A Multicast Packet Forwarding Mechanism for WCDMA Networks using Routing Lists

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ABSTRACT
This paper proposes a multicast scheme for the packet forwarding mechanism in the Universal Mobile Telecommunications System (UMTS). The scheme relies on the introduction of the Permanent Multicast Routing List (PMRL) and Temporary Multicast Routing List (TMRL) in each node of the network except UEs. In the PMRL we record the nodes of the next level that the messages for every multicast group should be forwarded. The TMRL is useful for the temporary record of information from the path from the mobile users to the GGSN. Additionally, a Multicast Group List (MGL) is kept in the GGSN which records the members of each multicast group. These lists lead to the decrement of the transmitted packets and the more efficient use of the network resources in the multicast routing in UMTS. We analyze the exact steps that the multicast packets are transmitted to the members of each multicast group. Furthermore, special issues such as joining/leaving a multicast service are described.

Categories and Subject Descriptors
C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design – *wireless communication, packet-switching networks, network communications.*

General Terms
Algorithms, Performance, Design, Experimentation, Verification.

Keywords
Multicast, UMTS, MBMS, Multiple Unicast

1. INTRODUCTION
Universal Mobile Telecommunications System (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 [1].

Multicast communications for wireline users has been deployed in the Internet for at least the past ten years. The multicast transmission of real time multimedia data is an important issue in many current and future emerging Internet applications, such as videoconference, distance learning and video distribution. The multicast mechanism offers efficient multi-destination delivery, since data is transmitted in an optimal manner with minimal packet duplication [2]. However, in the multicast transmission of the data we have to take care of security issues, but this is beyond the scope of this paper. There are several proposed schemes providing IP multicast routing over wired networks such as Protocol Independent Multicast (PIM), Multicast over Open Shortest Path First (MOSPF), Distance Vector Multicast Routing Protocol (DVMRP) and Core Based Tree (CBT) and Border Gateway Multicast Protocol (BGMP) [3].

Compared with multicast routing in the Internet, mobile networks such as UMTS pose a very different set of challenges for multicast. First, multicast receivers are nonstationary, and consequently, may change their point of attachment to the network at any given time. Second, mobile networks are generally based on a well-defined tree topology with the nonstationary multicast receivers being located at the leaves of the network tree. The construction of a source-rooted shortest-path tree over such a topology is trivial and may be achieved by transmitting only a single packet over the paths that are shared by several multicast recipients. However, as a result of user mobility the shortest-path tree may change subject to the mobility of the multicast users [4].

Several multicast mechanisms for UMTS have been proposed in the literature. In [7], the authors discuss the use of commonly deployed IP multicast protocols in UMTS. In [4] the authors present an alternative solution to the use of IP multicast protocols for multicast routing in UMTS that can be implemented within the existing network nodes with simple modifications to the standard location update and packet forwarding procedures. In [8] a multicast mechanism for circuit-switched GSM and UMTS networks is outlined. The Multimedia Broadcast / Multicast

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WMuNeP'06, October 6, 2006, Torremolinos, Malaga, Spain.

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Service framework of UMTS is currently being standardized by the 3rd Generation Partnership Project (3GPP) [9] [10].

In this paper, we present an approach for the multicast transmission of the data in the UMTS. More specifically, we introduce the Temporary Multicast Routing Lists (TMRL) and the Permanent Multicast Routing Lists (PMRL) in each node of the network except the UEs. These lists lead to the decrement of the transmitted packets and the more efficient use of the network resources in the multicast routing in UMTS. Additionally, the GGSN keeps the members of every available multicast group in the Multicast Groups List (MGL). The exact steps that are necessary for the successful transfer of the multicast data are described in detail. Finally, we implement our approach in the NS-2 simulator [5] and present the performance of the multicast mechanism.

This paper is structured as follows. Section 2 provides an overview of the UMTS in the packet-switched domain. In Section 3 we present the multicast packet forwarding mechanism for UMTS using TMRL and PMRL analyzing the exact steps for a successful transmission of the multicast data. Section 4 is dedicated to the experiments' results. 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 switching/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) service domain 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 packet-switching mechanism.

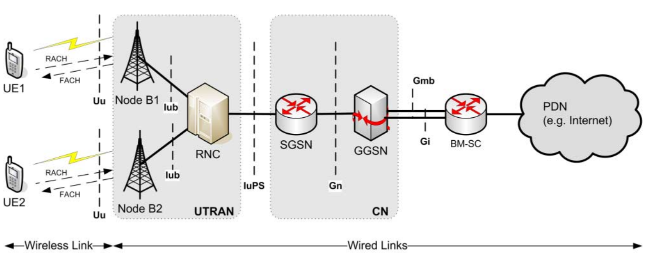


Figure 1. UMTS Architecture

The PS portion of the CN in UMTS consists of two General Packet Radio Service (GPRS) Support Nodes (GSNs), namely Gateway GPRS Support Node (GGSN) and Serving GPRS Support Node (SGSN) (Figure 1). An SGSN is connected to the GGSN via the Gn interface and to the UTRAN via the Iu interface. The UTRAN consists of the Radio Network Controller (RNC) and the Node B which is 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 (based on the W-CDMA technology) and to the RNC via the Iub interface.

