Multimedia Session Reconfiguration for Mobility-aware QoS Management: Use Cases and the Functional Model

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Abstract Evolution of communication networks envisages providing mobile users with seamless Quality of Service (QoS) support. This paper presents a session reconfiguration approach that dynamically manages QoS for multimedia services in response to session mobility and terminal mobility. It considers changes (referred to as *events*) that are induced by mobility and utilizes those affecting QoS to steer the session reconfiguration. As the result, basic operations, called *reconfiguration primitives*, are applied to maintain or adapt QoS. Use cases that illustrate motivation for this work are described, along with the proposed functional model. An initial performance evaluation of the model is also outlined.

1 Introduction

The need to deliver multimedia services "anywhere-anytime" has largely increased over the last ten years [3]. This highlights one of the key requirements envisaged by the evolution of communication networks – providing mobile users with seamless Quality of Service (QoS) support for multimedia services. Such a support must consider various mobility aspects. In this work, we focus on two aspects. First aspect, referred to as *session mobility*, allows a user to continue communication when replacing her terminals, while the second aspect, i.e. *terminal mobility*, enables a user terminal to maintain communication while changing its network attachment point. In order to achieve an adaptive QoS management, the support must regard variable mobility-induced constraints [1, 2, 5], thus achieving a form of *mobility-awareness*.

Mobility-aware QoS support described in literature mainly focuses on applying transport/network-level operations that consider individual mobility aspects and "conventional" mobility-induced changes. The *Trigger Management Framework* [4]

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handles notifications caused by conventional changes, e.g. based on received signal strength indications and network load, but also by "higher-level" changes, such as end-to-end QoS degradation. The *Multi-User Session Control* solution [2] provides mobile users with access to sessions, while supporting QoS adaptation against terminal mobility. This approach is centered around a transport/network-level signaling between the specified entities and the adaptation in terms of assigning different QoS classes to session flows or adding/dropping flows from a session.

A service delivery framework for multimedia applications described in [1] is adaptable to terminal and session mobility, which includes customizing session parameters to bandwidth of access networks and encodings/formats supported by user terminals, but does not involve QoS negotiation and network resource reservation. A solution that provides session continuity between different access networks is presented in [5]. It enables transfer of agreed QoS parameters across the access networks, but assumes that the QoS settings stay the same after the change.

The work presented in this paper complements the current research efforts and presents a session reconfiguration approach that dynamically manages QoS for multimedia services in response to mobility. It employs the application level, which offers independence of an access technology or a service scenario, and ability to make application-dependent decisions. The approach considers changes (referred to as *events*) that stem from session and terminal mobility, and utilizes those affecting QoS to steer the reconfiguration. As the result, basic operations, called *reconfiguration primitives*, are applied to maintain or adapt QoS. The latter involves interacting with control entities that reserve network resources to assign the required allocation.

The remainder of the paper is organized as follows. In Section 2, we define the mobility events and reconfiguration primitives, and describe use cases that illustrate application of the approach. The proposed functional model is presented in Section 3, with the emphasis on necessary functional entities, and on the signaling that facilitates event notification and session reconfiguration. Section 4 depicts an initial performance evaluation of the model. We then conclude the paper.

2 Session Reconfiguration and Use Cases

For the purposes of this work, we define a *multimedia session* as a collection of *media flows* within a group of *participants*. *Media flow* is a stream of media data (e.g., audio or video), to which these parameters are assigned: identifiers of *participants* between which the flow is established, chosen media format and encoding, and a QoS specification defining required network bandwidth, delay, delay variation, and packet loss ratio. *Session participant* relates either to a user terminal, which enables a user to engage in the session, or a server, which acts as a media source.

Mobility events and reconfiguration primitives

Session mobility may lead to heterogeneous terminals being used for accessing the services, while terminal mobility may result in changes to network connectivity and access technology. Using a concept of representing changes with *events*, similar to that proposed in [4], we identify changes induced by the mobility and model them as *mobility events* (illustrated in Figure 1) to be considered by the reconfiguration:

1. *Change of terminal* – represents a change of the user terminal due to *session mobility*;
2. *Change of location* – represents a change in user terminal's location due to *terminal mobility*; and
3. *Change of access network* – represents a change of access network (i.e., underlying access technology) for the user terminal due to *terminal mobility*.

