Cost Analysis of the MBMS Multicast Mode of UMTS

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Abstract

Along with the widespread deployment of the third generation cellular networks, the fast-improving capabilities of the mobile devices, content and service providers are increasingly interested in supporting multicast communications over wireless networks and in particular over Universal Mobile Telecommunications System (UMTS). To this direction, the third Generation Partnership Project (3GPP) is currently standardizing the Multimedia Broadcast/Multicast Service (MBMS) framework of UMTS. In this paper, we present an overview of the MBMS multicast mode of UMTS. We analytically present the multicast mode of the MBMS and analyze its performance in terms of packet delivery cost under various network topologies, cell types and multicast users' distributions. Furthermore, for the evaluation of the scheme, we consider different transport channels for the transmission of the data over the UTRAN interfaces.

1. Introduction

Although UMTS networks offer high capacity, the expected demand will certainly overcome the available resources. The 3GPP realized the need for broadcasting and multicasting in UMTS and proposed some enhancements on the UMTS Release 6 architecture that led to the definition of the MBMS framework. MBMS is a point-to-multipoint service which allows the network resources to be shared [8].

Several multicast mechanisms for UMTS have been proposed in the literature. In [1], the authors discuss the use of commonly deployed IP multicast protocols in UMTS networks. However, in [2] the authors do not adopt the use of IP multicast protocols for multicast routing in UMTS and present a scheme that can be implemented within the existing network nodes with only trivial changes to the standard location update and packet-forwarding procedures. Furthermore, in [3] a multicast mechanism for circuit-switched GSM and UMTS networks is outlined.

In this paper, we present an overview of the MBMS multicast mode of UMTS and analyze its performance in terms of packet delivery cost under various network topologies, cell types and multicast users' distributions. Furthermore, for the evaluation of the scheme, we consider different transport channels for the transmission of the data over the UTRAN interfaces.

2. Overview of the UMTS in the Packet Switched Domain

A UMTS network consists of two land-based network segments: the Core Network (CN) and the UMTS Terrestrial Radio-Access Network (UTRAN) (Figure 1). The CN is responsible for switching/routing voice and data connections, while the UTRAN handles all radio-related functionalities. The CN consists of two service domains: the Circuit-Switched (CS) service domain and the Packet-Switched (PS) service domain. The PS portion of the CN in UMTS consists of two kinds of General Packet Radio Service (GPRS) Support Nodes (GSNs), namely Gateway GSN (GGSN) and Serving GSN (SGSN). An SGSN is connected to GGSN via the Gn interface and to UTRAN via the Iu interface. UTRAN consists of the Radio Network Controller (RNC) and the Node B. Node B constitutes the base station and provides radio coverage to one or more cells. Node B is connected to the User Equipment (UE) via the Uu interface and to the RNC via the Iub interface [8]. In the UMTS PS domain, the cells are grouped into Routing Areas (RAs), while the cells in a RA are further grouped into UTRAN Registration Areas (URAs) [7].

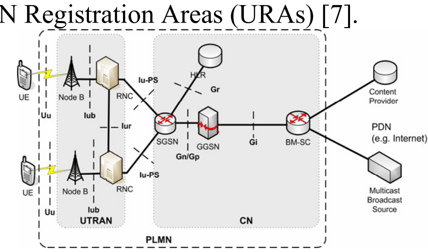


Figure 1. Release 6 UMTS Architecture

3GPP is currently standardizing the MBMS [5]. The MBMS is an IP datacast type of service, which can be offered via existing GSM and UMTS networks. The major modification in the existing GPRS platform is the addition of a new entity called Broadcast Multicast - Service Center (BM-SC) (Figure 1). The BM-SC communicates with the existing UMTS GSM networks and the external Public Data Networks [4], [5].

