MBMS Power Planning in Macro and Micro Cell Environments

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Abstract

Multimedia Broadcast Multicast Services (MBMS), introduced in Third Generation Partnership Project (3GPP) Release 6, is a point-to-multipoint downlink bearer service that addresses the need for the efficient usage of the expensive radio resources. 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. Consequently, the analysis of transmitted power plays a fundamental role in the planning and optimization process of Universal Mobile Telecommunications System (UMTS) radio access networks. This paper investigates several factors affecting Node B's transmission power levels such as, cell deployment, propagation models, Quality of Service (QoS) requirements, users' distributions and mobility issues. Finally, different transport channels for the transmission of the multicast data over the UTRAN interfaces are considered.

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].

Along with the widespread deployment of the third generation cellular networks, the fast-improving capabilities of the mobile devices, content and service providers are increasingly interested in supporting multicast communications over UMTS. To this direction, the 3GPP is currently standardizing the MBMS framework of UMTS.

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 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). Each channel has different characteristics in terms of power control. In this paper, FACH and DCH channels will be examined and a power based scheme for the selection of the most efficient channel will be investigated.

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 issues that affect the Node B's transmission power during an MBMS session, while Section 4 is dedicated to the results. Finally, some concluding remarks and planned next steps are briefly described.

2. UMTS and MBMS architecture

A UMTS network consists of two land-based network segments: the Core Network (CN) and the UMTS Terrestrial Radio-Access Network (UTRAN) (Figure 1). The CN is responsible for switching/routing voice and data connections, while the UTRAN handles all radio-related functionalities. The CN consists of two service domains: the Circuit-Switched (CS) service domain and the Packet-

Switched (PS) service domain. 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). An SGSN is connected to GGSN via the Gn interface and to UTRAN via the Iu interface. UTRAN consists of the Radio Network Controller (RNC) and the Node B. Node B constitutes the base station and provides radio coverage to one or more cells. Node B is connected to the User Equipment (UE) via the Uu interface and to the RNC via the Iub interface [1], [8].

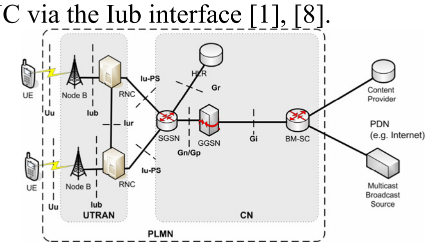

Figure 1. UMTS and MBMS Architecture

3GPP is currently standardizing the MBMS framework. Actually, the MBMS is an IP datacast type of service, which can be offered via existing GSM and UMTS cellular networks. The major modification in the existing GPRS platform is the addition of a new entity called BM-SC. The BM-SC communicates with the existing UMTS GSM networks and the external Public Data Networks [9].

3. Power planning of MBMS in UTRAN

Power planning of MBMS is investigated separately for macro and micro cell environments. The amount of intercell interference is lower in microcells where street corners isolate the cells more strictly 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 micro than in macro cells is assumed [1].

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

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 [2] and can be applied both in macro and micro cell environments.

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

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: [2]:

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

On the contrary, a FACH 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, irrespective of the 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 [3].

The main requirement is to make an efficient overall usage of the radio resources: this makes the common channel, FACH, the favorite choice, since many users can access the same resource at the same time. However, other crucial factors such as the number of users belonging to the multicast group and their distance from the serving Node B, the type of service provided and the QoS requirements (represented by E_b/N_0 targets) affect the choice of the most efficient transport channel. The impact of these factors is presented analytically in next sections.

3.1. Macrocell planning

In this section, the topology deployment (Figure 2) as well as the main simulation assumptions (Table 1) for the case of the macro cell environment is presented [4], [6], [7]. 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):

$$L = 128.1 + 37.6\, Log_{10}(R) \qquad (3)$$

where R represents the BS–UE separation (in Km) [4].

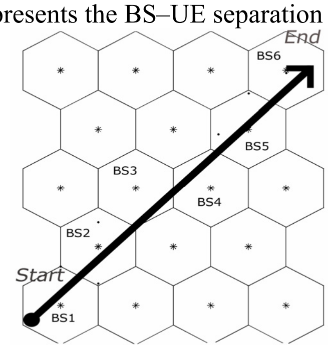

Figure 2. Macrocell Topology

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 [6], [7].

