The Second International Conference on Next Generation Mobile Applications, Services, and Technologies

NETQOS Policy Management Architecture for flexible QoS Provisioning in Future Internet

P. A. Aranda Gutierrez
Telefonica R&D
paag@tid.es

I. Miloucheva, D. Wagner, Ch. Niephaus
Fraunhofer, Schloss Birlinghoven, Germany
{ilka.miloucheva,david.wagner, christian.niephaus}@fokus.fhg.de

A. Flizikowski
Adam Mickiewicz University
adamf@amu.edu.pl

N. Van Wambeke, F. Armando, Ch. Chassot
LAAS-CNRS, Université de Toulouse
{nvanwamb, farmando, chassot}@laas.fr

S. Pietro Romano
Universita' di Napoli Federico
spromano@unina.it

Abstract

This paper is focussed on the NETQOS architecture for automated QoS policy provisioning, which can be used in Future Internet scenarios by the different actors (i.e. network operators, service providers, and users) for flexible QoS configuration over combinations of mobile, fixed, sensor and broadcast networks.
The NETQOS policy management architecture opens the possibility to specify QoS policies on a “business” level using ontology descriptions and policy management interfaces, which are specific to the actors. The business level policy specifications are translated by the NETQOS system into intermediate and operational QoS policies for automated QoS configuration at the managed heterogeneous network and transport entities.
NETQOS allows QoS policy specification and dependency analysis considering Service Level Agreements (SLAs) between the actors, as well as automated policy provisioning and adaptation. The interaction of the NETQOS components is based on a common policy repository.
The particular focus of the paper is aimed to discuss ontology and actor oriented QoS policy specification and configuration for heterogeneous networks, as well as NETQOS QoS policy management interfaces at business level and automated translation of business QoS policies to intermediate and operational policy level.

1. Introduction

The Future Internet targets at convergence of different kind of networks (fixed, mobile, sensor and broadcast media), autonomous networking, self-management and configuration, as well as realization of the visions of the Internet of Things [1]. The Future Internet should be able to offer much more flexibility to the users, service and network providers in selecting QoS (Quality of Service) facilities for applications and tuning them to the capabilities of the particular network.
Advances in the identity management and user centric communication technologies will require new policy management architectures with focus on the user QoS requirements and actors interactions (ISP operators, service providers and customers).
The policy management for flexible selection and configuration of QoS will be an important concept of the future Internet infrastructures.
In order to provide flexible QoS guarantees for different kind of multimedia services and applications, such as content delivery, VoIP, IP television, GRID and mission critical applications, in the future heterogeneous Internet networks, automated configuration, adaptation, and optimisation of QoS mechanisms according the requirements of the different actors (ISP operators and users) considering SLA objectives and different network context will be supported.
Considering the network context in the policy framework is especially important in order to provide flexible QoS guarantees for users with different kind of applications in future Internet environments with high technological diversity, where UMTS, WLAN, WIMAX, WLAN DVB-T, DVB-H, sensor networks and other technologies will coexist.
The particular focus of this paper is the NETQOS hierarchical ontology based QoS policy framework for different kind of actors, as well as design and implementation of the experimental policy management interfaces for flexible QoS guarantees in future heterogeneous infrastructures.
The work is based on the research and development in EU IST project NETQOS [2], [3]. The architecture is aimed at automating policy specification, adaptation and provisioning effectively delivering QoS guarantees for different actors considering SLAs and specific network context.
QoS policy specifications on different layers, as well as policy transformation from business QoS policy rules to unified intermediate QoS policy requests and technology dependent operational QoS policies and configuration mechanisms are discussed.
The experimental NETQOS policy management interfaces are designed and implemented using ontology descriptions, actors and SLA requirements, as well as policy dependencies.
The automated policy provisioning, adaptation and QoS control is based on the storage of unified policy presentations in common repository, which is used by the different components of the NETQOS system depending on their specific roles and functions.

