Critical analysis and elaboration of three prevailing approaches to model quality of service

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The service-oriented architecture (SOA) becomes dominant paradigm in the development of web-based systems. The paper critically analyses three prevailing approaches to SOA quality of service (QoS) modelling, namely, SQuaRE based Web Services Quality Model, OASIS Quality Model for Web Services and an ontology based QoS modelling approach proposed by Beanchini and co-authors. The main contribution of this paper is that it highlights both conceptual similarities and differences of the analysed approaches, examines their shortcomings and the reasons for their inability to model QoS adequately in service-oriented enterprise systems context. It also gives arguments for the need to develop a new, holistic QoS modelling approach.

Introduction

Software system is typically thought of in terms of its functionality. However, the functionality does not completely describe the system. In order to specify software system non-functional properties must also be defined. The term *Quality of Service* (QoS) is used to refer to the non-functional properties of a software service. According to (Ludwig, 2003) quality of service is expressed by observable parameters relating to the non-functional properties.

Quality of service (QoS) in service-oriented enterprise information systems is key factor for a number of reasons (Aiello, Giorgini, 2004): 1) autonomous services depend on one another; 2) services can compete one another – a service consumer's decision on a service may be based on its QoS properties; 3) a service provider can offer the same functionality but different qualities, and different qualities of the same service should be declared. However, common consensus on QoS in general is not achieved, as well as on QoS concept in service-oriented enterprises.

For example, the view inherited from computer network community considers QoS in terms of performance and availability of service only. Some researchers assume that any custom characteristic that can be modelled as non-functional service requirement may be considered as a constituent of quality of service (Aiello, Giorgini, 2004). In addition, there are different understandings of the nature of quality in general and different points of view on software quality. A number of new issues of QoS are raised by service-oriented computing, service-oriented architecture (SOA), and service-oriented enterprise systems:

- quality of service parameters should be defined from different stakeholders' perspectives;
- many requestors access services via Internet which is not under control of service owner;
- business processes are supported by composite services, so it is necessary to understand how QoS properties of the constituent services contribute to the overall quality of composite ones.

The first step to solve these issues is to understand and define precisely the concept *quality of SOA service*. The analysis of different understandings of QoS, systematisation and generalisations of these understandings is the necessary prerequisite to get the required result. The next step towards defining service quality should take into account different human roles in different service life cycle phases. These actors are individuals, solve different problems, have diverse knowledge, perceive quality differently, and express different preferences. The notions of views, viewpoints, and perspectives (Leite, 1988) can be employed as basic tools in communicating about service quality. A viewpoint describes from where an actor is looking – a standing or mental position used when observing or specifying quality of service. A perspective is a set of facts observed or modelled from a particular viewpoint and according to a particular aspect. A view is an integration of perspectives.

This paper shows the diversity of points of view on quality of service and critically assesses service quality modelling approaches. Short analysis and evaluation of three prevailing approaches to model quality of service is intended to highlight their similarities and differences, and give special attention to their inability to model QoS adequately in service-oriented enterprise systems context. It also presents reasons for the need of an alternative holistic QoS modelling approach.

The remainder of this paper is organised as follows: section 1 considers web service and SOA service concepts and their similarity, short analysis and evaluation of representative quality of service modelling approaches is presented in section 2. Section 3 provides related works and finally we conclude with a summary and remarks on the state of affairs on the field.

1. Web services vs SOA services

During the past few years "service" and "service oriented architecture" are the most exploited concepts in the domain of enterprise systems engineering. However, these concepts are being interpreted differently in different contexts. The analysis of definitions and classification of services puts some light on this ambiguity.

Categorising services by their visibility public and private services are identified. European Interoperability Framework defines public services as services "developed primarily for direct use by the public administration that created them, or by their direct customers, i.e. businesses and citizens" (EIF, 2010). A public service can be accessed by any potential consumer, a private service has restricted accessibility. In order to access such service it is required to contact the provider's organisation. Categorising services by their business value it is important their relations with business tasks or processes. In addition, any activity depends on the organisation's competencies. For example, (ERL, 2005) makes a distinction between application, business and process services. Such the services, i.e. services

in an enterprise or, to be more precise, in an enterprise information system context, we discuss in this paper. The term "SOA service" is used by many authors to indicate this type of services.

