An Efficient Multicast Packet Delivery Scheme for UMTS

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ABSTRACT
In this paper we present an efficient scheme for the multicast transmission of the data in the Universal Mobile Telecommunications System (UMTS). We take advantage of the tree topology of the examined network and we introduce the use of Routing Lists (RLs) in the nodes of the UMTS. The adoption of these lists leads to the decrement of the transmitted packets and the efficient use of network resources during the multicast transmission of the data. We describe in detail the necessary steps for the successful multicast transfer of data. Furthermore, we analyze the handling of special cases such as user mobility scenarios. Especially, the various handover types are examined along with the Serving Radio Network Subsystem (SRNS) relocation procedure.

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 routing, UMTS, MBMS, Mobility

1. INTRODUCTION
Third generation (3G) mobile networks are being deployed to provide enhanced voice and data services from anywhere and at anytime. Universal Mobile Telecommunications System (UMTS) constitutes the main standard of the third generation of cellular wireless networks. UMTS aims to provide high-speed data access along with real time voice calls [1]. Although UMTS networks offer high capacity, the expected demand will certainly overcome the available resources. Thus, the multicasting over the UMTS networks remains a challenge and an area of research [2], [3].

Several mechanisms have been proposed to support multicast routing in UMTS. In [4], the authors discuss the use of commonly deployed IP multicast protocols in UMTS. However, the authors in [3] do not adopt the use of IP multicast protocols for multicast routing in UMTS and present an alternative solution that can be implemented within the existing network nodes with trivial changes to the standard location update and packet forwarding procedures. Furthermore, in [5] a multicast mechanism for circuit-switched GSM and UMTS networks is outlined. Finally, the Multimedia Broadcast/Multicast Service (MBMS) framework of UMTS is currently being standardized by the 3rd Generation Partnership Project (3GPP), [6], [7].

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In this paper we present an efficient scheme for the multicast transmission of the data in the UMTS. We take advantage of the tree topology of the examined network and we introduce the use of Routing Lists (RLs) in the nodes of the UMTS. We describe in detail the necessary steps for the successful multicast transfer of data. Furthermore, we analyze the handling of special cases such as user mobility scenarios. Especially, the various handover types are examined along with the SRNS relocation procedure.

This paper is structured as follows: In Section 2 we present the multicast packet forwarding mechanism for UMTS. In Section 3 we present issues related to the user mobility. Finally, some concluding remarks and planned next steps are briefly described.

2. DESCRIPTION OF THE MULTICAST MECHANISM
In this section, we describe the multicast packet forwarding mechanism with the use of Routing Lists (RLs). Our analysis is based on the MBMS system architecture [6], [7]. For simplicity, we consider that the Gateway GPRS Support Node (GGSN) incorporates the functionality of the Broadcast Multicast – Service Center (BM-SC).

2.1 MBMS Functionality
As the term Multimedia Broadcast/Multicast Service indicates, there are two types of service mode: the broadcast and the multicast. In broadcast mode, data is delivered to a specified area without knowledge of the receivers and whether there is any receiver at all in this area. However, in the multicast mode the receivers have to signal their interest for the data reception to the network and then the network decides whether the user should receive the data or not.

Since the multicast mode is more complicated than the broadcast mode, it is more useful to present the operation of the MBMS multicast mode and the way that the mobile user receives the multicast data of a service. Actually, 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 of transferring data. Moreover, Subscription, Joining, Leaving, Service Announcement and MBMS Notification may run in parallel to other phases [6], [7].

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 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 [6], [7].

2.2 Packet Forwarding Mechanism

Our multicast mechanism introduces RLs in every node of the network apart from the User Equipments (UEs). In the RL of a node, information is kept about which nodes of the lower level connect the current node with the UEs belonging to a specific multicast group. Consequently, there is one RL for each multicast group in each node (except for the UEs). For example, consider the network topology illustrated in Figure 1. Assume that UE1, UE2, UE11 and UE12 belong to multicast group MG1. GGSN preserves a RL for this multicast group which contains all the Serving GPRS Support Nodes (SGSNs) which connect GGSN with the UEs belonging in MG1. These SGSNs are SGSN1 and SGSN2. Then, each SGSN preserves a RL with the Radio Network Controllers (RNCs) which connect it with the UEs belonging in the examined multicast group. The RL of SGSN1 contains RNC1, the RL of SGSN2 contains RNC3 and RNC4, while RL of SGSN3 for MG1 is empty. Similarly, the RL of RNC1 contains UE1 and UE2, the RL of RNC3 contains UE11 and that of RNC4 contains UE12. The rest RNCs have empty RLs.

