Evaluating Different One to Many Packet Delivery Schemes for UMTS

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Abstract

It is known that multicasting is an efficient method of supporting group communication as it allows the transmission of packets to multiple destinations using fewer network resources. Thus, service providers are increasingly interested in supporting multicast communications over wireless networks and in particular over UMTS. Multicasting is a more efficient method of supporting group communication than unicasting or broadcasting, as it allows transmission and routing of packets to multiple destinations using fewer network resources. In this paper the three above mentioned methods of supporting group communication are analyzed in terms of their performance.

1. Introduction

UMTS constitutes the third generation of cellular wireless networks which aims to provide high-speed data access along with real time voice calls. Wireless data is one of the major boosters of wireless communications and one of the main motivations of the next generation standards. The multicast transmission of real time multimedia data is an important component of many current and future emerging Internet applications. The multicast mechanism offers efficient multidestination delivery, since data is transmitted in an optimal manner with minimal packet duplication [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 an alternative solution. The scheme presented in [2], 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, while in [4], an end to end multicast mechanism for software upgrades in UMTS is analyzed. Finally, the Multimedia Broadcast / Multicast Service (MBMS) framework of UMTS is currently being standardized by the 3GPP [5].

In this paper, we present an overview of three different one to many packet delivery schemes for UMTS, namely Broadcast, Multiple Unicast and Multicast. We analytically present these schemes and analyze their performance in terms of the packet delivery cost and the scalability of each scheme. The parameters used for the evaluation of the schemes are the number of the multicast users, the density of the multicast users' distribution within the cells, the number of cells with multicast users in comparison to those that have no multicast users and finally the number of the total packets per multicast session.

The paper is structured as follows. Section 2 provides an overview of the UMTS. In Section 3, we present a number of packet delivery schemes for UMTS with the cost analysis of each scheme, while Section 4 presents some numerical results that characterize the schemes. Finally, some concluding remarks and planned next steps are briefly described.

2. Overview of the UMTS

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 routing calls and data connections to the external networks, while the UTRAN handles all radio-related functionalities. The CN consists of two service domains: the Circuit-Switched (CS) and the Packet-Switched (PS) service domain. The CS domain provides access to the PSTN/ISDN, while the PS domain provides access to the IP-based networks. In the remainder of this paper, we will focus on the UMTS PS mechanism. The PS portion of the CN in UMTS consists of two General Packet Radio Service (GPRS) Support Nodes (GSNs), named Gateway GPRS Support Node (GGSN) and

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Serving GPRS Support Node (SGSN). An SGSN is connected to the GGSN via the Gn interface and to UTRAN via the Iu interface. The UTRAN consists of the Radio Network Controller (RNC) and Node B, that constitutes the base station and provides radio coverage to a cell (Figure 1). Node B is connected to the user equipment (UE) via the Uu interface and to the RNC via the Iub interface. The GGSN interacts with external Packet Data Networks (PDNs) through the Gi interface. The GGSN provides connectivity with IP networks. The Broadcast/Multicast Service Center (BM-SC) serves as the entry point of data delivery for internal sources [8]. In the UMTS PS domain, the cells are grouped into Routing Areas (RAs), while the cells in an RA are further grouped into UTRAN Registration Areas (URAs) [7].

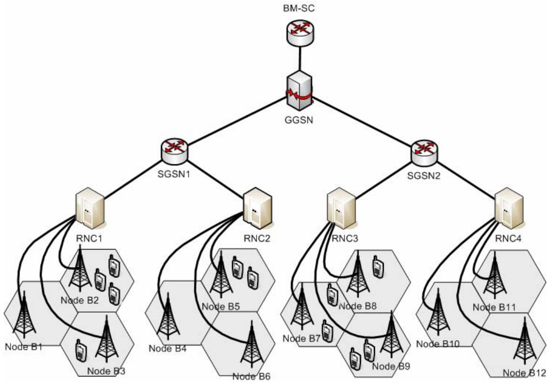


Figure 1. Packet delivery in UMTS

3. One to many packet delivery schemes for UMTS

In this section we present an evaluation, in terms of the telecommunication costs, of three different one to many delivery schemes. These schemes include the Multiple Unicast, the Broadcast and the Multicast scheme. More specifically, we consider a general UMTS network topology providing a flexible mechanism to differentiate the user distribution.