978-0-7695-3333-9 /08 $25.00 © 2008 IEEE
DOI 10.1109/NGMAST.2008.65

The automated NETQOS policy translation and provisioning is shown based on a scenario involving an end-user oriented QoS policy management interface.
This paper is organized as follows. In section 2, an overview of policy and ontology research and standardisation is given. Section 3 is focussed on design and benefits of the NETQOS policy management. Section 4 describes the hierarchical and SLA driven policy framework. User-centric QoS policy management scenarios for heterogeneous environment are addressed in section 5

2. QoS policy issues in the Future Internet

The Future Internet envisages a diversity of networks integrated in converged platforms, applications with different kinds of traffic (multimedia, sensor, real-time, GRID, VoIP) each with its specific QoS requirements, as well as actors, which will be able to select services and automatically control the QoS of their particular applications depending on specific requirements or policies.
Current QoS policy concepts proposed by different standardisation organisations, as well as new policy management concepts derived from reinforcement learning and ontology research build the background for development of efficient policy management systems meeting the requirements of new applications and services of the future Internet networks.
The IETF defines policies as a set of rules to administer, manage and control access to network resources by applications and users (see RFC, 3198 [4]).
Policies specifying conditions and actions can express specific business goals and objectives of policy actors (network operator, service providers and users).
Policy information models [7], ontologies and repositories are used to specify, design and implement policies.
The purpose of QoS policy management is to allow automated configuration of the QoS mechanisms in managed entities based on policy requirements. The IETF policy framework uses the Policy Core Information Model (PCIM) (RFC 3060 [5]) and the Policy Core Information Model Extension (PCIMe) (RFC 3460 [6]) for the structural representation of policies independent on the devices and applications.
The QoS Information Model (QPIM) (RFC 3644 [8]) is aimed at describing QoS policy information based on IntServ and DiffServ technologies. The network device QoS data path information model (RFC 3670 [9]) specifies a hierarchical QoS policy refinement (called "continuum") of high-level, device-independent and device-dependent QoS configuration policies.
Related to IETF is the DMTF (Distributed Management Task Force) Common Information Model (CIM) [10]. The standardization within the TM Forum (TeleManagement Forum) and NGOSS (New Generation Operational Systems and Software) architecture is based on the DEN-ng (Directory Enabled Networks - New Generation) policy management framework. DEN-ng involves a layered set of models, including business and system views of entities for management domains [11].
Policy definitions are related to specific scenarios. To support formal and interoperable policy definitions, ontologies are used. Ontology oriented QoS policy management is an important approach for future Internet systems, for specification of variety of new business services and models. In particular, ontologies can be used to

- support formal policy specification and refinement,
- reduce the complexity for understanding of service conversion,
- support interoperability and enhanced machine reasoning,
- provide key terms, inference rules and semantic interconnections,
- serve as common vocabulary for access services, QoS information, SLA and policy descriptions.

In policy management research, ontologies are proposed for semantic specifications of QoS policies in different scenarios, as for instance, QoS selection [12], SLA specification [13], QoS monitoring and measurement [14], personalisation services [15]. Ontologies allow to integrate the different tasks of the QoS provisioning – policy specification, monitoring, configuration and other.
Other emerging technologies for policy management in the Future Internet are based on the identity management [16], context-aware reasoning for users, as for instance using the fuzzy logic [17] and service customization considering specific models, such as Belief-Desire-Intention model [18].
In the framework of the NETQOS project, QoS policies are defined in a hierarchical manner using ontologies, which allow the refinement of policies with a special focus on heterogeneous environment enhancing current IETF considerations [19], [20]. The usage of ontologies in NETQOS supports a large, modular, expanding, hierarchical and scalable policy framework considering the specific business requirements of the different policy actors for selection of QoS, resources and monitoring facilities according to the SLAs.

3. NETQOS Architecture and Interaction of policy management components

In order to select appropriate QoS mechanisms and guarantees dynamically, in the NETQOS framework, QoS policies can be specified by different actors based on their SLAs. Ontology and scenario oriented policy management interfaces for specification and configuration of business level policy requirements according the actor's expertise are used. Scenario oriented management interfaces are designed to support different kind of business policies allowing automated configuration of specific QoS mechanisms dependent on the particular actor.
To automate the policy provisioning tasks (e.g. QoS configuration using business level QoS policy), the NETQOS system involves interaction of different components based on common policy repository. These components are:

- Actor Preference Manager (APM);
- Policy Description and Management (POLD);
- Automated Policy Adaptor (APA);
- Monitoring and Measurement (MoMe);
- Network and Transport Agents for policy configuration at the managed entities
- Context Manager (CM).

