A Novel Algorithm for SOA-based Cross-Layer QoS Support in Multiservice Heterogeneous Environments

GORDANA GARDASEVIC[1,*], DEJAN STJEPANOVIC[2], ALEKSANDAR DAMLJANOVIC[3], DEJAN CVIJANOVIC[2]
[1]Department of Communications, Faculty of Electrical Engineering, Patre 5, 78 000 Banja Luka, BOSNIA AND HERZEGOVINA
[2]Department of Computer Science and Information Technology, Faculty of Electrical Engineering, Patre 5, 78 000 Banja Luka, BOSNIA AND HERZEGOVINA
[3]LANACO Information Technologies, Knjaza Milosa 15, 78 000 Banja Luka, BOSNIA AND HERZEGOVINA
* gordana.gardasevic@etfbl.net, http://www.etfbl.net

Abstract: - There are many challenging issues involving in design of contemporary networking systems. The ultimate goal is to provide end-to-end Quality of Service (QoS) support in multidomain and multiservice interactive environments. The paper proposes an algorithmic framework for cross-layer QoS adaptation in multiservice heterogeneous environments (MHEs) based on Service-Oriented Architecture (SOA) principles. This algorithm takes into account the diversity of user/application requirements, networking technologies, terminal and provider capabilities. Service description and reasoning rules are accomplished by using Web Ontology Language (OWL) and Semantic Web Rule Language (SWRL). The paper also discusses relevant issues for an overall QoS implementation in MHE.

Key-Words: - Multiservice Heterogeneous Environments; Quality of Service; Cross-Layer; Service-Oriented Architecture; Adaptive; Ontology

1 Introduction

The actual challenge in developing high capacity, multiservice heterogeneous environments (MHEs) is to design a functional Quality of Service (QoS) architecture that will be able to support the implementation of diverse networking standards, as well as the requirements for broadband multimedia transmission in transparent and optimized way [1]. Today’s telecommunication facilities are relying on advanced adaptive processing techniques applied at physical layer such as Orthogonal Frequency Division Multiplexing (OFDM), cognitive radio, Software Defined Radio (SDR), multiple antenna systems, adaptive antenna arrays, Ultra-Wideband (UWB) technology, etc. Adaptive coding and modulation techniques are efficient tools for supporting required QoS adaptation mechanisms.

The QoS general framework must be able “to sense” the networking environment and to timely adapt to available bandwidth and other relevant system resources. One possible approach is to assign the QoS profile to each end-user with preferences describing the route selection, network resources, user's expectations, terminal's capability, application requirements, and so on. Such profile has to be self-adaptive and self-organized. The preliminary set of obtained QoS preferences represents the input for chosen cross-layer adaptation mechanism. Layer-specific QoS parameters need to be mapped in order to support "end-to-end" QoS architecture. The environment for MHE implementation is highly dynamic and the possibility to react fast is of crucial importance. The selection of cross-layer adaptation strategy is based on obtained preferences and will have the influence on cooperation between layers in terms of getting the best QoS performances. The possible solution to support these requirements is to apply the cognitive reasoning for creating specific learning rules, Fig.1 [2].

The cross-layer QoS design may overcome some obstacles related to adaptation and optimization issues in MHEs [3]. This is particularly important in wireless networking due to numerous parameters involved in radio-transmission (physical environment, multi-mode operations/terminals, handover issues, interference problems, roaming capabilities, mobility support, signalization mechanisms, power consumption, etc.). The framework for QoS provisioning and management should be able to support various QoS representations, interlayer mappings between different QoS traffic classes and types of QoS parameters, as well as mobility management, handover procedures, and security constraints. Moreover, a framework should have the adaptive and modular structure that provides flexible addition, reuse or removal of necessary functionalities and services.

Many research papers focus on adaptation only at one or two layers at a time, and the adaptation process generally includes a limited number of parameters without taking into account the dynamics of MHEs.

networking infrastructure has gained a particular attention. SOA is a mechanism for providing functionality via composition of separate independent services that interact by using standard communication protocols.

Moreover, the SOA provides platform independency, loose coupling, service reuse, adaptation and modularity [8]. Distributed computing and Web services are the main areas of SOA applications, whereas there is a lack of the implementations in heterogeneous networking systems. This fact motivated us to examine the research in this particular field.

