Scalable multimedia delivery with QoS management in pervasive computing environment

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Abstract People are increasingly demanding rich-media and bundled services. However, the diverse terminals, heterogeneous networks as well as various user requirements constrain the multimedia access to low quality in the pervasive computing environment. In order to enable rich-media delivery across a wide range of devices and networks, multimedia adaptation with scalable QoS management is an important issue. Our research introduces a Scalable Multimedia Delivery (SMD) framework with QoS management. This framework utilizes the CAM4Home metadata model to aggregate multimodal rich media services into a bundle. MPEG-21 metadata is integrated into the CAM4Home model to enforce interoperable QoS management. The issues in supporting QoS are addressed on both fidelity and modality. We further develop the SMD system in IP Multimedia Subsystem (IMS) architecture, where multimedia adaptation is implemented through application-level QoS negotiation.

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1 Introduction

The past decade has witnessed a revolution in mobile multimedia technologies. With the proliferation of mobile devices and deployment of wireless networks, people can access multimedia contents anytime and anywhere, which is the vision of Universal Multimedia Access [1, 2]. Under this trend, wireless networks and multimedia services are converging to the ubiquitous multimedia system. Unlike traditional data, multimedia contents have more stringent Quality of Service (QoS) requirements. However, the diverse terminals, heterogeneous networks as well as various user requirements constrain the multimedia access to low quality in the pervasive computing environment. Meanwhile, the emerging pervasive services are getting more and more complicated when the rich-media services are aggregated, known as service composition [3–5]. As a result, a uni-model for QoS provisioning is not suitable for the application-driven and mission-critical pervasive services. It is desired to have a scalable and quality-assured multimedia delivery system.

A ubiquitous multimedia system needs to adapt multimedia contents to various constraints of terminals and networks as well as user preferences, while providing the best possible quality to the end user. Thang et al. [6–8] have intensively studied the quality in multimedia content delivery. They identified the quality from two aspects: perceptual quality and semantic quality. The former known as fidelity refers to a user's satisfaction, while the latter is the amount of information the user obtains from the content. The semantic quality is sometimes referred as Quality of Experience (QoE) or Information Quality (IQ). In some cases, the perceptual quality of an adapted content is unacceptable or its semantic quality is much poorer compared with that of a substitute modality. A possible solution for this problem is to convert the modality of contents. For example, when the available bandwidth is too low to support the video streaming service for a football match, the text-based statistics service would be more appropriate than the adapted video with poor perceptual quality. This is a typical case of video-to-text modality adaptation. Apparently, the combination of fidelity and modality can enhance user experiences. Smith et al. [9] proposed a scalable model named InfoPyramid, which manages the different variations of media objects with different fidelities and modalities in order to adapt the delivery to different client devices. However, it considered only the diversity of terminal devices, which is far less than enough for heterogeneous networks. Besides, this article did not give details on the data model such as description language. Considering the diverse devices and heterogeneous networks, we argue that a scalable model with end-to-end QoS management is critical for rich-media delivery in the pervasive computing environment. Without such as a model, the quality-assured pervasive services would not be really feasible, especially from the viewpoints of service providers. If the service providers could specify a service model with service requirements, they would be relieved from implementing complex QoS decision making functionality for each new service being introduced, hence leading to simplified provisioning and quicker time-to-market for new services [10].

In this paper, we present a Scalable Multimedia Delivery (SMD) framework with QoS management in the pervasive computing environment. The advanced multimedia delivery supports the aggregation of multimodal media including video, audio, image, and even text. Most prominently, the framework provides scalable QoS management for multimodal media delivery. The concept of scalability in this paper means that the rich-media contents can be tailored and adapted with the assured quality to diverse terminals and heterogeneous networks. We address the issues in supporting QoS from two levels, namely fidelity and modality. The former supports quality adaptation to guarantee QoS, while the latter provides modality transformation to maximize QoE. To support this notion of scalability, we utilize CAM4Home [11] as the model that combines multimodal media into a bundle on the level of metadata. CAM4Home is an ITEA2 project implementing the concept of Collaborative Aggregated Multimedia (CAM). We further propose to integrate MPEG-21 metadata within the CAM4Home model in order to enable interoperable QoS management. Accordingly, MPEG-21 metadata aims to provide the best user experiences across multimodal services. To verify the proposed model is network applicable, we develop the SMD prototype system based on IP Multimedia Subsystem (IMS) architecture. SMD is implemented during session negotiation by two-step adaptation, presession and insession.

The rest of the paper is organized as follows. Section 2 reviews the background and related works. In Sect. 3, we describe the requirements on SMD and present the scalable service model. Section 4 discusses the approach to apply the metadata-based SMD model into IMS service architecture. A prototype system and the performance evaluation are described in Sect. 5. Section 6 concludes the paper and presents some issues for future research.

2 Background and related works

Providing QoS support is one of the most challenging problems toward ubiquitous multimedia. The issue of QoS can be addressed at different levels [12], namely user level, application level, transport level, and network level, as well as across different stakeholders [13], namely content provider, service provider, network provider, and end user. In terms of application level, dynamic adaptation of multimedia content is seen as an important feature of pervasive systems enabling terminals and applications to adapt to changes in access network, and available QoS due to mobility of users, devices or sessions [14]. Generally, it is a computing intensive process for adaptation decision-taking involved for choosing the right set of parameters that yield an adapted version. The computational efficiency of adaptation can be greatly enhanced if this process could be simplified, in particular by metadata that conveys precomputed relationships between feasible adaptation parameters and media characteristics obtained by selecting them [15]. Moreover, the development of an interoperable multimedia content adaptation framework has become a key issue, in order to cope with this heterogeneity of multimedia content formats, networks, and terminals. To address above problems, MPEG-21 Digital Item Adaptation (DIA) specifying metadata for assisting adaptation has been finalized as part of the MPEG-21 Multimedia Framework [16].

The past researches on multimedia adaptation are more concerned with the perceptual quality from the perspective of end user. However, the intensive studies in

[6–8] state that the semantic quality should be considered in some cases. They argue that modality conversion could be a better choice than unrestricted adaptation on fidelity. The Overlapped Content Value (OCV) model is introduced in [6] to represent conceptually both content scaling and modality conversion. The past research works made most efforts to optimize mathematic model for modality adaptation [6, 15, 17], focusing on two questions "when to change the modality?" and "what is the substitute modality?" However, the question on "how to do modality adaptation" is usually ignored, especially from the viewpoints of content providers and service provider. Apparently, the combination of fidelity and modality can bring the best user experiences. Smith et al. [9] presented the InfoPyramid model that support multimedia delivery with different fidelities and modalities in order to adapt the delivery to different client devices. However, it considered only the diversity of terminal devices. Moreover, the proposed model is neither standard interoperable nor network applicable.

