A Mobility-aware Reconfiguration of Multimedia Sessions for QoS Management: Simulation and Performance Evaluation

Ognjen Dobrijevic, Maja Matijasevic
University of Zagreb, Faculty of Electrical Engineering and Computing
Unska 3, HR-10000 Zagreb, Croatia
Email: {ognjen.dobrijevic, maja.matijasevic}@fer.hr

***Abstract*—Communication networks that evolve along a Next Generation Network (NGN) concept must provide users with the ability to communicate and access services regardless of changes in location and technical environment. These strict requirements impose research challenges on offering Quality of Service (QoS) support for multimedia services. This paper describes simulation and performance evaluation of a mobility-aware session reconfiguration at the application level that maintains and adapts QoS for these services. The approach relies on handling generic *mobility events* that affect QoS and executing basic operations, called *reconfiguration primitives*, in response. Proposed functional model is depicted in the scope of ITU-T NGN architecture, along with the specified signaling procedures. Model simulation and its performance evaluation, which considers scalability issues against number of session participants, are presented in more detail.**

I. Introduction

Communication networks that evolve along a Next Generation Network (NGN) concept must provide *generalized mobility* [1], which is the ability of users to communicate and access services regardless of changes in location and technical environment. This feature includes various mobility aspects, such as *terminal mobility* and *session mobility*. While the former enables communication continuity when a user terminal changes its network attachment point (even between different access technologies, which refers to as *vertical handover*), the latter allows communication to go on while a user replaces the terminal. These strict requirements impose research challenges on offering Quality of Service (QoS) support for multimedia services [2], which must include modalities to handle mobility-stemming changes and to adjust to them [3]–[6]. Such a support also requires coordination of QoS demands among all the involved parties.

This paper describes simulation and performance evaluation of a mobility-aware session reconfiguration at the application level that maintains and adapts QoS for multimedia services. The approach relies on handling information about changes affecting QoS that are induced by terminal and session mobility, thus achieving *mobility-awareness*. These changes are modeled as generic *mobility events* to direct the session reconfiguration, which, in response, executes basic operations, called *reconfiguration primitives*. As the result, multimedia session parameters are modified to manage QoS. What other approaches do not provide is a QoS support that focuses on applying application-level operations which consider various mobility aspects and use the means of QoS (re)negotiation to accommodate them. Performing management operations at that level offers the possibility to take service-specific decisions and to apply the operations selectively, as well as provides an access-agnostic approach.

The remainder of the paper is organized as follows. We give an overview of related work in Section 2. Section 3 defines the mobility events and reconfiguration primitives. In Sections 4 and 5, we depict proposed functional model of the approach in the scope of ITU-T NGN architecture, along with the specified signaling procedures that enable the session reconfiguration and QoS management. Section 5 presents model simulation and its performance evaluation, which considers scalability issues against number of session participants, followed by the conclusion section.

II. Related work

Numerous approaches that combine QoS management with mobility mainly focus on performing transport-level and/or network-level procedures that regard changes stemming from a single mobility aspect. The *Trigger Management Framework* [7] is proposed to manage notifications caused by various mobility-induced changes. These include "common" changes, for instance, the ones that are derived from received signal strength indications or network loads, and "high-level" changes, e.g., QoS degradations on an end-to-end path or network access cost changes. The *Multi-User Session Control* approach [4] provides multimedia sessions to mobile users and adapts QoS in response to terminal mobility. This solution enfolds around a transport/network-level signaling among the defined network entities and QoS adaptation that involves adding or dropping media flows from a session and assigning different QoS classes to the flows. The *Proactive and Adaptive Handover* (PAHO) [6] is an application-level approach that supports three adaptation procedures for multimedia sessions. They include changing network attachment point for user terminals, replacing user terminals for session mobility, and switching between different media encodings to achieve service customization. PAHO invokes the adaptation in response to notifications which are based on degradations of received signal strength and network congestion, but does not involve negotiation of QoS parameters and allocation of network resources.

The 3GPP's IP Multimedia Subsystem (IMS) [8] is a standardized NGN architecture. A multimedia service delivery framework for IMS is presented in [3]. It provides adaptation to terminal and session mobility, which includes conforming session parameters to access network bandwidth and to user terminal media encodings, but does not involve QoS negotiation and network resource reservation. An IMS approach that offers session continuity across different access networks is described in [5]. It enables transfer of agreed QoS parameters between entities controlling the access networks, but assumes that the QoS settings remain unchanged after the vertical handover. A mobile QoS framework for IMS inter-working is proposed in [9]. To overcome impact of terminal mobility on QoS guarantees, user terminals initiate advanced resource reservations at neighboring networks which they may visit during lifetime of the established sessions. However, this solution does not include the means to renegotiate QoS parameters at the application level.