The goal of the session reconfiguration is to modify the elements of a session in order to maintain or adapt QoS. It introduces three *reconfiguration primitives*: (a) *start media flow*, (b) *stop media flow*, and (c) *modify media flow*. Starting a media flow includes several steps. First, the associated session participants need to agree upon a QoS specification for the considered flow, after which the allocation of required network resources is invoked. Finally, the participants set up media transceivers with the agreed format/encoding and transport parameters, and start the flow. On the other hand, when participants reach a decision to stop a flow, the reserved resources are released and the corresponding media transceivers suspended. Modifying a media flow refers to changing its format/encoding and QoS specification, which leads to adjusting the allocation of the resources for the flow.

Use cases

Each of the use cases, which illustrate motivation for and application of the approach, is associated to an introduced mobility event.

1) Use case for *Change of terminal*

Maria establishes a video conference with an associate while traveling to work. She uses her smartphone to go over the materials for a meeting. Once at work, she goes to a room with a high-definition plasma screen. Maria decides to transfer the

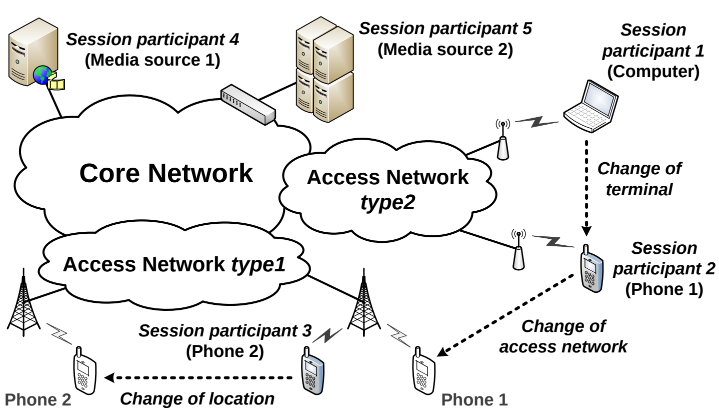

Fig. 1 Illustration of the mobility events

video flow of the conference to the plasma screen and to leave the audio flow on the phone. Prior to the flow transfer, new flow parameters (with a QoS specification) are produced regarding the hardware and software features of the targeted terminal. The reconfiguration applies *start media flow* to initiate video flow to the screen and *stop media flow* for the same flow on the phone.

2) Use case for *Change of location*

After boarding a train, Sofia establishes a QoS-supported session with a "local" game server and starts playing. The session involves several media and data flows. As the train travels to the destination, Sofia's laptop computer changes location and network attachment point, which leads to seamless reconnection to another game server instance, to maintain QoS. The session flows are transferred by invoking *start media flow* and *stop media flow*, but the applied QoS specifications are kept. Prior to the transfer, flow parameters are updated to match the new server instance.

3) Use case for *Change of access network*

While going home by a subway, Zoe is playing a multi-player game on her smartphone, which supports several access technologies. The only available access at the time is UMTS (Universal Mobile Telecommunications System). After a while, a HSPA (High Speed Packet Access) network comes to reach. Since Zoe's preferences state that HSPA is preferred, due to a higher bandwidth and improved QoS, her phone changes the access. Then, *modify media flow* is applied to produce new flow parameters (with QoS specifications) and reserve resources in the new network.

3 Functional Model

In order to achieve a mobility-aware QoS management at the application level, the presented approach encompasses several functional aspects:

- session-level signaling for negotiation and dynamic renegotiation of the flow parameters (notably, QoS specifications), in particular due to the mobility events;
- producing QoS specifications for media flows within a multimedia session;
- interacting with control entities that reserve access network resources; and
- generating and conveying the mobility event notifications, as well as deciding upon the reconfiguration primitives to apply in response.