The 3rd Generation Partnership Project (3GPP) is currently standardizing the Multimedia Broadcast / Multicast Service (MBMS) [9] [10]. Actually, the MBMS is an IP datacast type of service, which can be offered via existing GSM and UMTS cellular networks. The major modification in the existing GPRS platform is the addition of a new entity called Broadcast Multicast - Service Center (BM-SC). The function of the BM-SC can be separated into five categories: Membership, Session and Transmission, Proxy and Transport, Service Announcement and Security function. As Figure 1 presents, the BM-SC communicates with the existing UMTS network and the external Public Data Networks (PDNs).

The BM-SC Membership function provides authorization to the UEs requesting to activate an MBMS service. According to the Session and Transmission function, the BM-SC can schedule MBMS session transmissions and shall be able to provide the GGSN with transport associated parameters such as QoS and MBMS service area. As far as the Proxy and Transport function is concerned, the BM-SC is a proxy agent for signaling over Gmb reference point between GGSNs and other BM-SC functions. Moreover, the BM-SC Service Announcement function must be able to provide service announcements for multicast and broadcast MBMS user services and provide the UE with media descriptions specifying the media to be delivered as part of an MBMS user service. Finally, MBMS user services may use the Security functions for integrity or confidentiality protection of the MBMS data, while the specific function is used for distributing MBMS keys (Key Distribution Function) to authorized UEs.

3. THE MULTICAST PACKET FORWARDING MECHANISM

In this section, we describe the multicast packet forwarding mechanism, with the use of the Temporary Multicast Routing Lists (TMRL) and Permanent Multicast Routing Lists (PMRL). The introduction of these lists in every node of the network except the UEs leads to the decrement of the transmitted packets and the more efficient use of the network resources in the multicast routing in UMTS. For simplicity, we consider that the functionality of the BM-SC can be incorporated in the functionality of the GGSN (Figure 1). Thus, in our analysis, the GGSN is used instead of the BM-SC for the better understanding of the mechanism. In the following paragraphs we describe the mechanism of the multicast routing in UMTS, presenting the steps of the messages' handling in each node of the network.

3.1 Description of the Mechanism

Consider the scheme shown in Figure 2 for the analysis of the mechanism and suppose that a UE wants to join a multicast group provided by the GGSN. In this case, the UE sends a message to the GGSN, requesting the list of the available multicast groups. When the message reaches the GGSN, the GGSN sends a reply to the UE with the available multicast groups. The UE decides the multicast group(s) that wants to join and sends this information to GGSN so as to add it to the specific multicast group(s). Thus, every time that, packets for the specific multicast group are available, the correspondent UE will receive them. Additionally, the UE can send a leave message and the GGSN has to delete from the members of the specific multicast group.

For the multicast transmission we introduce the TMRL and PMRL in every node of the network except the UEs. In the TMRL of a node we temporary keep information from the messages coming from the UEs that it serves, with destination the GGSN.

Thus, when the messages finally reach the GGSN, the reply messages are routed appropriately by checking the corresponding record in the TMRL of each intermediate node so as to be delivered to the correct UE. In parallel, when a message coming from the GGSN to a UE is routed, the PMRL of the intermediate nodes are updated appropriately from the corresponding record of the TMRL which in turn, is deleted. An update in the PMRL means either a new record or an update in an existing record. The first case occurs when the specific node does not serve any other users that are members of the multicast group, while the second case occurs when there are already members of this multicast group served by the specific node.

