Chapter 2

THE MULTIMEDIA BROADCAST/MULTICAST SERVICE OF THE UNIVERSAL MOBILE TELECOMMUNICATIONS SYSTEM

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The Universal Mobile Telecommunications System (UMTS) constitutes the premier third generation (3G) wireless technology that is dominating the global market. Multicasting is an efficient method of supporting group communication as it allows the transmission of packets to multiple destinations, using fewer network resources. The need for broadcasting and multicasting in UMTS led to the definition of the Multimedia Broadcast/Multicast Service (MBMS) framework, which targets the efficient utilization of radio and network resources of the UMTS network. This chapter introduces the key concepts of UMTS and in particular the MBMS framework of UMTS. Moreover, it investigates the power profiles of several transport channels (common and dedicated) which could be employed for the transmission of MBMS services to mobile users. Problems regarding the high power requirements for the realization of MBMS are also presented. The reader will become familiar with these problems and the proposed techniques/solutions.

1. Introduction

Due to the rapid growth of mobile communications technology, the demand for wireless multimedia communications is thriving in consumer and corporate markets. The need to evolve multimedia applications and services is at a critical point given the proliferation and integration of wireless systems. Consequently, there is a great interest in using IP-based networks to provide multimedia services. One of the most important areas in which these issues are being debated is the development of standards for UMTS.

UMTS has been specified as an integrated solution for mobile voice and data with wide area coverage. Universally standardized via the 3rd Generation Partnership Project (3GPP) and using the globally harmonized spectrum in paired and unpaired bands, 3G/UMTS in its initial phase offers theoretical bit rates of up to 384 kbps in high mobility situations, rising as high as 2 Mbps in stationary/nomadic user environments. Through 3G mobile networks, mobile users have the opportunity to run applications and realize services that are currently only offered by wired networks. Such services include mobile Internet, mobile gaming, video calls, etc.

MBMS is a novel framework, extending the existing UMTS infrastructure, that constitutes a significant step towards so-called mobile broadband. MBMS is intended to efficiently use network and radio resources, both in the core network and, most importantly, in the air interface of the UMTS Terrestrial Radio Access Network (UTRAN), where the bottleneck is placed for a large group of users. Infact, MBMS is a Point-to-Multipoint service in which data is transmitted from a single source entity to multiple destinations, allowing the network resources to be shared. MBMS is an efficient way to support the plethora of emerging wireless multimedia and application services, such as IP video conferencing and streaming video by supporting both broadcast and multicast transmission modes.

The main target of this chapter is the investigation of the selection of the most efficient radio bearers for the transmission of MBMS multicast data. MBMS services can be provided in each cell by either multiple Point-to-Point (PTP) channels or by a single Point-to-Multipoint (PTM) channel. PTM transmission uses a single channel reaching down to the cell edge, which conveys identical traffic. On the other hand, PTP transmission uses dedicated channels allocated to each user separately. Obviously, a decision has to be made on the threshold between these two approaches in order to maximize capacity and resource efficiency.

The fundamental selection criterion for channel type is the amount of base station power required to transmit multicast data to a group of users. The choice of the most efficient transport channel in terms of power consumption is a key point for MBMS since the wrong transport channel selection for the transmission of MBMS data could result in a significant decrease in the total capacity of the system. In this regard, the role of power control in MBMS multicast transmission in UMTS is extensively described and analyzed. A power control scheme for the efficient radio bearer selection in MBMS is then proposed for minimizing the power consumption and consequently maximizing network capacity.

2. Background

In UMTS, bandwidth is a limited resource since the available radio resources can support only a handful high data-rate users simultaneously. Multicasting is an efficient method of supporting group communication as it allows the transmission of packets to multiple destinations using fewer network resources. 3GPP realized the need for broadcasting and multicasting in UMTS and proposed some enhancements on the UMTS Release 6 architecture that led to the definition of the MBMS framework [1, 2].

Transmission of MBMS data may be performed over Dedicated/PTP resources [one Dedicated Channel (DCH) for each user] or Common/PTM resources [one Forward Access Channel (FACH) shared by all the users] to distribute the same content in a cell. Yet no decision has been made within 3GPP on how to optimize the MBMS data flow. However, it is proposed to avoid the duplication of data flows over the air interface and hence, only one data flow per MBMS service should be used [3, 4].

The main requirement during the delivery of MBMS services is to make an efficient overall usage of radio and network resources. This makes a common channel the favorite choice, since many users can access the same resource at the same time. The MBMS counting mechanism [5] constitutes a mechanism that decides whether it is more economic to use the PTP or PTM MBMS transmission mode. According to this mechanism the decision on the threshold between PTP and PTM bearers is operator dependent, although it is proposed that it should be based on the number of serving MBMS users. In this regard, several studies have been carried out focusing on the threshold for switching between dedicated and common resources. In certain papers [6, 7] it is claimed that for a FACH with transmission power set to 4 Watts, the threshold for switching between dedicated and common resources is around seven users per cell and five users, respectively.

However, the current MBMS counting mechanism (using a user-based switching criterion between PTP and PTM) is not always efficient and may result in significant wastage of expensive power resources since it does not take into account the base station's downlink transmission power. Power budget in UMTS networks is the scarcest resource. Thus, power control has become one of the most important aspects in MBMS. The main purpose of power control is to minimize the transmitted power, thus avoiding unnecessarily high power levels and eliminating inter-cell interference. MBMS transmission power strongly depends not only on the number of serving users but also on the cell deployment, on propagations models, quality of service (QoS) requirements, users' distributions and on mobility issues. Therefore, it has become clear that only the information regarding the number of users in a cell may not be sufficient so as to select the appropriate radio bearer (PTP or PTM) for the specific cell. The decision has to take into consideration the total downlink power required for the transmission of the multicast data in the PTP and PTM cases.

Under these assumptions, a switching point, based on power consumption, of five users between dedicated and common resources may be configured [8]. Finally, Ref. 9 presents an analysis of the factors that affect the power allocation and the switching point between multiple DCHs and FACH in micro and macro cell environments. This analysis is indicative of how complicated the determination of appropriate threshold can be.

3. Multimedia Broadcast/Multicast Service

In MBMS rich wireless multimedia data is transmitted simultaneously to multiple recipients, by allowing resources to be shared in an economical way. MBMS efficiency is derived from the single transmission of identical data over a common channel without clogging up the air interface with multiple replications of the same data.

The major factor for integrating MBMS into UMTS networks was the rapid growth of mobile communications technology and the massive spread of wireless data and wireless applications. The increasing demand for communication between one sender and many receivers led to the need for PTM transmission. PTM transmission is opposed to the PTP transmission, using the unicast technology, which is exclusively used in conventional UMTS networks (without the MBMS extension). Broadcast and multicast technologies constitute an efficient way to implement this type of communication and enable the delivery of a plethora of high-bandwidth multimedia services to a large user population.

From the service and operators' point of view, the employment of the MBMS framework involves both an improved network performance and a rational usage of radio resources, which in turns leads to extended coverage and service provision. In parallel, users are able to realize novel, high bit-rate services, currently only experienced by wired users. Such services include mobile TV, weather or sports news as well as fast and reliable data download [10].

3.1. *MBMS Operation Modes*

As the term MBMS indicates, there are two types of service mode: the broadcast mode and the multicast mode. Each mode has different characteristics in terms of complexity and packet delivery.

The broadcast service mode is a unidirectional PTM transmission type. In fact, with broadcast, the network simply floods data packets to all nodes within the network. In this service mode, content is delivered using PTM transmission to a specified area without knowing the receivers and whether there is any receiver in the area. As a consequence, the broadcast mode requires no subscription or activation from the users' point of view.

In the multicast operation mode, data is transmitted solely to users that explicitly request such a service. More specifically, the receivers have to signal their interest for the data reception to the network and then the network decides whether the user may receive the multicast data or not. Thus, in the multicast mode there is the possibility for the network to selectively transmit to cells, which contain members of a multicast group. Either PTP or PTM transmission can be configured in each cell for the multicast operation mode.[1]

Unlike the broadcast mode, the multicast mode generally requires a subscription to the multicast subscription group and then the user joining the corresponding multicast group. Moreover, due to the selective data transmission to the multicast group, it is expected that charging data for the end user will be generated for this mode, unlike the broadcast mode.

3.2. *MBMS Architecture*

The MBMS framework requires minimal modifications in the current UMTS architecture. This fact enables the fast and smooth upgrade from pure UMTS networks to MBMS-enhanced UMTS networks. MBMS consists of an MBMS bearer service and an MBMS user service. The latter represents applications, which offer for example multimedia content to the users, while the MBMS bearer service provides methods for user authorization, charging and QoS improvement to prevent unauthorized reception [1].

UMTS network is split into two main domains: the user equipment (UE) domain and the Public Land Mobile Network (PLMN) domain. The UE domain consists of the equipment employed by the user to access the UMTS services. The PLMN domain consists of two land-based infrastructures: the core network (CN) and the UTRAN (Fig. 1). The CN is responsible for switching/routing voice and data connections, while the UTRAN handles all radio-related functionalities. The CN is logically divided into two service domains: the circuit-switched (CS) service domain and the packet-switched (PS) service domain [10]. The CS domain handles voice-related traffic while the PS domain handles packet transfer. In the remainder of this chapter, we will focus on the UMTS packet-switching mechanism.

The PS portion of the CN in UMTS consists of two kinds of General Packet Radio Service (GPRS) support nodes (GSNs), namely Gateway GSN (GGSN) and Serving GSN (SGSN) (Fig. 1). SGSN is the centerpiece of the PS domain. It provides routing functionality, interacts with databases [like Home Location Register (HLR)]

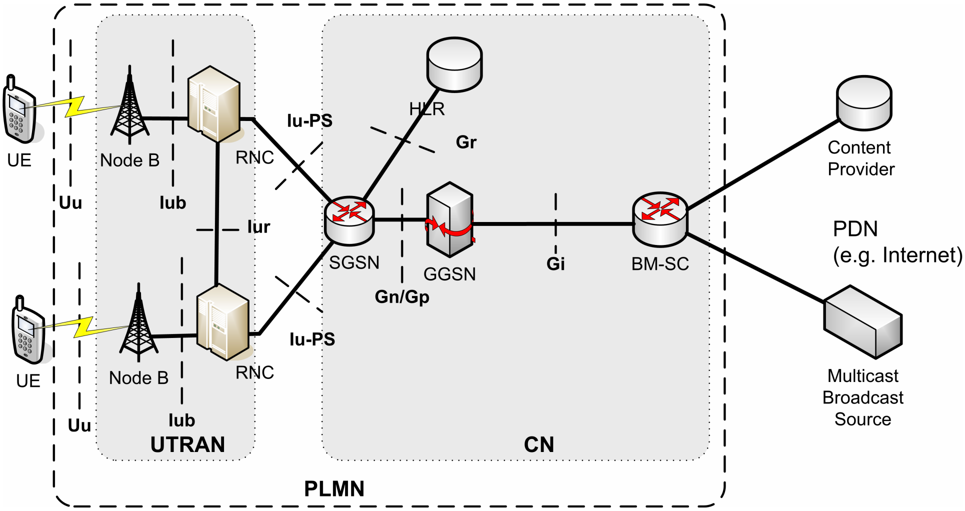


Fig. 1. UMTS and MBMS architecture.

and manages many Radio Network Controllers (RNCs). SGSN is connected to GGSN via the Gn interface and to RNCs via the Iu interface. GGSN provides the interconnection of UMTS network (through the Broadcast Multicast-Service Center) with other Packet Data Networks (PDNs), like the Internet.