Identified functional model (Figure 2) comprises generic control entities that provide the given aspects. *User Terminal Entity* (UTE) represents a *session participant* used for accessing multimedia services. Each UTE is described with a hardware and software configuration, including supported access technologies, which is stored in a *user profile* at *User Profile Repository Entity*. The *user profile* holds a "knowledge" about the user in terms of her preferences and the available terminals. UTE contains these functions: *Session control function* (SCF), *Event analysis function* (EAF), *QoS monitoring function* (QSMF), and *Media transmission function* (MTF).

EAF processes *User inputs* and produces the *Change of terminal* notifications. SCF is then invoked to signal the notifications to *Session Configuration Management-*

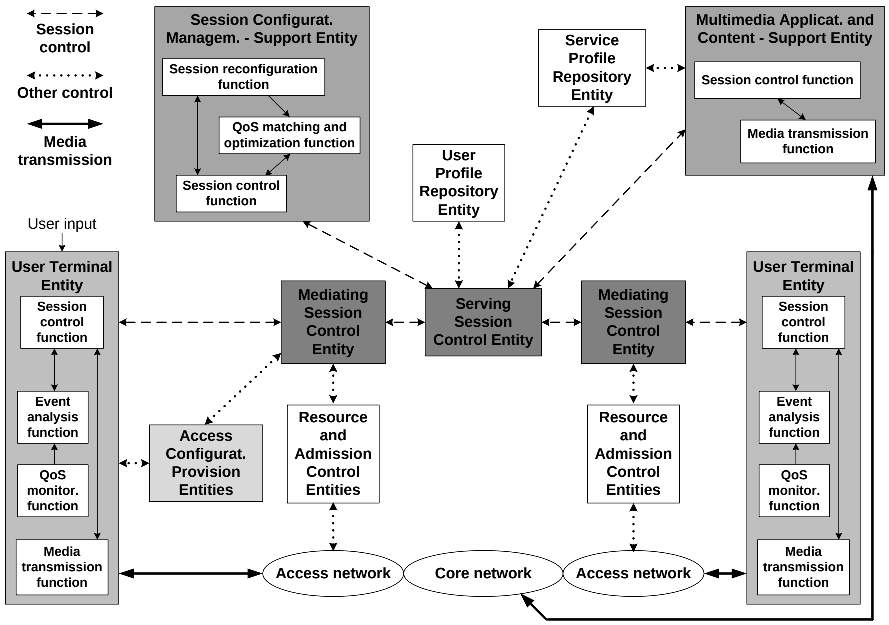

Fig. 2 Functional model for the mobility-aware QoS management

Support Entity (SCM-SE), which decides about the reconfiguration. SCF also performs signaling for session establishment and QoS (re)negotiation. When the media flow parameters are agreed, SCF invokes MTF to set up and start, modify, or stop media delivery. QSMF measures actual QoS performance for a media flow.

Mediating Session Control Entity (MSCE) is a signaling proxy for each UTE that wants to establish the sessions. It forwards session control messages between UTEs and the chosen *Serving Session Control Entity* (SSCE), and invokes the allocation of access network resources by interacting with *Resource and Admission Control Entities* (RACEs). MSCE extracts required flow parameters from the control messages and conveys them to RACEs. SSCE is the central signaling proxy, which forwards the control messages between *session participants*. SSCE includes, e.g., SCM-SE in the signaling path, thus invoking functions that SCM-SE provides.

Multimedia Application and Content-Support Entity (MAC-SE) is a *session participant*, which refers to a server that executes multimedia applications and hosts media content. Each application is described with its requirements and constraints, which are stored in a *service profile* at *Service Profile Repository Entity*. The *service profile* represents a “knowledge” about a multimedia service that the application offers. MAC-SE also incorporates SCF and MTF. Similarly to UTE, SCF handles session control messages, but MAC-SE exchanges them directly with the chosen SSCE. SCF invokes MTF to control media delivery (e.g., streaming).

