QoS Attributes of Web Services: A Systematic Review and Classification

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***Abstract*—Up until now, there have been several reviews of QoS attributes of web service from research papers published during 1997- Feb 2014. We found those reviews lack of robust review procedure and purposeful classification. This study offers a systematic review and a new classification of QoS attribute of web service. Our Systematic review shows a clear understanding of the scope, rationale and principles used in construction of the review. The main method of systematic review was done according an established protocol in 6 steps based on 3 research questions grouping from 1,281 papers. According to this systematic review, we found a new valuable classification of QoS web service scenario. Our classification puts each QoS attribute into single category to be used by all stakeholders. By this method, we used only 6 non-overlapping categories; meanwhile, the traditional methods used at least 9 categories. Furthermore, we also discusses the uses of information about QoS attributes in service discover and design context.**

***Index Terms*—QoS, QoS attributes, QoS classification, web service**

I. Introduction

Web service is a representation technology of Service Oriented Architecture (SOA). Web services rely on networking infrastructure. Web service partners–provider, consumer, and developer–search service registry for web service identification and location. Service registry is a part of web service's traditional model [1], as shown in Fig. 1.

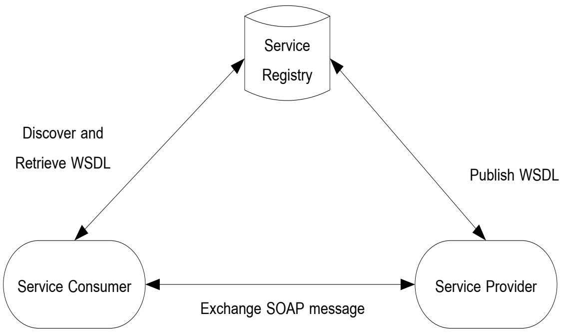

Figure 1. Web service's traditional model.

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A provider is an organization that provides a web service which is developed by a developer who may work for the organization or work as an external team of specialists. A provider registers a web service with a service registry that stores the location of the web service. A provider calls up a web service by using web service description language (WSDL). A provider also needs to provide the necessary infrastructures: network and server infrastructures. Network infrastructure includes equipment for switching and load balancing. Server infrastructure includes storage for web services and shared resources of database server and web server [2].

A consumer is an organization that wants to use a web service. A consumer finds a desired web service in a service registry. When it is found, the consumer sends a request for that web service to the provider, using WSDL language.

Web services are composed of functional and non-functional attributes. The non-functional attributes are referred to as Quality of Service (QoS). QoS is defined in [3], adapting from the definition of quality in ISO 8402, as a set of non-functional attributes of the entities used in the path from a web service repository to the consumer who relies on the web service' ability to satisfy its stated or implied needs in an end-to-end fashion. Some examples of QoS attributes are performance, reliability, security, availability, usability, discoverability, adaptability, and composability [4]-[6].

A QoS attribute of web service may have a metric for quantification that can be used to assess the service's performance. This metric is specified in the web service contract between service partners. Measure or metric in software engineering is explained in [7] as follows: "Measure provides a quantitative indication of the extent, amount, dimensions, capacity, or size of some attributes of a product or process."

The increasing uses of web services in business operation of a growing number of companies make QoS attributes and their metrics ever more important. In our review, we offer a clear understanding of the scope, rationale, and principles used in constructing the review and anew classification that provides non-overlapping categories; all of these were not included in previous reviews.

The content of this paper is divided into 5 sections. Following this introduction section, section 2 describes

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review methodology; section 3 presents 9 traditional categories of QoS attributes; section 4 presents our 6-category classification of QoS attributes, the classified attributes, and their metrics; and lastly, section 5 concludes the paper.

II. Review Methodology

Systematic review is the distinctive research methodology of this study. To date, there are several reviews of QoS attributes, but they were not done systematically. A systematic review is a process of identifying, evaluating, and interpreting all available research works relevant to a particular research question, or topic area, or phenomenon of interest [8], [9].