The analysis presented in the following paragraphs, covers the forwarding of the data packets between the BM-SC and the Node Bs. Regarding the transmission of the packets over the Uu interface, it may be performed on common (ex. Broadcast Channel - BCH), dedicated (Dedicated Channel - DCH) or shared transport channels (ex. High Speed Downlink Shared Channel - HS-DSCH). DCH is a point-to-point channel and hence, it suffers from the inefficiencies of requiring multiple DCHs to carry common data to a group of users. BCH, is a shared channel, thus, even with a large number of multicast receivers, only one BCH is required for a multicast service in the cell. Furthermore, a transport channel named HS-DSCH has been introduced as the primary radio bearer in Release 5 of UMTS with better performance than BCH.[8].

We consider a subset of a UMTS network consisting of a single GGSN and N_{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:

$$N_{RNC} = N_{SGSN} \cdot N_{ra} \tag{1}$$

$$N_{RNC} = N_{SGSN} \cdot N_{ra} \cdot N_{rnc} \tag{2}$$

$$N_{URA} = N_{SGSN} \cdot N_{ra} \cdot N_{rnc} \cdot N_{ura} \tag{3}$$

$$N_{NODEB} = N_{SGSN} \cdot N_{ra} \cdot N_{rnc} \cdot N_{ura} \cdot N_{nodeb} \tag{4}$$

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 processing costs at nodes and transmission costs on links, both for paging and packet deliveries. Similar to [6], we assume that there is a cost associated with each link and each node of the network, both for paging and packet deliveries. We apply the following notations:

D_{gs}	Transmission cost between GGSN and SGSG
D_{sr}	Transmission cost between SGSN and RNC
D_{rb}	Transmission cost between RNC and Node B
D_{BCH}	Transmission cost over the air with BCHs
D_{DCH}	Transmission cost over the air with DCHs
$D_{HS\text{-}DSCH}$	Transmission cost over the air with HS-DSCHs
S_{sr}	Cost of paging between SGSN and RNC
S_{rb}	Cost of paging between RNC and Node B
S_a	Cost of paging over the air
p_g	Processing cost of packet delivery at GGSN
p_s	Processing cost of packet delivery at SGSN
p_r	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

The total number of the multicast UEs in the network is denoted by N_{UE}. For the cost analysis, we define the multicast session arrival rate as λ_s and the total packets per multicast session as N_p. In particular, multicast session arrival rate follows a Poisson distribution with $\lambda=\lambda_s$. Furthermore, 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}.

In the following analysis, 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 in [3], we classify the RAs into L_{RA} categories. For $1 \leq i \leq L_{RA}$ 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 $\lambda = \theta_i^{(RA)}$. In general, the probability that k exactly multicast users reside in the RAs of class i is calculated as follows:

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

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:

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

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 an SGSN does not have any such RA is:

$$p_{SGSN} = \binom{N_{RA} - N_{ra}}{n_{RA}} \Big/ \binom{N_{RA}}{n_{RA}} \quad , n_{RA} \leq N_{RA} - N_{ra} \qquad (7)$$

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

The total number of multicast users is:

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

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:

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

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 $\theta_i^{(B)} = \theta_i^{(RNC)} / \left(N_{ura} \cdot N_{nodeb}\right)$. 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:

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

3.1. Broadcast scheme (Bs)

In this scheme the packets are broadcasted to all the nodes of the network and no paging procedure is required. Regarding the transmission over the air, the transport channel that is used in this scheme is the BCH. It is obvious that the total cost of the packet delivery is independent from the number of the multicast users N_{UE}. The total cost of the packet delivery to the multicast users is computed as follows:

$$\begin{aligned} Bs = [&p_g + N_{SGSN}\left(D_{gs} + p_s\right) + N_{RNC}(D_{sr} + p_r) + \\ &+ N_{NODEB}(D_{rb} + p_b + D_{BCH})] N_p \cdot \lambda_s \end{aligned} \qquad (11)$$

