Optimizing MBMS Power Allocation Through HSDPA Transmissions

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***Abstract*— Multimedia Broadcast Multicast Service (MBMS) epitomizes the increasing popularity of enhanced end-user experience in Universal Mobile Telecommunications System (UMTS), since it allows the economical delivery of multimedia services to a large number of users. MBMS multicast supports both Point-to-Point (PTP) and Point-to-Multipoint (PTM) modes in order to confront the strict resource limitations in wireless environments and improve efficiency during data transmission. The aim of this paper is to highlight the performance enhancements of MBMS multicasting over the High Speed Downlink Packet Access (HSDPA) and underline the need for its integration in MBMS specifications. HSDPA can play an instrumental role in positioning MBMS services as a key enabler for true Mobile Broadband. Under this prism, we investigate the provision of MBMS services over HSDPA, through a direct comparison between HSDPA and Release '99 bearers. Since downlink transmission power is the most limited resource in UMTS networks, the evaluation is performed via an analytical dimensioning of the MBMS transmission power both in macrocells and microcells. Simulation results reveal that HSDPA can significantly optimize MBMS power allocation, bring more capacity and, consequently, enable the mass-market delivery of rich multimedia services in mobile networks.**

Keywords-component; UMTS; HSPA; MBMS; Power Control;

I. INTRODUCTION

The provision of multimedia services in UMTS necessitates an optimal resource allocation mechanism in order to overcome the radio and network limitations and adapt to dynamic changes in wireless environments. To this direction, the 3rd Generation Partnership Project (3GPP), in order to satisfy the above needs and simultaneously compensate for the massive spread of wireless multimedia applications, proposed the integration of the MBMS framework in the Release 6 UMTS architecture [1], [2]. MBMS is an efficient method of delivering multimedia content to multiple destinations, by allowing resources to be shared in an economical way.

Furthermore, the increasing demand for capacity in order to provide high data rate services in mobile networks stressed the need for enhanced radio transmission techniques and network protocol functionality. HSDPA was introduced in the Release 5 [3] of the UMTS standard so as to meet this demand and improve spectral efficiency. In fact, HSDPA is a mobile broadband extension to the UMTS radio interface that comprises a wide range of key features to improve peak data rates, increase cell throughput and provide better quality of service control [4].

The combination of the MBMS and HSDPA technologies can significantly benefit UMTS networks and further improve radio and network resources' utilization during MBMS multicast transmission. On the one hand, HSDPA is considered the undisputed choice for the realization of mobile broadband as it optimizes the air interface and supports higher data rate and delay-tolerant services while, on the other hand, MBMS ensures the optimal delivery of multimedia applications. The incorporation of the two frameworks is envisaged as a promising way for enhanced provisioning of a plethora of multimedia applications.

However, MBMS over High Speed-Downlink Shared Channel (HS-DSCH), the downlink transport channel used in HSDPA, is a relatively novel proposal, still in infancy phase. HS-DSCH is characterized as a PTP channel due to its unicast nature and, thus, can be used for the transmission of MBMS multicast data in PTP mode. One of the most critical impediments, though, that radio bearers face during MBMS multicast transmission, is the limited downlink power budget in UMTS networks. To this direction, the role of power control in the MBMS multicast transmission in UMTS is described and analyzed in this paper. A theoretical evaluation of power consumption for the HS-DSCH and Release '99 bearers is performed so as to illustrate all improvements emerging from the transmission of MBMS multicast data over the HSDPA technology. At this point, it should be mentioned that the main scope of this paper is not to just examine HSDPA performance, but more significantly to highlight the fact that HS-DSCH should be integrated in MBMS specifications. We will prove that the transmission of MBMS multicast data over HS-DSCH can strongly reduce MBMS power consumption, bring more capacity and, in turn, enable the mass-market delivery of higher bit rate MBMS services to mobile users.

The paper is structured as follows: Section II presents an overview of this research field and provides some background, related works. Section III presents the power profiles of the PTP downlink radio bearers, while Section IV is dedicated to the presentation of the evaluation results. Finally, in Section V concluding remarks and planned next steps are described.

II. PROBLEM FORMULATION

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 specifications [5], 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. On the contrary, MBMS over HS-DSCH is an open issue, still under investigation. However, all the key features characterizing HS-DSCH constitute it an ideal candidate for the delivery of multicast data, mainly in PTP mode.

