# Wireless access architectures for video applications: the approach proposed in the MEDIEVAL project

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***Abstract*—Video transmission is expected to be the next big thing in personal communication systems. While text messaging applications have already experienced an explosive growth, the exchange of multimedia content is still lacking architectural solutions which enable it to become the next killer application. The EU project MEDIEVAL (MultimEDia transport for mobIlE Video AppLications) [1] aims at filling this gap. In this paper we describe the approaches envisioned by the project for what concerns the data link layer, with special emphasis on wireless access and its related cross-layer issues. After presenting some general project aspects, we will review the state of the art and enumerate several open issues, concerning the identification of the most suitable radio technologies for video support, as well as their integration and required enhancements to enable efficient video transport.**

***Index Terms*—Wireless networks, Mobile communication, Video services, Radio optimization, Multicast/Broadcast.**

## I. Introduction

In recent years, personal messaging exchange through communication networks has shown an ever-increasing trend. The desire of people to communicate is shown by the success of short text messages, initially via cellular phones and subsequently the web (Twitter), as well as social networks. Nevertheless, humans live in a multimedia world, where all senses take part in the communication experience. The next frontier is now moving towards the diffusion of multimedia communications into society, to a level at least similar to the now accepted text-based communications. However, despite the successes we witnessed in communications in the last decade, current systems are still far away from realizing this ambition.

Based on many market predictions, it is likely that video flows will soon dominate the Internet traffic; for example, [2] forecasts that video will surpass in volume Peer-to-Peer (P2P) traffic already in 2010.[1] Also, still according to [2], the flows due to Internet TV, Video on Demand, interactive video, and P2P video streaming will account for close to 90% of the consumer traffic by 2012.

[1]Indeed, recent news claim this has already happened during these last months.

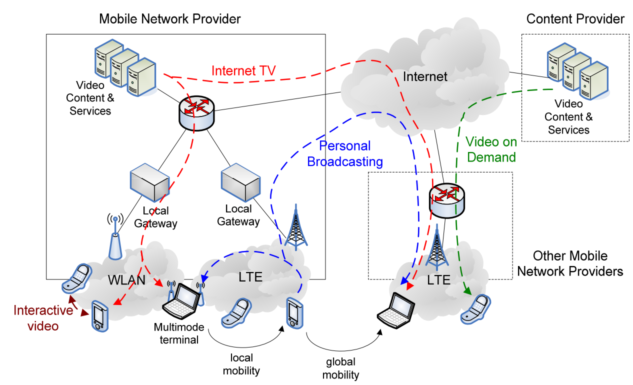


Fig. 1. Overview of the MEDIEVAL system

This paper aims at presenting the EU project MultimEDia transport for mobIlE Video AppLications (MEDIEVAL) [1], whose main goal is to evolve the current mobile Internet architecture to more efficiently support video services. Impacts and novel solutions will at the same time concern video-services for mobile networks, wireless access technologies, mobility architecture and protocols, and transport optimization.

More specifically, MEDIEVAL aims at designing potential video transport architectures suitable for commercial deployment by mobile network operators. Video-specific enhancements at the different layers of the protocol stack will be included, following the different standardization efforts on video specific mechanisms. Moreover, cross-layer approaches will be exploited to provide better video support at a lower exploration cost. Finally, the findings of the project will be fed back to the corresponding standardization bodies.

The general scenario and vision of the MEDIEVAL project is illustrated in Fig. 1, which highlights all the technical challenges that will be addressed. As a general rationale, a cross-layer approach, leading to clear innovations on multiple fronts, will allow a realistic evolution for mobile networks where users can benefit from our (multimedia) vision.

In this specific paper we will address the architecture proposed by MEDIEVAL for the fundamental issue of video-friendly wireless access, where network technologies are coordinated with video services to optimize the overall performance. As is visible from Fig. 1, MEDIEVAL will particularly focus on the Long Term Evolution (LTE) of the Universal Mobile Telecommunications System (UMTS) and on the IEEE 802.11 standards for Wireless Local Area Networks (WLANs). Thus, we will tackle wireless access technologies by classifying them into two main groups. On the one hand, cellular and cellular-like network architectures, with particular emphasis on LTE technology, will be studied as an instance of what we call *coordination-based access*. Another family of technologies, dubbed *contention-based wireless access*, will be considered, with principal reference to WLAN scenarios. Therefore, MEDIEVAL aims at considering an access scenario which is as general as possible, and where heterogeneous wireless techniques coexist. This will be done, as explained in the following, by carefully evaluating the aspects specific to each of the two classes, and also considering a wireless abstract interface, which guarantees a transparent interaction between the underlying technology and the upper layers.

