Efficient Assignment of Multiple MBMS Sessions in B3G Networks

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Abstract— **In Universal Mobile Telecommunication System (UMTS), the downlink capacity is limited by the base station transmission power. Therefore, power control plays an important role to minimize the transmitted power shared among unicast and multicast users within a cell. In Multimedia Broadcast/Multicast Service (MBMS), power control targets to the efficient utilization of radio and network resources. However, the expected high demand for such services stresses the need for an efficient scheme, capable of dynamically allocating radio resources to parallel MBMS sessions. This paper proposes a power control mechanism for efficient MBMS session assignment in next generation UMTS networks. The mechanism shares efficiently the available power resources of UMTS base stations to MBMS sessions running in the network. Furthermore, the mechanism is evaluated through several realistic scenarios and the results indicate the ability of the mechanism to utilize efficiently the radio resources and to ensure the service continuity when parallel MBMS services running in the network.**

Keywords— UMTS, MBMS, Power Control, Radio Resource Management

I. INTRODUCTION

One of the most important aspects of MBMS is power control. Power control aims at minimizing the transmitted power shared among unicast and multicast users within a cell [2]. Efficient power control mechanisms in MBMS should deal with two major aspects of MBMS. The first one is the selection of the appropriate transport channel for the transmission of the MBMS traffic to multicast users, while the second is the ability of the base stations to support many simultaneous MBMS sessions.

Current approaches deal efficiently with the first aspect. In particular, MBMS traffic can be provided in each cell by either multiple Point-to-Point (PTP) channels or by a single Point-to-Multipoint (PTM) channel. Current MBMS specifications deal with this issue with the introduction of MBMS Counting Mechanism of UMTS [3]. According to this mechanism the decision on the threshold for switching between PTP and PTM bearers is operator dependent, although it is proposed that it should be based on the number of serving MBMS users. However, the MBMS Counting Mechanism provides a non realistic approach because mobility and current location of the mobile users are not taken into account. An interesting study under these assumptions is presented in [4] where the authors propose a switching point between PTP and PTM bearers, based on power consumption. Furthermore, in work [2], the authors propose a power control scheme for the efficient radio bearer selection in MBMS.

On the other hand, none of the above MBMS power control mechanisms takes into account the ability of the base stations to support many simultaneous MBMS sessions. MBMS transmissions have increased power requirements and consume a large portion of the available power recourses of the base stations. Consequently, the number of parallel MBMS sessions that a base station could support is limited. Therefore, the selection of the appropriate radio bearer for a MBMS service should be done with respect to the other existing MBMS sessions in the corresponding cell.

Under this prism, in this paper we present a power control mechanism, called MBMS session assignment mechanism, which shares efficiently the available power resources of UMTS base stations to all MBMS services running in the network. The goal achieved by this work is threefold. At a first level, due to the fact that the MBMS Counting Mechanism is an open issue for the 3rd Generation Partnership Project (3GPP), our mechanism proposes a more realistic and adaptive to dynamic wireless environments approach, by employing a power based switching criterion when selecting transport channel for MBMS transmissions. At a second level, our mechanism contributes to Radio Resource Management (RRM) mechanisms of UMTS by presenting a novel framework for MBMS that optimally utilizes power resources. At a third level, a major advantage of our mechanism is its ability to ensure the service continuity in the system when multiple parallel MBMS services are delivered.

The paper is structured as follows: Section II is dedicated to an in depth analysis of RRM in MBMS. Section III presents the proposed MBMS session assignment mechanism, while Section IV is dedicated to the presentation of the results. Finally, concluding remarks and planned next steps are briefly described in Section V.

II. RADIO RESOURCE MANAGEMENT IN MBMS

Power control is one of the most critical aspects in MBMS due to the fact that downlink transmission power in UMTS is a limited resource and should be optimally utilized. In this paper, we will present two approaches of achieving efficient power control in MBMS. The first approach is the efficient transport channel selection, while, the second one is the efficient MBMS session assignment.

A. Transport Channel Selection

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 Forward Access Channel (FACH), the Dedicated Channel (DCH) and the High Speed Downlink Shared Channel (HS-DSCH). In this section, we analytically present their power consumption characteristics during MBMS multicast transmissions.