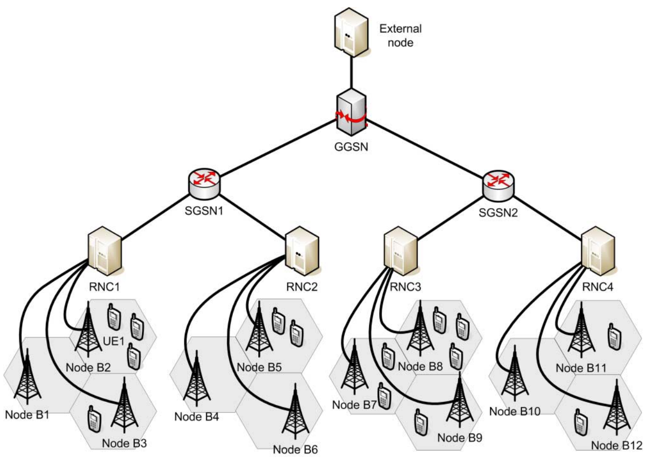


Figure 2. Multicast packet transmission

3.2 Routing Lists and Packet Forwarding

Before analyzing the multicast packet forwarding mechanism using TMRL and PMRL, we present the additional information that the nodes of the UMTS network should store. Obviously, the GGSN that organize the multicast group, ought to keep an additional list with the multicast groups (M-group_id) and the correspondent UEs that have joined them. This information is kept in the Multicast Groups List (MGL) (Figure 3) and the GGSN has the opportunity to retrieve the UEs belonging to a specific multicast group. It is essential that this list is fully updated at every moment for the correct transmission of the packets to the UEs that have joined a multicast group. Obviously, there is a possibility that a multicast group has no members, which in turn means that the correspondent record in the MGL in the GGSN does not contain any UEs.

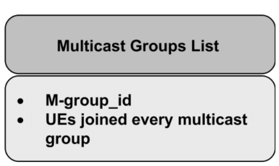


Figure 3. Multicast Groups List (MGL) in the GGSN

In addition, every node of the UMTS network (except the UEs) maintains two routing lists: the TMRL and the PMRL (Figure 4). The concept behind the introduction of the TMRL, is that when a UE sends a message to the GGSN (such as join or leave a multicast group), the nodes in the path between the UE and GGSN temporary keep useful information of the received packets from the node of the previous level. Likewise, in the PMRL of each node, we record the nodes of the next level that the messages for every multicast group should be forwarded.

As we will notice through the analysis of the mechanism, the TMRLs are used in cases that the traffic departs from the UE with destination the GGSN, such as a request for a service, a joining or a leaving of a specific multicast group. After a reply to this request from the GGSN, the corresponding record in the TMRL is deleted and either a new record in the PMRL of the node is created, or an existing record is updated. Thus, in the PMRL of a node, we keep the nodes of the next level that the packets of a specific multicast group should be forwarded.

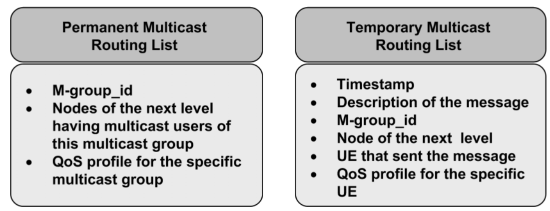


Figure 4. Permanent and Temporary Multicast Routing Lists (PMRL and TMRL)

Additionally, in the timestamp of the TMRL, we keep the moment that the packet was received, which is useful when a packet loss is occurred (Figure 4). More specifically, in case of a packet loss, a timeout of the response to the message is occurred and the specific record of the TMRL in the correspondent node is deleted. Thus, the PMRL of this node is not updated at this time as we described above. As Figure 4 presents, the PMRL and TMRL lists contain additional information such as the QoS profile. This information is useful for congestion avoidance or rate control of the flows and is updated every time that the network realizes a change to the QoS profile of the links.

The actual procedure of the reception of an MBMS multicast service is enabled by certain procedures. These are: Subscription, Service Announcement, Joining, Session Start, MBMS Notification, Data Transfer, Session Stop and Leaving. The phases Subscription, Joining and Leaving are performed individually per user, while the other phases are performed per service. The sequence of the phases may be repeated, depending on the need to transfer data. Also Subscription, Joining, Leaving, Service Announcement and MBMS Notification may run in parallel to other phases [9].

More specifically, Subscription establishes the relationship between the user and the service provider, which allows the user to receive the related MBMS multicast service. The phase that follows is the Service Announcement which allows the users to request or be informed about the range of the available MBMS user services. Joining is the process in which a subscriber becomes a member of a multicast group. However, the GGSN is ready to send data only when the Session Start phase has been occurred. In practical, Session Start is the trigger for the bearer resource establishment for Data Transfer. Additionally, with the MBMS Notification phase, the users are informed about forthcoming MBMS Data Transfer. The transmission of the multicast data occurs in the Data Transfer phase, when the users receive the data. After the transmission, there is the Session Stop that the GGSN determines that there will be no more data to send for some period of time and the bearer resources are released. Finally, if a subscriber does not want to be a member of the multicast group any longer, he proceeds to the Leaving phase [9].

