

SVC Multicast Video Mobility Support in MEDIEVAL Project

Sérgio FIGUEIREDO¹, Michelle WETTERWALD², Tien-Thinh NGUYEN², Lucas
EZNARRIAGA³, Noam AMRAM⁴, Rui L. AGUIAR¹

¹*Instituto de Telecomunicações, Aveiro, Portugal, {sfigueiredo, ruilaa}@av.it.pt*

²*EURECOM, Sophia Antipolis, France,
{michelle.wetterwald, tien-thinh.nguyen}@eurecom.fr*

³*Institute IMDEA Networks, Spain, lucas.eznarriaga@imdea.org*

⁴*LIVEU, Israel, noam@liveu.tv*

Abstract: The foreseen explosion in online video traffic over the upcoming years has left current mobile operators struggling to maximize their networks capacity and efficiency. MEDIEVAL project aims to evolve existing architectures through relevant cross-layer interactions, permitting to deliver expected QoE levels to users. In order to alleviate the impact of online video which potentially could be shared by a group of users in the core network, as well as maximize transport efficiency, the utilization of multicast and broadcast mechanisms is proposed. Moreover, the combination of multicast and network-based mobility protocols results in new problems which must be solved necessarily through network support. By using multicasting SVC, where a video is composed by one base layer and possibly multiple dependent enhancement layers, a single session may traverse the whole core and be adapted to the different terminal's characteristics.

In this article, we present the research being developed towards mobile multicast support in future networks, describing solutions for improving wireless access efficiency (in 802.11 and LTE), and for enabling IP multicast mobility support. Furthermore, the end-to-end (e2e) support provided by MEDIEVAL in a SVC-based Personal Broadcast Service (PBS) scenario is analyzed, where both mobile multicast listeners and sources participate. The interfaces enhancing mobile video support are examined, along with the key exchanged parameters.

Keywords: MEDIEVAL, video services, multicast.

1. Introduction

Recent studies have pointed to the explosion in mobile video traffic, leading to a great amount of research in several fields such as wireless access, network transport, content adaptation or traffic offloading mechanisms. One of these research efforts is being developed in MEDIEVAL [3], which relies on several cross-layer interactions for enhancing each layer with relevant information and the intelligence to process it. This provides such features as congestion-aware mobility operations, QoE-aware connectivity management, among others. In order to alleviate the impact of video in the core network and to maximize transport efficiency, the utilization of multicast and broadcast mechanisms is essential. The inclusion of these technologies in mobile video scenarios leads to problems such as IP multicast mobility support, selection of the proper SVC packetization scheme, and multicast wireless transmission mode selection. Besides, possible solutions need to be smartly adapted to each scenario. This article showcases the research being developed on multicast video support in future networks, and its structure is as follows. Next section briefly introduces the proposed MEDIEVAL architecture, listing its main sub-systems. Furthermore, it describes SVC multicasting, and gives an insight of the research being elaborated on multicast wireless transmission and mobility solutions. In section 3, the e2e

support provided by MEDIEVAL in a SVC-based Personal Broadcast Service (PBS) scenario is analyzed, considering both mobile multicast listeners and sources. The interfaces enhancing mobile video support are examined, along with the key exchanged parameters, before concluding the paper.

2. Downstream Multicast Modules in MEDIEVAL

2.1 Overall Architecture Concepts

MEDIEVAL architecture is designed towards the efficient delivery of mobile video in wireless networks, which is achieved through the interplay of four main subsystems architected in a cross-layer fashion. The role and main functions of those subsystems is described in [3] and summarized here: a) the **Video Services Control** deals with the provision of MEDIEVAL services to users, by providing the link between applications and network mechanisms; b) the **Transport Optimization** engineers optimized video traffic on the mobile core network, introducing intelligent caching and offloading, supported by Content Delivery Networks (CDN)s; c) the **Mobility Management** handles IP mobility, following a distributed and per-flow basis; d) the **Wireless Access** is responsible to adapt video transmission on the underlying wireless technologies, by taking into account both contention based (IEEE 802.11) and coordination based (LTE-A) technologies.