A systematic review functions as a source of information where researchers can find an overview of the accumulated research works on a particular subject, interesting points related to that subject, and detailed information on that subject. A systematic review can be in the form of narration or comparison with an aim to enable further research works related to the subject. It is a primary source of information that researchers consult first when they start an investigation [10].

Our systematic review procedure strictly follows the procedure reported in references [8], [9]. The steps of the procedure are the following: 1) research question, 2) data source, 3) search strategy, 4) study selection, 5) data extraction, and 6) data synthesis. The first 4 steps involve setting the scope and motivation of the study, and the last 2 steps involve reporting the results and conclusion, as shown in Fig. 2. These steps are explained below.

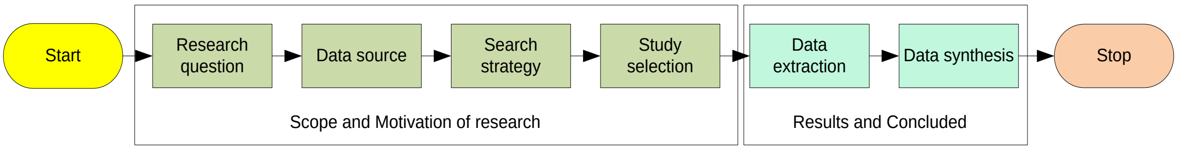

Figure 2. Systematic review protocol.

1. The step ‘research question’ is about forming questions that limit the scope of the study to the topic areas that are the focus of the review. For this study, our questions were the following:

i) “What are the QoS attributes of web services?”

ii) “How to group attributes into useful categories from a multi-stakeholders’ point of view?”

iii) “What are the metrics of these attributes?”

2. The step ‘data source’ is about specifying the sources of information. In this study, we used the 5 following data sources: i) Google Scholar (http://scholar.google.co.th); ii) IEEE-Xplore (http://ieeexplore.ieee.org/Xplore/home.jsp); iii) ACM Digital Library (http://al.acm.org/dl.cfm); iv) Springer Link (http://www.link.springer.com); and v) Science direct (http://sciencedirect.com). These sources are readily accessible data sources of computer technology.

3. The step ‘search strategy’ is about setting up search conditions within the scope of the research questions. In this study, our primary search condition was to search for 2 keywords, QoS and SOA, related by Boolean AND, and our secondary search condition was to search for synonyms of these 2 keywords, related by Boolean OR, as shown in Fig. 3.

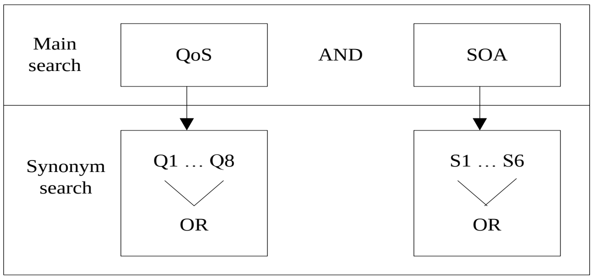

Figure 3. Search strategy concept.

Q1..Q8 and S1..S6 are synonyms of QoS and SOA respectively. Table I shows these synonyms.

TABLE I. Search Strategy Details

Main search	QoS	SOA
Synonyms search	-qos attributes -qos metrics -qos characteristics -qos classification -qos requirement -qos categorization -qos measurement	-Service oriented architecture -Web service -Service engineering -Service centric -Service oriented computing - Web service characteristics

4. The step ‘study selection’ is about setting up selection criteria to exclude papers outside the scope of the study. Filtering selections under these criteria is done in 3 stages: 1. scope; 2.data quality; and 3. inclusion and exclusion. Each stage uses a different set of criteria, described in Table II.

