Multimed Tools Appl
DOI 10.1007/s11042-010-0576-1

Adaptive IPTV services based on a novel IP Multimedia Subsystem

Julien Arnaud · Daniel Négru · Mamadou Sidibé · Julien Pauty · Harilaos Koumaras

Abstract Heterogeneous communication devices are emerging and changing the way of communication. Innovative multimedia applications are now accessible through these embedded systems. The 3GPP IP Multimedia Subsystem (IMS) provides a basic architecture framework for the Next Generation Network (NGN) supporting the convergence platform for service provisioning in heterogeneous networks. ETSI TISPAN standardization effort focuses on delivering IPTV services on such platform. Nevertheless, IPTV on IMS standardization suffers from a lack of efficient user-centric network management mechanisms as the end-user may consume IPTV service from different access networks, on different mobile devices, at anytime. User's Perceived Quality of Service (PQoS) or Quality of Experience (QoE) of IPTV service may also suffer from wireless access network impairments. This paper introduces new functionalities in IPTV over IMS architecture which optimize satisfaction of the end-user and resource utilization of the operator's networks. A context-sensitive User Profile (UP) model is used to deliver IPTV streams adapted to the user's environment. In order to optimize the operator network usage, the impact of spatiotemporal dynamics of the video content on the deduced perceptual quality is considered. A Multimedia Content Management System (MCMS) is proposed to

J. Arnaud (✉) · D. Négru
CNRS-LaBRI Lab, University of Bordeaux, Talence, France
e-mail: arnaud@labri.fr

D. Négru
e-mail: negru@labri.fr

M. Sidibé · J. Pauty
Viotech Communications, Versailles, France

M. Sidibé
e-mail: msidibe@viotech.net

J. Pauty
e-mail: julien.pauty@viotech.net

H. Koumaras
NCSR Demokritos, Institute of Informatics and Telecommunications, Athens, Greece
e-mail: koumaras@iit.demokritos.g

Published online: 23 September 2010

perform dynamic cross-layer adaptation of the IPTV stream based on PQoS measurements at the end-user side.

Keywords IMS · IPTV · User-profile · Adaptation · PQoS

1 Introduction

Computing is becoming more and more embedded and ubiquitous. One of the main issues in the telecommunication area is to provide multimedia consumers with personalized and effective services according to the current operational environment. End users are consuming same multimedia services through disparate devices which are connected to various access networks. The Quality of Experience (QoE) [3, 6] of the end-user consuming Internet Protocol TeleVision (IPTV) service varies depending mainly on device resource and network capacity. In order to optimize multimedia consumption experience, QoE targets should be defined for each service depending on initial consumer's environment. These targets should also change according to the end-user environment evolution. Interaction between an estimated quality of service such as Perceived Quality of Service (PQoS) [7] and the service delivery should then be considered. The IP Multimedia Subsystem (IMS) [19] is an overlay system that serves the convergence of mobile, wireless and fixed broadband data networks into a common network architecture where all types of data communications are hosted in all Internet Protocol (IP) environments. IMS is one Next Generation Network (NGN) believing that multimedia consumption should be controlled by an operator through multimedia sessions, also called Session Initiation Protocol (SIP) [13] sessions which guarantees the requested quality of service and enables the convergence of services. As recent public trials have shown, IMS technology still suffers from a number of confining factors; amongst them are the lack of context-awareness and PQoS. The existing IMS infrastructure [2, 10] does not take into account the environment of the user, the network conditions, and does not provide any PQoS aware management mechanism within its service provisioning control system.

It is expected that the success of multimedia services within the IMS infrastructure will depend on how end-users perceive the quality of the provided services. Thus, monitoring information needs to be retrieved at different locations along the delivery chain, gathered and then analyzed by the IMS. In order to maximize the end-user satisfaction while optimizing network resource, the combination of a user-centric network management and adaptive services according to user's environment and network condition is considered. Therefore, novel IMS compatible user centric network management solutions that employ adaptive techniques and user profile models are inevitable.

In this paper, we focus on the integration of such user profile modeling [1] and on PQoS aware management in the IMS architecture delivering IPTV services. More specifically, we focus on the media session control between the user's terminal, IMS elements and the PQoS aware management mechanism. Any multimedia streaming services would use the same architecture. We also consider the impact of the spatiotemporal dynamics of the video content on the deduced perceptual quality described in [8].

In the following section, related work is introduced. In the third section, the proposed architecture is overviewed and all the elements are introduced. The fourth section describes thoroughly the IPTV Client architecture with the integration of the user profile model. Section 5 describes the achievement of the adaptation process in the

IPTV scenario. Section 6 presents the test-bed and the performance evaluation. Section 7 concludes the paper.

2 Related work

Even though IMS is sometimes considered too expensive and complex, it is the only standardized architecture that enables convergence between different kinds of access network. Actually, many IMS elements are gateways interfacing non-IP based networks or systems. For this reason, telecommunication manufacturers have introduced the “light IMS” approach to provide operators with small scaled or simplified IMS architecture.

Current IMS standardization [2, 10] provides limited user customization and does not define any PQoS aware management mechanism within its service provisioning control system. ETSI TISPAN standardization effort [4] focuses on delivering IPTV services on such platform shown in Fig. 1. IPTV on IMS standardization suffers also from a lack of efficient user-centric network management mechanisms. In [16], a study and analysis on context-aware IPTV system is presented. The outcome analysis states that no existing contribution could satisfy service personalization in a complete and adequate manner.

Besides, the Perceived Quality of Service (PQoS) [7] of the IPTV services may also suffer from wireless access network impairments and is not discussed in IMS architectures. Papers [9] and [5] respectively introduce an IPTV client for IPTV over IMS services and a complete next generation IPTV over IMS platform. The client and the global architecture are handling presence, contact list, user generated content, remote control functionalities and media content service discovery for TV and Video on Demand (VoD) services. Dynamic adaptation of the Audio/Video (AV) content based on access network condition or user’s environment is not treated in these two papers.

