Power Saving Methods for MBMS Transmissions in UTRAN

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Abstract

The demand for wireless multimedia communications thrives in today's consumer and corporate market. The need to evolve multimedia applications and services is at a critical point given the proliferation and integration of wireless systems. 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 data, both in the core network and most importantly in the air interface of UTRAN (UMTS Terrestrial Radio Access Network). However, several obstacles, regarding the high power requirements, should be overcome for the realization of MBMS. 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 MBMS transmissions. Several techniques, such as Dynamic Power Setting and Macro Diversity Combining, have been proposed in order to reduce the power requirements of delivering multicast traffic to MBMS users. This paper examines the efficiency of the utilization of these power saving techniques, by presenting simulation results that will reveal the amount of power that is saved.

1. Introduction

Universal Mobile Telecommunication System (UMTS) is the prevailing mobile phone technology, known as 3rd Generation (3G). UMTS networks offer high capacity; however, the expected demand will certainly overcome the available resources [1].

MBMS is a point-to-multipoint framework, extending the already existing UMTS infrastructure, in which data is transmitted from a single source entity to multiple destinations, allowing the network resources to be shared. MBMS is a key element of the 3GPP UMTS standards, supporting Broadcast and Multicast transmission modes; and constitutes a significant step towards the so-called Mobile Broadband [2].

Power control is one of the most important aspects in MBMS. The main purpose of power control is to minimize the transmitted power, thus avoiding unnecessary high power levels and eliminating intercell interference. The analysis of the transmission power is the main objective of this paper. Moreover, this paper examines several techniques that have been proposed for the reduction of Node B's (the base station in UMTS is called Node B) transmission power. Succinctly, some of these techniques are: Dynamic Power Setting, Usage of longer Transmission Time Interval, Space Time Transmit Diversity and Macro Diversity Combining [3].

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, 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). This paper takes into consideration the first two channels by examining their power profiles and their efficiency, in terms of power consumption, for the transmission of MBMS data.

Several studies 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 during MBMS sessions. An interesting study about the appropriate switching point is presented in [4], where the authors propose a switching point of 5 User Equipments (UEs) between DCHs and FACH, based on power consumption. In [5] the authors have presented an analysis of the factors that affect the switching points. On the other hand, in [3], [6] and [7] the authors have investigated several techniques in order to reduce the FACH power levels, thus decreasing the switching thresholds.

The paper is structured as follows. In Section 2, we present the proposed techniques that could reduce the power requirements during MBMS transmissions. Section 3 constitutes an introduction in the analysis of the power control in MBMS and presents the main simulation assumptions, while the results of the analysis are presented in Section 4. Finally, some concluding remarks and planned next steps are briefly described in Section 5.

2. Problems and proposed techniques

The first problem during a MBMS session, in terms of power consumption, is the exceedingly high fixed power levels when allocating FACH as transport channel. The proposed techniques that partly overcome these problems, thus reducing the Node B's transmission power when FACH is employed, are stated in paragraphs 2.1, 2.2, 2.3 and 2.4.

The second problem is that by allocating only the FACH for the transmission of the MBMS data, Node B will suffer high losses of power, especially when the number of users is small. The possibility of serving a small number of UEs using multiple DCHs overcomes this problem. Therefore, a switch from dedicated to common resources should take place when the number of users becomes such, that the power required with multiple DCHs is higher than the power required with a single FACH. The latter is stated in paragraph 2.5.

2.1. Dynamic Power Setting (DPS)

DPS is the technique where the transmission power of the FACH can be determined based on the worst user's path loss. This way, the FACH transmission power is allocated dynamically; and the FACH transmission power will need to cover the whole cell only if one (or more) user is at the cell boundary. To perform dynamic power setting, the MBMS users need to turn on measurement report mechanism while they are on the Cell_FACH state. Based on such measurement reports, the base station can adjust the transmission power of the FACH channel [3].

2.2.Longer Transmission Time Interval (LTTI)

This method can be employed in the physical layer to benefit every member of the MBMS group in a cell. The usage of LTTI could benefit from the effect of interleaving and increase the efficiency of error-correction and compression techniques. Therefore, an increment in TTI length (from 20ms to 80ms) can provide significant power gain. However, the use of LTTI introduces more complexity and larger memory space requirement in the mobile station [8].

2.3. Space Time Transmit Diversity (STTD)

According to this technique multiple versions of the same signal are transmitted at different time instants (time diversity) or over several different propagation paths (space diversity). Basically, the diversity combining concept consists of receiving redundantly the same information bearing signal over two or more fading channels, and combine these multiple replicas at the receiver in order to increase the overall received Signal-to-Noise Ratio (SNR), reducing in that way the total power requirements [9].

