Evaluation of Different Radio Bearer Selection Approaches for MBMS in B3G Networks

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***Abstract*—The spread of multimedia data has drastically differentiated the current landscape of Universal Mobile Telecommunication System (UMTS) networks, posing the need for further enhancements in its Radio Resource Management (RRM) strategies. Introduced in 3rd Generation Partnership Project (3GPP) Release 6, the Multimedia Broadcast/Multicast Services (MBMS) framework aims at the efficient usage of network and radio resources for the transmission of multimedia services. The main requirement during the provision of MBMS multicast services is to minimize the transmission power of UMTS base stations. To this direction, several mechanisms have been proposed that either allow a simultaneous deployment of Point-to-Point (PTP) and Point-to-Multipoint (PTM) transmissions, or a single transport channel deployment (PTP or PTM) in a cell at any given time. Main objective of this paper is to study these mechanisms, compare them in terms of power consumption, underline the advantages that they may offer; and finally to propose enhancements that will ensure the lowest possible power consumption during MBMS transmissions.**

Keywords-UMTS, MBMS, Power Control.

I. INTRODUCTION

UMTS constitutes the main representative of the 3rd Generation (3G) cellular wireless networks. At first, UMTS offered tele-services for PTP transmissions, services with low requirements in general. However, the high requirements for multimedia content (such as Mobile TV) and the rapidly increasing demand for wireless multimedia applications, stressed the need for communication between one sender and many receivers, leading to the need of PTM transmission [1].

Introduced in 3GPP Release 6, MBMS framework may constitute the ideal method to confront the high requirements for multimedia content delivery. MBMS refers to a unidirectional service in which multimedia data is transmitted from a single source entity to multiple destinations, allowing resources to be shared in an economical way [2], [3].

The main requirement during the provision of MBMS multicast services is to make an efficient overall usage of radio and network resources. This necessity mainly translates into improved RRM and power control strategies, since the base stations' transmission power is the limiting factor of downlink capacity in UMTS networks. A critical aspect of MBMS performance that has a direct impact on the required power, is the selection of the most efficient radio bearer for the transmission of MBMS multicast traffic. A wrong channel selection may result to prohibitive power levels and significant capacity decrease. According to 3GPP specifications, MBMS traffic can be provided in each cell by either multiple PTP channels or by a single PTM channel [3]. More specifically, in PTP mode High Speed-Downlink Shared Channel (HS-DSCH) or multiple Dedicated Channels (DCHs) can be configured, while in PTM mode a single Forward Access Channel (FACH) is transmitted throughout a cell.

There exist two main research directions during the radio bearer selection procedure. According to the first approach, a single transport channel (either PTP or PTM) can be deployed in a cell at any given time. In this case, a switching threshold is actually set that defines when each channel should be deployed. This threshold is set either based on the number of serving users [4], or on the power that each transport channel consumes to serve all the MBMS users [5], [6]. On the other hand, the second approach performs a simultaneous deployment of PTP and PTM modes. A combination of these modes is scheduled and both PTP and PTM bearers are deployed [7], [8], [9].

Nevertheless, the selection of the most appropriate mechanism is plagued with uncertainty, since each mechanism may provide specific advantages. In this paper these mechanisms are presented and compared in terms of power consumption so as to highlight the advantages that each mechanism may offer. The main objective is to sort out the problem of selecting the most appropriate radio bearer selection mechanism; and to identify and propose improvements.

The paper is structured as follows: Section II is dedicated to an analysis of power control in MBMS. In Section III, the most common radio bearer selection approaches are presented and analyzed, while, in Section IV these approaches are evaluated and compared with each other. Finally, concluding remarks and planned next steps are briefly described in Section V.

II. POWER CONTROL IN MBMS

The transport channels that could be used in MBMS for the transmission of the data packets over the Universal Terrestrial Radio Access Network (UTRAN) interfaces are: the FACH, the DCH and the HS-DSCH. This section presents their power consumption characteristics during MBMS transmissions.

A. HS-DSCH Power Profile

HS-DSCH is a rate controlled rather than a power controlled transport channel. The required HS-DSCH transmission power ($P_{HS\text{-}DSCH}$) can be expressed as a function of the Signal-to-Interference-plus-Noise Ratio (SINR) value and the user location (in terms of Geometry factor (G)) [10]:

$$P_{HS-DSCH} \geq SINR[p - G^{-1}]\frac{P_{own}}{SF_{16}} \quad (1)$$

where P_{own} is the own cell interference experienced by the mobile user, p is the orthogonality factor (p = 0 for perfect orthogonality) and SF_{16} is the spreading factor of 16.