In the following, we present the exact steps of the packet forwarding mechanism for the multicast routing in UMTS with the use of the above described lists (Figure 3, Figure 4) in every node of the network. Since the UEs are known to the network, we consider that the Subscription phase is completed. Thus, the Service Announcement phase follows:

1. Suppose that a UE wants to become a member of an MBMS service of the network. Thus, it sends a message to the Node B that it resides, with final destination the GGSN requesting the available multicast services.
2. The correspondent Node B receives the message from the UE and stores the current time, the description of the message (request of the available multicast groups), the sender UE and the QoS profile of the specific UE in its TMRL. Then it forwards the message to the correspondent RNC.
3. The correspondent RNC receives the message from the Node B and stores the current time, the description of the message (request of the available multicast groups), the sender UE, the Node B that the message forwarded and the QoS profile of the specific UE in its TMRL. Then it forwards the message to the correspondent SGSN. The same procedure occurs in the SGSN and finally the message reaches the GGSN.
4. The GGSN try to authenticate the sender UE. If the authentication is successful, the GGSN sends an appropriate message to the corresponding SGSN with final destination the specific UE containing the list of the available multicast groups.
5. The SGSN receives the message from the GGSN. Then, it checks its TMRL for a record containing the specific UE and the correspondent description (request of the available multicast groups) and decides the correct RNC that the message should be forwarded so as to reach the correct UE. As the message is forwarded to the RNC, the correspondent record in the TMRL of the SGSN is deleted and an appropriate update occurs in the PMRL of the SGSN as described above. The same procedure occurs in the RNC and Node B and finally the UE receives the message from the GGSN.

At this time, the UE has the list of the available MBMS user services and the Service Announcement phase is completed. The Joining phase (Figure 5) follows:

1. The UE decides that it wants to join a specific multicast group and sends an appropriate message to the Node B that it resides with final destination the GGSN.
2. The correspondent Node B receives the message from the UE and stores in its TMRL the current time, the description of the message (join), the specific M-group_id of the requested multicast group, the sender UE and the QoS profile of the specific UE. Then it forwards the message to the correspondent RNC.
3. The correspondent RNC receives the message from the Node B and stores the current time, the description of the message (join), the specific M-group_id, the sender UE, the Node B that the message was forwarded and the QoS profile of the specific UE, in its TMRL. Then it forwards the message to the correspondent SGSN. The same procedure occurs in the SGSN and finally the message reaches the GGSN.
4. The GGSN adds the specific UE to the correspondent record of the MGL for the requested M-group_id and the UE becomes a member of this multicast group. Then, the GGSN searches the TMRL for the specific UE with description of the message "join" for the specific M-group_id and decides the correct SGSN that the reply message should be sent. As we described above, the correspondent record of the TMRL in the GGSN is deleted, while an existing record in the PMRL is updated, or a new record is created. The same procedure occurs in every path from the GGSN to the UEs that want to join a multicast group. Finally, the message reaches the UE.

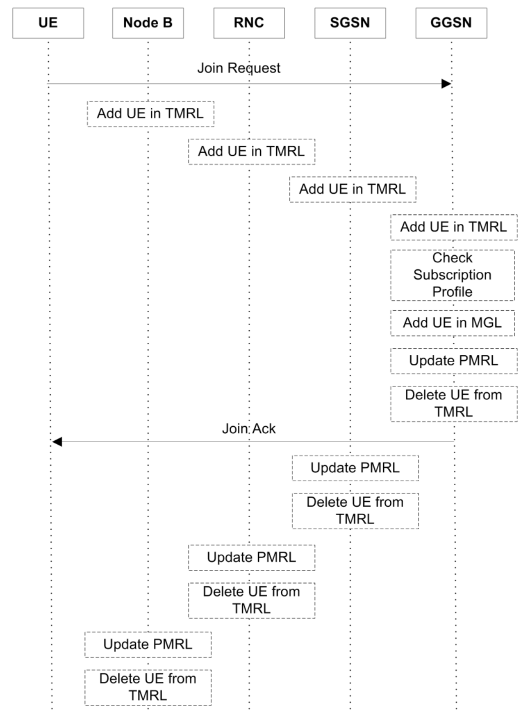


Figure 5. Joining Phase

The phases that follow are Session Start, MBMS Notification, Data Transfer, Session Stop, where the data are transferred from the GGSN to the UEs. In these phases each node of the network that receives a packet of a multicast group, it searches the PMRL for the record of this M-group_id and decides the nodes of the next level that the packet should be forwarded. Finally, the packet reaches the UEs that are members of this multicast group. Obviously, the Data Transfer phase constitutes the main phase of the multicast packet forwarding mechanism. Thus, in the following paragraphs, we describe the exact steps of this procedure:

1. Firstly, the GGSN is ready for the transmission of a packet with destination a specific multicast group. Then, it searches its PMRL for the specific M-group_id and determines which SGSNs serve UEs that are members of the specific multicast group and reside in their

respective service areas. Then, the packet is forwarded to these SGSNs.