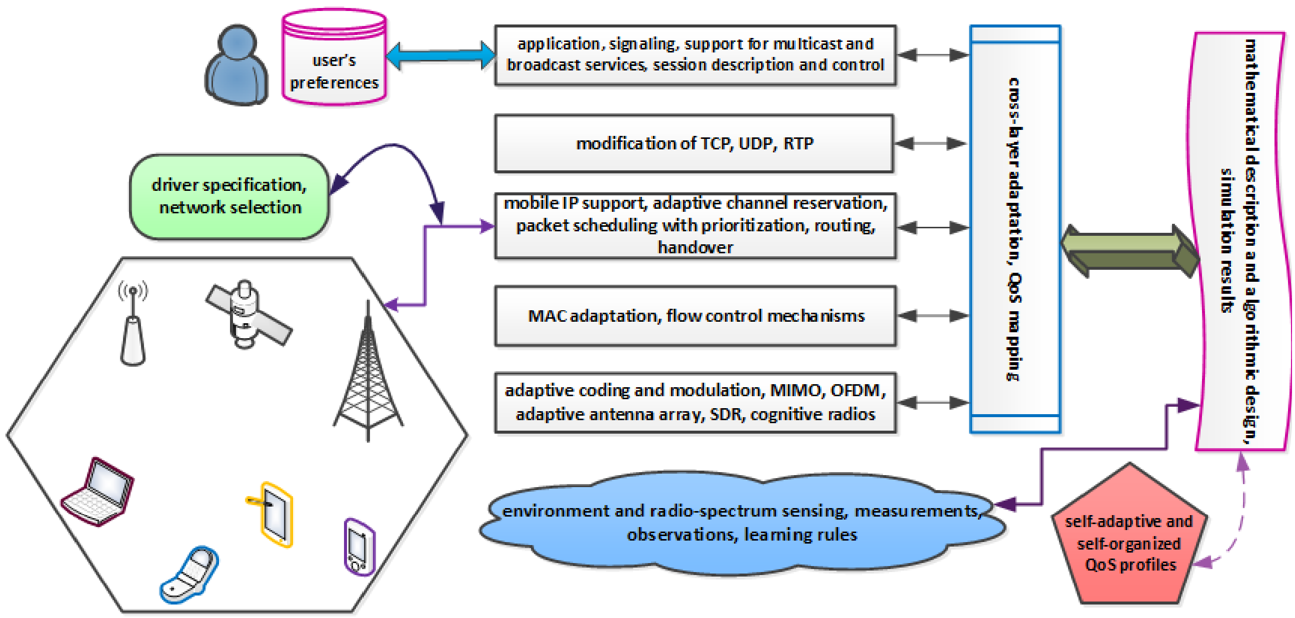

Fig.1. QoS issues in multiservice heterogeneous environments [2].

In paper [4], the authors propose QoS- and QoE-based adaptation taking into account the objective values of technical parameters and past user decisions or user feedback. A client-device QoS-based Web service selection has been proposed in [5]. This adaptation includes only the device QoS parameters and it does not represent a cross-layer framework. The paper [6] focuses on reducing the energy consumption of mobile devices. In [7], policy-based QoS management represents the crucial part of the framework but the real-time QoS parameters are not analyzed. Recently, the possibility to integrate the Service-Oriented Architecture (SOA) within the

The idea behind this algorithmic framework is to establish the efficient communication mechanisms among the layers in order to adapt dynamically to the diversity of user/application requirements, networking technologies and provider capabilities. To achieve this goal it is necessary to enable integration, understanding, reasoning and knowledge representation between various domains and entities. This work is the extension of our previous proposal. In [9] we have proposed the framework for an overall QoS support, whereas in this paper we present the detailed architecture, algorithm for end-to-end QoS support and related UML communication diagram.

The remainder of this paper is structured as follows. Section 2 explores the relevant SOA issues and discusses the benefits of applying SOA concept in MHE for QoS support and adaptation. Section 3 focuses on our proposal related to the optimal application delivery to end-user, where the main contribution is given in the form of algorithm and its structure in terms of service management, service configuration and monitoring, as well as the cross-layer QoS adaptation process. Section 4 draws conclusions.

2 Service-Oriented Architecture (SOA) in Multiservice Heterogeneous Environments (MHEs)

2.1 SOA Architecture and Its Application in Networking

An important aspect of MHE is to establish and maintain the access to different application providers without dependency on underlying transport protocol or access technology. Furthermore, there is a need for a mechanism that is able to discover a required application and deliver it to end-user based on parameters provided from both user and application. When a user sends a request for specific application (for example, a live video streaming), he expects that the best possible service will be delivered from the network provider, even during the time of handover. On the other side, service providers need to expose the services together with their properties and descriptions.

The possible solution for dealing with these requirements in MHE is to apply the SOA principles. The review of literature shows that most research papers consider the implementation of SOA principles for QoS-aware application layer. A typical SOA implementation is commonly related to Web services, and still there is no deployment in networking systems. A survey in [10] provides a good overview of SOA-based implementations in NGN (Next Generation Networks), related to service and data transport management, network and device monitoring, as well as the SOA management in NGN. The paper [11] proposes the network management based on Web services, specifically a service management and service composition/decomposition related to QoS parameters. Here, the ontology is applied for description and proper service selection in order to meet user's requirements.

Some promising results have been obtained in creating a multi-level service-oriented architecture for wireless sensor networks [12].

But, as a general conclusion, an overall SOA-based framework and its integration within the cross-layer QoS architecture in MHE is still missing.