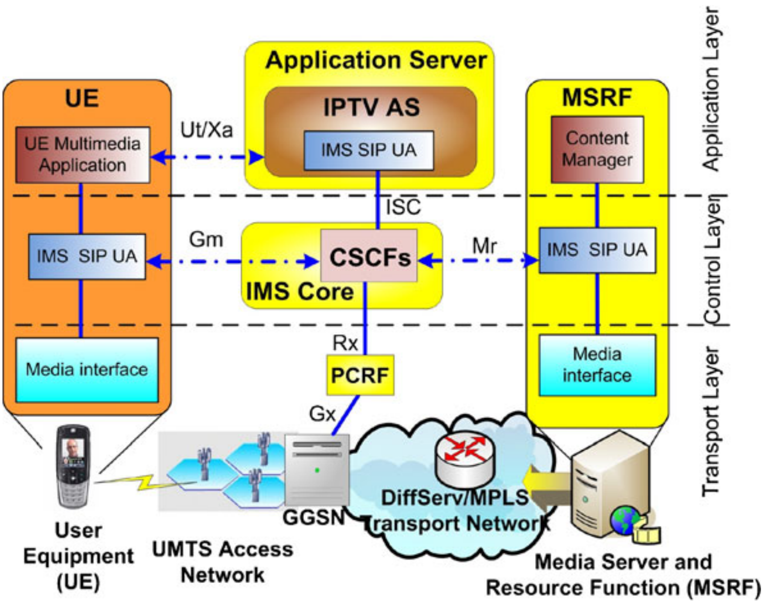

Fig. 1 Existing IPTV service within IMS architecture

3 Design of a new IMS-based architecture with PQoS mechanism

Our paper proposes a novel IMS-compatible user-centric network management solution that employs User Profile (UP) management and adaptive techniques for IPTV services in order to (a) compensate network impairments (Network QoS—NQoS) according to the time varying conditions of the network delivery chain, (b) perform a content dependent optimization of the encoding and/or streaming parameters, and to (c) improve the end user experience/satisfaction by maximizing the delivered PQoS level and delivering content adapted to the end-user environment. Cross-layer adaptive techniques include service layer adaptation (e.g. source/terminal coding parameters and Forward Error Correction—FEC), network layer adaptation (e.g. traffic policies) and link layer adaptation (e.g. service classification). This will provide an efficient solution for future networked multimedia making it possible to maintain the quality of the media at every step of the media stream lifecycle from delivery to consumption. The novelty of the IMS-based architecture is mainly located at the IMS Application Server (AS) layer with the integration of a Multimedia Content Management System (MCMS), at the end-user terminal or the User Equipment (UE), at the Media Server and Resource Function (MSRF) where the IPTV stream is created and at the edges of IP core transport and access networks as described in Fig. 2.

3.1 Multimedia Content Management System (MCMS) description

One of the essential components of the proposed solution is the MCMS, enhancing the existing IMS architecture as described in Fig. 2. This entity is in charge of intervening in the media delivery process when PQoS degradation occurs at the end-user side by

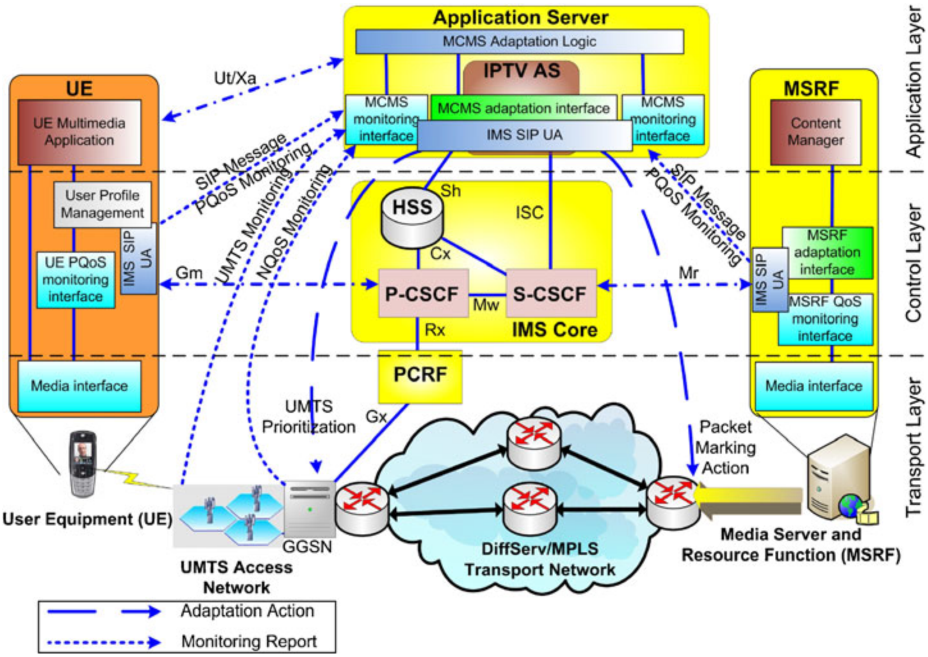

Fig. 2 New IMS-based architecture with PQoS mechanism

performing dynamic adaptation, aiming at enhancing and optimizing the delivered PQoS level of the degraded service session. When PQoS degradation occurs at the user terminal, a PQoS alarm is triggered by the UE. Then the MCMS monitoring interfaces are initiated. A decision is then taken to answer the following question: What are the necessary adaptation enforcement to improve the delivered PQoS?

The MCMS modules first focus on treating PQoS alarms coming from the UE. Then they trigger monitoring actions, gather the monitoring information until either alarm ceases or degradation persists/increases and finally launch the actual PQoS alarm. They collect the network statistics (i.e. core, access, terminal) and the service delivery information (i.e. MSRF) in order to define and apply an optimal cross layer adaptation action across the delivery network chain and media delivery lifecycle (i.e. service generation node, core network, access network and end-user terminal). The final objective is to maximize the user satisfaction. As shown in Fig. 2, MCMS modules are located in the Application Server (AS) Layer of the IMS architecture. MCMS modules widen the IPTV AS scope with real-time monitoring important information, including impairment information from source (e.g. content dynamics), core/access network (e.g. network/link QoS) and terminal (e.g. delivered PQoS). IPTV AS is mainly responsible for Service Control Function (SCF) as defined in TiSPAN v2 standardization [4], IPTV Service Provisioning, IPTV Service Personalization and other IPTV specific services such as voting or advertisement functionalities. The Service Control Function has a threefold responsibility:

- Service Authorization during session initiation and session modification, which includes checking IPTV users' profiles through the 'Sh' interface in order to allow or deny access to the service;
- Credit and limit control which collects charging information and sends it towards the charging system for consolidation with other charging information collected in other strategic network element;
- Selection of the relevant IPTV media functions. The SCF is choosing one of the three different IPTV services available which are Content on Demand, Broadcast and Network Personal Video Recorder.

The SCF then manages the IPTV session management constantly aware of the UE status. Therefore, IPTV AS can also be extended with the MCMS Adaptation Interface in order to trigger cross-layer adaptation including service layer adaptation (e.g. source/terminal coding parameters and FEC), network layer adaptation (e.g. traffic policies) and link layer adaptation (e.g. service classification). This MCMS Adaptation Module is controlled by some intelligent decision logic called MCMS Adaptation Logic within the MCMS system. The integration of the MCMS modules in the Application Layer makes the PQoS aware management available for any kind of access or transport network. Figure 2 only shows Universal Mobile Telecommunications System (UMTS) Access network, but this solution can also work for fixed access, Wireless Local Area Network (WLAN) or even cable access with corresponding policy and rule functions.

