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User Centric QoS Policy Management for Heterogeneous Internet Environment

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Abstract: QoS policy management architecture supporting the specification and automated configuration of QoS policies for mobile and fixed users in heterogeneous Internet environment based on Service Level Agreements (SLAs) is discussed. The new focus is to provide management interfaces for ontology based user centric policy specification, as well as automated dependency analysis, adaptation and optimisation of policies of different actors. Users can specify their own QoS policies, which are processed according SLAs, translated into policy repository presentations and used for automated configuration of QoS mechanisms. The hierarchical QoS policy framework involves mapping of business to unified and technology dependent QoS policies. The policy repository serves for storage, translation, evaluation and adaptation of the policies of different actors. Ontology-oriented policy management interfaces allow the efficient support of user-centric QoS policy scenarios.

Keywords: QoS policy, actor, repository, ontology, user centric, SLA, adaptation

1. Introduction

One challenge of the Next Generation Network (NGN) architectures is the provision of flexible QoS (Quality of Service) guarantees in heterogeneous mobile and fixed Internet environments considering user-centric QoS management strategies and complex business relationships of actors providing and using services. In order to respond to the end-user's and customer's needs for cost efficient and dynamically adaptable QoS communication according to the particular user requirements, different technologies have been considered:

- Dynamic service discovery dependent on the preferences of mobile users [1];
- Optimal access network selection for mobile users [2].
- Context-aware reasoning for users, as for instance based on the fuzzy logic [3];
- Policy specification language for non-technical users [4],
- User centric service customisation using Belief-Desire-Intention model [5];
- User-centric identity management [6].

This paper addresses novel ontology based QoS policy management architecture developed in the framework of the EU IST project NETQOS [7], [8], which supports user-centric QoS management approaches for fixed and mobile users in heterogeneous Internet environment. NETQOS is based on hierarchical QoS policy management and automated business policy mapping to QoS mechanisms at different OSI layers (transport, network, data link). Similar to the consideration of different actors in service delivery architectures [14], the NETQOS framework supports interactions of QoS policies of different actors (end-users, ISP operators) based on SLAs. Advanced functions are offered to facilitate user-oriented QoS policy provision, automated monitoring, evaluation, adaptation and configuration of policy parameters. The paper is organized as follows. In Section 2, QoS policy management issues are introduced. The NETQOS actor oriented QoS policy management architecture is discussed in Section 3. Section 4 is focused on user-centric policy management interfaces and scenarios. Section 5 summarises the system benefits.

2. User Centric QoS Policy Framework

2.1 QoS Policy Model for Multiple Actors

The purpose of the QoS policy management is to allow the automated configuration of QoS mechanisms of managed entities based on policy requirements. The IETF policy framework is based on the Policy Core Information Model (PCIM) (RFC 3060 [9]) and the Policy Core Information Model Extension (PCIMe) (RFC 3460 [10]). These models define the structural representation of policies independent on the devices and applications.

The QoS Information Model (QPIM) (RFC 3644 [11]) is aimed to describe QoS policy information based on IntServ and DiffServ technologies. The network device QoS data path information model (RFC 3670 [12]) 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) [13]. The standardisation within the TM Forum (TeleManagement Forum) and NGOSS (New Generation Operational Systems and Software) architecture is based on 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 [15].

In the NETQOS policy framework, *generic QoS policies* are specified by different policy actors (network operator, administrators, service providers, end users) based on SLAs.

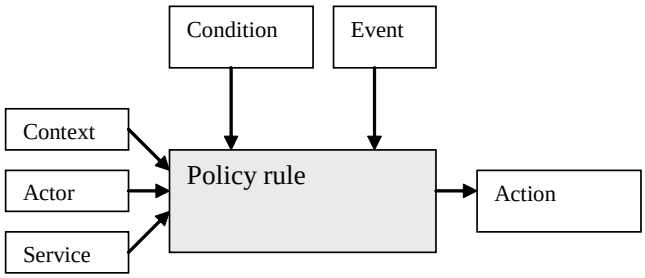

Figure 1: NETQOS Generic Policy Rule Definition

Generic policy rules of policy actors are defined by the mapping of conditions and/or events to resulting actions considering specific context, actor interactions and SLA's policy parameter restrictions.