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)

3.2. Microcell planning

Figure 3 represents the topology (Manhattan grid) in the case of a micro cell environment, while Table 2 represents the assumed simulation parameters [4], [5], [6], [7]. 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):

$$L = 24 + 45\, Log_{10}\,(d+20) \qquad (4)$$

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

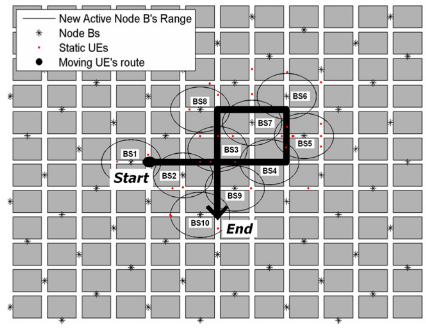

Figure 3. Microcell Topology

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 [5], [6].

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 (no STTD, 95% coverage)	0.36 W (64Kbps service)

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 or FACH 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 following figures depict the fluctuation of Node B's transmission power for varying simulation parameters in a macro cell environment.

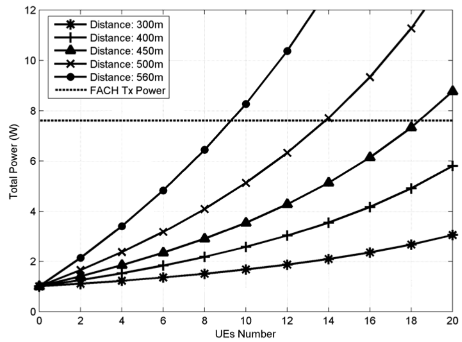

Figure 4. Macrocell - Tx power vs. Distance

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 FACH and DCHs changes with distance. For instance, the switching point for 450 m distance from BS is 18 UEs. Above this number, FACH is the most appropriate channel for the transmission of the multicast data in terms of power consumption. The switching point decreases drastically even for small increase in the distance from BS. For 500 m distance from BS (50 m further from the above mentioned distance) the switching point decreases in 13 UEs.

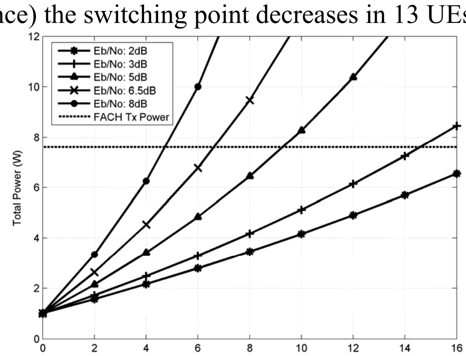

Figure 5. Macrocell - Tx power vs. Eb/No

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 FACH and DCHs.

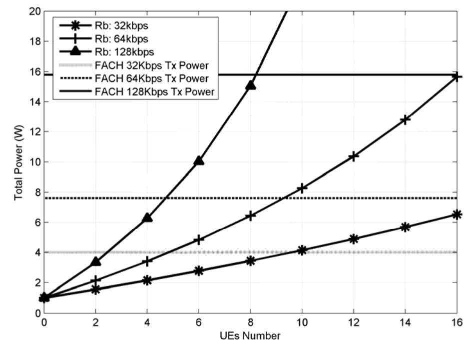

Figure 6. Macrocell - Tx power vs. bit rate

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.

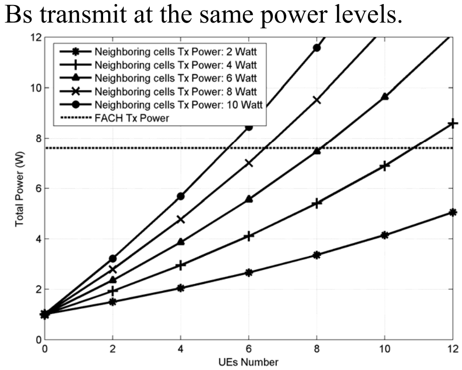

Figure 7. Macrocell - Tx power vs. Neighboring cells Tx power

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 uniformly distributed in the whole topology 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.

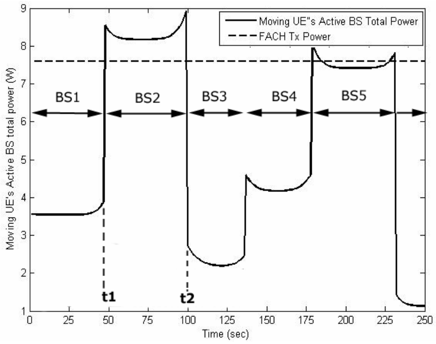

Figure 8. Macrocell - Moving UE's Active BS Tx power

Figure 8 presents the transmission power (both when using DCH and FACH transport channels) 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. It is worth mentioning that at time instances t1 and t2 the UE is at the cell edge, thus transmission power reaches a peak value, as shown in Figure 8. On the other hand while the UE moves through the area that is served by BS2 (time period between t1 and t2), its distance from BS2 initially decreases, at one point is minimised, and from that point increases (see Figure 2). The BS2's transmission power is changing in a similar way.