2.4. Macro Diversity Combining (MDC)

As already mention, diversity is a technique to combine several copies of the same message received over different channels. MDC is a special case of space diversity, where the user receives data from two (or three) Node Bs simultaneously. The required power of each Node B is decreased; however, the total required power remains the same [4].

2.5. Efficient Channel Selection (ECS)

This technique concerns the selection of the most efficient channel during a MBMS session in terms of power consumption. This selection is a key point for 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 decision should be taken dynamically, after calculating the total cell transmission power in both cases (when FACH or multiple DCHs are used) [5].

3. Power planning of MBMS in UTRAN

The Radio Network Controller (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 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 [10].

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

where P_T is the base station's total transmitted power, 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 [10]:

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

On the other hand, a FACH essentially transmits at a fixed power level since fast power control is not supported. FACH is a point-to-multipoint (PTM) channel and must be received by all UEs throughout the desirable cell part. Consequently, the fixed power should be high enough to ensure the requested Quality of Service (QoS) in the desired area of the cell, irrespective of users' location. FACH power efficiency strongly depends on maximizing diversity as power resources are limited. Diversity can be obtained by the use of a longer TTI in order 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 [8].

Table 1. FACH Tx power levels

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

Table 1 presents some indicative FACH downlink transmission power levels obtained for various cell coverage areas and MBMS bit rates, without assuming diversity techniques [8]. A basic constraint is that the delivery of high data rate MBMS services over FACH is not feasible, since excessive downlink transmission power would be required (overcoming the maximum available power of 20W). High bit rates can only be offered to users located very close to Node B.

The main assumptions that were used in our simulation are presented in Table 2 [8], [11]. 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).

$$L = 24 + 45\, Log_{10}\, (d+20) \qquad (3)$$

where R represents the distance between the UE and the Node B in Km [11].

Table 2. Simulation assumptions

Parameter	Value
Cellular layout	Hexagonal grid
Number of 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	0.5
E_b/N_0 target	5 dB

4. Results

In this section, analytical simulation results, distinctly for each of the aforementioned techniques, are presented. Furthermore, a combination of these techniques is examined in order to reveal the additional power gain.

4.1. Dynamic Power Setting (DPS)

Setting the Node B's transmission power to a level high enough so as to cover the whole cell is wasteful if not even one MBMS user is close to the cell edge. This is presented in Figure 1, where the Node B sets its transmission power based on the worst user's path loss. The information about the path loss is sent to the Node B via the Random Access Channel (RACH).

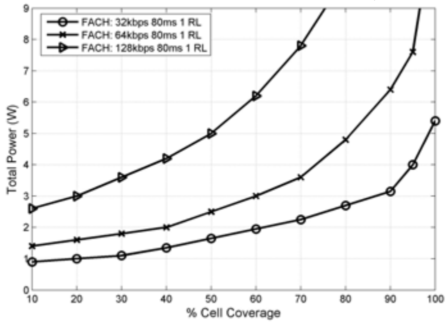

Figure 1. FACH Tx power with DPS

The examination of Figure 1 reveals that 4.0 W are required in order to provide a 32 kbps service to the 95% of the cell. However, supposing that all the MBMS users are found near the Node B (10% coverage) only 0.9 W are required. In that case, 3.1 W (4.0 W minus 0.9 W) can be saved while delivering a 32 kbps service, as with DPS the Node B will set its power so as to cover only the 10% of the cell. The corresponding power gain increases to 6.2 W for a 64 kbps service and to 13.4 W for a 128 kbps service.

4.2.Longer Transmission Time Interval (LTTI)

Fortunately, some MBMS services are not delay sensitive. In that case, diversity can be obtained by using a longer TTI, e.g. 80ms instead of 20ms, so as to provide time diversity against fast fading.

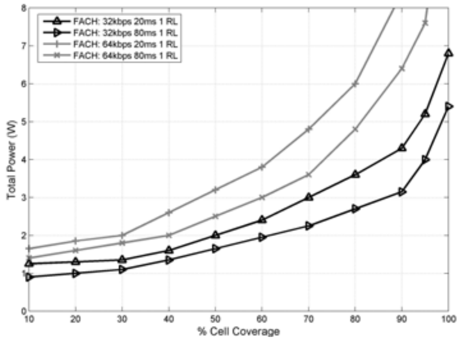

Figure 2. FACH Tx power with LTTI

Figure 2 presents power levels that are indicative of the sums of power that can be saved by using the LTTI technique, while delivering a 32 or a 64 kbps MBMS service. As depicted in Figure 2, the power levels of the FACH with 80ms TTI are lower than the power levels with 20ms TTI, in both cases. Moreover, the power gain increases as the desired coverage area of the cell increases. Therefore, this technique could be particularly useful when utilized in order to serve users near the cell borders.

