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MODEL OF WEB SERVICES QUALITY CRITERIA HIERARHY

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Internet services technologies offer advanced solutions for creating distributed business processes and applications. Nowadays, the number of Internet services continues to grow constantly. Consumers of Internet services are faced with the problem of selecting from services with the same or similar functionality, exactly the service that suits them best according to a set of criteria, for instance, cost, response time, throughput, security, reliability. Such criteria of the Web services quality are named non-functional characteristics of services or Quality of Service (QoS). Depending on the domain and the user categories and on the context of service usage the service may have many specific properties and QoS characteristics. There are many standards and specifications for the quality of Web services. Despite that, the researchers, developers, and customers often understand QoS differently. They can reduce or expand the list and even the meanings of the quality characteristics of Web services. The aim of this paper is to develop a model of criteria for the quality of Web services, which could take various aspects of the impact on the quality of Web services into account. In this paper, the specifications and standards of organizations such as OASIS, ISO/IEC and OMG was considered. The information retrieval was carried out in international citation databases such as Scopus and Web of Science. From the standards reviewed and relevant research papers, quality characteristics and criteria were selected to develop hierarchical quality models. The model for synthesizing collections of Web service QoS characteristics based on QoS meta-model standard of Object Management Group was proposed. As the result of study, the model based on the analysis of existing standards, scientific studies and reviews devoted to the study and classification of QoS characteristics and attributes of Web services was developed. The model can be useful when selecting Web service for direct applying, building composite Web and cloud services, and creating systems based on Service Oriented Architecture and the Internet of Things.

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Ключові слова: *якість сервісу, вебсервіс, критерії, модель, класифікація.*

Технології інтернет-сервісів пропонують передові рішення для створення розподілених бізнес-процесів та додатків. У наш час кількість інтернет-сервісів продовжує постійно зростати. Перед споживачами інтернет-сервісів постає проблема вибору із сервісів з однаковою або подібною функціональністю саме того сервісу, який їм найбільше підходить за набором критеріїв, наприклад, вартість, час відгуку, пропускна здатність, безпека, надійність. Такі критерії якості вебсервісів називають нефункціональними характеристиками сервісів або якістю сервісу (Quality of Service, QoS). Залежно від домену та категорій користувачів, а також контексту використання сервісу вебсервіс може мати багато специфічних властивостей та характеристик якості. Є багато стандартів та специфікацій якості вебсервісів. Незважаючи на це, дослідники, розробники та замовники часто по-різному розуміють якість вебсервісів. Вони можуть зменшити або розширити перелік і навіть значення характеристик якості вебсервісів. Метою цієї роботи є розроблення моделі критеріїв якості вебсервісів, яка могла б ураховувати різні аспекти впливу на якість вебсервісів. У цій роботі розглянуто специфікації та стандарти таких організацій, як OASIS, ISO/IEC та OMG. Здійснено пошук інформації у наукометричних базах даних, таких як Scopus та Web of Science. Із розглянутих стандартів та відповідних наукових робіт обрано характеристики якості та критерії для розроблення ієрархічних моделей якості. На основі стандарту метамоделі QoS від Object Management Group запропоновано модель для синтезу колекцій характеристик вебсервісу QoS. У результаті дослідження розроблено модель, засновану на аналізі наявних стандартів, наукових досліджень та оглядів, присвячених вивченню та класифікації характеристик якості та атрибутів якості вебсервісів. Ця модель може бути корисною для вибору вебсервісу з метою безпосереднього застосування, побудови композитних вебсервісів та хмарних сервісів, створення систем на основі сервіс-орієнтованої архітектури та інтернету речей.

Introduction. Progress does not stand still, and with the development of the Internet, applications with a monolithic architecture began to be replaced by applications with a distributed architecture. Service Oriented Architecture (SOA) refers to such architectures, and its main components are services [1].

Internet services are used in all spheres of human life. Every day the Internet resources provide diverse services: information services, search services, banking services, ticket booking services, services of transport companies, parcel tracking services, document sharing services, remote equipment management services, etc. By accessing the Internet through devices (computers, tablets, smartphones, i.e. desktop and mobile), there are possible to use many kinds of services such as Web services, Grid services, cloud services, the Internet of Things (IoT) services, etc.

There are a huge number of services on the Internet with the same functionality. Therefore, the problem of selecting a service with needed functionality arises, but with the quality characteristics that satisfy his quality requirements [2].