Other important contributions of the MEDIEVAL project lie in the following research areas: (i) Specification of an interface between video services and network mechanisms; (ii) Design of a novel dynamic mobility architecture adapted to video service requirements; (iii) Optimization of the video delivery by means of Quality of Experience (QoE) driven network mechanisms, including, e.g., network support for P2P video streaming; (iv) Support for broadcast and multicast video services, such as Internet TV and Personal Broadcasting, by introducing multicast mechanisms at different layers of the protocol stack.

All these tasks, and in particular those related to wireless access, will be developed while keeping in mind the key design principle of achieving an operator-driven architecture, resulting in an integrated video solution that can be implemented by an operator and offered to its customers. Video services are a very promising business case and operators are interested in offering video services in their networks.

The rest of the paper will be organized as follows. In Section II, we describe the general architectural approach employed by the MEDIEVAL project, and explain the key role played by wireless access aspects. In Section III, we discuss the main challenges for wireless access techniques aimed at video services. Section IV describes the project goal for video delivery over coordination-based wireless access, in particular LTE networks. Section V instead presents the proposed contributions for contention-based systems, i.e., WLANs using Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). Section VI outlines, as a further contribution, the proposed definition of an abstract interface operating at Layer 2.5, i.e., between the wireless access and network layers, in order to harmonize and enable cross-layer interactions and heterogeneous access techniques. Finally, we draw the conclusions in Section VII.

## II. MEDIEVAL Architecture

The reference network architecture of the MEDIEVAL project is the Third Generation Partnership Project (3GPP) Evolved Packet System, which represents the evolution of today's deployed Third Generation (3G) networks. It includes the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN, also referred to as LTE), and a new core network based on the Internet Protocol (IP): the Evolved Packet Core (EPC). Other functionalities have been standardized to include also non-3GPP networks (e.g., WLAN hotspots). We deem this architecture to be more promising than alternative means for video delivery, e.g., those based on digital video broadcasting (DVB), for which neither wide deployment is expected nor pervasive content generation is possible.

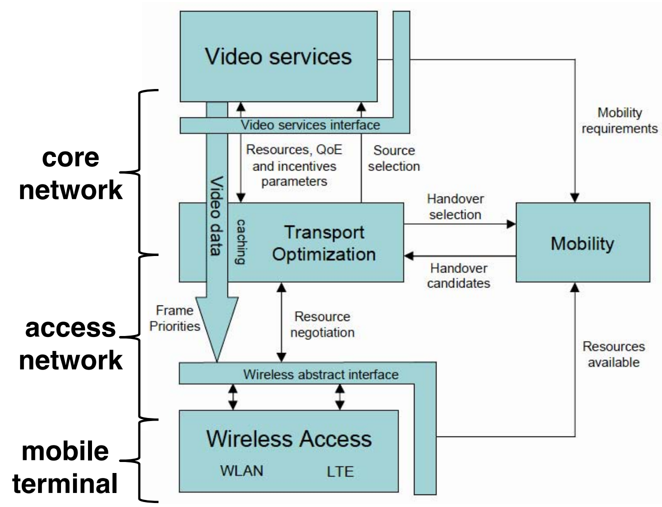


Fig. 2. The MEDIEVAL reference model

From a functional point of view, the key components of the model proposed by MEDIEVAL are illustrated in Fig. 2. A video-aware rationale will be implemented at different locations of the protocol stack. The design of video services will provide the bridge between video applications and the core network mechanisms. A video-optimized transport layer and specific solutions for the mobility component will provide resilient QoE for the users and support for handover [3]. Finally, wireless access will be carefully designed by exploiting the specific features of the different underlying wireless technologies. For instance, in case of resource shortage, the resource management of an LTE network can coordinate the resulting allocation, while WLANs need to use distributed mechanisms, such as degrading the performance gracefully. At the same time, MEDIEVAL considers a wireless abstract interface which is in a cross-layer relationship with the other parts of the architecture, in particular the video services, to exchange information about the capabilities of the underlying technology, as well as to configure them.