B. DCH Power Profile

The total downlink transmission power allocated for all MBMS users in a cell depends on their number, their distance from the base station, the bit rate of the MBMS session and the experienced signal quality E_b/N_0 for each user. Equation (2) calculates the base station's total DCH transmission power required for transmission of the data to n users in a cell [11].

$$P_T = \frac{P_P + \sum_{i=1}^{n} \dfrac{(P_N + x_i)}{\dfrac{W}{(E_b/N_0)_i R_{b,i}} + p} L_{p,i}}{1 - \sum_{i=1}^{n} \dfrac{p}{\dfrac{W}{(E_b/N_0)_i R_{b,i}} + p}} \quad (2)$$

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}.

C. FACH Power Profile

A FACH essentially transmits at a fixed power level since fast power control is not supported in this channel.

TABLE I. FACH TX POWER LEVELS

Cell Coverage (%)	*Required Tx power (W) (64 Kbps)*
10	1.4
20	1.6
30	1.8
40	2
50	2.5
60	3
70	3.6
80	4.8
90	6.4
100	7.6

FACH is a PTM channel and must be received by all users throughout the part of the cell that the users reside in. Therefore, the fixed power should be high enough to ensure the requested Quality of Service (QoS) in the desired cell area.

Table I presents some indicative FACH downlink transmission power levels obtained for various cell coverage areas [13]. These FACH transmission power levels correspond to a macrocell environment, when a 64 Kbps MBMS service is delivered. Moreover, Transmission Time Interval (TTI) is set to 80ms, Block Error Rate (BLER) target is 1% and no Space Time Transmit Diversity (STTD) is assumed [13].

III. RADIO BEARER SELECTION MECHANISMS

This section presents analytical simulation results for the evaluation of the most common radio bearer selection mechanism. The main assumptions that are used in our simulations are presented in Table II and refer to a macrocell environment [13]. In addition, no STTD is assumed, while BLER target is set to 1%.

TABLE II. SIMULATION PARAMETERS

Parameter	*Value*
Cellular layout	18 hexagonal grid cells
Sectorization	3 sectors/cell
Site-to-site distance / Cell radius	1 Km / 0.577 Km
Maximum BS Tx power	20 W
Other BS Tx power	5 W
CPICH Power	2 W
Common channel power	1 W
Propagation model	Okumura Hata
Multipath channel	Vehicular A (3km/h)
Orthogonality factor	0.5
E_b/N_0 target	5 dB

The figures that will be presented in Section III refer to the same scenario where a 64 Kbps MBMS service is delivered to a constantly increasing number of MBMS users. The group initially consists of 4 User Equipments (UEs); and 2 UEs join the MBMS session every 5 seconds. Each UE appears in random position and moves randomly throughout the cell area with speed 3Km/h. The main target is to demonstrate the operation and the power consumption of each mechanism.

A. MBMS Counting Mechanism (TS 25.346)

The 3GPP MBMS Counting Mechanism (or TS 25.346) constitutes the prevailing approach of switching between PTP (DCH) and PTM (FACH) radio bearers, mainly due to its simplicity of implementation and function [4].

According to this mechanism, a single transport channel (PTP or PTM) can be deployed in a cell at any given time. The decision on the threshold between PTP and PTM bearers is operator dependent, although it is proposed that it should be based on the number of users. A switch from PTP to PTM resources should occur, when the number of users in a cell exceeds a predefined threshold. Assuming that the threshold is 8 UEs (a mean value for the threshold proposed in research works), this mechanism will command the base station to switch from DCH to FACH when the number of users exceeds this threshold, since HS-DSCH is not supported (Figure 1).

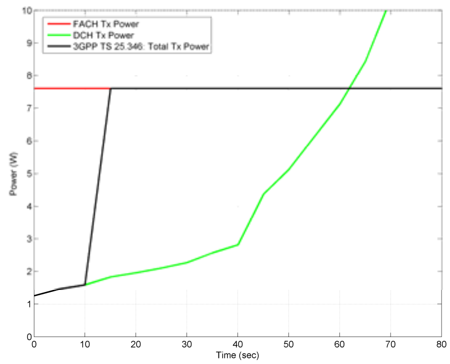

Figure 1. 3GPP TS 25.346 Tx Power Levels.

