Telecommun Syst (2010) 43: 109–119
DOI 10.1007/s11235-009-9197-2

An improved MBMS power counting mechanism towards long term evolution

Antonios Alexiou · Christos Bouras · Evangelos Rekkas

Published online: 21 October 2009

Abstract One of the key objectives of beyond 3rd generation mobile networks is the realization of enhanced end-user experience through the provision of rich multimedia services. Multimedia Broadcast/Multicast Services (MBMS) framework epitomizes the increasing popularity of such applications and is envisaged to play an instrumental role for the Long Term Evolution (LTE) proliferation in mobile market. For exploiting resource efficiency, MBMS specifications consider the Counting Mechanism which decides whether it is more efficient to deliver MBMS multicast traffic over Point-to-Point (PTP) or Point-to-Multipoint (PTM) bearers. However, the necessity to further improve MBMS resource efficiency and integrate new technologies in the frame of LTE stresses the need for an advanced Counting Mechanism. In this work we propose a novel Power Counting Mechanism for efficient selection of MBMS bearers. The proposed mechanism optimally utilizes power resources and exploits broadband characteristics and performance enhancements emerged from Multiple Input Multiple Output (MIMO) antennas used in LTE networks.

A. Alexiou · C. Bouras · E. Rekkas
Research Academic Computer Technology Institute,
"D. Maritsas" Building, Nikou Kazantzaki street, University
Campus of Patras, Rion, 26550 Patras, Greece

A. Alexiou
e-mail: alexiua@ceid.upatras.gr

C. Bouras (✉)
e-mail: bouras@cti.gr

E. Rekkas
e-mail: rekkas@cti.gr

A. Alexiou · C. Bouras · E. Rekkas
Computer Engineering and Informatics Department, University
of Patras, Patras, Greece

Keywords UMTS · HSPA · LTE · MBMS · MIMO · Multicast · Power counting mechanism

1 Introduction

Indisputably, tomorrow's mobile marketplace will be characterized by bandwidth-hungry, multimedia services that are already experienced in wired networks. 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, spectral efficiency and offers more capacity for simultaneous users in a cell. LTE is envisaged to ensure 3rd Generation Partnership Project (3GPP) competitive edge over other cellular technologies.

The major challenge that the mobile telecommunications industry faces is how to offer a wide range of appealing multimedia services, such as Mobile TV and streaming video, to mobile users. The expected high penetration of such services translates into optimal resource allocation strategies and improved network performance. A significant step to compensate for these requirements was the introduction of the MBMS framework in the Release 6 of UMTS architecture. MBMS constitutes an efficient way to compensate for this necessity since it allows resources' sharing during data transmission. Actually, MBMS is a unidirectional service which targets at the resource economic delivery of multimedia data from a single source entity to multiple recipients [1, 2]. MBMS, also called Enhanced MBMS (E-MBMS) in LTE terminology, remains a key framework and is characterized as a main standard prerequisite to boost LTE performance and ensure its dominance in global wireless market.

The main requirement during the provision of MBMS multicast services is to make an efficient overall usage of radio and network resources. The system should conceive and adapt to continuous changes that occur in such dynamic wireless environments and optimally allocate resources. Under this prism, a critical aspect of MBMS performance is the selection of the most efficient transport channel for the transmission of MBMS multicast data. In the frame of switching between different channels, MBMS specifications consider the so-called Counting Mechanism which decides whether it is more efficient to deploy PTP or PTM bearers [3]. Counting Mechanism is an open issue in today's MBMS infrastructure mainly due to its catalytic role in Radio Resource Management (RRM). In this work we deal with this contemporary topic and attempt to make a significant contribution in order to maximize resource efficiency during the delivery of MBMS multicast traffic and set the basis for a more successful MBMS deployment in LTE networks.

More specifically, we propose a novel MBMS Power Counting Mechanism which serves as an improved modification of the existing Counting Mechanism. The proposed scheme enriches MBMS performance with the incorporation of HSPA broadband characteristics and takes advantage of MIMO antenna systems. MIMO is a mandatory element for LTE and has the potential to address the emerging demand for wireless multimedia services and particularly for the MBMS. Additionally, our mechanism contributes to RRM mechanisms of LTE by adopting a novel framework for MBMS that efficiently utilizes power resources. As a consequence, the proposed Power Counting Mechanism ensures improved cell capacity, thus enabling the mass delivery of rich multimedia services in LTE networks.

The paper is structured as follows: In Sect. 2, we present the motivation behind our study and the related work in the specific field. Section 3 is dedicated to an in depth analysis of Power Control in MBMS. Section 4 presents the proposed MBMS Power Counting Mechanism, while Sect. 5 is dedicated to the presentation of the results. Finally, the planned next steps and the concluding remarks are briefly described in Sects. 6 and 7 respectively.

2 Motivation and related work

As previously referred, the main requirement during the delivery of MBMS services is to make an efficient overall usage of radio and network resources. Therefore, an important aspect in MBMS is the selection of the most efficient transport channel for the transmission of MBMS multicast content. A wrong channel selection could result to a significant decrease in the total capacity of the system. Release '99 transport channels have already been standardized for the delivery of MBMS multicast sessions. More specifically, according to current MBMS Counting Mechanism [3], which is the prevailing approach mainly due to its simplicity of implementation and functionality, in PTP mode multiple Dedicated Channels (DCHs) can be configured, while in PTM mode a single Forward Access Channel (FACH) is transmitted throughout a cell. However, current specifications of this mechanism suffer from two major performance inefficiencies. On the one hand Counting Mechanism may lead to significant power (capacity) wasting, while on the other hand it is characterized by the absence of any mobile broadband characteristics, inherited from HSPA networks and forthcoming along with LTE.