UTRAN consists of two kinds of nodes: the first is the RNC and the second is Node B. Node B constitutes the base station and provides radio coverage to one or more cells (Fig. 1). Node B is connected to the UE via the Uu interface [based on the Wideband Code Division Multiple Access (WCDMA) technology] and to the RNC via the Iub interface. One RNC with all the Node Bs connected to it is called Radio Network Subsystem (RNS) [10].

The major modification in the existing UMTS platform for the provision of the MBMS framework is the addition of a new entity called the Broadcast Multicast-Service Center (BM-SC). Actually, BM-SC acts as an entry point for data delivery between the content providers and the UMTS network and is located in the PS domain of the CN. The BM-SC entity communicates with existing UMTS networks and external PDNs [1, 2].

The BM-SC is responsible for both control and user planes of an MBMS service. More specifically, the function of the BM-SC can be separated into five categories: membership, session and transmission, proxy and transport, service announcement, and security function. The BM-SC membership function provides authorization to the UEs requesting to activate an MBMS service. According to the session and transmission function, the BM-SC can schedule MBMS session transmissions and can provide the GGSN with transport associated parameters, such as QoS and MBMS service area. As far as the proxy and transport function is concerned, the BM-SC is a proxy agent for signaling over the Gmb reference point between GGSNs and other BM-SC functions. Moreover, the BM-SC service announcement function must be able to provide service announcements for multicast and broadcast MBMS user services and provide the UE with media descriptions specifying the media to be delivered as part of an MBMS user service. Finally, MBMS user services may use the security functions for integrity or confidentiality protection of the MBMS data, while the specific function is used for distributing MBMS keys (key distribution function) to authorized UEs.

3.3. *Multicast Mode of MBMS*

MBMS multicast efficiency improvement in UMTS networks can be derived from the following figures. More specifically, Figs. 2 and 3 present UMTS multicast functionality without and with MBMS enhancement, respectively.

Without the MBMS enhancement, multicast data is replicated as many times as the total number of multicast users in all interfaces. Obviously, a bottleneck occurs when the number of users increases significantly. All interfaces are heavily overloaded due to multiple transmissions of the same data. On the other hand, MBMS multicast benefits UMTS networks through the radio and network resource

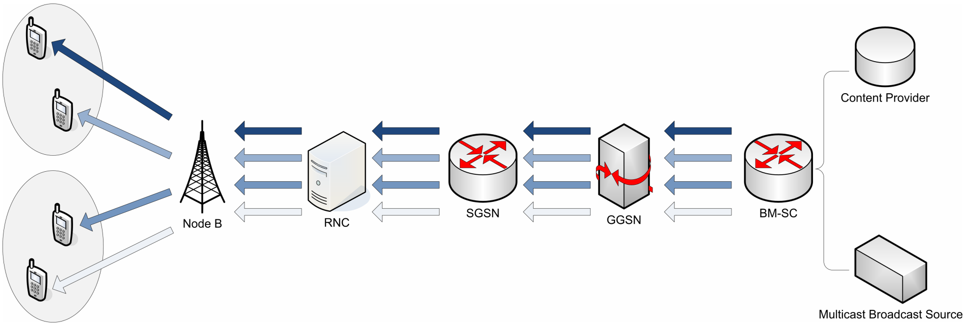


Fig. 2. UMTS multicast without MBMS enhancement.

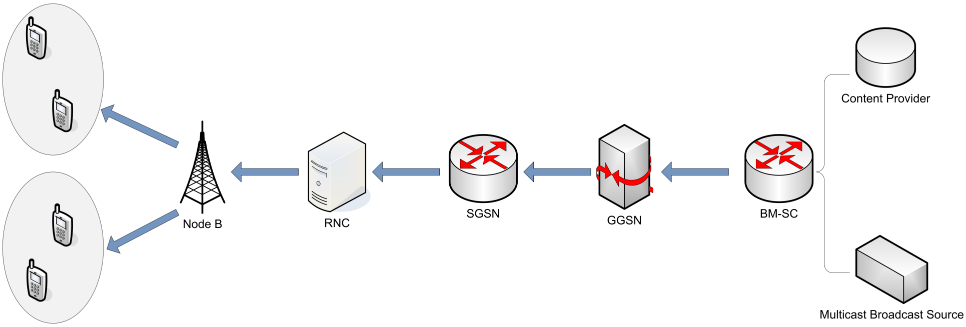


Fig. 3. UMTS multicast with MBMS enhancement.

sharing. Only a single stream per MBMS service of identical data is essential for the delivery of the multicast content, thus saving expensive resources. Consequently, MBMS multicast data distribution is optimally configured throughout the UMTS network.

3.3.1. *Packet Delivery Process*

An overview of the multicast data flow procedure during an MBMS service provision is presented in this section. Figure 4 depicts a subset of a UMTS-MBMS network. In this architecture, there are two SGSNs connected to a GGSN, four RNCs, and twelve Node Bs. Furthermore, eleven members of a multicast group are located in six cells. The BM-SC acts as the interface to external sources of traffic. In the presented analysis, we assume that a data stream that comes from an external PDN, through BM-SC, must be delivered to the 11 UEs as illustrated in Fig. 4.

The analysis presented in the following paragraphs covers the forwarding mechanism of the data packets between the BM-SC and the UEs. With multicast, the packets are forwarded only to those Node Bs that have multicast users. Therefore, in Fig. 4, the Node B2, B3, B5, B7, B8 and B9 receive the multicast

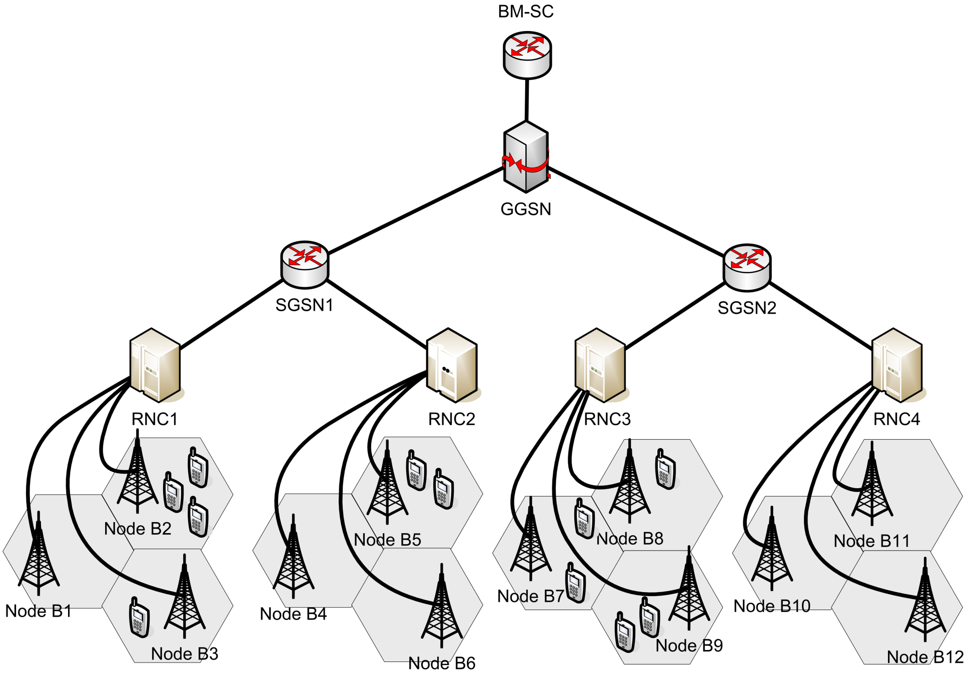


Fig. 4. Packet delivery in MBMS multicast mode.

packets issued by the BM-SC. We briefly summarize the five steps that are required for the delivery of multicast packets.

Initially, the BM-SC receives a multicast packet and forwards it to the GGSN that has been registered to receive multicast traffic. Then, the GGSN receives the multicast packet and, by querying its multicast routing lists, it determines which SGSNs have multicast users residing in their respective service areas. In Fig. 4, the GGSN duplicates the multicast packet and forwards it to SGSN1 and SGSN2 [11]. Then, both destination SGSNs receive the multicast packets and, having queried their multicast routing lists, determine which RNCs are to receive the multicast packets. The destination RNCs receive the multicast packet and send it to the Node Bs that have established the appropriate radio bearers for the multicast application. In Fig. 4, these are: Node B2, B3, B5, B7, B8, and B9. The multicast users receive the multicast packets on the appropriate radio bearers through dedicated channels transmitted to individual users separately or through common channels transmitted to all members in the cell [11].

3.3.2. *MBMS Multicast Mode Radio Bearers*

According to current MBMS specifications, the transmission of MBMS multicast packets over the Iub and Uu interfaces may be performed over common (FACH) and dedicated (DCH) transport channels. The main requirement is to make an efficient overall utilization of the radio resources. This makes a common channel the favorite choice since many users can access the same resource at the same time.

More specifically, the transport channel that 3GPP decided to use as the main transport channel for PTM MBMS data transmission is the FACH with turbo coding and quadrature phase shift keying (QPSK) modulation at a constant transmission power [2]. DCH is a PTP channel, and hence, it suffers from the inefficiencies of requiring multiple DCHs to carry the data to a group of users. However, DCH can employ fast closed-loop power control and soft handover mechanisms and is generally a highly reliable channel [3, 10].

4. Power Control in MBMS Multicast Mode

Power control is one of the most critical aspects in MBMS due to the fact that downlink transmission power in UMTS networks is a limited resource and must be shared efficiently among all MBMS users in a cell. Power control aims at minimizing the transmitted power, eliminating in this way the intercell interference. However, when misused, the use of power control may lead to a high level of wasted power and worse performance results.

On the PTP downlink transmissions, fast power control is used to maintain the quality of the link and thus to provide a reliable connection for the receiver to obtain the data with acceptable error rates. Transmitting with just enough power to maintain the required quality for the link also ensures that there is minimum interference affecting the neighboring cells. However, when a user consumes a high portion of power, more than is actually required, the remaining power allocated for the rest of the users is dramatically decreased, thus leading to a significant capacity loss in the system.

During PTM downlink transmissions, Node B transmits at a power level that is high enough to support the connection to the receiver with the highest power requirement among all receivers in the multicast group. This would still be efficient because the receiver with the highest power requirement would still need the same amount of power in a unicast link, and by satisfying that particular receiver's requirement, the transmission power will be enough for all the other receivers in the multicast group. Consequently, the transmitted power is kept at a relatively high level most of the time, which in turn increases the signal quality at each receiver in the multicast group. On the other hand, a significant amount of power is wasted and moreover intercell interference is increased.