SOA is the architectural style for crafting distributed business applications when the quick response to the endless changes in the business environment is needed. The SOA has several substyles (Tang et al., 2010). One among most popular substyles is web-based SOA. Web-based SOA is SOA that is implemented using web service standards called WS-*. The SOA based on Representation State Transfer (REST) architectural style and enterprise Web 2.0 is another example of SOA substyle. Therefore, web services is a technology used to implement service oriented architecture.

The concept "service" in SOA context can be differently interpreted. OASIS Quality Model for Web Services (Kim, Lee, 2005) defines service as the means by which the needs of a consumer are brought together with the capabilities of a provider. This definition puts emphasis on the interaction over a network (Fig. 1 a). In other words, web service plays role of a standard means of interoperating between different software applications (W3C, 2004).

According to SOA Reference Architecture specification (SOA, 2012) web service is "a mechanism to enable access to one or more capabilities, where the access is provided using a prescribed interface and is exercised consistent with constraints and policies as specified by the service description". It means that web services are used to wrap the distributed components and to implement service providers' interfaces, i.e. service provider is encapsulated to web service

(Fig. 1 b). The purpose of using the capability is to produce the real world effect. So, in this context services and web services can be seen as synonyms, and web service quality models, whose authors use this second web service interpretation, can be also analysed as SOA service quality models.

2. Quality of service modelling approaches: analysis and evaluation

The analysis of various service quality concepts and models showed that there is a big quantity and variety of interpretations of these concepts. Three representative of quality of services modelling approaches are selected and discussed in this paper:

- Web services quality modelling approach proposed in (Abramovicz et al., 2008) stands for the approaches based on the ISO/IEC Software Product Quality Requirements and Evaluation Model (ISO/IEC, 2005).
- Web services quality modelling approach proposed in (OASIS, 2012) stands for the approaches based on the activity-based separation of quality concerns.
- Quality of services modelling approach proposed in (Bianchini et al., 2004) stands for the approaches based on the service ontology (Guo, 2011; Dobson et al., 2005).

The choice of representatives also demonstrates the scheme for classification of QoS models. It expresses different points of view on QoS modelling.
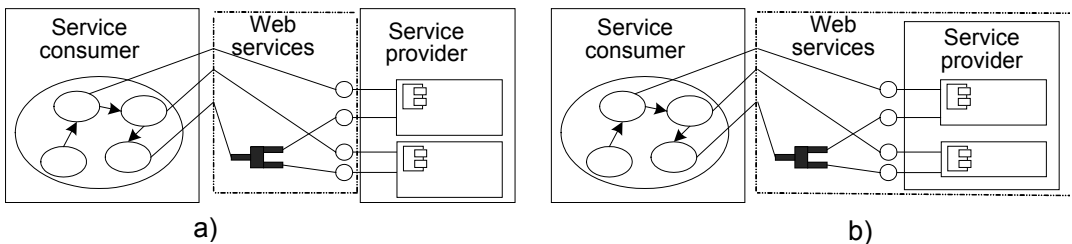

*F i g. 1. **The roles of web services***

The group of researches (Abramovicz et al., 2008), (Abramovicz et al., 2009) suggest that web services quality model should be compatible with traditional software quality model. For this moment, software quality model ISO/IEC 9126 (ISO/IEC, 2001) is widely used, but it is being replaced with ISO/IEC 25010 (SQuaRE) model (ISO/IEC, 2005). The reason for web services and software models compatibility is the following – "definition of quality requirements starts from the same set of requirements both for Web Service and software module" (Abramovicz et al., 2008). In addition, if web service can be replaced by software module then quality requirements for this service should be analogous to the ones of traditional software.