III. Mobility-aware session reconfiguration

The session reconfiguration refers to a *multimedia session* as an association of *participants* that exchange *media flows*. A *session participant* relates to a *service platform* (as defined in [10]), and is either a user terminal, which enables a user to take part in the session, or a server, which can act as a media source. We assume that each participant is uniquely determined by a fixed identifier, which corresponds to a Uniform Resource Identifier (URI), and that it is reachable in the network via assigned IP address. The latter may change due to terminal mobility. A unidirectional *media flow* is a stream of media data (e.g., audio or video), which associates these parameters: (a) identifiers of participants that exchange the media flow, (b) chosen media format and encoding, and (c) a QoS specification that defines required network treatment with bandwidth, delay, jitter, and packet loss ratio.

A. Reconfiguration primitives

For the purposes of this work, we define three *reconfiguration primitives* to achieve QoS management: (1) *start media flow*, (2) *modify media flow*, and (3) *stop media flow*. The *start media flow* primitive includes successful negotiation of QoS specification between the associated participants and reservation of network resources for the given flow. Afterwards, the participants establish corresponding media transceivers with the agreed format/encoding and transport parameters, and initiate media transmission. Modifying a media flow refers to adjusting its format/encoding and QoS specification, and may result in customizing the reservation of network resources for the flow. Once the participants apply *stop media flow*, the allocated network resources are released and the media transceivers are halted.

B. Mobility events

Based on changes which may stem from terminal and session mobility, for instance, changes in access technology or in user terminal characteristics, we propose these *mobility events* to be targeted by the reconfiguration:

(a) *Change of terminal* – denotes a change of the user terminal due to *session mobility*;

(b) *Change of location* – denotes a change in user terminal's location (i.e., IP address) due to *terminal mobility*;

(c) *Change of access network* – denotes a change of access network for the user terminal, when a *vertical handover* takes place.

IV. Functional model in the scope of NGN

Proposed functional model of the approach (Fig. 1) involves the set of generic network entities that handle session establishment and reconfiguration, negotiation and renegotiation of QoS parameters, event notification conveyance, and reservation of access network resources. In particular, it supports these QoS functional aspects:

(1) session-level signaling for QoS negotiation and dynamic renegotiation with respect to the mobility events;

(2) determining QoS specifications for media flows in a multimedia session;

(3) interaction with control entities that authorize and reserve the required resources; and

(4) producing and conveying the mobility event notifications, as well as processing them to decide which of the reconfiguration primitives to invoke.

A. Functional model

User Terminal Entity (UTE) denotes a *session participant* used for engaging in multimedia sessions. A UTE is described with its hardware and software configuration (including supported access networks), which is stored in a *user profile* in *User Profile Repository Entity* (UPRE). The *user profile* describes the preferences of a user in terms of, e.g., preferred media types and configurations of her/his terminals. Each UTE includes the signaling capability and the media transmission capability, and comprises these functions: *Session control function* (SCF), *Event analysis function* (EAF), *QoS monitoring function* (QSMF), and *Media transmission function* (MTF).

EAF handles *user inputs* that represent requests for replacing the terminals and produces the corresponding *Change of terminal* notifications, while QSMF measures QoS performance on the end-to-end basis for established media flows. SCF is, on the other hand, responsible for signaling that establishes/reconfigures sessions and negotiates the QoS specifications. Furthermore, SCF is invoked by EAS to convey the event notifications to *Session Configuration Management-Support Entity* (SCM-SE), which determines the reconfiguration primitive(s) to apply against the mobility. Upon receiving the media flow parameters, SCF calls MTF to start, modify or stop media transmission (e.g., media streaming).

Mediating Session Control Entity (MSCE) is the first contact point for a UTE on the signaling path. It forwards session control messages between UTEs and the chosen *Serving Session Control Entity* (SSCE). Moreover, MSCE initiates network resource authorization and reservation by extracting required media flow information from the control messages and passing it to *Resource and Admission Control Entities* (RACEs). SSCE is, on the other