Additionally, for the maximization of MBMS efficiency, MBMS Counting Mechanism constitutes a methodology that decides whether it is more economic to use PTP (multiple DCHs) or PTM (a single FACH) MBMS transmissions [5]. 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. However, this number of users' criterion for channel type switching is not always efficient and may yield significant wasting of the expensive power resources, since it does not take into account the base station's downlink transmission power. Power in UMTS networks is the most limited resource, thus, power control becomes one of the most critical aspects in MBMS. The fundamental criterion for maximizing resource efficiency should be the base station's total downlink MBMS transmission power [6]. MBMS Counting Mechanism should adopt downlink power as the optimum criterion for radio bearer selection due to the fact that any change in such dynamic wireless networks can be reflected in the transmission power.

However, with the deployment of HS-DSCH as an alternative MBMS bearer, the decision on the appropriate radio bearer is slightly differentiated, in the sense that the decision has to take into account not only the Release '99 transport channels, but also the HS-DSCH transport channel. In this way, both HS-DSCH and DCH may be used as PTP bearers, while FACH as a PTM bearer. Consequently, the investigation of bearers' power profiles is mandatory in order to create an efficient, resource economic MBMS Counting Mechanism that will always select the optimum transport channel for the efficient delivery of multicast data.

Several studies have been carried out on the power allocation of Release '99 bearers during MBMS transmission, mainly concerning FACH. In [7], [8] FACH power consumption is exhaustively investigated, while in [9] the authors perform an MBMS power planning both for DCH and FACH transport channels. Regarding HSDPA, MBMS over HS-DSCH was proposed as a multi-resolution technique during MBMS transmission in [10], while in [11] the authors present a short analysis of different scheduling algorithms for PTP MBMS video streaming using HSDPA.

In this paper, we further extend work in this research field by thoroughly analysing and evaluating HS-DSCH power consumption during MBMS PTP multicast transmissions. We perform a direct comparison between HSDPA and release '99 bearers in terms of power (capacity). Furthermore, our study steps over the conventional macrocell investigation and considers microcell environments too. Our goal is to evaluate the power and capacity improvements arising from the use of HSDPA in multicast transmissions and highlight the importance of HS-DSCH employment for the realization of an optimal, resource efficient MBMS Counting Mechanism.

III. POWER PROFILES OF DOWNLINK TRANSPORT CHANNELS

This section presents the main characteristics of the DCH and HS-DSCH power profiles, which can be used during PTP transmissions. In addition, an analytical method for the computation of their power consumption levels during the MBMS multicast transmissions is provided.

A. HS-DSCH Power Profile

HS-DSCH is a rate controlled rather than a power controlled transport channel. In HSDPA 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 2ms.

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 Node B is allowed to use any unused power remaining after serving other, power controlled channels, for HS-DSCH transmission. 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.

A major measure for HSDPA link budget planning is the HS-DSCH Signal-to-Interference-plus-Noise Ratio (*SINR*) metric. *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 [4]. *SINR* for a single-antenna Rake receiver is calculated from equation (1):

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

where $P_{HS\text{-}DSCH}$ is the HS-DSCH transmission power, P_{own} is the own cell interference experienced by the mobile user, P_{other} the interference from neighboring cells and P_{noise} the Additive Gaussian White Noise (AGWN). Parameter p is the orthogonality factor (p = 0 for 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* (Figure 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 (Figure 1).

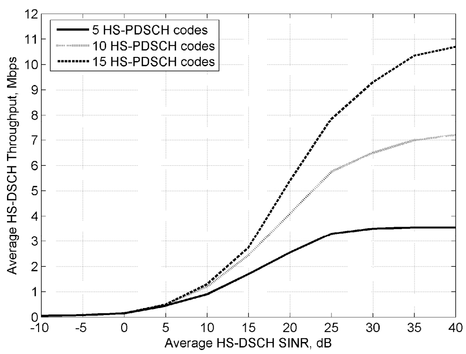


Figure 1. Actual Cell Throughput vs. SINR.

Finally, we can describe how the required HS-DSCH transmission power ($P_{HS\text{-}DSCH}$) can be expressed as a function of the *SINR* value and the user location (in terms of Geometry factor - G) through equation (2):

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

The Geometry factor is given by the relationship between P_{own}, P_{other} and P_{noise} and is defined from equation (3), while the Geometry CDF function values obtained for the macro and micro cell environments are depicted in Figure 2 [1]:

$$G = \frac{P_{own}}{P_{other} + P_{noise}} \tag{3}$$

The Geometry factor is another major measure that indicates the users' position in a cell (*i.e.* 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}).