The multicast routing mechanism is based on the processing of the RL in each node. If an incoming packet which addresses to a multicast group, reaches a node, the corresponding RL is scanned. If RL is non-empty, the packet is duplicated and is transmitted once to each lower-level node existing in the RL. This procedure is repeated recursively in the lower-level nodes until each copy of the packet reaches its destination. For example, consider the case when incoming traffic for the previously defined multicast group MG1, reaches the examined PLMN (see Figure 1). Suppose that there is an incoming packet to GGSN and the packet addresses to MG1. GGSN checks the relevant RL. If this RL contains lower level nodes, the packet is forwarded once to each one of them. The mechanism of the packet forwarding is repeated recursively by the lower level nodes until the packets reaches the UEs belonging to the specific multicast group.

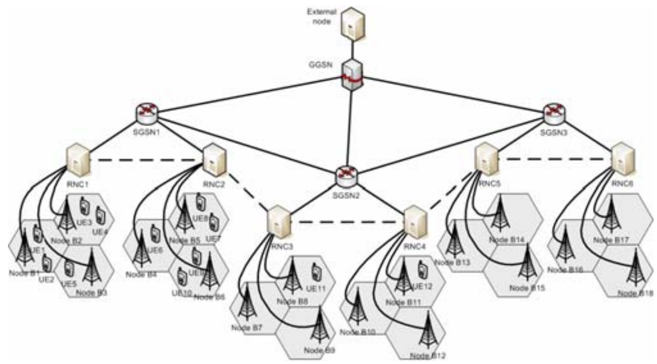

Figure 1. Multicast packet transmission.

In this point we must mention the existence of two other kinds of list. Additionally to the RLs, the Drift Routing Lists (DRLs) are used in the RNCs and the Multicast Group Lists (MGLs) in the GGSN. The DRLs are lists which are used when inter-RNS soft handover has occurred. Each DRL corresponds to a multicast group and contains pairs of RNC-UE. The use of these lists aims to the multicast transmission over the Iur interface and will be thoroughly explained in Section 3.1. Considering MGLs, each list corresponds to a specific multicast group and maintains the UEs which belong to the group. These lists give the opportunity to GGSN to retrieve the UEs belonging to a specific multicast group. Obviously, MGLs and RLs are not static elements but they are updated each time a UE joins or leave a multicast group or when user mobility events transform the mobile network topology. Thus, for the correct transmission of the multicast data, it is essential that these lists are fully updated at every moment.

2.3 Multicast Group Management

Consider a UMTS network providing MBMS service. Suppose that a UE has completed the Subscription phase and wants to join a multicast group provided by the GGSN. In this case, the Service Announcement phase is executed. UE sends a message to the GGSN, requesting the list of available multicast groups. When the message reaches the GGSN, GGSN sends a reply message to the UE with the available multicast groups and the phase is ended. UE decides which multicast group(s) wants to join in. The exact steps of the multicast group(s) Joining phase are listed below:

1. The UE sends a join-request message to the GGSN, specifying the multicast group MG which the UE wants to join in.
2. The GGSN checks the subscription profile and, assuming that it accepts the request, the GGSN adds the UE in the corresponding MGL. Then, it checks if the SGSN which serves the UE, exists in the relevant RL. If it does not exist, it adds it in the RL. Finally, the GGSN sends an acknowledgement message to the serving SGSN.
3. When the SGSN gets the acknowledgment, it examines if the serving RNC of the UE exists in the RL that it maintains for the MG. If the RNC does not exist, the SGSN adds it in the RL. Then it forwards the acknowledgment to the RNC.

4. When the RNC gets the acknowledgment, it adds the UE in the proper RL and forwards the acknowledgment to the UE.

When the UE receives the acknowledgment, the establishment of the context is finally confirmed.

In case a UE decides to leave a multicast group, the Leaving phase takes place. This phase is similar to the Joining phase described above. The message sequence during this phase is similar to the one described above.