2.2 Our Approach: SOA in Cross-Layer Framework

The SOA abstraction in our framework, which will be discussed in more detail in the next section, is implemented at the following three levels of cross-layer framework:

- Application layer, which performs the application orchestration and selection of proper application.
- Transport layer, whose task is to provide the management and monitoring of network and devices.
- Application provider side, where SOA framework is used to compose several services in order to obtain the best possible functionality and to enable reusability, adaptation as well as the platform independency.

This kind of organization provides the involvement of relevant entities and their functionalities in the process of making decisions and optimization procedures.

2.2.1. SOA at application layer

The SOA principles are applied at the application layer in order to design the modules, the client-application communication, and the selection of the most suitable application's provider. Most research related to SOA for NGN has been focused on the application layer. This layer is responsible for discovery, selection, connection, and execution of services.

The management framework offers API (Application Programming Interface) to application developers so they can efficiently add the application into application registry. This registry holds information about all available applications. When the user requests the specific application, the framework performs the registry search. The application may consist of one or several services. It can be implemented as only one service or it can be a composition of several services which are combined into one application at application provider layer.

In addition to the discovery, selection and execution of the application or service, the system as a whole should quickly respond to the failure of one or more services.

Upon the failure, a new service should be selected, and the functionality or requested application should adapt itself to a new context.

The user should not notice a significant impact when the system is in the process of adaptation. This scenario may be accomplished by applying SOA principles and design. In the service registry, services need to be described by additional parameters for QoS demand and service requirements.

The cross-layer framework uses these additional parameters to find the best functionality for user who requests the specific application with preferred parameters set.

2.2.2. SOA at transport layer

The SOA functionality at this layer provides the efficient management and monitoring of network devices. The network becomes more complex with the deployment of various devices. The implementation of an SOA-oriented device management should be platform/device manufacturer independent. This can be accomplished by adding the agents to network devices.

The agents communicate with the manager using SOA protocols and operate with device, for example by changing configurations, report statistics, etc. At physical layer, SNMP (Simple Network Management Protocol) still can be applied. In this case, the agent acts as a mediator between upper layers and devices. Furthermore, SNMP operations can be grouped as one of SOA functionality so the process of changing parameters in device's configuration can be automatically done in single operation.

At transport layer, each aspect of network functionality could be modeled as a suitable SOA component, for example: the IP address management, the VLAN management, prioritization, scheduling, monitoring, etc. All these mechanisms combined together offer an efficient underlying transport framework for user-application interaction. Several Web Service-based network management systems have been developed such as OASIS Web Services Distributed Management, Distributed Management Task Force WS-Management, and IETF NetConf that offers extension to Web Services.

2.2.3. SOA at application provider side

The application developer employs SOA principles to design and implement an application that is adaptive to user's context. The SOA platform enables service reuse, easier application management and better response in case of failures. For example, the video transfer may require the video compression/coding and/or audio compression/coding which can be modeled as independent services. For one user's context, the application chooses one specific coding service for audio and video. If a network senses the bandwidth downfall, the application can choose another video coding service with better compression capabilities.

By combining SOA principles at these three layers, we believe that this approach can bring benefits to an overall MHE orchestration. Users can request and receive applications with respect to their context; applications can be developed and added to service/application registry without considering the transport technology. On the other side, the management of that underlying transport layer is performed in SOA, a platform independent way.

At the application side we can see the benefits in decomposition of functionality into services and the application can be controlled more efficiently in case of adaptation or failure. At the service selection side, the framework benefits from SOA-based environment mostly because of the agent placed at user's side. It enables framework to communicate with user or application providers in standardized and platform-independent way.

3 Proposed Framework for Cross-Layer QoS Adaptation

3.1 Framework Description and Relevant Design Issues

The aim of our framework is not only to offer timely, transparent, and efficient transitions among various access networks (e.g. WLAN, GSM, UMTS, WiMAX, etc.), but also to select the optimal service by applying different QoS parameters, and to propose an adaptation to other layers of OSI model. The process of adaptation includes various entities (user, device, gateway, signalization entity, physical link, a virtual object such as IP sec tunnel, SNMP agent, etc.).

An important step in the adaptation process is to collect all relevant information about current system state. It is necessary to measure instantaneous values of required parameters, and based on the obtained results to create the adequate rules for adaptation mechanisms [13]. In our case, this process includes logging and analysis of application parameters, terminal capabilities, as well as end-user requirements (monitoring of service execution, environment and user experience). Also, it is very useful to have the history (records) of previous completed tasks/services.

Another relevant fact that should be taken into consideration is that heterogeneous multiservice network performs a large number of various functions and tasks. In order to support the overall QoS performance monitoring, one possible approach is to find a correlation between the KPI (Key Performance Indicators) selected by users and operators. Bandwidth and power management remains the most challenging task required for effective and optimal resource management in heterogeneous environments. The process of QoS optimization is usually related to the specific utility (UF) or cost function (CF) selection. This step requires accurate metrics selection and optimization. One possible approach in defining the cost function is given in paper [14].