3. Cost Analysis of the MBMS Multicast Mode

3.1 General assumptions

We consider a subset of a UMTS network consisting of a single GGSN and N_{SGSN} SGSN nodes connected to the GGSN. Furthermore, each SGSN manages a number of N_{ra} RAs. Each RA consists of a number of N_{rnc} RNC nodes, while each RNC node manages a number of N_{ura} URAs. Finally, each URA consists of N_{nodeb} cells. The total number of RAs, RNCs, URAs and cells are:

$$N_{RA} = N_{SGSN} \cdot N_{ra} \quad (1)$$

$$N_{RNC} = N_{SGSN} \cdot N_{ra} \cdot N_{rnc} \quad (2)$$

$$N_{URA} = N_{SGSN} \cdot N_{ra} \cdot N_{rnc} \cdot N_{ura} \quad (3)$$

$$N_{NODEB} = N_{SGSN} \cdot N_{ra} \cdot N_{rnc} \cdot N_{ura} \cdot N_{nodeb} \quad (4)$$

The total transmission cost for packet deliveries including paging is considered as the performance metric. The cost for paging is differentiated from the cost for packet deliveries. We make a further distinction between the processing costs at nodes and the transmission costs on links, both for paging and packet deliveries. Moreover, we assume that there is a cost associated with each link and each node of the network, both for paging and packet deliveries [6], [2].

Regarding the transmission over the Uu, the Dedicated Channel (DCH) and the Forward Access Channel (FACH) transport channels are examined. The main parameter that defines the transmission cost over the air is the amount of Node B's transmission power that must be allocated for these two transport channels.

The total number of the multicast UEs in the network is denoted by N_{UE}. For the cost analysis, we define the total packets per multicast session as N_p. Since network operators will typically deploy an IP backbone network between the GGSN, SGSN and RNC, the links between these nodes will consist of more than one hop. Additionally, the distance between the RNC and Node B consists of a single hop ($l_{rb} = 1$). In the presented analysis we assume that the distance between GGSN and SGSN is l_{gs} hops, while the distance between the SGSN and RNC is l_{sr} hops.

We assume that the probability that a UE is in PMM detached state is P_{DET}, the probability that a UE is in PMM idle/RRC idle state is P_{RA}, the probability that a UE is in PMM connected/RRC URA connected state is P_{URA}, and finally the probability that a UE is in PMM connected/RRC cell-connected state is P_{cell}. For the analysis, we apply the following notations:

D_{gs}	Transmission cost between GGSN-SGSN
D_{sr}	Transmission cost between SGSN-RNC
D_{rb}	Transmission cost between RNC-Node B
D_{DCH}	Tx cost of packet delivery over Uu with DCHs
D_{FACH}	Tx cost of packet delivery over Uu with FACHs
S_{sr}	Tx cost of paging between SGSN and RNC
S_{rb}	Tx cost of paging between RNC and Node B
S_a	Tx cost of paging over the air
p_{gM}	Processing cost of packet delivery at GGSN
p_{sM}	Processing cost of packet delivery at SGSN
p_{rM}	Processing cost of packet delivery at RNC
p_b	Processing cost of packet delivery at Node B
a_s	Processing cost of paging at SGSN
a_r	Processing cost of paging at RNC
a_b	Processing cost of paging at Node B

Moreover, we describe a method that models the multicast user distribution. We present a probabilistic method that calculates the number of multicast users in the network (N_{UE}), the number of SGSNs that serve multicast users (n_{SGSN}), the number of RNCs that serve multicast users (n_{RNC}) and finally the number of Node Bs that serve multicast members (n_{NODEB}).

As introduced in [3] and analyzed in [2], we classify the RAs into L_{RA} categories. For $1 \le i \le L_{RA}$ there are $N_i^{(RA)}$ RAs of class i. Therefore, the total number of RAs within the network is $N_{RA} = \sum_{i=1}^{L_{RA}} N_i^{(RA)}$. Suppose that the distribution of the multicast users among the classes of RAs follows the Poisson distribution with $\lambda=\theta_{iP}^{(RA)}$ where $1 \le i \le L_{RA}$. In general, the probability that k exactly multicast users reside in the RAs of class i is calculated as follows:

$$p\left(k,\theta_i^{(RA)}\right) = \frac{e^{-\theta_i^{(RA)}} \cdot \left(\theta_i^{(RA)}\right)^k}{k!} \quad (5)$$

Thus, the probability none of the RAs of class i serves multicast users is $p\left(0,\theta_i^{(RA)}\right) = e^{-\theta_i^{(RA)}}$, which in turn means that the probability at least one multicast user is served by the RAs of class i is $p = 1 - p\left(0,\theta_i^{(RA)}\right) = 1 - e^{-\theta_i^{(RA)}}$.