Figure 1 also reveals the inefficiencies of TS 25.346. This mechanism provides a non realistic approach because mobility and current location of the mobile users are not taken into account. Moreover, this mechanism does not support FACH dynamic power setting. Therefore, when employed, FACH has to cover the whole cell area, leading to power wasting. Finally, TS 25.346 does not support the HS-DSCH, a transport channel that could enrich MBMS with broadband characteristics.

B. MBMS PTP/PTM Switching Algorithm (TR 25.922)

3GPP TR 25.922 or MBMS PTP/PTM switching algorithm [5], assumes that a single channel can be deployed in a cell at any time. However, contrary to TS 25.346, it follows a power based approach when selecting the appropriate radio bearer.

In TR 25.922, instead of using solely DCHs, HS-DSCH can also be transmitted. However, the restricted usage of either DCH (Figure 2) or HS-DSCH in PTP mode may result to significant power losses. In both cases, the PTP (DCH or HS-DSCH, since the switching between HS-DSCH and DCH is not supported) and the PTM power levels are compared and the case with the lowest power requirements is selected. TR 25.922 overcomes several inefficiencies of TS 25.346; however it does not support FACH dynamic setting, leading in turn, to increased power consumption in PTM transmissions.

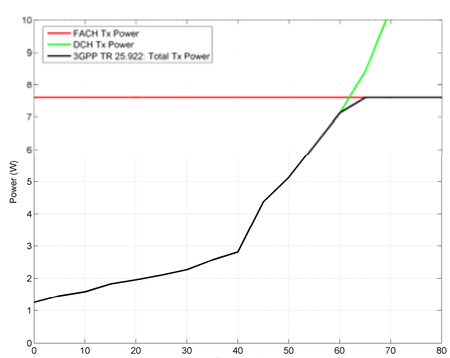

Figure 2. 3GPP TR 25.922 (with DCH) Tx Power Levels.

C. MBMS Session Assignment Mechanism

The MBMS Session Assignment Mechanism [6] can be considered as an enhancement of the 3GPP 25.346 and 25.922. This is due to the fact that contrary to TS 25.346, it considers users' mobility and location and takes into account the power requirements for switching between transport channels. Contrary to TR 25.922 both PTP (DCH and HS-DSCH) transmission modes are supported. Therefore, this mechanism does not only allow PTP transmissions, but it makes a further distinction between DCH and HS-DSCH transmissions. Furthermore, contrary to TS 25.346 and TR 25.922, this mechanism supports FACH dynamic power allocation, reducing in this way the power requirements during PTM transmissions. Finally, the major advantage of this mechanism is its ability to ensure the service continuity in the system when multiple parallel MBMS services are delivered.

The operation of this mechanism is as follows: the parameters of existing MBMS users (such as E_b/N_0 requirements, distance from base station, etc.) in each cell are retrieved through uplink channels; and based on these parameters the required power to be allocated when using HS-DSCH, multiple DCH or FACH is computed. The transport channel that ensures the lowest power consumption is selected at each instant (Figure 3). The MBMS Session Assignment Mechanism consists of one more step, that allows the parallel delivery of more than one MBMS services.

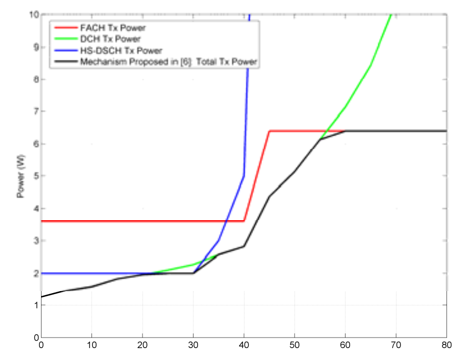

Figure 3. MBMS Session Assignment Mechanism Tx Power Levels.

In Figure 3, the transmission power levels when using DCHs, FACH or HS-DSCH are depicted. This mechanism will force the Radio Network Controller (RNC) to select, at each instant, the channel that ensures the lowest power consumption.

D. Mechanism proposed in 3GPP TSG RAN1 R1-02-1240

All the above mechanisms allow a single PTP or PTM transport channel deployment at any given time. However, the promising idea behind the simultaneous/combined usage of PTP and PTM bearers and the advantages that in may offer, motivated alternative approaches, suggesting that different transport channel may coexist and be deployed in parallel.