The heterogeneity and diversity of services and QoS requirements create a number of difficulties in selecting proper UF or CF. There are many strategies related to the resource optimization problem, and they may be splitted into two groups: distributed and centralized algorithms. Due to its effectiveness and complexity issues, the novel approaches are usually based on distributed algorithms for optimization. The selection of UF requires the balance between resource utilities and QoS specifications.

Another problem that should be taken into account relates to specific algorithms for ranking services with QoS parameters. For instance, how to compare metrics whose values have completely distinct ranges and units, that is how to combine bit rates, delay, cost, availability, different traffic models, etc. in a unique value so that the services can be ranked accordingly to the user’s requirements [15,16,17] .

One of the major goals of NGN concept are user-centric, personalized, context-aware, QoS supported services available across heterogeneous network environment. To achieve this goal, it is necessary to enable the integration, understanding, reasoning and knowledge representation between various domains and entities.

Semantic Web technologies are open standards that provide solution for building such unifying and automated system. Web Ontology Language (OWL) represents a description logic-based ontology language for providing well defined expressive syntaxes and semantics, and efficient reasoning support necessary for effective use of ontologies [18].

The basis of our framework (Fig.2) is the unified information structure contained in OWL ontologies and SWRL rules [19], which provides a common understanding of concepts and relationships maintained and shared by the service providers and users. It exposes various data across layers (users, services, QoS, applications, devices, networks, contexts, security policies) and facilitates networking and exchanging of information between different domains and entities.

As a summary, our proposed framework is designed to take into account the following facts:

- Various terminals support different services, and depending on the terminal capabilities (supported connectivity, camera and monitor resolution, memory resources, power, etc.) the system estimates the application/service to be provided.
- The end-user profile represented by the previous preferred list of services (the service history) is important in the process of making the decision, and it represents the base for applying the concept of personalized services.

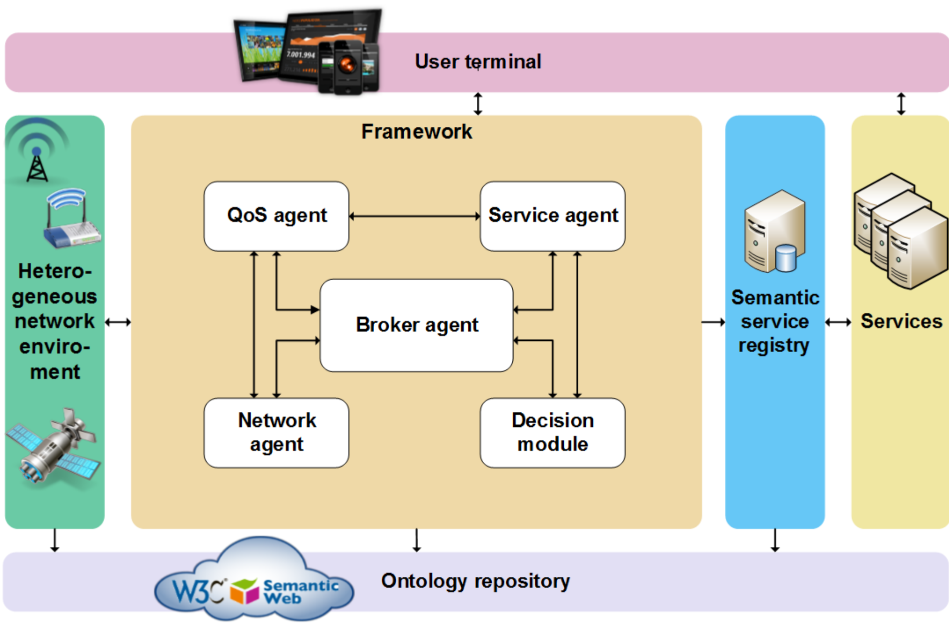

Fig.2. Proposed framework for cross-layer QoS adaptation [9].

- The wireless environment is highly dynamic, and the concept of obtaining fast and reliable response (in terms of localization, accessibility, power requirements, security, etc.) becomes crucial for achieving optimal performances.
- The Semantic Web open standards and interfaces are chosen for communication between entities, where the entities submit all required information in appropriate form.

Based on previous considerations, the proposed framework incorporates the following key modules: Broker, Decision module, Service agent, QoS agent, Network agent and Ontology repository, Fig.2. The main properties are summarized in the following:

3.1.1 Broker
The Broker has a role to mediate and connect to a content requester and provider by sending specific queries to semantic service registry in order to obtain services with requested functionalities.

This entity also coordinates the communication among other modules inside the framework, and merges the service requests to provider replies in order to match a service to a user. Therefore, it represents the access point for user's enquiries about service availability. The Broker agent can store results of these interactions for future use.

3.1.2 Decision module
The main task of Decision module is to generate the list of optimal services (virtual self-adaptive service, VSAS) based on the submitted profiles.

The list will be created based of several parameters (cost of service, power requirement for session, bandwidth utilization, etc.) that form the cost or utility function. This weighted function will be the metric for the generation of priority list.