As a consequence, downlink transmission power plays a key role in MBMS planning and optimization. This section provides an analytical description of the DCH and FACH power profiles that are employed during PTP and PTM transmission, respectively. It also presents the main characteristics of the MBMS counting mechanism. Finally, techniques for decreasing the power requirements during MBMS multicast delivery are discussed. The following analysis refers to a macrocell environment with parameters described in Table 1 [10, 12].

Table 1. Macrocell simulation assumptions.

Parameter	Value
Cellular layout	Hexagonal grid
Number of cells	18
Sectorization	3 sectors/cell
Site-to-site distance	1 km
Cell radius	0.577 km
Maximum BS Tx power	20 W (43 dBm)
Other BS Tx power	5 W (37 dBm)
Common channel power	1 W (30 dBm)
Propagation model	Okumura–Hata
Multipath channel	Vehicular A (3 km/h)
Orthogonality factor	0.5
E_b/N_0 target	5 dB

4.1. *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 location in the cell, the bit rate of the MBMS session, and the signal quality E_b/N_0 experienced by each user. Equation (1) calculates Node B's total DCH transmission power required for the transmission of the data to n users in a specific cell [13]:

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

where P_T is the base station's total transmitted power, P_P the power devoted to common control channels, $L_{p,i}$ the path loss, $R_{b,i}$ the ith user transmission rate, W the bandwidth, P_N the background noise, p is the orthogonality factor ($p = 0$ for perfect orthogonality), and x_i the inter-cell interference observed by the ith user given as a function of the transmitted power by the neighboring cells P_{Tj}, $j = 1, \ldots, K$ and the path loss from this user to the jth cell L_{ij}. More specifically [13]:

$$x_i \sum_{j=1}^{K} \frac{P_{Tj}}{L_{ij}}. \tag{2}$$

DCH may be used for the delivery of PTP MBMS services while it cannot be used to serve large multicast populations since high downlink transmission power would be required. Figure 5 depicts the downlink transmission power when MBMS multicast data is delivered over multiple DCHs (one separate DCH per user). Obviously, higher power is required to deliver higher MBMS data rates. In

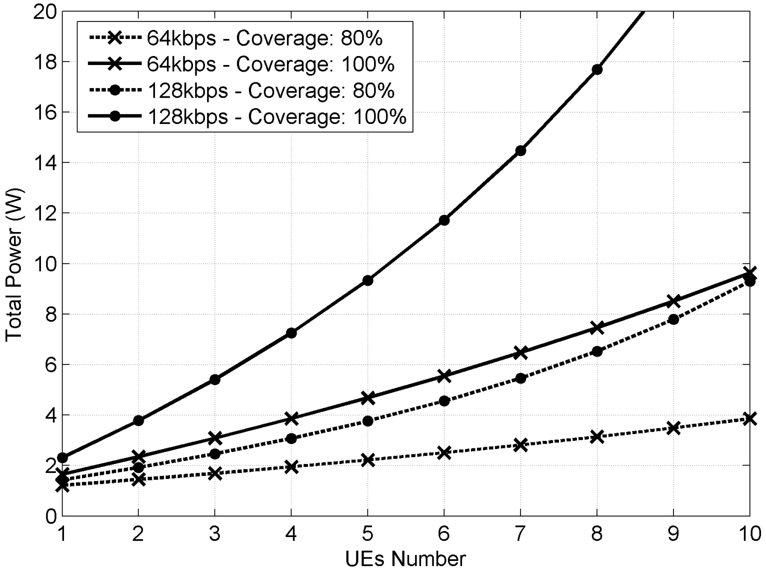


Fig. 5. DCH Tx power.

addition, increased cell coverage area and larger user groups lead to higher power consumption.

4.2. *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). Thus, the fixed power should be high enough to ensure the requested QoS in the desired coverage area of the cell, irrespective of users' location. FACH power efficiency strongly depends on maximizing diversity as power resources are limited. Diversity can be obtained by the use of a longer transmission time interval (TTI) in order to provide time diversity against fast fading (fortunately, MBMS services are not delay sensitive) and the combining of transmissions from multiple cells to obtain macro diversity [14, 15].

Table 2 presents some indicative FACH downlink transmission power levels obtained for various cell coverage areas and MBMS bit rates, without assuming diversity techniques [8, 15]. A basic constraint is that the delivery of high data rate

Table 2. FACH Tx power levels.

Cell coverage (%)	Service bit rate (kbps)	Required Tx power (W)
50	32	1.8
	64	2.5
95	32	4.0
	64	7.6

MBMS services over FACH is not feasible since excessive downlink transmission power would be required (overcoming the maximum available power of 20 W). High bit rates can only be offered to users located very close to Node B.

4.3. *Improved MBMS Counting Mechanism*

As mentioned earlier in this chapter, MBMS multicast operation mode can employ either PTP or PTM transmission over the air interface. In general, PTP connections are established when serving a small MBMS population, while PTM transmission is preferred when the number of users is high. Figure 6a depicts MBMS multicast transmission when using PTP bearers, while Fig. 6b presents the case of PTM bearer deployment for the delivery of multicast content over the air.

A key aspect for MBMS multicast efficiency is the so-called MBMS counting mechanism. The MBMS counting mechanism allows the network to determine the switching between PTP and PTM transmission. In fact, this mechanism aims to maximize radio resource efficiency through a threshold for switching between the two different transmission modes.

However, the current MBMS counting implementation [5] uses a threshold based on the number of simultaneous users receiving the same multicast content. This scheme, though, cannot always ensure resource efficiency, since it does not consider the dynamic nature (i.e., users' mobility, etc.) of a MBMS-enabled UMTS network. Therefore, the current form of this mechanism may lead to an erroneous threshold determination that, in turn, may result in inefficient utilization of network resources.

The fundamental criterion for maximizing resource efficiency should be the Node B's total downlink MBMS transmission power [16]. The MBMS counting

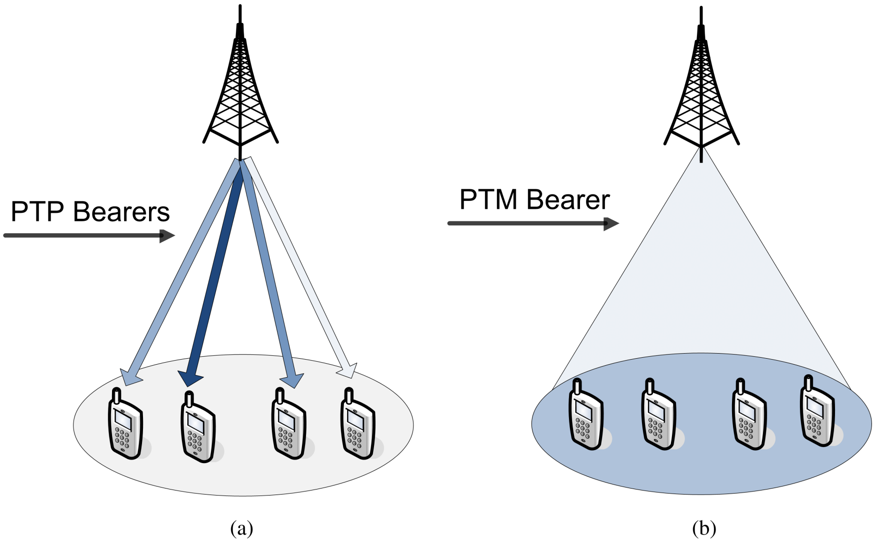
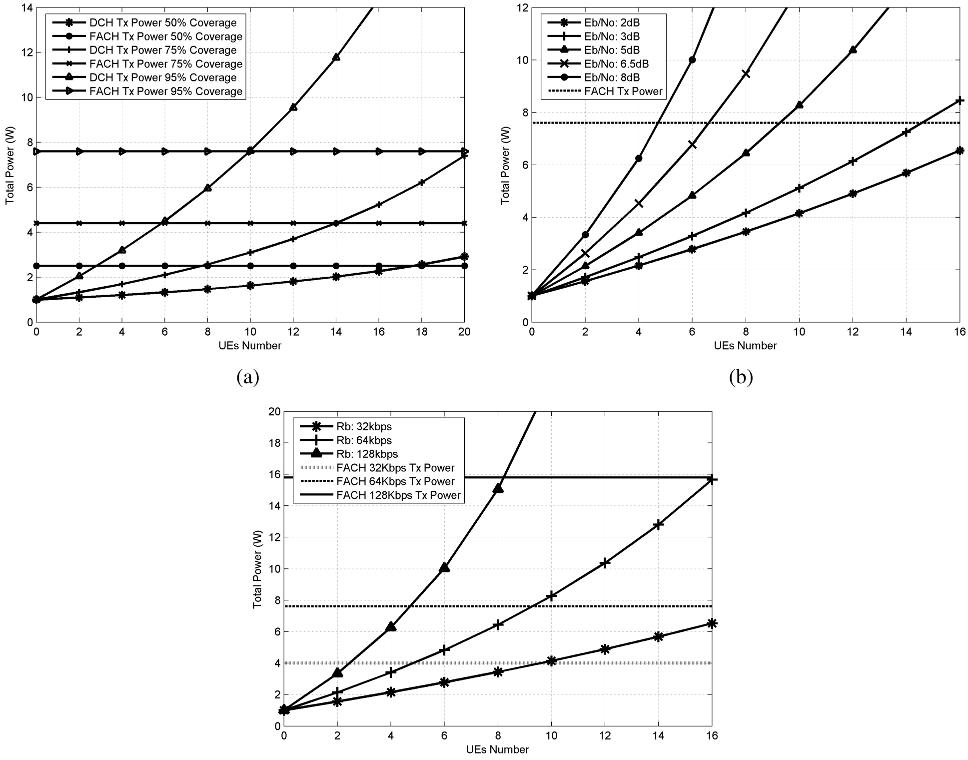


Fig. 6. MBMS bearers: (a) PTP and (b) PTM.

mechanism should adopt downlink transmission power as the optimum criterion for radio bearer selection due to the fact that any dynamic change can be reflected in the Node B's transmission power. MBMS transmission power strongly depends not only on the number of serving users but also on the QoS requirements, users distributions and on MBMS service bit rate.

The impact of the aforementioned factors on the transmission power levels when using DCH or FACH channels is depicted in the following figures. The aim of this parallel plotting is to determine the most efficient transport channel, in terms of power consumption, for the transmission of the MBMS data.

In Fig. 7a the effect of UE location throughout the cell is presented. When multiple DCHs are used, it is obvious that the further the UE is from Node B, the more power is required for successful delivery of MBMS service in a cell. Moreover, Fig. 7a depicts how the appropriate switching point between DCHs and FACH changes for different cell coverage areas. For instance, the switching point between DCHs and FACH (for a 64 kbps service) for 95% cell coverage is nine UEs. Above this number of UEs, FACH is the most appropriate channel for the transmission of multicast data in terms of power consumption. For 75% cell



(a) (b)

(c)

Fig. 7. DCH, FACH Tx power versus (a) cell coverage, (b) E_b/N_0 and (c) bit rate.

coverage the switching point between multiple DCHs and FACH is 14 UEs, while for 50% coverage the threshold further increases to 18 UEs. Similarly, Figs. 7b and 7c show that as E_b/N_0 and the MBMS bit rate increase, transmission power increases too. Simulation results presented in these figures correspond to the worst case scenario, where 95% coverage is assumed. Additionally, these figures depict the impact of these parameters on the switching point between DCHs and FACH.