According to existing Counting 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 [3]. 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 criterion for channel type switching is not always efficient and may result to significant wasting of the expensive power resources due to the lack of any adaptive functionality. For instance, no users' mobility, location throughout a cell and fading phenomena are considered. All these continuous changes that occur in such dynamic mobile networks directly reflect to the base station's downlink transmission power. Power in mobile networks is the most limited resource and may lead to significant capacity decrease when misused. Consequently, it is obvious that the idea behind the a priori information and predefined switching thresholds fails to optimally allocate power resources. Thus, the fundamental criterion for maximizing resource efficiency should be the base station's total MBMS transmission power. An interesting study under these assumptions is presented in work [4], where the authors propose a power control scheme for the efficient radio bearer selection in MBMS. Relative works are also presented in [5, 6] but all of these works focus on pure UMTS networks without taking into account HSPA or LTE standards.

Additionally, all the above works assume a fixed power allocation when FACH is used in PTM transmission mode, irrespective of users' location. Therefore, even if all users of a specific MBMS group are located near the base station, in PTM transmission the FACH will transmit at a high fixed power level so as to cover the whole cell (100% cell coverage), leading in turn to power waste. The ideal case, which is considered in our approach, would be a dynamic power setting for PTM transmission, where the FACH power is determined based on the area that needs to be covered. This way, the FACH transmission power is allocated dynamically based on the desired service area, saving in this way a significant power budget.

Another major inefficiency of the current Counting Mechanism specifications is that it does not take into account recent advances in mobile communications that rely on the broadband HSPA technology and on MIMO systems. HSPA, a broadband extension of UMTS, introduces a new downlink transport channel, named High Speed-Downlink Shared Channel (HS-DSCH) which optimizes the air interface to support higher data rate and delay tolerant services [7, 8]. Although Release '99 transport channels have already been standardized for the delivery of MBMS multicast sessions, MBMS over HS-DSCH is an open research topic, still in infancy phase. However, all the key features characterizing HS-DSCH constitute it an ideal candidate for the delivery of multicast data, mainly in PTP mode. Counting Mechanism should extend its functionality by deploying HS-DSCH along with the Release '99 channels in order to further improve MBMS efficiency. Furthermore, MIMO antenna systems are one of the most fundamental prerequisites for LTE networks, which are, however, not yet studied for MBMS transmissions. MIMO can significantly benefit MBMS since they can ensure even higher data rates without increase in the spectrum bandwidth.

In this work we deal with this contemporary topic and propose a novel Power Counting Mechanism that confronts all the above inefficiencies and enhances MBMS performance. Our main research motivation is to optimally utilize power resources during multicast data transmission, which translates into improved capacity; and enrich MBMS with broadband characteristics in the frame of the LTE. More specifically, the proposed scheme takes advantage of the HSPA technology (including MIMO support) and contributes to RRM mechanisms of LTE by adopting a novel framework for MBMS that efficiently utilizes power resources. We evaluate the proposed mechanism based on a theoretical analysis of downlink power consumption during MBMS multicast transmission. Finally, in order to prove our proposed mechanism's superiority against the current form of Counting Mechanism we present an explicit comparison between the two approaches and highlight all the performance improvements in power and capacity efficiency.

3 Power control in MBMS

Power control is one of the most critical aspects in MBMS due to the fact that downlink transmission power in UMTS, as well as in LTE, is the scarcest resource and, thus, should be optimally utilized. The main purpose of power control is to minimize the transmitted power, thus avoiding unnecessary high power levels and eliminating intercell interference. However, when misused, the use of power control may lead to a high level of wasted power and worse performance results.

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 becomes 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.

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 actually is 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, base station 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 HS-DSCH, DCH and FACH power profiles and their power consumption characteristics during MBMS transmissions.

3.1 HS-DSCH power profile

HS-DSCH is a rate controlled rather than a power controlled transport channel. In High Speed Downlink Packet Access (HSDPA), the downlink framework of HSPA, fast power control (characterizing Release '99 channels) is replaced by the Link Adaptation functionality, including techniques such as dynamic Adaptive Modulation and Coding (AMC), multicode operation, fast scheduling, Hybrid ARQ (HARQ) and short Transmission Time Interval (TTI) of 2 ms [7, 8].

There are two different modes for allocating HS-DSCH transmission power. In the first power allocation mode, a fixed amount of HS-DSCH transmission power is explicitly allocated per cell and may be updated any time later, while in the second mode the base station is allowed to use any unused power remaining after serving other, power controlled channels, for HS-DSCH transmission. Obviously, setting the HS-DSCH power too high would result in excessive interference in the network without essentially achieving higher cell throughput. On the other hand, if the HS-DSCH transmission power is too low, the highest data rates cannot be obtained [7].

However, next in this paper, we will focus on a dynamic method in order to provide only the required, marginal amount of power so as to satisfy all the serving multicast users and, in parallel, eliminate system interference. For the better understanding of this dynamic method we present two major measures for HSDPA power planning. These are the HS-DSCH Signal-to-Interference-plus-Noise Ratio (*SINR*) metric and the Geometry factor (G).

SINR actually constitutes a new evaluation metric that slightly differentiates HSDPA from that traditionally used in Release '99 bearers. Release '99 typically uses E_b/N_0 (received-energy-per-bit-to-noise ratio) that corresponds uniquely to a certain block error rate (BLER) for a given data rate. E_b/N_0 metric is not an attractive measure for HSDPA because the bit rate on the HS-DSCH is varied every TTI using different modulation schemes, effective code rates and a number of High Speed-Physical Downlink Shared Channel (HS-PDSCH) codes [7]. *SINR* for a single-antenna Rake receiver is calculated as in (1) [7]:

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

where $P_{HS-DSCH}$ is the HS-DSCH transmission power, P_{own} is the own cell interference experienced by the mobile user, P_{other} the interference from neighboring cells and P_{noise} the Additive White Gaussian Noise. Parameter p is the orthogonality factor ($p = 0$: perfect orthogonality), while SF_{16} is the spreading factor of 16.