The Decision module is used to infer the entailment from the asserted facts and rules in order to make the knowledge-based decisions. It consists of an inference engine for OWL ontologies and knowledge base. The rules of reasoning are determined by ontology language, i.e. the description logic underlying ontology language. The Inference engine must have the SWRL rule support. The Knowledge base stores the facts and rules used for the Decision module.

3.1.3 Service agent
The Service agent stores VSAS and returns on request the optimal service based on real-time network and context QoS parameters. It maintains VSAS until user's QoE parameters or device's QoS parameters change or until session expires. The proper timing and signalization should be established in order to return the service in accordance with the dynamics of particular communication environment.

3.1.4 QoS agent
The QoS agent is responsible for collecting the QoS parameters related to the user-service communication. For example, one possible parameter could be a user location obtained in order to determine to which cell the user is currently connected, or to find a new Base Stations, or to select the proper handover mechanism. In addition to user-specific parameters, the QoS agent also measures the network QoS parameters (e.g. mobile IP support attributes, adaptive channel reservation options, packet scheduling with prioritization, routing protocols selection, etc.). The Service agent uses these parameters to select the best possible service for the end-user. Next, the QoS agent maintains the QoS profiles for each application by mapping the user's and application's requirements (support for multicasting and broadcasting modes, session description and control preferences etc.) related to specific network environment for service assigning. Furthermore, it reports on dynamic changes in user, application or network QoS parameters, and triggers the adaptation process through the re-negotiation, or provides the adaptive QoS guarantees to the application.

3.1.5 Network agent
The Network agent is in charge of managing the network resources. It is responsible for the reservation and reallocation of network resources based on the user/application requirements and preferences, as well as on network availability. Moreover, the Network agent tracks the network events of interest in order to provide the services and to initiate the appropriate adaptations.

3.1.6 Ontology repository
The ontology based environment that is relevant for design of our framework, is illustrated in Fig.3. The knowledge base contains facts and rules used to define domains' dependencies, matching algorithms and adaptation's logic. The inference engine uses this rules and ontology classes and instances for reasoning and generation of results. This is used to automate and enrich the service discovery and selection, the QoS support and cross-layer adaptations.

After matching the functionalities of services and generating a list of available and suitable services, our framework performs QoS calculation, that consider non-functional QoS parameters described by QoS ontology, such as cost, performance, security, preferences, accessibility, availability, reliability, data quality, etc.

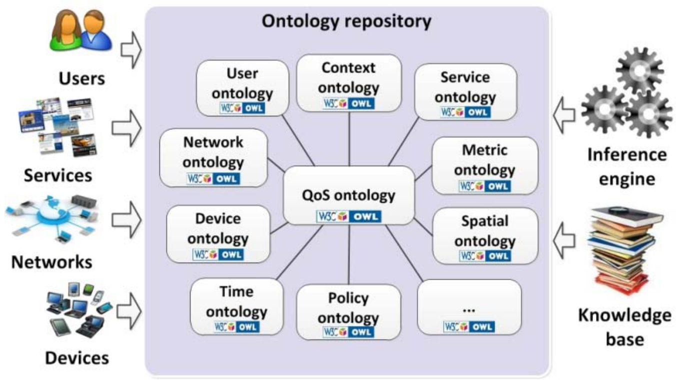

Fig.3. Ontology based environment

There are several papers in the literature that exploit optimization of matching process to reduce costs of semantic reasoning and to make the matching algorithm more efficient, as a necessary step towards the wide acceptance of semantic services [20,21,22]. The changes of the context or network environment can cause the framework to react by building the additional knowledge and suggesting and implementing appropriate adaptations.

The rule illustrated in Fig.4. describes the adaptation of video application's bandwidth in accordance with the channel properties by applying the bit rate transcoding. This approach illustrates the simplicity in describing various processing procedures which can be very important requirement in networks with many different tasks and timing/resource constraints.

VideoApplication(?app) $\wedge$
hasBandwidth(?app,?appband) $\wedge$
hasNetwork(?app,?net) $\wedge$
hasNetworkConditions(?net,?netcond) $\wedge$
availableBandwidthAvg(?netcond,?netband) $\wedge$
swrlb:lessThan(?netband,? appband) $\wedge$
BitRateAdaptation(?adapt) $\Rightarrow$
needBitRateAdaptation(?app,?adapt) $\wedge$
adaptationBitRateTargetValue(?adapt, ?netband))

Fig.4. Example of SWRL adaptation rule.

3.2 Proposed Algorithm for "End-to-End" QoS Support

The algorithm for delivering the optimal application to end-user is presented below. This algorithm describes the communication among the key modules that form the SOA-based framework for cross-layer QoS optimization.