Since every class i consists of $N_i^{(RA)}$ RAs, the total number of the RAs in the class i, that serve multicast users is $N_i^{(RA)}\left(1-e^{-\theta_i^{(RA)}}\right)$. Thus, the total number of the RAs of every class that serve multicast users is:

$$n_{RA} = \sum_{i=1}^{L_{RA}} N_i^{(RA)}\left(1-e^{-\theta_i^{(RA)}}\right) \quad (6)$$

where $\theta_i^{(RA)}$ represents the number of multicast users for the $N_i^{(RA)}$ RAs of class i.

If there are n_{RA} RAs that serve multicast users, the probability that an SGSN doesn't have any such RA is:

$$p_{SGSN} = \begin{cases} \binom{N_{RA} - N_{ra}}{n_{RA}} / \binom{N_{RA}}{n_{RA}}, n_{RA} \le N_{RA} - N_{ra} \\ 0 \qquad\qquad , \quad otehwise \end{cases} \quad (7)$$

Based on eqn (7), the total number of SGSNs that are serving multicast users can be calculated as follows: $n_{SGSN} = N_{SGSN}(1 - p_{SGSN})$.

The total number of multicast users is:

$$N_{UE} = \sum_{i=1}^{L_{RA}} N_i^{(RA)} \theta_i \quad (8)$$

where θ_i is the number of users in a RA of class *i*.

As in [2], we assume that all RNCs within a service area of class *i* have the same multicast population distribution density as in the RA case. Based on a uniform density distribution within a single RA, the multicast population of an RNC within the service area of a class *i* RA is $\theta_i^{(RNC)} = \theta_i^{(RA)} / N_{rnc}$. The total number of RNCs of class *i* is $N_i^{(RNC)} = N_i^{(RA)} \cdot N_{rnc}$.

Assuming that the number of RA categories is equal to the number of RNC categories (L_{RNC}=L_{RA}), the total number of RNCs that serve multicast users is:

$$n_{RNC} = \sum_{i=1}^{L_{RNC}} N_i^{(RNC)} \left(1 - e^{-\theta_i^{(RNC)}}\right) \quad (9)$$

The same are applied to the cells within the service area of an RNC. The average number of multicast users for a single cell of class *i* is $\theta_i^{(B)} = \theta_i^{(RNC)} / (N_{ura} \cdot N_{nodeb})$. The number of Node Bs belonging to class *i* is $N_i^{(B)} = N_i^{(RNC)} \cdot N_{ura} \cdot N_{nodeb}$. Assuming that the number of the RNC categories is equal to the number of the Node B categories (L_{RNC}=L_{NODEB}), the total number of Node Bs that serve multicast users is:

$$n_{NODEB} = \sum_{i=1}^{L_{NODEB}} N_i^{(B)} \left(1 - e^{-\theta_i^{(B)}}\right) \quad (10)$$

3.2 Cost Analysis of the Multicast Mode

In the multicast scheme, the multicast group management is performed at the BM-SC, GGSN, SGSN and RNC and multicast tunnels are established over the *Gn* and *Iu* interfaces. It is obvious that the cost of a single packet delivery to a multicast user depends on its MM and RRC state.