For over 20 years, researches have been carried out on the quality of Internet services. Publication statistics for scientific papers in international citation databases such as Scopus and Web of Science, and in digital databases such as ACM Digital Library and IEEE Xplore demonstrate this. International standards organizations and consortia such as W3C, The Open Group, ISO/IEC [3; 4; 5], OASIS [6; 7], OMG [8] have developed and continue to work on standards and specifications that define the quality of services at all stages of life cycle of services. The quality of communications of Internet services at the world level is supported by the recommendations and regulatory policies of the Telecommunication Standardization Sector of ITU [9; 10; 11].

The aim of this paper is to develop a model of criteria for the quality of Web services, which could take into account various aspects of the impact on the quality of Web services. The object of the research is the characteristics and attributes of the quality of Web services.

To achieve the research goal, the criteria and attributes for the quality of Web services need to be defined, the categories of users and other factors influencing the quality characteristics of Web services, and to develop a hierarchy of Web services quality characteristics.

Literature Review. In the last decade, SOA has received increasing attention [1; 12]. Many studies have highlighted the benefits of employing SOA for new technologies such as IoT [13; 14; 15], cloud computing [16; 17] and microservices [18]. This is because SOA offers flexible integration and service reuse through its service-based modular architecture.

Service providers offer a wide variety of simple, complex and composite Web services to integrate into business processes [19; 20]. The consumer faces the problem of selection a Web service from Web services with the same functionality, one that most satisfies the consumer in terms of the non-functional characteristics of the service [21]. Quality of Service (QoS) represents a set of quality criteria, e.g., cost, reliability, availability, security, etc [12; 22; 23].

Many standards, specifications and publications by researchers are devoted to the quality of Web services that are software kind. The ISO/IEC 9126 [3] and ISO/IEC 25010 [4] standards include descriptions of the non-functional properties of traditional software applications, but are not adapted for Web services. The OASIS quality model for Web services [5; 7] defines characteristics and attributes of the Web services but does not consider aggregation functions [2]. Many researchers, when developing their own quality model of Web services, take into account some aspects of software quality standards [12; 24; 25; 26; 27]. Although quality standards exist, studies of QoS attributes and their classifications are ongoing [23; 24; 25; 28].

ISO/IEC 25010:2011 provides the quality models for systems and software. The standard pays attention that in most cases it is practically not applicable to define or measure quality when used for all possible scenarios of user tasks. The relative importance of quality characteristics depends on the high-level goals and project objectives. In this regard, before being used to isolate those characteristics and subcharacteristics from the requirements that are most important, the quality model must be appropriately adapted, and resources must be allocated between different types of indicators depending on the goals of the stakeholders and the goals of the product [4]. The hierarchical structure of characteristics and attributes of quality model of this standard is shown in fig. 1.

One of the classification of Web service QoS elements from the article [28] is compiled and shown in fig. 2.

OASIS in 2012 presented standard [5] (Web Services Quality Factors Version 1.0) and specified Web services quality factors conceptually along with definition and explanation of sub-factors. The hierarchical structure of characteristics and attributes of quality model of this standard is shown in fig. 3.

Despite the existing standard [5], the characteristics (factors) of the quality of Web services were determined and described in the works [12; 23; 24; 25]. The hierarchical structure of characteristics and attributes of quality model [23] is shown in fig. 4.

The authors [25] conducted a study of the quality models of software and Web services and compiled a vocabulary of non-functional requirements of business processes and Web services. The standard [4] was used as the main reference document. This