Before describing in more detail the issues related to the implementation of a video-oriented wireless access, we will stress that this is not the exclusive contribution of the project. As visible from Fig. 2, the interrelationships between different research subjects are quite tight. For example, although wireless networks have recently experienced a tremendous development, the theme of adapting their management to some specific content to be delivered (as may be, for example, the

TABLE I
SUMMARY OF GOALS AND SCENARIOS RELATED TO WIRELESS ACCESS WITHIN THE MEDIEVAL PROJECT

| | |
|---|---|
| **Challenges** | |
| — | Video flow adaptation to different contexts |
| — | Coordination with other kinds of traffic |
| — | Error Control |
| — | General cross-layer optimization |
| — | Multicast/broadcast |
| **Technological scenarios** | |
| — | Coordination-based wireless access (LTE) |
| — | Contention-based wireless access (WiFi) |
| — | Layer 2.5 abstract interface |

case of video), is relatively new and unexplored. More in general, how to interrelate network dynamics and QoE requirements is an open problem. Current proposals for multimedia content transmission often do not use any session negotiation, or they allow it only before the connection establishment [4]. There are some proposal to adapt flows and provide variable QoE according to the variable network conditions; however, several elements, e.g., the codec, are not negotiable.

At the same time, handover is a quite well-studied subject, but the vast majority of handover optimization efforts do not consider specifically video. Efficient transport is a key for video transmission systems, where high bandwidth requirements are coupled with tight delay constraints. As a consequence, if the network is already heavily loaded, the transmission of an additional video stream may significantly congest the network. Hence, the impact of video users on the network capacity should be evaluated. Finally, there are also a lot of investigations dealing with P2P streaming solutions. However, in this context MEDIEVAL will adopt a system-wide perspective [5].

## III. CHALLENGES FOR VIDEO OVER WIRELESS ACCESS

Current radio communication architectures have significantly improved their data rates and availability, so as to make the idea of "video over wireless" realistic. However, this is not sufficient per se, as state-of-the-art technologies are still lacking systematic approaches for radio resource management to enable video delivery. Most network designs do not provide mechanisms to adapt the application requirements to channel conditions, nor do they take the wireless access standpoint into consideration. When cross-layer interactions are explored, the main focus is often on the application layer (e.g., the impact of distortion effects due to packet loss on user-perceived quality) rather than the access/physical layer (e.g., the estimation of transmission capabilities of the wireless medium), where an improved management is also key to achieve a reliable and smooth transmission. Thus, we believe that there are several directions to explore, and in this regard MEDIEVAL can introduce helpful contributions to the management of future networks. A summary of the challenges and scenarios of application can be found in Table I.

First of all, video content is often heterogeneous and translates into flows with highly variable characteristics, e.g., in terms of required bandwidth and delay; also the end devices are expected to be quite dissimilar to each other, thereby imposing different constraints for what concerns the QoE that the end user may request. Therefore, video flow adaptation emerges as an important challenge to study within the project. This involves several elements to be accounted for at the same time, such as the type of the end user devices as well as to the network and channel conditions, and is particularly important for mobile wireless networks, where these elements are typically more variable.

In addition, even though the share of video flows is expected to be dominant, in general-purpose networks, such as the Internet, they are expected to coexist with other kinds of traffic with even more different requirements. Scenarios where video traffic competes with non-real time traffic are already considered, e.g., in the recent extensions of the IEEE 802.11 standard [6]. To some extent, video users can be provided with a good QoE if an admission control mechanism is considered and they receive higher priority than data users [7]. However, this approach lacks generality and currently only guarantees good performance in limited scenarios. Recent schemes propose to improve the performance of the standard default configuration, without the need to change the specification. These proposals, either based on HCF (Hybrid Coordinator Function) Controlled Channel Access (HCCA) [8] or relying on the Enhanced Distributed Channel Access (EDCA) (e.g., [9]) adaptively divide the time devoted to real-time and non-real time service. Their major drawback is that they are typically based on heuristics and therefore do not guarantee optimal performance.

Another element of interest for the implementation of video transmission over the wireless channel, which is an inherently unreliable medium, is the application of error control paradigms. Currently, most techniques rely on Forward Error Correction (FEC) mechanisms, while it has been recently shown that also Automatic Repeat reQuest (ARQ) can be beneficial, especially if combined with FEC so as to realize a hybrid ARQ scheme [10].

