SINR-based Transport Channel Selection for MBMS Applications

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***Abstract*—Multimedia Broadcast Multicast Services (MBMS), introduced by Third Generation Partnership Project (3GPP) in Universal Mobile Telecommunications System (UMTS) Release 6 specification, have the aim to support downlink streaming and game services to groups of users. MBMS can supply users with resources in two different modalities: point-to-point (PtP) and point-to-multipoint (PtM). The power consumed by the network is an important topic to discuss when considering the presence of MBMS services. The UMTS system is, in fact, interference-limited; thus, the power available to Node B is limited and it must be enough to serve any user under its coverage. Therefore, the choice of the most efficient transport channel in terms of power consumption is a key aspect for the MBMS, since a wrong transport channel selection for the transmission of the MBMS data could adversely affect the overall capacity of the system. In this paper we search for the most efficient transport channel to convey MBMS data, by comparing the performance of the High Speed Downlink Shared Channel (HS-DSCH), the Dedicated Channel (DCH), and the Forward Access Channel (FACH), for given transmission power levels and cell coverage size.**

I. INTRODUCTION

Third generation (3G) cellular wireless networks, such as Universal Mobile Telecommunications System (UMTS), have been designed since the beginning to support multimedia communications. Thanks to their deployment, person-to-person communication is enhanced with high quality images and video, while the access to information and services in public and private networks is enhanced by a higher data rate [1]. High Speed Downlink Packet Access (HSDPA) is the new technology introduced into 3GPP Release 5 to enable high data rates for downlink transmissions [2]. The introduction of new services, i.e. video conferencing or streaming video, has originated the need of a communication between one sender and several receivers that is a point-to-multipoint (PtM) transmission. The use of a multicast or broadcast technology is an efficient method to carry out a PtM transmission [3]. Therefore, the third generation partnership project introduced a new protocol, called Multimedia Broadcast/Multicast Service (MBMS), used as a PtM service. The MBMS services can be delivered by using the UMTS Release 99 common or dedicated channels, i.e. Forward Access Channel (FACH) and Dedicated Channel (DCH), as well as HSDPA shared channel, i.e. High Speed Downlink Shared Channel (HS-DSCH). Power consumed by the network is an important issue to take into account when the MBMS protocol is considered. The limitation in the power that the Node B can use pushes towards the wise selection of the most efficient transport channel in terms of power consumption. The power saving is related to the number of users receiving MBMS data; in fact if such number increases, then one needs a higher amount of DCHs. Thus it is important to decide the maximum number of users that can use the DCHs, allowing a power saving. Such a number represents a threshold for switching from dedicated channel to either common or shared ones. In this paper we aim at investigating the cited switching thresholds from DCHs to HS-DSCH and from HS-DSCH to FACH, for different HS-DSCH assigned power values and several cell coverage sizes, while aiming at saving power for constant bit rate applications and User Equipment (UE) category 10 [2]. Results are obtained by means of analytical computation performed by MATLAB and a simulator implemented by Simulink. Several studies have been already conducted to find the thresholds for switching between dedicated, common and shared channels in terms of used power [4]; therefore, we also highlight our own new contribution to such studies. The present paper is organized as follows. Section II provides a brief overview about the MBMS, highlighting the architecture. In Section III the currently UMTS transport channels that can be used in MBMS are presented. Section IV shows a study in which the thresholds for switching from dedicated to either common or shared channels have been calculated, in different scenarios. The main results obtained by simulation campaigns are the focus of Section V. Conclusive remarks are presented in Section IV.

II. MBMS ARCHITECTURE

In Figure 1 the MBMS architecture is illustrated [5]. The new elements introduced to such architecture are the following:

BM-SC (Broadcast-Multicast Service Center) is an MBMS data source. MBMS data may be scheduled in the BM-SC, e.g. for transmission to the user every hour. It offers interfaces where the content provider can request data delivery to users.

The **Gmb** (or **Gi**) reference point between BM-SC and Gateway GPRS Support Node (GGSN) enables the BM-SC to exchange MBMS service control information with the GGSN.

CBC (Cell Broadcast Centre) may be used to announce MBMS services to the users.

The BM-SC might use **OSA-SCS (Open Service Access-Service Capability Server)** to interact with third parties.

The Serving GPRS Support Node (SGSN) may use the CAMEL (Customised Applications for Mobile Enhanced Logic) protocol to handle pre-paid services by utilizing the **CSE (CAMEL Service Enhanced)**.