Toward all-over-IP network architecture, IP Multimedia Subsystem (IMS) [18] has been recognized as the service architecture for Next Generation Networking (NGN). Many works related to QoS have been studied for IMS-based multimedia delivery. Skorin-Kapov et al. [19] described the application-level QoS negotiation and signaling for advanced multimedia services in the IMS. Ozcelebi et al. [20] presented a solution for multimedia streaming quality adaptation using resource management. Arnaud et al. [21] introduced an adaptation of IPTV service according to the perceived QoS degradation at the side of end user. Even though session negotiation mechanisms used above ensure QoS to some extent, it is still not enough for multimedia applications in pervasive computing environment due to the diversity of end devices and highly resource-consuming multimedia contents. Firstly, QoS negotiation occurs at the layer of signaling and control. However, it is the service provider who really knows and manages the quality of multimedia service. Secondly, IMS services are originally designed by service providers for specific end devices or access networks. It is time to move from special-purpose, one-of-a-kind to more widely deployable that can scale to user context. Therefore, mechanisms are needed providing a more advanced decision-making process based on matching restrictive user parameters, service requirements, and network constraints, with the goal of achieving maximum user experiences [19].

In this paper, we concentrate on both the user level by specifying user perceivable service parameter and the application level by adapting contents according to the resource availability of terminal and network. We present a SMD framework enforced by interoperable QoS management. The proposed model considers both fidelity and modality to meet QoS requirements in the diverse terminals, heterogeneous networks as well as dynamic network conditions.

3 Scalable multimedia delivery model

This section firstly describes the concept of SMD in detail. The SMD model is further decomposed into two essential parts: multimodal service aggregation and metadata-based QoS management.

Fig. 1 Sports live broadcasting user case
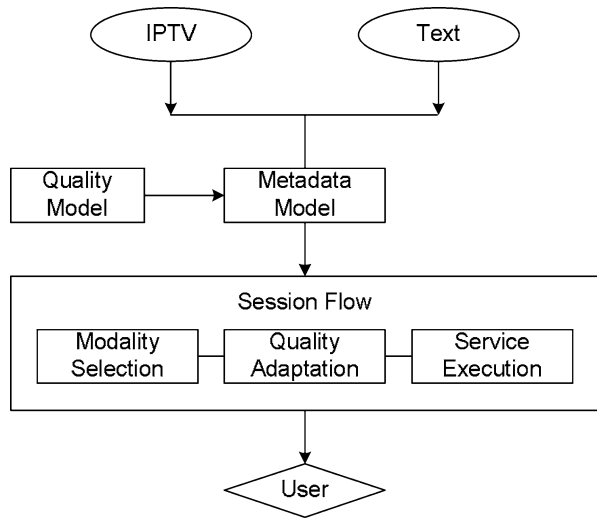
3.1 Concept of scalable multimedia delivery

The scalability in this paper is proposed on two levels: fidelity and modality. To support this notion of scalability, we consider a service as a collection of multimodal service components which are semantic-coherent but independent services offered for certain end devices, access networks, or user preferences. The breakdown of a service into service components supports its adaptation for a given device type, network, or user by allowing the sorting, filtering, and adaptation of its individual components [24]. Let us take "Sports Live Broadcasting" service as an example. The scenario is the last round of the football league where more than one team has the chance to win the championship. All teams start playing at the same time. Fans are watching the live TV broadcasting of their team. Obviously, they may also want to be updated on the information (e.g., goal, penalty, and red card, etc.) of other simultaneous matches. The "Sports Live Broadcasting" application contains two subservices. The first one is an IPTV program delivering a live football game, which is designed for high-end devices with broadband network. The second one is a real-time literal broadcasting service delivering statistics data synchronized to all football matches, which is designed for devices with narrowband network like mobile phones. Furthermore, the IPTV service component can be configured by a set of offered alternative operating parameters (e.g., frame sizes, frame rates and bit rates etc.), which can be adjusted dynamically according to user context. Before multimedia session, the scalable service model firstly selects the service version according to the static capabilities of terminals or networks. During session, this service element of IPTV can be adapted according to dynamic network condition or user preferences. Moreover, if the adapted IPTV service cannot provide the expected user-perceived quality, a cross-modal adaptation from IPTV to Text may occur. This user case is described in Fig. 1. Theoretically, the modality adaptation of video-to-audio occurs before that of video-to-text. We omit the first adaptation just for the reason of simplicity.

The requirements for SMD exist in three aspects. The first one is related to user requirements. People are demanding rich-media and bundled services that extend well beyond voice to include text, image, audio, and video [22]. The second requirement is related to service requirements [23]. For example, it is desirable for the service provider to design an application customized for different user contexts. To maximize user experience or information quality, there is a need for the support of cross-modality adaptation in case a terminal or network cannot support the consumption or transport of a particular modality. The third one is related to network requirements. QoS needs to be adapted to dynamic network conditions in real time. The concept of SMD covers the whole value chain across different stakeholders, namely content provider, service provider, network provider, and end user. In this paper, we are concerned more with the service provider.

To sum up, SMD is a sender-driven service model, which aims to create and deliver advanced multimedia experiences tailored to heterogeneous user devices, varying network conditions and diverse user requirements. This service model requires a service profile aggregating multimodal media types associated with pre-computed QoS parameters. There are two essential parts inside: multimodal service aggregation and metadata-based QoS management.

3.2 Multimodal service aggregation

The essential part of SMD is the multimodal service aggregation. In this paper, we use CAM4Home framework as the metadata model for multimodal service aggregation. The CAM4Home is an ITEA2 project implementing the concept of Collaborative Aggregated Multimedia (CAM) [11]. The concept of CAM refers to aggregation and composition of individual multimedia contents into a content bundle that may include references to content-based services and can be delivered as a semantically coherent set of content and related services over various communication channels. This project creates a metadata-enabled content delivery framework by bundling semantically coherent contents and services on the level of metadata. The CAM4Home metadata model supports the representation of a wide variety of multimedia content and service in CAM Element as well as its descriptive metadata. CAM Object is the integrated representation of CAM Element and CAM Element Metadata on the association rule "*isMetadataOf.*" CAM Bundles are the aggregation of two or more CAM Objects on the association rule "*containsCAMObjectReference.*" CAM Object and CAM Bundle can be uniquely identified by "*camElementMetadataID*" and "*camBundleMetadataID.*" Figure 2 illustrates a conceptual view of CAM Bundle and CAM Object.

