

An Early Technical Evaluation of Convergence between Cellular and Broadcast Media

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Abstract

Convergence between telecommunications and the broadcast worlds is one of the trends of current network evolution. The UMTS specifications are being enhanced to support broadcast and multicast down to the end-user terminal. The Multimedia Broadcast /Multicast Service (MBMS) Bearer Services define a point-to-multipoint capability on the UMTS radio interface.

The Institut Eurecom has developed, in the context of several research projects, an experimental software radio platform based on UMTS-TDD that provides direct interconnection with an IPv6 Core Network. Its contribution to the European research project DAIDALOS consists in integrating the MBMS point-to-multipoint Bearer Service in the radio platform and in the Daidalos architecture.

This integration requires the identification and resolution of several specific topics such as the sharing of radio channels with the unicast traffic. Also, the sequence model for the service activation and deactivation must be revised to ensure on-request radio resource allocation. Finally, as part of the IP mobility architecture, the project envisions a seamless handover between a DVB-T cell and an MBMS cell. This paper addresses all these issues and presents some results of the implementation of this service on a software radio experimental platform.

1. Introduction

Broadcast and Multicast are methods for transmitting datagrams from a single source to several destinations (point-to-multipoint). It happens that, for some applications, multiple users can receive the same data at the same time. The benefit of multicast and broadcast in the network is that the data are sent once on each link. Many users can receive the same content on a common radio channel, thus increasing the air interface usage efficiency.

Traditionally, broadcasting has been the domain of TV distribution and is now being enhanced to Digital

Video (DVB). The Mobile Terminals capabilities are exponentially increasing, making them able to receive broadcast transmissions as well. According to this trend, the DVB consortium is preparing new standards for handhelds (DVB-H) and the 3GPP is releasing new specifications for multimedia services, so called MBMS (Multimedia Broadcast /Multicast Service). MBMS is considered a big step towards integration of Broadcast services into telecom operators' networks. Nonetheless, the MBMS architecture is designed on top of a single well defined access technology. Its integration with the 4G architectures, usually denoted as "All-IP" architectures is therefore not trivial.

This paper presents the integration of a multicast bearer in a UMTS platform, through the MBMS, to be used in a heterogeneous technology environment, more specifically in the Daidalos [1] architecture. This architecture comprises also the integration of several access technologies, such as WLAN, WiMAX, and DVB. To support these technologies, operators need to rely in a homogeneous architecture integrating heterogeneous technologies. For the UMTS (and MBMS) integration, extensions of both the Daidalos architecture and the UMTS platform need to be carried out. The specification and implementation of these extensions will be the subject of this paper. Preliminary results of this integration will also be presented.

This paper is organized as follows. Section 2 presents the related work, starting with the European research project Daidalos and some of its target broadcast scenarios. Then the "Pure-IP" UMTS platform, which is the object of this work is described, followed by the main characteristics of the MBMS specification. Section 3 shows the design of this integration and the required adaptations at several protocol levels. Section 4 highlights the enhancements of the UMTS platform and presents some initial results, targeting mainly the Radio Resource Control Protocol. In section 5 we present the future evolutions of this integration, from two points of view: Quality of service and heterogeneous mobility. Finally, we draw our conclusions in section 6.

2. Related work

2.1. The Daidalos Project

DAIDALOS [1] is a research Integrated Project under EU Framework Programme 6 (FP6) dedicated to the design of advanced network infrastructures and access technologies for location-independent, personalized communication services. The main objective of Daidalos is to develop and demonstrate a future network operator architecture for Systems beyond 3G.

The project has selected IPv6 as its unique networking protocol.

One of the focuses of the project is the integration of mobility-enabled broadcast in advanced network infrastructures and access technologies. Broadcast covers two separate domains. Its architecture spans the whole network infrastructure. Broadcast services concern more precisely applications which can be supported by broadcast networks or other IP networks. In the core network, they are achieved using the enhanced IPv6 multicast infrastructure. Broadcast technologies consider the broadcast networks and broadcast capacities provided by the terrestrial networks. They apply mostly to the Mobile Terminal (MT) and the radio Access Router (AR). They provide a point-to-multipoint (p-t-m) radio transport media. In the first project phase, the study applies more specifically to the DVB-T/H and UMTS MBMS technologies.

An initial project's assumption was the existence of a return channel associated to the broadcast unidirectional link, to provide bidirectional connectivity. This channel provides an upstream connection between the MT and the AR in the broadcast network, enabling an interaction medium to the unidirectional broadcast channel to support services like security, mobility handling, Quality of Service (QoS) adaptation, and multicast cell join and leave.

