Key Function Interfacing for the MEDIEVAL Project Video-Enhancing Architecture

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Abstract. The FP7 MEDIEVAL project, which started in 2010, has been defining the necessary evolutions over today's mobile Internet architecture, in order to more efficiently support the upcoming growth of video services, in mobile wireless environments. This paper evolves from these initial definitions, by taking into consideration the requirements placed by a core set of next generation video services and defining a global architecture. We describe its main functionalities and subsystems as well as the necessary interfaces, towards the operation of these services in different use cases.

Keywords: Wireless networks, Mobile communication, Video services, Radio optimization, Multicast/Broadcast.

1 Introduction

The FP7 MEDIEVAL [1] project (MultimEDia transport for mobIlE Video AppLications) focuses on the problems faced by mobile operators when confronted with the expected huge traffic increase caused by the explosion of video services. [2] reports that, by 2012, video will comprise over 50% of the overall Internet traffic, increasing to 62% by 2015. To address this problem, the project proposes a set of mechanisms that individually provide enhancements in the efficiency of video transport while cumulatively exploiting their cross-layer functionalities to boost performance. The project aims at providing novel solutions that can be fed into existing network solutions for mobile operators based on future evolutions of the 3GPP Evolved Packet System (EPS) architecture. The mechanisms targeted in this project include enhanced wireless support (with general abstractions to address heterogeneous wireless technologies), improved mobility (to allow opportunistic

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handovers across technologies), improved video distribution (with embedded caches in the network), and flexible video service provisioning and control (exploiting the interaction with video applications).These mechanisms are aimed to be incorporated to future cellular networks, allowing for multiple evolution paths towards the deployment of the MEDIEVAL architecture, which considers an integrated framework that includes all these mechanisms.

Initial design specifications for the MEDIEVAL framework have already been presented [3], including the key requirements as well as goals and building blocks of the architecture [4]. Different parts of the project architecture have been covered in specific works, such as [5] for enhancement of wireless accesses, [6] for evolved mobility management procedures and [7] for transport optimization mechanisms over cellular networks. In this paper, we evolve these primary descriptions with the global architecture definition of the MEDIEVAL project, describing its main functionalities and subsystems as well as their interfaces, towards the support of a core set of video services operating in different use cases.

The remainder of this paper is organized as follows. Section 2 identifies a set of video services that establish the key requirements to be satisfied by MEDIEVAL. Section 3 presents a definition of the MEDIEVAL subsystems, with the project functionality split among them. This is followed by Section 4 which describes the interfacing used between modules of different subsystems. Section 5 presents a set of use cases that illustrate the functionality that the MEDIEVAL architecture has to support, identifying interactions of the different subsystems. Finally, we conclude in Section 6.

2 MEDIEVAL Services

The MEDIEVAL services refer to a list of challenging user services which are expected to dominate the traffic over the wireless networks in the near future. The MEDIEVAL architecture is studying and defining novel mechanisms and network procedures that enable such services to be deployed in an optimized way. The following sub-sections briefly describe the characteristics of these services, while highlighting challenges on how to interface the different sub-systems to support them. From these services we are able to derive a set of general requirements, which provide the base architectural areas of the MEDIEVAL framework.

2.1 Personal Broadcast

This is a content distribution service, based in [8], where each user is able act as a Content Provider (CP) to generate content and forward it to a group of other users, as a broadcast or multicast session. This requires the CP to own a subscription with a Service Provider (SP), which takes care of the mechanisms and technologies involved in the content delivery. When the CP wishes to produce some new content, it opens the service indicating the type of content (e.g., audio, video), allowing the SP to establish the necessary resources in terms of wireless access. This service procedures supports advanced MEDIEVAL mechanisms such as bandwidth aggregation, content splitting over a number of wireless networks, or using relay servers to store the information and disseminate it later on a per-request basis, or with different encoding options.