1) HS-DSCH Power Profile

HS-DSCH is a rate controlled rather than a power controlled transport channel. Although there are two basic modes for allocating HS-DSCH transmission power [5], in this paper we will focus on a dynamic method in order to provide only the required, marginal amount of power so as to satisfy all the serving multicast users and, in parallel, eliminate system interference. Two major measures for HSDPA power planning are the HS-DSCH Signal-to-Interference-plus-Noise Ratio (SINR) metric and the Geometry factor (G). SINR for a single-antenna Rake receiver is calculated as in (1) [5]:

$$SINR = SF_{16} \frac{P_{HS-DSCH}}{pP_{own} + P_{other} + P_{noise}} \tag{1}$$

where $P_{HS\text{-}DSCH}$ is the HS-DSCH transmission power, P_{own} is the own cell interference experienced by the mobile user, P_{other} the interference from neighboring cells and P_{noise} the Additive White Gaussian Noise. Parameter p is the orthogonality factor, while SF_{16} is the spreading factor of 16.

Geometry factor is another major measure that indicates the users' position throughout a cell. A lower G is expected when a user is located at the cell edge. G is calculated as in (2) [1]:

$$G = \frac{P_{own}}{P_{other} + P_{noise}} \tag{2}$$

There is a strong relationship between the HS-DSCH allocated power and the obtained MBMS cell throughput. This relationship can be disclosed in the three following steps. Initially, we have to define the target MBMS cell throughput. Once the target cell throughput is set, the next step is to define the way that this throughput relates to the SINR [5]. Finally, we can describe how the required HS-DSCH transmission power ($P_{HS\text{-}DSCH}$) can be expressed as a function of the SINR value and the user location (in terms of G) as in (3) [5]:

$$P_{HS-DSCH} \geq SINR[p - G^{-1}] \frac{P_{own}}{SF_{16}} \tag{3}$$

2) DCH Power Profile

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 serving users, 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 (4) calculates the base station's total DCH transmission power required for the transmission of the data to n users in a specific cell [6].

In (4), 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 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}.

$$P_T = \frac{P_P + \sum_{i=1}^{n} \dfrac{(P_N + x_i)}{\dfrac{W}{(E_b/N_0)_i R_{b,i}} + p} L_{p,i}}{1 - \sum_{i=1}^{n} \dfrac{p}{\dfrac{W}{(E_b/N_0)_i R_{b,i}} + p}} \tag{4}$$

3) FACH Power Profile

A FACH essentially transmits at a fixed power level since fast power control is not supported. FACH is a PTM channel and must be received by all users throughout the cell. Therefore, the fixed power should be high enough to ensure the requested QoS in the desired area of the cell, and in order to serve the user with the worst path loss in the cell [7].

The following table presents some indicative FACH downlink transmission power levels obtained for various cell coverage areas, without assuming diversity techniques [8].

TABLE I
FACH TX POWER LEVELS

Cell coverage	Service bit rate (Kbps)	Required Tx power (W)
30 %	64	1.8
50 %	64	2.5
95 %	64	7.6

B. MBMS Session Assignment

The increased power requirements of MBMS transmissions place a restriction on the number of parallel MBMS sessions that a base station could support. This number depends on many parameters. We could classify these parameters in three categories: user related parameters, MBMS session related parameters and provider related parameters. User related parameters are parameters such as UEs' distances from the base stations and UEs' QoS parameters. The number of active MBMS sessions per cell, the number of UEs per MBMS session per cell and the bit rates of the MBMS services are some of the MBMS session related parameters. Finally, the portion of the available power recourses of base stations that could be used for MBMS transmissions is a provider related parameter. All these parameters should be taken into account in the RRM of MBMS so as to have efficient power control.

III. MBMS SESSION ASSIGNMENT MECHANISM

This section presents the architecture and the functionality of the MBMS session assignment mechanism that is used for the efficient data transmission of parallel MBMS services in UMTS. The proposed mechanism incorporates all the basic functionalities of the standardized by the 3GPP MBMS Counting Mechanism and furthermore, it integrates several enhancements. These are:

--Power based transport channel selection.

--Parallel MBMS sessions and user mobility support.

The block diagram of the mechanism is illustrated in Fig. 1. According to Fig. 1, the mechanism consists of five distinct operation phases. These are: the initialization phase, the parameter retrieval phase, the power computation phase, the radio bearer (RB) selection phase and the RB assignment phase. The RNC is the responsible node of the MBMS architecture for the operation of this algorithm and the decision of the most efficient transport channel.