Moreover, most error control approaches often deal with the application layer, and implement techniques which are almost completely independent of other strategies applied at the lower layers. This limitation impacts an efficient network usage since it does not take into account the network status for the fine-tuning of the error control mechanism. To this end, it has been proposed to let FEC and ARQ strategies interact among different layers in a cross-layer fashion, e.g., by letting error control techniques in the Medium Access Control (MAC) phase also be controlled by the end receiver through Real-time Transport Control Protocol (RTCP) signalling [11].

More in general, cross-layer optimization is an entirely relevant challenge for the purposes of MEDIEVAL. As will be detailed in the next section, the exact implementation of cross-layer techniques depends on the specific wireless access technology under consideration. However, it is desirable to have a transparent and general approach, which is still compatible with the layered approach and possibly transparent to application, transport, and mobility elements. Moreover, we are also aware that cross-layer optimization may involve theoretically good approaches which are inapplicable in practice; thus, the exact amount of signalling required for cross-layer exchange must be carefully evaluated.

As examples, we mention here proposals involving active queue management [12], which can indeed reduce network congestion, and adaptive rate H.263 video encoders [13], which can improve the perceived QoE. The main limitation of these proposals is that they introduce significant complexity as they require the interaction between the codec and the MAC layer and consequently they are difficult to deploy with off-the-shelf devices.

For these reasons, we identify two challenges, namely, the definition of an abstract interface operating at Layer 2.5, and the need for practical feasibility assessment of any proposed optimization technique. Note that the former, as will be further discussed in Section VI, will enable a methodologically general approach to quantify the latter, through realistic evaluations of the proposed mechanisms.

Another challenge involving the rapid expansion of multimedia services is that they often have widespread diffusion within social networks, targeted to group usage. This is the case, for example, of photo and video exchange on Facebook, or via MMS. However, there is a lack of interconnection mechanisms which take this trend into account. Standardized approaches are still missing to include scale service announcement and discovery, mapping of service user groups into network-based groups and management of different content sources.

For this reason, it is important to consider video in multicast and broadcast contexts. A reference scenario in this sense may be the MBMS (Multicast/Broadcast Multimedia Service) [14], which is an enhancement to the UMTS system and provides a point-to-multipoint capability, minimizing the network and radio resource usage. The eMBMS (evolved MBMS) is its adaptation to the Evolved Packet System (EPS) architecture and the LTE access. However, it has major restrictions [15], such as the support of broadcast mode only (multicast mode is available only with the General Packet Radio Service (GPRS) entities). This new architecture introduces the mandatory usage of IP multicast in the user plane inside the cellular network, but it is the MBMS-GW, a functional entity of the Core Network, that allocates the IP multicast address to be used by the downstream nodes and operates as the actual head of the multicast distribution tree. The quantitative evaluation of mechanisms for video delivery in such scenarios represents an open research challenge that the project will investigate.

The best way to use the above techniques depends on the particular technology considered. For instance, in coordination-based technologies, admission control can be used to limit the amount of traffic in the network and thus congestion situations may be avoided. On the other hand, in contention-based technologies that lack admission control, congestion may occur and techniques are required to minimize its impact on video traffic. One major goal of MEDIEVAL is to enhance video QoE by exploiting both technology-independent and also technology-dependent features. Thus, in the following we discuss separately coordination-based and contention-based technologies in more detail.

## IV. Coordination-based Wireless Access

Current cellular architectures, such as LTE, have significantly improved their data rates and are expected to reach widespread coverage. Further increases of data rates and coverage are of course possible by augmenting the base station density. However, other more stimulating challenges involve a better allocation of the existing radio resource as the way to provide reliable video services over such technologies.

Therefore, one of the main goals of the MEDIEVAL project will be to design and enhance the wireless access layer management for coordination-based networks. In particular, a flexible mechanism will be sought to provide the users of wireless cellular networks with soft QoE based on adjustable video quality requirements. From the technical point of view, the control plane of the LTE Radio Access Network will be enabled to command the user plane entities to, for example, select, prioritize and transmit only those video frames which are adapted to the User Equipment capabilities. The proposed filtering will be performed inside the cellular network and, in the case of an MBMS multicast session, further correlated with the knowledge of the active mobiles who joined a specific service in each cell. In this way, video traffic can be reduced and the resource usage in the radio cell can be significantly improved.

Another alternative which the project aims at evaluating is the usage of the so-called *jumbo frames*. Packet aggregation techniques are in fact deemed to enhance video delivery mechanisms within LTE. The objective is to extend the cross-layer interaction of video services with the LTE architecture to enable the usage of jumbo frames in order to achieve higher video throughput.