If the multicast member is in PMM connected/RRC cell-connected state, then there is no need for any paging procedure neither from the SGSN nor from the serving RNC. In this case, the packet delivery cost is derived from eqn(11).

$$C_{cell} = p_{gM} + D_{gs} + p_{sM} + D_{sr} + p_{rM} \quad (11)$$

If the multicast member is in PMM connected/RRC URA connected state, then the RNC must first page all the cells within the URA in which mobile users reside and then proceeds to the data transfer. The cost for paging such a multicast member is:

$$C_{URA} = N_{nodeb}(S_{rb} + a_b + S_a) + S_a + a_b + S_{rb} + a_r \quad (12)$$

If the multicast member is in PMM idle/RRC idle state, the SGSN only stores the identity of the RA in which the user is located. Therefore, all cells in the RA must be paged. The cost for paging such a multicast member is:

$$\begin{aligned} C_{RA} &= N_{rnc}(S_{sr} + a_r) + (N_{rnc} \cdot N_{ura} \cdot N_{nodeb}) \times \\ &\times (S_{rb} + a_b + S_a) + S_a + a_b + S_{rb} + a_r + S_{sr} + a_s \end{aligned} \quad (13)$$

After the paging procedure, the RNC stores the location of any UE at a cell level. The SGSN and the RNC forward a single copy of each multicast packet to those RNCs or Node Bs respectively that are serving multicast users. After the correct multicast packet reception at the Node Bs that serve multicast users, the Node Bs, in turn, transmit the multicast packets to the multicast users via common or dedicated transport channels. The total cost for the multicast scheme is derived from the following equation, where n_{SGSN}, n_{RNC}, n_{NODEB} represent the number of SGSNs, RNCs, Node Bs respectively that serve multicast users.

$$\begin{aligned} Ms &= \begin{bmatrix} p_{gM} + n_{SGSN}(D_{gs} + p_{sM}) + \\ n_{RNC}(D_{sr} + p_{rM}) + Y \end{bmatrix} N_p + \\ &+ (P_{RA} \cdot C_{RA} + P_{URA} \cdot C_{URA}) N_{UE} = D_{packet\_delivery} + D_{paging} \end{aligned} \quad (14)$$

$$where \quad Y = \begin{cases} n_{NODEB} \cdot (D_{rb} + p_b + D_{FACH}), & if \quad channel = FACH \\ N_{UE} \cdot (D_{rb} + p_b + D_{DCH}), & if \quad channel = DCH \end{cases}$$

$$D_{packet\_delivery} = \left[p_{gM} + n_{SGSN}(D_{gs} + p_{sM}) + n_{RNC}(D_{sr} + p_{rM}) + Y\right] N_p$$

$$D_{paging} = (P_{RA} \cdot C_{RA} + P_{URA} \cdot C_{URA}) N_{UE}$$

Parameter Y represents the multicast cost for the transmission of the multicast data over the Iub and Uu interfaces. This cost depends mainly on the distribution of the multicast group within the UMTS network and secondly on the transport channel that is used. In case we use the FACH as transport channel, each multicast packet is sent once over the Iub interface and then the packet is transmitted to the UEs that are served by the corresponding Node B. However, in case we use DCHs each packet is replicated over the Iub as many times as the number of multicast users that the corresponding Node B serves.

4. Evaluation of the MBMS Multicast Mode

In this section we present some evaluation results regarding the MBMS multicast mode performance under different cell configurations, different user distributions and finally different transport channels for the transmission of the multicast data over the UTRAN interfaces. We assume a general network topology with N_{SGSN} =10, N_{ra} =10, N_{rnc} =10, N_{ura} =5 and N_{nodeb} =5.

4.1 Evaluation Parameters

The packet transmission cost (D_{xx}) in any segment of the UMTS network depends on two parameters: the number of hops between the edge nodes of this network segment and the capacity of the link of the network segment. This means that $D_{gs} = l_{gs} / k_{gs}$, $D_{sr} = l_{sr} / k_{sr}$ and $D_{rb} = l_{rb} / k_{rb}$. Parameter k_{xx} represents the profile of the corresponding link between two UMTS network nodes. In the high capacity links at the CN, the values of k_{xx} are greater than the corresponding values in the low capacity links at UTRAN. For the cost analysis and without loss of generality, we assume that the distance between the GGSN and SGSN is 8 hops, the distance between SGSN and RNC is 4 hops and the distance between RNC and Node B is 1 hop. (Table 1). The transmission cost of paging (S_{xx}) in the segments of the UMTS network is calculated in a similar way as the packet transmission cost (D_{xx}). S_{xx} is a fraction of the calculated transmission cost (D_{xx}) and in our analysis it is three times smaller than D_{xx}.

