An Enhanced Mechanism for Efficient Assignment of Multiple MBMS Sessions towards LTE

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ABSTRACT

The provision of rich multimedia services, such as Mobile TV, is considered of key importance for the Long Term Evolution (LTE) proliferation in mobile market. To this direction, Evolved - Multimedia Broadcast/Multicast Service (E-MBMS) that targets at the efficient delivery of multimedia data from a single source entity to multiple destinations, is envisaged to play an instrumental role during LTE standardization process. However, both LTE and E-MBMS performance are limited by the base station's transmission power. As an aftermath, efficient power allocation techniques should be implemented so as to ensure the mass provision of multimedia applications to mobile users. This paper proposes a novel mechanism for efficient radio bearer selection during E-MBMS transmissions in LTE networks. The proposed mechanism is based on the concept of transport channels combination in any cell of the network. Most significantly, the mechanism exploits the performance enhancements emerged from Multiple Input Multiple Output (MIMO) antennas used in LTE networks and manages to efficiently deliver multiple E-MBMS sessions. The proposed mechanism is thoroughly evaluated and compared with several radio bearer selection mechanisms existing in bibliography.

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

LTE, MBMS, MIMO, Power Control, UMTS.

MSWiM'09, October 26–29, 2009, Tenerife, Canary Islands, Spain.

1. INTRODUCTION

The bandwidth-hungry multimedia services that are already experienced in wired networks, will indisputably characterize tomorrow's mobile marketplace. LTE, the evolutionary successor of Universal Mobile Telecommunication System (UMTS) and High Speed Packet Access (HSPA) networks, addresses this emerging trend, by shaping the future mobile broadband landscape. LTE promises a richer, more immersive environment that significantly increases peak data rates and spectral efficiency. However, the plethora of mobile multimedia services poses the need for the deployment of a resource economic and efficient scheme.

In order to confront such high requirements for multimedia content, LTE networks rely on the E-MBMS framework. E-MBMS constitutes the evolutionary successor of MBMS, which was introduced in the Release 6 of UMTS [1], [2]. The main requirement during the provision of E-MBMS 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 most limiting factor of downlink capacity in LTE networks. Under this prism, a critical aspect of E-MBMS performance is the selection of the most efficient radio bearer for the transmission of multimedia traffic.

In the frame of power control and transport channel selection during multimedia data delivery several approaches have been proposed. The 3rd Generation Partnership Project (3GPP) specifications consider the TS 25.346 [3], TR 25.922 [4] and TSG-RAN WG1#28 R1-02-1240 [5] approaches. However, all of these works fail to take into account advances in mobile communications that rely on the broadband HSPA technology and on MIMO systems. MIMO systems are a prerequisite for LTE networks and have the potential to address the unprecedented demand for wireless multimedia services and particularly for the MBMS.

In this paper, we deal with the contemporary topic of transport channel selection and we propose a novel radio bearer selection mechanism for E-MBMS that constitutes an advanced and a more efficient version the 3GPP approaches. The mechanism dynamically determines the optimal E-MBMS radio bearer or radio bearer combination, based on the required transmission power to serve a multicast group. Therefore, Point-to-Point (PTP) and Point-to-Multipoint (PTM) transmission modes may be used separately or be combined and deployed in parallel.

The proposed mechanism takes advantage of the HSPA technology (including MIMO support) and contributes to Radio Resource Management (RRM) mechanisms of LTE by adopting a novel framework for MBMS that efficiently utilizes power resources. However, the most remarkable advantage of the proposed mechanism, that actually differentiates it from the 3GPP approaches, is that it conforms to LTE requirements for the simultaneous provision of multiple multimedia sessions. Our approach is compared with the 3GPP approaches in terms of both power consumption and complexity so as to highlight its enhancements and underline the necessity for its incorporation in E-MBMS specifications.