2.2 Mobile TV

Mobile TV [9] combines the two bestselling consumer products in history: TVs and mobile phones. It allows the users to watch TV in mobile devices while stationary or on the move, indoors and outdoors. Currently most operators are supporting Mobile TV services through non broadcast services over the available 3G technologies such as Universal Mobile Telecommunications System (UMTS) and High-Speed Downlink Packet Access (HSDPA). Maintaining this service over HSDPA is viable for now for many operators, but it is expected an exponential growth of users and only a Long Term Evolution Advanced (LTE-A) [10] based infrastructure might prove to be viable in both service quality and capacity on the long run. When concerning Mobile TV, MEDIEVAL targets to provide the best user Quality of Experience (QoE) by matching the Mobile Node (MN) characteristics, the profile of the user and extrapolated knowledge of the video into the network capabilities and performance. It forces adaptation of individual flows in order to improve the general aggregated QoE while predicting and evaluating the impact of such changes on the individual QoE, adapting where it produces the least individual impact but the best aggregated improvement.

2.3 Video on Demand

Users today want to consume what they want, when they want. Video on Demand (VoD) applies this concept to video. With a VoD software on a device, whether a set-top box, media centre, PC, tablet, smart phone, etc, the user can select a video and have it sent to the device for viewing on-demand. With the large number of high bandwidth wireless access technologies available today, the continuous user mobility and the rapid evolutions in mobile computing and communication technologies, mobile VoD has already gained its significant importance among mobile users. With an infrastructure/network equipped with high bandwidth capacity and the ability to guarantee better QoE, operators have early assumed a steady position as SPs in the VoD market in both fixed and mobile VoD. However, operators are no longer alone in the business as third party providers have also came up as a high competitor, a lot due to the recent massive integration of high bandwidth access technologies in the core/operators' networks. MEDIEVAL project aims to provide an architecture that is able to support VoD services for mobile users. For this, it will employ network access link information gathering and traffic optimization in accordance to the mobility scheme adopted by the MNs, and able to be supported by the content.

2.4 Derived Requirements

The previous presented services drive the key requirements of the project, as follows:

- Improve the user experience by allowing the video services to optimally customise the network behaviour.
- Optimize the video performance by enhancing the features of the available wireless accesses in coordination with the video services.

- Design a novel dynamic mobility architecture for next generation mobile networks tailored to the proposed video services.
- Perform a transport optimization of the video by means of QoE driven network mechanisms, including Content Delivery Networks (CDN) techniques and network support for Peer-to-Peer (P2P) video streaming.
- Introduce multicast mechanisms at different layers of the protocol stack to provide both broadcast and multicast video services, including Mobile TV and Personal Broadcast.

3 MEDIEVAL Architecture

The MEDIEVAL architecture relies on a cross-layer design which exploits multiple areas impacting the enhanced support of video transport with mobility support over wireless networks. The MEDIEVAL architecture is composed of four subsystems depicted in **Fig. 1**, namely video services control, wireless access, mobility and transport optimization, described in the following sub sections, followed by a description of the global physical MEDIEVAL deployment.

3.1 Video Services Control

The main focus of the Video Services Control subsystem is to provide MEDIEVAL services to users. It is responsible for linking these to the underlying network delivery entities, enabling their reliable delivery over an evolved mobile network while offering improved resource utilization towards an enhanced user experience. The service defines a set of innovative service controllers allowing the operation and management of new video-related services:

3.1.1 Provisioning

This component stores information related to user, content and service provisioning. This data is aggregated to provide applications with the ability to register users and personalize the streaming functions according to service capabilities, such as supporting dynamic IP address changes and multicast delivery.

3.1.2 Session Management

This component is responsible for a set of two actions. The first one is the management and monitoring of service sessions. It initiates services and creates session context from information collected from the different involved network elements. The second one relates to the QoE engine and video control, coordinating different functions in collecting offline information about the video reception. This information is then translated into instructions on how to best stream the content, encoding parameters to use, and other QoE-optimization mechanisms.