The QoS support in the Daidalos network is, in simplistic and general terms, performed through the interaction between QoS enforcement points in the routers and QoS decision points in the QoS Brokers. The QoS Brokers manage the network resources, providing admission control and triggering resource reservation, both for unicast and multicast/broadcast flows. They also include the maintenance of the available multicast groups and respective QoS, and necessary procedures to unroll a multicast tree in a series of unicast flows representing each of the tree branches.

"The car is able to move this broadcast session to the local cellular operator's 4G Daidalos-enabled network."

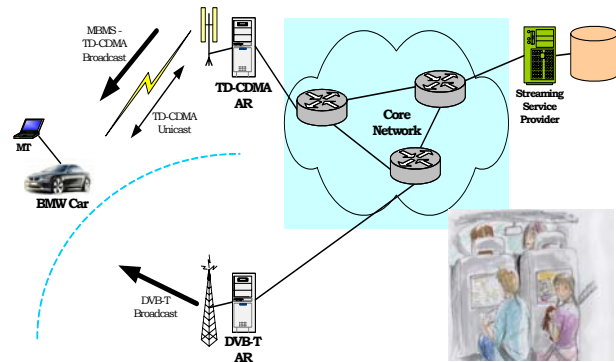


Figure 1. Broadcast transmission through heterogeneous access networks

Since its beginning, the project has defined some scenarios to assess and demonstrate its main technologies. Figure 1 shows an example of these scenarios related with broadcast transmissions. Bart's family is traveling in its car equipped with the Daidalos broadcast system. The children are watching a movie received from their local provider, in a DVB cell. Then, the car crosses a border and enters a country where DVB is not available anymore. Their provider has local roaming agreements with a 4G operator, whose network is equipped with broadcast-enabled UMTS cells. The program is thus transferred seamlessly from DVB to UMTS and the children continue watching their movie. In Figure 1, we can notice an advantage of the UMTS cell, providing both the broadcast (MBMS) unidirectional radio link and the return channel.

In another scene, Bart is in his car, waiting to pick up a customer. He resumes watching the newscast he had not finished before he left home in the morning, while updates his calendar with his new appointment. The UMTS, associated to the new MBMS features, allows him to transfer at the same time multicast and unicast traffic on a single radio link, or access technology, provided by a single operator.

2.2. "Pure-IP" in the UMTS platform

The UMTS Software Radio Platform developed in Institut Eurécom can be used in Beyond-3G (B3G) wireless network experimentations [2]. It implements the UMTS-TDD (Time Division Duplex) standard [3]. The hardware architecture is centered on a PC system complemented by a data acquisition card and a RF (Radio Frequency) module. The software portion of the platform is an extension to the Linux Operating System and makes use of a hard real-time micro-kernel.

The Layer 2+ of the radio protocol stack deviates from 3GPP, in the sense that it provides a direct interconnection with an IPv6 network in the base station (or AR). Running IP up to the AR has a strong impact on the overall network architecture of the system, since it bypasses some basic 3GPP entities of the Core Network (CN) and enables a more distributed vision where some of the functions usually located in the CN are embedded in the AR components. The IPv6 functionalities replace the UMTS mobility management and other functions, e.g. security and QoS. An UMTS-TDD cell is considered as an IPv6 subnet, with its own prefix. Each AR is able to control its own IPv6 subnet. This allows the usage of the IPv6 stateless auto configuration and seamless roaming between various access technologies, in particular between UMTS and WLAN (Wireless Local Area Network). The QoS attributes of DiffServ are mapped onto the UMTS QoS architecture. Security and accounting are performed using a Diameter Server. The radio System Information Broadcast is adapted to forward IP-subnet signaling in the cell through the broadcast channel (BCH), avoiding the use of dedicated channels and the waste of resources. The major advantage relies however in the data traffic operation, where packets are directly routed through some standard and cheap IPv6 routing in the AR. This architecture can be qualified of «pure-IP» architecture to differentiate from the “all-IP” architectures, which bring the IPv6 protocol statically on top of existing protocol stacks. The benefits are the avoidance of a non optimal “IP-in-IP” encapsulation and taking full advantage of IPv6 enhancements. Another benefit is a simplified deployment and management for the operator of a heterogeneous network offering several access technologies, e.g. UMTS and WLAN.