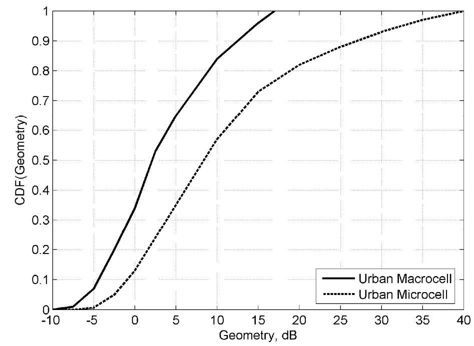


Figure 2. Geometry CDF Macrocell – Microcell.

B. DCH Power Profile

The total downlink transmission power allocated for all MBMS users in a cell that are served by multiple DCHs is variable. It mainly depends on the number of serving users, their distance from the base station, the bit rate of the MBMS session and the experienced signal quality E_b/N_0 for each user. Equation (4) calculates the base station's total DCH transmission power required for the transmission of the data to n users in a specific cell [12].

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

where P_{DCH} is the base station total transmitted power, $P_T i$ is the power devoted to the i^{th} user , P_P is the power devoted to common control channels $L_{p,i}$ is the path loss, $R_{b,i}$ the i^{th} user transmission rate, W the bandwidth, P_N the background noise, p is the orthogonality factor (p=0: perfect orthogonality), $(E_b/N_0)_i$ is the signal energy per bit divided by noise spectral density. Parameter x_i is the intercell interference observed by the i^{th} user given as a function of the transmitted power by the neighboring cells P_{Tj}, j=1,…K and the path loss from this user to the j^{th} cell L_{ij}. More specifically [12]:

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

DCH may used for the delivery of PTP MBMS services, while cannot be used to serve large multicast populations since high downlink transmission power would be required. In general, higher power allocation levels are required to deliver higher MBMS data rates. In addition, increased cell coverage area and larger multicast groups lead to higher power consumption when multiple DCHs are deployed.

IV. PERFORMANCE EVALUATION

For the purpose of our evaluation analysis we consider a typical 64Kbps MBMS service. Furthermore, both macro and micro cell environments are assumed, with simulation parameters presented in Table I [1], [13].

Initially, in sub-section IV.A, due to that fact that HS-DSCH, as well as DCH, is a PTP channel, a comparison between DCH and HS-DSCH power consumption is presented. Finally, in sub-section IV.B, a parallel plotting of PTP (DCH, HS-DSCH) and PTM (FACH) bearers is depicted. The aim of this plotting is to illustrate the fact that HS-DSCH can optimize and significantly improve the performance of the MBMS Counting Mechanism.

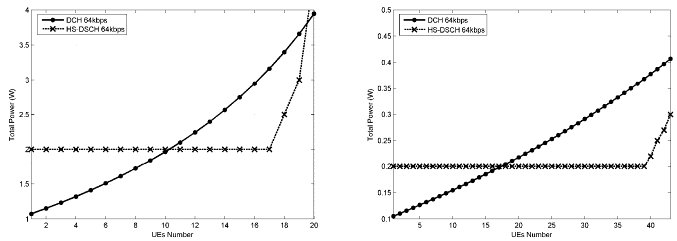
TABLE I. MACROCELL AND MICROCELL SIMULATION PARAMETERS

Parameter	Macrocell	Microcell
Cellular layout	Hexagonal grid	Manhattan grid
Number of cells	18	72
Sectorization	3 sectors/cell	No
Site-to-site distance	1 Km	67 m
Maximum BS Tx power	20 W	2 W
Other BS Tx power	5 W	0.5 W
CPICH Power	2 W	0.2 W
Common channel power	1 W	0.1 W
Propagation model	Okumura Hata	Walfish-Ikegami
Multipath channel	Vehicular A (3km/h)	Pedestrian A (3Km/h)
Orthogonality factor (0 : perfect orthogonality)	0.5	0.1
Eb/N0 target	5 dB	6 dB

A. *MBMS PTP Multicast Power Allocation*

Figure 3 – Figure 5 depict the MBMS transmission power of DCH and HS-DSCH transport channels, for 60%, 80% and 100% cell coverage areas respectively. These figures present the performance of HS-DSCH downlink power during MBMS multicast transmissions and reveal the power optimization through the use of HS-DSCH for MBMS PTP multicast transmissions. Actually, these figures may be used in order to determine the appropriate transport channel in PTP mode, thus, reducing MBMS power consumption. At this point, it should be mentioned that for HSDPA simulation, 15 HS-PDSCH codes are assumed to be allocated for each MBMS user.