Table 1. Chosen values for the calculation of transmission costs in the links

Link	*Link Capacity factor (k)*	*Number of hops (l)*	*Transmission cost (D)*
GGSN-SGSN	$k_{gs} = 0.8$	$l_{gs} = 8$	$D_{gs} = 10$
SGSN-RNC	$k_{sr} = 0.7$	$l_{sr} = 4$	$D_{sr} = 4/0.7$
RNC–Node B	$k_{rb} = 0.5$	$l_{rb} = 1$	$D_{rb} = 2$

As we can observe from equations of the previous section, the costs of the multicast scheme depend also on a number of other parameters. The chosen values of these parameters are presented in Table 2.

Table 2. Chosen parameters' values

S_{sr}	S_{rb}	S_a	p_{gM}	p_{sM}	p_{rM}	p_b	a_s	a_r	a_b	P_{RA}	P_{URA}	P_{cell}
4/2.1	2/3	4/3	2	2	2	1	1	1	1	0.6	0.2	0.1

It is reminded that the fundamental parameter that defines the transmission cost over the air (D_{DCH} and D_{FACH}) is the amount of allocated Node B's transmission power when transmitting multicast data with these transport channels.

More specifically, a FACH channel essentially transmits at a fixed power level since fast power control is not supported in this channel. A FACH channel must be received by all UEs throughout the cell. Consequently, the fixed power should be high enough to ensure the requested QoS in the whole coverage area of the cell and independently of the location of UEs.

The total downlink transmission power allocated for DCHs is variable and mainly depends on the number of UEs, their locations throughout the cell, the required bit rate of the MBMS service and the experienced signal quality (E_b/N_0) for each user. Eqn(15) calculates the total Node B's transmission power required for the transmission of the data to n users in a specific cell [9]. The total Node B's transmission power is the sum of Node B's power allocated to each DCH user in the cell.

$$P_T = \sum_{i=1}^{n} P_{Ti} = \frac{P_P + \sum_{i=1}^{n} \frac{\frac{(P_N + x_i)}{W}}{\frac{W}{(E_b/N_0)_i R_{b,i}} + p} L_{p,i}}{1 - \sum_{i=1}^{n} \frac{p}{\frac{W}{(E_b/N_0)_i R_{b,i}} + p}} \qquad (15)$$

where P_T is the base station total transmitted power, P_{Ti} is the power devoted to the ith user , 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 (p=0: perfect orthogonality) 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,…K and the path loss from this user to the j^{th} cell L_{ij}. More specifically:

$$x_i = \sum_{j=1}^{K} \frac{P_{Tj}}{L_{ij}} \qquad (16)$$

Furthermore, we have chosen appropriately the probabilities P_{RA}, P_{URA} and $P_{cell.}$ The probability that a UE is in PMM idle/RRC idle state is P_{RA} =0.6. The probability that a UE is in PMM connected/RRC URA connected state is P_{URA} =0.2 and the probability that a UE is in PMM connected/RRC cell-connected state is P_{cell} =0.1. Finally, there is a probability, equal to 0.1, when the UE is not reachable by the network.

In our analysis, we assume that we have two classes of RAs. A class i=1 RA has multicast user population of $\theta_1 = 1/\delta$ and a class i=2 RA has a multicast user population of $\theta_2 = \delta$. If δ>> 1, the class i=1 RA has a small multicast user population and the class i=2 RA has a large multicast user population. Let α be the proportion of the class i=1 RAs and (1-α) be the proportion of the class i=2 RAs [3]. Thus, the number of class i=1 RAs is $N_1^{(RA)} = \alpha N_{RA}$ and the number of class i=2 RAs is $N_2^{(RA)} = (1-\alpha) N_{RA}$. Each RA of class $i \in \{1,2\}$ is in turn subdivided into N_{rnc} of the same class i and similarly, each RNC of class $i \in \{1,2\}$ is subdivided into $N_{ura} \cdot N_{nodeb}$ Node Bs of the same class i.