2.2 Hierarchical QoS Policy Specification and Translation

The hierarchical NETQOS policy framework is based on policies for different layers:

- Business policies (high-level or actor-oriented policies),
- Intermediate QoS requirements (unified QoS policy specifications) and
- Device/technology oriented policies (QoS mechanisms of management entities).

The QoS policies on *business level* are concise specifications of the QoS goals of the particular actors and related to the SLA objectives. The business policies are automatically transformed using expertise functions and procedures into intermediate level QoS policy specification. The QoS specifications at the intermediate level are based on QoS facilities and mechanisms defined in ITU-T X.641 [16]. The *intermediate* policies are unified QoS specifications, expressed by selection of specific QoS parameters and QoS management procedures for a given 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 *technology dependent* QoS parameters and mechanisms of management entities (routers, transport protocol and application entities).

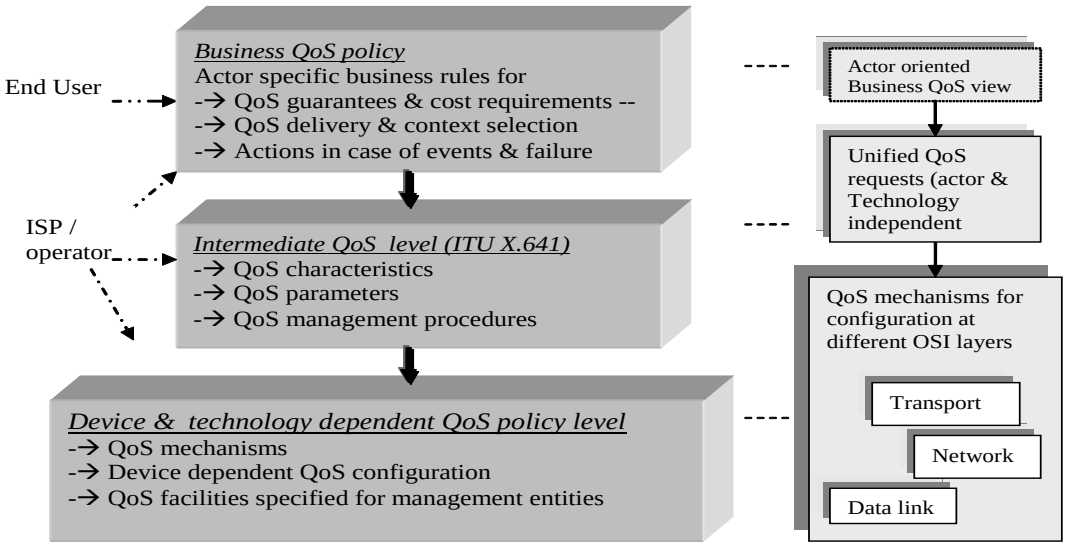

Figure 2: Hierarchical QoS Policy Specification

Generic QoS policies (fig1.) are used for policy representation and modelling at different abstraction layers. In addition, the NETQOS allows specification of business policies on actor oriented way using appropriate Graphical User Interfaces (GUIs).

