A Novel Mechanism for Radio Capacity Maximization during MBMS Transmissions in B3G Networks

Antonios Alexiou, Christos Bouras, Vasileios Kokkinos, Evangelos Rekkas
Research Academic Computer Technology Institute, Greece and
Computer Engineering and Informatics Dept., Univ. of Patras, Greece
University of Patras, Rio Campus, 26500 Rio, Patras, Greece
+302610996951, +302610996954
alexiua@cti.gr, bouras@cti.gr, kokkinos@cti.gr, rekkas@cti.gr

ABSTRACT

This paper proposes a novel mechanism for efficient power control during multicast transmissions in Beyond 3rd Generation (B3G) mobile networks. The mechanism utilizes optimally the available power resources of Universal Mobile Telecommunication System (UMTS) base stations, resulting to network capacity maximization. The proposed mechanism is based on the concept of transport channels combination (point-to-point and/or point-to-multipoint radio bearers) in any cell/sector of the network in which Multimedia Broadcast/Multicast Service (MBMS) users are residing. In particular, the transport channel combination that minimizes the transmission power of the base station is selected for the transmission of the MBMS traffic to the corresponding cell. The mechanism is evaluated through several realistic scenarios and the results indicate the ability of the mechanism to utilize optimally the radio resources of the network. Furthermore, our approach is compared with several power control mechanisms existing in the bibliography, including the 3rd Generation Partnership Project (3GPP) approaches (presented in 3GPP TS 25.346 and 3GPP TR 25.922), in order to highlight the enhancements that it provides.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design – *Wireless communication*; C.2.3 [**Computer-Communication Networks**]: Network Operations – *Network Management, Public networks*; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems – *Evaluation/methodology*.

General Terms

Design, Management, Performance, Verification.

Keywords

UMTS, HSDPA, MBMS, RRM, Power Control.

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1. INTRODUCTION

Indisputably, there is a rapidly increasing market for wireless multimedia applications, such as Mobile TV, that are expected to face high penetration in future mobile communications industry. As a consequence, in B3G mobile networks the amount of multimedia data traffic will surpass the amount of voice traffic. In order to confront such high requirements for multimedia content, the MBMS framework was introduced in the Release 6 of the UMTS architecture. MBMS is 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 [1], [2]. As the term indicates, MBMS consists of the broadcast and the multicast operation modes.

However, the spread of multimedia data differentiates the current landscape of Radio Resource Management (RRM) in MBMS and poses the need for further enhancements. 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 power control strategies, since the base stations' transmission power is the limiting factor of downlink capacity in UMTS networks. Under this prism, a critical aspect of MBMS performance is the selection of the most efficient radio bearer for the transmission of MBMS multicast traffic. A wrong channel selection may result to a significant capacity decrease, thus, preventing the mass delivery of multimedia applications.

In this paper, we propose a power control mechanism for efficient radio bearer selection in MBMS. The mechanism enhances MBMS performance in the frame of maximizing radio capacity in B3G networks. The proposed scheme adopts downlink transmission power as the optimum criterion for radio bearer deployment and selects the transport channel combination that minimizes the transmission power of the base station. Point-to-Point (PTP) and Point-to-Multipoint (PTM) transmission modes may be used separately or may be combined and deployed in parallel. In this way, the mechanism optimally utilizes power resources and significantly improves radio resources' allocation.

The paper is structured as follows: In Section 2, we present the motivation behind our study and the related work in the specific field. Section 3 is dedicated to an in depth analysis of RRM in MBMS. Section 4 presents the proposed power control mechanism, while Section 5 is dedicated to the presentation of the results. Finally, concluding remarks and planned next steps are briefly described in Section 6.

2. MOTIVATION

The main requirement during the provision of MBMS multicast services is to make an efficient overall usage of radio and network resources. The system should conceive and adapt to continuous changes that occur in such dynamic wireless environments and optimally allocate resources. Under this prism, a critical aspect of MBMS performance is the selection of the most efficient radio bearer for the transmission of MBMS multicast data. It is worth mentioning that this is still an open issue in today's MBMS infrastructure mainly due to its catalytic role in RRM.