As managed entity, the NETQOS architecture considers not only routers, but also configurable services and protocols, such as the configurable Enhanced Transport Protocol (ETP) [26]. The interactions of the NETQOS components are mediated and synchronized using events and messages processed by the Context Manager.
At the business level, QoS policies are entered in the NETQOS system by the actors using built-in relations and vocabulary defined by their specific ontology (actor-domain model), scenario and actor oriented Graphical User Interfaces (GUIs) for QoS policy management. The design of the particular GUI and QoS policy specifications depend on the role, knowledge and expertise of the actors (ISP operator, end-user, customer).
Business level QoS policy content related to the specific business models, scenarios and particular ontology of the different actors is checked for consistency by the APM component. Using the POLD component, the business QoS policy specifications are translated into unified intermediate QoS policy presentations, which are stored in the policy repository. The automated provisioning of the policies of the different actors is based on translation of intermediate policy descriptions into operational policies, which are configured in the managed entities by the corresponding Agents.
Using the policy repository, the system components are able to interact and efficiently provide automated policy provisioning for the different actors, which includes tasks for dependency analysis, translation, decision, adaptation, monitoring and configuration of policies. The NETQOS components integrated in the policy management architecture, and their main interactions aimed at automated policy provisioning and adaptation are given in fig. 1:

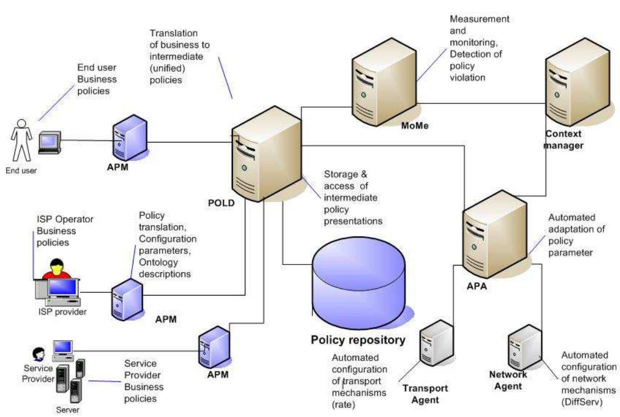

Fig. 1. Interaction of components in the NETQOS architecture

The access to the policy repository based on unified policy descriptions is provided by the POLD (policy description) component. POLD functions store the translated business policies of the actors as intermediate in the repository.
Using POLD, the APA (Automated Policy Adaptor) component obtains the unified intermediate policies and transforms them into operational policies (represented as XACML messages) allowing the configuration of the QoS mechanisms at the managed entities (routers, services protocols) of the heterogeneous Internet topology.

The Network Agent, which is invoked by the APA, receives the operational policies and applies them on routers considering the specific device capabilities and requirements for mapping to device specific configurations. The Network Agent handles commercial and Linux based routers.
The Transport Agent, which is also invoked by the APA, applies the operational XML policies at the transport entities supporting the Extended Transport protocol (ETP) [25].
APA uses the POLD facilities to access the unified policy representations of the different actors and automatically tune the parameters of the intermediate policies stored in the repository. There are different scenarios for automated policy adaptation. One approach is, when the policy monitoring and evaluation, e.g. the MoMe component, detects the specific events (i.e. congestion, overloaded connection, etc.), and triggers temporary or permanently update of the actor's policy parameters in the policy repository (for instance, change of required QoS, redirection of traffic, assignment of another router, etc.).
Another possibility for automated policy adaptation is to consider dependencies of policy parameters of the different actors and to change actor's policy parameter, in order to optimize the resource usage for all actors.

4. Hierarchical QoS policy framework

QoS policies in NETQOS are defined according to the Service Level Agreements (SLAs) between ISP operators and users, which restrict the resource usage and QoS selection in the heterogeneous network environment.
The QoS policies are specified in a hierarchical way based on mappings between different abstraction levels (business, intermediate, operational and configuration). To describe the policy refinement (Policy Continuum) between the layers and policy mappings, the NETQOS system uses ontology.

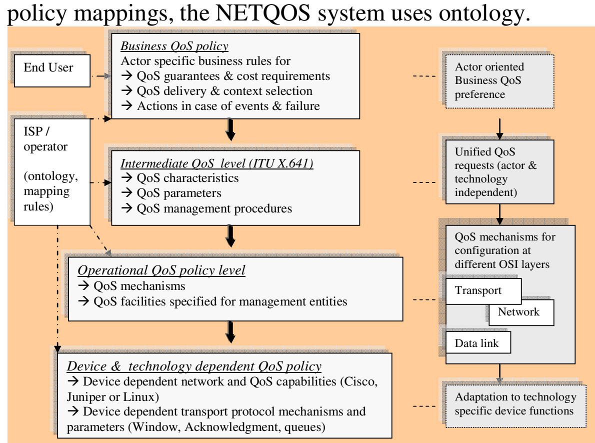

Fig. 2. Hierarchical NETQOS framework for heterogeneous Internet

Considering fig. 2, the NETQOS framework is defined by:

- Business policies (high-level or actor-oriented policies),
- Intermediate QoS policies (unified specifications) ,
- Operational (QoS mechanisms of managed entities), and
- Configuration policies, which are technology oriented policies applied at the heterogeneous entities (devices).