2.2 Video Layering

Previous works have explored SVC as a method to deliver layered multicast video [1], with its advantages over simulcast delivery coming from the protocol inherent scalability options (in terms of spatial, temporal and quality-driven levels), which is turned into efficiency. A SVC stream is constructed from NALUs (Network Abstraction Layer Units) to represent a part of the picture's encoded bit stream, which belong to a single layer. The stream is constructed from a basic layer which is not dependent on any other layers, and enhancements layers, dependent on lower layers. Due to this scalable property, the SVC encoding is an ideal technique for providing multimedia multicasting to heterogeneous networks and devices as explained here and in section 3.

In order to transport multicast SVC in RTP packets over heterogeneous environments, Multi-Session Transmission (MST) was specified in [2]. Using this mode, multiple RTP sessions are used to carry the SVC data. Albeit, depending on the application requirements, this may translate into transporting one layer per RTP session or encapsulating multiple layers in one RTP session, by using a Media-Aware Network Element for aggregating RTP sessions into a single RTP stream for each client (unicast) or group (multicast). Besides, different layer combinations (base layer only, enhancement layer(s) only or base and enhancement layer(s)) are possible. Additionally, distinct packetization modes exist.

2.3 Mobility

Efficient mobility support is one of the key issues in MEDIEVAL architecture. It follows a flat mobility architecture, which is based on the distributed mobility management (DMM) [7] concept. The proposed solution provides mobility services only for the IP flows (and/or applications) that really require service continuity. As such, the centralization placed at the data and control planes in anchor modes (e.g. Home Agent (HA) in MIPv6 [16]) is considerably reduced along with the number of required mobility tunnels. MEDIEVAL places a significant effort in solving these and other issues [7][8], and to apply this knowledge to IP multicast sessions.

In MEDIEVAL, the access network is organized in Localized Mobility Domains (LMDs) in which a network-based mobility scheme is applied. Users are expected to be most of the time roaming within a single LMD, but, for the cases where this is not possible (e.g. roaming to a network owned by a different operator or running a different mobility support scheme), a host-based approach is followed. In order to integrate both approaches, a novel architectural element called Mobility Access Router (MAR) is introduced - a network entity implementing all the functionalities of its counterparts from the standard mobility protocols (MIPv6 and PMIPv6 [15]). Therefore, it is able to play the role of plain access router, HA, local mobility anchor (LMA) and mobile access gateway (MAG) on a per address basis. IP multicast mobility is only considered in the intra-LMD case. If the mobile node (MN) changes LMD, multicast traffic will be disrupted and will need to subscribe again to the content (for listener mobility) or to use a different source address (for source mobility).

Two possible methods of multicast mobility support are considered, and can be derived for both the source and the listener: (i) using a tunnel between the previous MAR (A-MAR) and the serving MAR (S-MAR), or (ii) using the multicast infrastructure for sending/receiving the traffic. Besides, a MAR can act as a MLD Proxy (as in [17]) or multicast router (MR).

The first method follows the unicast mobility solution as proposed in [9], and the multicast traffic is sent through the mobility tunnel. This behaviour resembles that of PMIPv6: the A-MAR, where the flow was initially created, plays the role of Local Mobility Anchor (LMA) while the S-MAR is analogous to the Mobile Access Gateway (MAG). However, the existence of the tunnel raises some issues like packet and processing overhead, and non-optimal routing. Moreover, when multicast listener mobility is considered, the tunnel convergence problem needs to be taken into account, especially in highly mobile environments [10].

The second method takes advantage of the native multicast infrastructure for delivering multicast traffic, hence avoiding the tunnelling overhead. However, this solution implies some modifications to the multicast protocol when multicast source is considered.

Our work is evaluating all possible methods in order to find the most appropriate one for each scenario, namely PBS and Mobile TV. At the moment, we consider the best option is to apply the first method for multicast source mobility, and the second one for multicast listener mobility, as described below.