According to 3GPP specifications, MBMS traffic can be provided in each cell by either multiple PTP channels or by a single PTM channel [2]. 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 (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. 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 dedicated and common bearers are established in parallel in a cell.

According to the first direction, in the frame of switching between PTP and PTM radio bearers several approaches have been proposed. The 3GPP MBMS Counting Mechanism (TS 25.346) was the prevailing approach mainly due to its simplicity of implementation and function [3]. According to this mechanism, the decision on the threshold between PTP (multiple DCHs) and PTM (FACH) bearers is operator dependent, although it is proposed that it should be based on the number of served MBMS users. In other words, a switch from PTP to PTM resources should occur, when the number of users in a cell exceeds a predefined threshold. However, this approach suffers from much inefficiency, mainly due to the difficulty of defining the appropriate threshold. Assuming that all User Equipments (UEs) are distributed uniformly across the cell, the MBMS Counting Mechanism provides a non realistic approach because mobility and current location of the mobile users are not taken into account. On the other hand, assuming that all UEs are found near the cell borders (worst case scenario), this mechanism may lead to misleading results, and thus to an inappropriate threshold, resulting to inefficient utilization of network resources. This way, the advantage of simplicity of implementation is overshadowed by the disadvantage generated from the difficulty of determining the appropriate switching point.

The inefficiencies of the MBMS Counting Mechanism and the power limitations motivated novel approaches, indicating that there is no need for a priori information and predefined switching thresholds; while, the assignment of the radio bearer should be performed in order to minimize the Node B's (base station in UMTS terminology) power requirements [4]. The MBMS PTP/PTM switching algorithm (3GPP TR 25.922) presented in [4] suggests that in PTP mode, instead of using solely DCHs, HS-DSCH can also be transmitted. HS-DSCH is the main transport channel in downlink used in High Speed Downlink Packet Access (HSDPA) technology that optimizes the air interface by enabling high data rate and delay tolerant services. However, the restricted usage of either DCH or HS-DSCH in PTP mode may result to significant power losses.

Another work that complies with the first approach is presented in [5]. In this work, the authors propose a power control scheme for efficient radio bearer selection in MBMS that on the one hand enhances the switching procedure between PTP and PTM modes and on the other hand enables the efficient assignment of multiple MBMS sessions in a cell. Nevertheless, even if this work takes into account all the available transport channels for MBMS content delivery, it does not allow their mixed usage.

The promising idea behind the 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 deployed in parallel. The mixed usage of transport channel was initially proposed in [6] and further analyzed in [7], [8]. These works consider the mixed usage of DCHs and FACH, which can significantly decrease the Node B's transmission power, depending on the number and the location of the users that receive the MBMS service. 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. The rest of the users are served using DCH to cover the remaining outer cell area. The total downlink power consumption, including FACH and dedicated channels, obviously depends on the number of users who are served by DCHs and their location. However, HS-DSCH deployment is not considered in the above works.

In this paper, we propose a novel mechanism that considers the parallel transmission of PTP and PTM modes and moreover, takes advantage of the benefits emerged through the HSDPA technology. Our mechanism, in contradiction to the aforementioned works, enables the simultaneous delivery of MBMS data over the three transport channels. This means that in PTP mode both DCH and HS-DSCH may be deployed in parallel, along with a FACH in PTM mode. 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 3GPP, our mechanism proposes a more realistic and adaptive to dynamic wireless environments approach, by employing a power based scheme when selecting the transport channel(s) for MBMS transmissions. At a second level, our approach enriches MBMS with broadband characteristics through the HSDPA incorporation. At a third level, the major advantage of our mechanism is that it contributes to RRM mechanisms of UMTS by presenting a novel framework for MBMS that, through the combination of all bearers, manages to optimally utilize power resources and maximize capacity in B3G networks.

3. RADIO RESOURCE MANAGEMENT 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. In this section, we analytically present their power consumption characteristics during MBMS multicast transmissions.