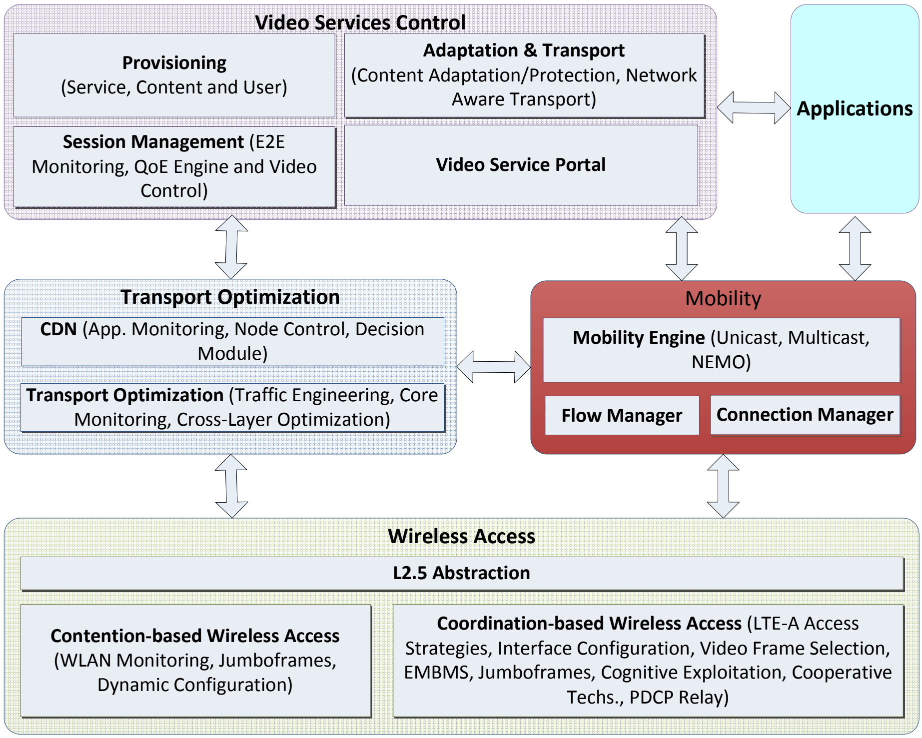

Fig. 1. The MEDIEVAL architecture design

3.1.3 Adaptation and Transport

This component is responsible for adapting the generated content to network conditions. In this way, content attributes can be adapted on the fly, have Forward Error Correction (FEC) codes generated to protect the content from corruption and loss, as well as maximizing QoE based on network conditions awareness.

3.1.4 Video Service Portal

The Video Service Portal (VSP) allows the advertisement of services and content to users. It contains interfaces that aim to simplify service management by application clients, and allows the sending of MN-related information through the network to the source.

3.2 Wireless Access

For wireless access, MEDIEVAL considers contention-based (e.g., IEEE802.11 Wireless Local Area Networks (WLAN)), and coordination-based (e.g., LTE-A) techniques. The main focus is to develop novel mechanisms to enhance video transmission over these wireless accesses, allowing adequate QoE support and cross-layer optimization [11]. This optimization is accomplished by a set of functions made available towards high-level entities which abstract the interactions with the different link technologies:

3.2.1 L2.5 Abstraction Layer

This is the heart of the video delivery optimization process, as it provides the means for the interaction between the radio access network and the upper layers in order to accomplish cross layer functionalities and underlying technologies transparency. This is made possible by the provisioning of optimized abstract interfaces with both upper and lower layers, enhancing and extending the Media Independent Handover concepts and components from IEEE802.21 [12].

3.2.2 Contention-Based Wireless Access

MEDIEVAL focuses on the IEEE802.11aa amendment [13] which provides enhanced multimedia services to WLAN. It also introduces three added main mechanisms. The first one is Dynamic Configuration, which uses classification functions, able to inspect special markings at the headers of IP packets, to decide the best unicast and multicast configuration. The second one is WLAN monitoring which retrieves link performance measurements for triggering optimization processes at the appropriate time. Lastly, MEDIEVAL is evaluating the usage of Jumbo frames mechanisms aiming for throughput increase.