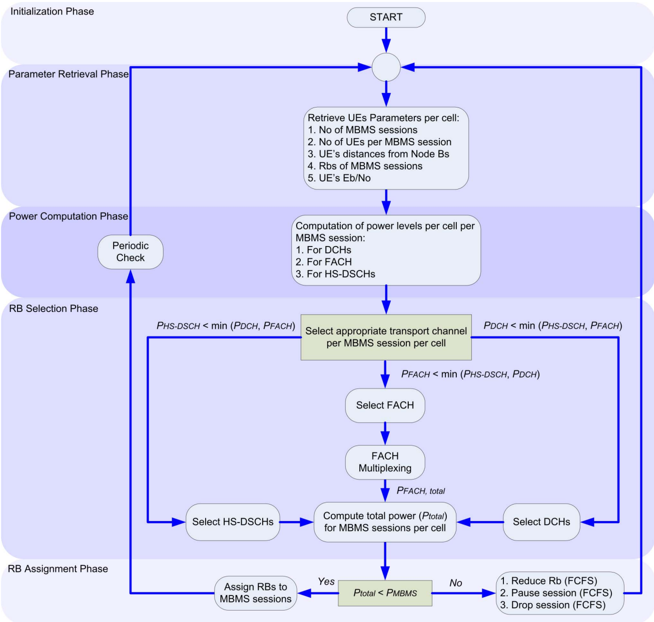

Fig. 1. MBMS session assignment mechanism

The initialization phase (Fig. 1) launches the mechanism when one user expresses his interest in receiving a MBMS service. In other words, the mechanism begins when the first user requests the first MBMS service.

The parameter retrieval phase is responsible for retrieving the parameters of the existing MBMS users and services in each cell. In this phase, the mechanism requires the two of the three types of parameters, mentioned in the previous section: the user related parameters and the MBMS session related parameters. Regarding the latter type of parameters, the mechanism requires information about the number of active MBMS sessions per cell, the number of UEs per MBMS session per cell and the bit rates of the MBMS sessions. This information is retrieved from the Broadcast Multicast – Service Center. On the other hand, the user related parameters are retrieved from the UEs through uplink channels.

The power computation phase substantially processes the data received from the parameter retrieval phase. During this phase, the required power to be allocated for any MBMS session in each cell is computed. The computation is based on the assumption that the transmission of the multicast data over the UTRAN interfaces can be performed with:

1) Multiple DCHs (DCHs case).

2) FACH with such power so as to serve the UE with the worst path loss (FACH Dynamic case).

3) HS-DSCHs (HS-DSCHs case).

In other words, the Node B's transmission power for any active MBMS session per cell is computed, assuming that all the UEs of each session in a cell could be served with the above three possible ways. The computation of the required power for the DCHs case takes into account the parameters defined in the parameter retrieval phase and calculates the required power (P_{DCH}) as in (4). For the FACH Dynamic case, the total required power (P_{FACH}) is computed depending on the user with the worst path loss as described in the previous section. Finally, for the HS-DSCH case, the mechanism computes the required power ($P_{HS\text{-}DSCH}$) as in (3).

In the RB selection phase, the P_{DCH}, the P_{FACH} and the $P_{HS\text{-}DSCHs}$ are compared in order to select the most efficient transmission method for any MBMS session in a cell. Thus, for any MBMS session, the algorithm decides which case consumes the less power and consequently, chooses the corresponding radio bearer for this session.

In the case of FACH there is another block in the mechanism's block diagram named FACH Multiplexing. When the number of MBMS sessions requiring FACH in cell is greater than one, these FACHs should be multiplexed onto a Secondary Common Control Physical Channel (S-CCPCH) [9], [10]. After the multiplexing procedure, the capacity of the S-CCPCH is calculated and based on this, the total power required for the common channels ($P_{FACH,total}$) in the corresponding Node B is estimated. In this paper we consider a one to one mapping between MBMS sessions (MBMS point-to-multipoint Traffic Channels - MTCHs) and FACHs.

The last action performed in the RB selection phase is the computation of the total Node B's power (P_{total}) required so as to support all the MBMS sessions in each cell of the network. However, at this point we have to mention that the selected radio bearers are not yet assigned to the MBMS sessions. This action is performed in the following phase.

During the RB assignment phase, the P_{total} is compared to the available power assigned by the network provider to MBMS sessions in each base station (P_{MBMS}). Obviously, the P_{MBMS} constitutes the third type of parameters mentioned in the previous section, known as provider related parameter. If P_{total} is smaller than P_{MBMS} then the selected from the RB selection phase transport channels are assigned to MBMS sessions and the MBMS data transfer phase begins. In case when P_{total} is bigger than P_{MBMS}, a session reconfiguration procedure should occur due to the fact that there are no available radio resources to the Node B so as to serve all the MBMS sessions. In this paper, we propose three possible reconfiguration events that could be used in such a case. The first is the reduction of the transmission rate of a MBMS session, the second is the pause of a MBMS session for a short period of time and the last is the cancellation of the service.