From the preceding analysis, it is obvious that the determination of the appropriate switching point between PTP and PTM bearers is a rather complicated procedure, indicating the need for a dynamic approach.

4.4. *Power Saving Techniques*

Apart from the determination of the appropriate thresholds for switching between PTP and PTM bearers, MBMS has to confront another problem regarding the power consumption in PTM mode. More specifically, in PTM mode, multicast data is transmitted over the FACH, which requires a relatively high power allocation level. This fact may lead to increased wastage of power resources and interference in the system, especially during the provision of high bit rate MBMS services. In this section, several power saving techniques are proposed that aim to overcome this problem and substantially decrease Node B's power consumption during PTM transmission.

4.4.1. *Dynamic Power Setting (DPS)*

Setting Node B's transmission power to a level high enough so as to cover the whole cell is wasteful if not even one MBMS user is close to the cell edge. Dynamic power setting (DPS) is the technique where the transmission power of the FACH can be determined based on the "worst" user path loss. This way, FACH transmission power is allocated dynamically, and the FACH transmission power will need to cover the whole cell only if one (or more) user is at the cell boundary. To perform DPS, MBMS users need to turn on a measurement report mechanism while they are on the Cell_FACH state. Based on such measurement reports, Node B can adjust the transmission power of the FACH [17]. This is presented in Fig. 8, where Node B sets its transmission power based on the worst user path loss (i.e., distance). The information about the path loss is sent to Node B via the Random Access Channel (RACH).

Examination of Fig. 8 reveals that 4.0 W is required in order to provide a 32 kbps service to 95% of the cell. However, supposing that all the MBMS users are found near Node B (10% coverage) only 0.9 W is required. In that case, 3.1 W (4.0 W minus 0.9 W) can be saved while delivering a 32 kbps service, since with DPS Node B will set its transmission power so as to cover only 10% of the cell. The corresponding power gain increases to 6.2 W for a 64 kbps service and to 13.4 W for a 128 kbps service.

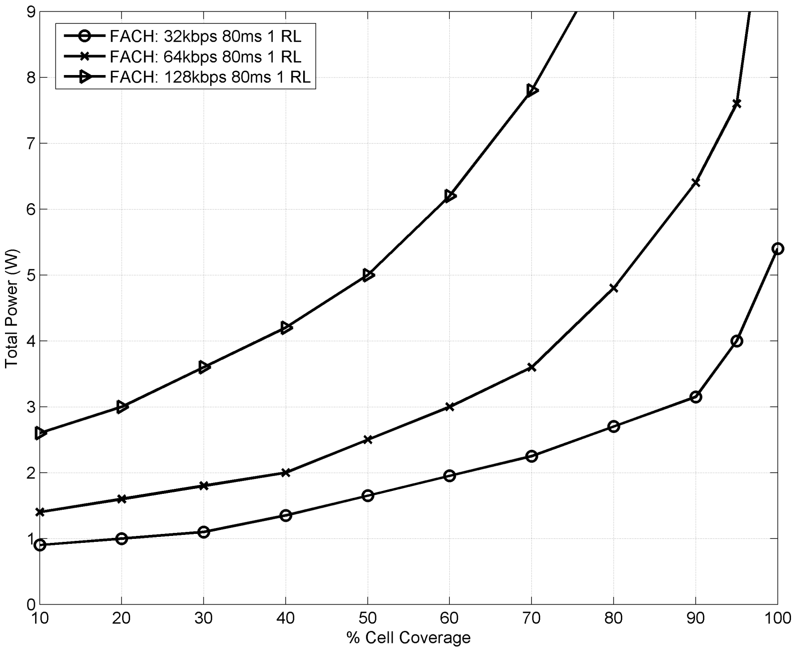


Fig. 8. FACH Tx power with DPS.

4.4.2. *Macro Diversity Combining (MDC)*

Diversity is a technique to combine several copies of the same message received over different channels. Basically, the macro diversity combining (MDC) concept consists of receiving redundantly the same information bearing signal over two or more fading channels, and combining these multiple replicas at the receiver in order to increase the overall received signal-to-noise ratio (SNR). As the user receives data from two (or three) Node Bs, simultaneously the required power of the first Node B is decreased; however, the total required power remains the same [8].

Figure 9 shows how the FACH transmission power level changes with cell coverage when MDC is applied. For the purposes of simulation we considered that a 64 kbps service should delivered, using 1, 2 or 3 Node Bs (or radio links). TTI is assumed to be 80 ms. In Table 3 we list some cases that reveal the power gains with this technique.

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

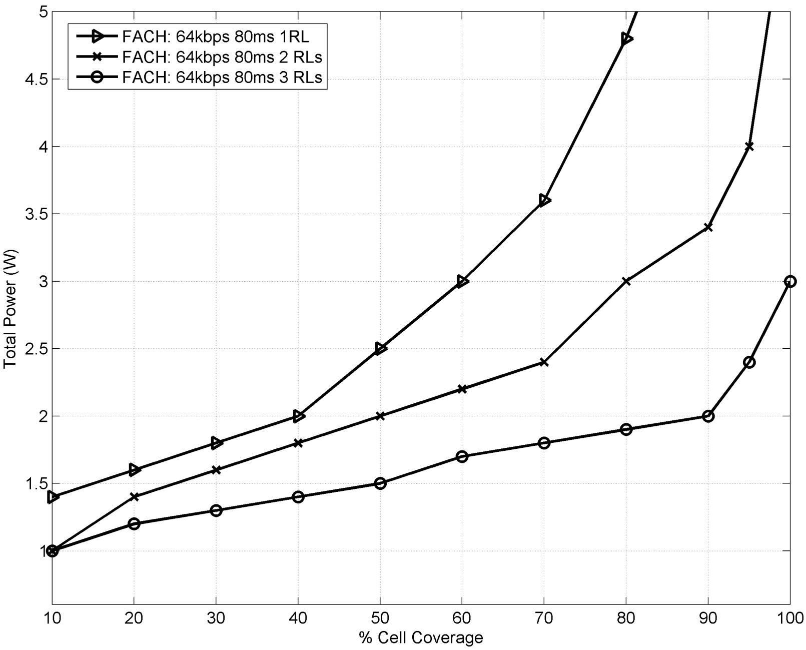


Fig. 9. FACH Tx power with MDC (1RL, 2RLs and 3RLs).

Table 3. Indicative FACH Tx power levels with MDC.

Cell coverage (%)	Radio links	Required power (W)
50	1	2.5
	2	2.0
	3	1.5
95	1	7.6
	2	4.0
	3	2.4

4.4.3. *Rate Splitting (RS)*

The RS technique assumes that the MBMS data stream is scalable and can thus be split into several streams with different QoS. Only the most important stream is sent to all the users in the cell to provide the basic service. The less important streams are sent with less power or coding protection and only the users who have better channel conditions (i.e., the users close to Node B) can receive those to enhance the quality on top of the basic MBMS stream. This way, transmission power for the most important MBMS stream can be reduced because the data rate is reduced, and the transmission power for the less important streams can also be reduced because the coverage requirement is relaxed [18].

In the scenario depicted in Fig. 10, we consider that a 64 kbps service can be split in two streams of 32 kbps. The first 32 kbps stream (basic stream of the

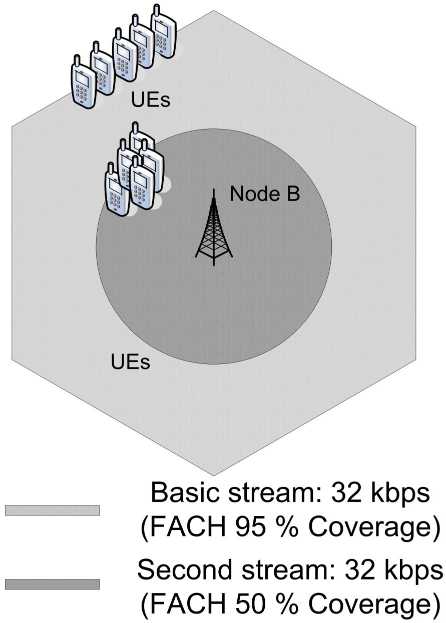


Fig. 10. MBMS provision with RS.

64 kbps service) is provided throughout the whole cell, as it is supposed to carry the important information of the MBMS service. In contrast, the second 32 kbps stream is sent only to the users who are close to Node B (50% of the cell area) providing the users in the particular region the full 64 kbps service. Figure 10 also depicts the way this technique functions, in terms of channel selection and cell coverage.

From Fig. 10 it can be seen that this technique requires 5.8 W (4.0 W for the basic stream and 1.8 W for the second). On the other hand, in order to deliver a 64 kbps service using a FACH with 95% coverage the required power would be 7.6 W. Thus, 1.8 W can be saved through the RS technique. However, it is worth mentioning that this power gain involves certain negative results. Some of the users will not be fully satisfied, as they will only receive the 32 kbps of the 64 kbps service, even if these 32 kbps have the most important information. As the observed difference will be small, Node B should weigh between the transmission power and the users' requirements.

4.4.4. *Usage of Longer TTI and Space Diversity (LTTI)*

These two methods can be employed in the physical layer to benefit every member of the MBMS group in a cell. An increment in TTI length (from 20 ms to 80 ms) can provide significant power gain. However, the use of longer TTI introduces more complexity and larger memory space requirement in the mobile station [15, 19].

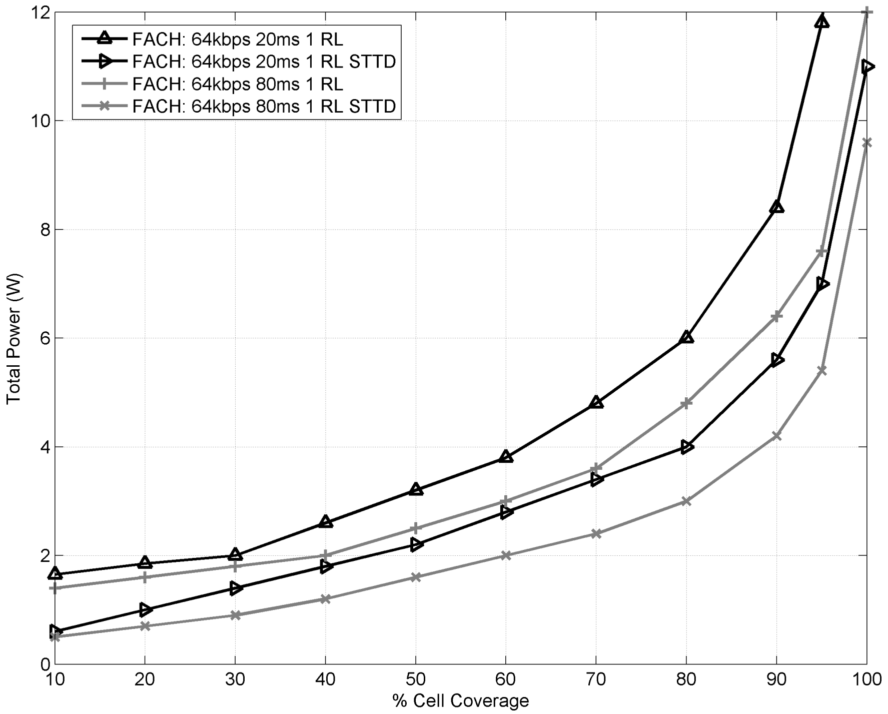


Fig. 11. FACH Tx power with LTTI.