3.2. Multiple Unicast scheme (MUs)

With MUs, each packet is forwarded once to each member of the group separately. For instance, in Figure 1, Node B2 would receive three duplicate copies of the same multicast packet from the RNC1. 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 a paging procedure neither from the SGSN nor from the serving RNC. In this case, the packet delivery cost is:

$$C_{cell} = p_g + D_{gs} + p_s + D_{sr} + p_r + D_{rb} + p_b \qquad (12)$$

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:

$$C_{URA} = N_{nodeb}\left(S_{rb} + a_b + S_a\right) + S_a + a_b + S_{rb} + a_r \qquad (13)$$

$$MUs=\begin{cases}\left[P_{cell}\cdot C_{cell}\cdot N_p+P_{URA}\left(C_{URA}+C_{cell}\cdot N_p\right)+P_{RA}\left(C_{RA}+C_{cell}\cdot N_p\right)+\left(P_{cell}+P_{URA}+P_{RA}\right)N_p\cdot D_{DCH}\right]N_{UE}\cdot\lambda_s & (15)\\ \left[P_{cell}\cdot C_{cell}\cdot N_p+P_{URA}\left(C_{URA}+C_{cell}\cdot N_p\right)+P_{RA}\left(C_{RA}+C_{cell}\cdot N_p\right)\right]N_{UE}\cdot\lambda_s+n_{NODEB}\cdot D_{BCH}\cdot N_p\cdot\lambda_s & (16)\\ \left[P_{cell}\cdot C_{cell}\cdot N_p+P_{URA}\left(C_{URA}+C_{cell}\cdot N_p\right)+P_{RA}\left(C_{RA}+C_{cell}\cdot N_p\right)\right]N_{UE}\cdot\lambda_s+n_{NODEB}\cdot D_{HS-DSCH}\cdot N_p\cdot\lambda_s & (17)\end{cases}$$

Table 1. Chosen parameters' values

D_{gs}	D_{sr}	D_{rb}	D_{BCH}	D_{DCH}	$D_{HS\text{-}DSCH}$	S_{sr}	S_{rb}	S_a	p_g	p_s	p_r	p_b	a_s	a_r	a_b	λ_s	P_{RA}	P_{URA}	P_{cell}
12	6	5	4	2	3	2	5/3	4/3	1	1	1	1	1	1	1	5	0.6	0.2	0.1

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:

$$C_{RA}=N_{rnc}\left(S_{sr}+a_r\right)+\left(N_{rnc}\cdot N_{ura}\cdot N_{nodeb}\right)\cdot \\ \cdot\left(S_{rb}+a_b+S_a\right)+S_a+a_b+S_{rb}+a_r+S_{sr}+a_s \quad (14)$$

Since the paging procedure is performed on the first packet of a data session, the total cost of the MUs is derived from the equations 15, 16 and 17 for the three different transport channels, where n_{NODEB} represent the number of Node Bs that serve multicast users.

3.3. Multicast scheme (Ms)

In Ms, 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 transmit the packets to the multicast users via DCHs, BCHs or HS-DSCHs. All multicast users that are in PMM idle/RRC idle or PMM connected/RRC URA connected state must be paged. After the paging procedure, the RNC stores the location of any UE at a cell level. The cost for this paging procedure is given by eqn(13) and eqn(14) respectively. The total cost for the Ms is derived from the eqn(18) where n_{SGSN}, n_{RNC}, n_{NODEB} represent the number of SGSNs, RNCs, Node Bs respectively that serve multicast users.

$$Ms=[p_g+n_{SGSN}\left(D_{gs}+p_s\right)+n_{RNC}\left(D_{sr}+p_r\right)+ \\ +n_{NODEB}\left(D_{rb}+p_b\right)+Y]N_p\cdot\lambda_s+ \quad (18) \\ +\left(P_{RA}\cdot C_{RA}+P_{URA}\cdot C_{URA}\right)N_{UE}\cdot\lambda_s$$

$$where\quad Y=\begin{cases}n_{NODEB}\cdot D_{BCH} & if\quad channel=BCH\\ N_{UE}\cdot D_{DCH} & if\quad channel=DCH\\ n_{NODEB}\cdot D_{HS-DSCH} & if\; channel=HSDSCH\end{cases}$$

4. Results

We try to estimate the cost of each scheme assuming a general network topology with N_{SGSN}=10, N_{ra}=10, N_{rnc}=10, N_{ura}=5 and N_{nodeb}=5. In the following paragraphs we evaluate the three methods in function of a number of parameters. These parameters include:

- The number of the packets per multicast session
- The density of the users' distribution in cells.
- The number of cells with multicast users compared to those that have no multicast users.

