Video-Enhancing Functional Architecture for the MEDIEVAL Project

Daniel Corujo† , Albert Banchs‡ , Telemaco Melia§ , Michelle Wetterwald+ , Leonardo Badia∗ , Rui L. Aguiar†

† Universidade de Aveiro, DETI, 3810-193 Aveiro, Portugal
‡ IMDEA Networks, Avenida del Mar Mediterraneo 22, 28918 Leganes (Madrid), Spain
§ Alcatel-Lucent, Route de Villejust, 91620 Nozay, France
+ Mobile Communications Dept., EURECOM, 06904 Sophia Antipolis, France
∗ Consorzio Ferrara Ricerche, via Saragat 1, 44122 Ferrara, Italy
dcorujo@ua.pt ,banchs@it.uc3m.es, telemaco.melia@alcatel-lucent.com, michelle.wetterwald@eurecom.fr, leonardo.badia@gmail.com, ruilaa@det.ua.pt

Abstract. The MEDIEVAL project aims to leverage today's Internet with the necessary fabric to provide optimized video services in a mobile wireless world. It is expected that video traffic will surpass Peer-to-Peer (P2P) in volume in the coming years, and thus novel mechanisms and techniques need to be provided to better suit its unique requirements. This article describes the key functional elements of the MEDIEVAL architecture, which provides a video-aware networking core coupled with abstracting interfaces which cater to service and access technology specific requirements, aiming to enable efficient video transport and novel video service development.

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

1 Introduction

The EU project MultimEDia transport for mobIlE Video AppLications (MEDIEVAL) [1] is a collaborative project with a three-year duration starting on 1st July 2010, having as partners Alcatel-Lucent Bell Labs France, Telecom Italia, Portugal Telecom Inovação, Docomo Communications Labs, LiveU Ltd., Instituto de Telecomunicações, Universidad Carlos III de Madrid, Consorzio Ferrara Richerche and Eurecom. It aims to evolve today's mobile Internet architecture to more efficiently support the upcoming growth of video services. According to [2] P2P, as the current dominant source of traffic in the Internet, will be surpassed by video in 2010 achieving volumes close to 90% of consumer traffic by 2012. This increase is motivated by a change in perception and usage of video services such as Internet TV, interactive video, Video on Demand (VoD), among others, which instead of being regarded as simple streaming of content, will become a tool for personal multimedia communication, resembling today's explosive usage of personal messaging (i.e., Short Message Service (SMS) and Twitter. However, the Internet, and the mobile technologies therein, have not been designed to properly sustain such an increase of video, in an optimized way. This is where MEDIEVAL intervenes by providing a more suitable video transport architecture, commercially deployable by network operators. This article is organized as follows. In the next section, we will present the vision of the MEDIEVAL project, focusing on its concept and main objectives. This is followed by section 3 where we discuss the general MEDIEVAL architecture, which provides video-specific enhancements at different layers of the protocol stack, by exploiting cross-layer approaches that aid in better video support. In the subsequent three sections we will describe the major points over which the architecture is impacted and aims to provide solutions, detailing some of the approaches: network requirements for video (Section 4), packetization (Section 5), and multicast mechanisms for video optimization (Section 6). Finally, we conclude in Section 7.

2 Vision

The vision of MEDIEVAL considers the evolution of video as a primary source of content, accessed as well as generated, over the Internet. This is exactly where MEDIEVAL aims to contribute: evolving the mobile Internet architecture for efficient video traffic support.