3.1 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 [9], 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) [9]:

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

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 ($p = 0$: perfect orthogonality), 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) [10]:

$$G = \frac{P_{own}}{P_{other} + P_{noise}} \quad (2)$$

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 [9]. 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) [9]:

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

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 [11].

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

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}.

3.3 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, or the part of the cell that the users reside in. 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 specific area [12].

The following table presents some indicative FACH downlink transmission power levels obtained for various cell coverage areas, without assuming diversity techniques [13].

Table 1. 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

These FACH transmission power levels correspond to a macrocell environment (site to site distance 1 Km), 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].

4. A PROPOSED MECHANISM FOR PTP AND PTM BEARERS COMBINATION

This section presents the architecture and the functionality of the proposed mechanism. The operation of the mechanism is based on the concept of PTM and PTP transport channels combination during MBMS transmissions. The block diagram of the mechanism is illustrated in Figure 1. According to Figure 1, the mechanism consists of four distinct operation phases. These are: the Initialization phase, the Parameter Retrieval phase, the Channels Selection phase, and the Event Scheduling phase. The Radio Network Controller (RNC) is the responsible node of the UMTS architecture for the operation of this mechanism.

The Initialization phase (Figure 1) launches the mechanism when one user expresses its interest in receiving a MBMS service. In other words the mechanism begins when the first user requests the MBMS service and the initialization phase is responsible for this procedure.

The Parameter Retrieval phase is responsible for retrieving the parameters of the existing MBMS users (through uplink channels) in each cell. These parameters are the distance of each UE from the Node B and the E_b/N_0 (or SINR) requirement per UE. In order to retrieve this information, the RNC broadcasts a message to the UEs belonging to a specific MBMS group and each user of the group responds to this message by indicating its location and its experienced signal quality. The MBMS service bit rate is assumed to be already known (in the Broadcast Multicast–Service Center, the responsible node of the UMTS architecture that includes functions for MBMS user service provisioning and delivery).

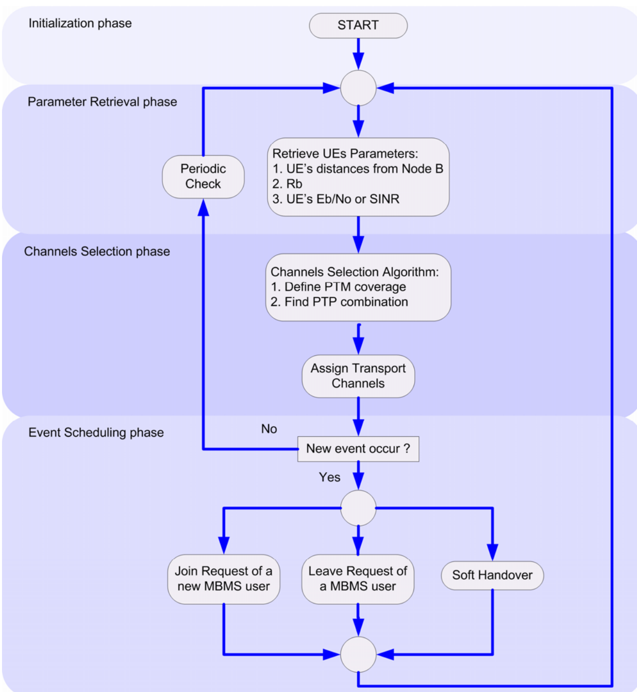

Figure 1. Block diagram of the mechanism

The Channels Selection phase is dedicated to the selection and assignment of the transport channels to the MBMS session in the corresponding cell. This phase consists of two blocks: the Channels Selection Algorithm block and the Assign Transport Channels block (Figure 1). The algorithm executed in the former block selects the combination of PTP and PTM bearers that minimizes the downlink Node B's transmission power for the corresponding MBMS session. In particular, the algorithm is executed in two steps. In the first step (Define PTM coverage) the algorithm estimates the optimum coverage of FACH for the specific users' distribution in the cell. This coverage area is called inner part of the cell as illustrated in Figure 2. In the second step (Find PTP combination), the mechanism decides which PTP bearer(s) will cover the rest part of the cell (outer part - Figure 2).