The taxonomy of CAM Element has two subclasses, Multimedia Element and Service Element. The Multimedia Element is the container of a specific multimedia content, which is further divided into four types, document, image, audio and video. The Service Element is the container of a specific service. The physical content in CAM Element is referred by the attribute "*EssenceFileIdentifier*" which is a Universal Resource Locator (URL). Actually, the physical content can be referred by the URL. The Service Element includes the other attribute "*ServiceAccessMethod*" indicating the methods used to access the service. With the instinctive of CAM, we use

Fig. 2 Conceptual view of
CAM bundle and CAM object

CAM Bundle

CAM Object
• CAM Element
• CAM Element Metadata

CAM Object
• CAM Element
• CAM Element Metadata
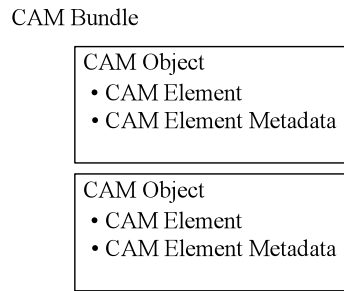
the metadata-based approach for the content and service delivery. For example, the attribute "*EssenceFileIdentifier*" can be used to indicate the Public Service Identity (PSI) of an application server in IMS. And the other attribute "*ServiceAccessMethod*" indicates the Session Initiation Protocol (SIP) methods (e.g., INVITE) accessing the service. However, the services are not limited to SIP-based. This model can be used to encapsulate any types of services.

Similarly, MPEG-21 Digital Item introduced a media-agnostic container for content. However, our proposed SMD focuses more on media service. Moreover, CAM4Home provides an open metadata model to integrate with external metadata schemas. MPEG-7 as well as TV-Anytime can be used to enrich content descriptions and facilitate content discovery. MPEG-21 can be introduced to enforce QoS management. Therefore, in this paper the CAM4Home metadata model is adopted as the rich-media aggregation model for SMD.

3.3 Metadata-based QoS management

It is necessary to provide a quality-guaranteed and interoperable content delivery across converged complex devices and distribution networks as well as an optimized use of underlying delivery network bandwidth and QoS characteristics. Toward this purpose, we propose to integrate MPEG-21 DIA into CAM4Home model enabling QoS management. MPEG-21 DIA aims to standardize various adaptation related metadata including those supporting decision-taking and the constraint specifications [15]. MPEG-21 DIA specifies normative description tools in syntax and semantic to assist with the adaptation. The central tool is the Adaptation QoS (AQoS) representing the metadata supporting decision-taking. The aim of AQoS is to select optimal parameter settings that satisfy constraints imposed by a given external context while maximizing QoS. The adaptation constraints may be specified implicitly by a variety of Usage Environment Description (UED) tool describing user characteristics (e.g., user information, user preferences, and location), terminal capabilities, network characteristics, and natural environment characteristics (e.g., location, time). The constraints can also be specified explicitly by Universal Constraints Description (UCD).

Syntactically, the AQoS description consists of two main components: Module and Input Output Pin (IOPin) [25]. Module provides a means to select an output value given one or several input values. There are tree types of modules, namely,
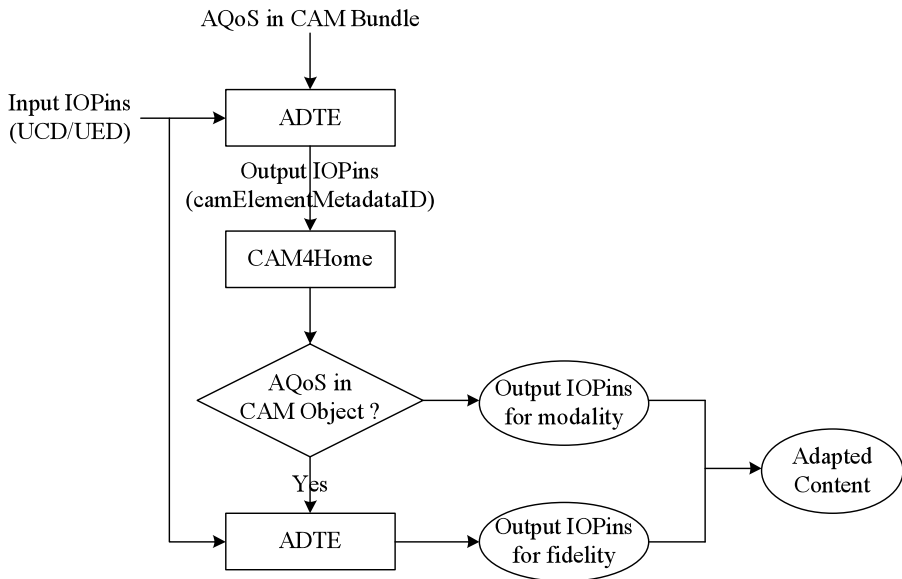
Fig. 3 Metadata-based multimedia adaptation

Look-Up Table (LUT), Utility Function (UF), and Stack Function (SF). IOPin provides an identifier to these input and output values. Originally in MPEG-21 DIA, the output values are utilized by Bitstream Syntax Description (BSD) [26] for content-independent adaptation. However, in the proposed SMD model, the adapted target is altered to CAM Bundle. As mentioned in Sect. 3.1, the multimedia adaptation is proposed on two levels: quality and modality. The quality adaptation is to adapt one of the aggregated service component adjusting QoS parameters. The modality adaptation is to select the most appropriate modality among aggregated multimodal services components. We propose to embed AQoS in each CAM Object for quality adaptation as well as to associate AQoS with CAM Bundle for modality adaptation. In this regard, for quality adaptation the output values (e.g., bit rate, frame rate, resolution) are utilized to yield an adapted version on a single service component. For modality adaptation, we set "IOPin" as the "camElementMetadataID" that identifies a specific service component within the CAM Bundle. The model of multimedia adaptation is illustrated in Fig. 3. In the value chain of SMD, the service providers take the responsibility on specifying these QoS management parameters.