The direct interconnection between UMTS and IPv6 is achieved by an inter-working function, located in the network device driver, as described in [2]. This function includes the middleware for interfacing IPv6-based mechanisms for signaling and user traffic, with 3GPP-specific mechanisms for the access network. The platform is completed by a 3GPP Access Stratum (AS) protocol stack, compliant with the UMTS specification as defined in [3], except for the Radio Resource Control (RRC) which has been adapted to the IPv6 direct interconnection.

This platform is further mentioned as UMTS-TDD or TD-CDMA (Time Division-Code Division Multiple Access) platform.

2.3. The MBMS specification

MBMS is an enhancement of the UMTS system to provide the capability for Broadcast and Multicast

Services in the network (under Release 6) [4]. It is a p-t-m service, allowing network resources to be shared. MBMS is divided into 2 parts: the User Services [5] and the Bearer services [6]. The User Services are provided by the Core Network to the mobile end user by means of the MBMS Bearer Services. The Daidalos architecture provides the same functionalities with features of the IPv6 protocol stack and with its IP-based service platform. The Bearer Services describe the operation of the radio link between the Radio Access Network (RAN) and the MT, and the capability to deliver IP multicast datagrams to multiple receivers using minimum network and radio resources.

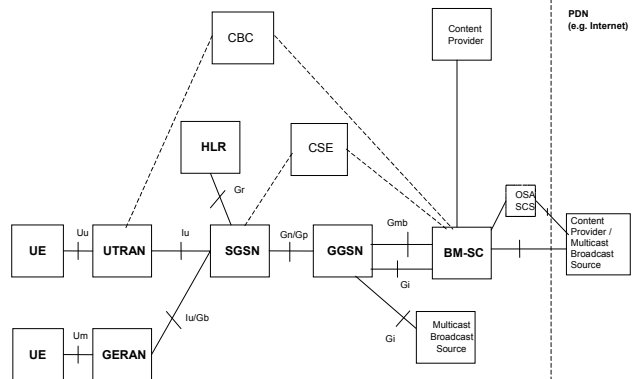


Figure 2. 3GPP reference architecture model

Figure 2 shows the 3GPP reference architecture model for MBMS. It enables the efficient usage of radio-network and core-network resources, with an emphasis on radio interface efficiency.

MBMS is achieved by the addition of new capabilities to existing functional entities and by the addition of a new entity, the Broadcast-Multicast Service Centre (BM-SC). The BM-SC provides functions for MBMS user service provisioning and delivery. It may serve as an entry point for content provider transmissions. It can also be used to authorize and initiate Bearer Services within the network, and to schedule and deliver MBMS transmissions. New features are introduced in the MT (or User Equipment, UE) to provide the user with MBMS services, mostly functions for the activation or deactivation of the bearer service and appropriate security. The UTRAN (Universal Terrestrial Radio Access Network) is responsible for efficiently delivering data to the service area, which is a strong requirement in the design of the MBMS service. It executes the start and stop of MBMS transmissions as requested by the CN. The SGSN (Serving GPRS Support Node) performs bearer service control for each individual MT and provides MBMS transmissions to UTRAN. The GGSN

(Gateway GPRS Support Node) serves as an entry point for IP multicast traffic as MBMS data.

Another important feature of the Bearer Service is its phasing model. The main steps of this model are described below. In this model, the AR and the MT operate independently. The first phase is the MBMS user service announcement / discovery when users can request or be informed about the services available. Joining (i.e. MBMS multicast activation by the user) is the process by which a subscriber joins a multicast group, i.e. the user indicates to the network that he/she wants to receive Multicast data of a specific MBMS bearer service. Session starts when the network is ready to send data. It is the trigger for bearer resource establishment and data transfer. During Notification, the MTs are informed about current and future MBMS multicast data transfer. In the data transfer phase, MBMS data are received by the MTs. Session stops when the network determines that there will be no more data to send for some period of time – this period being long enough to justify removal of bearer resources associated with the session. Finally, leaving (i.e. MBMS multicast deactivation by the user) is the process by which a subscriber leaves a multicast group.

Adding the MBMS Bearer Service required some modifications to the UMTS platform, both in the AR and in the MT. They were designed with the constraint to follow as much as possible the 3GPP specifications, even though most of them were still draft documents at the time of this study.