Multicast Source Mobility

As aforementioned, the considered method for source mobility support follows the unicast mobility solution as proposed in [9]. When mobility occurs, the multicast traffic is routed through the mobility tunnel from the S-MAR to the A-MAR, and then is transmitted to the multicast tree and to the listeners using multicast routing protocols. As a result, the activation of Shortest Path Tree (SPT) using this scheme seems not to provide any advantages since the traffic would follow a similar route to the listeners, and pass by the A-MAR. Moreover, it would bring signalling overhead which is proportional to the amount of listener's Designated Routers (DR) and to the number of PIM Joins/ Prunes [11].

From source multicast point of view, although this method involves the processing and signalling burden related to the tunnel, it is the easiest way to deploy and brings more advantages in mobile scenarios. Namely, the A-MAR may be set as the RP of the session (which implies multicast routing functionalities at the MAR), making sure the tunnel endpoint is simultaneously the RP. As such, the stability of multicast delivery tree is guaranteed. Besides, no extension is required for the Protocol Independent Multicast Sparse Mode (PIM-SM [11]) protocol.

Multicast Listener Mobility

Using the second method, the S-MAR simply sends join messages to the neighbour DRs on behalf of the MN. Thus, the multicast traffic is routed directly from the native multicast infrastructure to the S-MAR, and the mobility tunnel configured for unicast is not used for multicast operations.

When moving between MARs, a multicast listener experiences a certain delay in receiving multicast content, because of the extra time related to the MLD Report transmission, and possible PIM signalling by S-MAR, comparatively to unicast sessions. This means that the strict requirements of real-time applications like HD live video may not be fulfilled. Thus, a solution incorporating multicast context transfer is recommended for solving this problem. Thus, Context Transfer is proposed for exchanging multicast-related information between two MARs. Upon receiving the request from its Flow Manager (FM), the S-MAR triggers a Context Transfer request towards the A-MAR to request the MN's active multicast subscription information. More details on the handover preparation can be accessed in [14]. The receiving MAR will check multicast subscription information regarding the corresponding MN, based on multicast group management protocols. It then replies to the S-MAR with a Context Transfer response message which corresponds to the MN's multicast-related information. Upon receiving the multicast subscription information, the S-MAR joins the necessary multicast trees. From that instant, the multicast content is ready to be sent to the MN.

2.4 Wireless Access

MEDIEVAL cross-layer enhancements for video transport also require optimization on the multicast wireless access for both of the employed technologies: contention-based IEEE 802.11 WLAN and coordination-based Long Term Evolution (LTE).

Regarding MEDIEVAL contention-based access, the goal is to compute the MAC parameters which achieve the optimal performance taking into account the cross-layer packet marking for every video flow. However, current IEEE 802.11 standard [4] does not allow for intra-flow differentiation (e.g., prioritize an SVC video layer over another), and multicast transmission, namely No Ack/No Retry, offers poor performance. It imposes low rates and provides reduced reliability against collisions or interferences due to the lack of MAC-level recovery procedures (see Figure 1 a).

To address the previous limitations, IEEE 802.11aa Task Group [5] has: (i) defined the Groupcast with Retries (GCR) service which increases the reliability of group addressed frames (multicast groups) by employing Unsolicited Retry (UR) or the extension of Block Ack mechanism defined in IEEE 802.11e for multicast; (ii) adapted the already existing Directed Multicast Service (DMS) defined by IEEE 802.11v to group addressed frames; and (iii) defined a Stream Classification Service (SCS) which enables classification using layer 2 and/or 3 signalling (hence leveraging MEDIEVAL cross-layer packet marking) and allows for intra-Access Category (AC) Traffic Stream (TS) prioritization.

GCR UR preemptively retransmits a frame one or more times (up to a certain lifetime limit), to increase the delivery probability at the stations without introducing the associated overhead of an acknowledgement mechanism (see Figure 1b). DMS consists on the multicast to unicast conversion (as illustrated in Figure 1c for two group members). Hence, those frames transmitted to a multicast address are individually transmitted to each of the associated stations that joined the multicast group up to a retransmission limit. This mechanism provides high reliability but it has large scalability constraints as the required throughput increases with the number of group members.

GCR Block Ack transmits bursts of frames to a group address and sends BlockAck Request frames in turns to each GCR group member which replies with BlockAck frames.