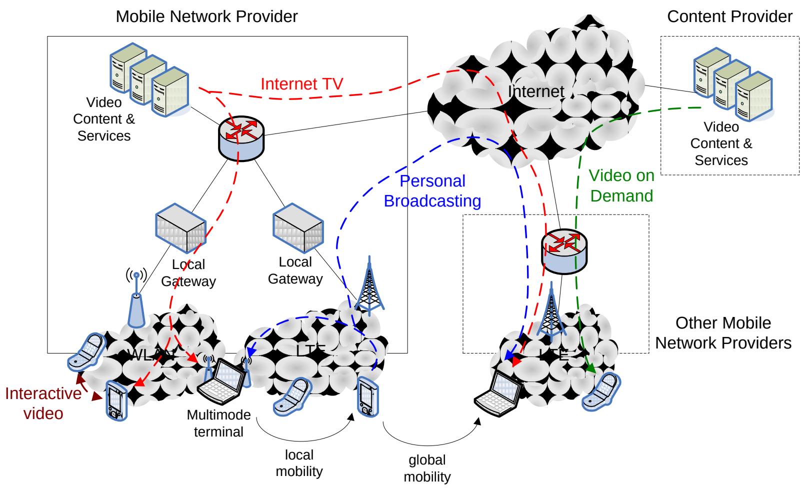

Fig. 1. The MEDIEVAL vision

Fig. 1 presents a visualization of this vision, highlighting what we foresee as the required evolutionary path for a true video-for-all philosophy, providing selected application examples. Four primary video services are considered, comprising VoD, Internet TV, Interactive Video and Personal Broadcasting, offered by the providers in the figure. These services are accessed by terminals supporting different access technologies (Long Term Evolution (LTE) and IEEE802.11 in the figure), while on the move, through both local as well as global mobility procedures, in intra and inter-domain scenarios. The video services are accessible from content and services providers available at a home operator domain (visible inside the Mobile Operator Provider part of the figure), as well as from content providers or other mobile network providers (visible in the separate Content Provider part of the figure). However, MEDIEVAL also envisages scenarios where users, and thereby their mobile terminals, are the source of generated video content, enabling scenarios of direct interactive video.

The necessary technical solution and problem solving that enable such vision span to all areas of mobile communications, starting from the need to enhance wireless access technologies, requiring efficient mobility management as well as optimized transport, to video distribution mechanisms and network-aware applications and services. We believe that a cross-layer approach will not only provide clear innovations in all the mentioned fields, but will also lead to a realistic evolutionary path for mobile networks, truly providing an environment where users can benefit from the MEDIEVAL vision.

This vision, and the subsequent architecture, will address the following five key issues:

- Design and specification of a set of interfaces between video services and the underlying network mechanisms, allowing the video services to customize the network behavior in an optimal way.
- Enhance the wireless access to provide an optimized video performance experience through the coordination of the features of the wireless technologies and the video services.
- Design and specification of a novel mobility architecture for the next generation of mobile networks, truly adapted to video service requirements.
- Optimize video delivery systems with Quality of Experience (QoE) driven network mechanisms through the combination of Content Delivery Networks (CDN) and P2P techniques for optimized video streaming focusing on the location of caches and peer selection.
- And lastly, support for broadcast and multicast video services, including Internet TV and Personal Broadcasting, through the introduction of multicast-aware mechanisms at the different layers of the protocol stack.

Through the addressing of these key issues, MEDIEVAL intends to perform technological developments based on an operator-driven architecture aiming to have an innovative impact in terms of video services performance improvement over existing solutions, while providing an integrated video solution that can be implemented by an operator. This integrated solution will observe better QoE of video to users by providing a joint view of user and video services requirements, wireless network conditions (such as performance and load) and transport optimization, all of which impact mobility decision taking.

The support of this vision requires not only the development of a video transport architecture, but also a high emphasis on its commercial deployment suitability. To further this, the design of a set of specific mechanisms and enhancements with application on video services will have to be developed and presented to the relevant standardization bodies.

Even though the architecture focuses on video, this kind of traffic is the most demanding in terms of bandwidth thus enabling other applications to work since the network is dimensioned for video, and with the same protocols (albeit using different algorithms) we can treat other kinds of traffic.

3 Architecture

The MEDIEVAL architecture relies on four functional cornerstones, which are depicted in **Fig. 2**, considering Wireless Access, Transport Optimization, Mobility and Video Services and described in the following subsections.