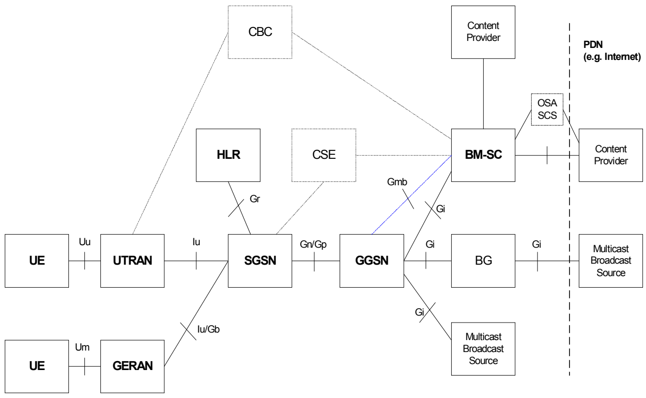

Fig. 1. MBMS architecture [5]

III. Transport channels Supported by MBMS

As introduced above, the MBMS data can be delivered to the users through three different transport channels: DCH, FACH and HS-DSCH [4], [6]. When a group of users requests a particular service, the choice of either one PtM channel or several PtP channels plays a fundamental role: if one chooses to allocate a PtM channel, then one single transport channel will be used, else several PtP transport channels will be utilised, one per user [6].

The FACH is a broadcast common downlink transport channel that carries control information to terminals known to be located in the given cell. This is used, for example, after a random access message has been received by the base station. It is also possible to transmit packet data on the FACH. It does not use fast power control, and the messages transmitted need to include in band identification information to ensure their correct reception [1].

The only dedicated transport channel is the DCH that carries all the information intended for the given user coming from layers above the physical one, including data for the actual service as well as higher layer control information. The DCH is characterised by features such as fast power control, fast data rate change on a frame-by-frame basis, and the possibility of transmission to a certain part of the cell or sector with varying antenna weights with adaptive antenna systems [1].

The HS-DSCH is the shared transport channel that carries the actual user data with HSDPA that is the downlink transmission technology of the High Speed Packet Access (HSPA) family.

IV. Radio Resource Management and Policies Based on Channel Switching Thresholds

Several studies have been conducted to find thresholds in terms of number of users for switching among *Dedicated*, *Common,* and *Shared* channels to allow saving power and increasing MBMS system capacity [6], [7]. In [4] it has been demonstrated that these thresholds depend on the following factors: *(i)* the cell coverage radius (that is the position of the users inside the coverage area); *(ii)* the MBMS service bit rate, *(iii)* QoS aspects, in terms of Eb/No; and *(iv)* neighboring cells' transmission power. These parameters play an important role on the *Switching Threshold* determination because they affect the power assigned to multicast channels. For instance, far users require a signal with higher transmitted power respect to users located in the neighbourhood of Base Station and higher bit rates imply higher required power values to assign to DCH and FACH channels. As it will be clarified in the following, the power assigned to HS-DSCH does not depend on the MBMS service bit rate.

For instance, in Table 1 the thresholds in terms of number of users for switching from DCHs to HS-DSCH and from DCH to FACH are reported, according to [4]. Such thresholds are evaluated considering: 64 kbps services, several values of cell coverage radius and the corresponding power allowed respectively to FACH and to HS-DSCH. From Table 1 it clearly emerges that when the distance of the users from the base station is equal to 550 meters a more efficient choice in terms of power consuming is to switch from DCHs to HS-DSCH channel; in others cases it is more advisable to switch from DCHs to FACH. Power values referred to DCH and FACH are obtained utilizing formulas reported in [1].