To further explain the use of MPEG-21 DIA in CAM4Home model, we take the aforementioned "Sports Live Broadcasting" service as an example. We will not go into detailed explanation of the elements and attributes of the above example, as the names of these are self-explanatory and the complete specification of all these elements and attributes and their associated measurement units are defined in detail in the MPEG-21 DIA standard. The constraint for modality adaptation is the average available bandwidth of network condition as defined in [27]. The utility function is utilized to reflect the semantic quality. The utility can be precomputed off-line as presented by [15, 28], which is beyond the scope of this paper. The constraints for
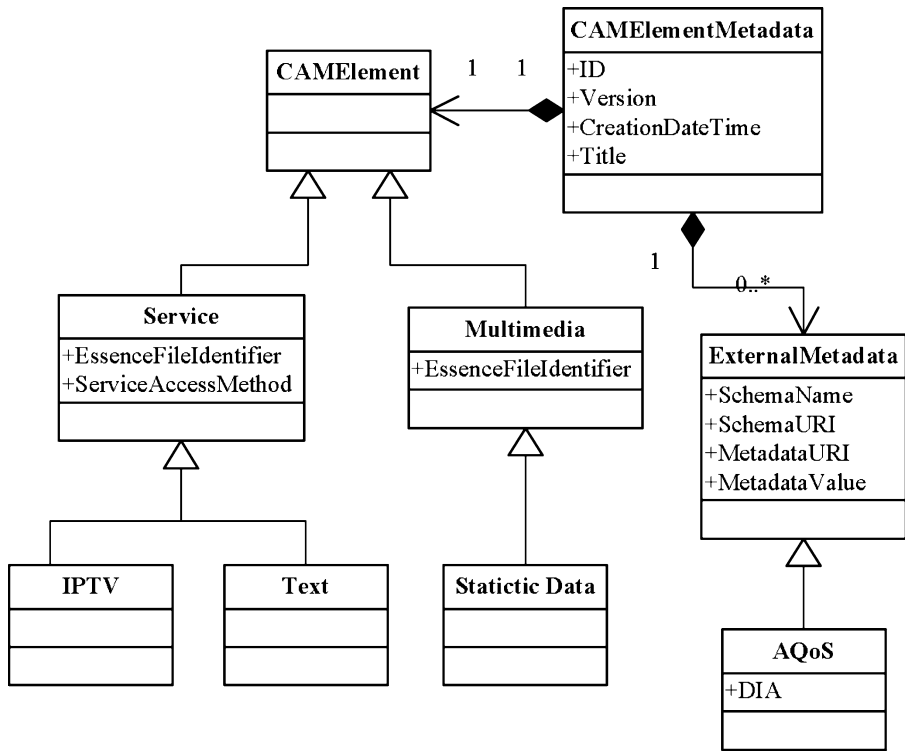
Fig. 4 CAM4Home metadata example

quality adaptation include the width and the height of display capabilities. Figure 4 shows the metadata extension for "Sports Live Broadcasting" service**.**

4 Scalable multimedia delivery framework

In this section, we firstly overview the IMS architecture. Then we propose the approach to implement SMD based on IMS from two aspects: multimedia adaptation and session negotiation.

4.1 IMS service architecture

IMS has been recognized as the service architecture for NGN, offering multimedia services and enabling service convergence based on diverse network access technologies. With the advantage of an All-over-IP network, the opportunity for integration and convergence is amplified in IMS. The IMS service framework can be used to implement new services, but its main strength might eventually be in its ability to seamlessly integrate existing services and deliver them to end-users in an optimized manner. The IMS architecture is made up of two layers: the service layer and the control layer. The service layer comprises a set of Application Servers (ASs) that host and

execute multimedia services. Session signaling and media handling are performed in the control layer. The key IMS entity in this layer is the Call Session Control Function (CSCF) which is a SIP server responsible for session control. There are three kinds of CSCF, among which Serving CSCF (S-CSCF) is the core for session controlling and service invocation. Home Subscriber Server (HSS) is the central database storing the subscriber's profile. Regarding the media delivery, the key component is Media Resource Function (MRF) that can be seen as media server for content delivery. In IMS, SIP is used as the signaling protocol and Real-time Transport Protocol (RTP) is used as the media transport protocol.

In order to support advanced media-rich applications across a wide range of user devices and access networks, IMS supports negotiable QoS for multimedia sessions. The goal of QoS negotiation is to determine "the best" service configuration and network resources allocation that would maximize user perceived service quality [19]. Technically, SIP is used for initiating and managing communication sessions. The application level signaling messages carry session descriptions which allow participants to exchange end-system capabilities and agree on a set of compatible media types. The session description is commonly formatted in Session Description Protocol (SDP) [29], while the session negotiation procedure is based on Offer/Answer model [30]. The syntax of SDP is extensible and new attributes are added to the standard occasionally. It is possible to negotiate QoS parameters at the beginning of session by SIP signaling messages. Considering resource-consuming and real-time multimedia services, the presession QoS negotiation is not enough. It is also necessary to renegotiate or modify QoS parameters to satisfy dynamic constraints. As a result, the session renegotiation depending on network conditions or application requirements is also specified.

In the IMS service architecture, AS hosting a specific service can be seen as a provider of media modality. Hereafter, an IMS service in this paper is referred to a content-based service. As a result, the SMD framework should firstly support the combined delivery of multimodal services based on CAM4Home model. Further, the QoS management enforced by MPEG-21 DIA metadata should be applied into IMS service architecture. Especially, the cross-modal adaptation is implemented as service switching among aggregated services. AS also interacts with MRF in order to ensure the adaptive delivery of media. Figure 5 illustrates the conceptual SMD framework in IMS.

4.2 IMS-based SMD framework

4.2.1 Adaptation framework

The essential component of SMD is Multimedia Service Management (MSM) shown in Fig. 5. This component is evolved from our previous research work [31] where MSM implements the metadata-based multimodal content delivery in IMS. As mentioned in Sect. 3.1, SMD is a receiver-driven service model. Therefore, MSM is firstly proposed as a generic component of Service Deliver Platform, responsible for service-related functionalities, such as service registration and service discovery, etc. Services represented as CAM metadata entities (e.g., object or bundle) are registered

Fig. 5 IMS-based SMD framework
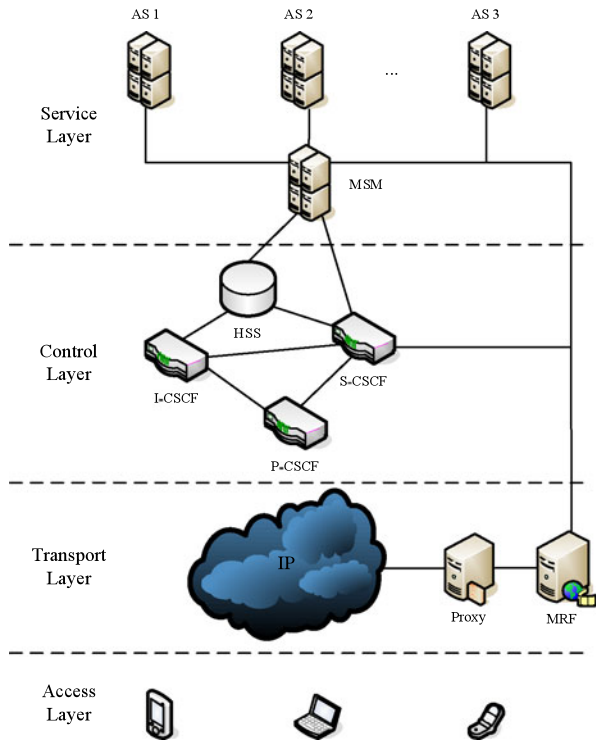
in MSM. To service providers, the rich semantic information may facilitate service composition and service discovery. To end users, they may also query a specific service registered in MSM, which helps them select or mash up services. The service repository holds both service objects and service bundles; to be noted that the service repository can be in MSM or in an external database alternatively. For instance, the CAM4Home project provides a web service platform for metadata generating, storing and searching. In this case, MSM needs to access the external platform through web service interface.