SCM-SE is the key QoS management component, which includes the *QoS matching and optimization function* (QMOF) [6] and *Session reconfiguration function*

(SRF). QMOF produces QoS specifications based on information obtained from considered *user* and *service profiles*. An event notification signaled to SCM-SE is delivered to SRF, which analyzes the change and decides about the primitive(s) to be applied. SCM-SE includes SCF to exchange session control messages with the given SSCE, allowing it to engage in QoS negotiation and receive the notifications.

RACEs authorize and allocate resources in access networks, and include *Policy Decision Entity* (PDE) and *Policy Enforcement Entity* (PEE). While PDE makes decisions regarding authorization, reservation and release of the resources, PEE imposes the decisions. *Access Configuration Provision Entities* provide information about UTE's access network and location, including a unique identifier of the network, thus notifying for *Change of location* and *Change of access network*.

Signaling procedures

This QoS management approach defines five signaling procedures. *Media flow establishment* specifies signaling that establishes one or more media flows, while *Media flow termination* relates to stopping the flows and releasing the allocated resources. The three remaining procedures define signaling in response to the corresponding events, and the *Change of user terminal* procedure is described in details.

1) The *Media flow establishment* signaling

This procedure creates an association of two participants for exchanging media flows, during which capabilities and demands of the participants are matched, and the flow parameters are agreed upon. Figure 3 depicts the Unified Modeling Language (UML) sequence diagram that specifies the procedure. It illustrates the flow establishment between a UTE and a MAC-SE. For a clearer presentation, the *User* and *Service Profile Repository Entities* are merged into the *Profile Repository Entity*.

Signaling is invoked when a user decides to access a multimedia service, which leads to establishing a session between user's UTE and the hosting MAC-SE. After the UTE sends a *session request* message to the MAC-SE (Figure 3, step 1), it traverses the UTE's MSCE and the given SSCE, which acquires the needed *user profile*, authorizes the user, and retrieves *service profile* for the requested service. Then, the MAC-SE accepts the request (*session response* is sent to the UTE), which triggers the SSCE to invoke the SCM-SE (step 10). The QMOF produces a *feasible service profile* by matching parameters from the given profiles. The feasible profile contains flow parameters that both the UTE and the MAC-SE support. It offers a set of media formats/encodings for each flow, with the associated QoS specifications.

The *feasible service profile*, which is referred to as an offer, is then sent to the MSCE to invoke authorization of the resources. The procedure continues at the UTE (step 17), where the user can accept, modify or deny (a subset of) parameters from the feasible profile (e.g., she can choose which media flows are to be established). The chosen parameters form a *feasible service profile answer* (step 18), which is conveyed to the MAC-SE and, then, to the SCM-SE. The QMOF performs the *optimization* (step 23), to determine an optimal usage of the resources that are needed for providing the chosen QoS specifications. The resulting *optimized service profile* is used by the PDE/PEE to allocate the resources (steps 26 and 27). As there are multiple combinations of the formats/encodings and QoS specifications which can