Moreover, 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. For instance, if a 64 kbps MBMS service should be delivered to a multicast group of 10 users, then the target throughput will be equal to 640 kbps. Once the target cell throughput is set, the next step is to define the way that this throughput relates to the *SINR* (Fig. 1). At this point, it is worth mentioning that as the number HS-PDSCH codes increases, a lower *SINR* value is required to obtain a target MBMS data rate (Fig. 1).

Finally, we can describe how the required HS-DSCH transmission power ($P_{HS-DSCH}$) can be expressed as a function of the *SINR* value and the user location (in terms of G) as in (3) [7]:

$$P_{HS-DSCH} \geq SINR[p - G^{-1}] \frac{P_{own}}{SF_{16}}. \quad (2)$$

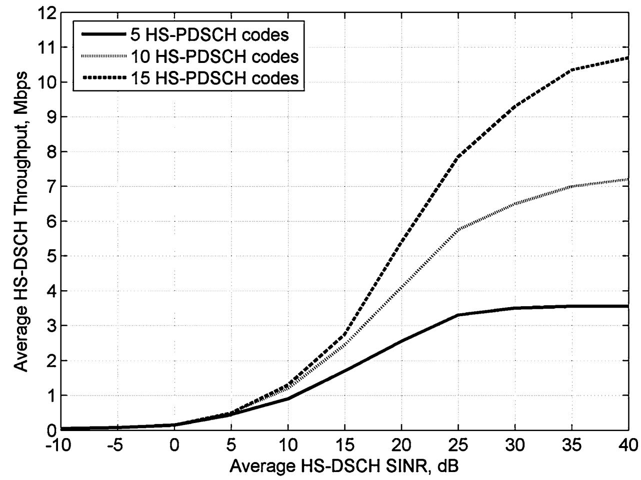

Fig. 1 Actual cell throughput vs. *SINR*

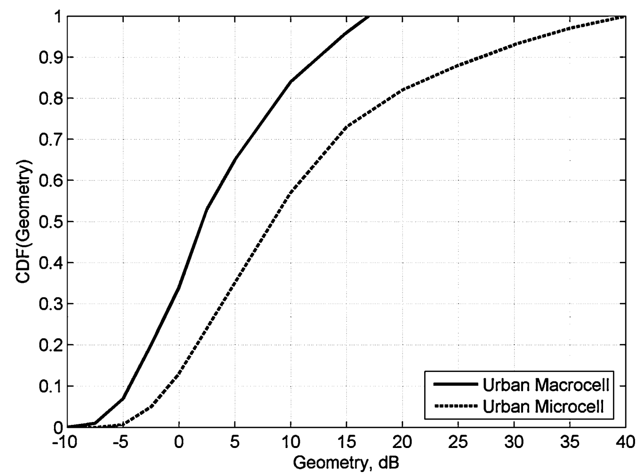

Fig. 2 Geometry CDF macrocell–microcell

The Geometry factor (G) is given by the relationship between P_{own}, P_{other} and P_{noise} and is defined from (3), while the Geometry CDF function values obtained for the macro and micro cell environments are depicted in Fig. 2 [13]:

$$G = \frac{P_{own}}{P_{other} + P_{noise}}. \quad (3)$$

The Geometry factor is another major measure that indicates the users' position in a cell (distance from the base station). A lower G is expected when a user is located at the cell edge (where interference received from the neighboring cell is higher than the interference experienced in its own cell). Moreover, in microcells MBMS users experience a better (higher) G due to the better environment isolation that leads, in turn, to lower intercell interference (P_{other}).

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 [9]. Early LTE requirements consider two transmit and receive antennas (MIMO 2x2) and approximately, double data rates are obtained with the same base station transmission 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. In other words, MIMO further contributes in saving significant power resources and, in parallel, maximizing system capacity.

3.2 DCH power profile

DCH is a PTP transport channel and may used for the delivery of PTP MBMS services to a small number of users, while cannot be used to serve large multicast populations since high downlink transmission power would be required. The total downlink transmission power allocated for all MBMS users in a cell that are served by multiple DCHs is variable. It mainly depends on the number of serving users, their distance from the base station, the bit rate of the MBMS session and the experienced signal quality E_b/N_0 for each user. Equation (4) calculates the base station's total DCH transmission power required for the transmission of the data to n users in a specific cell [10]:

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

In (4), 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 ith user transmission rate, W the bandwidth, P_N the background noise, p is the orthogonality factor and x_i is the intercell interference observed by the 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 [10]:

$$x_i = \sum_{j=1}^{K} \frac{P_{Tj}}{L_{ij}}. \tag{5}$$

Figure 3 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 addition, increased cell coverage area and larger user groups lead to higher power consumption.

3.3 FACH power profile

FACH is a PTM channel and must be received by all users throughout the MBMS service area of the cell. A FACH essentially transmits at a fixed power level since fast power control is not supported. The FACH fixed power should be high enough to ensure the requested QoS in the desired area of the cell and serve the user with the worst path loss, i.e. the user with the higher distance from the base station. As described in Sect. 2, this is another important difference between the proposed Power Counting Mechanism and its current form. Existing Counting Mechanism is not scalable and transmits at a power level so as to provide full cell coverage, irrespective of users' location, while Power Counting Mechanism dynamically adjusts its downlink power to a level high enough to serve only the desired cell coverage area.