By starting from the consideration reported above we have included a new contribution to such studies by demonstrating that HS-DSCH is limited in terms of *served users number*. As a consequence such a restriction allows to define a further *Switching Threshold* between HS-DSCH and FACH channel (i.e. when a cell coverage radius is equal to 550 m), being the latter one (being a broadcast channel) not limited in terms of *served users number*. Moreover, we demonstrate that the HS-DSCH assigned power depends on the cell coverage radius and on the channel radio condition. This implies the redefinition of *Switching Thresholds* between DCHs and HS-DSCH. Hence, the introduction of a second *Switching Threshold* is based on the fact that HS-DSCH does not support broadcast transmission. In fact, in a HSDPA environment, the number of users able to receive data at an assigned bit rate is limited and depends on the value of Channel Quality Information (CQI). The CQI is a typical HSDPA parameter that gives information about the maximum obtainable bit rate that can be shared between the users. Moreover, it includes information about the transport block size, the number of used physical channels and the modulation technique. The possible CQI values for *UE category 10* [2] are illustrated in the Table 2 where we highlighted the correspondent maximum number of served users for 64 kbps and 128 kbps MBMS applications [9]. From Table 2, it clearly emerges that HS-DSCH is limited in terms of *served users number*. As a consequence, if the number of users requiring MBMS services increases then it could be more efficient to switch from HS-DSCH to FACH channel. The choice of the CQI value depends on the radio channel condition. In particular, the *Signal to Interference Noise Ratio* (SINR) influences the CQI that can be considered; therefore, not always all CQI values reported in Table 2 can be utilized.

In the remaining part of this paper we show how the radio channel condition, the cell coverage radius, and the CQI influence the definition of the two *Switching Thresholds* (the first one between DCH and HS-DSCH, while the second one between HS-DSCH and FACH channel).

TABLE 1
THRESHOLDS FOR SWITCHING FROM THE DCH TO HS-DSCH FOR DIFFERENT CELL COVERAGE [4]

Cell Coverage Radius	Power Allowed to FACH	Threshold for Switching from DCHs to FACH	Power Allowed to HS-DSCH	Threshold for Switching from DCHs to HS-DSCH
550 m	7,6 W	9	7 W	8
430 m	4,4 W	14	7 W	19
290 m	2,8 W	18	7 W	37

TABLE 2
CQI MAPPING TABLE

CQI value	Transport Block Size (bits)	Number of codes	Modulation	Single Channel Bit Rate (kbps)	Total Bit Rate (kbps)	UE Number 64 kbps	UE Number 128 kbps
1	137	1	QPSK	480	480	7	3
2	173	1	QPSK	480	480	7	3
3	233	1	QPSK	480	480	7	3
4	317	1	QPSK	480	480	7	3
5	377	1	QPSK	480	480	7	3
6	461	1	QPSK	480	480	7	3
7	650	2	QPSK	480	960	15	7
8	792	2	QPSK	480	960	15	7
9	931	2	QPSK	480	960	15	7
10	1262	3	QPSK	480	1440	22	11
11	1483	3	QPSK	480	1440	22	11
12	1742	3	QPSK	480	1440	22	11
13	2279	4	QPSK	480	1920	30	15
14	2583	4	QPSK	480	1920	30	15
15	3319	5	QPSK	480	2400	37	18
16	3565	5	16-QAM	960	4800	75	37
17	4189	5	16-QAM	960	4800	75	37
18	4664	5	16-QAM	960	4800	75	37
19	5287	5	16-QAM	960	4800	75	37
20	5887	5	16-QAM	960	4800	75	37
21	6554	5	16-QAM	960	4800	75	37
22	7168	5	16-QAM	960	4800	75	37
23	9719	7	16-QAM	960	6720	105	52
24	11418	8	16-QAM	960	7680	120	60
25	14411	10	16-QAM	960	9600	150	75
26	17237	12	16-QAM	960	11520	180	90
27	21754	15	16-QAM	960	14400	225	112
28	23370	15	16-QAM	960	14400	225	112
29	24222	15	16-QAM	960	14400	225	112
30	25558	15	16-QAM	960	14400	225	112

V. OBTAINED RESULTS

A exhaustive simulation campaign has been conducted to determinate the *Switching Thresholds* among *Dedicated*, *Shared* and *Common* channels taking into account the same assumptions reported in [4]. We considered two different MBMS applications respectively with 64 and 128 kbps. The main simulation parameters are reported in Table 3.

TABLE 3
SIMULATION ASSUMPTIONS

Parameter	Value
Cellular layout	Hexagonal grid
Number of neighboring cells	18
Site to site distance	1 Km
Cell radius	290 - 550 m
Maximum BS Tx power	20 W
Other BS Tx power	5 W
Common channel power	1 W
Propagation model	Okumura Hata
Multipath channel	Vehicular A (3Km/h) Case 1 [9]
Orthogonality factor	0,5
BLER target	10%
Base station antenna gain	17,5 dBi [6]
Antenna beamwidth, -3 dB	70 degress [6]
Thermal noise	-100 dBm
Shadowing	10 dB
Cable losses	3 dB [6]

The first step of our simulation campaign aims to determinate the values of HS-DSCH transmitted power when considering (differently from as reported in [4]) also the radio channel condition and several cell coverage radius. The obtained values of HS-DSCH transmitted power will be utilized to determinate the new *Switching Threshold* values between DCHs and HS-DSCH channels.