In order to estimate the optimum coverage of FACH in Define PTM coverage step (see Figure 1), the algorithm initially divides the cell in ten zones (Z1 to Z10). Each zone Zi refers to a circle with radius equal to 10i% of the cell radius. Afterwards, the algorithm scans all the zones and calculates the total Node B's transmission power (based on the channel power profiles presented in Section 3) for the following 21 transport Channel Configurations (CC):

- CC1: No FACH used. All MBMS users in the cell are covered by DCHs.
- CC2: No FACH used. All MBMS users in the cell are covered by HS-DSCHs.
- CC3: FACH for UEs up to Z1. All the rest UEs covered by DCHs.
- CC4: FACH for UEs up to Z1. All the rest UEs covered by HS-DSCHs.
- ………..
- CC19: FACH for UEs up to Z9. All the rest UEs covered by DCHs.
- CC20: FACH for UEs up to Z9. All the rest UEs covered by HS-DSCHs.
- CC21: FACH for all the MBMS UEs (up to Z10). DCHs and HS-DSCHs are not used

The CC that consumes less power indicates the coverage of the FACH and determines the inner part of the cell. For example, if CC20 is the channel configuration with the lowest power requirements, the FACH will have to cover the area up to Z9, which in turn means that all the UEs that are located inside the 90% of the cell will be served by one FACH. All the above procedure is presented using pseudo code in Figure 3.

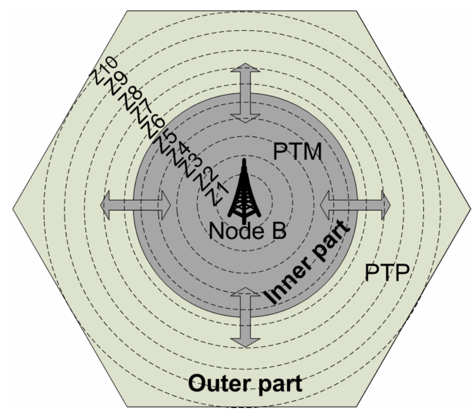

Figure 2. Cell areas and zones

Once the appropriate FACH coverage is defined, the algorithm enters the Find PTP combination step (see Figure 1), which determines the appropriate PTP radio bearer(s) that will cover the MBMS users residing in the outer part of the cell. The procedure is similar to the procedure described in the Define PTM coverage step. The algorithm scans all the zones in the outer part of the cell and calculates the total Node B's transmission power in order to cover all the outer part MBMS users only with PTP bearers (based on the channel power profiles presented in Section 3). The first zone of the outer part is Z(inner part+1), therefore the algorithm will have to scan the following PTP transport Channel Configurations (PTP_CC):

- PTP_CC1: DCHs for outer part UEs up to Z(inner part+1). All the rest outer part UEs (up to Z10) covered by HS-DSCHs.

- PTP_CC2: DCHs for outer part UEs up to Z(inner part+2). All the rest outer part UEs (up to Z10) covered by HS-DSCHs.
- ………..
- PTP_CC(10-inner part): All MBMS users in the outer part cell are covered by DCHs. HS-DSCHs are not used.
- PTP_CC(10-inner part+1): HS-DSCHs for outer part UEs up to Z(inner part+1). All the rest outer part UEs (up to Z10) covered by DCHs.
- PTP_CC(10-inner part+2): HS-DSCHs for outer part UEs up to Z(inner part+2). All the rest outer part UEs (up to Z10) covered by DCHs.
- ………..
- PTP_CC(2*(10-inner part)): All MBMS users in the outer part cell are covered by HS-DSCHs. DCHs are not used.