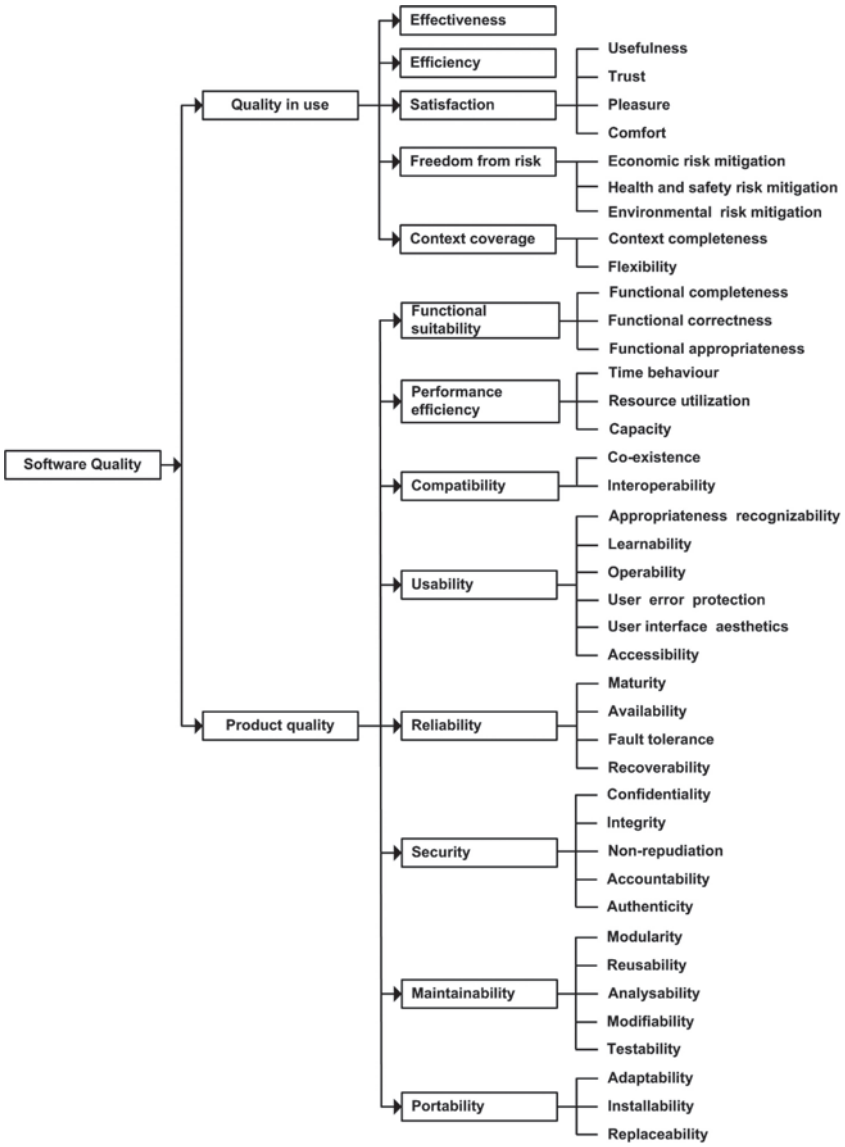


Fig. 1. System and software quality model (compiled from [4])

vocabulary contains 93 terms and is the first step towards simplifying the decomposition of non-functional requirements from process to service level, which is an important task in the context of business process automation through service composition.

Methods. In this paper, the research methods were used: information search, statistical analysis or data analysis, empirical analysis, modelling.

This study designed to answer the following research questions.

RQ1. What is the relevance of research on the quality of Internet services?

RQ2. How the existing quality standards influence the relevant research work?

RQ3. What characteristics and attributes of the quality of Web services are defined in the publications for review?

RQ4. What hierarchical structures of characteristics and attributes of quality of Web services are developed and proposed?

The model for further synthesis of qualitative characteristics collections presented in the UML class diagram (fig. 5). This diagram reproduces a piece of the QoS metamodel from the OMG standard [8], supplemented by two classes: *Collection* and *Aspect*. The class *Collection* is intended to model the structure of QoS criteria, which can define the target bundle and associations of QoS criteria. The class *Aspect* models such aspects as the type of Web service users, domain, location, scale, life cycle stage of Web service, etc. Class *Aspect* can specify the QoS characteristics usage context (e.g. running in real time or under critical condition) and constraints (e.g. range of values).

The conducted research consists of the following steps.