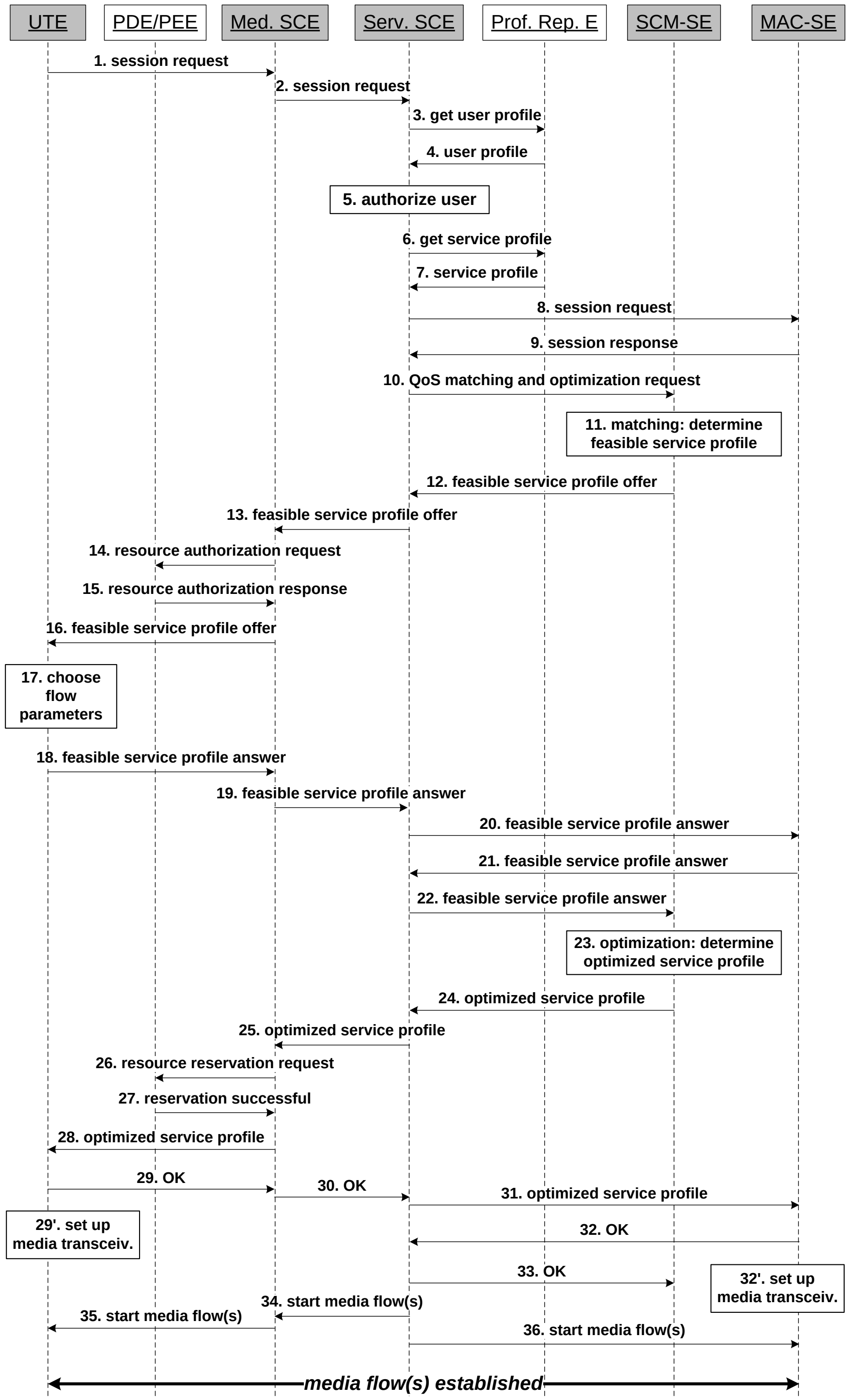

Fig. 3 The *Media flow establishment* signaling procedure

be applied, the PDE decides of the reservation considering current resource availability. The optimized profile is then sent to the UTE and the MAC-SE, to set up their media transceivers with the selected parameters and to initiate media flow(s).

2) The *Change of user terminal* signaling

Change of user terminal enables transfer of one or more media flows between session participants, without breaking the established communication. The procedure is depicted by the UML sequence diagram shown in Figure 4.