By taking into consideration the above parameters, eqn(8) can be transformed to eqn(17). It is obvious from eqn(17) that as α decreases and δ increases the number of multicast users increases rapidly.

$$\begin{aligned} N_{UE} &= \sum_{i=1}^{2} N_i^{(RA)} \cdot \theta_i = N_1^{(RA)} \cdot \theta_1 + N_2^{(RA)} \cdot \theta_2 \\ &= N_{RA}\left(\frac{\alpha}{\delta} + \delta - \alpha\delta\right) \end{aligned} \tag{17}$$

For the cost analysis, we consider the cases of urban macrocell (hexagonal, 3-sector cells, 1000m site-to-site distance) and urban microcell (Manhattan grid with 360m base station spacing) environments with Vehicular A and Pedestrian A multipath channel models respectively. Moreover, an 64Kbps MBMS service is assumed. The basic simulation parameters are presented in Table 3 [10], [11], [12].

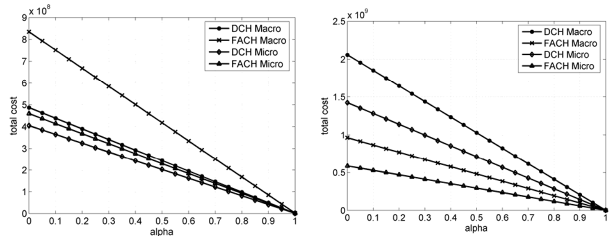
Table 3.Simulation Parameters

Parameters	*Macro Cell*	*Micro Cell*
BS Max Tx Power	43dBm	33dBm
Common channel power	30dBm	20dBm
orthogonality factor	0.5	0.9
Downlink Eb/N$_0$,	5dB	6.5dB
Other-to-own cell interference ratio i	0.65	0.4
Multipath channel	Vehicular A (3km/h)	Pedestrian A (3km/h)
Propagation model	Okumura Hata	Walfisch-Ikegami
FACH Tx Power (no STTD, 95% coverage)	7.6 W (38% of BS Tx Power)	0.36 W (18% of BS Tx Power)

In our analysis, we calculate each Node B's transmission power when using DCHs or FACH. Then, by comparing these power values with the total available Node B's transmission power of any cell, we select the appropriate values for parameters D_{DCH}, and D_{FACH}. Finally, we assume that the minimum value that the D_{DCH} and the D_{FACH} could take is the value of 10, since this value is the cost of the data transmission in the wired link between the GGSN and the SGSN and generally the transmission cost in a wired link is lower than the transmission cost in a wireless link.

4.2 Results

In Figure 2 the total costs for the multicast mode using different transport channels and cell environments in function of α are presented. It is obvious that the costs decrease as α increases. This occurs because as α increases the number of RAs with no multicast users increases and hence the multicast users are located in a small number of RAs.



(a) **(b)**

Figure 2. Total cost in function of *α* with (a) *δ* = 300, (b) *δ* = 3000

More specifically, in Figure 2a the cost in case we use DCHs is smaller than the cost in case we use a FACH channel both in macro and micro environments. This occurs because the small value of δ, results to a reduced number of UEs in the network and hence the DCH is more efficient for the data transmission in terms of total cost. The opposite occurs in Figure 2b where the value of δ is increased, which means that the number of UEs is also increased. Therefore, the use of DCHs is inefficient for the transmission of the data over the Iub and Uu interfaces while the FACH is the most suitable transport channel in terms of total cost.