3. Integration of an MBMS bearer in the Daidalos architecture

3.1. General issues

The objective of this study is to evaluate the possibility and impacts of enhancing the "Pure-IP" UMTS platform and integrate it in a system providing both point-to-point (p-t-p) and p-t-m capabilities. This enhancement means adding the MBMS Bearer Service functionality to the platform, included inside the general IPv6-based Daidalos architecture, while preserving the benefits of the original "Pure-IP" architecture. For this integration, we assumed the possibility to apply to the MBMS architecture the same modification performed to the p-t-p architecture and to adapt it to our requirements. This means that the basic 3GPP network nodes from the Core network are replaced by a single node, the AR, receiving directly the IPv6 multicast packets and routing them towards the UMTS Access Network. The lower radio layers of the UMTS sub-system being compliant with the 3GPP standard (Radio Interface Protocol), they will be enhanced according to the MBMS specification [3].

Figure 3 shows a simplified version of this adaptation. The p-t-m radio link is almost identical to its description in the standards. The cell is controlled by the UMTS AR, which establishes on request, as will be described later, an MBMS bearer; it also establishes an interactive return channel that can be used to carry bi-directional signaling. In the access network to which the AR belongs, some Service Provisioning entities provide functionalities similar to those of the BM-SC. A Content Adaptation Node is able to match the multicast flow to the reduced bandwidth provided by the UMTS physical layer.

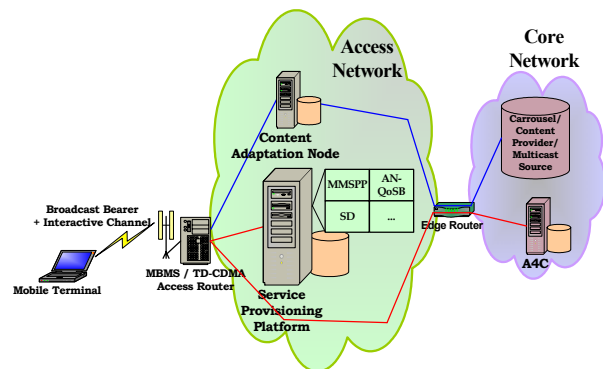


Figure 3. MBMS in a "Pure-IP" architecture

The arbitration between the 3GPP specifications and the standard IP multicast was performed on both directions. The integration of MBMS was adapted to conform to the "pure-IP" architecture, as described below. The Daidalos system was also modified to support some of the constraints introduced by the UMTS radio interface and its connection-oriented property (these constraints are different from the ones required to support IP multicast over DVB or WLAN).

One of these constraints is the need for content adaptation. Based on a study performed by the DVB consortium, we know that the video resolution adapted to a UMTS phone or a PDA (Personal Digital Assistant) would fit in a 384 kbit/s bit rate, when the same flow would use 10 or 20 Mbits/s for a TV set. Audio and Video content should be adapted according to the bit rate requirements corresponding to the capabilities and constraints of the destination node.

3.2. Service Activation

Another issue is that the UMTS is not a broadcast-dedicated technology like DVB. The MT is supposed to be able to support simultaneous services (for example the user can originate or receive a call) whilst receiving MBMS video content. This means that the MT resources (battery, processing power ...) must be shared with unicast traffic (same resources bandwidth

in the cell), and so the MBMS radio bearer should be allocated only when needed. The reception at the MT must also start only when (and if) needed. Some prioritization of services must be performed based on its capabilities, between MBMS and non-MBMS bearer services.

Because the radio channels must be established dynamically, the Phasing model described in section 2.3. has been adapted to the multicast service activation in Daidalos. It requires that the entities controlling the activation of the MBMS bearer interface with the upper layer entities at the service level.