The equation that puts into relationship SINR, HS-DSCH transmitted power ($P_{HS\text{-}DSCH}$), and cell coverage radius is the following [2]:

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

Where p is the orthogonality factor (that assumes a value equal to zero in case of perfect orthogonality), P_{own} is the own cell interference, SF_{16} is the spreading factor of 16, and G is the Geometry factor, defined according to the following equation [1]:

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

Where P_{other} is the interference from neighbouring cells and P_{noise} is the Additive Gaussian White Noise (AGWN). G is related to the user distance from the base station, for instance, a lower G value is expected when a user is at the cell edge where the interference from the neighbouring cells is higher than the interference at its own cell.

Figure 2 indicates the power to assign to the HS-DSCH channel by varying the SINR to guarantee, for different cell coverage radius. To carry out such a figure we fixed the cell radius to find G by means of the equation 2 and then we obtained the power to assign to the HS-DSCH by using *G* value in equation 1 for each possible SINR.

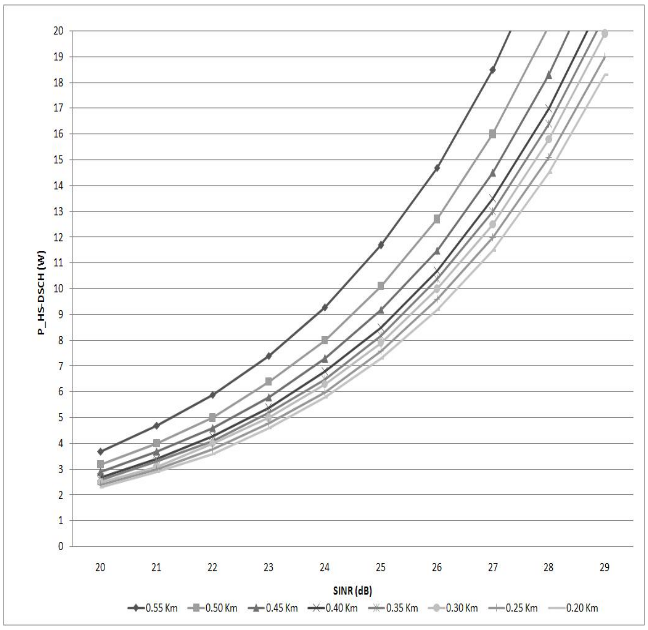

Fig. 2. Power to assign to the HS-DSCH per cell radius

It is worth noting that a value of SINR of 27 dB is the highest one that can be guaranteed in this scenario, because the maximum transmission power of the Base Station is 20 W (see Table 3). Such a value can be obtained in two different ways: *(i)* the HS-DSCH transmission power must be 12 W at least and the users have to stay at a distance lower than 250 meters from the base station. *(ii)* for distances between 250 and 550 metres from the base station the power to assign must be respectively between 12,5 and 18,5 W. Through Figure 2 (establishing the SINR to guarantee and the cell coverage radius) it is possible to determine the power needed to activate a HS-DSCH and hence the first *Switching Threshold* between DCHs and HS-DSCH.

The second step of our study aims to determine the second *Switching Threshold* between HS-DSCH and FACH channel. As explained in the previous section, the SINR influences the CQI that can be utilized. In Figure 3 the relationship between SINR and CQI is illustrated for four different targets Block Error Rate (BLER). We obtained such a figure through a simulator giving a SINR value, when a CQI parameter and a BLER target are selected. We carried out the simulator, by using Simulink, implementing the following step of HS-DSCH coding and modulation chains [10], [11]: *(i) CRC attachment*, *(ii) Scrambling*, *(iii) Segmentation*, *(iv) Turbo Coding*, *(v) Hybrid ARQ*, *(vi) Interleaving*, *(vii) 16QAM constellation rearrangement*, *(viii) Modulation Mapper*, *(ix) Scrambling*, *(x) Modulation*.