3.2.3 Coordination-Based Wireless Access

This component has been divided into several functional controllers. Controller number one considers video frames selection and interface configuration, affecting traffic when the wireless access is congested. Controller number two considers the cognitive exploitation of cooperative technologies, considering a cross-layer exploitation of video flow characteristics and link resource allocation. Controller number three employs measurements and medium access strategies, which provides rich PHY channel measurements towards decision entities. Controller number four considers the support for Evolved Multimedia Broadcast and Multicast Services (eMBMS) [14] optimizations. Controller number five introduces a new relaying scheme by forwarding packets at the Packet Data Convergence Protocol (PDCP) level. Lastly, controller number six evaluates the applicability of Jumboframes into LTE-A.

3.3 Mobility Management

Operators are migrating their infrastructure to full-IP based networks – for both voice and data – and therefore they need efficient IP mobility solutions that could be used to handle user device mobility, not only between access networks of the same technology, but also between different networks of different technologies. The mobility subsystem is based on the Distributed Mobility Management (DMM) concept [15] and enriched by its per-flow granularity awareness, which enables to provide differentiated treatment to video data packets – depending on their requirements – and to other traffic. It is composed by three components: Connection Manager (CM), Flow Manager (FM) and Mobility Engine (ME).

3.3.1 Connection Manager

The CM is capable of handling the access technologies in the MN such as powering on and off of network devices, performing scans and monitoring link layer conditions. The CM detects radio coverage issues and can send mobility triggers to the appropriate module. In addition it can perform access network discovery to select handover candidate. Given the nature of the heterogeneous wireless access the CM leverages the IEEE 802.21 protocol to achieve the above functions.

3.3.2 Flow Manager

The FM implements part of the session management and bearer setup upon network attachment and handover procedures. It implements the 802.21 protocol for controlling mobility subsystem operations in the network side, exchanging mobility signaling with the CM deployed at the MN.

3.3.4 Mobility Engine

This is the main component of the mobility subsystem and it takes care of handover control and IP address continuity. Three kinds of mobility mechanisms are supported. First, Unicast Mobility performs IP mobility operations and signaling following the DMM paradigm. Second, Multicast Mobility manages IP mobility network support for multicast flows. Lastly, Network Mobility (NEMO) [16] manages mobility support for mobile platforms.

3.4 Transport Optimization

The transport optimization subsystem provides optimized video traffic in the mobile operator's core network through intelligent caching and cross-layer interactions, reducing the load in the backbone while providing a satisfactory QoE. This is achieved by introducing CDN concepts into the MEDIEVAL fabric, aiding in optimal content location selection, aided by a Decision Module (DM) able to store content in CDN servers in demanding areas of the network. This is aided by CDN node control mechanisms which are able to interface with application monitoring modules, identifying content and services able to be stored and retrieved in the CDN. Equally important is the Transport Optimization component, which provides cross-layer and traffic engineering mechanisms, which aided by core networking monitoring modules, are able to improve video traffic flows.

3.5 MEDIEVAL Physical Deployment

The considerations developed within each specific subsystem have to consider as a base the functional overview of the MEDIEVAL architecture in terms of network topology and node architecture, as depicted in **Fig. 2**. As the MEDIEVAL project focuses on mobile operators' networks, entities such as the Mobility Access Router (MAR), Point of Attachment (PoA), MN, moving Mobility Access Router (mMAR) and Core Router (CR) compose the main entities existing in the system. As a video-oriented project, other concepts such as Video Servers and CDN nodes are also integral parts in the architecture. As such, interfaces between the different components have to consider the interaction (and challenges) involved in the interaction between such entities.