Besides above functionalities, the vital role of MSM is service routing. MSM provides address resolution decision-making on ASs. As shown in Fig. 5, MSM is located between S-CSCF and AS. For the consideration of scalability and extensibility, we collocate MSM in a SIP AS behaving as B2BUA. On one hand, MSM is configured to connect with IMS. On the other hand, MSM interfaces with SIP ASs which host those aggregated service elements. In order to enable SMD, we extend MSM mainly from two aspects: Adaptation-Decision Taking Engine (ADTE) and UED collecting. ADTE either selects appropriate content modalities among the aggregated service components or to choose adaptation parameters for a specific media service. Additionally, MSM needs to collect UED as inputs of ADTE. For modality adaptation, MSM can act on the incoming requests and route them to AS according to the outputs of ADTE. Thanks to MPEG-21 QoS management, it is more intelligent compared with the routing criterion in [31] where it is based on the user requested service element.
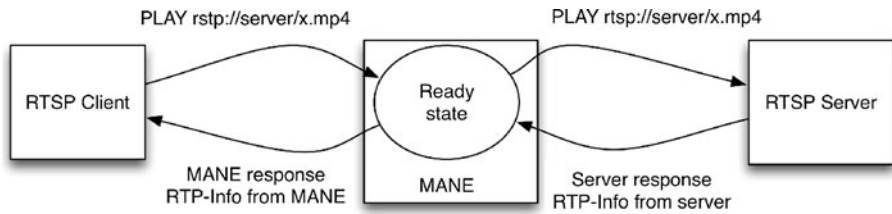
Fig. 6 RTSP/RTP message redirection

For quality adaptation, we hereafter take video as the target considering video is the most challenging media type. We introduce a Real-time Streaming Protocol (RTSP) proxy, as shown in Fig. 6. RTSP is an application-level protocol for control over the delivery of media data with real-time prosperities [32]. Behaving as a Media Aware Network Element (MANE) [33] between media client and media server, the RTSP proxy intercepts RTSP messages from media client and forwards back RTP traffic. Figure 6 describes the message redirection flow. The proxy is able to adapt video in real-time according to the configuring parameters that in fact come as the outputs of ADTE. The target configuration of video that can be generated, including bit rate, frame size, and frame rate (the frame rate must be a fraction of the original frame rate, 1/2, 1/4, 1/8, etc.). Currently, the RTSP proxy supports the reencoding of H.264 video, but it could be modified to support formats, such as MPEG-2 or MPEG-4 video. The RTSP proxy is a light-weight solution for video adaptation, because it introduces few impacts on the current media plane of IMS. To be noted, the configuring parameters generated by ADTE are firstly sent to AS hosting the service by MSM and then set to the proxy by the AS.

4.2.2 Session negotiation extensions

The scalability we describe in this paper relies on the information exchange between client and server, which includes both static capabilities (e.g., terminal or network) and dynamic conditions (e.g., network or user preference). It allows participants to inform each other and negotiate about the QoS characteristics of the media components prior to session establishment. SIP together with SDP is used in IMS as the multimedia session negotiation protocol. However, the ability is very limited for SDP to indicate user environment information such as terminal capabilities and network characteristics. The User Agent Profile (UAProf) [34] is commonly used to specify user terminal and access network constraints. It is also not enough because UAProf contains only static capabilities. Although RFC 3840 [35] specifies mechanisms by which a SIP user agent can convey its capabilities and characteristics to other user agents, it is not compatible with MPEG-21 based ADTE. It is important to reach interoperability between IETF approaches for multimedia session management and the MPEG-21 efforts for metadata-driven adaptation, in order to enable personalized multimedia delivery [36]. In our model, UCD and UED serve as the input of ADTE, as shown in Fig. 5. These input values are in the format of XML document with a known schema. UCD includes the constraints imposed by service providers. We can assume that UCD is available for ADTE. However, UED should be collected for

Table 1 Examples of semantic termID in DIA

termID	Semantic references
6.5.9.1	The horizontal resolution of Display Capability
6.5.9.2	The vertical resolution of Display Capability
6.6.4.1	The max capacity of Network Capability
6.6.4.2	The minimum guaranteed bandwidth of Network Capability
6.6.5.3	The average available bandwidth in Network Condition

Table 2 SDP extension

Method	Syntax
Offer (for query)	q= * (termID)
	a= * (recvonly:<value>)
Answer (as reply)	q= * (termID)
	a= * (sendonly:<value>)

dynamic multimedia session in real time since it is the constraint imposed by external user environment. Therefore, there should be a way to query and monitor UED, particularly terminal capabilities and network characteristics.

In order to collect UED, we propose to extend the Offer/Answer mechanism. According to [30], SDP negotiation may occur in two ways, which are referred to as "Offer/Answer" and "Offer/Counter-Offer/Answer." In the first way, the offerer sends an SDP, the answerer is only allowed to reject or restrict the offer. In the latter way, the answer makes a "Counter-Offer" with additional elements or capabilities not listed in the original SDP offer. We slightly modify the latter way to put querying information in the "Counter-Offer." DIA defines a list of normative semantic references by means of a classification scheme [27], which includes normative terms for the network bandwidth, the horizontal and vertical resolution of a display, and so on. For instance, the termID "6.6.5.3" describes the average available bandwidth in Network Condition. Table 1 shows some examples of the semantic references. To indicate these normative terms in SDP, we define a new attribute/value pair as shown in Table 2. "Offer" and "Answer" are distinguished by "recvonly" and "sendonly," respectively. The value in "Offer" means the threshold set by offerer, which is optional. The value in "Answer" is mandatory as return. In the adaptation framework, MSM extracts the semantic inputs of AQoS and format them into SDP formats. During the Offer/Answer session negotiation procedure, the requested parameters are sent to UE in SDP. We assume that there is a module in User Equipment (UE) responsible for providing answers and monitoring dynamic conditions if necessary (e.g., presented by [20]). Accordingly, the answering values are also conveyed in SDP sending back to MSM activating adaptation.