1. mobile client send request – request (application_description, device_profile, user_experience);
2. search services by description of the application functionality (application_description);
3. for each service in services
   if device meets the requirements of service (device.QoS ≥ service.QoS)
   add service in device_services;
   end if
   end for
4. order device_services by user.QoE, service.QoS DESC;
5. create new virtual self-adaptive service (vsas.services = device_services);
6. framework ask for real-time context of mobile client;
7. mobile client sends context and vsas request to framework;
8. get network.QoS from network agent;
9. for each service in vsas.services
   if context and network meets the requirements of service (context.QoS + network.QoS ≥ service.QoS)
   send service to mobile user with profile;
   break;
   end if
   end for
10. network agent adapts network in user environment by service_profile and context;
11. mobile client sends parameters and service request to the server that provide the service;
12. server sends service response to the mobile client;
13. if (the context of the mobile client is changed) send sessionid and context, and request the new service - vsasRequest(sessionid, context) (go to 7.);
14. else if (user_experience is changed)
   go to 4.;
15. else if (device is changed)
   go to 1.;

The client sends the request to cross-layer framework for particular application (Fig.5). This request contains the application description (i.e. semantic description of multimedia application/functionality), the device profile (terminal capabilities in form of QoS parameters) and QoE information. After receiving the request and the related semantic description of application functionality, the framework finds all services that offer required functionalities.

The preferred list of services will be created in accordance with specified cost/utility function. Only those services that are matched to the predefined terminal profile will be selected. In this way, a list of services (device_services) that are matching both user and device requirements is created. In case of the user mobility, the change of connection parameters (protocol, bandwidth, etc.) or handover procedure may appear, and the algorithm selects the appropriate scheme based on user preferences.

The list of services needs to be sorted in accordance to the user profile. Based on QoS parameters, the preferred best possible service will be returned first. The sorted list of services represents the input to the virtual self-adaptive service (VSAS).

The main property of VSAS is the self-adaptation in terms of processing the instantaneous QoS parameters and real-time context, and the selection of optimal service for end-user at the time.

The framework creates VSAS as a new session for user and then sends the VSAS link to the user requesting the real-time QoS parameters (context). After obtaining the response from the user, VSAS searches through the list of services and finds the first one that matches the QoS criteria. In the next step, it sends the information on the service link to the user, as well as the QoS service profile.

Based on the service profile and network abstraction layer, the user mobile terminal recommends the necessary adaptation on lower layers, it request service and obtains the requested functionality.

