A Framework for the Automatic Calculation of Quality of Experience in Telematic Services

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Abstract

This paper presents a framework based on ontologies, rules and mathematical semantic representation standards, for the automatic calculation of the level of quality of service perceived by the customers in telematic services. This automation is achieved by representing and using the mappings between technical quality of service and quality of experience in a knowledge-based framework supported by a mathematical tool. Quality adaptation and control or semantic web services matching are some fields where this approach can be applied.

Keywords

Quality of Experience, Telematic Services, Ontologies, Semantic Web, Rules, OpenMath.

1. Introduction

The user perception of the quality of telematic services is a interesting characteristic for the service providers because it is related to the user satisfaction and helps on preventing customer migration.

However, this quality of user experience (QoE [1]) is difficult to measure as the usual methods to retrieve this information are based on questionnaires (for instance ServQual [2], Mean Opinion Score [3]) and require continuous customer cooperation. Another handicap is the amount of time it takes to select the customers, retrieve their opinions and process them to obtain the level of QoE. It is necessary to develop new methods to allow providers the acquisition of the QoE information in a simpler and quicker way.

The approach of studying quality of service from a technical point of view (QoS) has been widely studied. Some projects (e.g. MUSE [4]) divide the existing services

depending on their characteristics such as elastic/inelastic or interactive/non-interactive and assign QoS classes (such as the defined in G.1010 [5]) to each division. Each one of these classes are related to a set of parameters and thresholds to be controlled. The measurements of these parameters is made using existing tools (such as Netflow [6]). Then, the information is gather through proprietary methods or using RMON [7] (Remote Monitorization) based technologies.

Finding the relationship between these two quality of service domains, QoE and QoS, may help in retrieving the QoE information in an automatic way. Some works have been oriented to describe this mapping (e.g: E-Model [8] in telephony or [9] for video delivery). The definition of these relationships is out of the scope of this paper.

Semantic web technologies, ontologies and rule languages, are open standards that can help on exchanging QoS information and calculating QoE levels. QoS Ontologies define a formalization of the QoS information to make easy the information management. They help on sharing common understanding between people and applications, enable reuse of domain knowledge and separate this kind of knowledge from the operational one [10]. The use of rules provides a way of generating new information depending on the collected data and even act upon the service architecture components in an autonomic computing style.

This paper presents a framework based on ontologies and rules to perform the mapping between QoS and QoE. First, an introduction to quality of experience and quality of service is presented. The application of Semantic Web technologies to the solution of this problem is also discussed. Later, a framework for the automatic calculation of QoE is proposed. Finally, different alternatives for the representation of the relationships between QoS and QoE are defined and compared.

2. QoS, QoE and the Semantic Web

As explained before, the measurement of the technical component of quality of service has been widely studied from a network and application point of view. The metrics used to calculate technical QoS are based on monitoring objective characteristics. The observed characteristics differ between services (or between classes of services). The required data can be collected in an automatic way, using available software.

However, there is a gap between this technical QoS based on objective characteristics and the quality perceived by the users, the quality of experience (QoE), based on subjective parameters. Traditional metrics to calculate QoE come from the Economy field and are based on questionnaires. The use of these metrics makes the data collection task time-consuming and requires manual operation.

The providers are interested in making the QoE acquisition process quick and automatic. This goal can be fulfilled by mapping the technical quality of service to the perceived quality. So, the relationship between both quality facets, sometimes called

utility function, has to be defined for each service.

Once the functions or formulas for the relationship are defined, the information has to be collected and an application can process the information, apply the functions and obtain the results. Traditional approaches are based on a specific development that cope with a particular service.

As services in the Semantic Web can be a composition of other simpler services, it is necessary to perform the QoS to QoE translation using a scalable and flexible framework based on open technologies. Although this framework may be originally tested with a reduced set of services and their quality relationships, it allows the inclusion of new services in an easy way, only including service specific information. This information is composed by the specific technical characteristics (e.g.: delay, throughput, cpu load) and metrics (e.g.: mean delay) of a service and the function that expresses the relationship between these technical characteristics and the QoE.

In the following it will be shown how ontologies contribute to make this scenario feasible. The importance of the ontologies in the QoS field is supported by different research papers that work on the creation of a quality of service ontology (e.g. [11] and its application to use cases (unpublished [12]).

3. Framework for QoE calculation

The proposed solution is based on knowledge-based technology. We opted to use the languages defined in the Semantic Web initiative because our problem have in common with this project the characteristics of distribution and data sharing. We work on the creation of a framework capable of expressing the existing relationships (functions or formulas) between the different domains and translating the quality level between domains. Thus, combining the automatic calculation of the technical QoS level and the inter-domain translation, it is possible to obtain the QoE level automatically. This could be used for QoS adaptation or dynamic service selection.