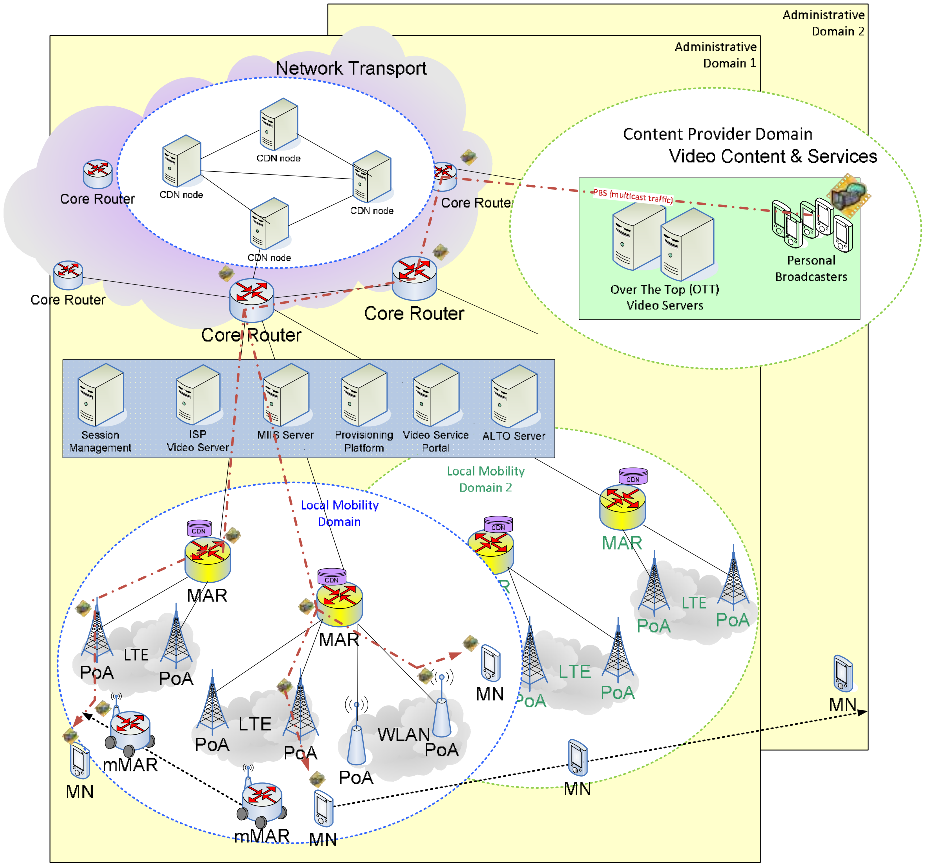

Fig. 2. Typical MEDIEVAL topology deployment

The MEDIEVAL network features heterogeneous wireless access including LTE-A and trusted WLAN access (common authentication mechanisms on both access networks by means of authentication, authorization and accounting (AAA) infrastructure) and split the geographical network in several local mobility domains (LMDs). While roaming within an LMD, MNs do not change their IP address, whereas inter LMD roaming is provided by means of client based mobility solutions. The SP operator network provides traffic engineering capabilities by means of the functions installed in the access and core network components. The core network includes also service provisioning, session management and video services. The SP network is an intelligent network providing CDN capabilities closer to the final user, able to provide service discovery mechanisms.

4 Key Function Interfacing for MEDIEVAL

In this section we analyze the inter-subsystem interaction between the four specified main areas of the MEDIEVAL architecture. We focus on providing a high-level view of the interfacing actions occurring between the key functions of the MEDIEVAL architecture presented in **Fig. 1**, while providing insight on the specific sub-system entities that are involved in the different processes.

4.1 Video Service Control and Mobility

The video service control provides video relevant information to the mobility functional entity using the video aware interface for heterogeneous wireless access, making possible to reach an optimal mobility decision. It can be used to get indications about when a handover is going to happen (so the video can be adapted). This allows the Video Service Control Subsystem to perform Content Adaptation during the handover process. This interface is also used by the Mobility subsystem to obtain information about the IP address session continuity requirements of the IP flows of each service/application.