3.2 PQoS aware IMS client

At the PQoS-enabled user terminals (e.g. 3G mobile handset, softphone, PDA), a monitoring module and a UP management are integrated in the UE as depicted in Fig. 3. The UP management enables the terminal's interaction with the appropriate interfaces/modules of the MCMS. The UP management is in charge of collecting information of the

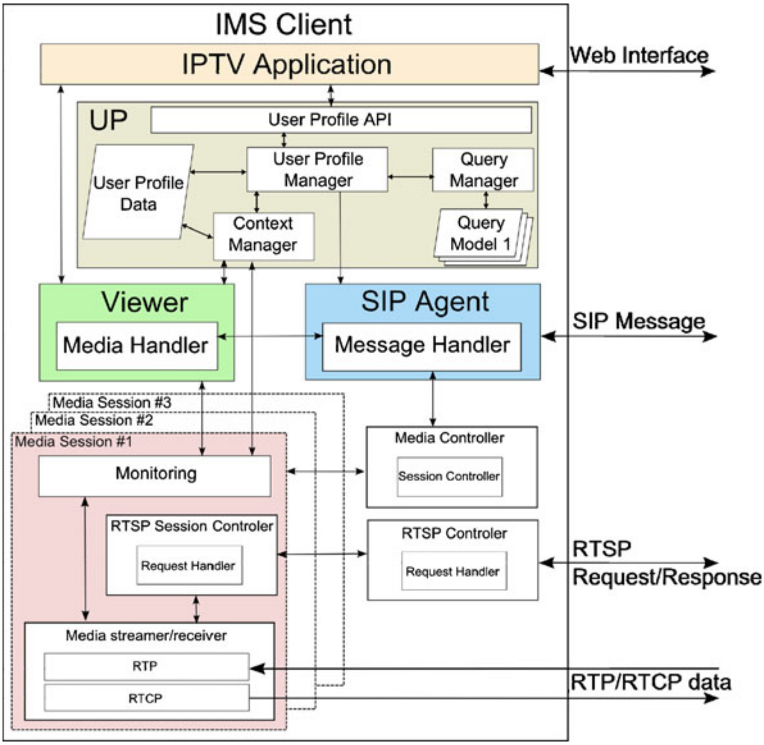

Fig. 3 PQoS aware IMS client architecture

user's environment and sending it to the MCMS. Based on the monitoring data gathered by the UP management, the UE initiates an IPTV media session with all the needed information to adapt the request service to its current environment. As soon as the IPTV session is established, UP management sends estimated PQoS values to the adaptation logic in the MCMS which initiates a dynamic adaptation procedure according to the monitored network statistics. The MCMS modules are implemented on a real IMS platform compose of a UMTS access network where IPTV over IMS services are integrated.

3.3 MSRF functions

The Multimedia Server and Resource Function (MSRF) is an IMS based Media Resource Function (MRF) [19] module with an additional threefold responsibility:

- IPTV service generation, session management and streaming,
- The monitoring of the spatial and/or temporal content dynamics along with the selected encoding/streaming parameters,
- The adaptation, according to the MCMS commands, of the IPTV encoding parameters and/or the respective FEC value.

The MSRF terminates the SIP session initiated by the end-user. It creates and manages IPTV media sessions taking into account the spatiotemporal content dynamics [7] in order to minimize the bandwidth usage while providing a satisfying user experience. When the MCMS PQoS alarm is triggered, it receives from the MCMS a request to monitor the corresponding RTCP information and sends it back to the MCMS. Then if the adaptation process is triggered, the MSRF receives the adaptation request and modifies the IPTV stream parameters.

3.4 Monitoring functions and adaptation enforcement at the access and transport networks edges

Our architecture considers a DiffServ/MPLS-enabled core network for the delivery of the requested multimedia service. We developed IMS and MCMS compatible modules and interfaces for the packet marking and traffic monitoring at the edges of the DiffServ/MPLS traffic network. All the core network nodes (i.e. routers) are considered as interworking and capable of treating appropriately marked traffic by the corresponding DiffServ/MPLS mechanisms, without any additional reconfiguration by IMS or MCMS modules.

A UMTS access network which provides service/bearer classification mechanisms to enforce QoS constraints on the delivered service type (e.g. video, voice, data, etc) is delivered. The classification mechanisms of the Gateway GPRS Support Node (GGSN) are exploited by the sophisticated PQoS-aware adaptation procedure to optimize the end-user experience. As a consequence, the Policy Decision Function (PDF @Release 6) or the Policy Control Rule Function (PCRF @Release 7) of the IMS will be exploited and further enhanced.

The overall architecture, including all the described components depicted in Fig. 2, enables novel capabilities of IMS system in terms of services.

4 User profile management in IPTV client architecture

The IPTV client is an enhanced context-aware IPTV client as shown in Fig. 3 gathering user's environment information into a context-dependent user profile. This user profile is defined in a XML format ordering pertinent context information into five components [1]: a **general user profile** which contains basic information about the user, a **device profile** which collects the descriptions of all user devices, a **network profile** which describes networks that the user can access, a **service profile** which records all the information about services and finally a **context profile** which contains data about the user environment information such as time, date, location, used device and network, the set of running applications, the PQoS parameters. This context profile constitutes the dynamic part of the user profile, mainly composed of volatile data. It must be filled automatically by sensing the environment.

4.1 User profile management architecture

The UP management is interfacing the IPTV application, the SIP Agent, the monitoring module and the Viewer (VLC for instance). The architecture of the UP management is shown in Fig. 3 and is composed of the following modules:

1. *User Profile Manager (UPM):* it is the central module of the UP management. It interacts with all other modules in order to construct the adequate user profile according to the needs of the application that performs the request. When the IPTV application starts to run, the UPM retrieves the application request from the API,

enables the context functions of the corresponding application, asks the query manager for the IPTV application's query model then performs the retrieved query on the user profile and finally transmits the new constructed user profile into the SIP INVITE request in a XML body.

2. *Context Manager (CM)* is composed of a set of functions that are designed to monitor the device and collect information about the operational environment. During a media session, the CM also listens to the monitoring module in order to trigger a PQoS alarm. Thanks to the CM, the dynamic part of the user profile, composed of volatile data representing a context, is regularly updated. This update is done in a reactive manner when CM receives events like the start of an application or notification about a new network attachment, and a proactive manner when the CM is configured to request the monitoring module.
3. *Query manager (QM):* is in charge of validating and saving a query model for each application. A query model is an XQuery [18] file that expresses all the needs of the application in terms of user information. It is constructed once at the IPTV application installation and used whenever this application requests the UP management. However, it can evolve according to the application needs. Besides the multiple facilities offered by XQuery in the presentation of the query results, we have chosen this language for its ability to express conditions thanks to its "Where" clauses. It then becomes easy to specify the information that should be returned according to the context.

4.2 User profile construction process

The different interactions between the components of the UP management that lead to the construction of an IPTV media session related to a user profile creation are illustrated in the sequence diagram of Fig. 4. These interactions are detailed in the following:

1. The IPTV application transmits its request to the UP management's API.
2. The API transfers the request to the UPM retrieving the application identifier in order to shape a new user profile.

3.1 The UPM asks the QM for the Query Model of the application.

3.2 The QM retrieves the Query Model of the corresponding application identifier, received from the UPM.

3.3 The QM replies to the UPM with the Query Model in its response.

4.1 In parallel to step 3, the UPM notifies the CM that the AppID application starts to run and asks it to update the User Profile with the current context information.

4.2 The CM retrieves the context parameters that must be monitored from the User Profile.

4.3 The CM enables the monitoring functions that collect the context information.

4.4 The CM updates the corresponding elements of the User Profile with the collected information.

4.5 It then notifies the UPM that the User Profile was updated.

5. The UPM executes the Query retrieved from the QM and constructs the new shaped User Profile that responds to the application needs.
6. The UPM transfers the new shaped User Profile to the Transport Manager (TM) with the request ReqToS (Request To Server) received at the beginning.
7. The SIP Agent, the Transport Manager in this case, encapsulates the received parameters in a SIP INVITE.
8. Finally, this module transmits the Signaling Message to the IMS Core.