The simplest policy that RNC could adopt in order to perform the three above reconfiguration events, is a First Come First Served (FCFS) policy. Following the FCFS policy and considering the available power, the RNC performs the optimum event to the most recent MBMS sessions.

The above description refers to a dynamic model, in the sense that the UEs are assumed to be moving throughout the topology and the number of MBMS sessions varies. The parameter retrieval phase is triggered at regular time intervals so as to take into account the user related parameters, the MBMS session related parameters and the operator related parameters. Therefore, the P_{DCH}, P_{FACH} and $P_{HS\text{-}DSCH}$ power levels must be computed periodically at a predetermined frequency rate. This periodic computation inserts a further complexity for RNC as this information is carried in through uplink channels. This entails that a certain bandwidth fraction must be allocated for the transmission of this information in uplink channels, thus resulting to a system's capacity reduction. A further complexity is inserted in RNC due to the fact that the mechanism is executed many times in each RNC. In particular, if we suppose that a RNC serves N Node Bs with multicast users, while each of these Node Bs serves M_i ($i = 1...N$) parallel MBMS sessions, then the number of executions of the mechanism is computed as in (5):

$$K = \sum_{i=1}^{N} M_i \tag{5}$$

IV. Performance Evaluation

In this section, analytical simulation results for the evaluation of the mechanism are presented. In particular, we examine the following key aspects of the mechanism:

--Selection of the most efficient transport channel.

--Handling of multiple parallel MBMS sessions.

The main assumptions that are used in our simulations are presented in the following table and refer to a macro cell environment [8], [11]. In addition, no Space Time Transmit Diversity (STTD) is assumed, while the Block Error Rate (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 (43 dBm)
other BS Tx power	5 W (37 dBm)
common channel power	1 W (30 dBm)
maximum BS power allocated to MBMS (P_{MBMS})	10 W (40 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

A. *Efficient Transport Channel Selection*

In this section we will present simulation results regarding the operation of the main phase of our mechanism, the RB selection phase. More specifically, we evaluate the ability of our mechanism to select the most efficient transport channel for the transmission of a single MBMS session. To this direction, transmission power levels of the different types of transport channels are presented.

The simulation scenario considers a 64 Kbps MBMS service transmitted to a multicast group in a cell/sector. The UEs appear in random initial positions and then move randomly throughout the cell. Moreover, the number of users receiving the service gradually increases, reaching 32 UEs at the end of the simulation time, as shown in Fig. 2.

In Fig. 2, the transmission power levels when using DCHs, FACH or HS-DSCH are depicted. These power levels constitute the overall output of the power computation phase of the mechanism. In the next phase, the mechanism will force the RNC to select, at each instant, the radio bearer that ensures the lowest power consumption, thus saving the expensive and limited power resources. Therefore, in the beginning of the simulation, when the number of UEs is small, the most efficient channel is DCH. The increase in the number of UEs and the continuous users' movement throughout the cell causes a switch from DCHs to HS-DSCH at simulation time 35 sec. An additional increase in the number of UEs results to a switch from HS-DSCH to a single FACH (at simulation time 83 sec when the UE population is 17) with transmission power high enough to cover the UE with the worst path loss. A further increase in the UE number 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 (simulation time 103 sec).

Generally, in cases where the number of users is small, PTP transmissions are preferred. DCH and HS-DSCH are both PTP channels; however, the results have shown that for very small multicast user population DCH is preferred, while, for relatively more users HS-DSCH is the most appropriate. Therefore, our mechanism does not only decide to use PTP or PTM transmissions (as the MBMS Counting Mechanism), but it makes a further distinction between DCH and HS-DSCH in PTP mode.

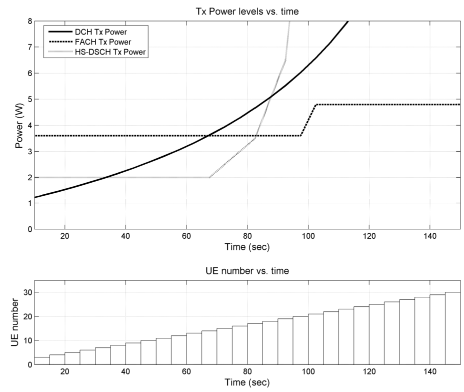

Fig. 2. Transport channel selection

B. *Managing Parallel MBMS Sessions*

The major advantage of the proposed mechanism is its ability to manage multiple parallel MBMS sessions. In order to evaluate this ability, we setup a simulation scenario where multiple MBMS services are transmitted in parallel to several user groups residing in a cell. In particular, we suppose that four user groups receiving four distinct MBMS services with characteristics presented in Table III. Fig. 3 depicts the power consumption of each MBMS session as well as the total, aggregative power required to support the transmission of all services to the multicast users in the corresponding cell. It is worth mentioning that Table III presents, apart from service related aspects, the appropriate transport channel (with respect to power consumption as presented in previous section) to serve each group at each time interval.