The involved interactions provide an interface between the CM and the VSP. It is used by local applications at the MN to request the list of services available on the network, as well as taking video application requirements as important criteria for choosing the best mobility scheme and the best connection. This interface also accommodates interactions between the CM and the QoE & Video Control (QoEVC) component located in the MN, used to allow mobility management mechanisms to trigger content adaptation for handover processes. This interface is replicated with the FM, in order to enable network mobility management.

4.2 Video Service Control and Transport Optimization

The Video Services Control subsystem interacts with the Transport Optimization module in order to exchange a set of quality parameters that will impact the network usage and the video service configurations. Here, requests can be received for content adaptation, triggered by QoE degradations in the network. The Transport Optimization component is able to indicate to the Video services that the QoE provided by the network requires content adaptation, activating mechanisms such as changing the video format or data rate. This is also communicated to the Session Management component in order to avoid or limit the amount of packets being dropped at the network.

These operations consider the interfacing between the QoEVC and the Cross-layer optimization module, to communicate video sensitivity information and the need of performing content adaptation at the application layer. Parallel to this, the Cross-layer optimization module also interfaces with the end-to-end networking monitoring module to communicate traffic conditions in the network. In this sense, the DM interfaces with the VSP, for checking cached versions of requested content, and exchange network information for mobility mechanisms. The Core Network Monitoring and QoEVC exchange information about the core network status, providing useful information for the video control, aiding in content adaptation.

4.3 Wireless Access and Mobility

The Wireless Access provides information about the link status and the availability of access networks. It receives configuration commands related to the network interface in the MN and flow quality to be set-up. It is used to exchange information with lower layers regarding the radio connectivity and availability of points of access. The communication is established through IEEE 802.21, and it also allows sending commands to the interfaces.

Concretely the interface between the CM and the FM allows the support of DMM and enhanced QoE support over the base 802.21 protocol, while enabling the inclusion of new parameters that enhance link information reporting, the integration of LTE-A indications and multicast support in the network.

4.4 Mobility and Transport Optimization

This interfacing allows the management of network congestion cases. It is used to enable the network trigger needed in selective video flow mobility process for MNs which may connect to different PoAs from the congested ones. The same interface is used during the handover initiated by the MN when it moves. In this case the Transport Optimization Subsystem is requested to weight the candidate target networks, according to the availability of content caches located nearby.

These processes consider the direct interfacing between the DM and the FM, and provide information regarding available PoAs in the vicinity of the MN and flow parameters. The FM also interfaces with the Cross-Layer Module to receive notifications on network congestion.

4.5 Wireless Access and Transport Optimization

The Wireless Access provides information about the access network status like signal-to-noise ration, packet loss, QoE levels, number of queues and buffer states, including its capacity. It receives commands to configure the access for an optimal processing of the data packets. It also receives information about specific Jumbo Frame functionalities and provides indications necessary for the transport of Jumbo Frames, such as frame size and queue delay. Finally, it receives information about the mobility scheme support and about the availability of multicast support in the access networks. Using this interface, the Transport Optimization module can trigger the wireless access when it is required to jointly perform an action, such as for instance packet dropping or re-prioritization of packets at the base station. It also communicates the flow requirements in order to best allocate wireless resources to users.

Here, these mechanisms are enabled through the interfacing of the Core Network Monitoring and Cross-Layer Optimization modules, providing information on the dynamics of the link layers, inform about MN capabilities, providing video-related services such as transcoding, scheduling and prioritization. This behavior is provided by thorough extension to the parameters and primitives available from the 802.21 protocol

4.6 Applications

In order to link the video applications with the evolved video delivery network, a set of signaling interactions are defined allowing the establishment, modification or release of transport channels to convey multimedia content towards multiple users. These new interactions bridge the applications to an improved distribution network allowing the multimedia contents to be delivered to groups of users in the most efficient way. New service primitives are defined to support dynamic multimedia channel management, taking into account content adaptation and forward error correction schemes usage for a reliable video distribution, maximizing user experience and operator resources utilization.

Concretely, the applications are able to interface with the CM for flow-aware service mechanisms, and with the VSP for service discovery and information retrieval.