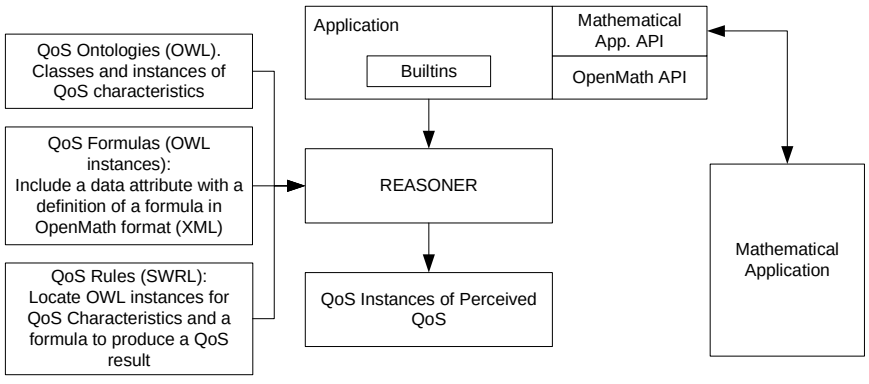

Figure 1: Framework for QoE Calculation

The designed architecture (Figure 1) uses a modification of the quality of service ontology models defined in [11] and instances of these ontologies. Next, the steps to be followed are described.

First, the providers retrieve data from different sources, measuring network and application characteristics by using standard metrics. There are tools that can help on this issue, e.g. Netflow. The output is a set of measures.

Then, these measures are aggregated and used to generate instances of the quality of service ontology. The formalization of the quality concepts clarifies which information is necessary and how it should be used to create the instances. This second point needs a programming interface to allow the automatic publication of the ontology instances from the values previously measured. Some existing projects, such as [13], provide interfaces to handle ontologies, appropriate for this purpose.

Later, a rule language is used to define the relationship, formulas or functions, between the different quality domains. The main problem consists in defining a method of expressing these relationships. If they are defined as analytical functions, several approaches are possible. They are discussed in next section.

Finally, the designed framework, including a reasoner, will use these rules and the instances of the ontology to generate new instances related to the QoE domain providing information about QoE level.

4. Representation of QoS-QoE relationship

There are several approaches for the semantic representation of the relationship between the technical component of quality of service and the quality of experience. An example of the functions to be defined could be the automatic calculation of the R factor (and the Mean Opinion Score) in telephony based on the network parameters.

The first option for the semantic representation issue could be the use of classes, individuals and data properties in the Web Ontology Language (OWL) to symbolize the functions. The applications would be in charge of identifying the individuals to be used in the function, and performing the operations (e.g: addition, subtraction).

The second option to represent the relationship is the use of a rule language such as the Semantic Web Rule Language (SWRL). SWRL allows the definition of rules to work with OWL ontologies and instances. It also includes a set of built-in atoms to write basic mathematical operations, such as sum or power. If the measurement values are available as ontology instances and the formula is defined as a rule, the reasoner can generate the QoE level values automatically. The SWRL rule has to identify the instances corresponding to the measured values (handling OWL instances) and define the mathematical operations between these instances (using built-ins).

There are two main problems. A high number of characteristics will make the rule too long and difficult to understand and manage, even with a simple formula. Complex mathematical operations (such as integrals) are not supported in SWRL.

To overcome these handicaps, a third approach is based on the combination of SWRL rules and a language to represent the semantic of mathematical objects, such as OpenMath [14]. SWRL is used to manage the OWL instances locating those required in the formulas and OpenMath defines the mathematical functions. A binding mechanism is used to identify which instance corresponds with each variable in the function. The callback mechanisms implemented in the reasoners will help on setting up a bridge between mathematical semantics and the Semantic Web world. This solution can be applied to any problem that requires the representation and application of mathematical functions in an ontology scenario.

To use this solution we have taken the following steps:

- Creation of a specific SWRL builtin type (mathext) that states the need of applying a mathematical formula defined in OpenMath to a set of instances.
- Generation of a class (QoSFunction) and a property (hasOM) to hold the OpenMath function. The value of the property is an OpenMath XML expression.
- Use of a existing reasoner (e.g.: Bossam [15]) and interfaces to communicate with a Mathematical tool and generate the results.

We recommend the use of this latter approach due to its flexibility in adding new services. In fact, flexibility is the main advantage when comparing the whole framework with other automatic approaches, such as PESQ (Perceptual Speech Quality Measurement) for the user perception of quality in telephony. Regarding performance, it depends on the reasoner and mathematical tool being selected.

5. Conclusions

This paper has presented a framework for the automatic calculation of QoE based on knowledge-based technology and values of technical QoS parameters. The automation is performed thanks to the formalization of the information and the representation of the relationship between QoS and QoE using rules and mathematical semantics. The addition of a new service is simple as only its particular semantics (characteristics and mathematical functions) have to be included in the system.

Future work is oriented to prove this framework in a more complex scenario. We have decided to apply it to video delivery through multimedia streaming.

ACKNOWLEDGMENT

This work has been partially funded by the Spanish Ministry of Education and Science under the projects VIDEORED (TIC2003-04406) and CASERTEL-NGN

(TSI2005-07306-C02-01).

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