TABLE III
SIMULATION SCENARIO

MBMS No.	Duration (sec)	Bit Rate	UEs Number	Maximum Coverage	Channel
1	0-600	64	10	80%	HS-DSCH
2	50-600	64	22	60%	FACH
3	100-150	64	2-13	60%	DCH
	151-300	64	14-19	60%	HS-DSCH
	301-600	64	20-27	60%	FACH
4	150-560	64	7	70%	DCH
	561-600	32	7	80%	DCH

Users of the 1st MBMS session are served with a HS-DSCH channel, due to the small population, throughout the whole service time. At simulation time 50 sec, MBMS service 2 is initiated (Fig. 3). At this time instant, the mechanism, through the RB selection phase, selects FACH as the most efficient transport channel for the transmission of the MBMS traffic, since MBMS session 2 is delivered to a large number of users (22 UEs).

MBMS service 3 starts at simulation time 100 sec. At this time the 3rd multicast group consists of only two UEs and thus the mechanism selects multiple DCHs for this MBMS service. The number of users receiving the service successively increases (join requests), reaching 13 UEs at simulation time 150 sec, 19 at simulation time 300 sec and 27 at the end of the simulation time. The increasing number of users in the group forces the mechanism to perform a channel switching from DCH to HS-DSCH at simulation time 151 sec and another one from HS-DSCH to FACH at simulation time 301 sec, securing, in this way, the efficient resource utilization.

At this point we have to mention that from simulation time 300 sec until the end of the simulation, MBMS services 2 and 3 employ FACHs for the transmission of the MBMS data (see Table III). During this time interval, the deployment of two parallel FACHs forces the mechanism to perform a FACH multiplexing procedure in the RB selection phase. Consequently, a single S-CCPCH with bit rate of 128 Kbps is used to deliver MBMS services 2 and 3. Moreover, P_{total} is lower than P_{MBMS}, which translates into efficient provision of the three parallel MBMS sessions.

At simulation time 150 sec, the MBMS service 4 is initiated and is targeted to a multicast group consisting of seven members. Multiple DCHs are selected by the mechanism to deliver the MBMS content to the 4th multicast group. Additionally, at the same time instance, P_{total} still remains smaller than P_{MBMS},which means that the MBMS service 4 is accepted for transmission in the system. From simulation time 150 until the end of the simulation, four parallel MBMS sessions running in the system and our mechanism handles them in an efficient way.

Due to the fact that the users of the 4th multicast group are moving towards the cell edge an increase in P_{total} occurs and at simulation time 560 sec, P_{total} exceeds P_{MBMS} value (Fig. 3). Thus, a session reconfiguration procedure is performed, forcing the MBMS service 4 to reduce its bit rate from 64 Kbps to 32 Kbps in order to ensure the efficient service of four parallel MBMS sessions without any interruption.

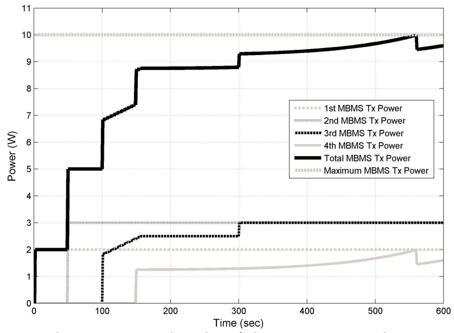

Fig. 3. Power levels of the MBMS sessions

V. CONCLUSIONS AND FUTURE WORK

In this paper we presented a novel power control mechanism for efficient MBMS session assignment in UMTS. The mechanism shares efficiently the available power resources of UMTS base stations to MBMS sessions running in the network. Furthermore, the mechanism supports all the available transport channels which could be used for transmission of the MBMS traffic to mobile users. The mechanism is evaluated through realistic scenarios and the results indicated the ability of the mechanism to handle efficiently multiple MBMS sessions. The steps that follow this work could be at a first level the evaluation of the mechanism through additional simulation scenarios and at a second level the study of the complexity that the mechanism inserts in RNCs due to its dynamic and periodic nature.

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