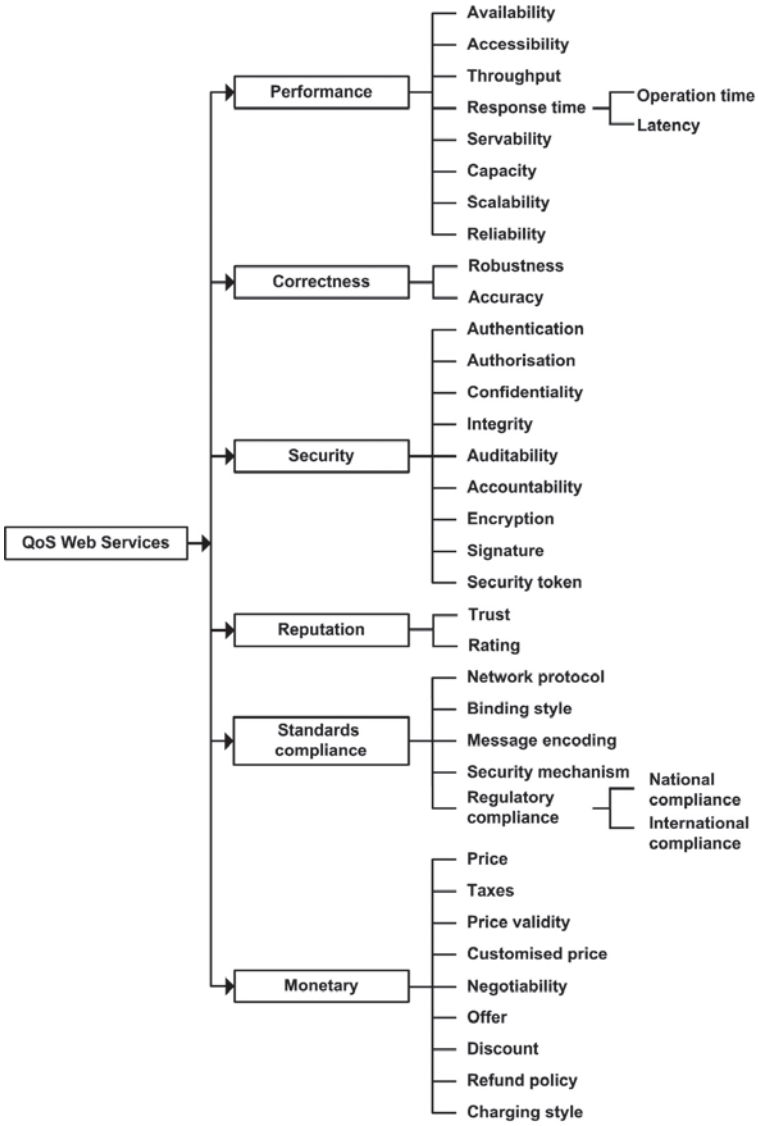


Fig. 2. QoS attributes and categories of Web Service (compiled from [28])

The international citation databases as data sources for searching information about publications were selected: Scopus (https://www.scopus.com) and Web of Science (https://www.webofknowledge.com).

The search query was compiled using keywords and Boolean expressions. The combination of the keywords "quality" and "web (grid/cloud/IoT) services" was applied. The search by publication was limited: the date from 2000 to 2019; and the field of scientific research was computer science; and the type of publications was the article, conference proceedings, reviews; and the language of publications was English. The statistics for graphing were received.

The search query was compiled using with combination of keywords "quality" and "web services" (or "software"). The next request was made for the characteristics and attributes of the quality of Web services. The statistics for analysis were collected. The relevant papers that described the characteristics and attributes of the quality of Web services were selected. The hierarchical structures of characteristics and attributes of quality of Web services have been depicted.

Results. Analysis of statistical data showed that research on the quality of Internet services is relevant (fig. 6). Also, the graphs indicated the growth of interest in the quality of cloud and IoT services. In addition, more research publications were found in Scopus. Therefore, further research was carried out in this database.

Citation analysis showed that the quality standards were little used in the relevant works ([4] in 650 citing publications, [6] in 9). That was less than 2% of the number of these publications.

The characteristics and attributes of the quality of Web services from the standards and relevant

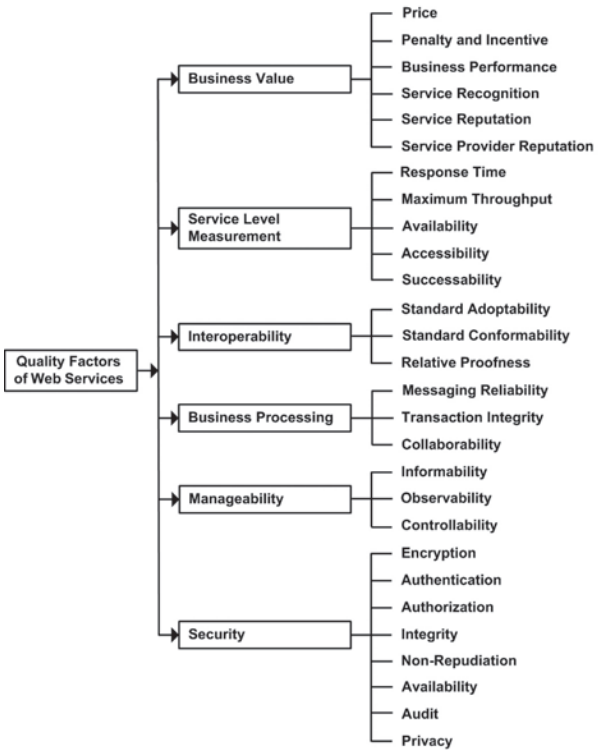


Fig. 3. Web services quality model (compiled from [5])