The QoS policies on *business level* are concise specifications of the QoS goals of the particular actors and are related to the SLA objectives. The business policies are automatically

transformed using expertise functions and procedures into intermediate level QoS policy specification.
QoS specifications at the intermediate level are based on QoS facilities and mechanisms defined in ITU-T X.641 [21]. The *intermediate* policies are unified QoS specifications, expressed by selection of specific QoS parameters and QoS management procedures for a specific network, service and application class (VoIP, IPTV, audio streaming, gaming, bulk data transfer). The automated policy configuration is based on the translation of the intermediate policies into operational QoS parameters and mechanisms of specific managed entities (e.g. router and transport functions).
These, in turn, are refined to configuration policies i.e. *technology dependent QoS mechanisms of heterogeneous entities (involving mechanisms of different vendors).*
The NETQOS hierarchical policy management supports automated configuration and adaptation of policies according to preferences of different actors considering SLAs.
The SLA rules describe objectives and restrictions for the parameters of the policy rules, for instance usage of specific QoS mechanisms, handling of QoS anomalies, service degradation options and QoS parameter thresholds.
Similar to the policy definition, the syntax and semantic of the SLA's objectives can be represented using an ontology or a specific rule oriented language. An example for a SLA-oriented rule specification language is RBSLA (Rule Based Service Level Agreements Language), which is based on a formal logic framework for knowledge representation (ContractLog) [22]. More generic ontology based approaches for formal semantic specification, such as OWL [23] and SWRL [24], can be also used to specify SLA rules and map their content to corresponding business level policies.

5. Automated QoS policy management

5.1. Policy management interface for dynamic QoS selection

Using the NETQOS actor oriented policy management interface, the end user can define policies for QoS guarantees in heterogeneous Internet environments for specific QoS management scenarios.
For instance, the user can specify QoS preferences for bandwidth allocation, transport service composition and QoS measurements, which are translated by the system in business, intermediate and operational QoS policies and configured for automated provisioning.
The example QoS policy management interface (fig.3) allows the dynamically specification of end user's preferences for the quality of communication applications (VoIP, Mobile TV, file downloads, multimedia streaming, etc) and the network delivery context. The interface supports the automated configuration of router's QoS mechanisms dependent on the end users requirements.
In addition, the end-user is enabled to analyse the dependencies of the QoS policy specifications and optimise the policy parameters considering specific criteria.
The user selects his preferences dynamically, such as "high quality", "best effort" and suitable network for the delivery of the communication application. The requirements of the end user are mapped into business QoS policy specifications dealing with resource allocation.
Each business policy is characterized by unique policy identifier, the corresponding SLAs and the actor descriptions.

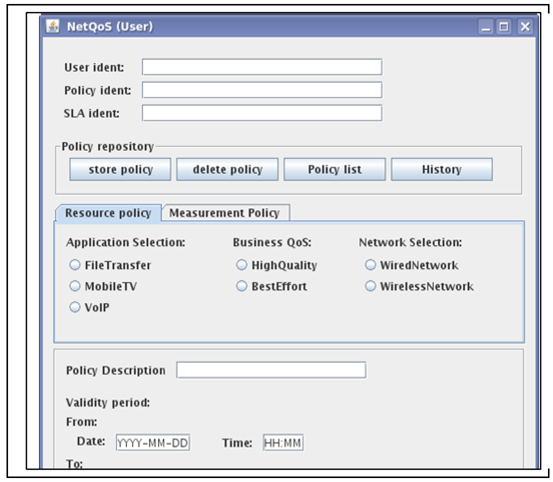

Fig. 3: User oriented interface for business QoS policy specification

The ontology oriented GUI implementation of the policy management interface facilitates the mapping of the specific preferences (parameters) to user's business level QoS policy rules, as well as their translation and storage as unified intermediate policies in the repository.
Based on the intermediate policies, the APA component supports the policy provisioning producing the corresponding operational policies. In particular case, the operational policy describes the QoS requirements for the application traffic flow of the end-user. When the end-user's application is launched, the Network Agent is invoked to configure the QoS requirements for the application traffic at the heterogeneous routers, as defined by the operational policy. The Network Agent operates mapping the operational policies to concrete configuration rules.