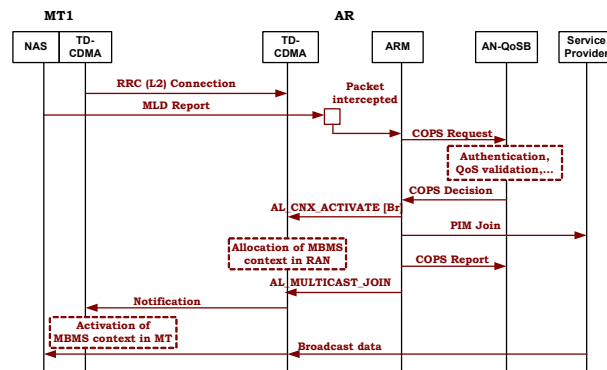


Figure 4. MBMS service activation

Figure 4 shows the MBMS service activation. First, an RRC connection is established between the UMTS radio interfaces of both MT and AR, to allow for messages exchange between these two modules. Then, the MT sends an *MLD (Multicast Listener Discovery) report* to join a multicast tree. In the AR, a Layer 3 module, which includes advanced functionalities for the establishment, maintenance and management of the multicast network (Advanced Router Mechanisms – ARM), intercepts this message and sends a *COPS (Common Open Policy Service) [7] Request* message to the QoS Broker in the access network (AN-QoSB) to authorize the multicast session. The AN-QoSB checks the user profile to decide if the user can have access to the requested service with its characteristics. It also checks if the available resources are sufficient to setup the required tree and to receive the service with the requested QoS. The AN-QoSB sends back a *COPS Decision* message with information on the service authorization. If the answer is positive, the AR activates the establishment of a connection in the UMTS layer (*AL_CNX_ACTIVATE*), which will then trigger an MBMS context in the RAN, and sends a *PIM (Protocol Independent Multicast) Join* message to the service provider, requesting the respective content. In the AR, the join in the multicast group of the UMTS

is also triggered (*AL_MULTICAST_JOIN*), and a notification is sent to the MT to activate the MBMS context. At this stage, the MT is able to properly receive the broadcast content.

The next section describes the implementation of the above mentioned functionalities to integrate MBMS in the Daidalos network.

4. Current implementation and first results

4.1 UMTS platform enhancements

The addition of the bearer service requires the enhancement of the UMTS platform at several levels.

The middleware described in section 2.2 must be modified in the AR to receive requests from the upper layer entities to establish or release resources when a multicast program starts or stops, and to forward notifications to the RRC layer about a MT joining or leaving a cell. This is a deviation from the 3GPP standard, where the MT is able to receive this information directly from its upper layers. Of course, both sides of the middleware must be able to forward multicast datagrams between the IP protocol stack and the MBMS bearer.

The major impact applies to the RRC protocol layer, which executes the resource establishment and release in the AR and the MT when requested by the network. The additional functions cover the establishment and release of the p-t-m Radio Bearer and the control of the MBMS activity in each node. These changes consist in adding new procedures, messages and parameters, as described in section 4.2, and modifying some of the unicast procedures. The other layers of the radio interface are not so severely impacted. The main change consists in the addition of new logical channels, the MCCH (for MBMS Control), MSCH (for MBMS Scheduling) and MTCH (for MBMS Traffic) in the MAC layer. These channels are very similar to the well-defined Common Control Channel (CCCH) of former 3GPP releases [3].

4.2 First results with the RRC protocol

The enhancements described in this paper are under progress. The major impact on the RRC is already implemented and tested.

In the UMTS Radio Interface [8], the RRC protocol layer handles the control plane signaling at level 2+ between the MT and the network. Its messages carry the parameters needed to setup, modify and release layer 2 and layer 1 resources. The RRC operation is defined as a set of procedures, specifying the behavior of a MT, and consequently that of the network. In the MBMS version of the RRC protocol, some procedures

have been introduced to describe the MBMS scheduling, the reception of MBMS control information and acquisition of information transferred on the MCCH, the MBMS notification by the network and the configuration and activation of the p-t-m radio bearer.

According to the Daidalos architecture, all the triggers are issued by the upper layer entities at service level in the AR. There are two groups of requests. The first group is similar to both the unicast requests for resource establishment, and to the request to start (or stop) an MBMS service. When such a command is received by the RRC in the AR, the p-t-m radio bearer is configured and activated, and the multicast session can start. A message indicating the modified services is sent on the MCCH channel to inform the users who previously joined the session that they can start listening. The second group of requests is somehow a deviation from the standard. As a user can join a multicast session only if he is authorized to do so, the information is not passed directly in the MT from the upper layers to the RRC. It is rather sent in a Notification message received in the AR and forwarded by the RRC to the concerned MT in a dedicated "MBMS Modified Services" message, which has been adapted to this usage. The MT is then able to acquire the p-t-m configuration and start listening to the multicast session.