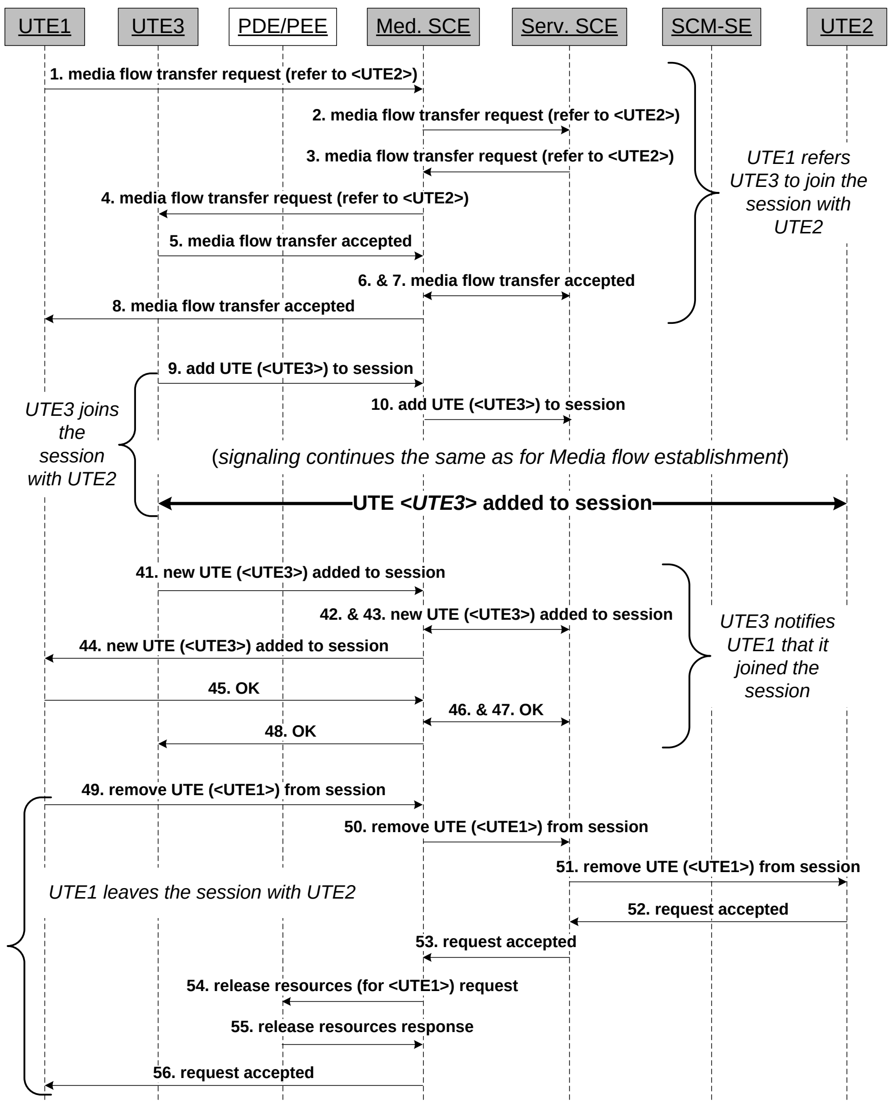

Fig. 4 The *Change of user terminal* signaling procedure

It illustrates signaling between three UTEs, assuming that media flows are established between UTE1 and UTE2, and that a user wants to transfer the flows from UTE1 to UTE3, which are both assisted by the same MSCE. The reconfiguration first establishes the flows between UTE3 and UTE2, and then terminates the corresponding flows between UTE1 and UTE2. For a clearer presentation, a MSCE and a PDE/PEE supporting UTE2 are omitted from the sequence diagram, as is the *Profile Repository Entity*.

Signaling is invoked when a user decides to replace her terminal (referred to as UTE1) in an ongoing session and identifies another terminal (UTE3) as the transfer target. User's request results in the associated *Change of terminal* notification being produced, which UTE1 sends as a *media flow transfer request* message to UTE3 (Figure 4, steps 1-4). This message contains identifier of the correspondent UTE (referred to as UTE2). After the request is accepted by UTE3 (steps 5-8), it sends an *add UTE to session* message to UTE2.

When UTE2 accepts this "join request" from UTE3, the procedure continues similarly as for *Media flow establishment*: the SRF and the QMOF produce the *feasible* and *optimized service profiles* for UTE3, which are used for reserving the network resources, and the media transmission is initiated towards UTE3 (thus adding the latter to the session). Afterwards, UTE3 initiates removal of UTE1 from the session (steps 41-44), which prompts UTE1 to end its participation (steps 49-56). Before the removal of UTE1, the resources allocated to it are released (steps 54-55).