For instance, if we suppose the BLER target equal to 10%, then for a given SINR that could be guaranteed (i.e. SINR equal to 25 dB) we can find the greatest CQI supported by the HS-DSCH (i.e. CQI equal to 22). From CQI we can determine the maximum number of users that could be served by HS-DSCH (i.e. 75 users considering 64 kbps services, see Table 2). Such numbers represent the thresholds for switching from the HS-DSCH channel to the FACH. In fact, even if the first channel is more performing in terms of power consumption, the second one has the advantage to be not limited in terms of *served users number*. By utilizing the results shown in Figures 2 and 3, in the next two subsections we determine the *Switching Thresholds* among *Dedicated*, *Shared*, and *Common* channels by fixing a BLER target equal to 10% , while varying the HS-DSCH transmission power and the cell coverage radius. Different radio channel conditions could affect the CQIs selection (see Figure 3). In fact, as showed in Table 1, the maximum number of multicast users served by HS-DSCH could vary, causing a ping pong effect in the channel switching. But, it is worth to note, that for adjacent CQI values, in several cases, the same number of multicast users corresponds.

This behaviour minimizes the ping pong effect. The reduction of ping-pong effect and the signalization due to channel change are interesting topics, but they are not tasks of this research work, future studies will aim at efficiently managing these issues.

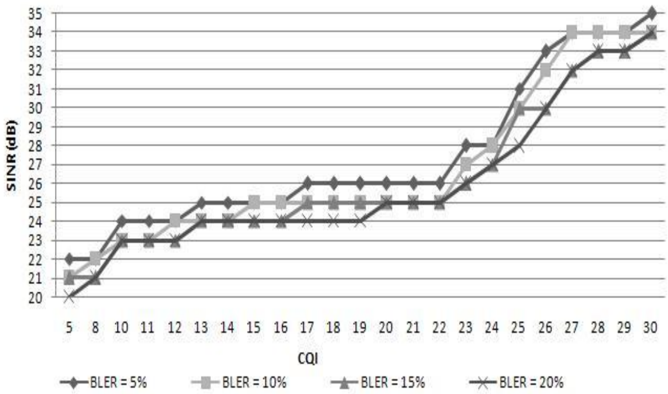

Fig. 3. SINR to guarantee per CQI

A. *More advisable channel when varying the cell coverage radius*

Table 4 summarizes the new *Switching Thresholds values* for two different MBMS applications (respectively with 64 and 128 kbps) when fixing to 7 W the HS-DSCH transmission power [4] and varying the cell coverage radius. The FACH transmission power for 64 kbps services are reported in Table 1, while for 128 kbps are 15,8, 8,9, and 6,3 W when considering a cell coverage radius equal to 550, 430, and 290 meters [12], respectively.

It is worth noting that with respect to Table 1 we added new thresholds between HS-DSCH and FACH. For instance, when the cell coverage radius is equal to 550 meters, then the maximum number of UEs that can be served by the HS-DSCH is 22 for 64 kbps applications and 11 for 128 kbps services. Therefore, if the number of users exceeds such values, then a use of the FACH is the only way to provide efficiently MBMS services regardless of the consumed power.

TABLE 4
SWITCHING THRESHOLDS VARYING THE CELL COVERAGE RADIUS

Bit Rate	Number of Users (N_u)	Utilized Channel	Cell Coverage Radius (m)
64 Kbps	≤ 8	DCHs	550
	$8 < N_u \leq 22$	HS-DSCH	
	> 22	FACH	
128 Kbps	≤ 4	DCHs	
	$4 < N_u \leq 11$	HS-DSCH	
	> 11	FACH	
64 Kbps	≤ 19	DCHs	430
	> 19	FACH	
128 Kbps	≤ 10	DCHs	
	$10 < N_u \leq 37$	HS-DSCH	
	> 37	FACH	
64 Kbps	≤ 37	DCHs	290
	> 37	FACH	
128 Kbps	≤16	DCHs	
	> 16	FACH	

B. *More advisable channel when varying the HS-DSCH transmission power*

Table 5 summarizes the *Switching Thresholds values* for two different MBMS applications (respectively with 64 and 128 kbps) when fixing the cell coverage radius to 550 meters and varying the HS-DSCH transmission power. The highest value of HS-DSCH power chosen is 12 W [13], while the FACH channel transmission power is equal to 7,6 W for 64 kbps applications and 15,8 W for 128 kbps ones.