5 Use Cases

This section presents the three use cases considered in MEDIEVAL. These are related to the services considered in Section 2 and will serve as validation of the proposed architecture and proof of concept of the consistency of the specified interactions between subsystems.

5.1 Use Case 1: David' Holiday Afternoon at the City Centre

This use case focuses on traffic optimization mechanisms aspects of the MEDIEVAL architecture. Here a user engages the Mobile TV service, where the different subsystems collaborate in order to establish a service flow under appropriate wireless link conditions taking into consideration both the user and the service requirements. The service is fully supported in a MEDIEVAL-enabled network meaning that is much faster starting the video stream, allows a very rapid pause and play, plus even on the peak hours is does not stop like other services the user has experienced before. The Video Services Control is able to, based on the channel choice from the user, evaluate the best PoAs for attaching the MN, and setup an appropriate video flow to support the service. Even when the user switches channel to watch the news (currently in view by other several users), the MEDIEVAL platform constantly monitors the on-going flows to have the MN handover to a PoA that best support this specific channel, when the network is under congestion. Once again, the different network elements are able to cooperate in establishing a new video flow, while taking the appropriate measures to ensure that the transition occurs with no QoE loss to the user.

5.2 Use Case 2: Arriving at the City

This use case focuses on mobility aspects. Here the user is engaged in a video session using MEDIEVAL's VoD service through a multi-interfaced smartphone able to connect to both LTE-A and WLAN access link technologies. As the user moves around, the MEDIEVAL framework is able to continuously monitor not only the current attached link conditions, but also the surrounding connectivity possibilities, trying to identify alternatives that increase the QoE of the user. The use case then provides the necessary interactions between the different subsystems to support different kinds of handovers between LTE-A and WLAN access links available to the user while he commutes: network-based handover within the same LMD, host-based handover into a different LMD and a NEMO-based handover when attached to a mMAR (e.g., inside public transportation).

5.3 Use Case 3: The News e-Club

This use case focuses on the Personal Broadcast Service (PBS) service and associated network functionalities. Here a small group of users decides to create an e-club for disseminating their own news. To this end, they set up a sort of social network, allowing each of them to broadcast video information from their own mobile, supported by MEDIEVAL. Here the Video Service Control interfaces with the applications creating and registering the service and the necessary networking procedures for their support. Most of these news are composed of real-time video footage being broadcasted while on the move, and thus all the sub-systems from the MEDIEVAL framework cooperate to achieve an optimized video experience from the different sources towards the end users, supporting source-mobility in multicast environments.

6 Conclusions

This paper presented the first milestone in the architecture of the MEDIEVAL project, where a first design of the complete architecture has been performed including the description of the different subsystems and of the interfaces between them, in addition to the breakdown of each subsystem in functional modules. The proposed architecture considers extensions at the functional areas of Video Services Control, Wireless Access, Mobility and Transport Optimization. The architecture also highlights a cross-layer approach to exploit the interactions between these subsystems, which are placed at different levels of the network stack.

The proposed design has focused on a set of video services which were selected to take full advantage of the video-aware functionality provided by the MEDIEVAL framework, and to enable different use cases for the services deployment and utilization. It is worth highlighting that a subset of these uses cases will be used in the final demonstration.

The architecture design provided in this paper included description of interfaces involving the interaction between the different key functions of the MEDIEVAL framework and their respective subsystems. The objective of this definition is, on the one hand, to provide feedback to the research being done on the different subsystems in the project and on the impact of their interactions and, on the other hand, to provide a starting point for the validation of the proposed architecture which will be further validated at a later stage with an experimental implementation.

The architecture described in this document marks the conclusion of the first of three years of the MEDIEVAL project duration. The second year of the project will see the final specification of each of the presented functional components, based on preliminary evaluations made in an integrated testbed and isolated simulations. This work will be fed into a final demonstrator, during the third and final year, highlighting the evolutions and solutions achieved in overall by the project.

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