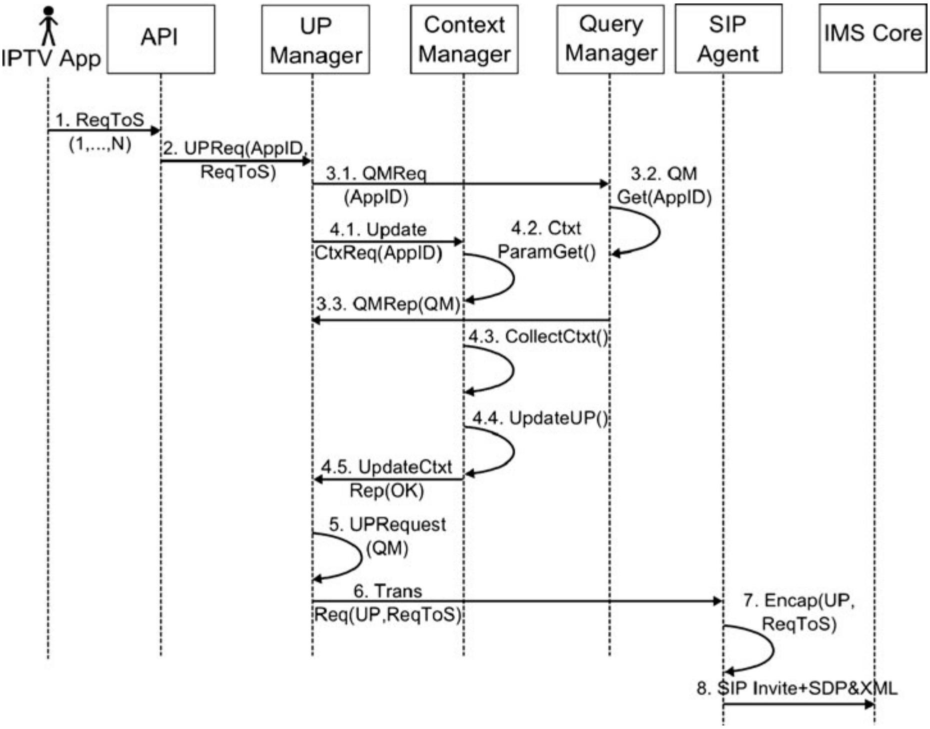

Fig. 4 User profile construction diagram

5 IPTV adaptation mechanism in IMS

5.1 IMS media session management

The Fig. 5 describes sequence diagram of the messages that are exchanged when an IPTV session is established and torn down between a UE and the MSRF through IMS. An example of adaptation mechanism with Session Description Protocol (SDP) [12] re-negotiation is also shown. For sake of simplicity in the diagram, we neither represent messages flowing through the Call Session Control Function (CSCF) elements nor do we represent the Rx interface between P-CSCF and PCRF. The Ut/Xa reference points, used for service profile configuration are also not shown. The successfully registered UE initiates the IPTV service sending a SIP INVITE request with two bodies. A first SDP body describes the media session (codec, video to play, framesize, framerate, bitrate) as depicted in Fig. 6 and the second XML body describes user environment as depicted in Fig. 7. The first SIP contact entry point for the UE is the Proxy-CSCF. Proxy-CSCF forwards the INVITE request to S-CSCF. The latter detects an IPTV service initiation thanks to the service-triggering information presented in the form of initial filter criteria (iFC) downloaded from HSS during the UE's Registration process. S-CSCF forwards the request to a specific IPTV AS through the IMS Service Control (ISC) interface. IPTV AS treats the request by parsing the SDP and XML bodies in order to retrieve the media filename to play and the user's environment information. The IPTV AS may also use the IPTV user profile

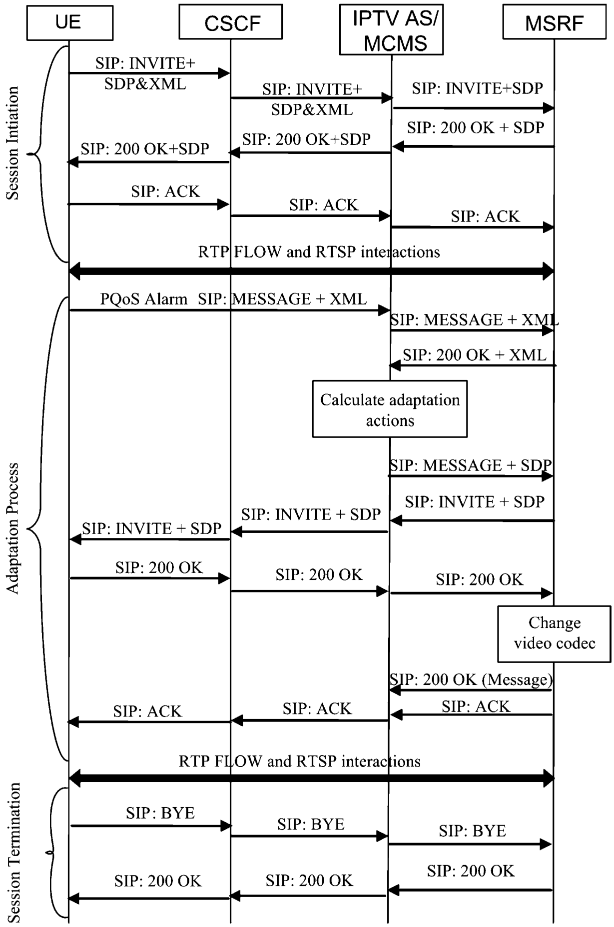

Fig. 5 IPTV session handling for adaptation with SDP re-negotiation

Fig. 6 Example of SDP body

```
v=0
o=aude 13460 13460 IN IP4 192.168.1.153
s=ADAMANTIUM streaming session
t=0 0
a=tool:GStreamer
a=type:broadcast
a=media:a.avi
m=video 5000 RTP/AVP 96 34 32
c=IN IP4 192.168.1.153
a=rtpmap:96 H264/90000
a=rtpmap:34 H263/90000
a=rtpmap:32MPV/90000
a=framerate:25.0
a=framerate:CIF
m=audio 5002 RTP/AVP 8
c=IN IP4 192.168.1.153
a=rtpmap:8 PCMA/8000
```