The paper is structured as follows: Section 2 is dedicated to an extended power profile analysis of the available bearers in MBMS. In Section 3, we present the related work in the specific field, while in Section 4 we describe the proposed MBMS power allocation mechanism. Section 5 is dedicated to the presentation of the results. Finally, concluding remarks and planned next steps are briefly described in Section 6.

2. POWER PROFILES OF DOWNLINK TRANSPORT CHANNELS

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

2.1 HS-DSCH Power Profile

HS-DSCH is a rate controlled rather than a power controlled transport channel. In this paper we will focus on a dynamic method for allocating HS-DSCH transmission power that provides only the required, marginal amount of power so as to satisfy all the serving users. Two major measures for HSPA power planning are the 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) [6]:

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

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' location throughout a cell. A lower *G* is expected when a user is located at the cell edge. *G* is calculated as in (2) [6]:

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

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* [6]. 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) [6]:

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

When MIMO is supported in HS-DSCH, multiple transmit antennas and receive antennas are used (different data streams are transmitted simultaneously over each antenna) and *SINR* is further improved [7]. Early LTE requirements consider two transmit and receive antennas (MIMO 2x2) and approximately, double data rates are obtained with the same base station power. Therefore, without loss of generality, half power is required, compared to conventional HS-DSCH single antenna systems, for the delivery of the same MBMS session.

2.2 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 distances 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 power in order to serve *n* users in a specific cell [8].

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

where P_{DCH} 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}.

2.3 FACH Power Profile

FACH is a PTM channel and must be received by all users throughout the MBMS service area of a cell. A FACH essentially transmits at a fixed power level that should be high enough to serve the user with the worst path loss, i.e. the user with the higher distance from the base station. Table 1 presents some indicative FACH downlink transmission power levels obtained for various cell coverage areas, without assuming diversity techniques [9].

Table 1. FACH Tx power levels for a 64 Kbps service

Cell Coverage (%)	Required Tx power (W)
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

3. RELATED WORK

The selection of the most efficient bearer is still an open issue in today's MBMS infrastructure, mainly due to its catalytic role in RRM. The following paragraphs present the main radio bearer selection approaches existing in the bibliography.

3.1 MBMS Counting Mechanism (TS 25.346)

The 3GPP MBMS Counting Mechanism (TS 25.346) constitutes the prevailing approach of switching between PTP (multiple DCHs) and PTM (FACH) radio bearers, mainly due to its simplicity of implementation and function [3]. According to this mechanism, a single transport channel can be deployed in a cell at any given time. The decision on the threshold between PTP and PTM bearers is operator dependent and 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 mechanism provides a non realistic approach because mobility and current location of the mobile users are not taken into account. Moreover, TS 25.346 does not support FACH dynamic power setting. In other words, when FACH is employed, it has to cover the whole cell area that generally leads to unnecessary power wasting. Finally, TS 25.346 does not support the HSDPA technology, which could enrich MBMS with broadband characteristics [6].

3.2 MBMS PTP/PTM Switching Algorithm (TR 25.922)

3GPP TR 25.922 or MBMS PTP/PTM switching algorithm [4], assumes that a single transport channel can be deployed in a cell at any given time. 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 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 in this mechanism) and the PTM power levels are compared and the case with the lowest power requirements is selected. Even though TR 25.922 overcomes several inefficiencies of the TS 25.346, it does not support FACH dynamic setting.

3.3 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. On the other hand, the mechanism proposed in 3GPP TSG RAN1 R1-02-1240 [5], considers the mixed usage of DCHs and FACH, which can significantly decrease the base station's transmission power, depending on the number and the location of the users. According to this approach, the FACH channel only covers a dynamically selected inner area of a cell 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.

However, 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 other existing MBMS sessions in the corresponding cell. The number of parallel MBMS sessions that a base station could support 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' (User Equipment) distances from the base stations and UEs' Quality of Service (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 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 considered in the RRM of MBMS so as to have efficient power control.