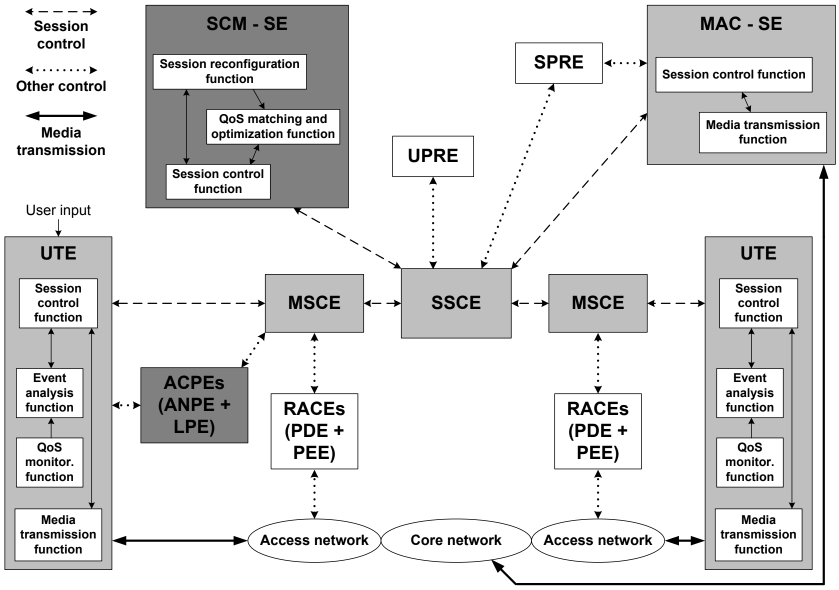

Fig. 1. Functional model for the mobility-aware QoS management

hand, the central point of the signaling path, which forwards the control messages between session participants. It includes SCM-SE in the signaling path, thus invoking functions that SCM-SE offers to the participants.

SCM-SE is the central QoS management component, which offers the *QoS matching and optimization function* (QMOF) [11] and *Session reconfiguration function* (SRF). QMOF produces QoS specifications by taking into account user terminal configurations, access network characteristics, and requirements and constraints of desired multimedia services, whereas SRF is provided with the event notifications, which are then analyzed to determine the needed reconfiguration primitive(s). SCM-SE interacts with SSCE over its *Session control function*, which enables SCM-SE to receive the notifications and to participate in the QoS (re)negotiations.

Multimedia Application and Content-Support Entity (MAC-SE) represents another *session participant*, i.e., a server which executes multimedia applications and hosts the media content that is transmitted to the users. A multimedia service that is provided by the hosted application is depicted with a *service profile*, which describes its requirements and constraints, and is stored on *Service Profile Repository Entity* (SPRE). MAC-SE includes two functions, similar to UTE: SCF and MTF. SCF is responsible for exchanging session control messages directly with the given SSCE, while MTF starts, modifies, and stops the media transmission.

RACEs authorize and reserve access network resources, and involve *Policy Decision Entity* (PDE) and *Policy Enforcement Entity* (PEE). PDE decides about policy rules regarding network resource control, which includes authorization, reservation and release of the resources, while PEE imposes these rules.

Access Configuration Provision Entities (ACPEs) include *Access Network Provision Entity* (ANPE) and *Location Provision Entity* (LPE), which provide information about access network a UTE is attached to, including a unique identifier of the network, and about location of the UTE, thus producing notifications for *Change of access network* and *Change of location*.

B. Mapping the model to ITU-T NGN architecture

ITU-T NGN architecture is described with a set of *functional entities* (FEs), which are regarded to as logical concepts and provide an inseparable group of specific functions [12]. Each model entity is mapped to the corresponding FE in the NGN, to show a feasibility of the proposed approach in an NGN-based network (Fig. 2). This includes introducing new, or extending the existing, FEs.

UTE is mapped to the *End-User Functions*, which depict user terminals that may be connected to a NGN. The functionality of UPRE is realized with the *Service User Profile FE* (SUP-FE) of the *Service Control Functions* (Fig. 2). SUP-FE is responsible for storing user profiles, user subscription data and subscriber-related location data. Furthermore, the *Service Control Functions* encompass session control FEs, most notably the *Service Call Session Control FE* and the *Proxy Call Session Control FE*. They conform to SSCE and MSCE, respectively.

Application Support Functions (Fig. 2) incorporate functions that are "used in common in two or more applications" and that can "improve Quality of Experience (QoE)" [12]. For these reasons, SCM-SE is introduced to the *Application Support Functions* (Fig. 2). Moreover, the functionality which SCM-SE provides can be reused and incorporated in every new request for session establishment and session reconfiguration, independently of a particular multimedia service. For MAC-SE, we assume that it is the responsibility of a service provider different from the NGN provider, which then locates MAC-SE in the *Functions from Other Service Providers* (Fig. 2). SPRE is not mapped, because there exists no FE foreseen