The proposed adaptation process is divided into three phrases: session initiation, session monitoring, and session adaptation. In the session initiation phrase, the party who invokes the service offers the default parameters in SDP by a SIP signaling message, normally SIP INVITE. Besides those well-known parameters as answer, MSM extracts input parameters in AQoS and offers them again as a request. Some input

parameters can be answered immediately such as terminal capabilities and network capabilities, which is enough for modality selection. However, some of them need to be monitored in real-time, for example, network conditions. In case that any parameter varies out of the threshold set by AQoS, a SIP UPDATE with the specific SDP is feedback to MSM. Once ADTE in MSM receives the inputs and makes a decision, the adaptation starts with session renegotiation. In case of quality adaptation, MSM commands the RTSP proxy with the new parameters.

5 Prototype system and performance evaluation

5.1 Prototype system

This section takes the "Sports Live Broadcasting" service as an example to show the proposed approach in detail. Figure 7 shows the two-phrase adaptation of "Sports Live Broadcasting" service. For the reason of simplicity, we omit some session messages and media plane data. The successfully registered UE initiates the service by sending a SIP INVITE request with a normal SDP. MSM parses the offered SDP in order to check whether the requested inputs exist. If not, MSM replies SIP 183 Session Progress with the SDP extension for querying capabilities. If the querying values can be retrieved immediately such as those static parameters (e.g., terminal capabilities or network capabilities), UE replies SIP PRACK with SDP as response. During presession adaptation, MSM makes an adaptation decision-taking based on the static device capabilities (e.g., width and height of display screen) and network capabilities (e.g., maxCapacity and minGuaranteed). The outputs include the "camElementMetadataID" indicating an appropriate service element for modality adaptation as well as the QoS parameters (e.g., bit rate and frame size) for quality adaptation. For example, in case of wide band connection MSM routes the request to the IPTV AS. Then the normal IPTV service is invoked. It is possible that the querying parameters are based on dynamic information in real-time, such as available bandwidth. In that case, UE sends back the response by SIP UPDATE with the payload of SDP. The insession adaptation starts when MSM receives SIP UPDATE containing the requested available bandwidth. In case of quality adaptation, MSM sends SIP UPDATE with configuration parameters to IPTV AS that set then the RTSP proxy. If it has to make a modality adaptation, MSM responds SIP 503 Service Unavailable together with the header "Retry-After." The retry request will be routed to Text AS and invoke the text-based statistic service as the modality adaptation of IPTV.

To verify the proposed approach, we develop a prototype system that is the integration of several open source projects. The prototype system is illustrated in Fig. 8. On the server side, Open IMS Core [37] is deployed as IMS testbed. We make use of UCT Advanced IPTV [38] to provide IPTV service. MSM and Text AS is set up by Mobicents SIP Servlet [39] and configured to connect with Open IMS Core. In order to simplify the development, the client is simulated in the signaling plane and in the media plane separately. We emulate IMS signaling client by SIPp [40]. In the media plane, we have three types of terminal: Apple iPhone, HP iPAQ, and Toshiba laptop.
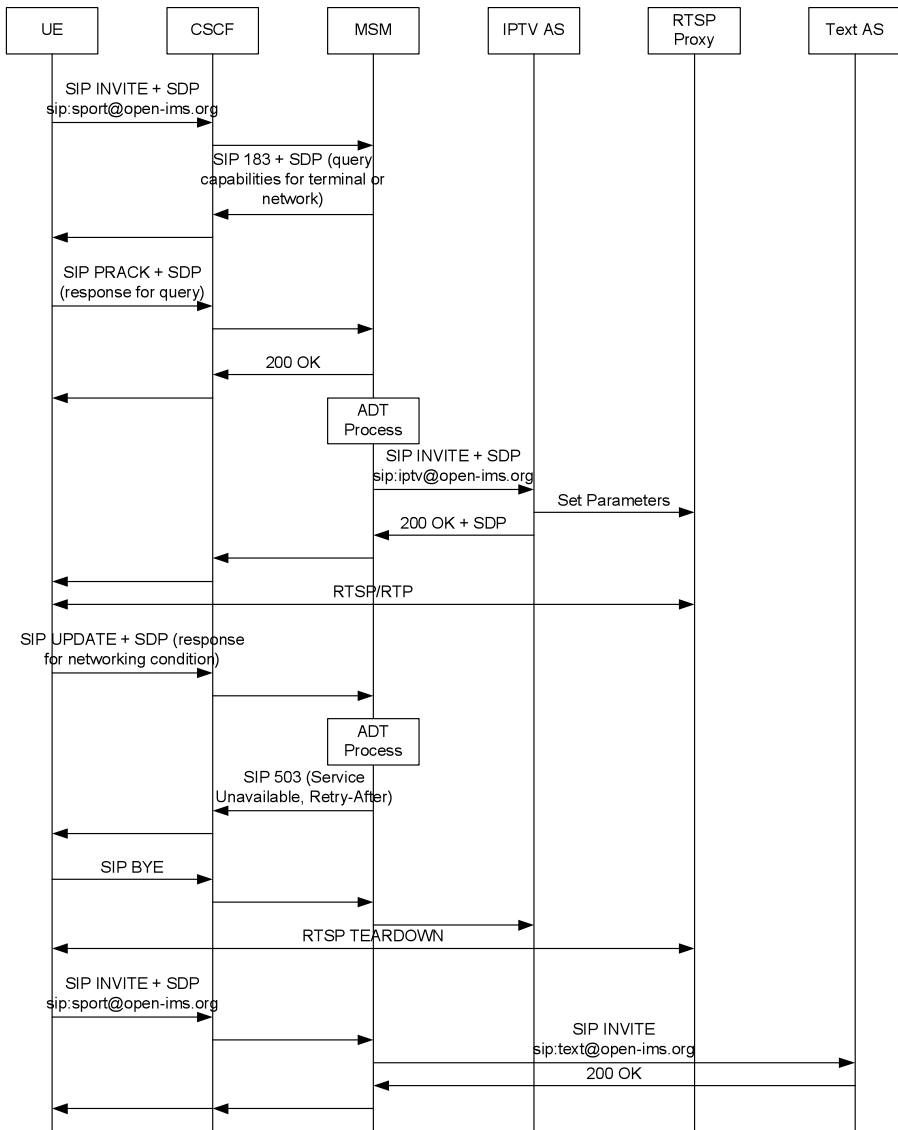
Fig. 7 Multimedia adaptation working flow