4. PROPOSED MECHANISM FOR PTP AND PTM BEARERS COMBINATION

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

- Power based transport channel selection.
- Combined usage of transport channels.
- Parallel MBMS sessions and user mobility support.
- Support of MIMO and HSDPA technology.

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 radio bearer (RB) selection phase and the RB assignment phase.

The initialization phase (Figure 1) launches the mechanism when one user expresses his interest in receiving a MBMS service (i.e. the mechanism begins when the first user requests the first MBMS service).

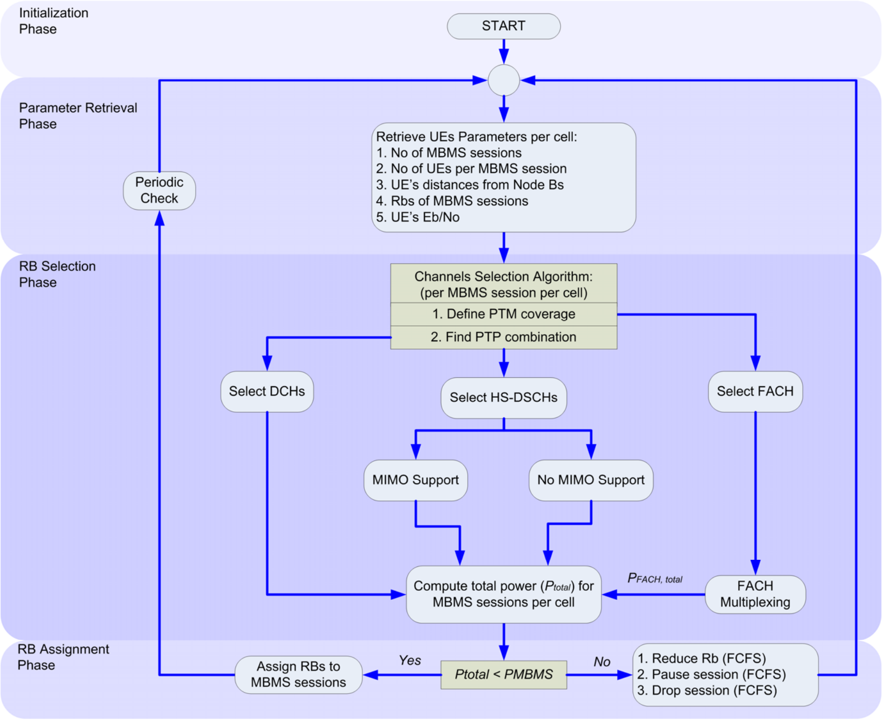

Figure 1. Block diagram of the mechanism.

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 (BM - SC). The user related parameters are retrieved from the UEs through uplink channels.

The RB selection phase is dedicated to the selection of the transport channels for the MBMS sessions in any cell of the network. The most critical operations of the phase are executed by the Channels Selection Algorithm block (Figure 1). The algorithm executed in this block selects the combination of PTP and PTM bearers that minimizes the downlink base station's transmission power in any cell of the network that multicast users are residing. 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 users' distribution of any MBMS session 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). It has to be mentioned that the above cell characterization is done for every MBMS session of the corresponding cell.

In order to estimate the optimum coverage of FACH (for any MBMS session in the cell) in Define PTM coverage step, 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 base station's transmission power for the following 21 transport Channel Configurations (CC):

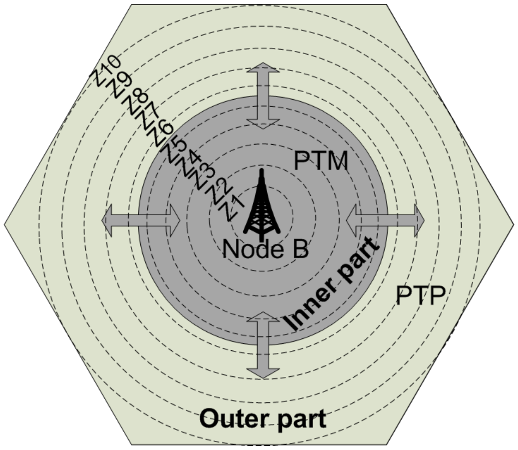

Figure 2. Cell areas and zones.