TABLE II. Selection Criteria

Phase	Criteria	Description
Scope	-Title -Abstract -Year	Filtering out by irrelevant title, abstract, and year of publication
Data Quality	-Peer reviews	Filtering out by absence of peer review
Inclusion and Exclusion	-Inclusion criteria -Exclusion criteria	Filtering out according to our inclusion and exclusion criteria concerning the scope

Filtering out by inclusion and exclusion criteria includes consideration of data quality, scope, and presentation. For example, a piece of information to be included may need to have already been reviewed by peers, to be directly related to the research questions, and to be presented exclusively in English. These criteria are described in Table III.

TABLE III. INCLUSION AND EXCLUSION CRITERIA

Inclusion	Exclusion
1. The paper has been reviewed by peers, demonstrating a degree of reliability by having been accepted by the board of reviewers of the journal or the conference.	1. The paper has not been reviewed by peers, so its information may not be reliable.
2. The paper must offer information directly pertaining to QoS attribute of web service or web service technology. These include web services for mobile and cloud computing.	2. The paper does not offer information directly pertaining to QoS attribute of web service or web service technology. Hence, it is outside the scope of our review.
3. The paper must be published in English because the language is most widely accessible throughout the world.	3. The paper was not published in English, and hence, not accessible to a lot of people.

5. The step 'data extraction' is about filtering and grouping information into relevant or irrelevant information according to the criteria specified in the 'study selection'.

6. The step 'data synthesis' is about composing the relevant information into an unbiased academic narration or comparison.

From our initial search of 2 keywords, QoS and SOA, we found 1,281 papers. These papers were uploaded to the following link: http://goo.gl/QptMB for anyone interested to download. Using our systematic review protocol, these 1,281 papers were filtered down to 80 relevant papers of good data quality. Some of these 80 papers were excluded further by using our inclusion and exclusion criteria down to 36 papers that fit the scope of our review.

III. TRADITIONAL CATEGORIES OF QOS

Studies on QoS attributes and their classification began in 1997, and papers about them were published up to February 2014, as shown in Fig. 4.

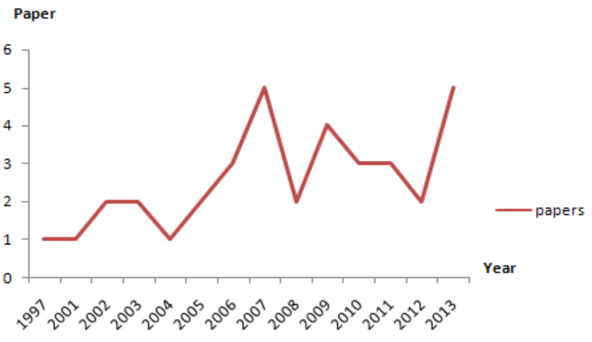

Figure 4. Number of research papers on QoS attributes.

From our review of the literature, we found 9 traditional QoS attribute categories: developer, consumer, provider, unique features of SOA, domain related, measureable and evaluation, multi-perspective, composition, and business and system viewpoints, as shown in Table IV. A particular attribute might be categorized into more than one category. For example, cost or service price was under both categories of provider and consumer. It is under the provider category because a provider considers cost (to the consumer) as its income, reflecting the costs of provision and administration of service resources that meet the need of a consumer. At the same time, it is under the consumer category because it is the price a consumer has to pay to the provider for a service, based on their mutual agreement. Another example is the security attribute. Security attribute appears both in the traditional provider and consumer categories, as shown in Table IV.

The following are meanings of each of these traditional categories. However, due to limited space, in-depth information about each attribute was not included. It can be found in the corresponding references in Table IV.