There are two possible GCR Block Ack mechanisms: Immediate Block Ack in which the recipient of a BlockAck Request replies immediately with a BlockAck frame (Figure1d), and Delayed Block Ack, in which after receiving a BlockAck Request the recipient starts a backoff process before sending the BlockAck frame. With the Delayed Block Ack, BlockAck management frames are acknowledged with ACK frames (Figure1e).

The performance optimization for MEDIEVAL contention-based wireless access includes the design of an algorithm to choose the most appropriate multicast mechanism for a given scenario.

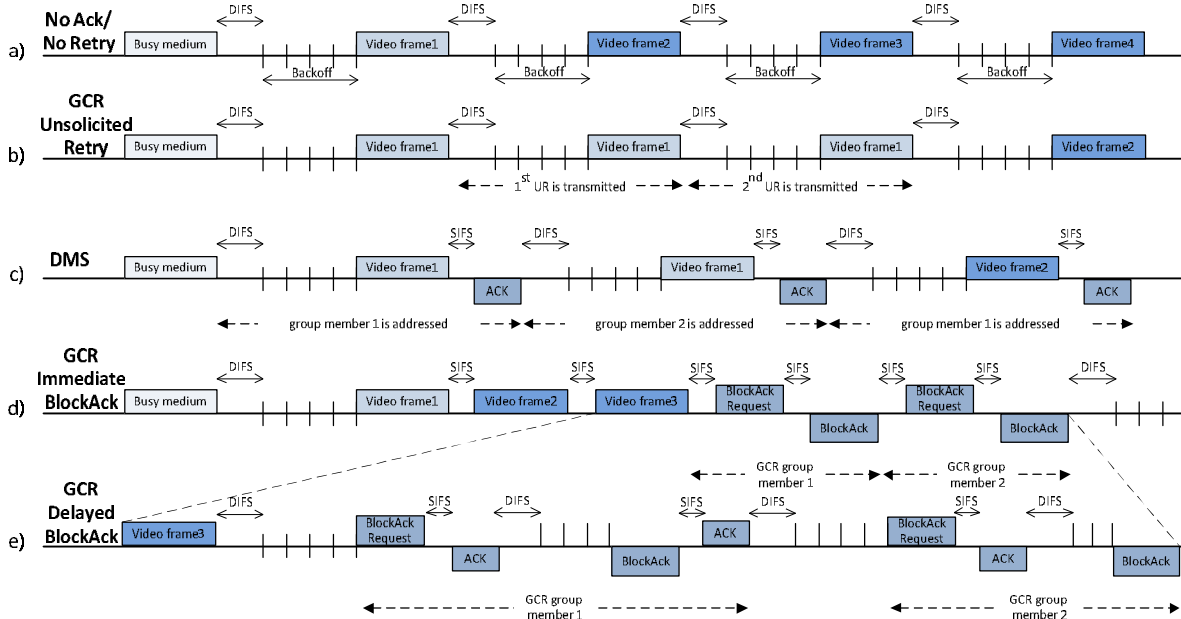


Figure 1: Example of video frames exchange for different group addressed frame MAC mechanisms

The eMBMS (evolved Multicast/Broadcast Multimedia Service) is an enhancement of the EPS (Evolved Packet System) which provides a point-to-multipoint capability for broadcast or multicast services, allowing resources to be shared in the network [12]. In the eMBMS version of the EPS [13], the broadcast mode is provided by tightly synchronised cells organized in semi-static MBSFN (Multicast Broadcast Single Frequency Network) areas. User mobility is ensured by the synchronization of the cells, with potential data loss being recovered by the applications. Multicast mode is not supported, which prevents from benefiting in a dynamic way of the resource sharing for sessions received by a reduced, but yet large enough, group. In MEDIEVAL, eMBMS is extended to provide several levels of QoS and improve its efficiency for the transfer of the video frames. Whenever possible, the opportunity of transferring the flow in a multicast bearer is exploited. The Session Start procedure is optimized to convey the maximum amount of information at once and reduce the number of steps needed for its completion, in particular by introducing some cross-layer parameters exchange to flatten the procedure at startup or handover.