Web services quality model proposed in (Abramovicz et al., 2008) is based on SQuaRE model and consists of three parts: external web service quality, internal web service quality, and web service quality in use. External quality is capability of a web service to provide the effects satisfying needs when this service is used under specific conditions. In other words, external quality characterise "black box" behaviour. Internal quality gives "white box" view to quality. The quality characteristics are the same for both external and internal qualities – security, interoperability, reliability, usability, efficiency, maintainability, and portability. Quality in use defines quality as utility for a specific user to achieve its specific goals in specific context. Quality in use covers usability in use, context in use, safety in use, security in use, support in use, and adaptability in use. External and internal web service qualities are the viewpoints for service provider, while quality in use – of web service consumer.

It should be noted that only the top-level quality characteristics were listed above. Quality model proposed in (Abramovicz et al., 2008) uses three levels – main characteristics can be decomposed to sub-characteristics and those – to quality measures.

In summary, the main shortcoming of this QoS model is that is not enough takes in account the specifics of services. Already (Reeves et al., 1994) pointed out that although services and products share many similarities, they differ in a number of ways: 1) services are intangible, cannot be stocked, and their attributes are difficult to demonstrate (intangibility); 2) services are heterogeneous and it is their fundamental characteristic, because results of service varies from day-to-day or from customer-to-customer and of this reason it is hard to standardise their quality (heterogeneity); 3) services are inseparable, because to a large extent they are simultaneously produced and consumed (inseparability); 4) services are extremely perishable, that is, they have zero inventory, cannot be saved for later use, can be used only once else they perish and once sold, they stand sold and cannot be returned (perishability). In addition, a service is a process rather than a thing and consumer's involvement in the production of many services creates additional quality control difficulties for managers. In research literature, the above-mentioned four service characteristics are usually referred to as IHIP characteristics (Moeller, 2010). Although some criticism exists whether services are really different from goods and whether the IHIP characteristics are characterising services, today, the service concept is operationalised mainly through these characteristics (Edvadsson, 2005). Even more complicated is the question whether or not existing service concepts, including IHIP characteristics and definitions of quality, are applicable to Internet services. Conflicting opinions exist on these issues. For example, (Moeller, 2010) argues that "The characteristics of intangibility, heterogeneity, inseparability, perishability (IHIP) that have been regularly applied to services have been subjected to substantial criticism, as more and more exceptions occur. The reasons for the criticism are twofold. The focus of services marketing has changed and the development of information and communication technology has advanced dramatically."

Edvardsson (2005) and many other researchers advocate also that technology-based services are, in fact, storable, repeatable, often standard-

ised and last, but not least, the service production does not involve any direct interactions with humans. On the other hand, (Hofacker, 2007) states that e-services are less tangible as traditional services, possible, more heterogeneous, taking into account instability of hardware, software and network environment, highly flexible in terms of physical separation between consumer and producer, and can be stored indefinitely by the provider (on server disk) or user. Abramowicz and his colleagues ignore the above-mentioned specific of services as well as service related business issues.

These issues are considered in some other QoS models including OASIS Committee Specification (OASIS, 2005; OASIS, 2012). It points out that web services differ from installation-based software. The differences cause the distinct web service quality model and characteristics. First of all, service consumer and provider as a rule belong to different ownership domains and relationships between their instances can be established ad-hoc. This includes possibility of web client to dynamically change the server. The changes can also be done in real time when quality is not sufficient. Secondly, the quality of web services depends on the run-time environment. Consequently, variation of service quality can occur. Thirdly, service consumer must tolerate some acceptable deviation of required quality because it may be not obtainable.

OASIS' web service quality model consists of three components: quality factors, quality associates, and quality activities (OASIS, 2005). A quality factor is a group of characteristics, which represent web service's properties. A quality associate is the person or organisation (in other words, role) related to web services life cycle stages. The quality activity refers to various actions performed by associates to ensure web services quality and its stability. OASIS Specification emphasis on quality model establishment from the view of service but not product quality. It implies different views of using a service; so, quality can be considered in different layers: user's view layer, interoperability view layer, and management and security view layer (OASIS, 2005).