The mechanism initially proposed in 3GPP TSG RAN1 R1-02-1240 [7] and further analysed in [8], considers the mixed usage of DCHs and FACH. According to this approach, the FACH channel only covers a dynamically selected inner area of a cell/sector and provides the MBMS service to the users that are found in this part, with power according to Table I.

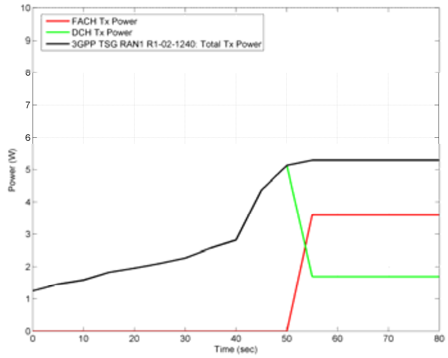

Figure 4. 3GPP TSG RAN1 R1-02-1240 Tx Power Levels.

The rest of the users are served using DCH to cover the remaining outer cell area. The power for serving the outer part users is calculated as in equation (2). The total downlink power consumption, including FACH and dedicated channels, is the sum of these two power levels (Figure 4).

IV. Approaches' Evaluation

In order to further evaluate the radio bearer selection mechanisms we will compare them in terms of power requirements. This comparison aims firstly at revealing the disadvantages and advantages of each mechanism; and secondly at detecting enhancements that could further relax the power requirements and improve their performance.

A. Scenario 1

The mechanisms' total transmission power levels (Figure 1 to Figure 4) have been gathered in Figure 5 for comparison reasons. The scenario remains the same. A 64 Kbps MBMS service is delivered to a gradually increasing number of users (as in Section III) that appear in random positions and then move randomly throughout the cell area with speed 3Km/h.

As shown in Figure 5, the MBMS Counting Mechanism (3GPP TS 25.346) has in general the worst performance in terms of power consumption. For small number of multicast UEs, all the mechanisms have similar behavior except the 3GPP TS 25.346, in which the switching threshold from PTP to PTM and vice versa, is predefined and based on the number of MBMS users. Moreover, the MBMS PTP/PTM Switching Algorithm (3GPP TR 25.922) with HS-DSCH has a poor performance, since it does not support DCH transmissions.

From simulation time 22 sec to 32 sec, the mechanisms that consume less power are the 3GPP TR 25.922 with HS-DSCH and the MBMS Session Assignment Mechanism [6]. The fact that these two mechanisms support HS-DSCH transmissions explains why they outperform the other mechanisms. For the time interval from 32 sec to 50 sec, all mechanisms apart from 3GPP TS 25.346 consume the same power in order to serve the gradually increasing population of MBMS users.

Evident differentiation in the performance of the mechanisms is observed after simulation time 60 sec, when the large number of users makes the usage of PTM transmissions imperative.

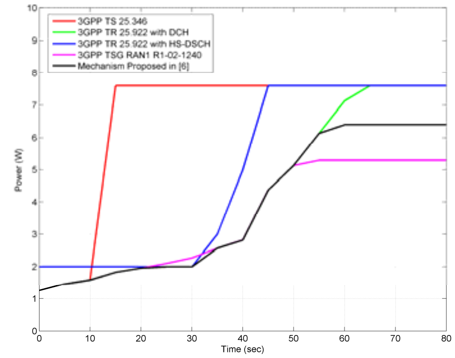

Figure 5. Tx Power Levels for Scenario 1.

After this simulation time, the mechanism proposed in 3GPP TSG RAN1 R1-02-1240 is the most efficient mechanism; since this mechanism allows the combined usage of PTP and PTM transmissions. As depicted in Figure 5, this mechanism requires 5.3 Watt to serve all the MBMS users and may offer a power gain of 1.1 Watt compared to MBMS Session Assignment Mechanism and 2.3 Watt compared to the other three approaches. The MBMS Session Assignment Mechanism outperforms the remaining three approaches due to the fact that this approach supports FACH dynamic power setting. Therefore, the FACH will have to transmit with such power so as to cover the part of the cell that the users reside in (requiring 6.4 Watt and not 7.6 Watt).

B. Scenario 2

The second scenario lasts for 250 sec and can be divided into four time periods, depending on the number of MBMS users. According to this scenario, a 64 Kbps service should be delivered to a group of users, whose initial position at each time period is presented in Table III. For example, for the time period 0 to 50 sec, 25 UEs receive the 64 Kbps service at distance 50% of the cell radius and 7 UEs at distance 80% of the cell radius.