4.3. Space Time Transmit Diversity (STTD)

The power requirements during MBMS transmissions could also be reduced as the users receive multiple versions of the same signal. These signals are transmitted at different time instants and/or over several different propagation paths. Figure 3 examines the power consumptions when STTD is applied for two different TTI lengths, 20ms and 80 ms. The utilization of STTD reduces the power consumption, independently of the TTI length. Indeed, as presented in Figure 3 the power levels when STTD is applied are lower than the corresponding power levels without STTD, in both cases. More specifically, for TTI equal to 20ms the power gain with STTD varies from 0.6 W (for 30% coverage) to 4.8 W (for 95% coverage), while for TTI equal to 80ms the power gain with STTD varies from 0.8 W (for 40% coverage) to 2.2 W (for 95% coverage). The power gain in both cases is high enough to justify the necessity for utilizing this technique during MBMS transmissions.

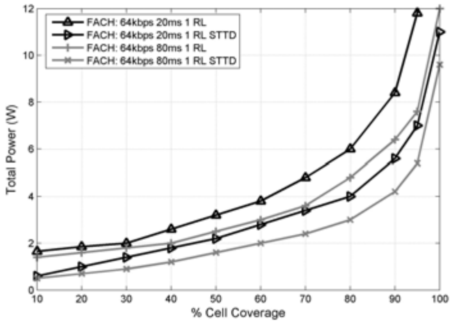

Figure 3. FACH Tx power with STTD

4.4. Macro Diversity Combining (MDC)

Figure 4 presents how the FACH transmission power level changes with cell coverage when MDC is applied. For the needs of the simulation we considered that a 64 kbps service should be delivered, using 1, 2 or 3 Node Bs (or Radio Links). TTI is assumed to be 80 ms.

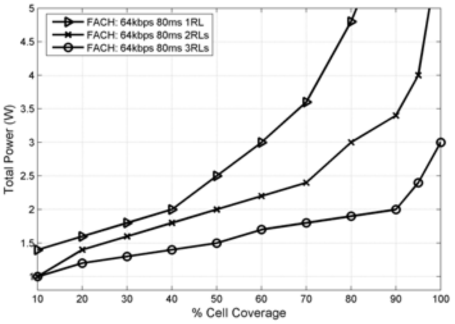

Figure 4. FACH Tx power with MDC

The main idea with regard to MDC is to decrease the power level from a Node B when it serves users near the cell edge. However, as we assume 3 sectors per cell (see Table 2), this technique can also be used for distances near the Node B, where each sector is considered as one radio link. As the user receives data from two (or three) Node Bs, the required power of each Node B is decreased; however, the total required power is the same and sometimes it is higher. MDC technique however, is particularly useful when the power level of a specific Node B is high, while respectively the power level of its neighboring Node B is low.

4.5. Efficient Channel Selection (ECS)

The above sections examine certain cases in order to present the way techniques could be utilized for reducing the FACH power requirements. The UE population was kept high and constant during the simulations so as to ensure MBMS transmissions through the FACH.

The particular scenario indicates how the ECS technique could be utilized in order to reduce the power requirements during MBMS transmission. It constitutes a more realistic scenario, since the UEs appear in random initial positions and then move randomly throughout the cell, while, the number of users varies during the simulation. More specifically, the number of users that receive a 64 kbps MBMS service initially increases, reaching 35 UEs at simulation time 175 sec. For the following 80 seconds, the number of users remains constant. From simulation time 255 sec, the number of users is decreasing and finally, at the end of the simulation only 6 UEs receive the 64 kbps MBMS service (Figure 5b).

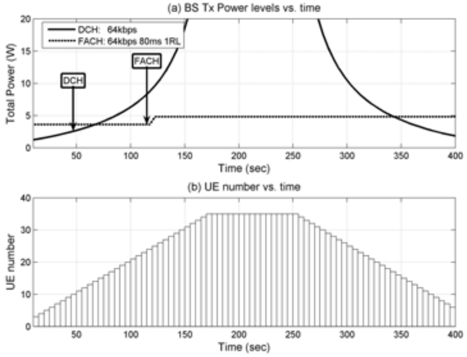

Figure 5. Node B's Tx power with ECS

Transmission power levels when using DCH or FACH channels are depicted in Figure 5a. 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. As already mentioned, the total transmission power when multiple DCHs are used mainly depends on the number of users. Indeed, as presented in Figure 5a, each new user occupies one more DCH increasing in this way the total required power. On the other hand, the total required power with FACH is independent of the UE number; however, it depends on their location (actually it only depends on the location of the user with the worst path loss). This fact explains why the FACH power level is constant during long time intervals, while, it changes only when the user with the worst path loss moves closer or further from the Node B.