% **Mechanism for PTP and PTM Bearers Combination**

% **Define PTM coverage (Estimate FACH coverage)**

Define **cell radius**
% *Divide the cell in 10 zones and calculate their radius*
For **i**=1 to 10
    Calculate **Radius Zi**
% *Compute the less power demanding CC*
Min Power = P(CC1)
Selected Zone = Z0
For **j**=2 to 21
    Calculate **P(CCj)**
    if **P(CCj)** < **Min Power** then
        Min Power = P(CCj)
        % *Find FACH coverage*
        Selected Zone = $Z\left\lceil \frac{j}{2} - 1 \right\rceil$
Return **Min Power**, **Selected Zone**
%---
% **Find PTP combination (PTP bearers for outer part)**

% *Compute the less power demanding PTP_CC*
Outer Part Min Power = P(PTP_CC1)
Selected PTP_CC = 1
For **i**= 2 to 2*(10- **Selected Zone**)
    Calculate **P(PTP_CCi)**
    if **P(PTP_CCi)** < **Outer Part Min Power** then
        Outer Part Min Power = P(PTP_CCi)
        % *Find the PTP_CC with min power*
        Selected PTP_CC =i
Return **Outer Part Min Power, Selected PTP_CC**

Figure 3. Pseudo code of the Channels Selection Algorithm executed in Channels Selection phase.

After these calculations, the different PTP_CCs are compared and the PTP_CC with the lowest power requirements determines the PTP transport channel configuration for the outer part MBMS UEs. All the above procedure is presented using pseudo code in Figure 3.

Generally, the output of the Channels Selection Algorithm block is the combination of PTM and PTP transport channels that consumes the lowest power resources (from the available Node B's power resources) between all possible combinations in the corresponding cell. This information is given as input in the Assign Transport Channels block (Figure 1), which is the responsible block of the mechanism for assigning the selected transport channels to the MBMS session in the corresponding cell.

The last phase of the mechanism is the Event Scheduling phase. The mechanism enters this phase, only if one of the following events occurs during a MBMS session: a join request from a new MBMS user, a leave request from an existing MBMS user or handover. The algorithm handles these three events with the absolutely same way, since the parameters of all the users are updated in regular time intervals. The only difference is that a join and a leave request influence the power of only one cell, while handover influences the power of two different cells (the source and the destination cell).

The above description refers to a dynamic model, in the sense that the UEs are assumed to be moving throughout the topology. The parameter retrieval phase is triggered at regular time intervals so as to take into account the users' mobility and the three events of the Event Scheduling phase. This periodic computation inserts a further complexity for RNC as this information is carried in an uplink channel. This entails that a certain bandwidth fraction must be allocated for the transmission of this information in the uplink channel, thus resulting to a capacity reduction. However, it should be mentioned that the computation frequency is beyond the scope of this paper and should be further studied.

5. PERFORMANCE EVALUATION

In this section, analytical simulation results for the evaluation of the proposed mechanism are presented. Moreover, our approach is compared with the approaches presented in Section 2 in order to highlight all performance enhancements that the mechanism offers in terms of power consumption.

Table 2. 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)
Propagation model	Okumura Hata
Multipath channel	Vehicular A (3km/h)
Orthogonality factor	0.5
E_b/N_0 target	5 dB

The main assumptions that are used in our simulations are presented in the Table 2 and refer to a macrocell environment [13], [14]. In addition, no STTD is assumed, while the BLER target is set to 1%.

Our goal is to demonstrate the advantages of our mechanism through a mathematical analysis, which however totally simulates the macro cell environment. We illustrate how the Node B's transmission power could be reduced by selecting different transport channels' combination for the transmission of the MBMS data over the UTRAN interfaces.

5.1 Operation of the Channels Selection phase

This section presents simulation results regarding the operation of the main phase of our mechanism, the Channels Selection phase. More specifically, we evaluate the ability of our mechanism to select the most efficient transport channel combination for the transmission of a 64 Kbps MBMS session.

Table 3 presents the users' distribution throughout the cell during the 250 sec of the simulation period. Actually, Table 3 defines the UE population per zone for each time interval. During each time interval, the UEs are moving randomly; however, they remain in their predetermined zone. An exception occurs during the time interval 151-200 sec, when the group of 20 UEs move towards the cell edge, switching gradually from zone Z4 to Z6.