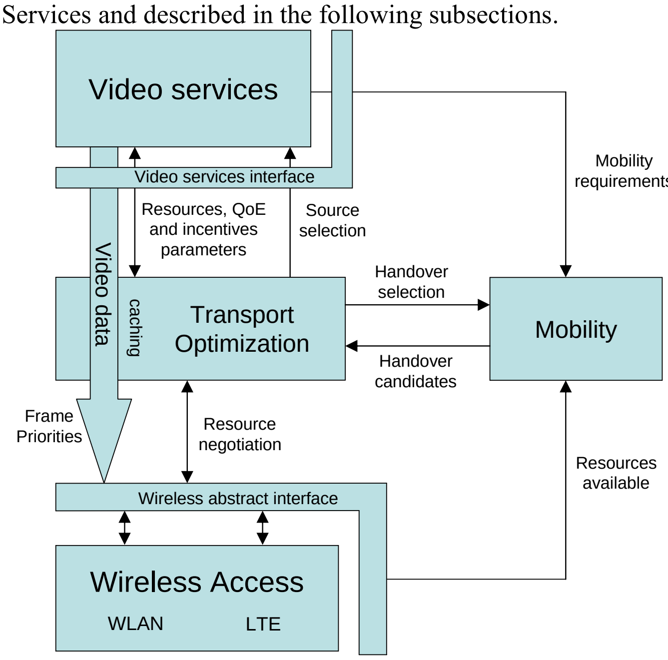

Fig. 2. The MEDIEVAL architecture

3.1 Wireless Access

Wireless access considers coordination mechanisms between video services and the different wireless access technologies in order to optimize overall performance. MEDIEVAL will focus on the LTE of the Universal Mobile Telecommunications System (UMTS) for coordination-based access, and the IEEE802.11 standards for contention-based wireless access, enabling a "video over wireless" concept. On the IEEE802.11 side, the high rates placed by video services when this kind of traffic is prioritized against non-real time traffic allow for good QoE, but only in limited scenarios [16][17]. To counter this, numerous approaches have been presented but are either based on heuristics and do not guarantee optimal performance [18][19] or introduce significant complexity while requiring the interaction between codecs and the MAC layer, increasing their deployment difficulty [20][21][22][23]. On the LTE side, cross-layer optimizations are key improvements over existing cellular technologies regarding the support of video services, along with data rate increase obtained through intelligent exploitation of radio resources, which enable interesting scenarios complemented with the introduction of point-to-multipoint capability such as Multicast/Broadcast Multimedia Service (MBMS) [5] and evolved MBMS (eMBMS). An interesting project concerning cross-layer mechanisms to improve multimedia performance over wireless links is OPTIMIX [25], but it derives a new wireless architecture from scratch which can seriously hinder deployability with operators and does not consider entirely mobile scenarios.

In MEDIEVAL, interaction with different technologies will be achieved through heterogeneous cross-layer mechanisms for interface abstraction (i.e., IEEE802.21 [6]), facilitating interfacing with the upper layers and their exploitation of specific features for video optimization. Another key innovation will be the introduction of enhanced dynamic configuration procedures based on the current network conditions, while also exploiting advanced terminal features such as multiple-input multiple-output (MIMO) capabilities, cognitive networks and multi-hop transmission in centralized technologies.

3.2 Video Services

Video services control will provide these services with the tools for reliable video delivery over an evolved mobile network. Some approaches already consider content adaptation and the use of RTSP (Real Time Streaming Protocol) but they do not consider, in the first case, the dynamicity of the network, the various network policies, QoS requirements and, in the second case, do not allow session negotiation. Other measures, such as packet prioritization, are not yet investigated in relatively new codecs (i.e., H.264, AAC audio and SVC), and Forward Error Correction (FEC) mechanisms negotiation at application level does not exist. All of these are imperative requirements in mobile environments. PHOENIX [26] proposes a cross-layer optimization of wireless access where video is an application of the proposed optimization framework. However it does not consider entirely mobile scenarios and video is just regarded as another application.

MEDIEVAL will provide video services with an interface enabling them to interact with core network mechanisms, considering requirements and features from both, and properly adapt the service execution. Through this interface, video services are able to provide indications regarding the type of video data in order to request frame prioritization to the wireless layers, as well as providing resources, QoE and incentive parameters to better optimize transport procedures. Other measures such as algorithms to better adjust video streaming to the network conditions will be tackled considering cross-layer dynamic adaptation management techniques, prioritization methodologies and appropriate FEC mechanisms.

3.3 Transport Optimization

To capitalize from the video-aware features of both the wireless access and video services functional components, the architecture also provides video-aware transport optimization mechanisms for efficient video delivery, offering resilient and mobility-aware QoE to video services. Several techniques already exist such as analysis of interactions of video transport with other layers [29] and CDN. However, they miss a global system view and there is a lack of knowledge about the operation of CDN in the context of mobile networks. The NAPA-WINE [27] project considers P2P systems for high quality TV delivery, managing traffic and quality degradation, albeit not considering mobile networks nor broadcast/multicast solutions as well as operator-controlled mechanisms.