5.2. Policy translation

The business policies for automated QoS configuration depend on the particular QoS management scenario and application. They are processed by APM considering the ontology descriptions and restrictions of the SLAs for the particular actor. For NETQOS scenarios, different types of business policies have been defined:

- QoS reservation policies for specific application traffic considering network context (X.641 specification);
- Bandwidth reservation policies;
- Measurement and monitoring policies.

The policy processing in NETQOS is based on the hierarchical policy translation. The business policies are mapped into corresponding lower layer policies. This allows that the provisioning of user business policies can be controlled automatically using the corresponding intermediate and configuration policies.
When the performance of the business policies is not satisfactory for the user, then the business policy provisioning can be enhanced based on adaptation and

change of the corresponding lower layer policies. Adaptation and change of policy parameters is done considering the SLA of the users and policy dependencies of different actors. Policy dependencies can be analysed based on the unified policy representations stored in the repository.
Figure 4 shows the interactions of the NETQOS components in respect of the hierarchical policy abstraction framework.

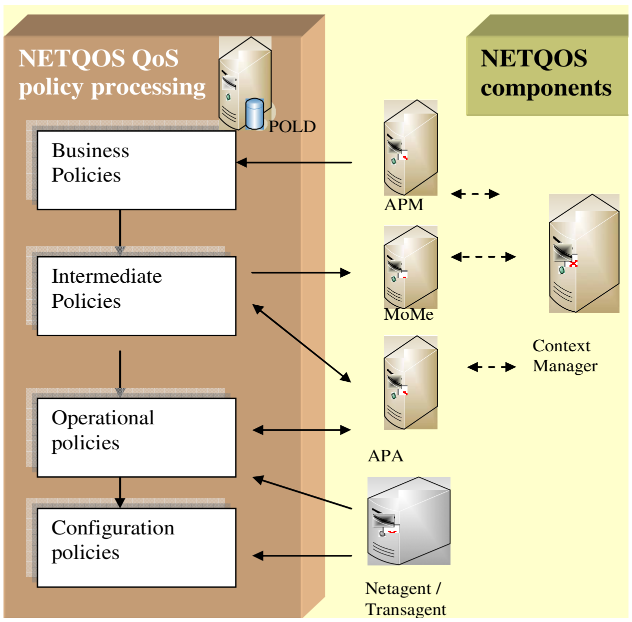

Fig. 4: Processing of hierarchical policies by the NETQOS components

The internal presentation of the NETQOS business policies is structured based on generic and specific policy content:

- The generic part describes basic information about policy identification, related SLAs, actor identifier, the context for policy usage, service and policy type.
- The specific policy description part includes the information describing the parameters of the specific policy type.

Figure 5 shows the generic and specific policy content for some kinds of business policies considered in different NETQOS policy management scenarios.

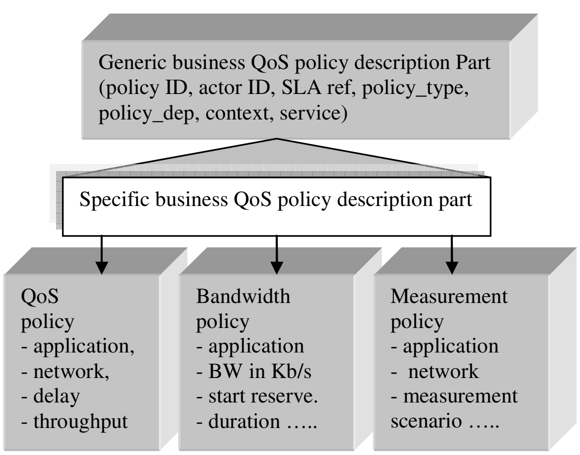

Fig. 5: Generic and specific part of NETQOS business policies

Using semantic operations and SWRL rules, the NETQOS business policies are translated by the POLD component into unified intermediate policies and stored in the common repository. Intermediate policies are based on a common (unified) QoS vision considering the IETF QoS Policy Framework concepts using "condition and action" paradigm (see RFC 3644 [8]) and the NETQOS enhancements of the IETF policy information model for heterogeneous network environment [19].
Intermediate policies include policy identification and type, QoS request and time requirements, as well as references to ontology, SLA and actor descriptions, policy conditions, actions, functions and parameters used to present the required QoS. They are used by the NETQOS components for:

- Policy monitoring and validation (MoMe component);
- Policy adaptation, optimization and translation into operational policy (APA component).

