transmitted power. In spite of the Node B knowing exactly what the instantaneous transmitted power of each user is, the RNC does not have this information and needs to know what is the exact number of PtP connections that are "equivalent" to a single PtM connection. After taking into account the comparison between HS-DSCH and FACH we will determine the exact switching point between the available transport channels.

The analysis revealed that in the case of macro cell environments, for a small number of UEs the most appropriate channel to deliver an MBMS service is the DCH. If the number of UEs that desire the MBMS data increases, HS-DSCH should be selected, while for even bigger numbers of UEs the FACH is the most appropriate channel. As an example, for a 64 kbps service the switching point between multiple DCHs and HS-DSCH is about 8 to 9 UEs (assuming the parameters' values of Table 1). For MBMS groups with a number of users higher than 35, FACH should be established to provide the required MBMS service. The above mentioned switching points may increase or decrease, depending on the value that the parameters of Table 1 have.

In the case of micro cell environments, the Node B should weigh the allocated power and the *per user throughput* so as to decide which is the most appropriate channel for the delivery of the MBMS data. If the requirement is the reduction of the allocated power, for a small number of UEs (up to 7) the appropriate solution would be the usage of multiple DCHs. For groups with more than 7 users FACH should be established. On the other hand, if the requirement is the *per user throughput*, a continuous increase in the number of users would lead to a switch from DCHs, to HS-DSCH and finally to FACH.

5. 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 efficient optimization of UMTS networks. Moreover, we investigated the impact of several factors (propagation models, QoS requirements, users' distributions and mobility issues) affecting Node B's transmission power for macro and micro cell environments; and we highlighted the degree of effect that each factor has on the Node B's transmission power. Finally, a power based switching scheme between DCH, FACH and HS-DSCH channels was presented in order to minimize power resources. The results revealed that all these transport channels could efficiently be used to deliver the MBMS services, depending on the number of users that desire the service and their requirements.

The step that follows this work is to analytically examine the impact of the HS-DSCH power allocation on achievable throughput. HSDPA is a key technology for MBMS as it improves performance and increases bit rate speeds. Experiments using the NS-2 simulator will be carried out for the purpose of this investigation. Experiments will also be carried out, in order to examine the power savings when using mixed DCH and FACH channels.

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