Fig. 7 XML body in SIP requests sent by the UE before and after adaptation


```
⊟ <context>
  ⊟ <used_cpu>
      13.14 %
      </used_cpu>
  ⊞ <available_ram>
  ⊟ <time>
      18:03:12
      </time>
  ⊞ <date>
    <location/>
  ⊟ <running_application>
      iptv/ftp
      <running_application/>
  ⊟ <current_network>
    ⊟ <used_bitrate>
        scale="KB/s"
        2344.250
        </used_bitrate>
    ⊞ <error_rate>
    ⊟ <packet_loss>
        10.49 %
        </packet_loss>
    ⊟ <bitrate>
        24 Mb/s
        </bitrate>
    ⊟ <rtt>
        scale="ms"
      ⊟ <avg>
          3.348
          </avg>
      ⊞ <min>
      ⊞ <max>
        </rtt>
    ⊟ <link_quality>
      ⊞ <signal_level>
      ⊞ <noise_level>
      ⊞ <quality>
        </link_quality>
      </current_network>
  ⊟ <service>
      id="iptv"
    ⊟ <service_throughput>
        401.410
        </service_throughput>
      </service>
    </context>
</user_profile>
```

```
⊟ <context>
  ⊟ <used_cpu>
      15.50 %
      </used_cpu>
  ⊞ <available_ram>
  ⊟ <time>
      18:03:21
      </time>
  ⊞ <date>
    <location/>
    <running_application>
      iptv/ftp
      <running_application/>
  ⊟ <current_network>
    ⊟ <used_bitrate>
        scale="KB/s"
        2005.450
        </used_bitrate>
    ⊞ <error_rate>
    ⊟ <packet_loss>
        2.44 %
        </packet_loss>
    ⊟ <bitrate>
        24 Mb/s
        </bitrate>
    ⊟ <rtt>
        scale="ms"
      ⊟ <avg>
          1.624
          </avg>
      ⊞ <min>
      ⊞ <max>
        </rtt>
    ⊟ <link_quality>
      ⊞ <signal_level>
      ⊞ <noise_level>
      ⊞ <quality>
        </link_quality>
      </current_network>
  ⊟ <service>
      id="iptv"
    ⊟ <service_throughput>
        54.800
        </service_throughput>
      </service>
    </context>
</user_profile>
```


to customize the user experience according to the user's preferences. Then, the IPTV AS forwards the "customized" INVITE request to a corresponding MSRF which terminates the SIP dialog. The MSRF sends back a 200 OK message with the final negotiated SDP body and the CSCF elements forward it to the UE. Then, the MCMS adaptation interface is informed about the active service sessions since it belongs to IPTV AS. The MCMS modules do not perform any monitoring or adaptation actions (idle mode) but simply wait for the reception of a PQoS-degradation alarm from the end-user terminal, indicating poor perceptual quality and therefore bad user experience. The idle mode is essential for the MCMS scalability abilities, because during this passive operating mode resources are not consumed.

From this point, we distinguish two main use cases:

1. The MCMS adaptation interface triggers an adaptation that requires a renegotiation of the SIP session. In that case, the MCMS adaptation interface will send a SIP Message

to the MSRF. The latter will renegotiate the session with the user terminal, in order to inform the terminal of the new video parameters such as changing the video codec. A Re-INVITE is used to renegotiate the SDP parameters because the INVITE process acknowledges the renegotiated SDP (request, response, acknowledgment) contrary to an UPDATE process [11] (request, response).
2. The MCMS adapts the required parameter without informing the user terminal. The user terminal adapts itself to the changed video and audio streams such as a new bitrate of the video. A simple SIP UPDATE is sent from IPTV AS on the behalf of the MSRF.

Only the first case is depicted in Fig. 5 as the adaptation process involving SDP renegotiation is more complex than the second case.

5.2 MSRF adaptation process

The MSRF is driven by an IMS SIP UA. It instantiates a streaming session when it receives a SIP INVITE message from the IPTV. Each streaming session is composed of:

- A Media Streamer that streams media resources to the requesting client;
- A Real Time Streaming Protocol (RTSP) [14] session controller that controls the Media Streamer with respect to the commands received from the client;
- A MSRF/MCMS InterFace (MMIF), which sends monitoring data to the MCMS monitoring interface and enforces adaptation commands received from the MCMS.

5.2.1 MSRF components involved in the adaptation process

The different components of the MSRF are the following:

- The IMS SIP UA Component handles all SIP incoming requests destined for MSRF. During the session initialization, it communicates with the Media Controller for media resource availability and the streaming session creation (session streamer instantiation to serve one user). Then, during the streaming, the IMS SIP UA listens to monitoring and adaptation requests and forwards them to the MMIF. It then sends back then SIP requests/responses depending on the MMIF status. Finally, the IMS SIP UA also listens to session release by communicating with the Media Controller for the session teardown.
- The MMIF collects monitoring data from the media streamer and sends them back to the MCMS monitoring interface. MMIF also receives adaptation orders from the MCMS adaptation interface through a SIP Message communication. With respect to the state of the RTSP session, the MMIF will then forward these orders to the Media Streamer. The Media Streamer will finally enforce the adaptation actions. The RTSP Session Controller is responsible for particular User session streaming control using the RTSP protocol. The session itself is initialized by the IMS SIP UA. The RTSP Server bloc listens to the RTSP request messages and forwards them to the given RTSP Session Controller, based on the request URL.
- The Media Streamer component is responsible for streaming multimedia resources, using Real Time Protocol (RTP) [15]. The Session Controller subcomponent is responsible for effective session streaming creation or removal based on IMS SIP UA request, respectively after successful SIP INVITE or SIP BYE methods.

5.2.2 Streaming and adaptation use case elementary tasks

This section describes the use case for the media resource streaming and the adaptation with renegotiation focusing on the message exchanges that take place in each elementary task. We distinguish five elementary tasks carried out by the MSRF in this use case chain as described in Fig. 8:

1. The IMS-SIP compliant ***session initiation phase***, started from the IPTV client towards CSCFs with a SDP body and a XML body. The XML body depicted in Fig. 7 (left side) describes the user context. The dynamic part of the UP is inserted in the initial SIP INVITE sent by the UE. The AS/MCMS is able to parse and decode the XML body and adjusts the SDP according to the user environment. The INVITE message then contains the terminal's SDP offer corresponding to its capabilities (video size, codecs, etc.) and the name of the requested media resource. On reception of an INVITE + SDP message, the IMS SIP UA in the MSRF asks the Media Controller for the media resource availability and for a new session creation. The Media Controller instantiates a new session and, based on the resource availability the MMIF generates a SDP answer (new adapted SDP). Then, a response is sent back to the terminal using SIP OK + SDP message. If the terminal accepts the MSRF SDP answer, it acknowledges with a SIP ACK. Finally, the Media Streamer and the related RTSP session at the RTSP Server and the RTSP Session Controller are initialized.
2. The ***media resource streaming phase***, based on RTP/RTCP/RTSP protocols. More specifically, only the PLAY and PAUSE RTSP methods are used to start and pause the current media resource streaming. In fact, the terminal requests are received by the RTSP Server and forwarded to the RTSP Session Controller in order to play or pause the media resource at the Media Streamer. The responses are reported to the terminal through the reverse path. The media resource is streamed to the terminal using the classic RTP/RTCP protocol.
3. The ***session monitoring phase***, triggered by the MCMS on PQoS degradation detection at the terminal. The MSRF monitoring procedure uses the SIP MESSAGE with a XML body to send the QoS information of the RTCP session back to the MCMS. On monitoring request, the MCMS contacts the monitoring subcomponent of the MMIF. The latter retrieves the monitoring data from the Media Streamer, aggregates them and sends the results back to the MCMS.
4. The ***session adaptation phase***, also triggered using SIP signaling, by the MCMS to enforce the adaption decision based on the previous monitoring task. This adaptation phase is MCMS driven on PQoS degradation and after a successful monitoring procedure. It aims at adapting the media streaming parameters to the new network conditions for better media resource consumption at the terminal.