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. More specifically, 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 6 hops, the distance between SGSN and RNC is 3 hops and the distance between RNC and NODE B is 1 hop. The above parameters as well as the values of the k_{xx} are presented in detail in Table 2. Regarding the transmission cost of paging (S_{xx}) in the segments of the UMTS network, it is calculated in a similar way as the packet transmission cost (D_{xx}). More specifically, S_{xx} is a fraction of the transmission cost (D_{xx}) and in our case we assume that it is three times smaller than D_{xx}.

Table 2. Transmission costs in the links

Link	*Link Capacity*	*Number of hops*	*Transmission cost*
GGSN - SGSN	$k_{gs}=0.5$	$l_{gs}=6$	$D_{gs}=12$
SGSN - RNC	$k_{sr}=0.5$	$l_{sr}=3$	$D_{sr}=6$
RNC – Node B	$k_{rb}=0.2$	$l_{rb}=1$	$D_{rb}=5$

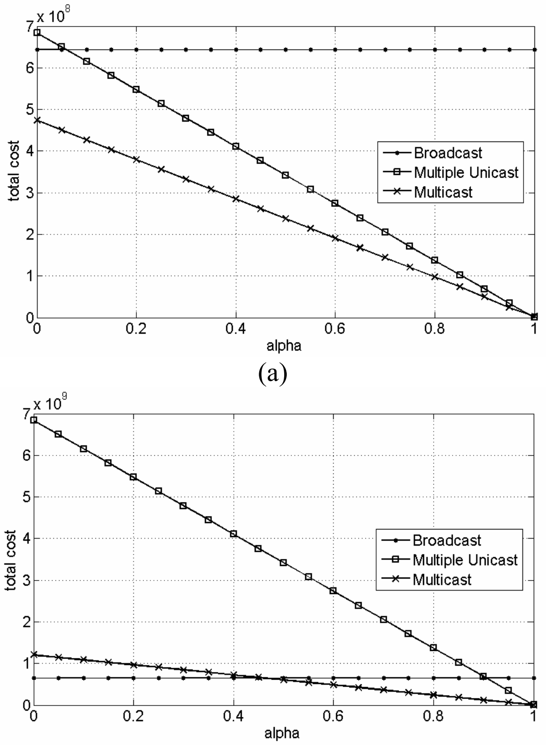
As it is shown in Table 1, the values for the transmission costs of the packet delivery over the air with each of the three transport channels are different. More specifically, the transmission cost over the air with BCH (D_{BCH}) is bigger than the $D_{HS\text{-}DSCH}$, which in turn is bigger than the transmission cost of the packet delivery over the air with DCH (D_{DCH}). This occurs because the BCH requires high transmission power in order to reach all the users within the coverage area even if they are not members of the multicast group. Additionally, even if the HS-DSCH is shared among the users of a specific sector, it is associated with one DCH which means that the cost of the HS-DSCH is bigger than a single DCH.

Furthermore, we have chosen appropriately the probabilities P_{RA}, P_{URA} and P_{cell}. More specifically, 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.

In the 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. Each RA of class $i \in \{1,2\}$ is in turn subdivided into N_{rnc} RNCs of the same class i and similarly, each RNC of class $i \in \{1,2\}$ is subdivided into $N_{ura}N_{nodeb}$ Node Bs of the same class i.

In Figure 2 we plot the cost of the three schemes in function of α, for different values of δ. Since in our model we consider three different transport channels over the air for the MUs and the Ms in the following figures only the channel with the lowest cost of each scheme is presented and then we provide the comparison of the costs of every scheme using different transport channels in separate figures. Generally, we observe from Figure 2, that the cost of the broadcast scheme is constant, while the costs of the other two schemes decrease as α increases. Since δ>>1, there are not any multicast users in a RA of class i=1 and there are many multicast members in a RA of class i=2. Furthermore, as α increases, the number of class i=1 RAs with no multicast users increases and hence, the costs of the MUs and the Ms decrease as it is shown in Figure 2.