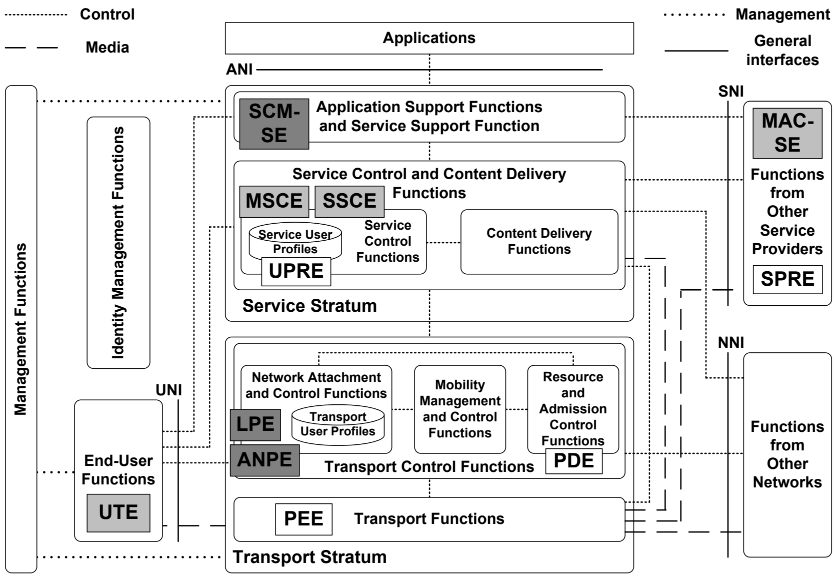

Fig. 2. The functional model in the scope of ITU-T NGN architecture

to store the service profiles. One approach to manage them is to introduce the corresponding database in the *Functions from Other Service Providers*.

The NGN architecture specifies entities that control the resources. PEE, thus, conforms to the *Policy Enforcement FE* of the *Transport Functions*, while PDE provides the functionality of the *Policy Decision FE* in the *Resource and Admission Control Functions* (Fig. 2). The *Network Attachment and Control Functions* in Fig. 2 include the *Network Access Configuration FE* (NAC-FE) [13], which allocates IP address to the user terminals and can also send other access network configuration parameters to them. The latter include parameters that uniquely identify the access network to which a user terminal is attached. Hence, ANPE and LPE are mapped to the NAC-FE.

V. Signaling procedures

In order to facilitate event notification, session reconfiguration and the QoS management, five signaling procedures involving entities of the proposed model are specified:

(a) *Media flow establishment*,
(b) *Media flow termination*,
(c) *Change of user terminal*,
(d) *Change of user terminal's location*, and
(e) *Change of user terminal's access network*.

Media flow establishment refers to negotiation of parameters which are needed to establish one or more media flows between two session participants, while *Media flow termination* results in terminating one or more media flows and releasing the allocated network resources. *Change of user terminal* specifies signaling in response to the corresponding mobility event, which produces QoS specifications for the media flows that need to conform to the capabilities of the targeted user terminal and adjusts the reservation of required network resources. *Change of user terminal's location*, on the other hand, reflects a change in user terminal's location and defines signaling which results in transfer of one or more media flows for the goal of maintaining QoS. Finally, *Change of user terminal's access network* relates to renegotiation of QoS parameters due to new characteristics imposed by a change of the underlying access and to the need to reserve resources in the new network.

A. Media flow establishment

This procedure sets up an association between two session participants for exchanging media data, during which capabilities and requirements between them are harmonized. In particular, it results in agreeing upon one or more media flows that the participants want to exchange, and upon the accompanying QoS specifications and other flow parameters. During *Media flow establishment*, QoS negotiation is performed to assure a feasible level of QoS for the participants and an optimal reservation of the required resources, which are affected by user preferences, user terminal configurations, access network characteristics and resource availability, and multimedia service requirements and constraints. Fig. 3 depicts the Unified Modeling Language (UML) sequence diagram that specifies the signaling procedure. The diagram illustrates flow establishment between a UTE and a MAC-SE. For the goal of a clearer diagram presentation, we represent the *User Profile Repository Entity* and the *Service Profile Repository Entity* by a single *Profile Repository Entity* (PRE).

Media flow establishment is invoked when a user accesses a multimedia service, for which a session must be established with the associated MAC-SE. Upon user's request, her/his UTE sends a *session request* message to the MAC-SE (Figure 3, step 1). The message first traverses the UTE's MSCE, which forwards it to the SSCE. The latter acquires the corresponding *user profile* from the PRE, authorizes the user, and retrieves the *service profile* that is associated to the requested service. Following these actions, the SSCE forwards the request