Table 3. UE distribution

	UE population per zone									
Time (sec)	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10
1-50	10	20	-	-	2	-	-	8	2	-
51-100	5	10	15	-	-	-	-	3	-	-
101-150	3	8	9	14	-	-	-	2	-	-
151-200	-	-	-	20	20	20	-	-	-	-
201-250	-	-	-	-	-	20	2	-	4	-

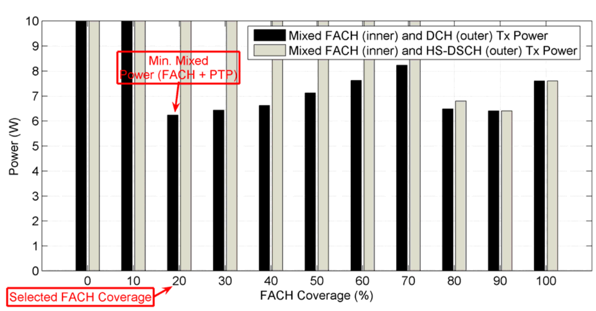

Figure 4. Transport CCs in "Define PTM coverage" step

Initially, we describe the operation of the Define PTM coverage step of the proposed mechanism. More specifically, Figure 4 depicts all the 21 discrete CCs computed during the initial scan, at simulation time 1 sec (actually there are 22 CCs in Figure 4; however the last two CCs correspond to the same case, i.e. for 100% FACH coverage). From these levels, the algorithm estimates the optimal PTM coverage and, therefore, the power allocated for the FACH transport channel (from Table 1). For instance, from Figure 4 we may conclude that the CC that corresponds to the combination of FACH with 20% coverage (to serve the inner part) and DCH (for the users residing in the outer part) is less power consuming. Therefore, for the specific scenario, the optimal PTM coverage is set to 20% of the examined cell. The PTP_CCs are scanned in a similar way in order to define the appropriate PTP combination.

During the first 50 sec of the simulation FACH transmission power is set to 1.6 W, corresponding to 20% coverage in order to cover the inner part of the users residing in zones Z1 and Z2. Simultaneously, in PTP mode both HS-DSCH and DCH are used in order to serve the rest of the users. Thus, we have a mixed usage of all three available channels. During the time interval 51-150 sec, we observe that only DCH is used in PTP, while in time interval 151-200 sec MBMS data should be delivered only over PTM bearers (FACH with dynamic power setting). Finally, during the last part of the simulation, the optimal channel combination comprises FACH with 60% coverage and HS-DSCH for the rest 6 users residing in zones Z7 and Z9.

The aim of the presented scenario was to present the procedure of selecting the optimal channels' combination during the Channels Selection phase. In general, the analysis reveals that the bearer combination that minimizes power consumption during the MBMS data delivery is selected.

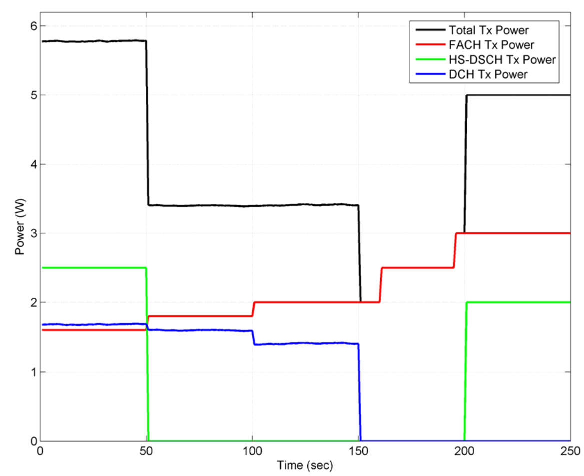

Figure 5. Comparison for variable number of MBMS UEs

5.2 Comparison with other approaches

In order to further evaluate the proposed mechanism, we will make a comparison between our approach and several approaches existing in the bibliography. These are:

- MBMS Counting Mechanism (3GPP TS 25.346 [3]).
- MBMS PTP/PTM switching algorithm (3GPP TR 25.922 [4]).
- MBMS Session Assignment Mechanism proposed in [5].
- Mechanism proposed in 3GPP TSG RAN1 R1-02-1240 [6] and research work [8].