1. The UE sends a leave-request message to the GGSN, specifying the multicast group MG which the UE wants to quit.
2. The GGSN removes the the UE from the corresponding MGL. Then, it examines if there is another UE in the MGL which is served by the same SGSN. If there is not, the SGSN is removed from the relevant RL. Finally, the GGSN sends an acknowledgement message to the SGSN.
3. When the SGSN receives the acknowledgment, it examines if there is another UE which is served by the RNC and participates in the MG. If there is not, the RNC is removed from the RL. Then, the SGSN forwards the acknowledgement to the RNC.
4. When the RNC gets the acknowledgment, it removes the UE from the relevant RL and forwards the acknowledgment to the UE.

3. USER MOBILITY

In this section we describe how our mechanism handles the user mobility in order to assure MBMS service continuity. We investigate the impacts of soft handover over the proposed mechanism. Moreover, we describe the adaptation of the mechanism to the SRNS relocation procedure.

3.1 Soft Handover

Consider a UE that is a member of a multicast group and a MBMS multicast service provision that is in the Data Transfer phase. While the multicast packets are transmitted to the members of this multicast group, the specific UE changes cell. There are three possible scenarios for this soft handover [8]:

1. Inter-Node B/intra-RNS soft handover.
2. Inter-Node B/inter-RNS/intra-SGSN soft handover.
3. Inter-Node B/inter-RNS/inter-SGSN soft handover.

In the first case, the existing RLs at the nodes of the network remain unchanged and thus there is no impact in the proposed mechanism. In the last two cases, the handling is identical. The basic concept of inter-RNS soft handover is that the handover is transparent to the SGSN(s). This is achieved with the introduction of a new interface, the Iur interface. Thus, when an inter-RNS handover takes place, the data is transmitted through the Iur interface. In the proposed mechanism we use the DRLs in order to introduce multicast packet transmission over the Iur interface. This kind of transmission takes place when multiple handovers from the same source RNS to the same target RNS have occurred. Note that Iur interface does not exist in GSM networks where soft handover is not applicable. Instead of that, GSM networks use the hard handover procedure.

The source RNC is called Serving RNC (SRNC) and the target RNC is called Drift RNC (DRNC). In case that subsequent handovers take place, multiple DRNCs are used. Only the SRNC has a connection to the CN for that session and the data reaches the DRNC via the Iur interface. In our mechanism we introduce multicast packet transmission over the Iur interface.

Figure 2 describe the steps of the inter-RNS soft handover procedure. The proposed mechanism is based on the existing handover procedure of UMTS but it incorporates several extensions in order to assure MBMS service continuity. These extensions are pointed out during the analysis.

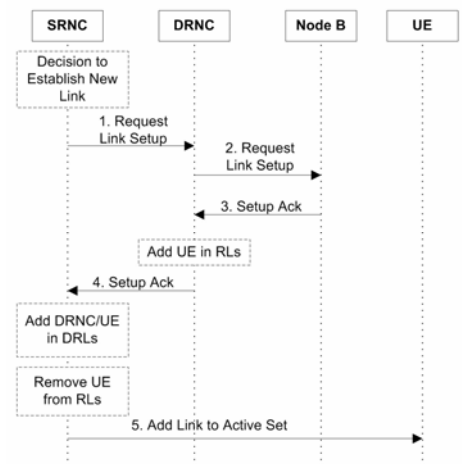

Figure 2. Inter-RNS soft handover.

1. The SRNC decides to make a handover based on the measurements from the UEs. An Iur connection is established between SRNC and DRNC and the SRNS requests radio link.
2. If radio resources are available, the DRNC forwards the request to the Node B in which the new cell belongs.
3. When the allocation of the radio resources is completed, the Node B sends an acknowledgement message to the DRNC and starts receiving uplink data from the UE. When the DRNC gets the acknowledgement, it adds the UE in the RLs related to the multicast groups that the UE belongs. Then, the DRNC forwards the acknowledgment to the SRNC.
4. When the SRNC gets the acknowledgment, it inserts the UE/DRNC pair in the DRLs related with the multicast groups that the UE belongs in. Then, the UE is removed from the relevant RLs.
5. Finally, the UE is informed of the handover and receives the connection information.