2.3 User Centric QoS Policy Management Issues

User-centric QoS policy management issues for mobile and fixed heterogeneous Internet environments have been addressed in different concepts primary focussing on:

- *Dynamic service adaptation for mobile users* based on computation of new user policies, when domains are changed [17].
- *Customisation of user's communication services and policies dependent on the modelling of the context,* as for instance the approach using Belief-Desire-Intention model [5], which is applicable to scenarios where users define complex policies on how communication should be handled based on the context.
- *Context* dependent user policy specification considering the user's location, environment (including also sensor information, such as RFID), preferences and service history [6].
- *User-centric service adaptation for ubiquitous environment based on reasoning and modelling of context.* An example is the User Centric Adaptation Middleware (UCAM) that implements dynamic user profiles and applies a fuzzy logic in order to provide a customized service for individual users [3].
- *DEN-ng architecture*, in which policies can be defined by users or automatically derived to manage and control the state of managed objects in context-aware manner to achieve a seamless user experience [15].
- *User-oriented policy specification languages for automated configuration of QoS mechanisms*. An example is the usage of the description logic for management of policies of non-technical users in pervasive environments [4]. This technology allows policies to be specified by non-technical user using their knowledge about the services, and to automatically translate the non-technical policy representations into configuration actions.
- *Identity management* - an emerging service aimed at identifying individuals uniquely within a given environment and at managing identity information [6]. Advanced solutions make it possible to consider user's QoS policies as part of identity management solutions.

A summary of user-centric QoS policy management research and technology approaches is given in the Figure 3.

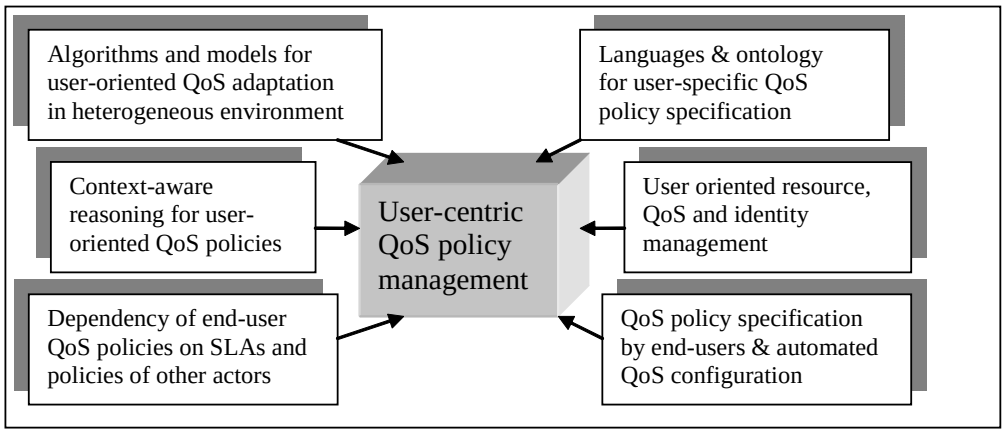

Figure 3: Issues of User-Centric Policy Management

The novel focus of the NETQOS is the specification and provisioning of user-centric QoS policies based on automated configuration and adaptation of policies of different policy actors considering actor-specific roles and interactions, business goals and SLAs relationships. The user centric approach allows actors, such as ISP operators, end-users and customers, to specify different kinds of business QoS policy requests depending on their preferences, which the NETQOS system automatically translates into configuration policies aimed at bandwidth reservation, transport parameter selection, measurement set-up and other tasks. The NETQOS user-centric approach includes facilities for user oriented QoS policy specification, translation and automated provisioning, as shown in fig. 4:

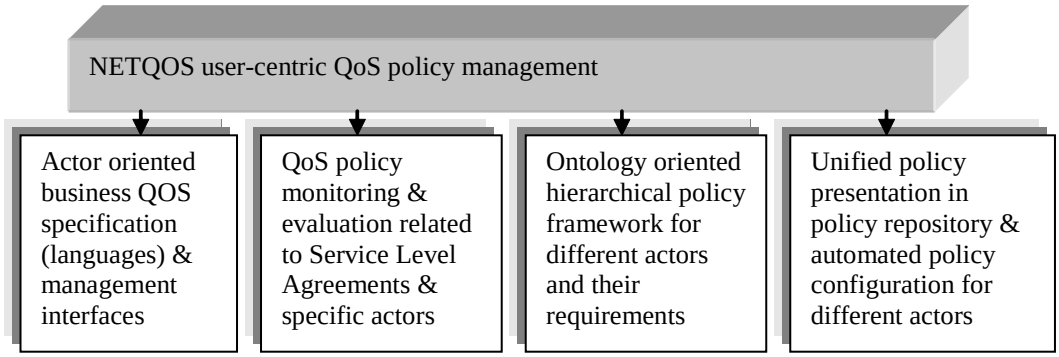

Figure 4: User-Centric QoS Policy Management Support Based on NETQOS Architecture

3. User-Centric QoS Policy Management Based on NETQOS

3.1 NETQOS Policy Management Architecture

In the NETQOS framework [8], QoS policies can be specified by different actors based on their SLAs, in order to select dynamically appropriate QoS guarantees for heterogeneous Internet environment. The NETQOS policies at the business level are entered in the system using ontology and actor oriented policy management interfaces (GUIs) considering the specific QoS requirements of the actors. The QoS policy specification depends on the role, knowledge and expertise of the different actors (ISP operator, end-user and customer).

The QoS policy descriptions related to specific business models, scenarios and particular ontology of the different actors are checked for consistency by the Actor Preference Manager (APM) component and translated into unified intermediate QoS policy presentations, stored in the policy repository. The automated provisioning of the policies of the different actors is based on the unified and ontology driven policy repository.

Based on the unified policy repository and policy access functions for different actors, the system components are able to interact and provide efficiently the automated policy provisioning, which includes dependency analysis of policies of different actors, translation, adaptation and configuration of policies. To support automatically the policy provisioning tasks, the NETQOS system involves interaction of different components:

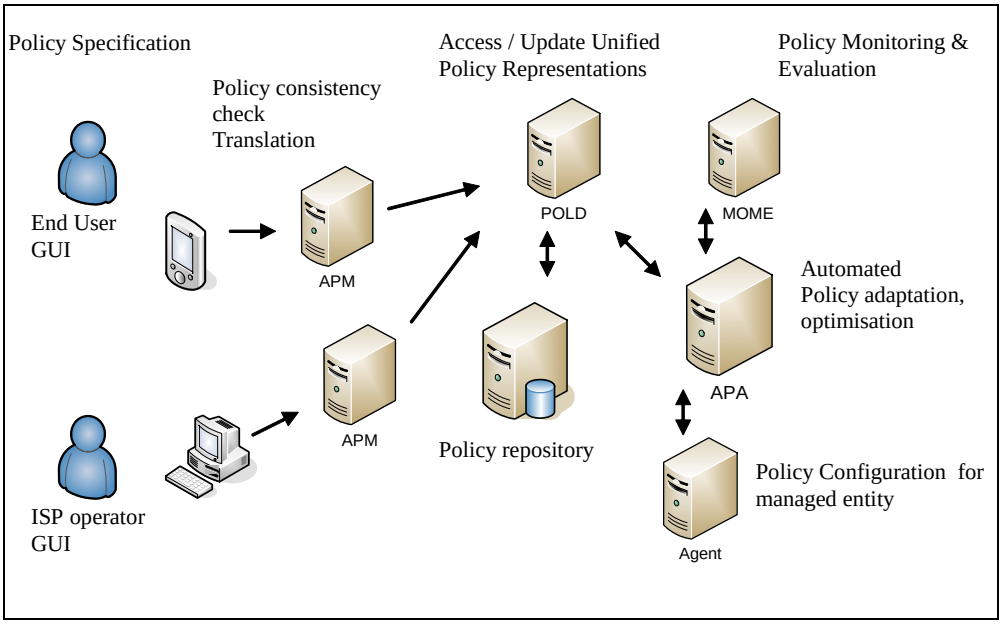

Figure 5: Interaction of Components of NETQOS Policy Management Architecture

The access to the policy repository based on unified policy descriptions is managed by the POLD (policy description) component. POLD functions store the translated business policies of the actors in the repository. The APA (Automated Policy Adapter) uses the POLD facilities to access unified policy presentation of different actors and automatically updates the policies in the repository. There are different possible scenarios for automated policy adaptation, as for instance based on the policy monitoring and evaluation provided by the MoMe (Measurement and Monitoring) component. The MoMe tool can detect specific events based on the policy specification (for instance congestion, overloaded connection) which can trigger temporary or permanently updates 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 optimise the resource usage for all actors.