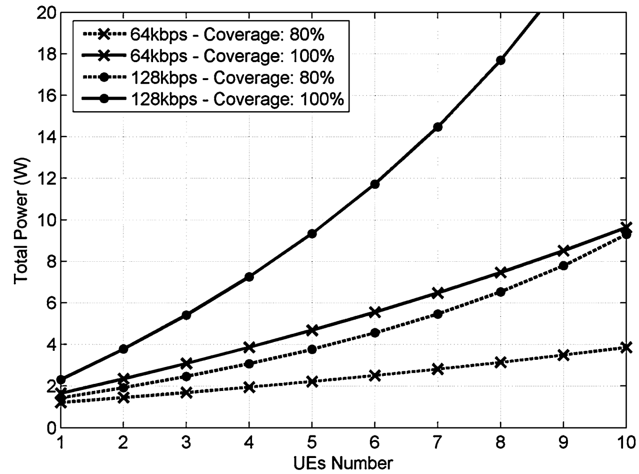

Fig. 3 DCH downlink Tx power

Table 1 FACH Tx power levels vs. cell coverage–macrocell environment

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

Table 1 presents some indicative FACH downlink transmission power levels obtained for various cell coverage areas [11]. These FACH transmission power levels correspond to a macrocell environment (site to site distance 1 km), when a 64 kbps MBMS service is delivered. Moreover, Transmission Time Interval (TTI) is set to 80 ms, BLER target is 1% and no Space Time Transmit Diversity (STTD) is assumed [11]. Depending on the distance of the user with the worst path loss from the serving base station, the Radio Network Controller (RNC) dynamically sets FACH transmission power at one of the levels presented in Table 1.

4 Proposed MBMS power counting mechanism

As presented in Sect. 1, Power Counting Mechanism improved performance relies on the exploitation of power resource efficiency and on the integration of HSPA and MIMO technologies in MBMS functionality.

More specifically, the proposed mechanism adopts downlink transmission power as the optimum criterion for radio bearer selection. The transport channel with less power requirements is selected for the delivery of the multicast traffic contributing, in this way, to the power efficiency of the power-limited LTE networks. Moreover, due to the fact that any changes in such dynamic environments are directly reflected to the base station transmission power, our mechanism is highly adaptive.

Furthermore, the proposed scheme incorporates the premier HS-DSCH transport channel used in HSPA, in contradiction to the existing Counting Mechanism which considers only Release '99 bearers (DCH and FACH). HS-DSCH in many cases is less power consuming, which combined to the power-based bearer switching criterion further improves MBMS power efficiency. However, even more power resources can be saved when MIMO is supported (which is highly expected to occur in LTE networks).

Next in this section, we present the architecture and the functionality of the proposed Power Counting Mechanism, the block diagram of which is illustrated in Fig. 4. More specifically, the mechanism consists of three distinct operation phases: the parameter retrieval phase, the power level computation phase and the transport channel selection phase. Additionally, a periodic check is performed at regular time intervals. The RNC is the responsible node of the MBMS architecture for the operation of this algorithm and the final decision on the most efficient transport channel for the delivery of MBMS multicast data.

During the parameter retrieval phase (Fig. 4) the mechanism retrieves parameters of the existing MBMS users and services in each cell. User related parameters, such as the number of users requesting a specific MBMS session; their distances from the base station and their QoS requirements are received from the RNC through appropriate uplink channels. In addition, we assume that the MBMS bit rate service is already known through the Broadcast Multicast-Service Center (BM-SC) node of the MBMS architecture. BM-SC serves as the interconnection node between UMTS and the external data networks that provide multimedia content.

The power level computation phase (Fig. 4) substantially processes the information received from the parameter retrieval phase. In this phase, the required power to be allocated for MBMS session delivery in each cell is computed.

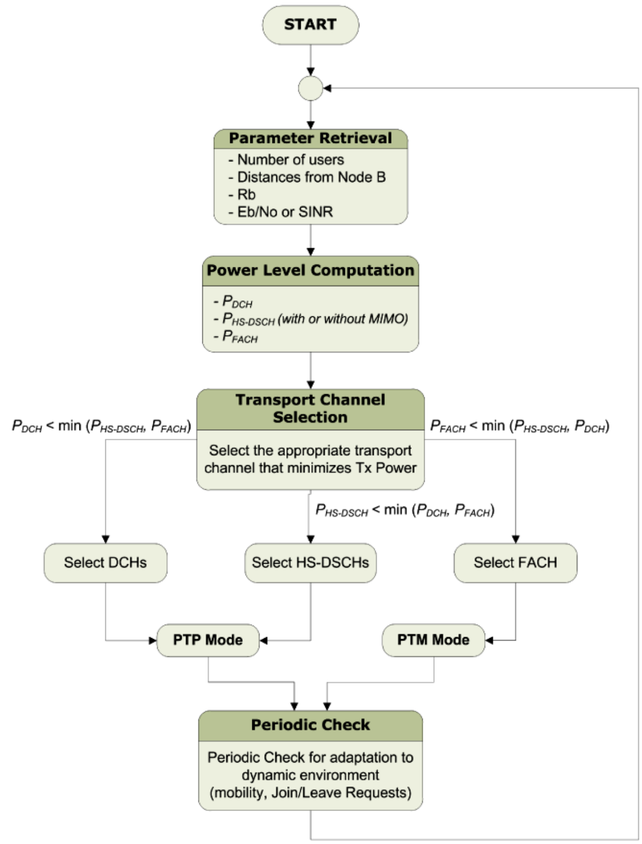

Fig. 4 Power counting mechanism with MIMO functionality

The computation is based on the assumption that the transmission of the multicast data can be performed over multiple DCHs, HS-DSCHs or over a single FACH. Consecutively, P_{DCH}, $P_{HS-DSCH}$ (with or without MIMO) and P_{FACH} power levels are computed respectively for each type of transport channel, according to the analysis presented in Sect. 3.

During the transport channel selection phase (Fig. 4), the appropriate transport channel for the transmission of the MBMS multicast content is selected. More specifically, P_{DCH}, $P_{HS-DSCH}$ and P_{FACH} values are compared in order to select the most power efficient bearer for an MBMS session in a cell. The algorithm dynamically (as opposed to current Counting Mechanism) decides which case requires less power and consequently, chooses the corresponding transport channel for the session. This is a key point of our mechanism that actually differentiates Power Counting Mechanism from the existing Counting Mechanism (that uses the number of simultaneous serving users as a selection criterion).