Moreover, LTE systems are also envisioned to evolve from the traditional cellular architecture into multi-hop architectures, where relaying is superimposed to the cellular system [16]. When relaying is combined with the Orthogonal Frequency Division Multiplexing (OFDM) access of LTE, the resulting OFDM-based multi-hop scenario opens up several challenges in the definition of efficient allocation strategies for the radio resource (time, frequency). However, relaying is currently performed at the lower physical (PHY) layer, and cannot benefit from the transmission quality and error recovery mechanisms executed by the link layer protocols. The project will therefore aim at designing these allocation strategies for the multi-hop OFDM scenarios in a cross-layer manner. This implies to quantify and validate possible architectures where different amounts of cross-layer information are exchanged. A possible practical approach will be to introduce another relaying scheme at Packet Data Convergence Protocol (PDCP) level and study the constraints it will imply on the network. This scheme can extend the network beyond the Node-B and but still benefit from the transmission quality and error recovery introduced by layer 2 (datalink), which is not possible when the relay is performed at the PHY layer. It will be configured by the control plane entities at the time of resource reservation and establishment.

Additional features can be introduced in LTE to provide high data rates and spectrum efficiency. These include Multiple-Input-Multiple-Output (MIMO) terminals, which enables interference mitigation and/or cancelation techniques [17]. Other interesting improvements are expected from cognitive radio paradigms [18], where unused radio resources are intelligently exploited, provided that this does not degrade the QoE of already served multimedia users. It is also likely that technological support for cooperation-based wireless access will exist in the near future; thus, the project will tackle also these aspects.

Another goal of the project is to design network management techniques with limited amount of signalling for internode communication. Channel state information exchanges, opportunistic and cognitive communication, and more in general cross-layer interactions can be exploited to improve the transmission of video flows, but may also negatively affect the available bandwidth. In this sense, the project will explore the use of semi-static coordination techniques, where the current configuration is kept over several scheduling instants, and subsequently updated periodically. To this end, the required timing will be evaluated to have a viable yet practical access scheme where all nodes are coordinated and the channel state information is up-to-date, but the system performance does not significantly degrade due to excessive signalling.

Finally, multicast/broadcast solutions will also be investigated and optimized. For example, the "MBMS Session Start" procedure will be enhanced, to convey the maximum amount of information at once and reduce the number of steps needed for its completion. With this mechanism, the procedure when changing to a new cell can be made more dynamic by introducing some bearer service preparation early in the process, according to the arrival or the departure of an active mobile terminal and its capabilities, and by taking advantage of the properties of native IP multicasting. Cross-layer parameters exchange will be introduced, with the mobility entities in the case of handover, and with the transport optimization entities in case of initial session establishment, to flatten the procedure and reduce the starting delay observed at the application level.

Last but not least, all these elements will be integrated in a comprehensive approach to find a practical solution for usable video transmission systems. All the above innovations will contribute towards all the objectives of the project. They will profit from the cross-layer network architecture to improve the users' quality of experience within the cellular networks of future deployment (such as the advanced version of LTE, LTE-A) and reduce the cost for the operators.

## V. Contention-based Wireless Access

Wireless LANs where video transmission is employed are quickly becoming widespread. As a supporting evidence, it is possible to mention the creation of the new IEEE 802.11aa task group, whose contributions are very relevant to the scope of MEDIEVAL on video delivery. For example, IEEE 802.11aa addresses how to tackle the challenges of graceful degradation of video flows and to improve multicast reliability through the use of unsolicited retries. This attempts at overcoming the limitations of EDCA, which does not use acknowledgement frames for multicast services and makes use of a single rate out of the various rates included in the Basic Service Set (BSS) defined by the IEEE 802.11 standard.

The challenges for contention-based scenarios (in particular, WLANs based on the IEEE 802.11 standards) complement those discussed in the previous section, with the additional need, due to terminal simplicity, to avoid complex extensions (such as MIMO and interference cancelation) and deep packet inspections.