'Developer' means a developer of web service who may create a totally new service or extend a previously developed service. In references [4], [11], [12], attributes related to both kinds of service development are discussed, as well as those related to maintenance of service to meet an agreed-upon specification. For example, Reusability means the extent to which a previously developed web service can be reused after a thorough analysis of its software components and software documents such as testing documents, design documents, and system documents. Good service reusability helps reduce cost and time of a new development, [13], [14]. According to [15], to determine reusability, all of the codes have to be considered regarding the following strategy management issues: 1) technology transfer, 2) sustenance of reused program, 3) reuse and corporate strategy, 4) organization issue, and 5) process focus. On the other hand, according to [16], reusability is determined by 4 technical features: readability, publicity, coverage of variability, and commonality as follows: Reusability= (Readability value + Publicity value + Coverage of variability + Commonability feature value). Stability refers to the ability of a web service to continue to operate without errors after a modification of its interface or function, [17] and [18]. Stability can be subdivided into service interface stability and method signature stability [17]. They are affected by an addition of a new function, an update, a code refactoring, and an internal change as well as anew user requirement. Stability can be determined by the number of emerged adverse impacts on the system after a service modification, as follows: Stability= (Number of emerged adverse impacts in the system after modification/Total number of modifications made) [18]. And others attributes are such as maintainability, reusability, conformance, security, reliable messaging, transaction, and accounting.

TABLE IV. CATEGORIES AND QOS ATTRIBUTES OF WEB SERVICE

Categories	QoS attributes	Ref .
1.Service Developer	Maintainability, Reusability, Conformance, Security, Reliable Messaging, Transaction, Accounting, Availability, Response time	[4],[11], [12],[53], [54],[55]
2.Unique feature of SOA	Availability, Reliability, Performance, Usability, Discoverability, Adaptability, Composability	[5],[12], [55],[56]
3.Service Provider	.Availability, Reputation, Security, Discoverability, Accountability, Interoperability, Throughput, Performance, Dependability, Price, Reputation, Security, Response time, Capacity, Robustness, Exception Handling, Transaction Integrity, Regulatory, Cost, Support standard, Stability,Completeness, Reliability, Time out, Exception duration, Penalty rate, Compensation rate, Scalability, Resource utilization, Dynamic Discoverability, Dynamic Adaptability, Dynamic Composability	[4],[6], [7],[24], [25],[26], [27],[28], [29],[55], [57], [58], [59],[60]
4.Service Consumer	Price, Response time, Reputation, Successability, Throughput, Availability, Reliability, Latency, Accuracy, Availability, Scalability, Resource utilization, Security, Usability, Composability, Robustness,Security	[4],5], [6],[19], [20],[23], [25],[26], [27],[28], [29],[61], [62],[63], [65]
5.Domain related	Performance, Availability, Reliability, Failure-semantic, Robustness, Accessibility, Scalability, Capacity, Continuous Availability, Transaction support, Security, Configuration Management, Network and Infrastructure, Routes set, Detail level, Accuracy, Completeness, Validity, Timeliness, Coverage, Correctness, Accuracy, Precision, Input output parameters, Efficiency, Availability Consistency, Load Management	[3],[33], [34],[66]
6.Measurable and Evaluation	Availability, Accessibility, Successability, Response time, Throughput, Security, Interoperability, Management, Service Price, Service Suitability, Service Effect, Service Brand Value, Scalability, Reliability, Composability, Efficiency, Reusability, Adaptability, ,Measure attribute, Estimate attribute, Computed attribute	[7],[32], [42],[65], [67],[68]
7.Multi-perspectives	Performance, Security, Relative importance	[37],[45]
8.Composition	Response time, Throughput, Scalability, Capacity, Availability, Reliability, Security, Reliable message, Integrity, Interoperability, Execution Cost, Reputation, Execution duration	[36],[40], [69],[70]
9.Business and System	Business values, Service Level Management, Interoperability, Business Processing, Manageability	[21],[38], [35],[39]

‘Consumer’ means a consumer of web service who may have specified its need for the service. In references [4]-[6], [19], [20], attributes related to service price and performance are discussed such as price, throughput, usability, and utilization. For Example, Usability means the ease of users’ understanding, learning, and using a web service [4], [21]. Usability is described in ISO-9241-10 [22] as the extent to which a product can be used by a specified user to achieve a specified goal effectively, efficiently, and satisfactorily in the user’s specified context. According to the descriptions in [4], [21], [22], attributes of usability can be grouped into 2 groups: understandability and configurability, also discussed in [23]. Usability of a web service can be determined by the users’ experiences of that web service [6]. A survey [22] questioning several features of web service—quality of information, responsiveness, assurance, controllability, navigation, integration of communication, and reliability—shows that the usability of a web service depends mostly on the users’ satisfaction. Besides the studies mentioned, another study, [5], proposed measuring usability from the syntactic completeness of a service interface and the well-described semantic elements in WSDL.