Fortunately, MBMS services are not delay sensitive. In that case, diversity can be obtained by using a longer TTI, e.g., 80 ms instead of 20 ms, so as to provide time diversity against fast fading. Figure 11 shows the power levels that are indicative of the sums of power that can be saved by using the LTTI technique.

Table 4, on the other hand, demonstrates certain cases that reveal the sums of power that can be saved while delivering a 64 kbps service, by increasing the TTI length and obtaining STTD. The power levels are indicative of the sums of power that can be saved by using the LTTI technique.

Table 4. Indicative FACH Tx power levels with LTTI.

Cell coverage (%)	TTI (ms)	Required power (W)
50	20 — no STTD	3.2
	20 — with STTD	2.2
	80 — no STTD	2.5
	80 — with STTD	1.6
95	20 — no STTD	11.8
	20 — with STTD	7.0
	80 — no STTD	7.6
	80 — with STTD	5.4

4.4.5. *Mixed Usage of Multiple DCHs and FACH (MDF)*

MDF can significantly decrease Node B's transmission power, depending on the number and the location of the users that receive the MBMS service. In this approach, the FACH channel only covers the inner part of the sector (e.g., 50% of the sector area) and provides the MBMS service to the users that are found in this part ("inner part" users). The rest of the users are served using DCH to cover the remaining outer cell area ("outer part" users). Figure 12 shows the way of providing an MBMS service according to the MDF technique. 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 [20].

The main goal is to examine how the transmission power is affected by the number of users. Figure 13 represents Node B's total transmission power as a function of the number of "outer part" users. The total power in Fig. 13 includes the power that is required in order to cover the 50% of the cell with FACH (i.e., 2.5 W). Moreover, the number of "inner part" users is assumed to be high enough so as to justify the choice of FACH as the transport channel in the inner part.

Apart from the power required for the MDF technique, the power allocation level of a FACH with 95% cell coverage is depicted. This parallel plot intends to highlight the fact that a switch from MDF to a pure FACH has to be performed, or *vice versa*. For instance, in Fig. 13 when the "outer part" users exceed seven, the total power (i.e., the power to cover the inner part with FACH plus the power to cover the outer part with DCHs) exceeds the power that is required in order to cover the whole cell with a single FACH. Thereby, it is more "power efficient" to use a FACH with 95% coverage.

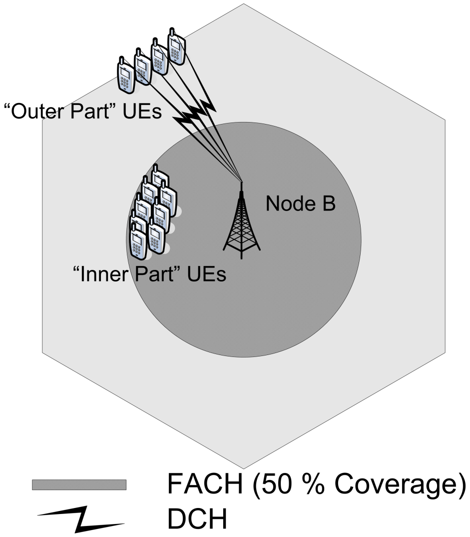


Fig. 12. MBMS provision with MDF.

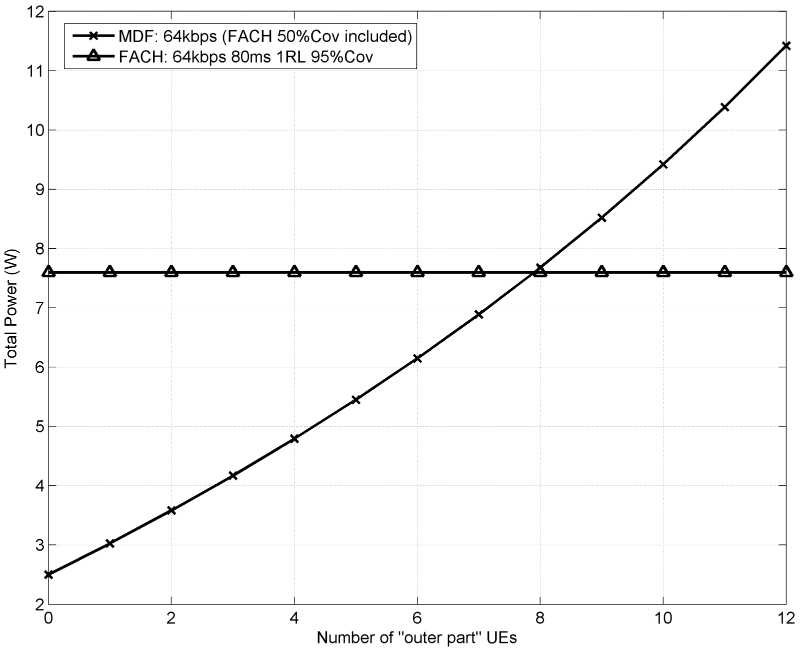


Fig. 13. Node B's Tx power with MDF.

Except for the power gain described above, the MDF technique ensures one more advantage. This advantage relies on the fact that DCH supports soft handover, while FACH does not. Since with this technique the users that are found near the cell edge are served with DCHs, their transition to another cell will be smoother, as the MBMS service will be provided uninterruptedly.

5. Thoughts for Practitioners

In the context of switching between PTP and PTM transmissions several techniques have been proposed. The MBMS counting mechanism was the prevailing approach mainly due to its simplicity of implementation and function [5]. According to this approach, a switch from dedicated to common resources occurs when the number of multicast users in a cell exceeds a predefined threshold. However, this approach suffered from much inefficiency mainly due to the difficulty of defining the appropriate threshold.

Assuming that all UEs are distributed uniformly across the cell, the MBMS counting mechanism provides an unrealistic 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), the conventional counting mechanism may lead to misleading results, and thus to an inappropriate threshold resulting in inefficient utilization of network resources.

That the total downlink transmission power allocated for DCHs is variable and depends on several factors makes the problem even more complicated. All these factors should be taken into consideration in order to define the appropriate threshold. Moreover, the utilization of the proposed power saving techniques would lead to a multidimensional threshold scheme, making the situation even more complicated. This way, the advantage of simplicity of implementation is overshadowed by the disadvantage generated from the difficulty of determining the appropriate switching points. Summarizing, we can say that the research in the field of the MBMS counting mechanism was motivated mainly due to its simplicity of implementation. However, the difficulties regarding the determination of the switching threshold proved to be significant and in most cases insurmountable.

On the other hand, the efficiency of a power control mechanism where there is no need for *a priori* information and predefined switching thresholds has been studied in previous work [16]. In this work, the authors propose a power control scheme for efficient radio bearer selection in UTRAN. However, this approach does not take into consideration users' mobility as well as the power saving techniques. All these parameters are taken into account in the proposed power control mechanism, the description and architecture of which follows in the next section.

5.1. *Architecture of MBMS Power Control Mechanism*

This section presents and analyzes the architecture and the functionality of the proposed MBMS power control mechanism, which is used for efficient data transmission during an MBMS service. The block diagram of the mechanism is illustrated in Fig. 14.

According to Fig. 14, the mechanism consists of five distinct operation phases. These are: the initialization phase, the parameter retrieval phase, the power computation phase, the radio bearer selection phase, and the event scheduling phase. The RNC is the responsible node of the MBMS architecture for the operation of this algorithm and the decision of the most efficient bearer.

The initialization phase an launches the mechanism when one user expresses his interest in receiving an 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 Node B and the E_b/N_0 requirement per UE. The MBMS service bit rate is assumed to be known (in BM-SC). This information is later used as input in the power computation phase.

The power computation phase substantially processes the data received from the parameter retrieval phase. During this phase, the required power to be allocated for each cell is computed. The computation is based on the assumption that the

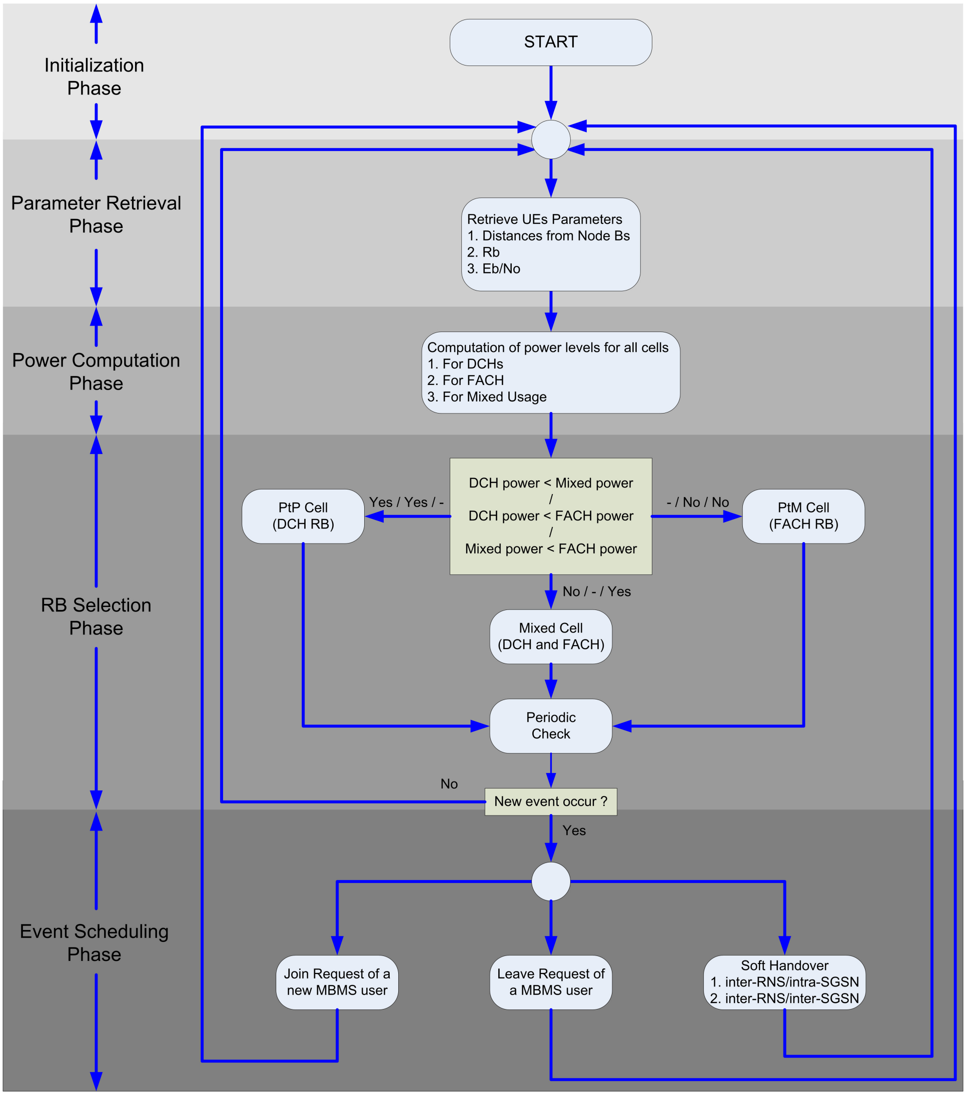


Fig. 14. Block diagram of the proposed MBMS power control mechanism.

transmission of the multicast data (for each cell separately) over the Uu interface can be performed with:

- multiple DCHs (DCHs case),
- one FACH with power so as to serve the UE that is farthest from Node B, and therefore all the UEs in the cell (FACH dynamic case), or
- one FACH with power so as to serve the UEs that reside in 50% of the cell area, while the remaining UEs are served with DCHs (mixed case).