The implementation required an extension of the Service Access Point (SAP) interface between the RRC and its upper layer. The establishment requests, not related to any specific MT, are transferred through the General Control SAP, while the second group goes through the Dedicated Control SAP associated with the target MT. The experimentation has also shown the need to maintain a detailed Finite State Machine (FSM) in both the AR and the MT in order to avoid contention cases and ensure a synchronized operation of the p-t-m radio bearer in both nodes. Some simulations were performed, first with a standalone demonstrator containing only the RRC messages and the MBMS scheduling, but allowing the simulation of several MTs. Later on, the UMTS platform simulator was used, where the new SAP interface described above was implemented. Some tests with scenarios activating and deactivating randomly several radio bearers were executed. Playing with these tests and scenarios generated many results that had not been foreseen in the initial study. Even though the MT and the AR are uncorrelated in the Phasing Model, the decision of action to be taken in the MT depends on the notifications from the AR, but also on the presence of the multicast session in the Modified, Unmodified or Activated Services Lists it maintains. The simulations introduced major refinements in the FSMs of these

entities. The main lesson learned is that a tight coupling across the layers in the MT, the AR and network related entities is mandatory, which is not standard in p-t-m communications. It is also important that they know each others' capabilities. Both RRC peer entities must keep track of their own status as well as their peer's, which can be achieved through the MBMS scheduling scheme made of modification and repetition periods [9].

The implementation also takes into account scalability issues in the messages handling, in order to avoid problems, e.g. in the case when many users join the same session in a short time frame. The case of an MT listening to a non-existing p-t-m radio bearer did also arise and had to be carefully removed.

5. Future evolutions

As the platform is close to provide the stable transfer of IP multicast packets over a point-to-multipoint radio bearer, we are entering a new project phase, enhancing this functionality and experimenting new capabilities. This research activity will target our two main topics of interest, mixing them when possible. They are QoS and Terminal Mobility.

5.1. QoS considerations

In 3GPP, the network controls the QoS parameters for sessions of MBMS bearer services. Compared to p-t-p bearer services, only the background and streaming traffic classes are considered. MBMS bearer services of background class are best suited for the transport of MBMS user services such as messaging or downloading. The streaming class is mostly for the transport of services such as streaming. As for p-t-p services, the network should minimize the packet transfer delay of streaming class bearer services as far as possible. The Allocation and Retention Priority of the MBMS bearer service allows for prioritization between MBMS bearer services, and between MBMS and non-MBMS bearer services.

The number of users within a cell prior to and during MBMS transmission could be used to choose an appropriate radio bearer, either dedicated or MBMS. In the same idea, in order to achieve some resource optimization, the network entities may decide to move users from p-t-p link to p-t-m link and vice-versa. This may be very beneficial when the number of users, in the same or in neighboring networks, receiving the same content increases. This process needs to address several issues. Some of them can be listed as: (1) unicast to multicast switching and vice-versa; (2) control information to recognize that the same content

is sent to “neighboring” users; (3) signaling overhead for the switching processes vs. unicast traffic overhead.

5.2 Multicast mobility

In the MBMS specification, the UTRAN is supposed to support the mobility of MBMS receivers, both inside and outside of its service area. This mobility may cause some limited data loss and MBMS user services should be able to cope with them.

In our architecture, mobility for unicast traffic is performed by using Mobile IPv6 features. As stated in [9], MIPv6 only roughly treats multicast mobility. Several topics have to be studied and resolved for terminal mobility, such as the multicast tree reconstruction after a handover and the temporary flow interruption. When the Mobile enters a new cell, it may face several cases. If the MBMS bearer is already established in the cell, the Mobile just starts listening to that flow. In another case, the new AR may be able to handle MBMS bearers, but the session is not started in its cell and the handover must be executed while limiting the data loss. Quite different is the case when the AR is not able of operating MBMS, and the traffic must be transferred to a dedicated radio channel. The handling of these decisions could be improved by a handover preparation phase and the use of context transfer for the multicast session [11].

Besides the study of intra-technology handover, as the Daidalos architecture supports heterogeneous access technologies, it enables the study of inter-technology handovers, when the Mobile moves, for example, from a DVB cell to an MBMS cell.

6. Conclusion

This paper presented the implementation of a multicast radio bearer in an experimental UMTS platform and its integration in the 4G architecture developed inside the European research project Daidalos. This integration required some modifications in most of the Radio Interface, and also impacted the IP-based Service layers, which had to take into account the connection-oriented property of UMTS resource activation. The simulations described in the paper focused on the RRC protocol and demonstrated the need for tight coupling between the Mobile Terminal and the network, at the opposite from traditional broadcast technologies. Future evolutions of this integration are planned towards an enhanced QoS support and heterogeneous mobility.

This study has allowed an early evaluation and understanding of the convergence of the mobile/cellular telecommunications world with the broadcast/media world. This is the first step for the

development and support of seamless handover between these technologies (from different worlds), while guaranteeing the level of QoS contracted by the user with his operator.

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