- CC1: No FACH used. All users of the specific MBMS session in the cell are covered by DCHs.
- CC2: No FACH used. All users of the specific MBMS session in the cell are covered by HS-DSCHs (with or without MIMO, depending on whether the mechanism supports MIMO or not).
- 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 (with or without MIMO).
- ………..
- 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 (with or without MIMO).
- CC21: FACH for all UEs (up to Z10) for the specific session. 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. The same procedure is executed simultaneously for any MBMS session in the cell. The output of the Define PTM coverage step is the coverage of the FACH for any MBMS session in the cell.

Once the appropriate FACH coverage for any MBMS session in the cell 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 for any MBMS session. 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 base station's transmission power in order to cover all the outer part MBMS users only with PTP bearers. 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 (with or without MIMO).
- 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 (with or without MIMO).
- ………..
- 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 (with or without MIMO) 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 (with or without MIMO) 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 for the specific session are covered by HS-DSCHs (with or without MIMO). DCHs are not used.

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 of the specific MBMS session in the cell.

Generally, the output of the Channels Selection Algorithm block is the combination of PTM and PTP transport channels that consumes the lowest power resources between all possible combinations in the corresponding cell.

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) [10], [11]. 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 base station is estimated. In this paper we consider a one to one mapping between sessions and FACHs.

The last action performed in the RB selection phase is the computation of the total base station's power (P_{total}) required so as to support all 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 with the available power assigned by the network provider to MBMS sessions in each base station (P_{MBMS}). Obviously, 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 base station so as to serve all the MBMS sessions in the examined cell. In this paper, we propose three possible reconfiguration events: the reduction of a session's transmission rate, the pause of a session for a short time period and the service cancellation.

The simplest policy that the mechanism 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 mechanism 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.

5. PERFORMANCE EVALUATION

In this section, analytical simulation results for the evaluation of the mechanism are presented. In particular, through two different scenarios we examine the following aspects of the mechanism: Enhancements through MIMO technology support, Comparison with current 3GPP approaches, Managing multiple parallel MBMS sessions.

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 Table 2 and refer to a macrocell environment [9]. In addition, Transmission Time Interval (TTI) is set to 80ms, Block Error Rate (BLER) target is 1% and no Space Time Transmit Diversity (STTD) is assumed.

5.1 Enhancements through MIMO Support

In this section we present a scenario that reveals the enhancements offered through the MIMO technology support. According to the scenario a group of 12 users with initial position at 60% of the cell area, moves towards the cell edge with speed 3 km/h. The simulation lasts for 150 seconds and during this time period the users receive a 64 Kbps service.

Main objective of this scenario is to demonstrate the sums of power that could be saved during HS-DSCH transmissions via the MIMO technology support. Therefore, without loss of generality, we assume that during their route, the users are served only by HS-DSCH (with and without MIMO support).

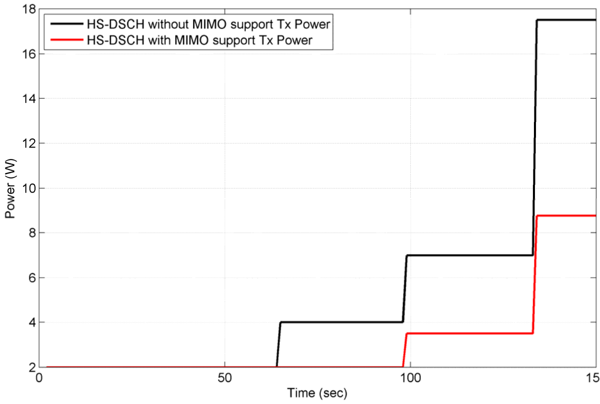

Figure 3. Power Levels of HS-DSCH (with and without MIMO support).