5.2 Performance evaluation

The prototype system demonstrates that the proposed SIP/SDP extension works compatibly with the standardized IMS platform. Regarding the performance, we analyze it in the signaling plane and in the media plane respectively. In the signaling plane, we observe that there are notably two kinds of latency: UED collecting and ADTE. The first one is more related to the characteristics of UED themselves. For instance, if the screen size is considered in UED, it could be retrieved immediately by UE. But
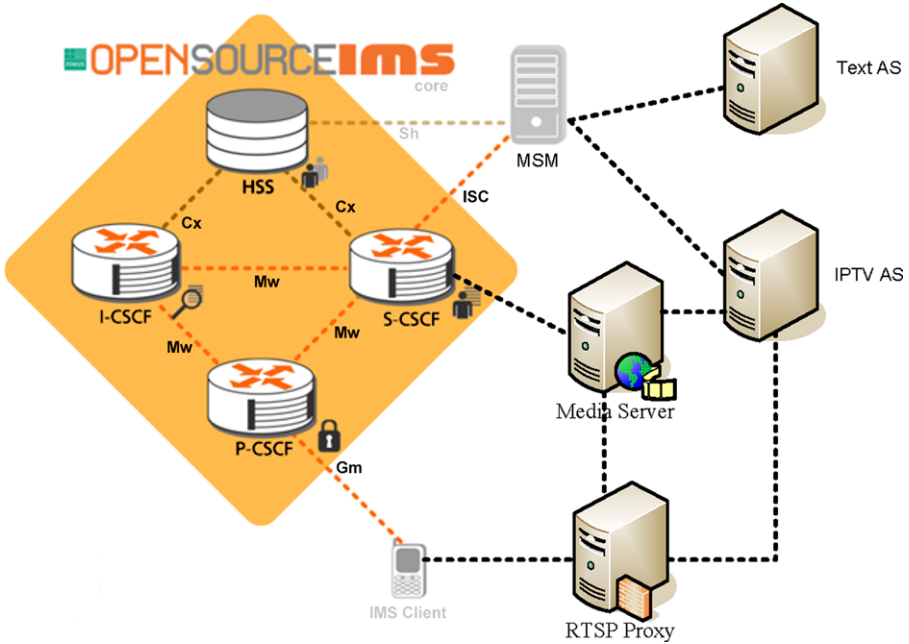
Fig. 8 Prototype system

Table 3 Terminal, access network and settings

Terminal	Access network	Bitrate setting	Frame size setting
Apple iPhone	EDGE	150 Kbits	320×480
Apple iPhone	UMTS	1.5 Mbits	320×480
HP iPAQ	UMTS	1.5 Mbits	489×640
Toshiba Laptop (CPU: Intel Core 2 Duo P8700 @ 2.53 GHz, RAM: 4 GBytes)	Ethernet	4 Mbits	720×576

in terms of available bandwidth, it depends on the time for sampling. Without considering UED, we further observe that ADTE-incurred delay is 0.1 s in average. To some extent, this result confirms that the metadata-based adaptation is efficient, because the pre-computation saves significant time over parameter selection. The media plane is related to quality adaptation. We run tests with three terminals in three types of access network, as listed by Table 3. The test sample is a promotion video file for CAM4Home project with the bitrate of 3.9 Mbps and the frame size of 720×576. As shown in Fig. 9, the output bitrates of adapted videos are basically consistent with the settings. Figure 10 presents the output Peak Signal to Noise Ratio (PSNR) curves of adapted videos within 180 seconds. It can be seen that the adapted videos have different qualities, measured by means of PSNR. And the fluctuation of bitrate affects the PSNR in real-time.
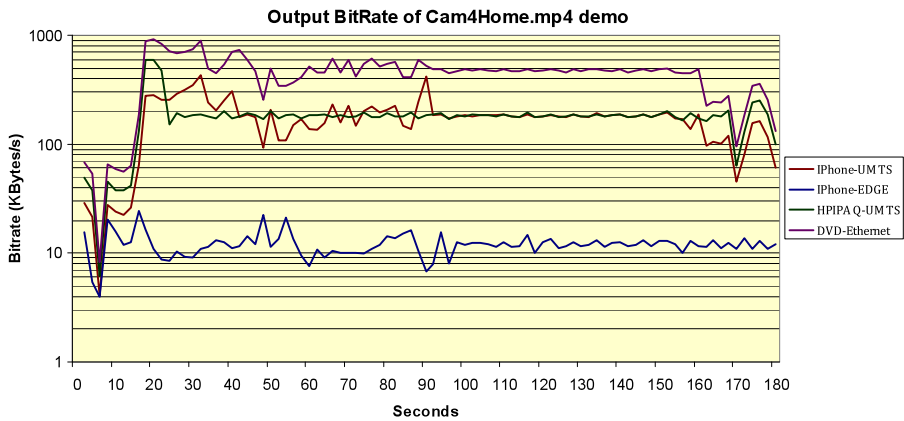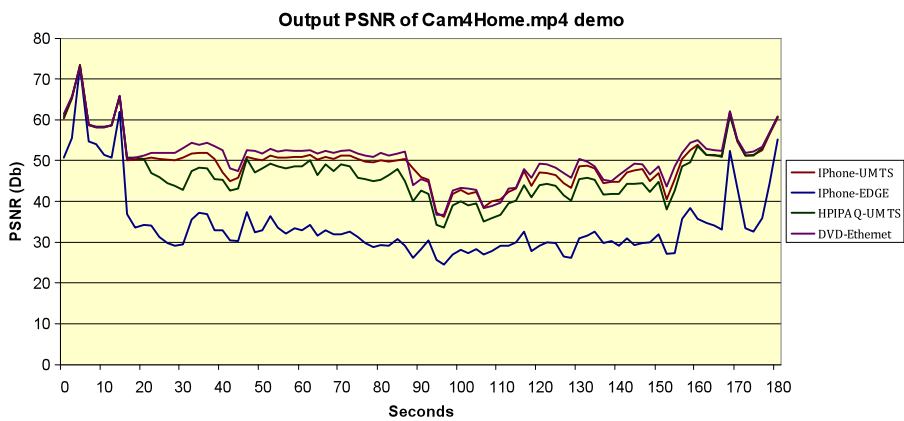
Fig. 9 Output bitrate of adapted video

Fig. 10 Output PSNR of adapted video

6 Conclusions

This paper presents the SMD system in pervasive computing environment. It not only provides a novel way of multimedia provisioning but also assures the quality of multimedia delivery. To achieve that, we propose a flexible framework that introduces the CAM4Home metadata model as a bundle of multimodal media. MPEG-21 DIA is further integrated into CAM4Home model to meet end-to-end QoS requirements. We address the issues in supporting QoS from two aspects, namely fidelity and modality, in order to tailor and adapt multimedia to the diverse terminals and the heterogeneous networks, as well as dynamic network conditions. A prototype system is developed on IMS architecture to validate the proposed model. With the use of rich metadata, context awareness, and personalization could be challenging topics in the future.