5.2.1 Comparison for fixed number of MBMS UEs

This scenario considers a 64 Kbps MBMS service transmitted to a multicast group in a cell. Regarding the position of the MBMS users in the cell, 50 MBMS users reside in the cell area up to zone Z2, 10 users reside in the borders of zone Z8, while 2 users appeared in zone Z9. The users are moving randomly throughout the topology with speed 3Km/h. For comparison reasons, we will examine the power requirements of our mechanism and the above mentioned approaches for the corresponding scenario. Figure 6 illustrates the comparison results.

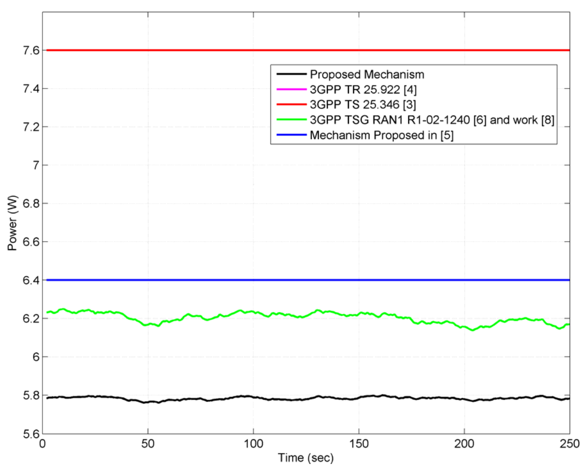

Figure 6. Comparison for fixed number of MBMS UEs

As Figure 6 presents, the proposed mechanism outperforms all the other mechanisms for the specific scenario. More specifically, according to MBMS Counting Mechanism (3GPP TS 25.346), the decision for switching between PTP and PTM bearers is based on the number of serving MBMS users. Assuming that the threshold is 8 UEs (a mean value for the threshold proposed in the majority of research works mentioned in this paper), the MBMS Counting Mechanism will command the Node B to switch from DCH to FACH when the number of users exceeds this predefined threshold, as HS-DSCH is not supported. In our scenario, the number of users in the cell is 62 and this means that a FACH with 100% cell coverage is selected (7.6 W according to Table 1), since the corresponding mechanism does not support FACH dynamic power setting. The inefficiency of the MBMS Counting Mechanism is obvious as this mechanism follows a fixed, predefined scheme that does not consider mobility and current location of the users.

As it has already mentioned in Section 2, the MBMS PTP/PTM switching algorithm (3GPP TR 25.922) follows a power based approach when selecting the appropriate radio bearer for the transmission of the MBMS data; however it does not allow transport channels' combination. The fact that the total users' population in our scenario is high (62 UEs), favors the deployment of FACH in order to serve all the UEs. Even though the MBMS PTP/PTM switching algorithm overcomes several inefficiencies of the MBMS Counting Mechanism, still it does not support FACH dynamic setting. This is the reason why the MBMS PTP/PTM switching algorithm has the same power requirements with the MBMS Counting Mechanism (7.6 W for a FACH with 100% coverage).

On the other hand, FACH dynamic power setting is supported by the MBMS Session Assignment mechanism [5]. According to this mechanism, the increased number of users in the cell favors the deployment of a FACH with such power so as to cover the MBMS user with the worst path profile. In our case this user resides in the borders of zone Z9, which means that a FACH with 90% coverage (6.4 W according to Table 1) should be deployed.

The mechanism presented in [6] and [8] allows the mixed usage of DCHs and FACH, and as shown in Figure 6, this channel configuration requires less power resources than the three above mentioned schemes for the corresponding scenario. The FACH channel only covers a dynamically selected inner area of a cell (in our case up to zone Z2) and provides the MBMS service to the users that are found in this part. The rest of the users are served using DCHs to cover the remaining outer cell area, as HS-DSCH deployment is not considered in this mechanism.