In Figure 3, the total costs using different transport channels and cell environments in function of δ are presented. We choose a small value for the parameter α because the multicast mode becomes efficient when there is an increased density of UEs in the network. Therefore, a value of α=0.1 is chosen which means that there are many RAs in the network with a great number of multicast users in these. From Figure 3, it is clear that as parameter δ increases (which means that the number of multicast users increases), the total cost for all cases increases too. However, the increase in total cost for DCHs is greater than that of FACH due to the fact that a DCH is a point-to-point channel and strongly depends on the number of multicast users.

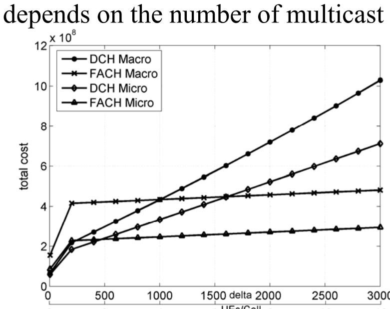
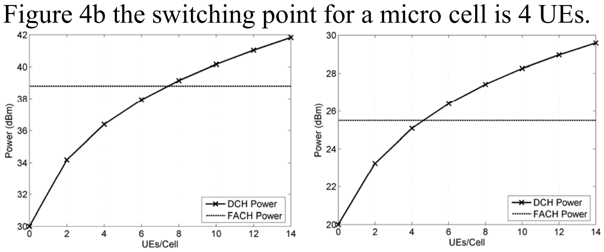


Figure 3. Total cost in function of *δ*, *α* = 0.1

More specifically, in Figure 3, we observe that for small values of δ, the total cost using DCHs is small because there is a small number of UEs in the network, while for bigger values of δ, which implies bigger number of UEs, the total cost using DCHs overcomes the cost of using FACH. Thus, for small values of δ the use of DCHs is more efficient while for bigger values of δ, the use of FACH is more appropriate. The switching point between multiple DCHs and a single FACH, in terms of total transmission cost, is 4 UEs (or δ=1000) for a macro cell and 2 UEs (or δ=500) for a micro cell as shown in Figure 3. This means that, in the case of a macro cell, for 4 UEs and above a FACH should be used, while for less than 4 UEs the use of multiple DCHs is the most efficient choice.

In Figure 4a, the total Node B's transmission power for a macro cell when using multiple DCHs and a single FACH is presented. Similarly, in Figure 4b the same power profiles are presented but for the case of a micro cell. From Figure 4a, it is obvious that for a macro cell, by taking into account only the Node B's transmission power, the switching point between DCH and FACH channels is 7 UEs per cell, while from Figure 4b the switching point for a micro cell is 4 UEs.



(a) (b)

Figure 4. Switching point for (a) macro cell, (b) micro cell

However, as shown previously in Figure 3, these switching points are reduced to 4 UEs and 2 UEs for macro and micro cells respectively, when taking into account the total transmission cost and not just the Node B's transmission power. This reduction is caused by the additional cost introduced by the Iub interface, representing the transmission cost of packet delivery between RNC and Node B. Recall from eqn(14) that computes the total cost of the multicast scheme, the parameter Y represents the multicast cost for the transmission of the multicast data over the Iub and Uu interfaces. The cost added from Iub is not negligible and depends on the link capacity which is, however, operator dependent. For the simulations presented above, the link capacity factor was set to k_{rb} = 0.5. For greater values of k_{rb}, the switching points converge to the values presented in Figure 4.

From the above observation, it is clear that the selection of an appropriate radio bearer for the multicast data transmission is dramatically affected by the cost added by the Iub interface. The Node B's transmission power should not be the only criterion for the selection of a transport channel, but the total transmission cost (including the Iub cost) should always be taken into account.

5. Conclusions and Future Work

In this paper we presented and investigated the performance of the MBMS multicast mode in terms of packet delivery cost through a theoretical model and by simulations based on this model. The investigations were made assuming various network topologies, cell environments and multicast users' distributions. In addition, we examined the DCH and FACH transport channels in terms of data transmission cost over the Iub and Uu interfaces. The step that follows this work is to examine the total transmission cost of HS-DSCH introduced in the Release 5 of UMTS as the transport channel for the transmission of the MBMS data.

6. References

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