2. The correspondent SGSNs receive the multicast packet and they search their PMRL to determine which RNCs are to receive this packet. Then, the packet is forwarded to the appropriate RNCs. The same procedure occurs in the RNCs and the Node Bs. Finally, the multicast packet is transmitted to the UEs that are members of the multicast group.

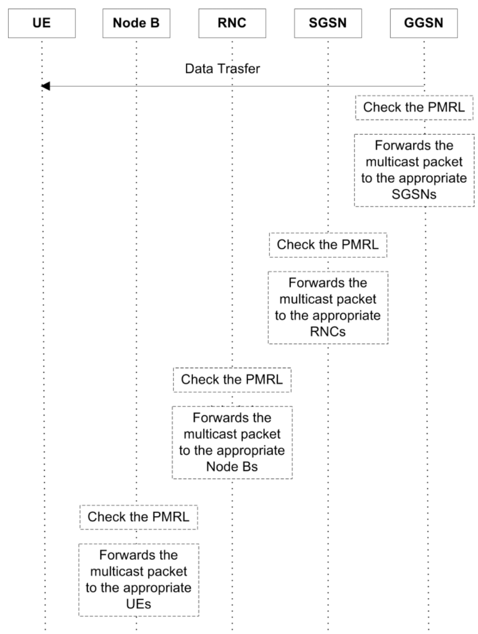


Figure 6. Data Transfer Phase

The above described procedure occurs until all the packets of the specific multicast service are transmitted to appropriate UEs. The latest phase, Leaving, is a little different from the above, since the UE sends the message to the GGSN (Figure 7). The exact procedure is described with the following steps:

1. The UE decides that it wants to leave a specific multicast group that until then it was a member of it. Thus, it sends an appropriate message to the Node B that it resides, with final destination the GGSN.
2. The correspondent Node B receives the message from the UE and stores in its TMRL the current time, the description of the message (leave), the M-group_id of the multicast group that the UE wants to leave, the sender UE and the QoS profile of the specific UE. Then it forwards the message to the correspondent RNC.
3. The correspondent RNC receives the message from the Node B and stores the current time, the description of the message (leave), the M-group_id of the multicast group that the UE wants to leave, the sender UE, the Node B that the message forwarded and the QoS profile of the specific UE in its TMRL. Then it forwards the message to the correspondent SGSN. The same procedure occurs in the SGSN and finally the message reaches the GGSN.
4. The GGSN removes the specific UE from the correspondent record of the MGL. Thus, the UE is not any more a member of this multicast group and future packets for this multicast group would not be transmitted to this UE. Then, the GGSN searches the TMRL for the specific UE with the description of the message "leave" and the specific M-group_id and decides the correct SGSN that the reply message should be sent. As we described above, the correspondent record of the TTRL in the GGSN is deleted, while an existing record in the PMRL is updated, or a new record is created. The same procedure occurs in every node of the network and finally the message reaches the UE. At this time, the UE knows that the procedure of the leaving of the multicast group has been finished successfully.

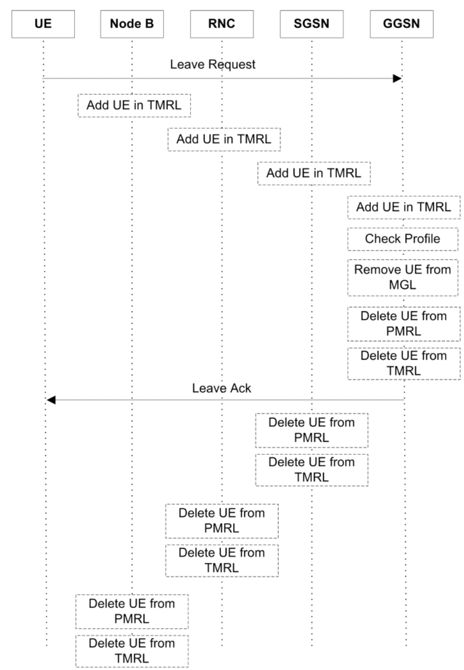


Figure 7. Leaving Phase

3.3 Data Transmission over the Iub Interface

It has to be mentioned that no decision has yet been made within 3GPP on how to optimize the MBMS data flow over the Iub. It has been proposed to avoid the duplication of Iub data flows and hence, only one Iub data flow per MBMS services should be used [13] [14].

As presented in [10], the point-to-multipoint MBMS data transmission uses the forward access channel (FACH) with turbo coding and QPSK modulation at a constant transmission power. Multiple services can be configured in a cell, either time multiplexed on one FACH or transmitted on separate channels, although in the latter case a single UE may not be able to receive multiple services. Control information, for example, available services, neighboring cell information indicating which of the neighboring cells that transmit the same content and so forth, is transmitted on a separate FACH.