The intermediate policies are translated by APA into XACML (eXtensible Access Control Markup Language) or XML based operational policies, which are applied by the NetAgent and TranAgent components at the different kind of heterogeneous devices (routers and/or Transport level entities). The XACML / XML policies include the generic parameters for the configuration of QoS mechanisms at the managed heterogeneous devices (routers / transport entities), such as topology (source and destination addresses), the specific QoS mechanisms and QoS configuration information.

5.3. Automated configuration of operational policies for heterogeneous devices

Two levels of configuration and adaptation are considered in NETQOS, the Network (IP) and the Transport (ETP) level.

5.3.1. Automated configuration at the Network level

The operational policy is aimed to specify QoS mechanisms to control the treatment of the packets to/from the end-user at the level of managed entity. In NETQOS, an operational policy for network level entity can be based on DiffServ technology, including source address, destination address and DSCP-field (RFC 2474 [25]). DSCP-field of the packets at the ingress routers effects that the application traffic will be assigned to a particular service class with specific priority. Packets of the same service class (application) will be treated in the same way. Depending on the management entity capabilities (router architecture), the NetAgent maps the operational XACML policies into configuration policies, i.e. CLI (Command Line Interface) batches of commands for the corresponding router (Cisco, Juniper or Linux).

5.3.2. Automated configuration at the Transport level

The Transport Agent represents the final step in policy enforcement at the Transport Level. Depending on the type of modular transport to be configured, the APA contacts the adequate Transport Agent instance. In order to be able to target a wide diversity of existing systems, the adaptor design principle has been applied.

The ETP Agent represents the instance of such adaptor component at the Transport level [26]. It is responsible for translating NETQOS Transport Operational Policies into system specific ETP Composition Descriptions. After this translation, it contacts the ETP entities for deployment.

ETP is a configurable Transport level protocol that follows the hybrid approach, where a hierarchical plane implements QoS control functions and a non-hierarchical plane performs QoS management functions. This approach allows separating the different planes that contribute in providing a given Transport service. The modular approach introduced by both the hierarchical and non-hierarchical propositions provides an effective way to satisfy a wide variety of applicative requirements by way of composing and fine-tuning different transport functions, such as loss or rate controls.

6. Conclusions

This paper presents the NETQOS actor oriented policy management architecture for QoS policy management. The novel actor-oriented concepts of the NETQOS system enable emerging business scenarios and service required for NGN, addressed in the ITU NGN-GSI efforts [28]. The benefits of the NETQOS technology and its novel functions in respect to the NGN concepts are based on the following main points:

- *User centric QoS policy management* allowing dynamic and flexible QoS policy specification by the end-users based on their preferences for applications and networks in heterogeneous fixed and mobile environment [27].
- Actor oriented policy management facilitating the interoperation and *integration of the policy framework with emerging identity management architectures [29]*.
- *Hierarchical policy management for heterogeneous networks based on automated business policy* translation to unified, operational and configuration policies for heterogeneous transport and network layer entities.
- *Controlled and efficient usage of network resources by NETQOS components based on a*utomated policy configuration, monitoring, policy violation detection and adaptation considering SLAs.
- *Ontology oriented design* supporting formal policy specification and refinement on different abstraction layers, translation of policies and interoperation.

Acknowledgement

EU IST NETQOS project [3] is supported by the European Commission in the 6th Framework Program.

7. References

[1] ITU Internet Report 2005: The Internet of Things, Nov., 2005.

[2] S. Avallone, P. Di. Gennaro, I. Miloucheva, M. Roth, S. Rao, "NETQOS: Policy based management of Heterogeneous Networks for guaranteed QoS", QoS workshop, Coimbra, Portugal, May 2006.

[3] IST project, Policy Based Management of Heterogeneous Networks for Guaranteed QoS (NETQOS), www.ist-netqos.org .

[4] A. Westerinen, J. Schnizlein, J. Strassner, M. Scherling, R. Quinn, S. Herzog, A. Huynh, M. Carlson, J. Perry, J. and M. Waldbusser, "Terminology for Policy-based Management", IETF RFC 3198, November 2001.