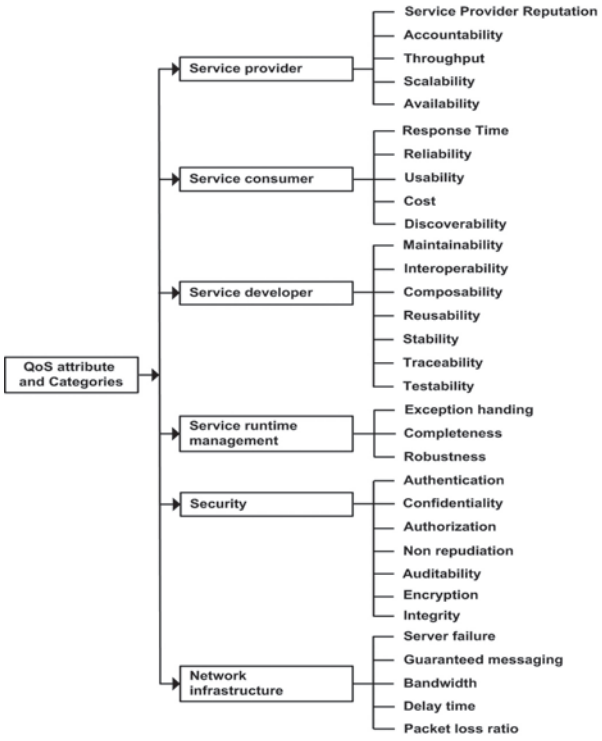


Fig. 4. QoS attributes and categories of Web Service (from [23])

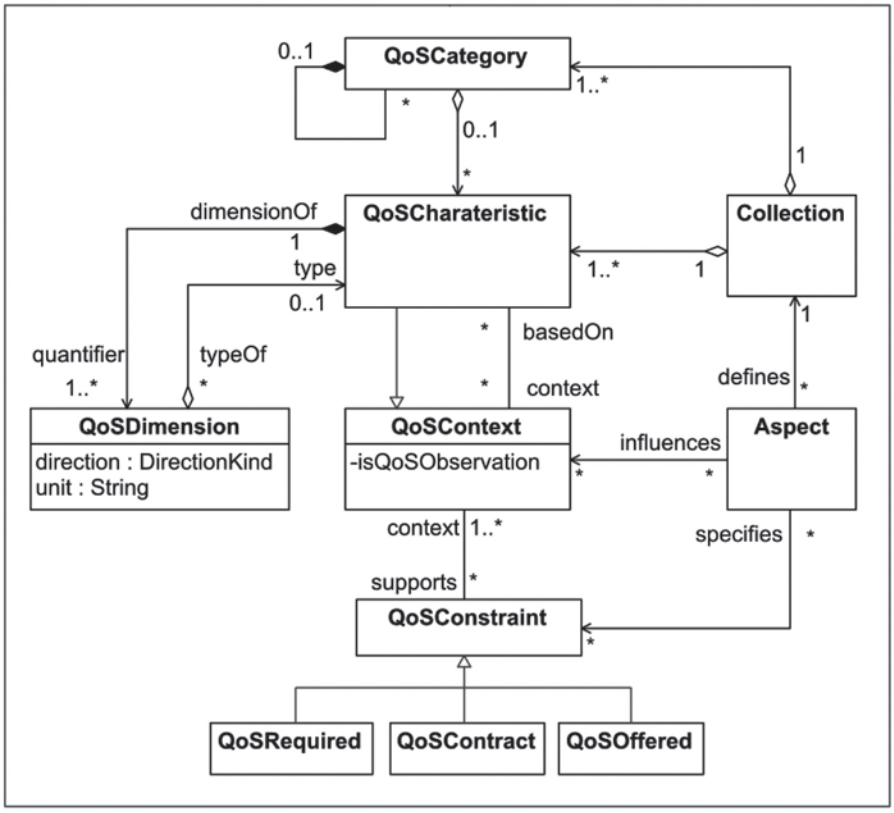
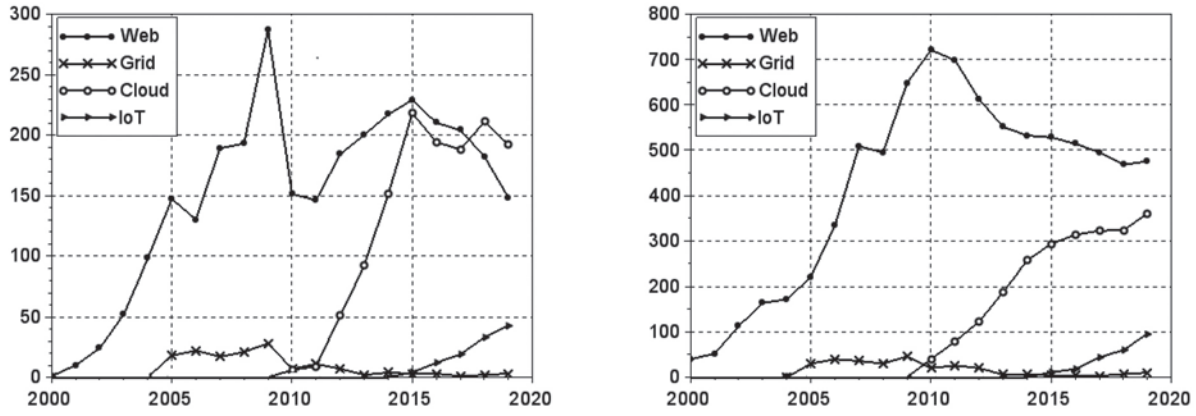