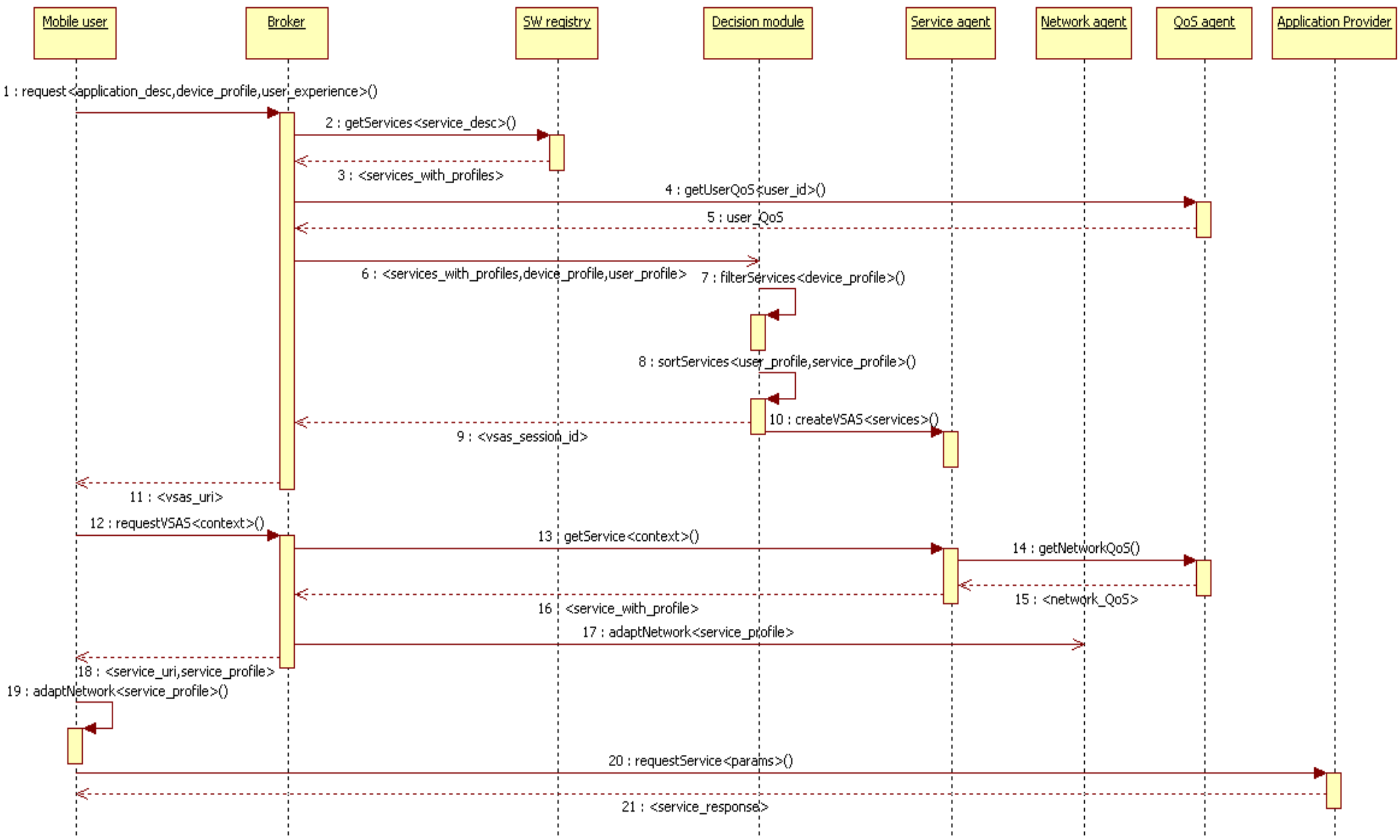

Fig.5. UML Sequence Diagram.

As the service list in VSAS has been sorted as described previously, the user is provided with the preferred optimal service and requested functionality that corresponds to the terminal capabilities.

The user terminal performs a permanent monitoring of the environment and system in general, and keeps track of all changes and modifications. If the change appears, the context is also changing and the terminal will detect it.

The next step is to call VSAS and send the instantaneous context. In accordance with this step, VSAS chooses the optimal service. If parameters are enhanced, VSAS sends the advanced service to the user, and vice versa.

In case of user's QoE change, the list of services will be rearranged in accordance with new parameters. If the terminal profile changes or the new service is required, the user sends new request (step 1 in algorithm) and the framework creates new VSAS service with new parameters.

The processor time and memory usage of the user terminal needed for the self-adaptive service execution are slightly higher in this case. The additional tasks assigned to the user terminal are monitoring of the environment and two additional calls to the framework during the creation of the self-adaptive service and receiving the optimal service profile. In the future work, we will focus on the optimization of communication flows between the mobile client and framework server, as well as the algorithm implementation and execution, following the similar approach as in [23,24].

4 Conclusions

MHEs are complex systems that face many challenges related to networking issues, terminal reconfigurability and demanding applications development. One of the major goals of NGN concept are user-centric, personalized, context-aware, QoS supported services available across heterogeneous network environment. To achieve this goal it is necessary to enable integration, understanding, reasoning and knowledge representation between various domains and entities. Semantic Web technologies are open standards that provide solution for building such unifying and automated system.

Current research activities are oriented towards the internetworking of heterogeneous technologies and integrated "end-to-end" QoS solutions with IP-based transient domains. The efficient network design and management should be based on open platforms and frameworks with adaptive and modular structure that enables flexible addition, reuse or removal of necessary functionalities and services.

To provide an optimal and efficient ″end-to-end″ QoS support and adaptation over the MHEs, we have proposed the algorithm for cross-layer QoS support based on SOA principles of service creation and delivering. There is a lack of SOA implementations in the networking systems, so we investigated the possibilities for its usability in this field. The main contributions of this paper include a proposal of framework for cross-layer QoS adaptation in order to support characteristics of various heterogeneous networking technologies and terminals, to discover and select the proper network services that support QoS requirements of different applications and QoE of end-users.

We also propose the ontology for description of most relevant concepts like QoS profiles (models), QoS parameters, parameter's attributes, relationships between parameters, relevant contexts etc.

The practical implementation of this framework will be, at a global level, the complex process because it takes into account all relevant issues in MHE. At the same time, it is a challenging task that motivates us to direct research towards its practical implementation based on analytical model of parametric cost function and simulation model for the various application and networking scenarios.

References:

[1] G. E. Mapp, F. Shaikh, D. Cottingham, J. Crowcroft, and J. Baliosian, ″Y-Comm: a global architecture for heterogeneous networking″, *In Proceedings of the 3rd international conference on wireless Internet* (WICON '07), Brussels, Belgium, Article 22.

[2] G. Gardasevic, "A framework for an overall Quality of Service (QoS) analysis in 4G systems", *55th ETRAN Conference*, Banja Vrućica (Teslić), Bosnia and Herzegovina, June 6 – 9, 2011.

[3] Jiann-Liang Chen, Ming-Chiao Chen, Shih-Wei Liu, Jyun-Yu Jhuo, "Cross-layer QoS architecture for 4G heterogeneous network services", *11th International Conference on Advanced Communication Technology*, ICACT 2009, vol.01, no., pp.73-77, 15-18 Feb. 2009.

[4] A. Papageorgiou, A. Miede, D. Schuller, S. Schulte, and R. Steinmetz,"Always Best Served: On the behaviour of QoS- and QoE-based algorithms for Web service adaptation", in *Proc. PerCom Workshops*, 2011, pp.76-81.