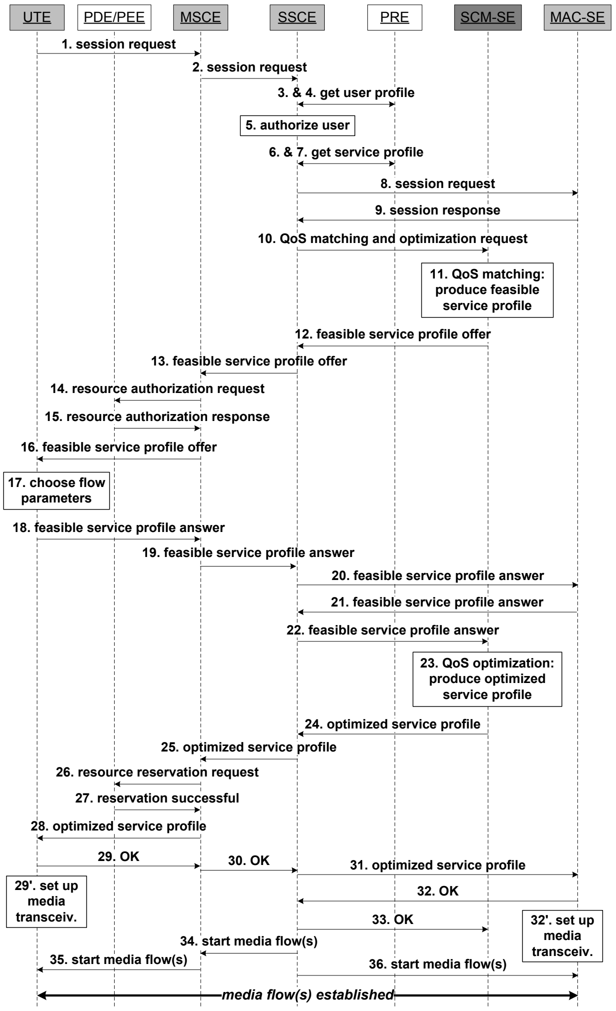

Fig. 3. Signaling related to *Media flow establishment*

to the MAC-SE, which accepts the request and sends a *session response* message back to the UTE (step 9). Upon receiving the response, the SSCE calls the SCM-SE by sending *QoS matching and optimization request*. This invokes the QMOF to produce a *feasible service profile* based on the parameters in the user profile and the service profile. The feasible profile contains a set of offered media flow parameters both the UTE and the MAC-SE support. We assume that each UTE is attached to one access network during the establishment procedure, leading to calculation of the feasible profile for that particular network.

The feasible profile is then forwarded to the MSCE (steps 12 and 13), which uses information from it to authorize network resources by invoking the PDE and the PEE (steps 14 and 15). The negotiation procedure continues at the UTE, where the user has the opportunity to accept, modify or deny (a subset of the) parameters offered in the received, feasible profile (step 17). The result of that action forms a *feasible service profile answer* (Figure 3, step 18), which is conveyed to the MAC-SE and, afterwards, to the SCM-SE. The QMOF is called to perform the *QoS optimization* and to calculate optimal usage of required network resources. The resulting *optimized service profile* is used by the PDE and the PEE to reserve the resources (steps 26 and 27) and, then, it is forwarded to the UTE and the MAC-SE (steps 28 and 31, respectively). After receiving the optimized profile, the UTE and the MAC-SE configure operating transport parameters and set up media transceivers. The last step is to initiate media transmission (the *start media flow(s)* messages), which results in the media flows being established.

B. Change of user terminal

This procedure specifies signaling that enables transfer of one or more media flows between different UTEs. It includes moving media flows from one UTE to another, without breaking the established communication. The procedure is the response to an instance of *Change of terminal*.

Fig. 4 depicts the UML sequence diagram that describes the signaling procedure. The diagram illustrates signaling between three UTEs, assuming that one or more media flows are already established between two of them, namely UTE1 and UTE2, and that a user wants to transfer the media flows from UTE1 to UTE3. The procedure is divided in two parts. The first part is to add the targeted UTE (UTE3) to the existing media exchange (applying the *start media flow* primitive), and then to remove the initiating UTE (UTE1) from the exchange (applying the *stop media flow* primitive). For clearer diagram presentation, we assume that UTE1 and UTE3 are assisted by the same MSCE. Moreover, the MSCE and the PDE/PEE facilitating UTE2 have been omitted from the diagram, as is the *Profile Repository Entity*.

The procedure is invoked when a user decides to replace her/his user terminal in an ongoing multimedia