MEDIEVAL aims to develop transport optimization cross-layer mechanisms able to execute resource negotiation with the wireless layers, considering an optimized source selection, while adapting the video service to current network conditions. The usage of CDN architectures in mobile environments will also be pursued as well as providing solutions for dynamic rate-control and caching schemes. Resource reservation procedures are considered to be in place and MEDIEVAL will use them as implemented by each technology (LTE and WIFI). However, here we go one step further addressing QoE in a different manner by enabling the network to understand what traffic is traversing the routers and will be able to take decisions before routing the packets (e.g., dropping specific video frames, using a different path, etc.).

3.4 Mobility

The reference network architecture for MEDIEVAL is the EPS specified by 3GPP (Release 8), and Proxy Mobile IPv6 (PMIPv6) [12] and Dual Stack Hosts and Routers (DSMIPv6) [24] are the two major IP mobility protocols proposed. However, these efforts are still based on anchor points and tunnels, and mobility is offered as a general service which can employ unnecessary overhead when not needed. CARMEN [28] addresses a mesh architecture with mobility support, while considering video at carrier grade. MEDIEVAL also aims at the design of a novel mobility architecture but focuses more on video efficiency rather than just support it.

Considering the mobile environments over which video services will be used, the architecture will provide mobility mechanisms which are also video-aware, and will interact with the core network to ensure optimized connectivity for the terminals. This is achieved through the collection of handover requirements from video services, the identification of available resources and their impact in handover candidate selection taking into consideration an optimized transport execution. These four architectural components will feed handover selection algorithms through the provision of parameter values that consider an overall view of the best choice possible.

These mobility mechanisms will address both local mobility and global mobility, considering, in the first case, the provision of service continuity customized to the different requirements of video services and, in the second case, addressing inter-operator roaming issues without requiring the deployment of global anchor points in the operator's network. Here the focus is also on session continuity. An important innovative point from MEDIEVAL is to consider mobility in terms of specific flows.

Thus, the mobility architectural part will consider three main areas of intervention: i) mobility mechanisms for multi-mode terminals and moving networks supporting mobile and network initiated handovers; ii) video-aware interface for heterogeneous wireless access conveying video relevant information for optimal decision taking by the mobility function and iii) IP multicast mobility by both sources and receivers, (i.e. considering their issues with tree-based approaches).

4 Cross-layer Mechanisms for Addressing Network Requirements

For an optimized video experience, the full set of MEDIEVAL's functional architecture needs to work cooperatively, providing the bridge that allows video services, and their traffic, to be adapted to current network conditions based on the user terminal's selected technology while on the move. An open problem to be tackled is how to interrelate network dynamics and QoE requirements for video services in wireless environments. Proposals addressing these issues don't consider session negotiation or only allow it before the connection is established [3], which prove unfeasible in dynamic environments. Under these environments, mobility has been thoroughly studied, leading to extensive optimization efforts for handover execution, but never considering video specifically. The transport video traffic under these conditions gains a key importance where increasing requirements for more bandwidth are coupled with stringent delay constraints, while operating in heavily congested networks. Network requirements have to be considered under the general-purpose behavior of the Internet, where other different kinds of traffic coexist, raising the interest of the IEEE802.11 in previous extensions [4].

To address network requirements in such environments, we explore cross-layer interactions, focusing on all layers of the network stack, applying improved management towards reliable and smooth transmission. An important tool to be used for this cross-layer interaction is the IEEE802.21 Media Independent Handovers (MIH) standard. MIH considers the optimization of handovers in multi-technology environments, by providing mechanisms that rely on the abstraction of the different connectivity technologies and provide media independent information and control to deciding entities, regarding the medium status. The introduction of MIH mechanisms work as a layer 2.5 abstraction concept, enabling MEDIEVAL to encompass future communication systems while tackling their inherent heterogeneous characteristics and challenges. Also, the media-independent signaling provided by the IEEE802.21 MIH protocol will provide the interaction between the different cross-layer components on which MEDIEVAL intends to impact.