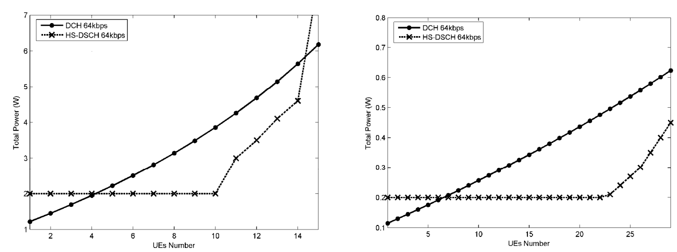
More specifically, Figure 3 presents the case of MBMS power consumption for 60% cell coverage area in macro and micro cell environments. It is obvious that HS-DSCH, compared to DCH, requires less transmission power when the number of users exceeds 10 in the case of a macrocell, as shown in Figure 3(a), or 17 in the case of a microcell, Figure 3(b). For less than 10 and 17 users respectively, DCH is less power consuming and should be used instead of HS-DSCH in PTP mode.



(a) (b)

Figure 3. MBMS Tx Power 64Kbps, 60% coverage (a) Macrocell, (b) Microcell.

Power improvements in PTP mode through the use of HS-DSCH can be better get understood from the following example. For instance, in PTP mode, without the use of HS-DSCH, 3 Watt would be required in a macrocell for serving 16 multicast users with multiple DCHs, while with the use of HSDPA technology 2 Watt would be enough for serving 16 users. A significant power saving equal to 1 Watt is, thus, obtained with the deployment of HS-DSCH in PTP mode in this example (Figure 3(a)).

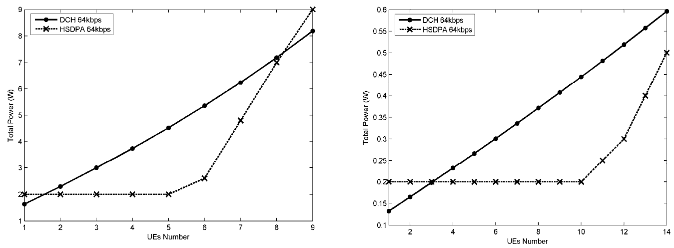


(a) (b)

Figure 4. MBMS Tx Power 64Kbps, 80% coverage (a) Macrocell, (b) Microcell.

Similarly, Figure 4 presents MBMS power consumption for 80% cell coverage area in both environments. In this case, however, HS-DSCH performs even better than DCH and the threshold for switching from DCH to HS-DSCH is decreased to 4 and 7 users for macrocell and microcell respectively, compared to the case of 60% cell coverage. As a consequence, HS-DSCH is preferred and should be exclusively employed in PTP mode, since it is less power consuming even for a very small number of serving users.

Regarding the 100% cell coverage case, from Figure 5, we may conclude that HS-DSCH is superior to DCH and should be always used in PTP mode. Even in the case of serving only one or two MBMS users, HS-DSCH requires significantly less power than DCH and, obviously, should be employed for PTP transmissions in both environments.



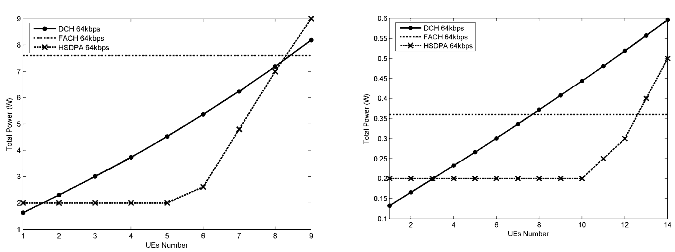
(a) (b)

Figure 5. MBMS Tx Power 64Kbps, 100% coverage (a) Macrocell, (b) Microcell.

Another important issue emerging from the above figures is that the HS-DSCH performs better in microcells, rather than in macrocells and results to higher power gains. For instance, in Figure 4 for 80% macrocell coverage, base station should allocate 15% of its total power (or else 3 Watt) for HS-DSCH in order to serve 11 multicast users, while for the same power allocation percentage (or else 0.3 Watt) in a micro cell environment, 26 multicast users can be served. This is due to the higher isolation and the less propagation characterizing microcells compared to macrocells.

B. Improved MBMS Counting Mechanism

As presented in Section II, MBMS Counting Mechanism constitutes a mechanism that decides whether it is more economic to use PTP or PTM transmission mode during MBMS multicast transmission and, subsequently, perform a switching between these two modes. From the above figures, though, it was clear that HS-DSCH can offer significant power savings in the PTP mode. However, the performance enhancement that HSDPA technology offers during MBMS transmission can be better realized in this section, when considering the PTP/PTM switching procedure.



(a) (b)

Figure 6. MBMS Power Allocation 64Kbps, 100% coverage (a) Macrocell, (b) Microcell.