With respect to the MAC layer itself, MEDIEVAL will analyze mechanisms currently under standardization in 802.11aa, namely: i) approaches for frame marking and discarding, supporting a graceful performance degradation; ii) dynamic MAC prioritization, supporting e.g., layer-encoded video; and iii) improved multicast delivery, both in efficiency and reliability. These mechanisms will be investigated and quantitatively evaluated in practical cases, to assess their suitability for the scenarios considered in MEDIEVAL. Furthermore, other MAC layer mechanisms (e.g., support of jumbo frames) will be considered, as they suit naturally recent standardization efforts, such as the Transmission Opportunity (TXOP) mechanism in 802.11e. This will require a two-fold approach: first, to analyze the suitability of current 802.11 features, e.g., the TXOP parameter, for the transport of jumbo frames for video services optimization; second, the interface between layers needs to be extended to convey the cross-layer information, so as to optimize the usage of larger frame size for increased video performance.

Cross-layer mechanisms are also required, in particular when considering both channel-aware and network-aware solutions. While in the former ones the access to the wireless medium will be influenced by channel quality estimates, in the latter network congestion metrics will be considered so as to avoid overload due to video flows. Therefore, examples of activities that will be developed in the project include solutions based on intra access category scheduling, supporting graceful degradation of video flows in the case of unreliable wireless channel and/or network congestion. This will also result in the design of an enhanced MAC functionality, following the ideas of [19] for what concerns data traffic.

Additionally, interactions between transport and access layer will be identified. Along the lines of [20] for service-oriented incentives, the project will also tackle the mapping of the throughput and delay-based incentives over WLAN. To this aim, the set of MAC parameters as well as queue management will be considered, so as to provide the final application with the means to choose the best bearer, depending on the throughput/delay requirements.

In practice, this will be realized by defining incentive based mechanisms into different service paradigms in contention-based access, e.g., low delay low reliability vs. large throughput large delay (the former can well represent video-conferences, the latter video-streaming). This trade-off in services could be mapped into the use of different Access Categories, for the case of unicast traffic, or different reliability/efficiency parameters, for the case of multicast traffic.

## VI. Layer 2.5 Abstraction

Another concept introduced by the MEDIEVAL project is referred to as the "Layer 2.5 Abstraction." Its goal is twofold. On one hand, it serves to hinder the different wireless access technologies that are expected to co-exist in future communication systems, which, as outlined in the previous sections, are heterogeneous in terms of characteristics and challenges. This is realized by informing the upper layers, in particular video applications, of the functionalities available at the wireless layer in a general manner. At the same time, up-to-date information on the channel quality can be fed to intermediate layers (e.g., mobility and transport components).

On the other hand, the abstraction will also provide an interface for video applications to optimally configure the behavior of the underlying wireless technology. For instance, in case of reservation-enabled wireless technologies, this information is provided to the upper layers which can then reserve the resources required for video applications. In case of technologies that do not admit reservations but allow intra-flow priorities, video applications can identify the relative priorities of their packets to exploit this functionality. Thus, the standardized Layer 2.5 abstraction will allow such cross-layer functionalities between the video and the wireless layers without needing to know all the specifics of each underlying wireless technologies, only their features which are relevant to the interactions with video services.

As a result, the interface will enable cross-layer optimizations by exchanging appropriate primitives in both directions. From the upper layers to the wireless technologies, it provides the priorities or reservation parameters to fed the wireless access technology. From the wireless technologies to the upper layers, it reports the wireless access capabilities and availability, also involving mobility and traffic optimization.

Such an idea shares some similarities with other contributions (also made in some European projects) but, according to our knowledge, this is the first time that a similar rationale is applied to video. One of the novelties of this Layer 2.5 abstraction as compared to previous proposals is that MEDIEVAL does not aim at providing the same abstraction for different technologies, as we argue that technologies that are based on different principles cannot be joined into a common abstraction. Instead, our aim is to provide a set of abstract interfaces that allow each technology to inform the upper layers about its own capabilities, and in turn allow the video applications to exploit these capabilities by using this abstract interface as well.

## VII. Conclusions

We presented the challenges and the key points that the MEDIEVAL project will tackle in order to deliver video services over wireless access. The project will start on July 1st, 2010, lasting three years.

The expected results of MEDIEVAL will fall into several different areas. However, we stress that the methodological perspective of MEDIEVAL is to achieve a set of explicit and measurable outputs. The main objective of the project is to design a global architecture, suitable for commercial deployment of video services, that natively supports video transmission enabling cross-layer interactions with the underlying wireless networks. Possible solutions for this architecture will be carefully evaluated and quantitatively assessed.

The project also expects to have a significant number of standardization contributions to relevant fora, patent applications, demonstration activities and prototype deployment. The outcome of the above outputs will determine the progress of the project and, in particular, its ability to impact the development of video services over mobile networks.

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