However, the IEEE802.21 standard was not conceived for any specific kind of traffic and does not attempt to take the optimization perspective of the network for video delivery. Its introduction in the MEDIEVAL framework will leverage and enhance it to support video specific extensions (e.g., link capacity versus packet prioritization), by taking advantage of its intrinsic signaling primitives. Concretely, MEDIEVAL will extend the interfaces with higher layer services considering the interaction between mobility and transport optimization components, enabling IEEE802.21 to provide fine granular IP flow mobility management, while the interaction between the video service and the mobility components will also leverage already existing protocols, such as DIAMETER [7], through the creation of the required extensions. Thus, IEEE802.21 will be extended to convey video-specific information (such as encoding parameters, real-time QoE parameters, among others) enabling the provision of indications to handover decision entities which assist in applying the best procedure possible, depending as well on user credentials.

Although the extension of the MIH protocol to execute new personalized behavior has already been proposed in other contributions (such as European projects), to our knowledge, this is the first time that a similar rationale is applied to video and its inherent services. An important distinguishing point is that the objective is not to use media independent mechanisms to provide the same abstraction for different technologies, since in this case they are based on different principles that operate very differently when it comes to video traffic. As such, our aim is to provide a set of abstract interfaces allowing each medium to report its capabilities to decision video-aware entities which can then exploit them through the same interfaces.

MEDIEVAL will benefit from the inclusion of ODTONE [8], standing for Open Dot Twenty ONE, which is an open-source implementation of the IEEE802.21 standard from the Instituto de Telecomunicações (Aveiro, Portugal). ODTONE is implemented in C++ using Boost and provides an operating system independent Media Independent Handover Function (MIHF), the core entity of the IEEE802.21. To enable its integration with the different link layer technologies, being managed by different operating systems, ODTONE provides a library based on the MIH protocol, which can be used to implement the different link Service Access Points (SAP). This provides an ample platform able to be executed in different environments, featuring different terminals and access technologies and thus not being dependant of a single operating system, which is the case of other initiatives such as [15]. The open-source nature of the project, and the expertise gained by its development, will provide to the MEDIEVAL project with the necessary tools with which to extend the base IEEE802.21 behavior, enabling it to provide optimized execution for video services aware mobility and data transport.

5 Packetization

MEDIEVAL will exploit packet-level mechanisms and techniques available to its functional elements and core network in the various types of technologies. The control plane of the LTE Radio Access Network (RAN) will intervene at user plane entities with the aim of selecting and prioritizing video frames. With respect to the lower layers of the wireless technologies, the project will evaluate mechanisms, such as the ones under standardization in 802.11aa, where dynamic prioritization for frame marking and discarding are supported, and techniques such as graceful performance degradation are employed.

The usage of jumbo frames to aggregate packets while enhancing video delivery mechanisms to achieve higher video throughputs will be evaluated, taking into consideration the necessary extensions for the cross-layer interaction of video services with LTE and IEEE802.11 networks. Jumbo frames allow the usage of larger frames extending them to 9KB which take advantage of reduced MAC overhead, increased throughput and less CPU usage. However, they also introduce new problems such as larger hardware requirements on routers, and more video data is lost when a packet is lost or delayed. This is crucial in wireless environments running interactive video services, requiring the adoption of important measures such as zero-loss mechanisms, needing a feasibility study considering their effect in mobile environments and their impact on real-time services and video buffers. In this feasibility study, the suitability of current IEEE802.11 mechanisms (i.e., such as the TXOP (Transmission Opportunity) parameter of the MAC protocol) will be analyzed for the case of jumbo frames aiming towards video services optimization. The TXOP parameter has been extensively used as the means for modification of the standard transmission procedure to achieve optimized results [9][13]. However, the MEDIEVAL framework intends to provide a comprehensive cross-layer approach towards the optimization of video services and thus application of jumbo frames at the MAC layer is not enough (or even only at the IP level itself [10]): the other layers, involving the video services, the transport and mobility procedures, must be aware of this factor and to know if the conditions are favorable towards its usage. As such, the interface between layers needs to be extended to convey this cross-layer information, towards the optimization of the usage of larger frame sizes to increase video performance. The studies executed at these two fronts will determine whether jumbo frames will be used in WLAN technologies or not, and, in parallel, the feasibility for the usage of this kind of frames will also be analyzed within LTE, towards the enhancement of video delivery mechanisms. Here the objective is to extend the cross-layer interaction of video services evidenced in the WLAN case, with the LTE architecture [14], enabling the usage of jumbo frames to achieve higher throughputs for video under this wireless technology as well.