   In this task, MCMS sends a new SDP offer to the MMIF based on the MCMS adaptation decision available in SIP MESSAGE + SDP request. The generated SDP offer by the MMIF is sent to the terminal using SIP INVITE + SDP. If the terminal accepts this new SDP offer, it replies with a SIP INVITE OK. Then, the MMIF stops (PAUSES) the streaming process through the RTSP Session Controller and adapts the streaming parameters at the Media Streamer. After a successful adaptation, the IMS SIP UA acknowledges to the terminal and requests the RTSP Session Controller to restart (PLAY) the streaming process. Finally, a SIP MESSAGE OK is sent back to the MCMS.

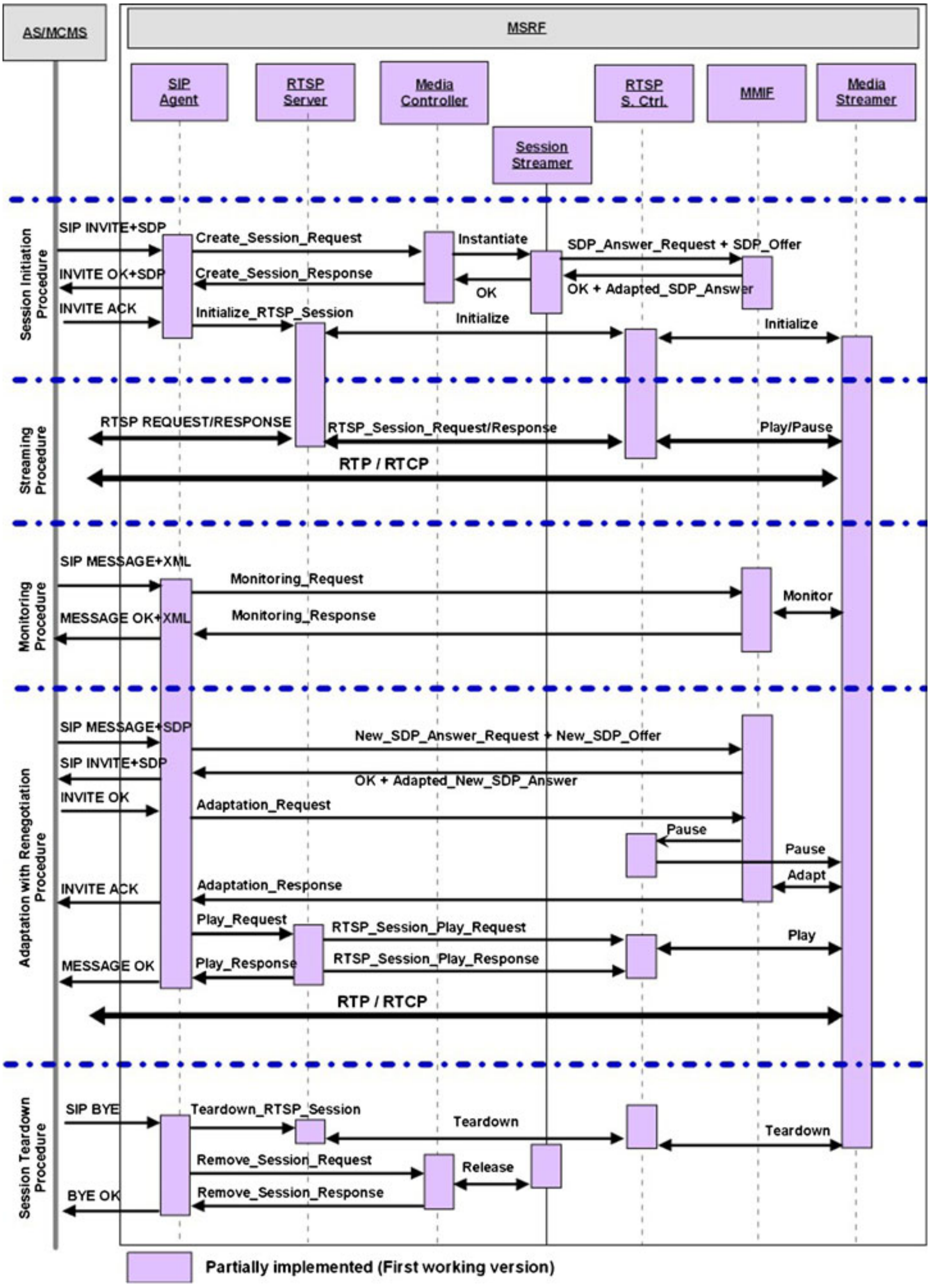

Fig. 8 MSRF adaptation procedure

Figure 7 (right side) depicts end user's context after the adaptation process. We can see that the IPTV service has a reduced throughput compared to the left XML body.

5. The IMS-SIP compliant ***session teardown phase***, requested by the terminal to free resources allocated in the aforementioned phases. This session clean-up procedure is

Table 1 System configuration

Component	Hardware	Software	Access network
TV HD connected to a desktop	Screen: Dell P2310H (1920×1080) Desktop: Dell Optiplex 745	Ubuntu 9.04, Python, Twisted, VLC	Wired
Notebook	Dell XPS 1530m (1440×900)	Ubuntu 9.04, Python, Twisted, VLC	Wifi
Netbook	Eeepc (800×600)	Ubuntu 9.04, Python, Twisted, VLC	Wifi
CSCFs	Dell Optiplex 745	Ubuntu 9.04, OpenIMSCore, VLC	–
AS/MCMS	Dell Optiplex 745	Ubuntu 9.04, Python, Twisted	–
MSRF	Dell Optiplex 745	Ubuntu 9.04, Python, Twisted	–

started by the terminal which sends an SIP BYE message through the CSCFs, the IPTV AS and is treated by the MSRF. Then, the MSRF's SIP UA sends a teardown request through the RTSP Server, the RTSP Session Controller, and the Media Streamer. The SIP UA also releases the reserved resources at the Media Controller and Session Streamer. Finally, the SIP BYE OK is reported back to the terminal.

6 Performance evaluation

This section presents the scenario used to validate the benefits of the User Profile management, the MCMS and MSRF modules and the adaptation process according to the video spatio-temporal activity also called content dynamics. The test-bed of this paper is composed of a UE, an OpenIMS Core, an AS/MCMS and a MSRF. The purpose of this test-bed is to estimate the QoE based on subjective tests in a live system. We use MOS estimations. 30 people estimated an HD IPTV (1920×1080) stream quality on an HD TV ready, a notebook and a netbook. We could not test the benefit of the PQoS aware IMS plateform on a mobile handset as no open source phone supports VLC [17]. Table 1 gathers the testbed information.