However, the RNC, for radio efficiency reasons, can also use dedicated resources (one Dedicated Channel (DCH) for each UE in the cell) or shared channels (High Speed Downlink Shared

Channel (HS-DSCH) shared by all the UEs in a cell) to distribute the same content in a cell.

In general, the selection of the bearer type is operator-depended, typically based on the downlink radio resource situation so that the efficiency of the resource usage can be maximized. The main parameters that may be taken into account while selecting the appropriate radio bearer for the MBMS data transmission over the Iub and Uu interfaces are presented below:

1. **Bit rate**. The target in the MBMS standard in release 6 is set to broadcast/multicast services on FACH to a bit rate of 256 kbps depending on the radio conditions and the service requirements. Current specifications, however, are nevertheless more likely to offer 32 to 64 kbps bit rates. Such bit rates would be sufficient for multimedia download but not for video streaming. On the other hand DCH offers higher bit rates (up to 384 kbps) but the DCH is a point to point channel reserved for a single user. Finally, HS-DSCH offers bit rates up to 14,4 Mbps (per cell). The HS-DSCH resources can be shared between all users in a particular sector. The primary channel multiplexing occurs in the time domain. In each TTI, the scheduler decides to which user(s) the data should be transmitted. Therefore, depending on the bit rate demands of the MBMS application the appropriate transport channel should be used.
2. **Number of multicast users per cell**. One of the key assumptions is that if the number of UEs within a cell using a particular MBMS service is high enough, it will be advantageous to broadcast the MBMS data stream over the whole cell. If the number of UEs is small, serving each UE through DCHs means might be more efficient. For this achievement, new functionalities have to be introduced in the RNC for supporting point to point or point to multipoint radio bearers and switching between them. A reasonable threshold for switching from point to point radio bearers to point to multipoint radio bearers in the multicast case is the number of 7-15 active MBMS users per cell [13].
3. **Power control issues**. Fast power control is the most important aspect in WCDMA technology because it optimizes the radio transmission power. The main difference between the dedicated and common resources is that FACH does not allow the use of fast power control. In particular, as presented in [15], the MBMS service can take significant portion of the sector power if FACH is used to carry the MBMS traffic. FACH, as a Common Channel, needs to be received by all the UEs in the cell, also those near the cell's border and hence, it requires more radio resources (power) than a DCH. Therefore, few DCHs might outperform one Common Channel in terms of radio resource efficiency, whenever the users are "few" and located "near" the Node B. On the other hand, if the number of users increases it is more efficient to use a Common Channel. The total downlink transmission power allocated for FACH is fixed, while the total downlink transmission power allocated for Dedicated Resources (DCH) is variable and increases exponentially while the UE distance from the Node B is increasing. Also, the more the UEs in the cell thus the higher the interference, the more exponential the increase in the total power required [17]. Regarding the HS-DSCH, it is not power controlled but rate controlled. In HS-DSCH a certain fraction of the total downlink radio resources available within a cell, channelization codes and transmission power, is seen as a common resource that is dynamically shared between users, primarily in the time domain [16].
4. **Mobility issues**. The multicast users that are on the move and receive an MBMS Service may have to deal with dynamic changes of network resources when crossing the cell edge. FACH does not support handover in addition to the DCHs and HS-DSCHs [1]. Therefore a handover control mechanism should be implemented in the RNC in order to provide MBMS service continuity when a multicast user travels over cell boundaries in a cellular infrastructure [17].

4. SIMULATION RESULTS

To present the functionality of the proposed multicast scheme, we implement the mechanism with the TMRL and PMRL in the NS-2 simulator [5] and the extensions for the UMTS support provided by EURANE [6].

4.1 Simulation Parameters and Topology

For our simulation model, we consider the topology presented in Figure 2. More specifically, we consider that our network consists of two SGSNs, each SGSN serves two RNCs and each RNC serves three Node Bs. Since we do not want to create a symmetrical topology, we differentiate the number of the UEs located in each Node B. In this approach, we have the opportunity to present the efficiency of the multicast mechanism compared to the unicast transmission of the data.

In our simulation model we use several transport channels for the transmission of the data over the radio interface. In particular, in order to simulate the number of radio bearers established in the Iub interface as well as the data traffic in the Iub interface we consider transport channels such as High Speed – Downlink Shared Channels (HS-DSCH), Dedicated Channels (DCH), and Forward Access Channels (FACH).