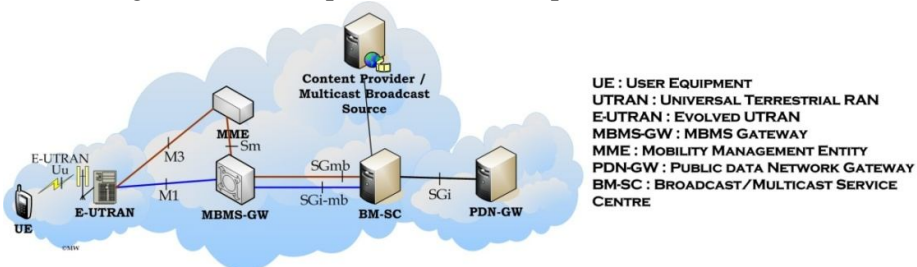


Figure 2: 3GPP Reference Architecture for eMBMS (without UTRAN)

The eMBMS model has been integrated in the global MEDIEVAL architecture. The eNodeB is considered as the LTE PoA while the WLAN AP is seen as a trusted non-3GPP access. The session start and resource setup procedures at eNodeB are executed when receiving the request from the FM. The control plane functions for the communication between the e-UTRAN and the MBMS-GW, collocated with the MME, are handled in the MAR. So far, the eMBMS does not really consider seamless mobility, which gives all freedom for a flexible solution. If the core network is multicast enabled, the multicast mobility procedures are executed. The MBMS-GW operates as a MR and is mapped to a combination of the FM and the MUME. If the network is not multicast enabled, the multicast tree starts at the MBMS-GW, linked with the existing functions for unicast mobility located in the MAR. In both cases, the final hop is multicast on the wireless link, as defined in the settings of the flow description. The BM-SC functions are located inside the Core Network. Multicast/unicast decision based on network conditions should be part of the transport optimization sub-system. In MEDIEVAL, this decision is made based on the service type (multicast is default for Mobile TV and PBS services). User service provisioning and announcement are handled by the Video Services Control which takes care of the streaming functions.

3. Architectural Operation

This section describes a Personal Broadcasting Service (PBS), depicting how MEDIEVAL architecture is expected to enhance mobile networks towards the efficient support of mobile and, live video. By PBS, we refer to a video service provided by the mobile operator in which the video content source is a network consumer i.e. any mobile terminal attached to the network that supports the service functions.

The scenario (depicted in Figure 3) is as follows: Mike has just started his own e-club channel for broadcasting video. Using this service, he shares with his subscribers the latest news and events in his town, thus sometimes needing to record on the move (represented in section (a) of the figure).

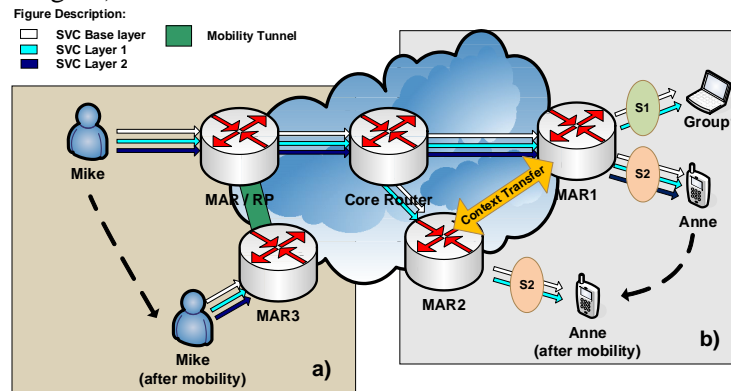


Figure 3. SVC multicast mobility scenario

Anne, one of his subscribers, has a MEDIEVAL-enabled mobile phone. As such, she wants to take the most of it, watching videos with high level of quality even when moving. The MAR where she started viewing the live video has already some subscribers requesting the same video (stream S1 in the figure), but with inferior level of quality associated to their profiles, either because of their terminal characteristics or due their service level agreement (SLA) with the mobile operator. At a later time, Anne is associated to a new MAR due to mobility; nevertheless the service is not interrupted.