In other words, the total Node B transmission power per cell for the given MBMS session is computed, assuming that all the UEs of the session can be served three possible ways. The computation for the DCHs case takes into account the parameters defined in the parameter retrieval phase and calculates the total required power (P_{DCH}) according to Eq. (1). For the FACH dynamic case, the total required power (P_{FACH}) is computed depending on the user with the worst path loss and according to Table 2 and Fig. 8. Finally, the mixed case assumes that if there are UEs in 50% of the cell area, they are served with one FACH (requiring 2.5 W for a 64 kbps service according to Table 2), while the power required for the rest of the UEs is calculated according to Eq. (1). The total required power for this case (P_{Mixed}) is the sum of the two mentioned power levels.

In the radio bearer selection phase, P_{DCH}, P_{FACH} and P_{Mixed} are compared in order to select the most efficient transmission method for the specific MBMS session. Thus, for each cell separately, the algorithm decides which case consumes the least power and, consequently, chooses the radio bearer that minimizes the Node B transmission power per cell. Therefore, a cell can be characterized as a PTP cell (data is carried through multiple DCHs), as a PTM cell (data is carried through the FACH channel) or as a mixed cell (data is carried through FACH and DCHs). The categorization of the cells is done for each MBMS session in the system.

The algorithm enters the event scheduling phase only if one of the following three different events occurs during an MBMS session: a Join request from a new MBMS user, a Leave request from an existing MBMS user, or a Soft Handover. The algorithm handles these three events absolutely the same way since the parameters of all the users are updated at regular time intervals. The only difference is that a Join and a Leave request influences the power of only one cell, while a Soft 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 users' mobility and the three events of the event scheduling phase. Therefore, the P_{DCH}, P_{FACH} and P_{Mixed} power levels must be computed periodically at a predetermined frequency rate. This periodic computation introduces 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 in a capacity reduction.

5.2. *Scenarios*

This section illustrates how the Node B's transmission power for an MBMS session could be reduced by selecting different transport channels for the transmission of the MBMS data over the Iub and Uu interfaces. To this end, five different scenarios are examined. The users' initial locations for the first four scenarios are presented in Fig. 15. During the simulation each UE is moving randomly throughout the

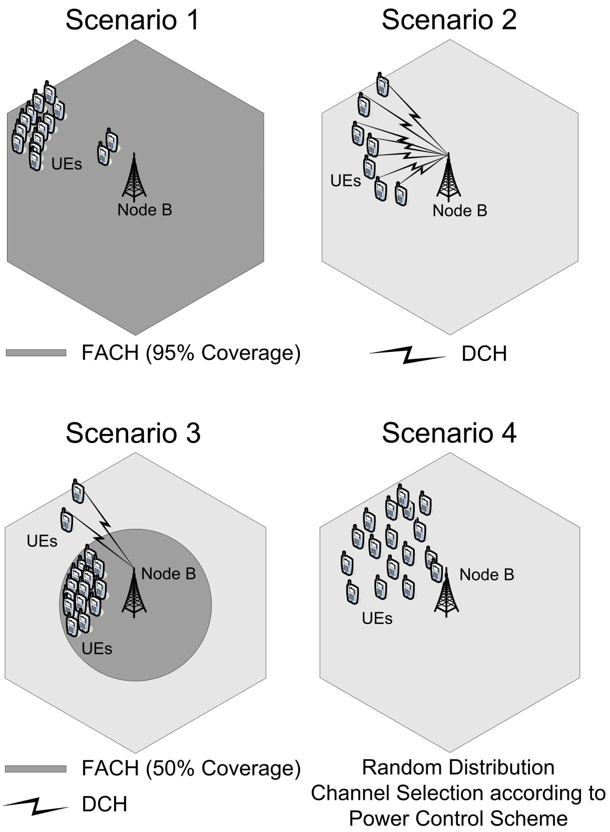


Fig. 15. UEs' initial locations for Scenarios 1–4.

topology. It is worth mentioning that in the first three scenarios the users' initial locations are selected so as to favor the transmission of the MBMS data through FACH, multiple DCHs, and the combination of these channels, respectively. Without loss of generality, these three scenarios constitute possible cases during an MBMS session in a real-world scenario. On the other hand, Scenarios 4 and 5 illustrate how the mechanism handles the three different events of the event scheduling phase.

Transmission power levels when using DCH, FACH or mixed channels are depicted in each of the following figures (Figs. 16–18, 21). These power levels constitute the overall output of the power computation phase in each scenario. In the next phase, the mechanism will force the RNC to select at each instant the radio bearer that ensures the lowest power requirements.

5.2.1. *Scenario 1: PTM Cell*

According to the first scenario, 12 UEs near the cell borders and two UEs close to Node B receive a 64 kbps MBMS service (Fig. 15). Figure 16 reveals the total power

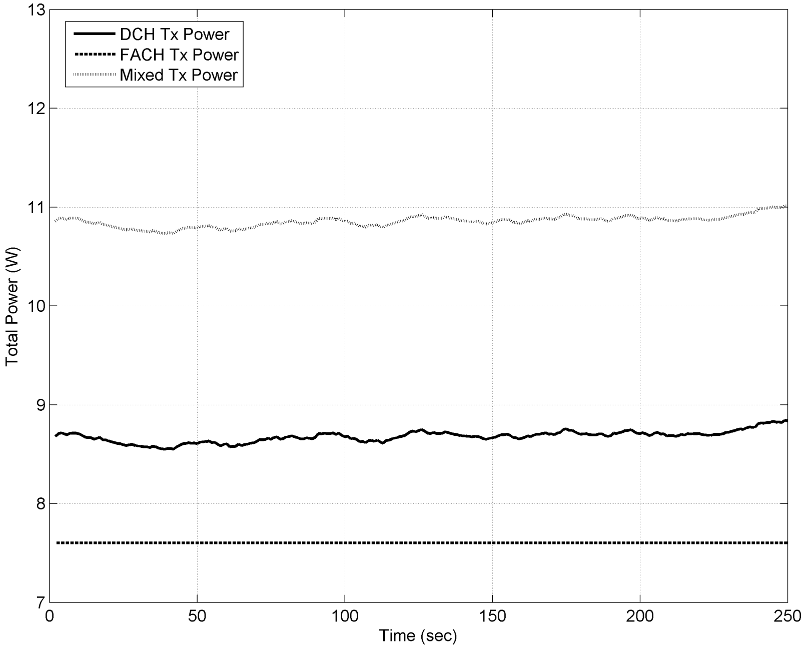


Fig. 16. Scenario 1: Tx power levels.

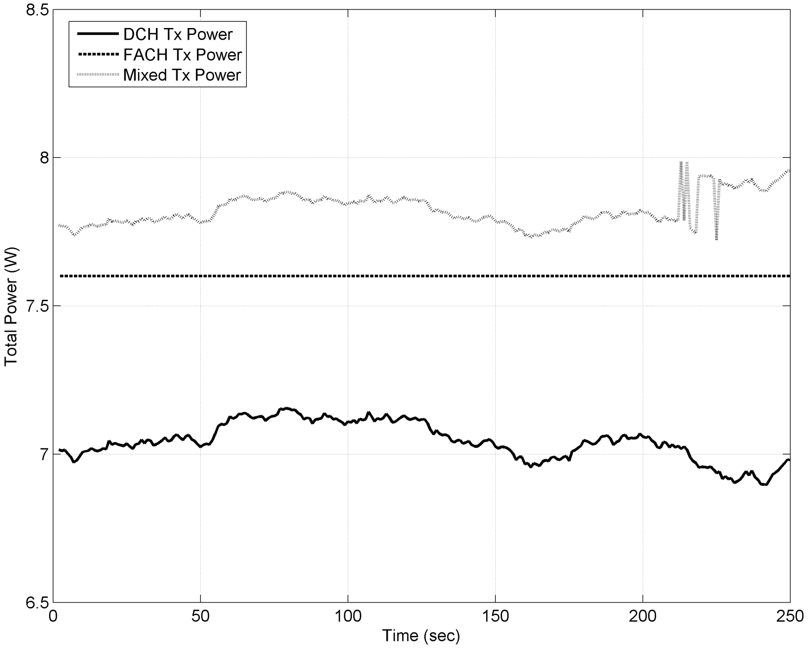


Fig. 17. Scenario 2: Tx power levels.

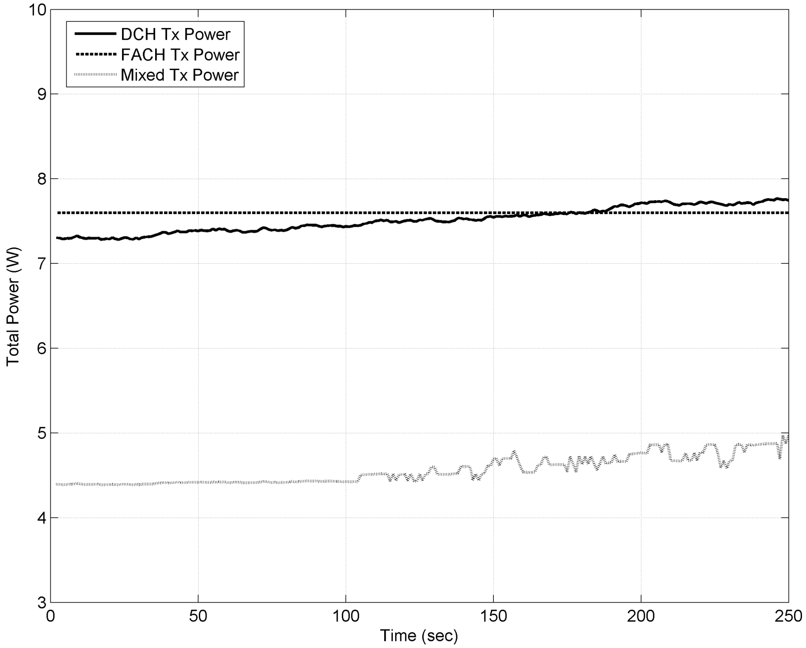


Fig. 18. Scenario 3: Tx power levels.

that is required for the successful reception of the MBMS service by all UEs, when DCHs, FACH or mixed channels are deployed.