[5] J. C. Estrella, R. T. Toyohara, B. T. Kuehne, T. C. Tavares, R. C. Santana, M. J. Santana, and S. M. Bruschi. “A performance evaluation for a QoS-aware service oriented architecture”. *IEEE Congress on Services*, pp. 260-267, 2010.

[6] E. Park, H. Shin, "Reconfigurable service composition and categorization for power-aware mobile computing," *IEEE Transactions on Parallel and Distributed Systems*, vol.19, no.11, pp.1553-1564, Nov. 2008.

[7] E. Badidi, L. Esmahi, “A scalable framework for policy-based QoS management in SOA environments”, *Journal of Software*, vol. 6, no. 4, April 2011.

[8] M. Bell, "Introduction to Service-Oriented Modeling". *Service-Oriented Modeling: Service Analysis, Design, and Architecture*. Wiley & Sons, 2008, ISBN, 978(0): 470-14111-3.

[9] Gardasevic, G., Stjepanovic, D., Damljanovic, A., Cvijanovic, D., "A SOA-based framework for cross-layer QoS adaptation in next generation networks", *IEEE 30th International Performance Computing and Communications Conference (IPCCC) 2011*, pp.1-2, 17-19 Nov. 2011.
doi: 10.1109/PCCC.2011.6108096.

[10] B. Giovanni and A. Luigi, A survey of SOA technologies in NGN network architectures, *IEEE Communications surveys & tutorials*, in press.
doi: 10.1109/surv.2011.051111.00127.

[11] W. Dong, ‘The research on Web service based network management”, *Journal of Networks*, vol. 5, no. 7, July 2010.

[12] Leguay, J.; Lopez-Ramos, M.; Jean-Marie, K.; Conan, V.; "An efficient service oriented architecture for heterogeneous and dynamic wireless sensor networks," *33rd IEEE Conference on LCN*, vol., no., pp.740-747, 14-17 Oct. 2008, doi: 10.1109/LCN.2008.4664275.

[13] Neri F. "Cooperative evolutive concept learning: an empirical study", *WSEAS Transaction on Information Science and Applicationss*, WSEAS Press (Athens, Greece), 2005, issue 5, vol. 2, pp. 559-563.

[14] Sehgal, A., Agrawal, R., "QoS based network selection scheme for 4G systems", *IEEE Transactions on Consumer Electronics*, vol.56, no.2, pp.560-565, May 2010.
doi: 10.1109/TCE.2010.5505970.

[15] Z. Milicevic, Z. Bojkovic, K.R. Rao, "An Approach to Interactive Multimedia Systems Through Subjective Video Quality Assessment in H.264/AVC Standard", *WSEAS Transactions on Systems*, vol. 11, no. 8, pp. 305-312, August 2012.

[16] Mohammad S. Saraireh and Nidal A. Al-Dmour “Novel mechanisms for quality of service improvements in wireless ad hoc networks” *WSEAS Transactions on Systems*, vol. 10, no. 7, pp. 209-225, July 2011.

[17] Cornel Balint, Georgeta Budura, and Adrian Budura, “Mixed traffic models for dimensioning radio resources in GSM/GPRS networks”, *WSEAS Transactions on Systems*, vol. 9, no. 3, pp. 233-242, March 2010.

[18] W3C OWL-S submission, http://www.w3.org/Submission/OWL-S

[19] W3C SWRL submission, http://www.w3.org/Submission/SWRL/

[20] Giallonardo, E.; Zimeo, E.; "More Semantics in QoS Matching", *IEEE International Conference on Service-Oriented Computing and Applications, SOCA '07*, vol., no., pp.163-171, 19-20 June 2007.
doi:10.1109/SOCA.2007.30
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4273423&isnumber=4273394

[21] Kritikos, K., Plexousakis, D.;"Semantic QoS-based Web Service Discovery Algorithms," *Fifth European Conference on Web Services ECOWS '07*, vol., no., pp.181-190, 26-28 Nov. 2007.
doi:10.1109/ECOWS.2007.20
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4399747&isnumber=4399723

[22] Guangjun G.; Fei Y.; Zhigang C.; Dong X.; "A Four-Level Matching Model for Semantic Web Service Selection Based on QoS Ontology", *International Symposium on Information Science and Engineering ISISE 2010*, vol., no., pp.630-634,Dec.2010.
doi:10.1109/ISISE.2010.149
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5945025&isnumber=5945022

[23] Gardasevic G., Jevtovic M., Constantinou P.,”Optimization of Application QoS Protocols for 3G/4G Mobile Networks”, *WSEAS Transactions on Communications*, Iss.9, Vol.7, Sept. 2008, ISSN 1109-2742.

[24] Calinescu, R.; Grunske, Lars; Kwiatkowska, M.; Mirandola, R.; Tamburrelli, G., "Dynamic QoS Management and Optimization in Service-Based Systems", *IEEE Transactions on Software Engineering*, vol.37, no.3, pp.387-409, May-June 2011.
doi: 10.1109/TSE.2010.92