3.1 Key Architectural Interactions

Finally, we delve into some of the crucial cross-layer communications that underpin the network behaviour throughout the previous scenario. One core protocol to achieve this in MEDIEVAL is IEEE 802.21 MIH (Media Independent Handover). A reader familiar to the architectural modules [3] is aware that entities acting as MIH users, both in the user terminal (Connection Manager - CM) and access network (previously referred FM), are able to act towards the selection of the best available access network, not only taking into account radio properties but also information such as the availability of multicast routing capabilities. Besides, IEEE 802.21 is used for tasks such as notifying a MAR which router is supposed to act as the A-MAR, required for the tunnel establishment. It is also involved in informing the wireless access layers of resources to be established, enabling multicast session and SVC frames priorities.

In order to support a node acting as multicast source, at the service request and registration the uplink provisioning must be initiated. As such, Mike's application requests the terminal properties and network conditions. When Mike's terminal is associated to a new MAR, its session starts to be tunnelled from the S-MAR to the A-MAR, which was configured as the Rendezvous Point (RP) for the session. Besides, a vital interaction occurs between the terminal's CM and the Content Adaptation (CA) module located in the network. CA receives input relative to network conditions, and in this particular case, is required for preparing the uplink before and after the occurrence of a handover operation.

Another feature introduced in MEDIEVAL is the interaction between transport-aware entities (Decision Module – DM) and mobility-related ones (e.g. FM). This interface avoids mobility operations towards congested access points, due to a candidate network weighting process, and other intelligent decisions.

A proposal is to use a different multicast group for each expected quality (temporal, spatial, SNR) set. This can be seen as a hybrid simulcast-layered solution, splitting the pros and cons of each transport mechanism. We foresee that in real networks the number of deployed layers per video will typically be low (e.g. four), and therefore the replication of information is bearable, and inferior to current simulcast proposals. On the other hand, most terminals will be spared from the SVC decoding effort, having an IP multicast session addressed to it. As such, when Anne starts receiving the video, MAR1 subscribes the missing layers, aggregates them in a single RTP session (represented as S2 in the figure) adapted to her terminal's needs.

In order to reduce the packet loss and delay during the mobility process, a multicast context transfer process, as described in section 2.4, takes place when Anne moves from MAR1 to MAR2. As the new MAR is informed by DM that there is limited bandwidth available in its upstream link to the core, it doesn't subscribe to all the layers corresponding to the expected quality by Anne, aggregating a lower-quality version in a new RTP session to the same multicast destination address. Such mechanism is analogous to the SVC layer drop that may occur at wireless transmission, but takes place before the last hop. This means that, having two versions of the same video, V1 and V2, where V1 has more enhancement layers than V2, at some point in time V1 may actually be delivered with the same quality as V2, by network decision. Regarding the example, when the context transfer takes place between MAR1 and MAR2, the DM, which establishes a mapping between the multicast group being requested and the effective layers to be requested, is responsible for informing the FM placed the MAR2 about the subscriptions to be made for this multicast session. In practice, it leads to MAR2 not joining all the multicast groups (layers) of the video during the congestion period. This same kind of content adaptation may also be done as a consequence of a different trigger, such as QoE level decrease.

At that point there would be a single user requesting that stream in MAR2, so an adaptation of the scheme in [6], in the case of LTE, or DMS mode in the case of 802.11, may be used, increasing transmission reliability. As soon as MAR2 verifies it is able to support a better (and more bandwidth-demanding) version of the video, informed by DM, it subscribes to the missing channels and aggregates them transparently to Anne's mobile.

4. Conclusions and Future Work

This paper focused on the work being developed in MEDIEVAL for video distribution towards groups of users in mobile environments. It also discussed the support of mobile video sources, which translates into a class of service we refer to as Personal Broadcasting Service. The involved mechanisms related to transport, multicast mobility and wireless access transmission were described, and pictured with the relevant decisions and parameters exchange in a small use case example based on the PBS scenario.

Future research will be aimed at simulation and experimental performance evaluation of the presented mechanisms, either solely or combined with each other.

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