The APA is also responsible to translate the unified intermediate policies it reads from POLD into technology dependent policies for QoS configuration at the managed devices in the heterogeneous Internet topology. In fig. 5 the Network Agent is used, which configures required network QoS mechanisms dependent on the device characteristics.

3.2 Ontology Oriented Policy Specification

NETQOS uses ontology for description of QoS oriented policy specifications at different abstraction levels related to Service Level Agreements, actor profiles and context characteristics in heterogeneous network environment [8]. Ontology oriented QoS based systems for user oriented services are discussed in different context, for instance [18], [19] and [20]. In NETQOS, the modular ontology approach for policy specification enables:

- A common vocabulary for actor interactions and QoS policy understanding at different abstraction levels;

- Formal policy specifications, consistency check and translation of policies between different abstraction levels;
- Efficient implementation of policy management interfaces, considering the specific GUI requirements of the policy actors and QoS policy management scenarios;
- Design of interoperable and extendable QoS policy management system, which can be used in different contexts, as for instance QoS policy management for mobile users in heterogeneous Internet environment.

Ontology languages, such as OWL (Web Ontology Language [21], and its extension SWRL (A Semantic Rule Language) [22], standardised by W3C, are designed to support ontology descriptions and to translate them to specifications expressed in XML and RDF/XML. Using OWL, the policy parameters and values can be represented based on individuals, properties and classes. The implementation of policy classes is done based on ontology, defining the semantics (restrictions) of the policy parameter values.
In the NETQOS architecture, the ontology oriented approach and OWL language are used to describe policy information related to actors, SLAs, applications and services, QoS, policy events, conditions and actions, measurement and monitoring data, transport parameters and protocols, network capabilities and devices.

3.3 SLA Driven Policy Specification

The NETQOS 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 QoS parameter objectives for actors and specific service class or service degradation options.

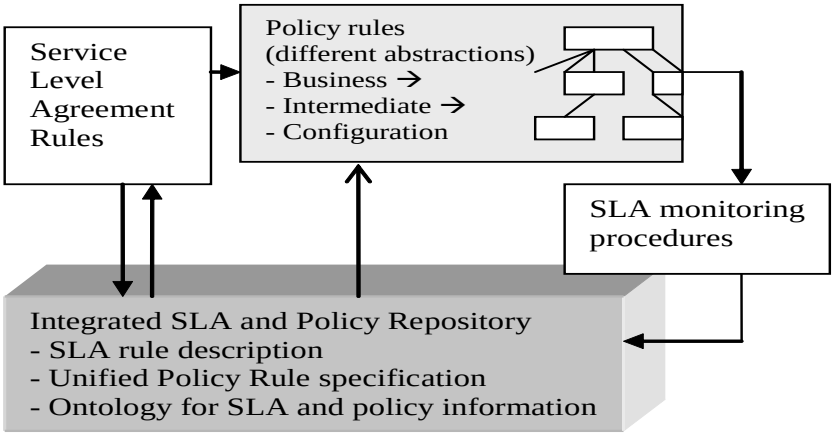

Figure 6: SLA Based Policy Specification and Evaluation

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) [23]. More generic ontology based approaches for formal semantic specification, such as OWL [21] and SWRL [22], can be also used to specify SLAs and map their information to corresponding policy presentations.