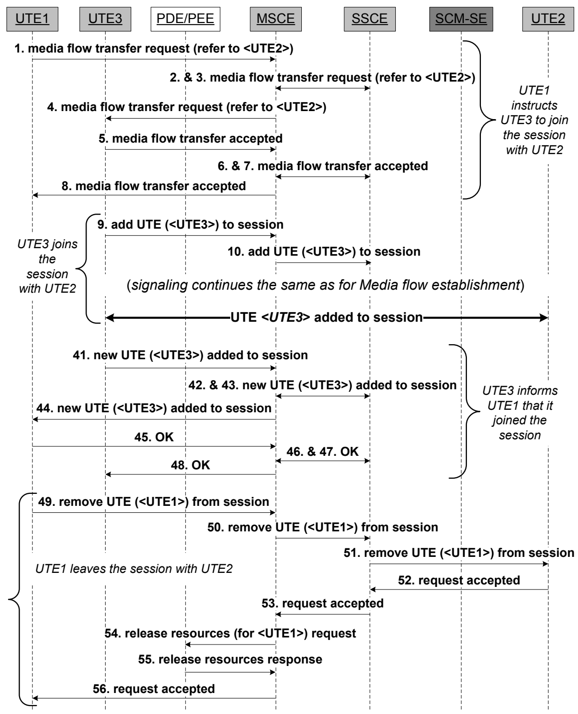

Fig. 4. Signaling related to *Change of user terminal*

session. This request results in a *Change of terminal* notification, which identifies the targeted user terminal (UTE3). The notification "maps" to the initiating UTE (UTE1) sending a *media flow transfer request* message to the UTE3 (Fig. 4, steps 1-4). The latter message contains identifier of the correspondent UTE (UTE2). After accepting the transfer request and sending the accompanying response to the UTE1 (*media flow transfer accepted*), the UTE3 continues with joining the existing session and sends an *add UTE to session* message to the UTE2 (step 9).

The procedure then continues similarly as for *Media flow establishment*. When the UTE2 accepts "the joining request", the SSCE calls the SRF and the QMOF to produce a *feasible service profile* and an *optimized service profile* for the new UTE, while the PDE and the PEE authorize and reserve the needed resources. The UTE3 is then added to the session. Thereafter, the UTE3 invokes process of removing the UTE1 from the session (it informs the UTE1 about joining the session, steps 41-48) and the UTE1 sends *remove UTE from session* to the UTE2 (step 49). Before the UTE1 leaves the session, the PDE and the PEE can release the reserved network resources (steps 54 and 55).

C. Change of user terminal's access network

This procedure maintains or adapts QoS when the underlying access network for a user terminal changes. It is invoked when the ACPEs associated to a UTE are informed of the new access network the UTE has attached to. This results in the corresponding notification conveyed to the SCM-SE (Fig. 5, steps 1-3), where the SRF processes the change and then invokes the QMOF to produce a new *feasible service profile* (step 4). The produced profile considers newly imposed access characteristics and constrains, and is forwarded to the UTE. The procedure then follows the course of *Media flow establishment* until the resources are reserved and media transceivers of the participants are updated with new flow parameters.

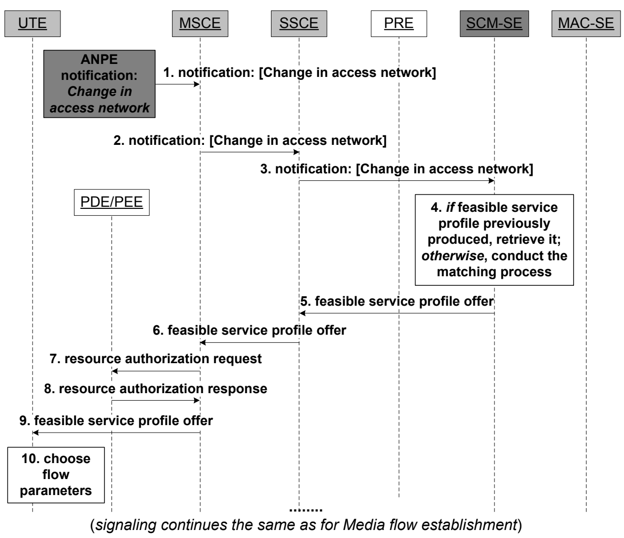

Fig. 5. Signaling related to *Change of user terminal's access network*

VI. Simulation and Performance Evaluation

To simulate the proposed functional model and to evaluate its performance, we specify the model by using Discrete Event System Specification (DEVS) [14]. DEVS is a formalism for modeling and simulation of general discrete event systems, which offers *atomic DEVS models* to impose the systems' behavior and *coupled DEVS models* to build their structure. Each atomic model is determined by the set of sequential states with their duration and by the sets of input and output *events*, which manage state transition. An atomic DEVS model is defined with the following 7-tuple:

$$M =< X, Y, S, t_a, \delta_{ext}, \delta_{int}, \lambda >, \quad (1)$$

in which:

- X is the set of input events;
- Y is the set of output events;
- S is the set of sequential states;
- $t_a : S \rightarrow T^{\infty}$ is the *time advancing function*, which is used for determining the duration of a state;
- $\delta_{ext} : Q \times X \rightarrow S$ is the *external transition function*, which defines how an input event changes a state of the model, where $Q = \{(s, t_e)|s \in S, t_e \in (T \cap [0, t_a(s)])\}$ is the total set of states, and t_e is the time elapsed since the last input event;
- $\delta_{int} : S \rightarrow S$ is the *internal transition function*, which defines how a sequential state of the model changes "internally" (i.e. when the elapsed time comes to the duration of the state);
- $\lambda : S \rightarrow Y^{\phi}$ is the *output function*, where $Y^{\phi} = Y \cup \{\phi\}$, and $\phi \notin Y$ is an *unobserved* output event. This function specifies how a sequential state of the model produces an output event when the elapsed time comes to the duration of the state.