According to Figure 3, when the users approach the cell edge, half power is required when MIMO is supported in HS-DSCH, compared to conventional HS-DSCH single antenna transmissions. In other words, the support of MIMO technology could contribute in saving power resources and, in parallel, maximizing system capacity. In the remaining of this paper we will assume that during HS-DSCH transmissions, the MIMO technology is supported.

5.2 Comparison with 3GPP approaches

This scenario lasts for 200 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 3. For example, for the time period 0 to 50 sec, 25 UEs receive the service at distance 50% of the cell radius and 7 UEs at distance 80% of the cell radius.

Figure 4a depicts the power levels of the examined radio bearer selection mechanisms. The proposed mechanism and the mechanism presented in 3GPP TSG RAN1 R1-02-1240 have the best performance in general. For example, for the period 0-50 sec, the total number of users in the cell is 32. By assuming that the threshold for switching between DCH and FACH in TS 25.346 is 8 UEs (a value proposed in the majority of research works), TS 25.346 will deploy a FACH with 100% cell coverage (7.6 W).

Table 3. Users' number, coverage per time period

Time (sec)	UEs Number	Coverage (%)	Best Performance
0-50	25	50	Our Mechanism
	7	80	
51-100	25	50	R1-02-1240 and Our Mechanism
	2	80	
101-150	17	50	TR 25.922 (HS-DSCH) and Our Mechanism
151-200	4	50	All except TR 25.922 (HS-DSCH)

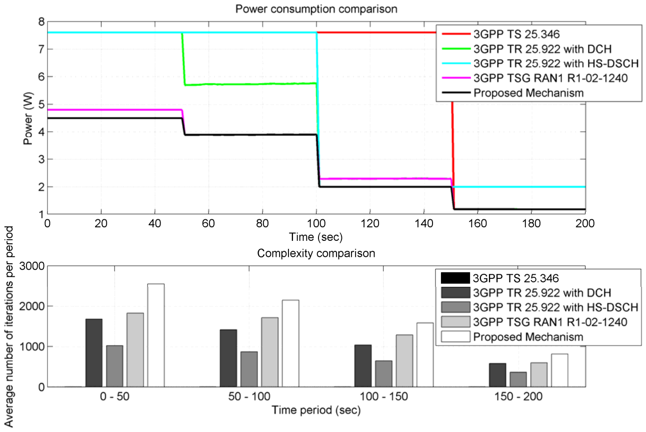

Figure 4. (a) Power consumption and (b) complexity comparison between the proposed mechanism and the 3GPP approaches.

The high initial users' population favors the deployment of FACH in order to serve all the UEs in 3GPP TR 25.922. However, as TS 25.346, TR 25.922 does not support FACH dynamic setting. This is the reason why TR 25.922 (with DCH or HS-DSCH) has the same power requirements with TS 25.346 (7.6 W) for the time period 0-50 sec.

The mechanism proposed in 3GPP TSG RAN1 R1-02-1240 allows the mixed usage of DCHs and FACH and supports FACH dynamic power setting. As shown in Figure 4a, this mechanism requires 4.8 W in order to serve all the users in the cell, for the first time period. This derives from the fact that for the specific scenario, this mechanism will deploy only a FACH with 80% coverage, while the user with the worst path loss resides in the borders of zone Z8.

Finally, Figure 4a depicts the power requirements of the proposed mechanism for the examined scenario. For the time period 0-50 sec, the output of the Channels Selection Algorithm block (Figure 1) specifies that the users up to Z5 should be server by a FACH. Moreover, the most efficient combination of PTP bearers for the outer part MBMS users is to serve the remaining 7 users in zone Z8 with HS-DSCH (incorporating MIMO technology). Therefore, 4.4 W in total are required in order to serve all the MBMS users with this mechanism. Obviously, the proposed mechanism ensures minimized power consumption. A significant power budget, ranging from 0.4 to 3.2 W, may be saved for the period 0-50 sec compared with the other approaches.