OASIS (2012) divides web service quality factors* into two groups – business quality group and system quality group. Business quality group enables evaluating the business value of web services, i.e. the economic worth delivered by applying these services on a business (OASIS, 2012). The business value depends on quality subfactors such as price, penalty and incentive, business performance, service recognition, service reputation, and service provider reputation. OASIS Specification notifies that in addition to those factors business benefit, profit and return of investment can be included to this group. System quality group consists of variant quality part and invariant quality part. The values of quality factors of variant quality subgroup can be dynamically varied in run-time, while the values of quality factors of invariant quality subgroup can be determined immediately after the service development process is completed. This subgroup includes interoperability, business processing quality, manageability and security. OASIS (2012) points out that dynamically vary the values of response time, maximum throughput, availability, accessibility, and successability.

The activity-based layered approach to quality model gives good separation of quality concerns. The main shortcoming of OASIS Web Service Model is that it does not consider domain specific nature of some quality characteristics. It should be also noted here, that, first, as a rule more layers gain attention in SOA enterprise context, i.e. model gives poor views on quality. Second, layers are related with each other – the layer may be related directly with any of the layers above or only with the layer below it. However, these two aspects are not discussed in (OASIS, 2005; OASIS, 2012). Thus, there is a need to develop framework that integrates all viewpoints and perspectives on service quality at a higher abstraction level.

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* The concept *quality factor* is broader than *quality attribute* in the other papers; it includes dimensions and measures of the quality.

Domain specific nature of quality characteristics is considered at the top level of QoS model proposed in (Bianchini et al., 2004). The authors argue that ontology-based approach should be used to categorise services. The proposed ontology classifies services on the basis of their functional characteristics enriched with a quality of service model. It provides three abstraction levels – subject categories, abstract services, and concrete services. Concrete services stand for implemented services and can be accessed by service consumer. For each quality characteristic a range of values it can guarantee should be provided. Similar concrete services are grouped into clusters[*]. Abstract service represents the cluster of similar concrete services. Subject categories represent application domains.

The subject categories are organised into *is-a* hierarchies and give the possibility to classify abstract services. In addition, even at the top level (i.e. inside of subject categories) quality characteristics are divided into generic and domain-specific characteristics (Bianchini et al., 2003). The authors propose to use as generic quality characteristics a set of quality parameters provided by the international standard ISO 8402 (part of ISO 9000 standard), which describes quality of any type of service. Examples are reliability, response time, and latency. Examples of domain specific characteristics include payment mode, type of credit card accepted, and legal constraints. So, a domain, a set of admissible values, the measure units, and a set of rules to convert value from one to the other measure form a description set for quality characteristics.

Quality of services characteristics are added to the all three abstraction layers. Quality characteristics in the category layer are associated to each leaf of the defined taxonomies. If an abstract service is associated to more than one subject category, it inherits the union of corresponding quality characteristics sets. A concrete service from the similarity cluster inherits its quality characteristics of corresponding abstract service, and the range of its values is defined by the set of admissible values for the quality characteristics for this abstract service.

The ontology based QoS model enables dynamic definition of quality characteristics because of possibility to specialise the top-level concepts. So, the specifics of particular domain can be made available by defining an abstract service quality and its characteristics. The shortcomings of this model are: 1) it purports to be for service classification only, and 2) like the other above discussed models it ignores quality of experience (QoE) (Ullah et al., 2012).

3. Related works

The reviews of various service quality models are presented in (Seth et al., 2005; Benbernou et al., 2010), the critical analysis of these models can also be found in many papers including (Frankova et al., 2006; Kuyoro et al., 2012). The meta-level analysis of quality models is presented in (Shekhovtsov, 2011).

Seth et al. (2005) examine 19 different service quality models. The review shows that neither some model of service quality is commonly accepted, nor some operational definition of how to measure service quality is commonly approved. Its authors conclude that service quality outcome and measurement depends on the type of service, situation, time, and other factors. In (Benbernou et al., 2010) the review of the main approaches that have been proposed in the literature is presented. This survey also revealed the lack of a well-established and standard QoS model for services. It pointed out that the majority of QoS models for services were proposed by the Web service community and describe only technical attributes. In addition, authors conclude that most of the models lack the richness needed in specifying the QoS of different types of services.