4 Performance Evaluation

The proposed functional model is formally defined by using *Discrete Event System Specification* (DEVS) [7]. DEVS is a formal framework for simulation of general discrete event systems, which offers *atomic DEVS models* to capture systems' behavior and *coupled DEVS models* to build their structure. Each proposed model entity is realized as an atomic DEVS (aDEVS), while the associated signaling messages are "mapped" to input and output events of the aDEVS. Defined aDEVS models are integrated by using coupled DEVS. The definition is the basis for an implementation and simulation of the proposed model in the DEVS-Suite Simulator [8].

An initial performance evaluation of the model is conducted to assess its scalability. It introduces the *duration* metric, which is measured in relation to the number of UTEs that simultaneously execute a particular signaling procedure. Each procedure defines *duration* as the interval to exchange all the messages (e.g., for *Media flow establishment*, this is the interval between *1. session request* and *36. start media flows*), with its *reference value* implying single procedure execution. As the proposed model is generic, these values may be set as seen fit. For this evaluation, the values for *Media flow establishment* and *Change of user terminal* are set to 14.0 and 25.5 "time units" (with regards to message number ratio between these procedures). The results (Table 1) indicate that average *duration* for the analyzed procedures increases almost linearly with the number of UTEs, thus offering a good scalability.

Table 1 Average *duration* for the analyzed signaling procedures

Number of UTEs	1100	1400	1700	2000
Media flow establishment [time units]	17.5	19.4	22.3	25.0
Number of UTEs	50	100	150	200
Change of user terminal [time units]	30.0	30.5	31	31.7

5 Conclusions and Future Work

This paper presents use cases and a proposed functional model of mobility-aware QoS management for multimedia services. The approach employs session reconfiguration at the application level to maintain or adapt QoS dynamically, and independently of an access type or a service scenario. Generic mobility events and the applicable reconfiguration operations are defined. We illustrate model application in the signaling procedure for managing QoS against session mobility, while initial evaluation indicates a good scalability to number of the participants. Future work includes an extensive model evaluation and application in a real-network prototype.

Acknowledgements This work was carried out within the research project 036-0362027-1639 “Content delivery and mobility of users and services in new generation networks”, supported by the Ministry of Science, Education and Sports of the Republic of Croatia.

References

1. Balakrishna, C., Al-Begain, K.: Towards a user-centric and quality-aware multimedia service delivery implementation on IP multimedia subsystem. In: Al-Begain, K. (ed.) Proc. of the 2007 Int. Conference on Next Generation Mobile Applications, Services and Technologies (NGMAST 2007), pp. 36-42. IEEE Computer Society (2007)
2. Cerqueira, E., Veloso, L., Neto, A., Curado, M., Monteiro, E., Mendes, P.: Mobility management for multi-user sessions in next generation wireless systems. Comput. Commun. **31**, 915–934 (2008)
3. Gomes, D., Aguair, R. L., Sargento, S.: A cross-system approach for multimedia services with IP multicast in 4G networks. Wireless Pers. Commun. **52**, 651–668 (2010)
4. Mäkelä, J.: Towards seamless mobility support with cross-layer triggering. In: Papaoulakis, N., Tragos, E. (eds.) Proc. of the 18th IEEE Int. Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2007), pp. 1-5. IEEE (2007)
5. Renier, T., Larsen, K. L., Castro, G., Schwefel, H.-P.: Mid-session macro-mobility in IMS-based networks. IEEE Veh. Technol. Mag. **2**, 20–27 (2007)
6. Skorin-Kapov, L., Matijasevic, M.: Modeling of a QoS matching and optimization function for multimedia services in the NGN. In: Pfeifer, T., Bellavista, P. (eds.) Proc. of the 12th IFIP/IEEE Int. Conference on Management of Multimedia and Mobile Networks and Services (MMNS 2009), pp. 55-68. IFIP International Federation for Information Processing (2009)
7. Zeigler, B., Prähofer, H., Kim, T. G.: Theory of Modeling and Simulation. Academic Press, New York (2000)
8. DEVS-Suite Simulator. http://sourceforge.net/projects/devs-suitesim/. Cited 15 April 2011