For δ=100 the Ms has the lowest cost while the Bs has the higher cost independently of the value of α. This occurs because in small values of α, there are many RAs with large multicast users' population (class i=2 RAs). However, the value of δ=100 results to a small number of multicast users within the network and hence, the costs of MUs and Ms are kept in lower values than the value of the cost of the Bs. In addition, if δ=1000 (Figure 2b), the number of multicast users within the network is increased and this results to an increased cost for the MUs. The costs of the other two schemes behave as follows: for α<0.45 the Bs has the lowest cost and for α>0.45 the Ms has the lowest cost. The latter occurs because for small values of α and increased value of δ, the number of the multicast users within the network is increased and furthermore, there are many class i=2 RAs in the network with large multicast users' population. This means that the multicast users within the network are spread to many RAs and hence, the cost of the paging which is required in the Ms is increased, making the Ms inefficient for this network topology. On the other hand, when the value of α is increased, the number of class i=1 RAs with no multicast users is increased and all the multicast users are located in a small number of class i=2 RAs. Thus, the Ms is more efficient than the Bs as it is shown in Figure 2b.

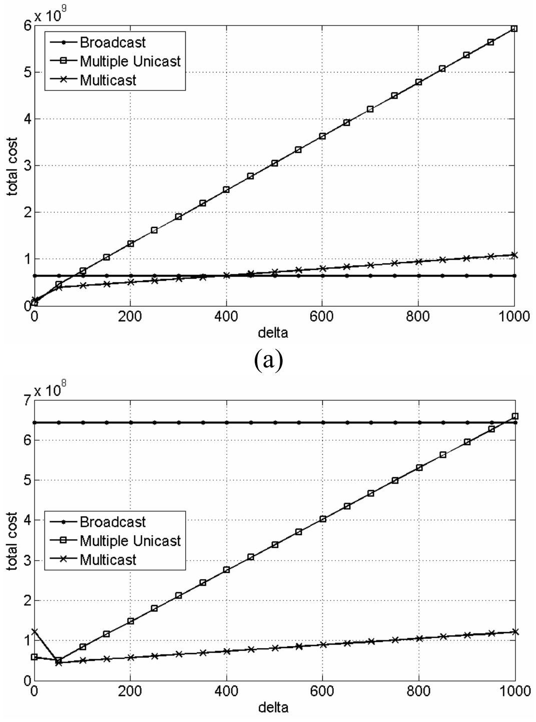


(a)

(b)

Figure 2. Total cost for the schemes against alpha with N_p=500. (a)delta=100, (b)delta=1000

Figure 3 presents the costs of the three schemes in function of δ for α=0.1 (Figure 3a) and α=0.9 (Figure 3b). Our first observation is that the cost of the Bs is constant, while the costs of the other two schemes increase as δ increases. Furthermore, if α converges to 1 (Figure 3b) the number of class i=2 RAs in the network is small. Thus, the multicast users are located in a small number of RAs and as a result, the cost of the Ms is kept in lower values than the cost of the MUs and the Bs (Figure 3b). The later, obviously, has the higher cost as it is shown in Figure 3b. On the other hand, Figure 3a shows that the Ms performs efficiently if $\delta<400$, but it is outperformed by the Bs for $\delta>400$. This occurs because the value of α is small and the number of class $i=2$ RAs with large multicast users' population is increased and hence, as the number of multicast users in a class $i=2$ RA increases, there are many users among many cells in the network making the Bs more appropriate for the packet delivery.