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 type 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 transmission power is constant.

In the first case, the Node B's power consumed when using multiple DCHs is less compared to the power consumed when using FACH. 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 more compared to the power consumed when using FACH. 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.

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 more (when the moving UE is at the edge of the cell served by BS5) or less (when the UE is close to the BS5) compared to the power consumed when using FACH. In this case the obvious solution would be to deploy FACH (when the moving UE enters the specific cell), multiple DCHs and FACH (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

Simulation results regarding a micro cell environment are presented in this section.

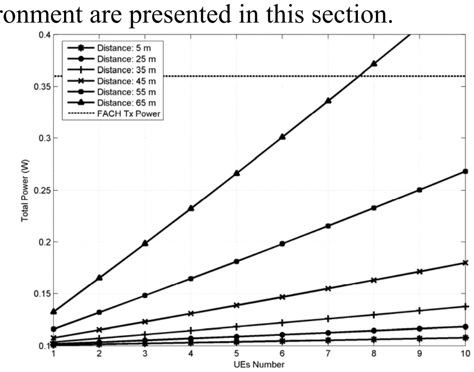

Figure 9. Microcell - Tx power vs. Distance

As in the macro cell environment, the impact of distance, 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 fixed power level is presented.

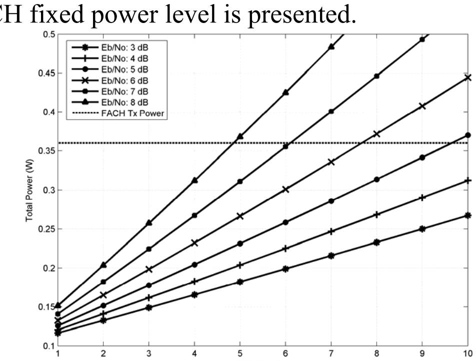

Figure 10. Microcell - Tx power vs. Eb/No

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.

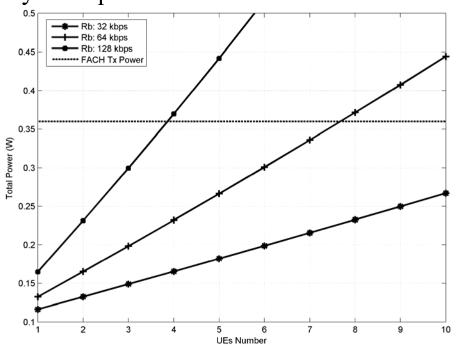

Figure 11. Microcell - TX power vs. bit rate

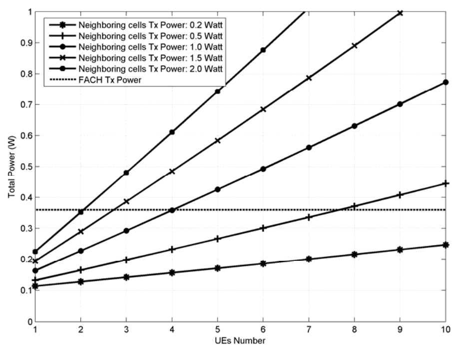

Figure 12. Microcell - Tx power vs. Neighboring cells Tx power

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 and FACH transport channels) of every Node B that serves the moving UE during its route.

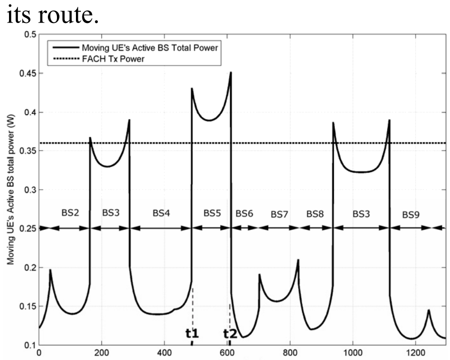

Figure 13. Microcell - Moving UE's Active BS Tx power

Similar to the analysis described in the macro cell case, the transport channel that requires less power resources is preferred to serve MBMS users. For instance, when the moving UE is served by BS5 (during period t2-t1), the most efficient channel should be the FACH. In the rest cases, multiple DCHs should be used for the transmission of the multicast data.

5. Conclusions and future work

In this paper we highlighted 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. Finally, a power based switching scheme between DCH and FACH channels was presented in order to minimize power resources. The step that follow this work is the examination of the efficiency of the shared channel, named HS-DSCH, which was introduced in the Release 5 of UMTS for the transmission of the MBMS data over the Iub and Uu interfaces.

6. References

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