References

1. Timmerer C, Hellwagner H (2005) Interoperable adaptive multimedia communication. IEEE Multimedia Mag 12(1)
2. Vertro A, Timmerer C (2005) Digital item adaptation: overview of standardization and research activities. IEEE Trans Multimed 7(3):418–426
3. Williams MH, Yang Y, Taylor N, McBurney S, Papadopoulou E, Mahon F, Crotty M, (2006) Personalized dynamic composition of services and resources in a wireless pervasive computing environmen. In: The first international symposium on wireless pervasive computing. January 2006
4. Gu X, Nahrstedt K (2006) Distributed multimedia service composition with statistical QoS assurances. IEEE Trans Multimed 8(1):141–151
5. Kalaspur S, Kumar M, Shirazi B (2005) Personalized service composition for ubiquitous multimedia delivery. In: The sixth IEEE international symposium on world of wireless mobile and multimedia networks. June 2005
6. Thang TC, Jung YJ, Ro YM (2005) Modality conversion for QoS management in universal multimedia access. IEE Proc, Vis Image Signal Process 152(3):374–384
7. Thang TC, Jung YJ, Ro YM (2005) Semantic quality for content-aware video adaptation. In: Proceedings of the IEEE MMSP2005. Shanghai
8. Thang TC, Kim JG, Kang JW, Yoo JJ (2009) SVC adaptation: standard tools and supporting methods. EURASIP Signal Process, Image Commun 24:214–228
9. Smith JR, Mohan R, Li C-S (1999) Scalable multimedia delivery for pervasive computing. The seventh ACM international conference on multimedia
10. Grgic T, Huskic V, Matija M (2008) Resource authorization in IMS with known multimedia service adaptation capabilities. Studies in Computational Intelligence. Springer, Berlin, 10.1007/978-3-540-68127-4
11. Bilasco IM, Amir S, Blandin P, Djeraba C, Laitakari J, Martinet J, Gracia EM, Pakkala D, Rautiainen M, Ylianttila M, Zhou J (2010) Semantics for intelligent delivery of multimedia content. In: ACM symposium on applied computing
12. Shaha N, Desai A, Parashar M (2001) Multimedia content adaptation for QoS management over heterogeneous networks. In: International conference on Internet computing, June 2001
13. Ahmed T, Asgari A, Mehaoua A, Borcoci E, Equille LB, Georgios K (2007) End-to-end quality of service provisioning through an integrated management system for multimedia content delivery. Comput Commun 30(3):638–651
14. Szwabe A, Schorr A, Hauck FJ, Kassler AJ (2006) Dynamic multimedia stream adaptation and rate control for heterogeneous networks. J Zhejiang Univ Sci A 7:63–69
15. Mukherjee D, Delfosse E, Kim JG, Wang Y (2005) Optimal adaptation decision-taking for terminal and network quality-of-service. IEEE Trans Multimed 7(3):454–462
16. Information technology (2002) Multimedia framework (MPEG-21)—Part 1: vision, technologies, and strategy
17. Tong MW, Yang ZK, Liu QT (2010) A novel model of adaptation decision-taking engine in multimedia adaptation. J Netw Comput Appl 33(1):43–49
18. Multimedia Subsystem IP (IMS). Stage 2, v7.6.0, TS 23.228, 3GPP, December 2006
19. Skorin-Kapov L, Mosmondor M, Dobrijevic O, Matijasevic M (2007) Application-level QoS negotiation and signaling for advanced multimedia services in the IMS. IEEE Commun Mag 45(7):108–116
20. Ozcelebi T, Radovanovic I, Chaudron M (2007) Enhancing end-to-end QoS for multimedia streaming in IMS-based networks. In: The second international conference on system and networks communications, August 2007
21. Arnaud J, Negru D, Sidibe M, Pauty J, Koumaras HG (2009) Adapted IPTV service within novel IMS architecture. In: The fifth international ICST mobile multimedia communications conference
22. El Saghir B, Crespi N (2006) A new framework for indicating terminal capabilities in the IP multimedia subsystem. In: IEEE global telecommunications conference
23. Sahinoglu Z, Vetro A (2009) Mobility characteristics for multimedia service adaptation. J Signal Process, Image Commun 18(8):699–719
24. Durand G, Kazai G, Lalmas M, Rauschenbach U, Wolf P (2005) A metadata model supporting scalable interactive TV services. In: The eleventh international multimedia modeling conference, January 2005
25. Burnett IS, Pereira F, de Walle RV, Koenen R (2005) The MPEG-21 book. Wiley, New York. pp 308
26. Devillers S, Timmerer C, Heuer J, Hellwagner H (2005) Bitstream syntax description-based adaptation in streaming and constrained environments. IEEE Trans Multimed 7(3):463–470

27. Vetro A, Timmerer Ch, Devillers S (2003) Information technology—multimedia framework—Part 7: Digital item adaptation. ISO/IEC JTC 1/SC 29/WG11/N5933, October 2003
28. Prangl M, Hellwagner H, Szkaliczki T (2006) Fast adaptation decision taking for cross-modal multimedia content adaptation. In: IEEE international conference on multimedia & expo
29. IETF RFC 2327 (1998) SDP: session description protocol. April 1998
30. IETF RFC 3264 (2002) An offer/answer model with session description. June 2002
31. Zhang H, Nguyen H, Crespi N, Sivasothy S, Le TA, Wang H (2010) A novel metadata-based approach for content and service combined delivery over IMS. In: The 8th conference on communication networks and services research, May 2010
32. IETF RFC 2326. Real Time Streaming Protocol (RTSP). April 1998
33. IETF RFC 3984. RTP Payload Format for H.264 Video. February 2005
34. OMA-UAPROF. User Agent Profiling Specification (UAPROF) 1.1. Open Mobile Alliance, 12 December 2002
35. IETF RFC 3840 (2004) Indicating user agent capabilities in the session initiation protocol (SIP), August 2004
36. Kassler A, Guenkova-Luy T, Schorr A, Schmidt H, Hauck F, Wolf I (2006) Network-based content adaptation of streaming media using MPEG-21 DIA and SDPng. In: The seventh international workshop on image analysis for multimedia interactive services
37. Magedanz T, Witaszek D, Knuettel K (2005) The IMS playground@FOKUS an open testbed for next generation network multimedia services. In: First international conference on testbeds and research infrastructures for the development of networks and communities
38. UCT Advanced IPTV. http://uctimsclient.berlios.de/. Accessed 12 September 2009
39. Mobicents. http://www.mobicents.org/. Accessed 18 September 2009
40. SIPp. http://sipp.sourceforge.net. Accessed 18 September 2009