On the other hand, Figure 4b presents the computational overhead that each mechanisms inserts (number of iterations required to calculate the power of the available transport channels and assign the ideal channel), based on the above scenario.

In general, TS 25.346 inserts the lowest computational overhead (number of iterations constant and equal to one), because TS 25.346 requires only the number of served MBMS users in order to assign the appropriate transport channel. On the other hand, the other approaches have higher computational overhead due to the fact that these mechanisms have to periodically retrieve the parameters of existing MBMS users. Moreover, these approaches have to calculate the power consumption of the transport channels that each mechanism supports; and based on this calculation to assign the ideal radio bearer. The fact that the proposed mechanism supports all the available transport channels and examines all possible transport channels configurations explains why the number of iterations in this case is higher than the other approaches.

5.3 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 receive four distinct MBMS services with characteristics presented in Table 4. Moreover, Table 4 presents the appropriate transport channel (with respect to power consumption as presented in previous sections) to serve each group at each time interval.

Figure 5 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.

Users of the 1st MBMS session are served with a HS-DSCH channel (that supports MIMO), due to the small population, throughout the whole service time. At simulation time 50 sec, MBMS service 2 is initiated (Figure 5). At this time instant, the mechanism, through the RB selection phase, selects FACH (for the 22 inner part users) and DCHs (for the 6 outer part users) as the most efficient transport channel combination for the transmission of the MBMS traffic.

Table 4. Scenario parameters

MBMS No	Duration (sec)	Rb (Kbps)	UEs Number	Maximum Coverage	Channel
1	0 - 600	64	10	80%	HS-DSCH
2	50 - 600	64	22 + 6	20%+50%	FACH and DCH
3	100 - 150	64	2 to 13	60%	DCH
	151 - 300	64	14 to 19	60%	HS-DSCH
	301 - 600	64	20 to 27	60%	FACH
4	150 - 560	64	7	70%	DCH
	561 - 600	32	7	80%	DCH

MBMS service 3 starts at simulation time 100 sec. At this time the 3rd multicast group consists of only two UEs; 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 4). 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 sessions.

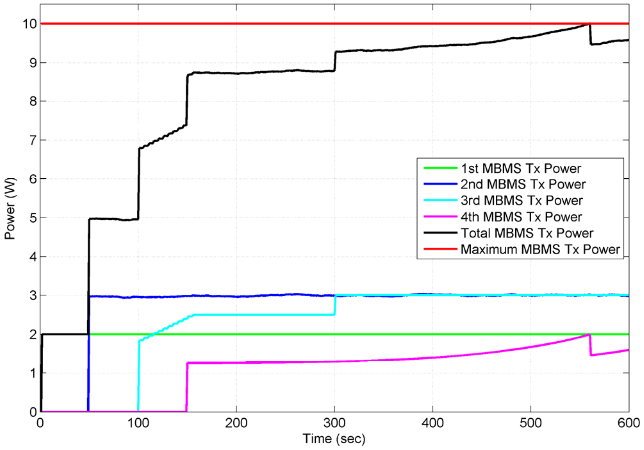

Figure 5. Power levels of the MBMS sessions.

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 (Figure 5). 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.

To sum up, Table 5 presents a cumulative, direct comparison between all mechanisms analyzed in this paper. The main conclusion extracted is that the proposed mechanism outperforms the other approaches in terms of power consumption, since significant power budget is saved. It puts together the benefits of all mechanisms by providing a scheme that is based on the concept of transport channels combination; and performs an optimal power resource allocation in LTE base stations. And even if the complexity of the proposed mechanism is higher than the complexity of the other mechanisms, the benefits from the optimal power planning counterbalance the complexity issues raised. This fact is strongly enhanced mainly due to the power limited LTE networks, which entails that power strategies are of key importance in order to obtain high capacity.