‘Provider’ means a provider of system resources for readily available web service. In references [4], [6], [7], [24]-[28], [58], attributes related to administration of system resources and handling of exceptional conditions are discussed such as capacity, accountability, exception handling, transaction integrity, regulatory, time out, exception duration, compensation rate, and resource utilization. For Example, Accountability means that a provider’s administration of service components is fully accountable. For example, in developing a service, the provider may divide the project into parts and outsource some of the parts. In this case, the provider must devise a mechanism or method to ensure that each service component works as declared in the specification [30].

‘Unique features of SOA’ means characteristics of web service that pertains to SOA. In references [5] and [12], attributes related to the pertaining SOA are discussed such as discoverability, adaptability, composability, reliability, availability. For example, Discoverability means the ease and accuracy of consumers’ search for an individual service, based on the description of functional and non-functional operations of the service [32]. Discoverability can be quantitatively determined by the following equation: (Number of Appropriate Interface/Total number of Interfaces to discover) [5].

‘Domain related’ means dependency of non-functional attributes under study on their domain. In references [3], [33], [34], such attributes are discussed. For example, some attributes of the domain of driving speed limit problem are such as validity, coverage, correctness, precision, input and output parameters, and load management are covered in [3].

'Measureable and evaluation' refers to the fact that some attributes are measureable or can be evaluated. For example, service price can be calculated from the cost of web service provision or the cost of usage. In references [7], [32], [67], such attributes are discussed, such as, service price, suitability, effect, and brand value. For example, Service brand value may refer to Service provider reputation is means to the level of satisfaction of the users after using a web service. This level reflects several qualities of the service provider such as its financial soundness, brand value, technical support, and sustainability [35]. Scores of the current users and reviewers' feedback are ranked. Open forum for experts and general consumers to share their opinions about the service can be arranged. All of this information is available for a new consumer to consider before making a decision. Reputation can be calculated as follow: Reputation = (The sum of end user's rankings on a services' reputation/the number of times it has been assessed) [36].

'Multi-perspective' means that attributes can be viewed in many different ways, depending on the point of view of the authors or the principles they adhere to. Three examples of points of view are as follows: grey box view, black box view, and system ontology view. Grey box view only concerns attributes related to service interface, while black box view concerns internal business process [37]. System ontology view focuses on the method of analysis of relationship between attributes. Three subcategories under this view are relative importance attribute, estimate attribute, and measure attribute [16].

'Business and system' refers to the emphasis of attribute consideration, whether it is on an internal or external business process. These attributes are such as business value, business process, and manageability [21], [35], [38], [39].

'Service composition' refers to the arrangement of a web service to work in tandem with a business operation in order to achieve a targeted business goal. System resources supporting service composition are such as database, network, and server. In references [22] and [40], [41], such related attributes are discussed: response time, capacity, and execution cost.

IV. New Classification of QoS Attributes

The categories of attributes listed in Table 4 are overlapping traditional categories. Based on these traditional categories, we created a new non-overlapping classification according to a multi-stakeholders point of view of web services. We defined multi-stakeholders to mean all of the people and infrastructures involve in an effective implementation of a web service. We were inspired by the diagram of traditional web service model in Fig. 1 showing components that are necessary for effective implementation. We thought of these components, and any hidden ones, as our stakeholders. In order for a category to be applicable to all stakeholders, not just one or two, we created the 6 following categories: provider, consumer, developer, service run time management, security, and network infrastructure, shown in a tree list in Fig. 5.