Each coupled model is determined by the set of building components (i.e. atomic and coupled DEVS models) and by the coupling sets, which specify how are the components connected with each other. A coupled DEVS model is defined with the following 8-tuple:

$$N =< X, Y, D, \{M_i\}, C_{xx}, C_{yx}, C_{yy}, Select >, \quad (2)$$

in which:

- X is the set of input events;
- Y is the set of output events;
- D is the name set of the building components;
- $\{M_i\}$ is the set of the building components, where for each $i \in D$, M_i can be either an atomic or a coupled DEVS model;
- $C_{xx} \subseteq X \times \bigcup_{i \in D} X_i$ is the set of *external input couplings*;
- $C_{yx} \subseteq \bigcup_{i \in D} Y_i \times \bigcup_{i \in D} X_i$ is the set of *internal couplings*;
- $C_{yy} : \bigcup_{i \in D} Y_i \rightarrow Y^{\phi}$ is the *external output coupling function*;
- $Select : 2^D \rightarrow D$ is the *tie-breaking function*, which specifies how to select the event from the set of simultaneous events.

Each entity of the proposed model is realized as an atomic DEVS (aDEVS) model, while its associated signaling messages are "mapped" to input and output events of the aDEVS. Defined aDEVS models are combined by using coupled DEVS (cDEVS) models. The specification is the basis for an implementation and simulation of the proposed model based on the DEVS-Suite Simulator [15].

A. Evaluation methodology and settings

Performance evaluation of the proposed model is conducted to assess its scalability. For the purposes of this evaluation, we introduce the *duration* metric. Each signaling procedure defines *duration* as the time 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* denoting single procedure execution in "time units". The reference values are set as shown in Table I (with regards to message number ratio among the procedures). As the proposed model is generic, these values may be set as preferred.

This evaluation of the proposed model includes the following goals:

(a) measure average *duration* for the procedures in relation to the number of UTEs that simultaneously execute a particular signaling procedure, and

(b) measure average *duration* for the procedures in relation to the number of *message handlers*.
Message handlers are associated to the proposed model entities, where a *message handler* is able to "process" a single incoming signaling message during the required time and to "produce" the corresponding outgoing message. The handlers capture the ability of the model entities to concurrently handle multiple messages. In order to evaluate performance of the proposed model when its entities combine a different number of *message handlers*, three model configurations are defined (Table II). These configurations may also be defined as preferred.

Simulation scenario, during which the measurements are collected, includes these steps:

(1) the UTE instances are invoked to simulate *Media flow establishment* with the MAC-SE instances, and

(2) a predefined group of UTEs simultaneously start executing *Change of user terminal's access network*, at the same time, the second group of UTEs start *Change of user terminal*, while the last group of UTEs simultaneously invoke *Change of user terminal's location*.

B. Simulation results

Fig. 6 depicts average *duration* (per UTE) for the *Media flow establishment* procedure in relation to the number of UTEs executing it and *Configuration3*. The average was derived by dividing sum of values that were measured for all the UTE instances with the overall number of UTEs. It can be noticed that *duration* almost linearly increases with the number of UTEs executing the procedure and avoids an exponential growth, thus indicating a good scalability of the model.

We have also applied step (2) of the simulation scenario on the same configuration (*Configuration3*), modifying the number of UTEs executing a particular procedure, while the number of UTEs invoking other two reconfiguration procedures is set to predefined values. Fig. 7 depicts average *duration* (per UTE) for the reconfiguration procedures in relation to the number of UTEs involved in *Change of user terminal's access network*. The number of UTEs invoking *Change of user terminal* and *Change of user terminal's location* is set to 200 and 600, respectively. The average values were derived by dividing sum of the measured values with the number of UTEs involved in the particular procedure. It can be noticed that *durations* almost linearly increase with the number of *changing access network* UTEs, namely for each of the procedures, again indicating a good scalability.

Fig. 8 depicts average *duration* (per UTE) for the *Media flow establishment* procedure with respect to the specified simulation configurations, *Configuration1*, *Configuration2*, and *Configuration3*. This average was derived by dividing sum of the measured values with the overall number of UTEs, which equals to 2000. For a linear

TABLE I
REFERENCE VALUES FOR THE *duration* METRIC

Signaling procedure	***duration*** [time units]
Media flow establishment	14.0
Change of user terminal	21.0
Change of user terminal's location	9.0
Change of user terminal's access network	10.0