Fig. 5. Model for synthesis of QoS characteristics collections



a) WoS *b) Scopus*

Fig. 6. Number of research papers on the topic quality of services in database

works were compiled and analyzed. The hierarchical structure of characteristics and attributes of quality of Web services were built (fig. 1–4).

Web services quality model (from [5], fig. 3) of the hierarchical structure of characteristics and attributes of quality of Web services were modified for further research (fig. 7).

Discussion. In this paper, a comparison of hierarchical representations of quality criteria models for systems, software applications and Internet services was performed. Such quality criteria are proposed in existing standards and discussed in numerous publications. A comparative analysis showed that there is no generally accepted approach to the presentation and interpretation of quality criteria in the IT community. Apparently, the reason for this is a very wide range of applications and a wide range of stakeholders in software and Internet services. The analysis of relevant publications shows that the process of selecting Web services based on quality characteristics remains relevant in the practical selection and use of Web services. Most likely, research on quality models of Web services will continue for a long time. This is due to unresolved problems in the development and use of Web services, in particular, the automation of the creation of composite Web services, security, and the absence of metrics for some criteria. Also, one of the unsolved problems is the lack of a generally accepted approach to declaring quality criteria in Web service artifacts, such as describing a Web service using WSDL-files and messages using SOAP, Rest, and other protocols. These issues can be partially addressed by revising existing standards [6; 8] and developing new standards on Web service quality.

The main results achieved in the study are as follow. It was revealed that, despite the growth in the number of publications devoted to quality

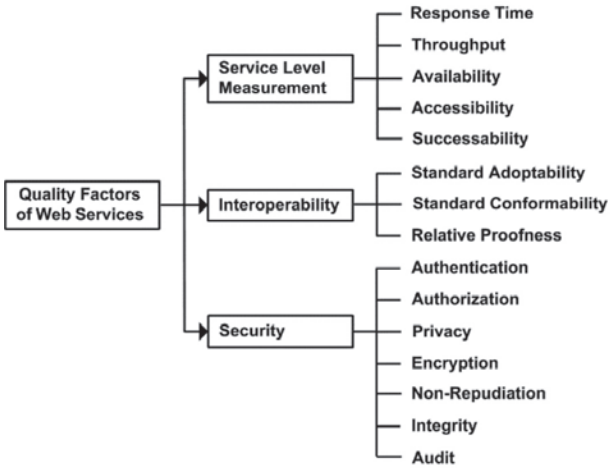


Fig. 7. Modified Web services quality model

models of Web services, they do not always use the recommendations of existing standards. This fact may indicate the need to develop new standards. A modified model of the quality of Web services was proposed (Fig. 5). In this model, the need to take into account aspects (a type of user, domain, etc.) was explicitly indicated. This ability was realized through the introduction of the Aspect, Collection classes, as well as associations with other elements of the existing OMG model [8]. The hierarchy of the minimum necessary collection of quality criteria (Fig. 7) was compiled on the basis of the OASIS standard [6] and will be used to develop methods for ranking Web services based on quality criteria. The statistical analysis of publications devoted to models of the quality of Internet services was performed. It showed that the issues of modelling the quality of Web services and cloud services continue to be relevant, and interest in the quality of IoT services is growing.

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