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[*] A hierarchical clustering algorithm is used to form the similarity sets (Bianchini et al., 2004).

To specify the provided or required quality of service some language is necessary. WSDL (W3C, 2001) and its extensions as a rule are used in SOA and web services context. The conceptualisations behind the languages can be quite different (Čaplinskas et al., 2003). Consequently, WSDL is associated with the particular service quality model based on the particular conceptualisation and ontology. The group of researches from University of Trento (Frankova et al., 2006) pay attention to the main idea of such a language – it provides syntax to define terms, which refer to non-functional properties of operations. However, this ties quality of service to its individual operations, not to the service as a whole.

The framework giving base for comparing different software quality models, more exactly – quality conceptualisations* behind these models, is defined in (Shekhovtsov, 2011). The above cited conclusion, that service quality outcome and measurement depends on the type of service, situation, and other aspects, motivates the need for further research to answer question on the applicability of this framework for the comparison of different SOA service models.

Conclusions and remarks

The critical analysis of different approaches to QoS modelling demonstrates that these approaches can roughly be divided into these categories: taxonomy-based, activity-based and ontology-based ones. Although all the analysed approaches are intended to be used in different service life cycle phases and for different purposes, they have some conceptual similarities. They do not take into account differences caused by business-to-business, business-to-consumer and utility service models and completely ignore the QoS specifics in the enterprise systems context. Besides, they are predominantly technology-oriented.

On the other hand, SQuaRE based Web Services Quality Model, OASIS Quality Model for Web Services and an ontology based QoS modelling approach proposed by Beanchini and co-authors conceptualise quality of services quiet differently They model QoS using different quality characteristics, group these characteristics to different categories, and organise them in different ways forming sets, trees, taxonomies, etc. Each of these approaches focuses on different viewpoints and perspectives on service quality and any approach do not relate them to each other. It means that it is not possible to balance conflicting service quality requirements among different stakeholders of an enterprise system applying QoS modelling approach of any mentioned category. For this reason, a holistic modelling approach, for example, view-based approach that uses viewpoints and perspectives to structure QoS models is required. It is a solvable, but enough complicated problem. The development of such approach is the subject of our further research.

Finally, to the best of our knowledge, any of current QoS modelling approaches does not define the meaning of QoS at fundamental, theoretical level. Generally they are ad hoc ones. So, further research on this subject is required. The present paper gives deeper understanding of this subject and can be considered as a step towards this goal.

Acknowledgments

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* In this paper a conceptualisation of quality is thought of as "representation of the system quality on the same level of abstraction as the conceptual model of the functionality of this system" (Shekhovtsov, 2011).

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TRIJŲ DOMINUOJANČIŲ PASLAUGŲ KOKYBĖS MODELIAVIMO BŪDŲ KRITINĖ ANALIZĖ IR VERTINIMAS

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Santrauka

Paslaugų stiliaus architektūra tampa vyraujančia saityno paslaugomis grindžiamų sistemų kūrimo paradigma. Šiame straipsnyje pateikiama trijų dominuojančių paslaugų kokybės modeliavimo būdų: SQuaRE grindžiamo saityno paslaugų kokybės modelio, OASIS sudaryto saityno paslaugų kokybės modelio ir ontologija grindžiamo paslaugų kokybės modeliavimo būdo, pasiūlyto Beanchini su bendraautoriais, kritinė analizė. Pagrindinis darbo rezultatas yra straipsnyje parodomi analizuojamų būdų koncepciniai panašumai ir skirtumai, nagrinėjami trūkumai ir priežastys, neleidžiančios juos taikant adekvačiai modeliuoti paslaugų kokybės paslaugų stiliaus architektūros įmonių sistemose. Taip pat pateikiami argumentai, kad reikia sukurti naują, holistinį, paslaugų kokybės modeliavimo būdą.