Table 5. Comparison of the mechanisms

Mechanism	Advantages	Disadvantages
TS 25.346	1) Low complexity 2) Easy to implement 3) 3GPP standardized	1) High power requirements 2) No mobility support 3) No HS-DSCH support 4) No MIMO support 5) No dynamic FACH support
TR 25.922	1) Support all transport channels 2) 3GPP standardized	1) High power requirements 2) No switching between HS-DSCH and DCH 3) No MIMO support 4) No dynamic FACH support
3GPP R1-02-1240	1) Power efficient 2) Support combined FACH and DCH 3) Support dynamic FACH	1) High complexity 2) No standardized 3) No HS-DSCH support 4) No MIMO support
Proposed Mechanism	1) Power efficient 2) Support combined usage of all channels 3) Support dynamic FACH 3) Support MIMO 4) Support multiple MBMS sessions	1) High complexity 2) No standardized (Novel Mechanism)

6. CONCLUSIONS AND FUTURE WORK

In this paper we proposed a novel mechanism for efficient transport channel selection during MBMS transmissions in LTE networks that defines downlink power as the switching criterion between different radio bearers. The proposed mechanism adopts the concept of radio bearer combination (PTP and/or PTM) so as to reduce the power requirements of the base stations and shares efficiently the available power resources of LTE base stations to MBMS sessions running in the network. Moreover, the proposed mechanism conforms to LTE requirements and takes advantages of MIMO antennas to further improve resource efficiency. Simulation results prove that our scheme strongly outperforms current 3GPP approaches in terms of power consumption, underlining the necessity for its incorporation in E-MBMS.

The step that follows this work could be at a first level the evaluation of the mechanism through additional simulation scenarios in the ns-2 simulator so as to measure, except from the performance of our mechanism, other parameters such as delays in air interfaces during MBMS transmissions. At a second level, we plan to further optimize the provision of MBMS over LTE/MIMO-enabled networks and investigate power saving techniques that can further enhance E-MBMS performance.

7. REFERENCES

[1] 3GPP TS 22.146 V8.3.0. “Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service; Stage 1 (Release 8)”, 2007.

[2] 3GPP TR 23.846 V6.1.0. “Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service; Architecture and functional description (Release 6)”, 2002.

[3] 3GPP TS 25.346 V8.1.0. “Technical Specification Group Radio Access Network; Introduction of the Multimedia Broadcast Multicast Service (MBMS) in the Radio Access Network (RAN); Stage 2, (Release 8)”, 2008.

[4] 3GPP TR 25.922 V7.1.0. “Technical Specification Group Radio Access Network; Radio resource management strategies (Release 7)”, 2007.

[5] 3GPP TSG-RAN WG1#28 R1-02-1240. “Power Usage for Mixed FACH and DCH for MBMS, Lucent Technologies”, 2002.

[6] Holma, H., Toskala, A.: HSDPA/HSUPA for UMTS: High Speed Radio Access for Mobile Communications. John Wiley & Sons (2006)

[7] Zihuai Lin; Sorensen, T.B.; Mogensen, P.E.: Downlink SINR Distribution of Linearly Precoded Multiuser MIMO Systems, IEEE Communications Letters, 11(11), 850-852, (2007)

[8] Perez-Romero, J., Sallent, O., Agusti, R., Diaz-Guerra, M.: Radio Resource Management Strategies in UMTS. John Wiley & Sons (2005)

[9] 3GPP TS 25.803 V6.0.0, Technical Specification Group Radio Access Network; S-CCPCH performance for MBMS, (Release 6)

[10] 3GPP TS 25.211 V7.4.0. “Physical channels and mapping of transport channels onto physical channels (FDD) (Release 7)”, 2007.

[11] 3GPP TS 25.212 V8.0.0. “Multiplexing and channel coding (FDD) (Release 8)”, 2007.