As far as the video sequence is concerned, it is encoded to ITU-H.263 [10]. The video trace we use is taken from [12] and we consider that there is an external node, connected to the GGSN that is the media server and transmits the video to the multicast group. For simplicity, we consider that all the UEs of the network are members of it. For the transmission of the video data we use RTP traffic, which means that with the use of the RTCP reports, the GGSN has the opportunity to gain useful statistical information like the total transmitted packets, the packet loss rate and the delay jitter during the transmission of the data. The bit rate of the video is 64 kbps and the size of the packets is 800 bytes. In the experiments that follow, we focus on the data transfer phase that consists on the main phase of the MBMS multicast service provision. We assume that the simulation time is 200 seconds.

4.2 Results

The first parameter that we calculate is the throughput in the links of the UMTS network using the multicast scheme. In our experiments, we present only the link SGSN1–RNC1 of Figure 2. Additionally, a red line is used for the demonstration of the theoretical video transmission rate (64 kbps).

As we can observe from Figure 8, the throughput in the link is approximately the same with the theoretical video bit rate. The same observation stands for every link of the network that has traffic except the Iub and Uu interfaces that their behavior depends on the transport channel used for the transmission of the data and it will be discussed later in this section. This occurs because in the multicast scheme, the packets are transmitted only once in each link of the network so as to reach the mobile users. This procedure implies that the growth of the packets in the multicast transmission is by far less than the growth of the packets in the unicast transmission. Thus, possible congestion in the network is limited compared to congestion in the unicast transmission of the video.

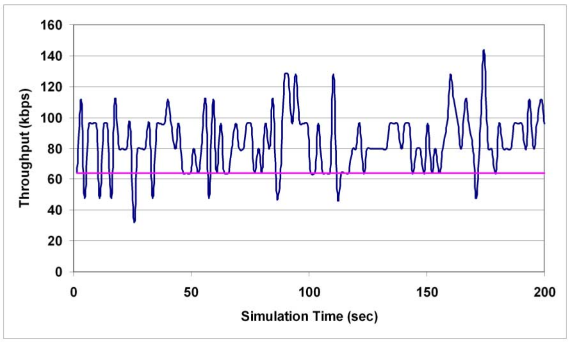
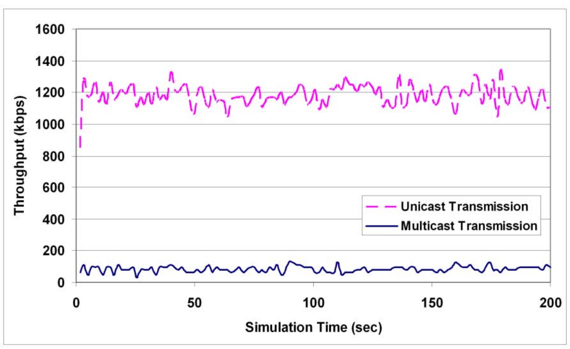
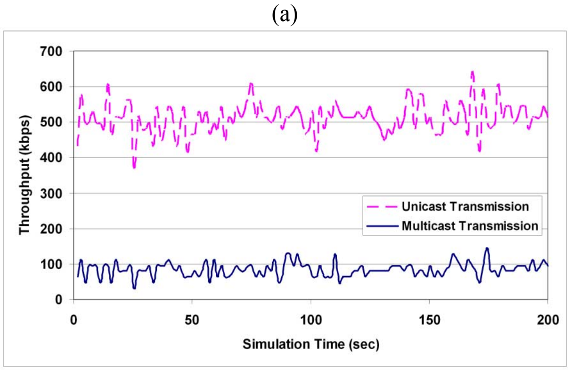


Figure 8. Throughput in the link SGSN1 - RNC1



(a)



(b)

Figure 9. Throughput in the links external node–GGSN and GGSN–SGSN1 in the multicast and unicast transmission

Another interesting statement comes from the comparison of the multicast and the unicast transmission of the video. We consider again the topology of Figure 2 and we calculate the throughput of some links of the network using the multicast and the unicast scheme (Figure 9, Figure 10). In these figures, we observe that the throughput in the unicast mechanism is by far bigger than the throughput in the multicast mechanism. Even if the bigger throughput entails better performance, in our case the opposite happens. More specifically, in the unicast scheme the same packets are transmitted many times in every link which means that we observe increased throughput. In the case of the multicast scheme, only one copy of each packet is transmitted in each link of the network and thus, the throughput is small.