(a)

(b)

Figure 3. Total cost for the schemes against delta with $N_p=500$. (a) alpha=0.1, (b) alpha =0.9

The costs of the three schemes in function of the number of packets per multicast session are presented in Figure 4 for $\delta=1000$ and $\alpha=0.1$. Our first observation is that as N_p increases, the total cost of each scheme increases. When $\alpha=0.1$ and due to the big value of δ ($\delta=1000$) the number of multicast users in the network is increased. The increased number of multicast users in the network makes the MUs inefficient for the data transmission. Regarding the other two schemes, we can observe that, for values $N_p<1400$, the cost of the Bs is smaller than the cost of the Ms. This occurs because the gradient of the line representing the cost of the Ms is smaller than the gradient of the line representing the Bs, according to eqn(11) and eqn(18). Similarly, for values $N_p<1400$, the Ms is more efficient than the Bs.

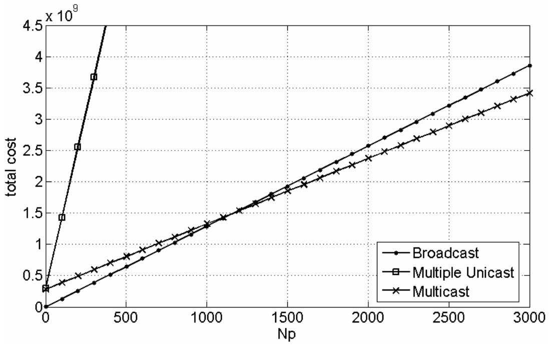
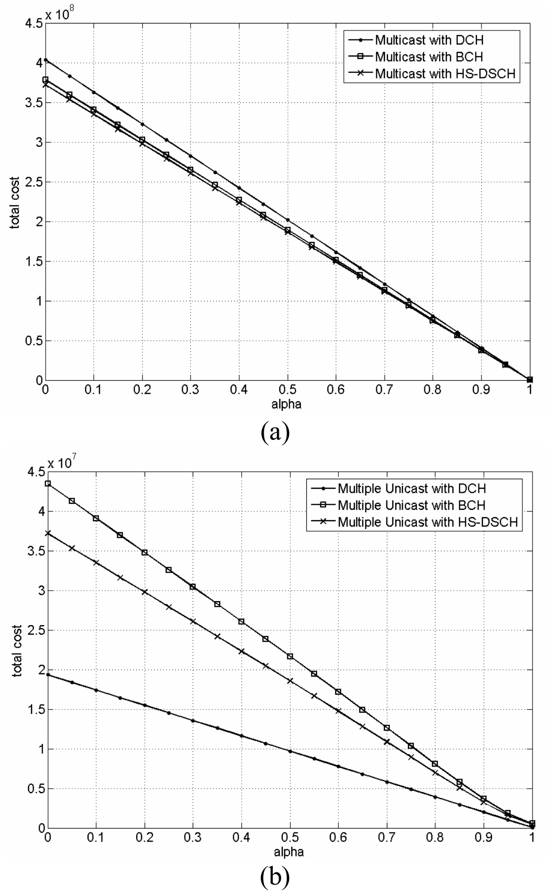


Figure 4. Costs of the schemes against N_p



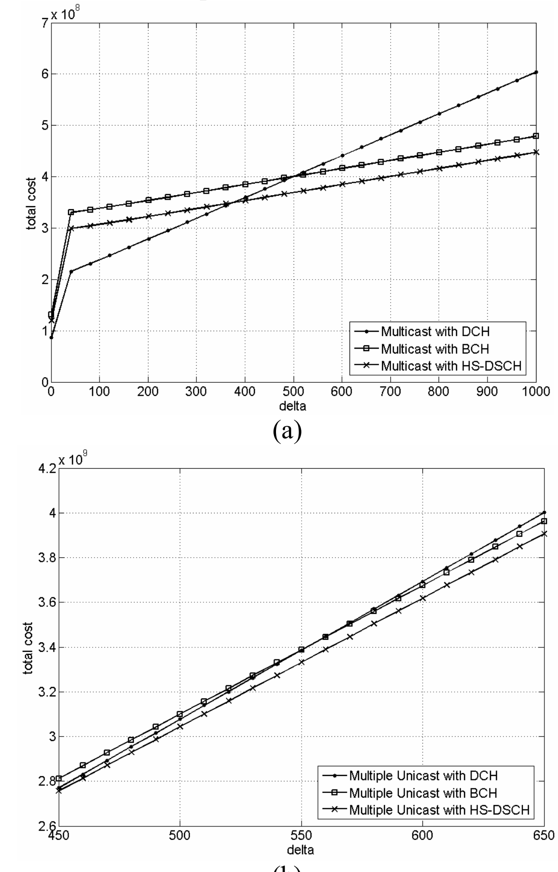
(a)