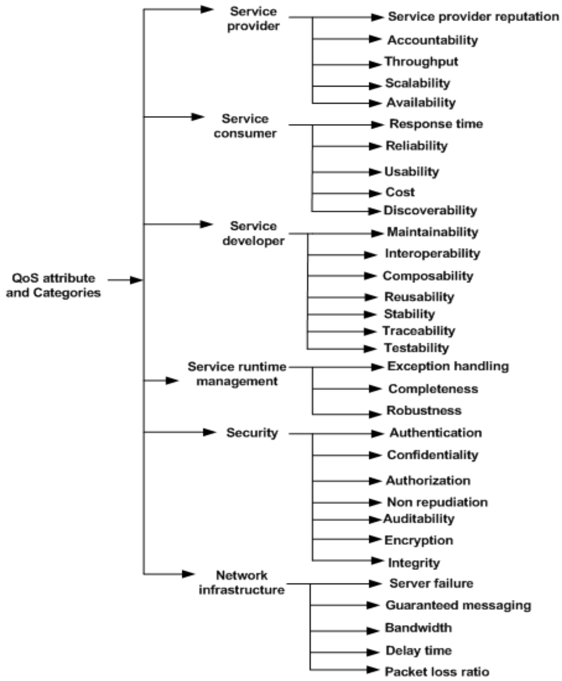

Figure 5. QoS attributes and categories.

Provider: this category consists of attributes related to the administration of system resources for readily provision of web service. They reflect the reputation and trustworthiness of the web service provider. These attributes are availability, accountability, scalability, throughput, and reputation.

Besides the attributes mentioned above, there are some others that are related in some ways to the category provider. These attributes are data handling [16], efficiency [31], and compliance [42].Compliance means the ability of a provider to provide a service that meets an agreeable specification to a consumer. Compliance attribute is closely related to the design process for conformance because, in the process, service contract template and system dictionary have to be created for verification of consumer specification. Another such attribute is data handling by provider [16]. Data handling by provider refers to the ability of a provider to store and administer to-be-processed data sent by a consumer. The provider needs to be able to tell where and how such data are stored in the provider's server system when it is necessary to do so. Yet another such attribute is efficiency. Efficiency refers to the performance of a service—how efficient the service uses the available system resources, such as storage capacity, CPU usage, and network bandwidth, to perform functional and non-functional operations of the service under some constraints such as time.

Consumer: this category consists of attributes related to service cost, waiting time, and fulfillment of claimed specification. These attributes are used as the conditions for employing a web service or as the criteria for differentiating similar web services. These attributes are cost, usability, response time, discoverability, and reliability.

Besides the attributes mentioned above, other attributes related to the consumer category are penalty and incentive [35]. Penalty means a fine for lost business opportunity from an unexpected turn of events that breaks the agreement between the consumer and the provider. Either the consumer or the provider is fined depending on their prior mutual agreement. A fine may be determined from the service down time, maximum response time, average response time, or security requirement of the service.

Developer: this category consists of attributes related to service life cycle [3]. These attributes are such as follows: attributes related to the development of a web service from a previously developed service or legacy code; attributes related to an orderly arrangement of operations of several web services in order for them to work together successfully as a whole system to achieve a business goal or a consumer requirement; attributes related to the maintenance of a web service. These attributes are maintainability, interoperability, stability, reusability, and composability.

Besides the attributes mentioned above, our review also found other attributes related to developer: modifiability, testability, and traceability. Modifiability means the extent to which a web service's interface can be modified by the developer [11]. The service's interface may be currently in use or in the near future; hence, the developer or provider needs to change the service's entry in the service registry and notify the current consumer of the update to the interface. Testability refers to the ability of a developer to test the service system operation [11]. Since a service system consists of loosely connected resources, not owned by any particular developer, a service component may or may not be available at a particular time. Therefore, a developer needs to have a way to test whether all service components work together successfully as a whole system as designed. Traceability refers to the possibility that a developer or provider can trace the history of a service in the log collection system when a request was served [43].