Finally, the mechanism performs a periodic check and reretrieves user and service parameters in order to adapt to any changes during the service provision (Fig. 4). This periodic check is triggered at a predetermined frequency rate and ensures that the mechanism is able to conceive changes, such as users' mobility, join/leave requests or any fading phenomena and configure its functionality so as to maintain resource efficiency at a high level.

5 Performance evaluation

For the purpose of the Power Counting Mechanism evaluation we consider the delivery of a typical 64 kbps MBMS service. Furthermore, the case of a macro cell environment is examined, with parameters presented in Table 2 [12, 13]. In addition, no STTD is assumed, while the BLER target is set to 1%.

Initially, we present some indicative results concerning the operation of the transport channel selection phase in order to highlight the key role of power control in MBMS transmissions and its contribution to RRM efficiency. Moreover, HS-DSCH's (with and without MIMO support) contribution in further enhancing MBMS performance is discussed. Next, we address the superiority of the proposed mechanism through an explicit comparison, on power and capacity performance between the Power Counting Mechanism and the existing form of Counting Mechanism.

Table 2 Macrocell simulation parameters

Parameter	Macrocell
Cellular layout	Hexagonal grid
Number of cells	18
Site-to-site distance	1 Km
Maximum BS Tx power	20 W
Other BS Tx power	5 W
CPICH Power	2 W
Common channel power	1 W
Propagation model	Okumura Hata
Multipath channel	Vehicular A (3 km/h)
Orthogonality factor	0.5
(0 : perfect orthogonality)	
E_b/N_0 target	5 dB

5.1 Efficient MBMS transport channel selection

In this subsection we present performance results concerning the most critical aspect of the Power Counting Mechanism which is the transport channel selection phase. The proposed mechanism computes the downlink transmission power required for all types of channels and based on these values selects the transport channel with less power requirements. This power efficient channel deployment is illustrated in Figs. 5–7, for 60%, 80% and 100% cell coverage areas respectively. More specifically, in these figures transmission power levels for DCH, HS-DSCH (with and without MIMO support) and FACH channels are depicted. These power levels, actually, constitute the overall output of the power level computation phase. Users are assumed to be in groups (of varying population), located at the bounds of the above coverage areas each time.

Regarding the 60% cell coverage case (Fig. 5), we observe that for a multicast group with 10 or fewer users DCH is the optimal transport channel. For a multicast population of 10–17 users HS-DSCH (without MIMO) is less power consuming and, thus, it should be preferred for MBMS content transmission (PTP mode). When MIMO 2x2 is supported the above upper threshold is further increased to 20 users. For more than 17 users (or 20 users with MIMO support), FACH is more power efficient and should be deployed (PTM mode).

Similar results can be extracted for the cases of 80% and 100% cell coverage from Fig. 6 and Fig. 7 respectively. However, from these figures we may additionally conclude that for higher cell coverage areas HS-DSCH is prevailing over the DCH even for a small multicast group and should be exclusively used instead of DCH in PTP mode.