Finally, Figure 6 depicts the power requirements of the proposed mechanism for the examined scenario. The output of the Channels Selection Algorithm block of our mechanism (Figure 1) specifies that the users up to Z2 should be server by a FACH. Moreover, the most efficient combination of PTP bearers for the outer part MBMS users is to serve the 10 users in zone Z8 with HS-DSCH and the 2 users in zone Z9 with DCHs. With this channel deployment we could save a significant amount of Node B's power resources as depicted clearly in Figure 6.

Obviously, the proposed mechanism ensures minimized power consumption. More specifically, a significant power budget, ranging from 0.45 to 1.8 W may be saved compared to the other approaches. By taking into account that 3GPP specifications consider a maximum MBMS power allocation equal to 10 W, the proposed mechanism significantly relaxes the transmission power requirements and improves network capacity, which in turn, enable the mass market delivery of multimedia services to mobile users.

5.2.2 Comparison for variable number of UEs

Figure 7a presents the comparison of all the above mentioned mechanisms for variable number of MBMS UEs. The UEs appear in random positions throughout the cell and move randomly with speed 3Km/h. Initially, the number of UEs that consist the multicast group is 4, and 2 UEs join the MBMS session every 5 seconds (Figure 7b). As shown in Figure 7a, for small number of multicast UEs (1-20 UEs), where PTP bearers are favored, all the other mechanisms have similar behavior except the MBMS Counting Mechanism (3GPP TS 25.346) in which the switching threshold from PTP to PTM is 8 UEs. As the number of users increases, the usage of PTM bearer is imperative. However, only the usage of PTM bearer - as in the cases of the MBMS Counting Mechanism, the MBMS PTP/PTM Switching Algorithm (3GPP TR 25.922) and the MBMS Session Assignment Mechanism ([5]) - produces great amounts of wasted power. MBMS Session Assignment Mechanism has better performance than the other two due to the fact that it has the FACH dynamic power setting enabled.

In general, the mechanisms with the best performance are the mechanism presented in [6] and the proposed power control mechanism. These mechanisms follow a combined usage of PTM and PTP channels approach, which is essential when the number of users in the cell increases. However, the reason that our mechanism has lower power requirements, as shown in Figure 7a, is twofold. Firstly, it takes advantage of the benefits emerged through the HSDPA technology, and secondly, it can be efficiently adapted to any user distribution in any cell, by selecting one, two or three transport channel simultaneously (when it is necessary) in order to transmit the MBMS traffic to the users.

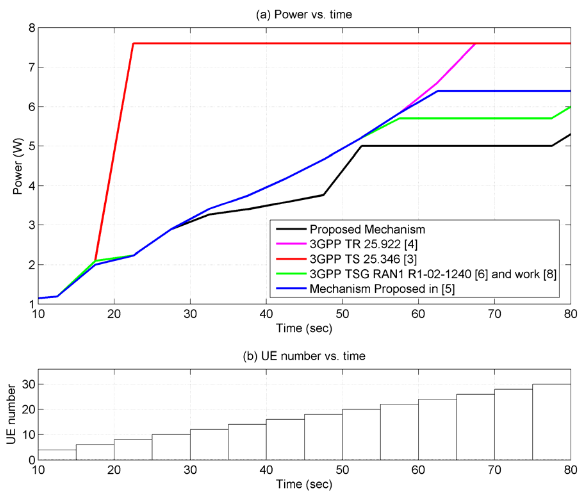

Figure 7. Comparison for variable number of MBMS UEs

6. CONCLUSIONS AND FUTURE WORK

In this paper we presented a novel power control mechanism for efficient radio bearer selection in MBMS enabled UMTS networks. The proposed mechanism provides a realistic and adaptive to dynamic wireless environments approach, by adopting the concept of radio bearer combination (PTP and/or PTM) in any cell/sector of the network in order to reduce the power requirements of the base stations. The mechanism is evaluated through several scenarios and the results indicated the efficient operation of the mechanism. In order to highlight the enhancements provided by the proposed mechanism, we provided a comparison of the mechanism with approaches existing in the bibliography, including 3GPP approaches. The main conclusion is that our mechanism outperforms them, underlining in this way the necessity for its incorporation in MBMS.

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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