[5] B. Moore, E. Elleson, J. Strassner, A. Westerinen, "Policy Core Information Model-Version 1 Specification", RFC 3060, Febr. 2001.

[6]B. Moore, Policy Core Information Model (PCIM) Extensions, RFC 3460, January 2003.

[7] R. Sahita, S. Hahn, K. Chan, K. McCloghrie, "Framework Policy Information Base", RFC 3318, March 2003.

[8] Y. Snir, Y. Ramberg, J. Strassner, R. Cohen, B. Moore, "Policy Quality of Service Information Model", RFC 3644, Nov. 2003.

[9] B. Moore, D. Durham, J. Strassner, A. Westerinen, W. Weiss, "Information Model for Describing Network Device QoS Datapath Mechanisms", RFC 3670, January 2004.

[10] DMTF, Common Information Model (CIM) Standards, http://www.dmtf.org/standards/cim/.

[11] J. Strassner, D.Raymer, "Implementing Next Generation Services using policy-based management and autonomic computing principles", NOMS Conference, 2006.

[12] G. Dobson, A. S. Marcian, "Towards unified QoS / SLA ontologies", Third International Workshop on Semantic and Dynamic Web Processes, Chicago, USA, September 2006.

[13] L. Green, "Service Level Agreements: An Ontological Approach", Proc. of ICEC, August 2006.

[14] Ch. Zhou, L.-T. Chia, B.-S. Lee, "QoS Measurement Issues with DAML-QoS Ontology", Proc. of the IEEE International Conference on e-Business Engineering, (ICEBE), 2005.

[15] C. M.F.A.Ribeiro, N. S. Rosa, P. R.F.Cunha, "An Ontological Approach for Personalized Services", International Conference on Advanced Information Networking and Applications, IEEE, 2006.

[16] M. Hoffmann, "User-centric Identity Management in Open Mobile Environments", Workshop on Security and Privacy in Pervasive Computing, Vienna, Austria, April 20, 2004.

[17] H.-I Ahn, J.-E. Lee, Y.-I- Yoon, "A Middleware for user centric adaptation based on Fuzzy in Ubiquitous Environment", Conference on Advanced Language Processing and Web Information Technology, 2007.

[18] R. Plesa, L. Logrippo, "An Agent-Based Architecture for Context-Aware Communication", IEEE Conference on Advanced Information Networking and Application Workshops, 2007.

[19] I.Miloucheva, D.Wagner, P.A.A.Gutierrez, "Architecture for dynamic management of QoS policies for heterogeneous Internet environments", Next Generation Mobile Applications, Services and Technologies (NGMAST), Cardiff, Wales, UK, September, 2007.

[20] D. Hetzer, I. Miloucheva, K.l Jonas, "Policy based resource management for QoS aware applications in heterogeneous network environments", International Conference on Communications and Networking (CHINACOM), Shanghai , China , August 22-24, 2007.

[21] ITU-T Recommendation X.641, Series X: Data Networks and Open System Communication, OSI networking and system aspects – Quality of Service: Framework, 12, 1997.

[22] A. Paschke, "RBSLA A declarative Rule-based Service Level Agreement Language based on RuleML", Conf. on Computational Intelligence for Modelling, Control and Automation, Nov. 2005.

[23] OWL Web Ontology Language Semantics and Abstract Syntax, http://www.w3.org/TR/owl-features/ .

[24] SWRL: A Semantic Web Rule Language Combining OWL and RuleML, W3C, http://www.w3.org/Submission/SWRL/.

[25] K. Nichols, S. Blake, F. Baker, D. Black, Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers, RFC 2474, December 1998.

[26] E. J. Exposito, Design and implementation of quality of service oriented transport protocol for multimedia applications, Ph.D. thesis, National Polytechnic Institute of Toulouse, Network and Telecommunications (2003).

[27] I. Miloucheva, D. Wagner, Ch. Niephaus, "User centric QoS policy management for heterogeneous Internet environment", ICT-Mobile Summit, Stockholm, Sweden, June, 2008.

[28] Next Generation Networks Global Standards Initiative, NGN-GSI, ITU, http://www.itu.int/ITU-T/ngn/.

[29] Focus Group on Identity Management, FG IdM-GSI, ITU, http://www.itu.int/ITU-T/studygroups/com17/fgidm/.