As already mentioned this scenario favors the deployment of FACH for the transmission of MBMS data. Indeed, as presented in Fig. 16 the FACH transmission power level is lower throughout the whole simulation. More specifically, 7.6 W are required in order to cover 95% of the cell area and provide the 64 kbps MBMS service to all UEs that reside in this area (Table 2). This power level is independent of the UE population and stays constant as the user with the worst path loss remains between 90% and 95% of the cell area. If all the users moved towards Node B, the DPS technique would have forced Node B to decrease the FACH transmission power level (e.g., to 6.4 W if the user with the worst path loss remained between 80% and 90% of the cell area).

5.2.2. *Scenario 2: PTP Cell*

In the second scenario the population of the UEs that receive the MBMS service is supposed to be small. More specifically, in this scenario seven UEs with random initial locations are moving throughout the cell while receiving a 64 kbps MBMS service. The fact that the UE population is small favors the deployment of multiple DCHs. Therefore, each user should be served by one DCH.

The proposed mechanism calculates the power that is required for each user separately and calculates the total required power (for the case of DCHs) according to Eq. (1). The fact that the UEs are moving explains why the power level does not remain constant. However, even if it is not constant, the DCH power level is always lower than in the other two cases (Fig. 17).

5.2.3. *Scenario 3: Mixed Cell*

Regarding the third scenario, as depicted in Fig. 15, there are a total of 16 UEs that receive the 64 kbps MBMS service. Fourteen of the 16 UEs are found inside 50% of the cell area ("inner part" UEs), while only two UEs are outside this area ("outer part" UEs). As Fig. 18 shows, the best way to serve these UEs is to serve all the "inner part" UEs with one FACH with power so as to cover only the 50% of the cell area (2.5 W). On the other hand, each of the "outer part" UEs is served with one DCH, thereby increasing the total transmission power.

The power required with the mixed usage case is not constant, as there are UEs that are served by DCHs. Moreover, as shown in Fig. 18 the increase in the power required in this case is more obvious 100 s after the simulation starts. This occurs because some of the "inner part" UEs leave 50% of the cell area and, therefore, they are also served by DCHs. Nevertheless, the mixed usage transmission power remains lower than in the other two cases.

5.2.4. *Scenario 4: Join and Leave Requests*

All the above scenarios examine certain cases where the users appear in predefined initial positions and then move randomly throughout the cell. The UE population and the initial positions were selected in order to favor the deployment of certain channels, while simultaneously the number of UEs was kept constant during the simulation.

Scenario 4 examines a more realistic situation with main target to present how the Join and Leave requests by MBMS users are handled by the mechanism. According to this scenario, the UEs appear in random initial positions (Fig. 15) and then move randomly throughout the cell. Moreover, the number of UEs changes during the simulation. More specifically, the number of users that receive a 64 kbps MBMS service initially increases (successive Join requests by MBMS users) in order to reach 35 UEs at a simulation time of 175 s. For the following 80 s, the number of users remains constant. From a simulation time of 255 s the number of users decreases (successive Leave requests by MBMS users), and finally at the end of the simulation only six UEs receive the 64 kbps MBMS service (Fig. 19).

The transmission power levels when using DCH, FACH or mixed channels are presented in Fig. 19. The power control mechanism will force Node B to select the channel with the lowest power requirements. Thus, at 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 causes a switch from DCHs to a mixed usage of DCHs and FACH (at simulation time 113 s). An additional increase in the number

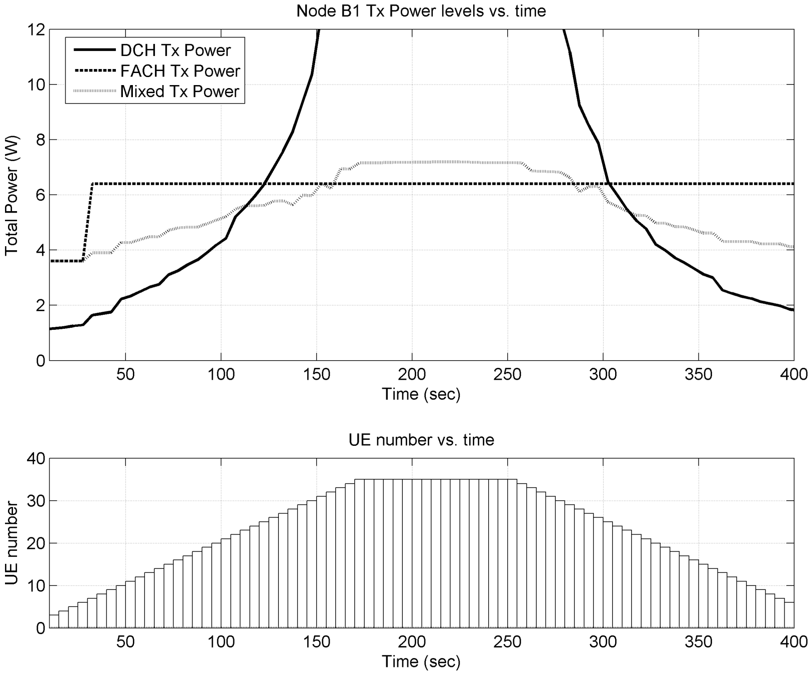


Fig. 19. Scenario 4: Tx power levels versus UE number.

of UEs results in a switch from mixed usage of DCHs and FACH to a single FACH (at a simulation time of 158 s) 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 FACH to transmit at a higher power level (this case does not appear in this particular scenario). The decrease in the number of UEs causes the exact opposite results.

5.2.5. *Scenario 5: Soft Handover*

The last scenario presents the operation of the mechanism during soft handover. The UEs' initial positions according to the scenario are presented in Fig. 20. Each Node B in the topology has to serve a number of randomly moving UEs. However, Node B1 is initially serving eight UEs, four of which will follow a predefined route so that soft handover will take place. More specifically, as shown in Fig. 20, UE1 and UE2 will move towards Node B2, while UE3 and UE4 move towards Node B3.

The simulation lasts for 300 s, a time interval sufficient for the process of soft handover to be completed. Figure 21 depicts the transmission power levels of the Node Bs under study when DCH, FACH or mixed channels are used. The three Node Bs under study — in other words, the three Node Bs that participate in the process of soft handover — are: Node B1, Node B2 and Node B3.

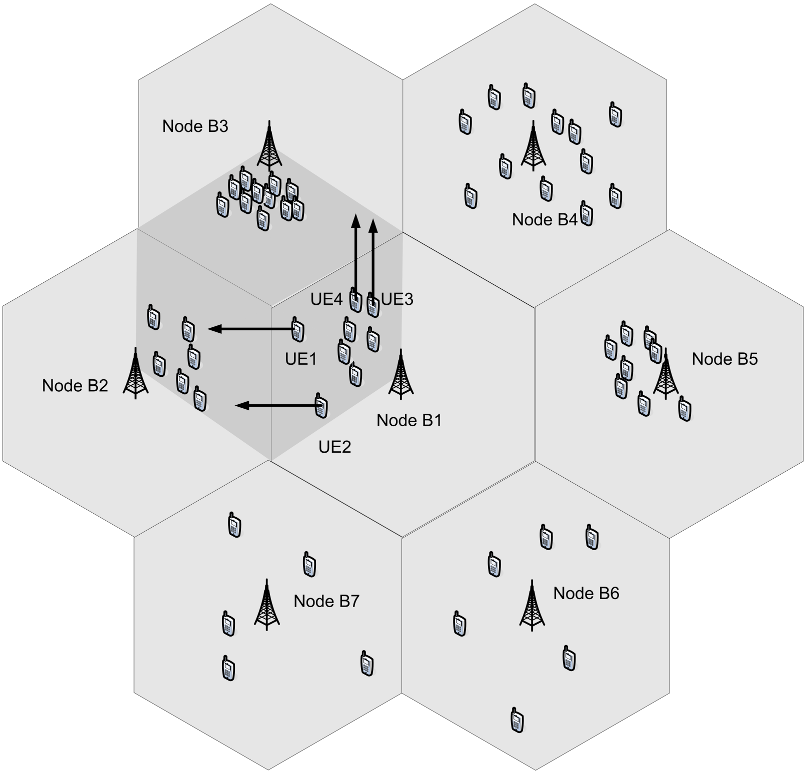


Fig. 20. Scenario 5: UEs' initial locations and routes.

More specifically, regarding Node B1, we observe that four UEs in total leave its coverage area. In Fig. 21a, this is presented by the four abrupt decrements in DCHs and mixed power level. The FACH power level remains high, until the four UEs leave the cell (about 255 s after the simulation starts), when an abrupt decrement in its power level is observed. This happens because after the UEs leave the cell the FACH will only have to serve UEs that are found at a small distance from Node B1 (Fig. 20). Nevertheless, even if the four UEs leave the cell area, multiple DCHs should be deployed as the power level in this case remains the lowest (Fig. 21a).

On the other hand, a decrement in Node B1's power levels is followed by a simultaneous increment in another Node B's power levels. For example, at simulation time 205 s, UE4 leaves the coverage area of Node B1 and enters the coverage area of Node B3 (Fig. 20). The FACH power level in Node B3 simultaneously increases because the new user (UE4) is the user with the worst path loss. The DCH and mixed power levels are also increased because in both cases Node B3 will have to serve one more user with DCH. Nevertheless, according to Fig. 21c, UE4 will force Node B3 to switch from a single FACH to mixed usage of DCHs and FACH, as the power requirements in the second case is lower.

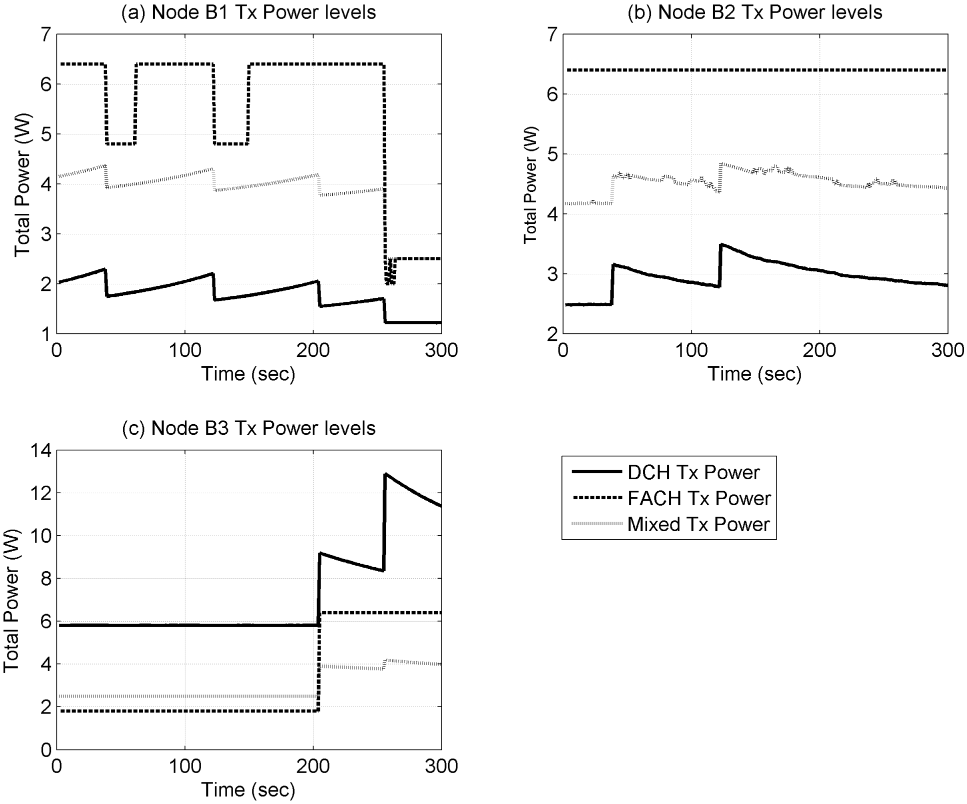


Fig. 21. Scenario 5: Tx power levels of cells under study during soft handover.