Figure 9 examines the impact of the spatiotemporal activity of the content on the perceptual acceptance threshold for various test signals. The lowest acceptable perceptual level is fixed to 3.5 in the MOS scale. Based on these experimental results, it is shown that for both

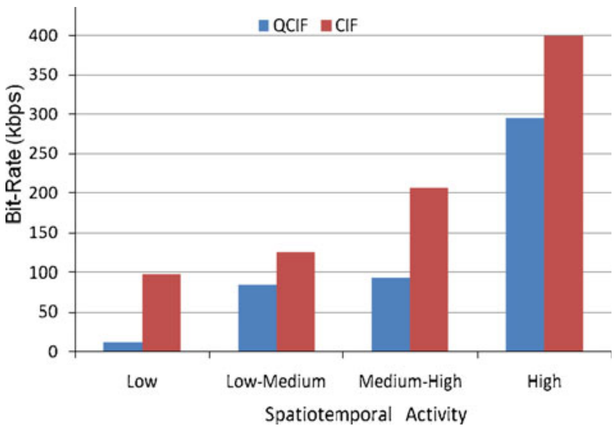

Fig. 9 Impact of dynamics on the acceptance PQoS threshold

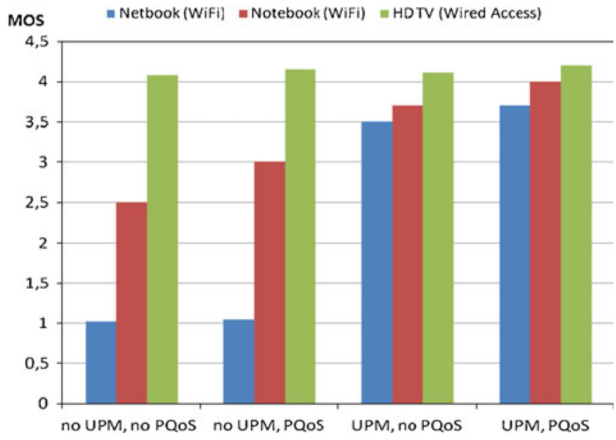

Fig. 10 MOS estimation with or without UPM and PQoS adaptations

CIF and QCIF spatial resolution need higher bit rate in order to achieve the perceptual acceptance threshold when the spatiotemporal activity becomes more complex. More specifically in the case of CIF, the demand in terms of bit rate becomes higher than for the case of QCIF. We use these results in our test-bed in order to optimize the video bitrate sent by the MSRF.

Figure 10 depicts the average MOS estimation for the different UEs. We distinguish 2 types of adaptation, the UPM adaptation starting when the end-user initiates the IPTV service and the PQoS adaptation when the PQoS alarm is triggered and the MSRF performs dynamic adaptation. We have four use-cases depending on whether the User Profile management and the PQoS mechanism are activated or not. The HD TV Desktop has no problem decoding an HD Video Stream and does not suffer from network impairment as it possesses a wired access. The addition of UPM and PQoS mechanism do not improve the MOS values. The Dell XPS 1530 notebook benefits from using PQoS mechanism as it suffers from network impairments. Finally, the Netbook suffers mainly from its hardware limitations. Indeed, the Netbook is not able to decode an HD IPTV stream. The User Profile management notifies the Netbook hardware limitation to the MSRF from the initiation of the media stream. Thus, the user is consuming an adapted stream from the start of the video content.

Fig. 11 Adaptation delay depending with or without UPM and PQoS adaptations

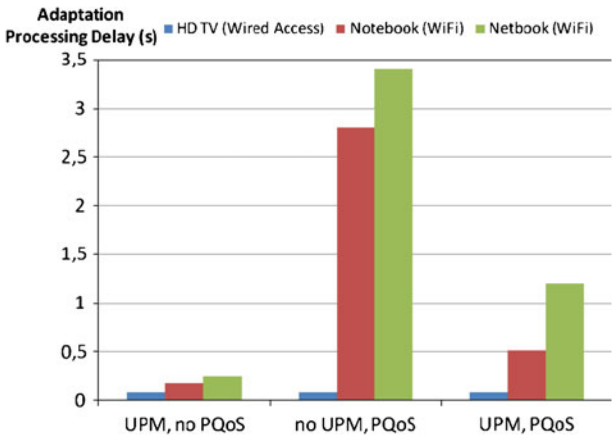

Figure 11 presents an overview of the response time evaluation of the overall adaptation process. The measured time starts from the service initiation for UPM adaptation process and the first alarm sent in the PQoS adaptation to the adaptation enforcement. We use the same four use-cases with and without UP and PQoS management. We consider that the MSRF is always able to deliver the requested IPTV stream. UPM adaptation processing delay corresponds to the time elapsed for the IPTV service to initialize with customized parameters. PQoS adaptation processing delay represents the time elapsed to adapt the content to the terminal and the access network condition of the end user. PQoS adaptation without UPM needs more time to deliver an acceptable IPTV stream as it requires a monitoring phase at the UE and MSRF sides. The HD TV Desktop does not need to trigger PQoS adaptation as the HD IPTV stream suits to its environment. As far as the Notebook and the Netbook are concerned, the time of UPM without PQoS adaptation is the sum of packets transmission delay and video transcoding/transrating. When the PQoS adaptation is enabled without UPM, PQoS adaptation mechanism requires few seconds to enforce the adaptation due to the monitoring and end-to-end session renegotiation delay (transcoding). However, in our test-bed configuration, when a PQoS adaptation is triggered with the UPM enabled, no end-to-end media session renegotiation is required: only transrating and/or transsizing is processed.

Thanks to these enhanced adaptation mechanism, end user satisfaction is guaranteed with a non significant overhead. For a 10 min video streaming with an average bitrate of 800 KB/s (considering that the PQoS monitoring SIP messages is sent every second), the overhead of the adaptation mechanism is 0,2% of the total traffic. Furthermore, adaptation is triggered by the UE only when the PQoS goes below an adjusted threshold. So the 0,2% overhead is thought to be the worse case in these use-cases.

7 Conclusion

This paper introduced a dynamic cross layer adaptation mechanism complying with IMS architecture for PQoS improvement of the entire IPTV content delivery chain. This is mainly achieved by the design of the MCMS and User Profile management in combination with cross-layer adaptation techniques. The overall architecture has been described and the adaptation use case has been introduced and discussed. An interesting adaptation approach based on video content dynamics is also introduced at the streaming server side. Nevertheless, further study concerning the protection of the user profile information and performance evaluation needs results with a complete live UMTS system is still ongoing.

Acknowledgment This work is supported by the European Commission in the context of the ADAMANTIUM project (ICT-2007.1.5-214751). Further information is available at http://www.ict-adamantium.eu/.