6 Multicast Mechanisms

A key development for the proliferation of video traffic is its widespread diffusion within social network, as witnessed today on Facebook or MMS. However, the deployment of such features in today's Internet while considering video traffic being generated by millions of mobile wireless users, emphasizes the lack of interconnection mechanisms supporting this trend. It is just not feasible to send independently video feeds towards users viewing the same content. Although solutions for multicast exist, these approaches do not consider scale service announcement and discovery as well as mapping video service groups into network-based groups while managing different content sources. MEDIEVAL will focus on providing a common interface that allows different applications to efficiently deliver video content to user groups, leveraging multicast and broadcast context solutions (MBMS and eMBMS). The inclusion of these mechanisms at IP level, with special nodes acting as the heads of the multicast distribution trees, will also be enhanced with bearer service preparation to optimize scenarios where terminals change into a new cell not yet in the session topology.

Another key intervention point for MEDIEVAL is the crossing of multicast and mobility mechanisms, particularly network-based localized mobility management solutions. For this, a thorough analysis on optimal multicast support in PMIPv6 [12] will be done. Here, the project will benefit and contribute to standardization via a recently formed IETF working group in the Internet Area: Mobility Multicast (MULTIMOB) [11], aiming to provide guidance and multicast support in a mobile environment. An important consideration to tackle, considering that a mobility management protocol that is network-based such as PMIPv6 does not consider the user terminal as an entity that is involved in the mobility signaling, and thus its integration into mobility-aware group subscription is problematic. In the context of MEDIEVAL we plan to study not only receiver mobility but also the impact of sender mobility in a network-based localized mobility management architecture. Concretely, this area of the project intends to address:

- Mechanisms for mobility support of listener nodes in a non-relying way to bi-directional tunneling
- Topological correctness and transparency of source addressing
- Mechanisms for optimized multicast distribution tree updating

Additionally, another study item will be the coupling between the handover process, the change between layer-2 point of attachment and the actual group subscription. The strategy for the multicast distribution update depends on the envisioned service in MEDIEVAL, with two possible paths: specific to the source, or related to any source. Regarding this point, and in the context of localized mobility management, the multicast tree creation may interact with route optimization in a mobility point of view.

The use of cross layer information to better synchronize subscription information and actual point of attachment especially in case of predictive handover will be a key study point, particularly in the cases where the change between L2 point of attachment is not synchronized with the L3 change (i.e., homogeneous and heterogeneous handovers). Cross layer information can be used to better synchronize subscription information and actual point of attachment especially in case of predictive handover. Here, the application of IEEE802.21 mechanisms is a possible tool to ensure the feasibility of these processes. Also, IP multicast optimizations will be proposed both from the network mobility perspective (i.e., due to handovers) as well as from the service perspective (i.e., fast change of multicast groups, required by IPTV). MEDIEVAL will also benefit from the on-going efforts for the development of a PMIPv6-compliant protocol stack, performed by several partners of the MEDIEVAL project.

7 Conclusion

In this article we have presented the key points and challenges that the MEDIEVAL project will address aiming to deliver video services in an optimized way over wireless mobile access. The major architectural areas have been highlighted as being wireless access technologies, mobility, transport optimization and video services, which reflect the general work items of the project. We also have detailed key innovation points and research objectives for the areas of jumbo frames, MIH signaling extension and network localized mobility management with multicast support, which are important tools and mechanisms in the overall MEDIEVAL design. The work will start with the exploitation of the individual work items into the development of a cross-layer design that leverages the joint effort of each item, into an evolution of the Internet architecture for efficient video traffic support. The results achieved with the project will fall in a number of research subjects and will provide a set of extensive and measurable outputs, where possible solutions for this architecture will be evaluated and quantitatively assessed, particularly its impact to standardization and the development of new video services. Lastly, the resulting architecture will be implemented in a demonstrator showcasing the developed functionalities. These results will be further disseminated in scientific fora, including leading conferences and journals in the field, as well as active pursuit of opportunities for standardization bodies influencing.

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