(b)

Figure 5. Costs for the Ms and MUs against alpha with $N_p=50$. (a)delta=1000, (b)delta =20

In Figure 5, the total costs for the Ms and MUs using different transport channels in function of α, are presented. Generally, the cost of each scheme decreases as α increases. This occurs because the increment of α, and the big value of δ entail that the number of RAs that have small population increases. Thus, the total number of the multicast users decreases and the total cost for the data transmission decreases.

More specifically, in Figure 5a, we observe that the cost of the Ms using DCH is bigger than the cost of each of the other transport channels. On the other hand, the BCH and HS-DSCH that are shared channels are more efficient and hence, the corresponding costs are smaller. The opposite occurs in Figure 5b where the value of δ is small, which means that the number of multicast users is small. In this case, the DCH is the more efficient transport channel over the air.



(a)

(b)

Figure 6. Total cost for the Ms and MUs against delta with N_p=500. (a) alpha=0.5, (b) alpha=0.1.

In Figure 6, the total costs for the Ms and MUs using different transport channels over the air in function of δ are presented. More specifically, in Figure 6a, we observe that for small values of δ, the costs are small because there is a small number of multicast users in the network. Thus, we can use DCHs for the data transmission over the air which reduces the cost of the scheme. On the other hand, bigger values of δ imply bigger number of multicast users in the network and hence, the use of shared channels such as HS-DSCH is more appropriate. In Figure 6b, we present only a small range of values for the parameter δ because the cost of the MUs using the three transport channels is approximately the same. More specifically, the cost for the MUs using HS-DSCH is smaller than the other for big values of δ since the number of the multicast users is bigger and the use of shared channels reduces the cost. On the other hand, for small values of δ, the number of the multicast users is small and hence, the use of DCHs for the data transmission over the air is the most efficient.

5. Conclusions and future work

In this paper, we have presented an overview of three different one to many packet delivery schemes for UMTS. These schemes include the Broadcast, the Multiple Unicast and the Multicast scheme. We have analytically presented these schemes and have analyzed their performance in terms of the packet delivery cost and the scalability of each scheme. The step that follows this work is to carry out experiments using the NS-2 simulator. This means that we have to implement the above presented one to many packet delivery schemes and confirm the relation of the costs.

6. References

[1] M. Hauge and O. Kure, “Multicast in 3G networks: Employment of existing IP multicast protocols in UMTS”, in Proc. 5th ACM International Workshop Wireless Mobile Multimedia, 2002, pp. 96–103.

[2] R. Rummler, Y. Chung and H. Aghvami, “Modeling and Analysis of an Efficient Multicast Mechanism for UMTS”, IEEE Trans. on Vehicular Technology, vol. 54, no. 1, Jan. 2005, pp. 350-365.

[3] Y. Lin, “A multicast mechanism for mobile networks”, IEEE Communication Letters, vol. 5, Nov. 2001, pp. 450–452.

[4] R. Rümmler and H. Aghvami, “End-to-end IP multicast for software upgrades of reconfigurable user terminals within IMT-2000/UMTS networks”, in Proc. IEEE ICC’02, vol. 1, New York, Apr./May 2002, pp. 502–506.

[5] 3GPP, TS 23.246, V6.7.0, “Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description”.

[6] J. S. Ho and I. F. Akyildiz, “Local anchor scheme for reducing signaling costs in personal communications networks”, IEEE/ACM Trans. Networking, vol. 4, Oct. 1996, pp. 709–725.

[7] S. R. Yang and Y. B. Lin, “Performance evaluation of location management in UMTS”, IEEE Trans. on Vehicular Technology, vol. 52, no. 6, Nov. 2003, pp. 1603-1615.

[8] H. Holma, and A. Toskala, “WCDMA for UMTS: Radio Access for Third Generation Mobile Communications”, John Wiley & Sons, 2003.