It is worth mentioning that during the whole simulation the most efficient channel was selected independently of the UE number and their location. The corresponding power levels were compared and the channel with the lowest power requirements was selected. This fact makes the mechanism much more powerful and much more resistant to changes.

6. Directions for Future Research

A power-based scheme for the efficient selection of radio bearers for the MBMS multicast transmission has been presented. This scheme aimed to switch efficiently between PTP and PTM modes. As presented, accordingly to current MBMS specifications, in PTP mode multiple DCHs can be configured, while in PTM mode a single FACH is transmitted throughout a cell. However, an interesting issue that can further improve MBMS power efficiency and capacity is the transmission of MBMS multicast data over the High Speed-Downlink Shared Channel (HS-DSCH) transport channel. HS-DSCH is characterized as a PTP channel, as well as DCH, due to its unicast nature and is envisaged as a promising radio bearer for enhanced

MBMS PTP provision. Although Release '99 transport channels (FACH, DCH) have already been investigated and standardized for the delivery of MBMS multicast sessions, MBMS over HS-DSCH is a relatively novel proposal, still in its infancy.

HS-DSCH is the main transport channel used by High Speed Downlink Packet Access (HSDPA) technology. HSDPA was introduced in the Release 5 specifications [21] of the UMTS standard in order to improve spectral efficiency and enhance radio transmission techniques and network protocol functionality in wireless networks. In fact, HSDPA is a mobile broadband extension to the UMTS radio interface, characterized as 3.5G, targeting the optimization of the air interface to support higher data rate and delay-tolerant services. The main objective of HSDPA is to increase user peak rates up to theoretically 14 Mbps for best-effort packet data services, far beyond the 3G requirement of 2 Mbps [10, 22]. Consequently, HS-DSCH can play an instrumental role in positioning MBMS services as a key enabler for true "mobile broadband".

MBMS over HS-DSCH can offer significant power savings and enhancements on total MBMS capacity, thus enabling the mass market delivery of higher bit rate multimedia services to end users [22]. In order to prove the above statement, some indicative figures are presented and discussed in the following. These figures aim to make a direct comparison between Release '99 bearers and HS-DSCH power consumption. More specifically, the following figures present MBMS power allocation for DCH, FACH and HS-DSCH transport channels when a 64 kbps MBMS service and different cell coverage areas are assumed.

For instance, in Fig. 22a (60% coverage) it can be seen that for fewer than 10 users DCHs could be used for the MBMS multicast transmission, while for 10–19 users HS-DSCH is the optimal transport channel. For even larger MBMS populations FACH should be employed. The MBMS power control mechanism proposed in Sec. 5, on the other hand, using only DCH and FACH channels (and no HS-DSCH), would use DCHs for up to 16 users and a FACH for more users. For the cases of 80% and 99% cell coverage (Figs. 22b and 22c, respectively), HS-DSCH prevails over the DCH for a small MBMS population and should be used instead of DCHs in MBMS PTP multicast transmission.

Obviously, from the above figures, the HS-DSCH employment in MBMS multicast provides a significant power saving when serving a few users. More specifically, in the PTP mode, only HS-DSCH usage (Fig. 22c) or a combination of HS-DSCH and DCH (Figs. 22a and 22b) can be used, instead of an exclusive DCH usage. This can lead to important gains in power resources as HS-DSCH requires less power compared to DCH. In this way, MBMS PTP performance is significantly improved.

Another important point emerging from these figures is that power gain can, in turn, lead to a significant capacity enhancement for MBMS operators. For most types of MBMS services, such as streaming video, 64 kbps is enough to provide good quality. MBMS can deliver 64–128 kbps MBMS content with a very good coverage probability using DCH and FACH channels. From the end user point of

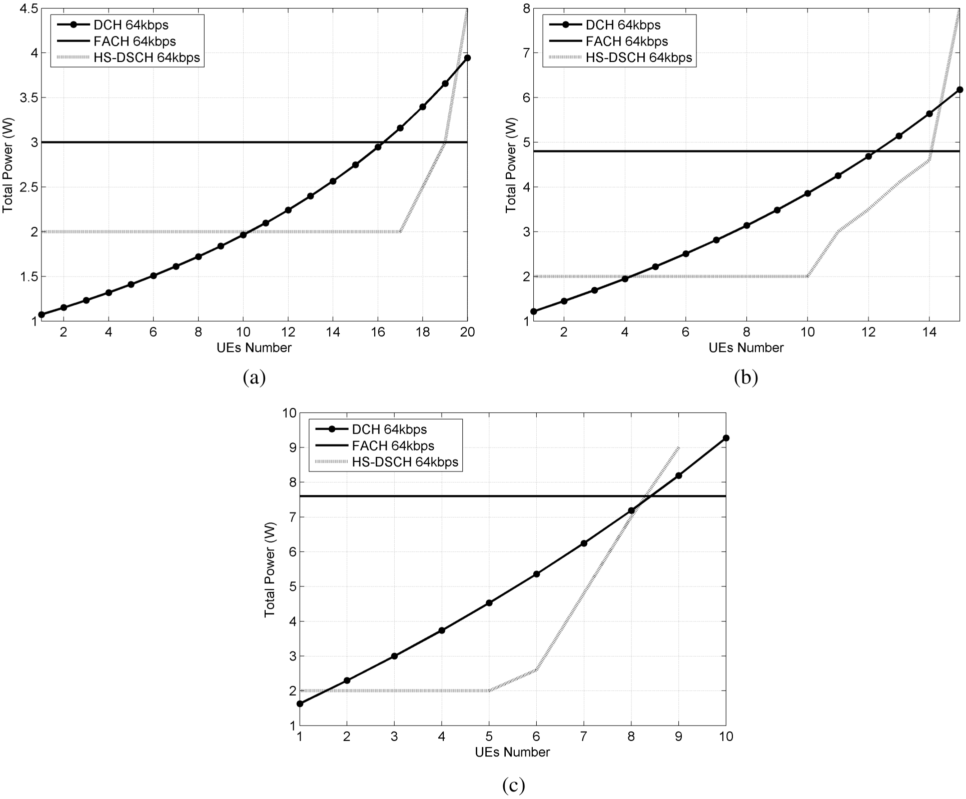


Fig. 22. DCH, FACH, HS-DSCH Tx power for (a) 60%, (b) 80%, and (c) 99% cell coverage.

view no significant improvement is expected from HS-DSCH usage at first glance. However, as can be inferred from the above figures, what HS-DSCH brings is more capacity, which, in turn, enables mass-market delivery of higher bit rate streaming to end users.

Hence, further investigation of MBMS over HS-DSCH is warranted. The preceding short analysis indicates that HS-DSCH can drastically benefit MBMS performance. An analytical dimensioning of HS-DSCH power consumption as well as the evaluation of HS-DSCH impact on MBMS capacity are considered of major importance. In addition, the integration of HS-DSCH in the architecture presented in Sec. 5 is a desirable future step. In this way, an optimal scheme that will make an efficient overall usage of radio and network resources will be realized.

7. Conclusions

This chapter introduced the key concepts of the MBMS framework of UMTS. The main target was to highlight the importance of power control and its commanding role during the delivery of MBMS multicast content, for the overall efficiency of a UMTS network. In this regard, the power profiles of several transport channels that could be employed for the transmission of MBMS services to mobile users were investigated. Moreover, the reader was introduced to certain problems that MBMS current specifications are facing and was made familiar with techniques/solutions proposed to overcome such limitations.

Finally, this chapter proposed a power control mechanism, which considers the Node B's transmission power level as the key criterion for the selection of the appropriate MBMS radio bearer. It was proved that a dynamic threshold between PTP and PTM transmission modes ensures the economic and rational usage of expensive radio and network resources. This mechanism constitutes a novel, dynamic and accurate approach for the determination of the most efficient radio bearer to deliver MBMS multicast data.

Terminology

3rd Generation Partnership Project (3GPP): The collaboration agreement that brings together a number of telecommunications standards bodies which are known as "organizational partners". The original scope of 3GPP was to produce globally applicable technical specifications and technical reports for a 3G mobile system based on the evolved global system for mobile communications (GSM) core networks and the radio access technologies that they support.

Dedicated Channel (DCH): A UMTS transport channel allocated to an individual user, initially used to support a speech channel. Additionally, it supports data transmission.

Forward Access Channel (FACH): A UMTS transport channel initially used for downlink signaling and small quantities of data. FACH is the main representative of PTM transmission.

High Speed Downlink Shared Channel (HS-DSCH): The main transport channel used by HSDPA technology.

Multimedia Broadcast/Multicast Service (MBMS): A novel framework extending the existing UMTS infrastructure. In an MBMS-enabled UMTS network data is transmitted from a single source entity to multiple destinations, allowing the network resources to be shared.

Power saving techniques: Techniques utilized in order to decrease power requirements during an MBMS session.

Point-to-Multipoint (PTM) transmission: Where a single channel is employed in order to cover the desired area of the cell. During PTM transmission, the channel conveys identical traffic and serves all the users in the area of the cell that it covers.

Point-to-Point (PTP) transmission: Where each user separately is served by a dedicated channel.

User equipment (*UE*): A portable device consisting of the mobile equipment and the USIM card. The mobile equipment is the hardware part of the portable device, while the USIM card contains all the essential information to make the access and the identification from the UMTS network possible.

Universal Mobile Telecommunication System (*UMTS*): A Code Division Multiple Access (CDMA) interface in air through which packets are exchanged, in combination with an evolved GSM/GPRS core network. The 3G system that has prevailed in Europe and is progressively extended in Northern America, with result the 3G of cellular mobile systems to be identified with this system.

Exercises

1. What is the motivation for the introduction of MBMS in UMTS networks?
2. What is the main difference between the multicast and the broadcast mode of MBMS?
3. How does the MBMS multicast framework improve network efficiency?
4. What is the main difference between DCH and FACH regarding power control?
5. What is the main scope of the MBMS counting mechanism?
6. Why is the conventional MBMS counting mechanism inefficient?
7. Name four techniques that could be utilized in order to reduce power requirements during an MBMS session.
8. Describe the dynamic power setting technique operation?
9. Name the five phases of the MBMS power control mechanism.
10. How could MBMS efficiency be further improved?

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