References

1. Ait-Chellouche S, Arnaud J, Négru D (2010) Flexible user profile management for context-aware ubiquitous environments, CCNC 2010, 1st IEEE International Workshop on Emerging Internet Video Technologies (EIVT 2010), Las Vegas, U. S. A., 9–12 January 2010
2. Camarillo G, Garcia-Martin MA (2004) The 3G IP Multimedia Subsystem, Wiley
3. DSL Forum TR-126 (2006) Triple-play services Quality of Experience (QoE) requirements

4. ETSI TS 182 027 V2.0.0 (2008) Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN); IPTV architecture; IPTV functions supported by the IMS subsystem (2008–02)
5. Friedrich O, Seeliger R, Gouveia F, Arbanowski S (2008) IPTV user equipment for IMS-based streaming services, Network Operations and Management Symposium Workshops, 2008. IEEE Digital Object Identifier: 10.1109/NOMSW.2007.6, pp 21–25
6. Khan A, Sun L, Ifeachor E (2010) QoE-driven adaptation scheme for video applications over wireless networks, IET communications, special issue on “video communications over wireless networks”
7. Koumaras H, Liberal F, Sun L (2008) Pre-encoding PQoS assessment method for optimized resource utilization, chapter contribution in “wireless multimedia: quality of service and solutions”, IGI Global Pub. ISBN: 978-1-59904-820-8, July 2008
8. Koumaras H, Arnaud J, Négru D, Kourtis A (2009) An experimental approach of video quality level dependence on video content dynamics, MobiMedia 2009, 3rd European Symposium on Mobile Media Delivery (EUMOB), London, U.K., 7–9 September 2009
9. Masonta, MT, Girod-Genet M, Oyedapo OJ, Chatelain D (2008) Light-weight IP Multimedia Subsystem (IMS) client for mobile devices, Electrical and Computer Engineering, 2008. CCECE 2008, Canadian Conference on Digital Object Identifier: 10.1109/CCECE.2008.4564575, pp 453–458
10. Poikselka M, Mayer G, Khartabil H, Niemi A (2006) The IMS IP multimedia concepts and services, Wiley
11. Rosenberg J (2002) The Session Initiation Protocol (SIP) UPDATE method, RFC 3311, September 2002
12. Rosenberg J, Schulzrinne H (2002) An offer/answer model with the Session Description Protocol (SDP), RFC 3264, June 2002
13. Rosenberg J, Schulzrinne H, Camarillo G, Johnston A, Peterson J, Sparks R, Handley M, Schooler E (2002) SIP: Session Initiation Protocol, RFC3261, June 2002
14. Schulzrinne H, Rio A, Lanphier R (1998) Real Time Streaming Protocol (RTSP), RFC 2326, April 1998
15. Schulzrinne H, Casner S, Frederick R, Jacobson V (2003) RTP: a transport protocol for real-time applications, RFC 3550, July 2003
16. Song S, Moustafa H, Afifi H (2009) Context-aware IPTV, 12th IFIP/IEEE International Conference on Management of Multimedia and Mobile Networks and Services, lecture notes in Computer science, vol 5842, pp 189–194, MMNS 2009
17. VideoLAN client: http://www.videolan.org
18. XQuery 1.0 (2007) An XML query language, W3C recommendation 23 January, http://www.w3.org/TR/xquery/
19. 3GPP TS 23.228 (2009) IP Multimedia Subsystem (IMS); Stage 2. V8.8.0, March 2009

Julien Arnaud received his MSc. Degree in Mobile Communication from the University of Aalborg, Denmark, in 2007. From 2007 to end 2008, he worked as a Customer Solution Manager for end-to-end IMS Solution in the headquarters of Ericsson Germany, Düsseldorf, and took part in several Proof-of-Concepts such as Deutsch Telekom IMS Test-Bed in Nürnberg. He started his PhD late 2008 at the LaBRI-CNRS in Bordeaux, France. He is currently involved in IST FP7 ADAMANTIUM, IST FP7 SEA and IST ALICANTE projects.

Daniel Négru after receiving his MSc. Degree in Computer Science from the University of Pierre and Marie Curie, Paris 6, in 2002, he worked in the centre of research of Motorola, Paris, specifying and developing a complete IPv6 stack from scratch, including Mobile IPv6 and multimedia components. Between 2003 and 2006, he worked at the CNRS laboratory, Paris area – French computer science research centre that does research in the underlying technologies for the next generation global information infrastructure – and participated in several national and European projects, such as ANR RIAM NMS, IST FP6 ATHENA, IST FP6 ENTHRONE, IST FP6 ENTHRONE2, IST FP6 IMOSAN, Eureka CELTIC eMotion. He received his PhD in 2006 in the field of Broadcast and Internet convergence solutions at the network and service levels. In 2007, he became Associate Professor at ENSEIRB School of Engineers / University Bordeaux, specializing in multimedia and networking and his main fields of research reside in the domains of mobility and multimedia over heterogeneous networks, IMS convergence, service accessibility and adaptation.

Mamadou Sidibé received his MSc. Degree in Computer Science from the University of Versailles, in 2003, in the domains of QoS monitoring and adaptation systems over heterogeneous networks. From 2004 to 2008, he worked as Associate Researcher at the CNRS-PRISM laboratory and participated in several European collaborative projects (Enthrone 1 & 2, ATHENA, IMOSAN). In 2008, he joined VIOTECH Communications as Research & Development Engineer and has been bringing his expertise in Multimedia and network monitoring into various national and European projects (ADAMANTIUM, MULTI@HOME and ARDHMANN) as well.

Julien Pauty received his Ph.D from the University of Rennes 1, France, in 2006. His research interests include ubiquitous and context-aware computing, with a strong emphasis on physical programming models. From 2002 to 2005 he worked at INRIA Rennes, France. To support his PhD work, he was granted a 3 years scholarship from the French research ministry. From 2005 to 2008, he worked as research engineer at the Katholieke Universiteit Leuven, Belgium. Most notably, he took part to the LOMS project, which received the ITEA 2008 Gold Achievement Award. In 2008, he joined VIOTECH Communications. As an R&D manager, he leads the development of a next generation home gateway. He's also participating to the IST ADAMANTIUM and ALICANTE projects.

Dr. Harilaos Koumaras was born in Athens, Greece. He received his BSc degree in Physics in 2002 from the University of Athens, Physics Department, his MSc in Electronic Automation and Information Systems in 2004, being scholar of the non-profit organization Alexander S Onassis, from the University of Athens, Computer Science Department and his PhD in 2007 at Computer Science from the University of Athens, Computer Science Department, having granted the four-year scholarship of National Centre of Scientific Research "Demokritos". He has received twice the Greek State Foundations (IKY) scholarship during the academic years 2000-01 and 2003-04. He has also granted with honors the classical piano and harmony degrees from the classical music department of Attiko Conservatory. Since 2004 he is a principal lecturer at the Business College of Athens (BCA) teaching modules related to Information Technology and Mathematics and Logic. From 2009, he has been elected as the Head of the Computer Science Department of BCA and Course leader of the respective franchised course of London Metropolitan University. He also joined the Digital Communications Lab at the National Centre of Scientific Research "Demokritos" in 2003 and since then he has participated in numerous EC-funded and national funded projects with presentations and publications at international conferences, scientific journals and book chapters. His research interests include objective/subjective evaluation of the perceived quality of multimedia services, video quality and picture quality evaluation, video traffic modeling, digital terrestrial television and video compression techniques. Currently, he is the author or co-author of more than 45 scientific papers in international journals, technical books and book chapters, numbering 64 non-self citations. He is an editorial board member of the Telecommunications Systems Journal and a reviewer of the IEEE Network magazine, the EURASIP Journal of Applied Signal Processing, the IEEE Transactions on image processing and the IEEE Transactions on Broadcasting. Dr. Koumaras is a member of IEEE, SPIE and National Geographic Society.