The ECS technique will force the Node B to select, at each instant, the channel with the lowest power requirements (Figure 5a). Thus, in the beginning of the simulation, when the number of UEs is small, the most efficient channel is the DCH. The increase in the number of UEs causes a switch from multiple DCHs to a single FACH, at simulation time 68 sec. An additional increase in the number of UEs does not involve any change, unless the user with the worst path loss moves towards the cell edge, forcing the FACH to transmit at a higher power level (this occurs at simulation time 121 sec). The decrease in the number of UEs causes the exact opposite results.

4.6. Combination of techniques

In this section we present simulation results through the combination of the techniques: DPS, LTTI and MDC.

For the purpose of our analysis, a real-world scenario which simulates the movement of a UE while receiving a 64 kbps MBMS service will be examined. The route of the moving UE is depicted in Figure 6. According to the scenario, we assume a moving UE that, at simulation time 0 sec begins moving from the Start point towards the End point, as shown in Figure 6. The simulation lasts for 1220 seconds. During its route, the moving UE enters and leaves successively the coverage area of two different sectors' areas, served by base stations BS1 and BS3. However, as we assume that the MDC technique is applied, the moving UE is served by 6 different sectors in total (BS1 to BS6 in Figure 6).

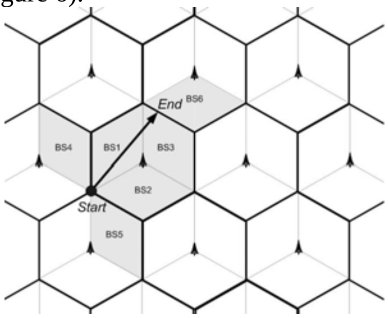

Figure 6. Route of the moving UE

Main objective of this scenario is to demonstrate the sums of power that could be saved via the combination of techniques DPS, LTTI and MDC. For simplicity reasons, we assume that the moving UE is served only by FACH during its route. In other words, each "active" sector detects the distance of the UE (through the RACH) and adjusts its power so as to provide the UE with the MBMS service through the FACH (DPS technique). The TTI is set to 80 ms throughout the whole simulation (i.e. the gain through the LTTI technique has been merged).

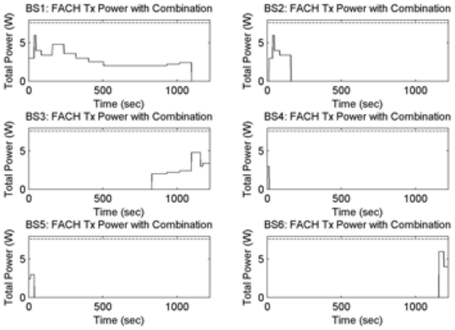

Figure 7. FACH Tx power with combination of techniques DPS, LTTI and MDC

Each of the graphics in Figure 7 depicts the transmission power of the FACH through the combination (continuous line). The fixed transmission power of the FACH in the "static power setting" case has been added with dashed line for comparison reasons. In the latter case, each sector uses a FACH with such power so as to cover the 95% of its area (i.e. 7.6 W for a 64 kbps service, 80 ms TTI). Figure 7 reveals that the power that is required with the combination never exceeds the power that is required with the static power setting. Even when the moving UE is found at the cell edge or at the sector edge, the power that is required from each sector is much smaller than the power that is required with the static power setting. This occurs because at the cell and sector edges MDC is applied.

Furthermore, according to Figure 7 at time period from 160 to 829 seconds the moving UE is served only by BS1. Even in this case, power is saved because BS1 adjusts its power based on the distance of the moving UE (DPS). This makes more sense after looking Figure 6 (shortly after the Start point until shortly before it enters the coverage area of BS3). During this period, BS1 does not have to cover its entire area, as the moving UE is never found at the cell edge. To sum up, each of the techniques contributes in decreasing the required power; however, the techniques' combination appears to be particularly attractive and imperative.

5. Conclusions and future work

In this paper, we underlined the importance of the analysis of transmission power, when delivering MBMS data in the downlink, for the optimization of UMTS networks. We presented an overview of several techniques which could be used for efficient power control in MBMS enabled UMTS networks. We further investigated these techniques through several simulations and determined the power gain that each technique and the combination of the techniques has.

Having examined all these techniques, an ambitious future step will be the determination of the most suitable technique, or the most suitable "technique combination" for the transmission of the MBMS session. Moreover, we will examine the efficiency of HS-DSCH as the transport channel for the transmission of the MBMS data over the Iub and Uu interfaces.

6. References

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