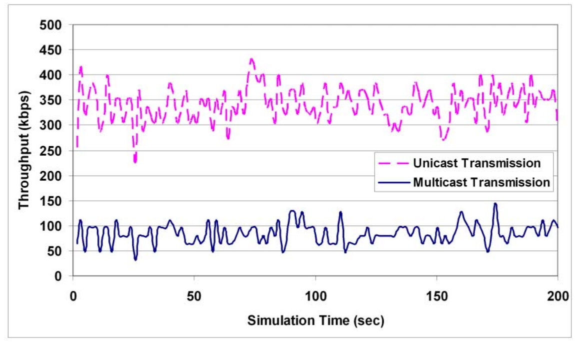


Figure 10. Throughput in the link SGSN1-RNC1 in the multicast and unicast transmission of the video

Totally, we understand that the fraction of the difference of the two lines, depicted in the figures, depends on the number of the members of the multicast group. For example, consider the Figure 9a where the throughput in the link between the external node and the GGSN is depicted. In this case, we observe that the throughput in the unicast scheme is approximately fourteen times bigger than the throughput in the same link using the multicast scheme. This outcome is reasonable and predictable since the number of the total UEs of the network is fourteen and the traffic in this link of the network is fourteen times increased in the unicast scheme. In the same way, in Figure 9b the throughput in the multicast case is six time smaller than in the unicast case since SGSN1 serves six UEs. Finally, in Figure 10, since RNC1 serves four UEs the throughput in the multicast case is four time smaller than in the unicast case.

In order to simulate the number of radio bearers established in the Iub interface as well as the data traffic in the Iub interface we consider several transport channels for the transmission of the multicast data over the Iub and Uu interfaces. In particular we use transport channels such as High Speed – Downlink Shared Channels (HS-DSCH), Dedicated Channels (DCH), and Forward Access Channels (FACH). In general, in case we use the FACH as transport channel each multicast packet send once over the Iub interface and then the packet is transmitted to the UEs that served by the corresponding Node B. In case we use DCHs for the transmission of the multicast packets, each packet is replicated over the Iub as many times as the number of multicast users that the corresponding Node B serves. Finally, with HS-DSCH, the resources can be shared between all users in a particular sector. The primary channel multiplexing occurs in the time domain, where each UE listens in a particular TTI. Regarding the resources in the Iub, a separate timeslot must be used to transport the multicast data to each multicast receiver. However, one could envision that all multicast receivers could receive the same timeslot that contains the multicast data, but in its current form the HS-DSCH has not been modified to allow this. Thus, the number of time slots required for the transmission of the multicast data to the multicast users is equal to the number of multicast users reside in the corresponding cell.

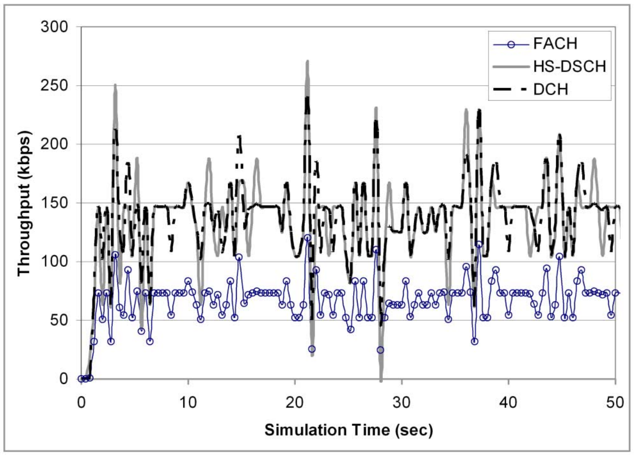


Figure 11. Throughput in the Iub (RNC2 – Node B5)

The above remarks are shown in Figure 11, where we measure the throughput in the Iub interface that connects the RNC2 and the Node B5 (Figure 2). Due to the fact there are two multicast users located in the cell served by the Node B5 (Figure 2) the total throughput in the corresponding Iub if we use DCHs or HS-DSCHs is twice as large as the throughput if we use FACH as transport channel.

5. CONCLUSION AND FUTURE WORK

In this paper, we proposed a multicast scheme for UMTS. The Permanent Multicast Routing List (PMRL) and Temporary Multicast Routing List (TMRL) were introduced in each node of the network except UEs. In these lists we record the nodes of the next level that the messages for every multicast group should be forwarded. As we shown, these lists lead to the decrement of the transmitted packets and the more efficient use of the network resources in the multicast routing in UMTS. Minor modification in the UMTS architecture is needed, which means that our mechanism is easily implemented. Therefore, we analyzed the exact steps that are essential for a successful MBMS multicast service provision. Since the Data Transfer phase is the most important phase in the multicast service, the experiments were focused in the transmission of the multicast data. Our simulation results show that the proposed mechanism for the multicast packet forwarding in UMTS works correctly and performs efficiently. The step that follows could be the study of the congestion control in the multicast scheme in UMTS. Thus, in cases that the mechanism realizes a possible congestion in a majority of the members of a multicast group, the transmission rate of the data could be reduced.

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