Regarding the packet forwarding mechanism, an additional check must be made in the RNCs. The new functionality is related to the existence of the Iur connections and it is based on the DRLs' processing. Actually, in addition to the packet forwarding to the UEs, if a multicast packet reaches an RNC, the corresponding DRL is scanned. If DRL is non-empty, the packet is duplicated and is transmitted once to each DRNC existing in the DRL. These transmissions are made over the corresponding Iur interfaces and follow the multicast forwarding concept. If a UE has performed subsequent handovers, multiple DRNCs correspond to its connection. In that case, this procedure is repeated recursively in the DRNCs until of the packet reaches the last DRNC. Finally, this DRNC will transmit the packet to the UE.

3.2 SRNS Relocation

The SRNS relocation procedure is applicable to UMTS networks and not to GSM ones. It is used to move the UTRAN to CN connection point from the SRNC to the DRNC. If the DRNC is connected to the same SGSN as the SRNC, an intra-SGSN SRNS relocation procedure is performed. Otherwise, if the DRNC is connected to other SGSN, an inter-SGSN SRNS relocation procedure takes place. Figure 3 illustrates the latter case which is the most general of the two. Note that the proposed mechanism uses existing mobility management mechanisms but with several extensions for multicasting.

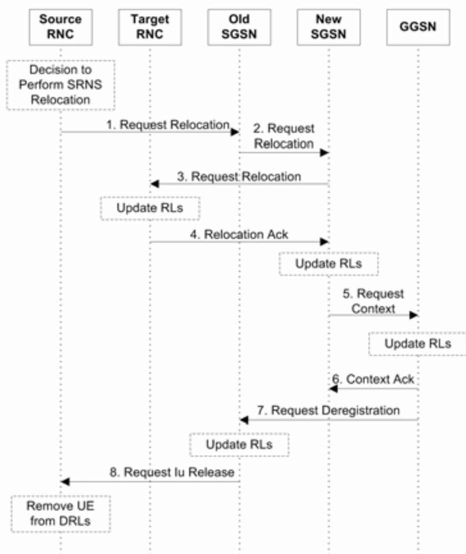

Figure 3. Inter-SGSN SRNS relocation.

1. The current SRNC detects that SRNS relocation of the UE to a DRNC is needed. The SRNC sends a "relocation required" message to the old SGSN which indicates that the SRNC is the source RNC and the DRNC is the target RNC.
2. The old SGSN sends message "relocation request" to the new SGSN. Additionally, the new SGSN gets aware of the multicast groups in which the UE participates. The MBMS related context is also transferred.
3. The new SGSN sends message "relocation request" to the target RNC. The target RNC is informed by the new SGSN in which multicast groups the UE belongs. Finally, the target RNC performs an update of the relevant RLs, although this is not mandatory because the UE has already been inserted in the RLs during the soft handover procedure.
4. A "relocation-ack" message is sent from the target RNC to the new SGSN. The new SGSN examines each RL related with the multicast groups that the UE participates. If the target RNC is not contained, it is added in the RL.
5. The new SGSN creates MBMS bearer context and registers on the GGSN. The GGSN examines each RL related with the multicast groups that the UE participates. If the new SGSN is not contained, it is added in the RL.
6. GGSN notifies the new SGSN of the UE registration. The connection is now switched from old SGSN to new SGSN.
7. The GGSN notifies the old SGSN that the service is deregistered for the specific UE. The old SGSN examines each RL related with the multicast group that UE participates. If there is no other UE which is served by the source RNC and participates in the corresponding multicast group, source RNC is erased from the RL.
8. The source RNC is notified by old SGSN that relocation is completed. All the records containing the UE are removed from all the DRLs of source RNC. From now on the target RNC is considered to be the SRNC of the UE.

The case of intra-SGSN SRNS relocation is similar. All the above steps are valid given the fact that both SRNC and DRNC are connected to the same SGSN.

4. CONCLUSIONS AND FUTURE WORK

In this paper, we proposed a multicast scheme for UMTS. The Routing Lists 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. Moreover, the Drift Routing Lists (DRLs) were added. These lists contain information relevant to soft handovers performed and their processing leads to multicast transmission of data between RNCs. The step that follows this work could be the study of the congestion control in the multicast scheme in UMTS.

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