In NETQOS, the policies of the specific actors can be related to the SLA objectives based on the ontology descriptions. This allows the integration of the policy and SLA rule repository, in order to simplify the policy consistency check dependent on the SLA restrictions, as well as policy evaluation considering SLA objectives.

4. Scenario for User Centric QoS Policy Management

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 automatically translated in business, intermediate and QoS configuration policies and stored in the policy repository. The considered QoS policy management interface (fig.7) allows the dynamic 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.

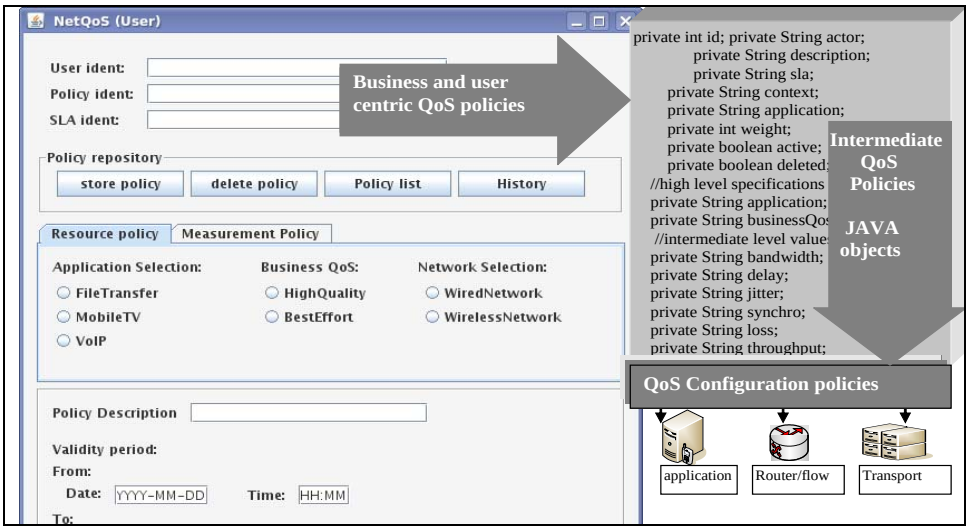

Figure 7: User Centric Policy Management Interface for Business QoS Specification

The user dynamically selects his preferences, such as "high quality", "best effort" and suitable network for the delivery of the communication application. The user's requirements are mapped into business QoS policy specifications, uniquely accessed by a policy identifier, the corresponding SLAs and the actor descriptions. The ontology oriented GUI implementation 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 invoking the POLD component.
Based on the intermediate QoS policy specification and the SLAs, the NETQOS Automated Policy Adapter produces corresponding technology dependent QoS policies describing bandwidth requirements for the user's traffic flows of the particular application. Finally, the Network agent is invoked to configure the technology dependent QoS policies for the user in the heterogeneous environment based on the ISP topology map.

Further function of the user oriented policy management GUI is aimed to study previous QoS policy specifications of the particular user (i.e. obtain policy history) and to consider the automated policy provisioning of different QoS policy specifications.

The user can also use a function to analyse policy dependencies in order to optimise policy parameters. For instance, the user can obtain a list of corresponding policies with recommended parameters for cost efficient communication or enhanced QoS delivery.

5. Conclusion

This paper presented user-centric QoS policy management strategies based on the ontology and actor oriented hierarchical NETQOS policy management framework. The NETQOS benefits for dynamic and automated provisioning of QoS policies of mobile and fixed users in heterogeneous Internet environment include:

- Flexible specification of QoS requirements and objectives considering the actor's knowledge and expertise for mobile and fixed Internet environments;
- Automated policy adaptation and optimisation based on actor dependencies;
- Dynamic planning and optimisation of QoS guarantees in heterogeneous ISP infrastructures based on unified multi-actor QoS policy management;
- Ontology based hierarchical QoS policy framework allowing the specification and consistency check of user-oriented QoS policies, their automated translation, configuration, monitoring and adaptation.

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