TABLE II
SIMULATION CONFIGURATIONS OF THE PROPOSED MODEL

Configuration1	***Configuration2***	***Configuration3***
different number of UTEs	different number of UTEs	different number of UTEs
2 * (PDE + PEE) * 50 handlers	2 * (PDE + PEE) * 75 handlers	2 * (PDE + PEE) * 100 handlers
1 * PRE * 100 handlers	1 * PRE * 150 handlers	1 * PRE * 200 handlers
2 * MSCE * 200 handlers	2 * MSCE * 300 handlers	2 * MSCE * 400 handlers
1 * SSCE * 300 handlers	1 * SSCE * 450 handlers	1 * SSCE * 600 handlers
1 * SCM-SE * 150 handlers	1 * SCM-SE * 225 handlers	1 * SCM-SE * 300 handlers
2 * MAC-SE * 150 handlers	2 * MAC-SE * 225 handlers	2 * MAC-SE * 300 handlers

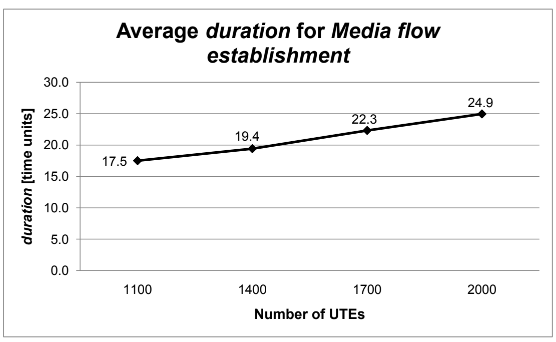

Fig. 6. Average *duration* against number of participants (part 1)

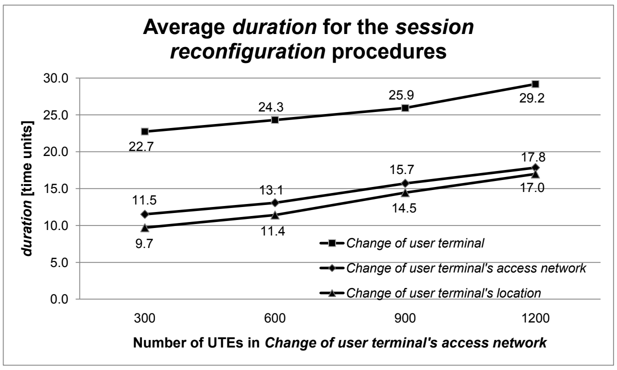

Fig. 7. Average *duration* against number of participants (part 2)

decrease in the number of *message handlers* over all the model entities, average *duration* indicates a tendency to increase in an exponential manner. A further analysis is needed to establish guidelines for dimensioning the proposed model entities regarding the number of *message handlers*. Similar results are obtained for all the *session reconfiguration* procedures.

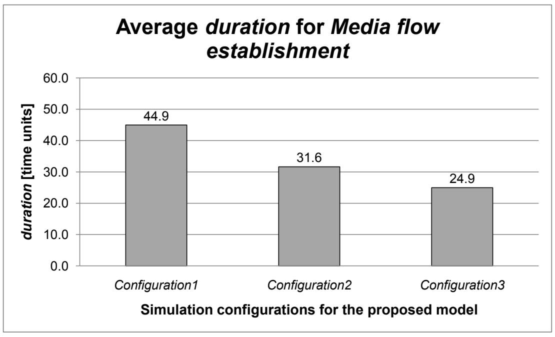

Fig. 8. Average *duration* against simulation configurations (part 1)

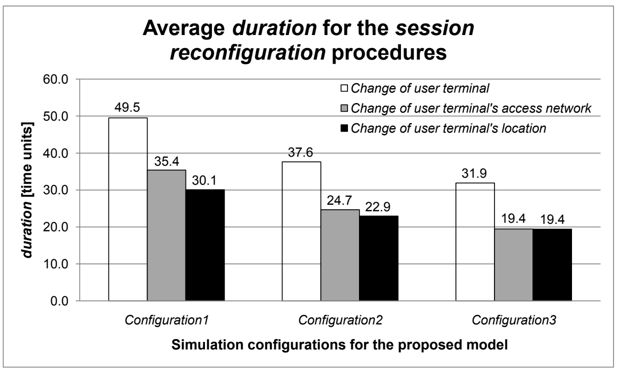

Fig. 9. Average *duration* against simulation configurations (part 2)

VII. Conclusion

This paper describes simulation and performance evaluation of an approach for mobility-aware QoS management of multimedia services. The approach enfolds around reconfiguration of multimedia sessions at the application level, which facilitates maintaining or adapting QoS independently of an access network type and according to the service specifics. We describe proposed functional model of the approach and the specified signaling procedures that enable the session reconfiguration in response to mobility. The functional model entities are mapped to ITU-T NGN architecture, showing a feasibility of the depicted approach in an NGN-realized network. Performance evaluation of the functional model, which considers its scalability issues with respect to time duration of the signaling procedures and number of session participants, is presented. Simulation includes up to 2000 participants executing the signaling procedures and the results show that the duration almost linearly increases with the number of participants for all the procedures, indicating a good scalability of the proposed model. Future work will focus on additional model evaluation and model application in an IMS-based prototype.

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