In order to illustrate this performance enhancement some indicative results only for 100% cell coverage are presented in Figure 6. This figure aims to make a direct comparison between Release ’99 bearers and HS-DSCH power consumption. More specifically, in Figure 6 MBMS power allocation is presented for DCH, FACH and HS-DSCH transport channels when a 64Kbps MBMS service is delivered. According to FACH specifications, transmission power for this transport channel is fixed, regardless of the number of serving users, as it is a common channel. For 100% cell coverage and without considering any transmit diversity technique, FACH power allocation is set at 7.6 Watt for a macrocell and at 0.36 Watt for a microcell [7], [9].

For a macro cell environment, from Figure 6(a), it can be observed that for less than 8 users, HS-DSCH (PTP mode) could be used for the MBMS multicast transmission, while for more than 8 users a FACH (PTM mode) is the optimal transport channel. Current MBMS Counting Mechanism, on the other hand, using only DCH and FACH channels (and no HS-DSCH), would use the same switching point of 8 users between DCHs and FACH. However, HS-DSCH requires less power than DCH and, thus, power resources would be better utilized in PTP mode if HSDPA is employed.

Results regarding a microcell are even more optimistic since HS-DSCH is prevailing over the DCH in PTP mode and further extends the switching point between PTP and PTM from 8 to 12 multicast users, while simultaneously leading to significant power savings. For more than 12 users, a FACH should be used for the MBMS multicast data delivery, while for less than 12 users HS-DSCH is the appropriate radio bearer. As a consequence, HS-DSCH can provide a great saving of the expensive power resources and optimize MBMS performance.

Additionally, the power gain, that was observed in the above figures, and was obtained through the use of HS-DSCH in PTP mode can, in turn, lead to a significant capacity enhancement for MBMS operators. More specifically, for most types of MBMS services, such as streaming video, 64 Kbps is enough to provide good quality. Current MBMS specifications ensure the delivery of 64 or 128 Kbps multimedia content with a very good coverage probability using DCH and FACH channels. From the end user point of view, no significant improvement is expected from HS-DSCH usage at first glance. However, as can be extracted from the presented results, what HS-DSCH brings is more capacity, which, in turn, enables mass-market delivery of higher bit rate streaming services to end users and concurrently ensures more resources for the provision of other, non-MBMS services.

V. CONCLUSIONS AND FUTURE WORK

In this paper we investigated the provision of MBMS multicast data over HSDPA and specifically over the HS-DSCH transport channel. We evaluated the performance of HSDPA in MBMS PTP transmission mode, when delivering multicast data in macro and micro cell environments, in terms of power consumption. The preceded analysis indicates that the transmission of MBMS multicast data over HS-DSCH, compared to Release ’99 bearers, can significantly reduce MBMS power consumption, bring more capacity and enable the mass-market delivery of higher bit rate MBMS services to mobile users. Conclusively, it is imperative that HSDPA should be integrated in MBMS specifications as it ensures optimized performance. The step that follows this work is to further examine the provision of MBMS over HSDPA and investigate additional improvements through the use of MIMO antennas in HSDPA.

REFERENCES

[1] 3GPP, TS 22.146 V7.1.0. Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service; Stage 1 (Release 7)

[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 25.308 V5.4.0. Technical Specification Group Radio Access Network; High Speed Downlink Packet Access (HSDPA); Stage 2 (Release 5)

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

[5] 3GPP, TS 25.346 V7.2.0. Introduction of the Multimedia Broadcast Multicast Service (MBMS) in the Radio Access Network (RAN), Stage 2, (Release 7)

[6] Alexiou, A., Bouras, C., Rekkas, E.: A Power Control Scheme for Efficient Radio Bearer Selection in MBMS. IEEE International Symposium on World of Wireless, Mobile and Multimedia Networks (WoWMoM) (2007)

[7] 3GPP TS 25.803 V6.0.0, Technical Specification Group Radio Access Network; S-CCPCH performance for MBMS, (Release 6)

[8] IST-2003-507607 (B-BONE). Final Results with combined enhancements of the Air Interface. Deliverable of the project (D2.5)

[9] Alexiou, A., Bouras, C., Kokkinos, V., Rekkas, E.: MBMS Power Planning in Macro and Micro Cell Environments. Second IEEE Workshop on multimedia Applications over Wireless Networks (MediaWiN) (2007) pp. 33-38

[10] Correia, A., Silva, J. C., Souto, N.S.: Multi-Resolution Broadcast/Multicast Systems for MBMS. IEEE Transactions on Broadcasting, Vol. 53, No. 1 (2007) pp. 224 - 234

[11] Silva, L., Gomes, P., Correia, A.: Point-to-Point MBMS Video Streaming using HSDPA. Sixth Conference on Telecommunications (ConfTele) (2007)

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

[13] 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)J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.