TABLE III. Scenario 2

Time (sec)	***UEs Number***	***Coverage (%)***	***Best Performance***
0-50	25	50	R1-02-1240 andWork [6]
	7	80	
51-100	25	50	R1-02-1240
	2	80	
101-200	17	50	TR 25.922 (HS-DSCH) and Work [6]
201-250	4	50	All except TR 25.922 (HS-DSCH)

Figure 6 depicts the power levels of the examined radio bearer selection mechanisms for the corresponding scenario. As it can be noticed from Figure 6, the MBMS Session Assignment Mechanism and the mechanism proposed in 3GPP TSG RAN1 R1-02-1240 have the best performance in general.

For example, from 0 to 50 sec, the power levels of these two mechanisms remain lower than the power levels of the other three 3GPP approaches. More specifically, both approaches require 4.8 Watt to serve the 32 UEs in total, while the other three 3GPP approaches require 7.6 Watt. Therefore, 2.8 Watt can be saved by using one of these mechanisms instead of the other three 3GPP approaches. The power gain for the corresponding time period derives from the fact that both mechanisms support FACH dynamic power setting.

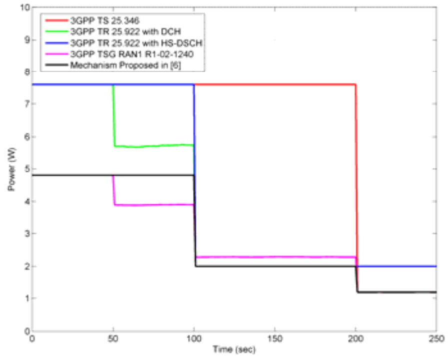

Figure 6. Tx Power Levels for Scenario 2.

TABLE IV. COMPARISON OF THE MECHANISMS

Mechanism	***Advantages***	***Disadvantages***
3GPP TS 25.346	1) Low complexity 2) Easy to implement 3) 3GPP standardized	1) High power requirements 2) No mobility support 3) Not support HS-DSCH in PTP mode 4) Not support dynamic FACH in PTM mode
3GPP TR 25.922	1) Support all transport channels 2) 3GPP standardized	1) High power requirements 2) Not support switching between HS-DSCH and DCH in PTP mode 3) Not support dynamic FACH in PTM mode
MBMS Session Assignment Mechanism	1) Support all transport channels 2) Support switching between HS-DSCH - DCH 3) Support multiple MBMS sessions 4) Support dynamic FACH in PTM mode	1) Not support combined usage of transport channels 2) No standardized 3) High complexity due to multiple session support
3GPP R1-02-1240	1) Power efficient 2) Support combined usage of FACH and DCH 3) Support dynamic FACH in PTM mode	1) High complexity 2) No standardized 3) Not support HS-DSCH in PTP mode

To conclude, Table IV presents the overall results of the analysis. The main conclusion is that 3GPP R1-02-1240 approach and MBMS Session Assignment Mechanism outperform the remaining approaches in terms of power consumption. The main reason is that TS 25.346 and TR 25.922 do not support FACH dynamic power setting in PTM mode. Regarding the last two mechanisms presented in Table IV, we could say that the benefits of the combined usage of FACH and DCH transport channels in 3GPP R1-02-1240 counterbalance the benefits of the efficient usage of all transport channels (including HS-DSCH) in MBMS Session Assignment Mechanism.

Therefore, no decision can be made about which of the above two mentioned mechanisms perform more efficiently in terms of power consumption. This observation indicates the necessity of implementing a new mechanism that will put together the benefits of the 3GPP R1-02-1240 and MBMS Session Assignment mechanisms and will allow the combination of all transport channels (PTP and/or PTM radio bearers including HS-DSCH) in any cell/sector of the network.

V. CONCLUSIONS AND FUTURE WORK

In this paper we examined several radio bearer selection mechanisms aiming at the efficient utilization of power resources during the transmission of multimedia services. We analyzed the operation of each mechanism, compared them in terms of power consumption and spotted their advantages and disadvantages. The analysis revealed that several enhancements could be incorporated in these mechanisms that will ensure the lowest possible power consumption during MBMS transmissions.

To this direction, our next step is to develop a mechanism that incorporates the advantages of all mechanisms, while simultaneously eliminates the effects of their disadvantages. The proposed mechanism will relax the transmission power requirements and improve network capacity, which in turn, will enable the mass market delivery of multimedia services to mobile users. At a second level, we plan to study the complexity that each mechanism inserts in RNCs.

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