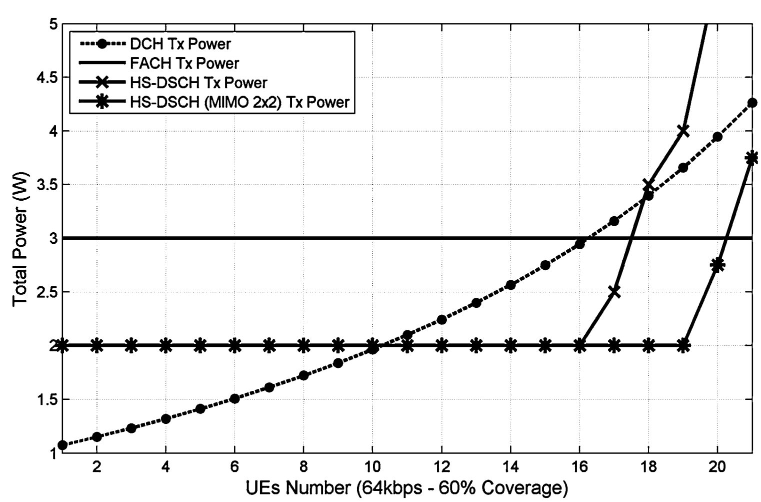

Fig. 5 MBMS power allocation, 64 kbps, 60% coverage

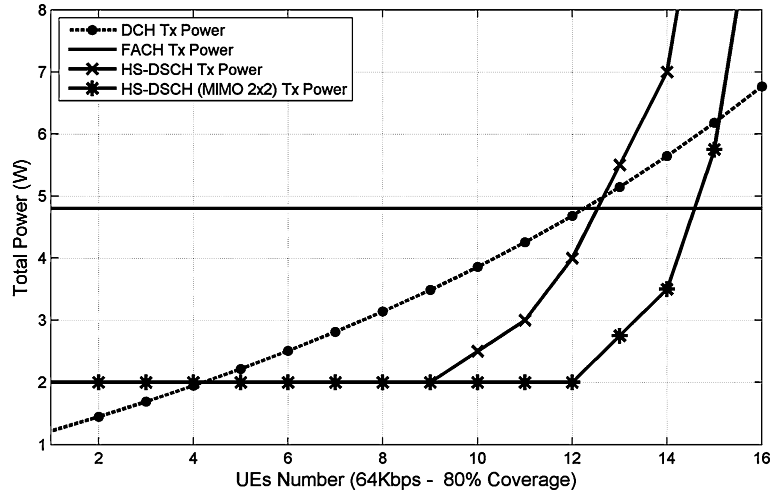

Fig. 6 MBMS power allocation, 64 kbps, 80% coverage

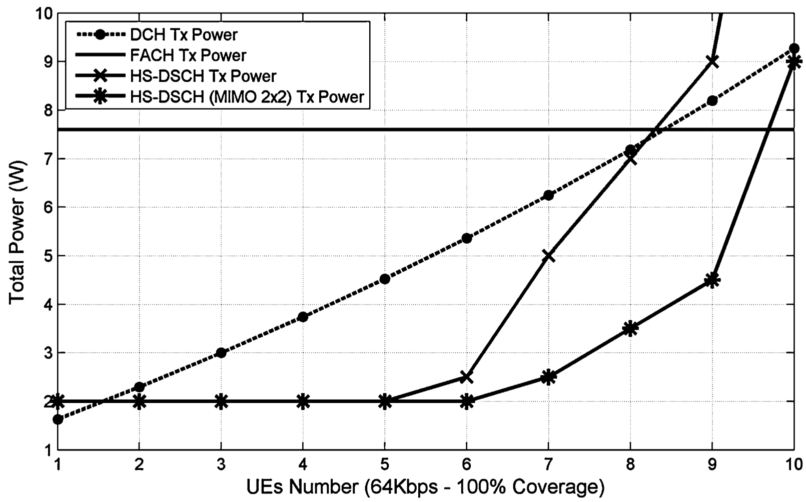

Fig. 7 MBMS power allocation, 64 kbps, 100% coverage

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

However, the most important notice, extracted from the above figures, is that the HSDPA technology provides significant power savings in MBMS PTP mode, when serving a few multicast users, since HS-DSCH appears to be less power consuming than DCH in most cases. Especially when MIMO is supported, MBMS power consumption may be significantly reduced and power efficiency is further maximized. The emerging power gain obtained through the use of HS-DSCH can, in turn, lead to a significant gain in capacity which enables the provision of multimedia services to a greater number of MBMS users in future mobile networks. As a consequence, it is imperative that HSDPA and MIMO technologies should be integrated in MBMS specifications in order to benefit both operators and mobile users and further improve MBMS resource efficiency.

5.2 Power counting mechanism vs. current counting mechanism

In the previous section, we presented that the Power Counting Mechanism can efficiently utilize power resources by selecting the bearer with less power requirements. However, the superiority of the mechanism can be better illustrated if we compare the performance of our approach with the current form of the Counting Mechanism. For a more realistic performance comparison, both mobility issues and varying number of serving users are taken into consideration and investigated.

At this point it should be reminded that current Counting Mechanism specifications consider a static switching point between PTP and PTM modes, based on the number of MBMS serving users. Such a reasonable threshold for a macrocell environment would be 8 multicast users. That means that for less than 8 users in PTP mode, multiple DCHs (and no HS-DSCH) would be transmitted, while for more than 8 multicast users in PTM mode, a single FACH, with such power so as to provide full coverage would be deployed.

For the purpose of the evaluation we set up a simulation scenario which considers the provision of a MBMS multicast session in a segment of a UMTS macrocellular environment. We examine the performance of both approaches for two neighboring cells (called source cell and target cell) as depicted in Fig. 8. A 64 kbps MBMS session with 2000 s time duration is delivered in both cells. Simulation results are depicted in Fig. 9 (source cell) and Fig. 10 (target cell).

More specifically, Figs. 9a and 10a depict the downlink power of the three transport channels, as extracted from the power level computation phase, in source and target cells respectively. Figures 9b and 10b depict the transmission power of the transport channel that is actually deployed both for the Power Counting Mechanism and the current Counting Mechanism, in source and target cell respectively. In case of the Power Counting Mechanism, this power level represents the power consumed by the channel selected in the transport channel selection phase. Regarding the existing Counting Mechanism this power level is either the total DCH power as computed in (4) for less than 8 users, or the fixed FACH power, equal to 7.6 W for full cell coverage, for more than 8 multicast users (Table 1).

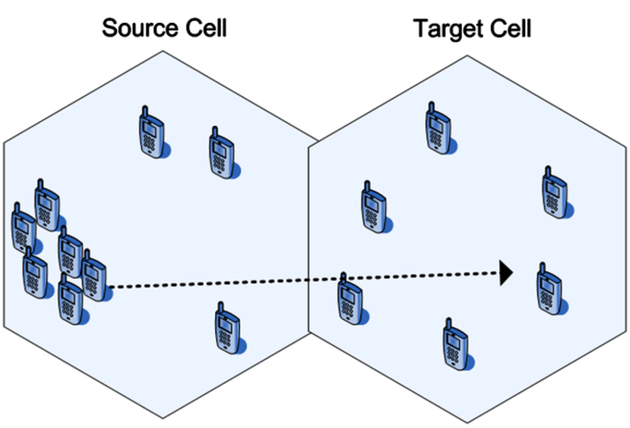

Fig. 8 Simulation topology

The source cell initially consists of 14 multicast users, while 6 users are residing in the target cell. During the first 200 s of the simulation time, all users in both cells are static. In source cell, the Power Counting Mechanism favors the transmission of MBMS content over FACH with power set to 6.4 W in order to serve users with the worst path loss, located at a distance of 90% cell coverage as depicted in Fig. 9a. On the other hand, current Counting Mechanism uses a FACH with 7.6 W to achieve full cell coverage, since it does not take into account the users' location, resulting in a power wasting of 1.2 W (Fig. 9b) in the source cell. Target cell is a PTP cell, since it serves less than 8 users. However, we observe that HS-DSCH has better performance than DCH, with almost 1 W power saving (Fig. 10b). Therefore, Power Counting Mechanism performs better than the existing Counting Mechanism in the target cell, too.

A group of 10 users in the source cell, which is located near the cell edge (90% cell coverage), starts moving at time instance 201 sec towards the target cell, according to the trajectory depicted in Fig. 8, while the rest users remain static. This group leaves the source cell and enters the target cell at time instance 1341 s. During the time period 201–1341 s we can make the following observations in the source cell. Power Counting Mechanism is able to track users' location, thus, it dynamically computes power allocation for all transport channels (including the FACH scalable power level) in order to further improve power efficiency. When multicast users get close to the source cell's base station, PTP bearers (DCH and HS-DSCH) are less power consuming than PTM bearer (FACH) even for a large number of serving users.