TABLE 5
SWITCHING THRESHOLDS VARYING THE HS-DSCH TRANSMISSION POWER

Bit Rate	Number of Users (N_u)	Utilized Channel	HS-DSCH power
64 Kbps	≤ 9	DCHs	8 W
	> 9	FACH	
128 Kbps	≤ 4	DCHs	
	$4 < N_u \leq 15$	HS-DSCH	
	> 15	FACH	
64 Kbps	≤ 10	DCHs	9 W
	> 10	FACH	
128 Kbps	≤ 5	DCHs	
	$5 < N_u \leq 15$	HS-DSCH	
	> 15	FACH	
64 Kbps	≤ 11	DCHs	10 W
	> 11	FACH	
128 Kbps	≤ 6	DCHs	
	$6 < N_u \leq 37$	HS-DSCH	
	> 37	FACH	
64 Kbps	≤ 12	DCHs	11 W
	> 12	FACH	
128 Kbps	≤ 6	DCHs	
	$6 < N_u \leq 37$	HS-DSCH	
	> 37	FACH	
64 Kbps	≤ 13	DCHs	12 W
	> 13	FACH	
128 Kbps	≤ 7	DCHs	
	$7 < N_u \leq 37$	HS-DSCH	
	> 37	FACH	

FACH always allows saving power in comparison with HS-DSCH, when 64 kbps is the service bit rate. While when 128 kbps is the application bit rate, the assigned HS-DSCH power allows to increase both the *Switching Threshold* between DCHs and HS-DSCH and the one between HS-DSCH and FACH. This result is very important because it highlights that in acceptable radio channel condition a greater amount of power could be assigned to HS-DSCH with a consequent improvement of the MBMS system capacity. The obtained result could be used to implement an efficient radio resource management able to improve the system capacity. It could select the suitable transport channel adapting dynamically the power to assign to FACH and HS-DSCH in according to radio conditions and the distribution of multicast users inside the coverage area.

VI. CONCLUSIONS

In providing MBMS services the choice of the most efficient transport channel is a key aspect, since a wrong transport channel selection could adversely affect the overall capacity of the system. In this paper we identify the *Switching Thresholds* among DCH, HS-DSCH, and FACH channels, by taking into account the radio channel conditions, the cell coverage radius, and several MBMS application bit rates. It has been demonstrated that the HS-DSCH is limited in terms of number of served users; in particular, we carried out a mapping between the CQI values and the corresponding SINR by explaining how a limitation of the CQI is directly related to a restriction in the number of users served through HS-DSCH. As future works, these consideration could be extended taking into account the effect of LTE enhancements in the proposed scheme.

REFERENCES

[1] H. Holma, A. Toskala - WCDMA for UMTS – Radio Access for Third Generation Mobile Communications, 2004 John Wiley and Sons.

[2] H. Holma, A. Toskala – HSDPA/HSUPA for UMTS – High Speed Radio Access for Mobile Communications, 2006 John Wiley and Sons.

[3] C. Christophorou, A. Pitsillides - An Efficient Handover Algorithm for MBMS Enabled 3G Mobile Cellular Networks, 11th IEEE Symposium on Computers and Communications (ISCC'06), Sardinia, Italy, 2006.

[4] A. Alexiou, C. Bouras, V. Kokkinos, E. Rekkas - Power Efficient Radio Bearer Selection in MBMS Multicast Mode, MSWIM'07, October 22-26, 2007.

[5] 3GPP TR 23.846 V6.1.0 Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description (Release 6).

[6] IST-2003-507607 (B-BONE). Deliverable D2.5. Final results with combined enhancements of the air interface.

[7] IST-2001-35125 (OverDRiVE), Deliverable of the project (D08), “Spectrum Efficient Multicast and Asymmetric Services in UMTS”.

[8] 3GPP TS 25.308 V5.7.0 Technical Specification Group Radio Access Network; High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2 (Release 5).

[9] 3GPP TS 25.211 V5.8.0 Technical Specification Group Radio Access Network; Physical channels and mapping of transport channels onto physical channels (FDD) (Release 5).

[10] 3GPP TS 25.212 V5.10.0 Technical Specification Group Radio Access Network; Multiplexing and channel coding (FDD) (Release 5).

[11] 3GPP TS 25.213 V5.6.0 Technical Specification Group Radio Access Network; Spreading and modulation (FDD) (Release 5).

[12] 3GPP TS 25.803 V6.0.0 Technical Specification Group Radio Access Network; S-CCPCH performance for MBMS (Release 6).

[13] J.-B. Landre, A. Saadani – Receive Diversity and LMMS Equalization Benefits for HSDPA: Realistic Network Throughputs, (PIMRC’07).