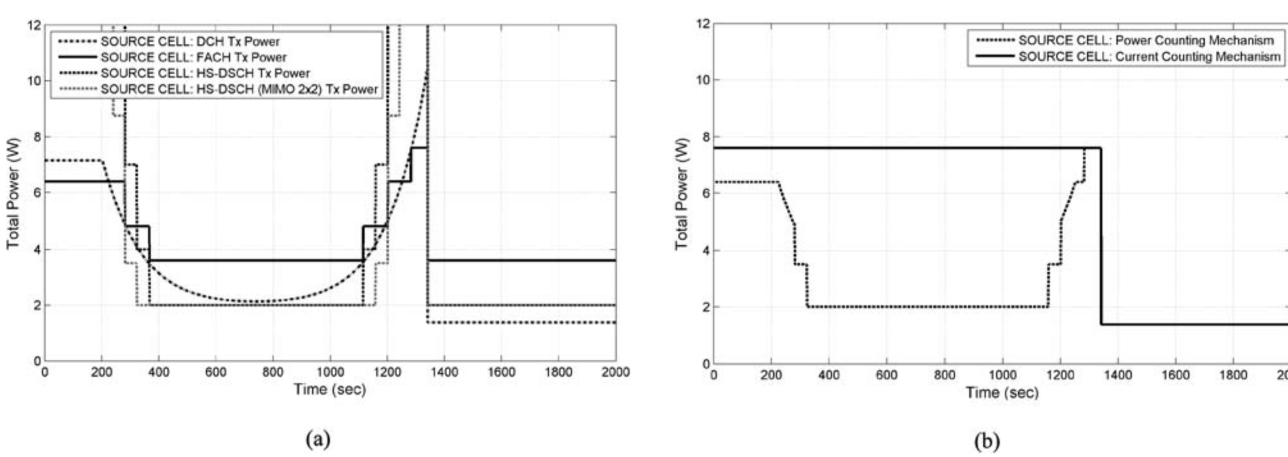

Fig. 9 Source cell: (**a**) operation of power counting mechanism, (**b**) power counting mechanism vs. UE counting mechanism

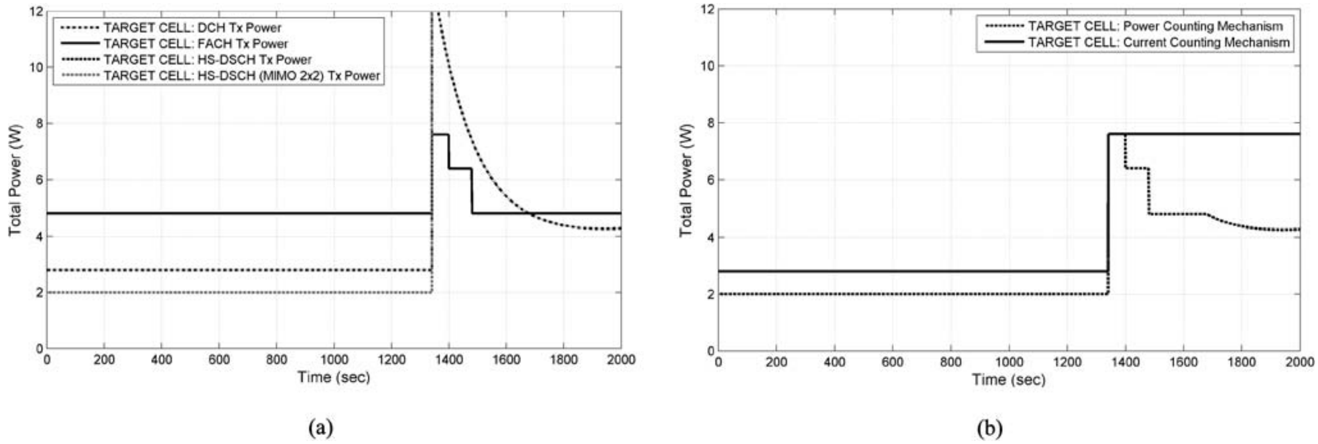

Fig. 10 Target cell: (**a**) operation of power counting mechanism, (**b**) power counting mechanism vs. UE counting mechanism

Similarly, when users reside near the cell edge FACH is more efficient. On the other hand, existing Counting Mechanism fails to deal efficiently with users' mobility, in the absence of any adaptive procedure, and uses exclusively FACH since simultaneous users receiving the MBMS service exceed the threshold of 8 users. As a result, we observe that a significant power budget, approaching 5.6 W, is wasted Fig. 9b. Both mechanisms have identical performance only when moving users are on the cell border (a FACH is deployed in both cases). Moreover, we observe that HS-DSCH with MIMO support requires less power compared to pure HS-DSCH for some time instances. Target cell still remains in PTP mode with the same power gains emerged from our scheme as during the first 200 s of simulation (Fig. 10b).

Finally, at time instance 1341 s, the group of 10 moving users enters the service area of the target cell. At this point, according to current Counting Mechanism, the source cell switches to PTP mode (multiple DCHs) since it serves only 4 users. Power Counting Mechanism also uses DCHs and, thus, both approaches have similar performance. At the same time, the target cell switches to PTM mode (a single FACH) and serves 16 users. However, as the moving group in the target cell keeps moving towards the base station, Power Counting Mechanism appropriately adapts its functionality and leads to better utilization of power resources in contradiction to the static transport channel assignment of the existing MBMS specifications. Power gains approach 3 W (Fig. 10b).

Conclusively, from Figs. 9b and 10b it is obvious that the proposed Power Counting Mechanism is prevailing over the current Counting Mechanism. The power based criterion for switching between different transport channels as well as the deployment of the HS-DSCH, especially when MIMO is supported, strongly optimizes resource allocation and enhances MBMS performance.

Similar results can also be extracted in the case of microcells. However, in microcells results are even more optimistic due to the fact that HS-DSCH performs better than in macrocells. This is mainly due to the fact that in microcells the higher cell isolation (which entails better geometry distribution—Fig. 2) and the less multipath propagation ensure the provision of higher MBMS data rate services.

6 Future work

The step that follows this work is to further optimize the provision of MBMS over LTE, MIMO enabled networks and investigate power saving techniques that can further enhance MBMS performance. Additionally, we could evaluate our mechanism through additional simulation scenarios conducted in the ns-2 simulator. In this way, we could measure, except from the power performance of our mechanism, other parameters such as delays in air interfaces during MBMS transmissions.

7 Conclusions

In this paper we proposed a novel mechanism, named MBMS Power Counting Mechanism, for efficient transport channel selection during MBMS transmissions in LTE networks. The proposed mechanism defines downlink power as the switching criterion between different radio bearers and is capable of conceiving any dynamic changes and, therefore, optimally adapting its functionality in order to maximize resource efficiency. Furthermore, the proposed mechanism integrates the HSDPA mobile broadband technology as a part of the overall architecture and conforms to LTE requirements since it takes advantage of MIMO antennas to further improve resource efficiency. Simulation results prove that our scheme strongly outperforms current Counting Mechanism of MBMS specifications, by maximizing power and capacity efficiency.

References

1. 3GPP TS 22.146 V9.0.0. Technical specification group services and system aspects; multimedia broadcast/multicast service; stage 1 (release 9) (2008).
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).
3. 3GPP, TS 25.346 V8.0.0. Introduction of the multimedia broadcast multicast service (MBMS) in the radio access network (RAN), stage 2, (release 7) (2008).
4. Alexiou, A., Bouras, C., & Rekkas, E. (2007). A power control scheme for efficient radio bearer selection in MBMS. In *IEEE international symposium on world of wireless, mobile and multimedia networks (WoWMoM)*, Finland, Helsinki.
5. Aho, K., Kurjenniemi, J., Haikola, V., Callender, C., & Ristaniemi, T. (2008). Multimedia broadcast multicast service performance and its enhancements in WCDMA networks. *Wireless Personal Communications*, *46*(2), 115–142.
6. Panayides, A., Christophorou, C., Antoniou, J., Pitsillides, A., & Vassiliou, V. (2008). Power counting for optimized capacity in MBMS enabled UTRAN. In *2008 IEEE symposium on computers and communications (ISCC 2008)*, Marrakech, Morocco, 6–9 July 2008.
7. Holma, H., & Toskala, A. (2006). *HSDPA/HSUPA for UMTS: high speed radio access for mobile communications*. New York: Wiley.
8. 3GPP TS 25.308 V8.3.0. Technical specification group radio access network; high speed downlink packet access (HSDPA); stage 2 (release 5) (2008).
9. Lin, Z., Sorensen, T. B., & Mogensen, P. E. (2007). Downlink SINR distribution of linearly precoded multiuser MIMO systems. *IEEE Communications Letters*, *11*(11), 850–852.
10. Perez-Romero, J., Sallent, O., Agusti, R., & Diaz-Guerra, M. (2005). *Radio resource management strategies in UMTS*. New York: Wiley.
11. 3GPP TS 25.803 V6.0.0, Technical specification group radio access network; S-CCPCH performance for MBMS, (release 6).
12. 3GPP, TR 101.102 V3.2.0. Universal mobile telecommunications system (UMTS); selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.2.0).
13. Holma, H., & Toskala, A. (2007). *WCDMA for UMTS: HSPA evolution and LTE* (4th ed.). New York: Wiley.

Antonios Alexiou obtained his Diploma from the Department of Electrical and Computer Engineering of the Aristotle University of Thessaloniki (Greece). Furthermore, he obtained his Master Degree and his PhD from the Computer Engineering and Informatics Department of Patras University (Greece). His research interests include data networks, mobile telecommunications networks, multicast routing and group management, radio resource management, radio network planning and optimization, wireless networks. He has published over 40 papers in Journals, International Conferences and Book Chapters.

Christos Bouras obtained his Diploma and PhD from the Department Of Computer Engineering and Informatics of Patras University (Greece). He is currently a Professor in the above department. Also he is a scientific advisor of Research Unit 6 in Research Academic Computer Technology Institute (CTI), Patras, Greece. His research interests include Analysis of Performance of Networking and Computer Systems, Computer Networks and Protocols, Telematics and New Services, QoS and Pricing for Networks and Services, e-Learning Networked Virtual Environments and WWW Issues. He has extended professional experience in Design and Analysis of Networks, Protocols, Telematics and New Services. He has published 250 papers in various well-known refereed conferences and journals. He is a co-author of 8 books in Greek. He has been a PC member and referee in various international journals and conferences. He has participated in R&D projects such as RACE, ESPRIT, TELEMATICS, EDUCATIONAL MULTIMEDIA, ISPO, EMPLOYMENT, ADAPT, STRIDE, EUROFORM, IST, GROWTH and others. Also he is member of experts in the Greek Research and Technology Network (GRNET), Advisory Committee Member to the World Wide Web Consortium (W3C), IEEE—CS Technical Committee on Learning Technologies, IEEE ComSoc Radio Communications Committee, IASTED Technical Committee on Education WG6.4 Internet Applications Engineering of IFIP, ACM, IEEE, EDEN, AACE, New York Academy of Sciences and Technical Chamber of Greece.

Evangelos Rekkas obtained his diploma from the Computer Engineering and Informatics Department of the University of Patras (Greece) in October 2007. He is currently an MSc Student in the Computer Engineering and Informatics Department. Furthermore, he is working as R&D Computer Engineer at the Research Unit 6 of the Research Academic Computer Technology Institute in Patras (Greece) since September 2006. His research interests include Mobile Telecommunications Networks, Multicast Routing, Radio Network Planning and Resource Management in Cellular Networks. He has published over 10 papers in Journals, International Conferences and Book Chapters.