Service run time management: attributes under this category are related to web service management during run time. During run time, erroneous operations can occur such as an erroneous input into the service or a failed service functional, not operating as specified by the provider or developer. These attributes are robustness, completeness, and exception handling.

Security: this category includes all attributes that are related to confirmation of valid user, encryption strategy, and examination of past access behavior. These attributes are such as non-repudiation, authentication, confidentiality, encryption, authorization, auditability, and integrity.

Besides the attributes mentioned above, there are other attributes related to web service security such as those related to accuracy [44]. Accuracy means that the data or response that a web service sends to a consumer is accurate. Inaccuracy may be traced to errors caused by the web service itself. Attributes related to accuracy can be subdivided into those related to the accuracy of data content and those related to the accuracy of computation [45].

Infrastructure: A web service needs full resources, or infrastructure, to deploy and run the service: communication system, server storage, and computing resource, [46], [47]. Attributes that come under this infrastructure category can be grouped into 2 subcategories: server and network. The following describes attributes in these 2 subcategories.

Server: this subcategory refers to server failure. An example of server failure is a server crash because of a brownout or blackout. In this case, a roll back of process operation to its initial state required [3] and guaranteed messaging; mean the ability of a web service to maintain the sequence and integrity of messages in their end-to-end transfer [3].

Network: attributes that come under this subcategory are bandwidth, delay time, and packet loss. The details of each of these attributes are described as follows.

Bandwidth is defined as the number of bytes per second supported by a network [48] or as the waiting time that a user experiences, constrained by the network condition [49]. Both definitions refer to data transfer rate and time. Network bandwidth is of 2 types: available bandwidth and actual bandwidth. To determine the actual bandwidth of an operating web service, several things need to be considered such as the operating system, IO adapter, and protocol used. The actual bandwidth is an average bandwidth of the whole network system for a particular time period [3], [48].

Delay time is the total transfer time, in milliseconds, of the first bit of a message sent from a local application to the last bit received by the remote application, including the transit time of data exchanges through intermediate switches and I/O adapter, [3], [48]. Delay time is determined as follows: Delay = (transmission + transaction). A simple example of delay time comparison is when a service A has a delay time of 100ms + 300ms and a service B has a delay time of 50ms + 200ms, service B is a better choice because its minimum delay time is lower than those of service A [50].

Packet loss ratio is the relative amount of data lost during transfer. Data loss may occur due to a security problem or a transfer process problem [51].

Besides the attributes mentioned above, we also found other attributes related to web service network infrastructure: web service caching, aborted connection, network fabric, and distance to the geographical location of web server. Web service caching reduces the response time of a web service because the provider caches the web service [47]. Aborted connection refers to the number of times a user aborted a connection because the time he or she had to wait for a successful connection to the website was too long [47]. Network fabric refers to the structure of a network such as the structure of a cluster area network, storage area network, local area network, and metro or wide area network [48]. Distance to the geographical location of a web server [48], [51], and Geographical location [49], [52]; refer to the physical distance between a provider and a consumer that sets the lower limit of a web service's response time. For example, a web service physically located in Thailand may take a request from a user in Tokyo, France, or New York; its response time for the same request from each of these users is very different, at 75ms, 90ms, and 110ms, respectively.

V. Discussion and Conclusion

In this article, we systematically reviewed and classified several well-known QoS attributes of web services. Our approach has been to review these attributes, their categorization, and their metric based on our specific research questions. To our knowledge, this is the first systematic review that covers all of the relevant literature from 1997 to February 2014. However, we do not claim that it is fully comprehensive, and we will gladly acknowledge any omissions.

We found, from reviewing the literature, 9 overlapping categories of QoS attributes: service provider, service consumer, unique feature of SOA, service developer, domain related, measurable and evaluation, business and system, multi-perspective, and composition. These overlapping categories make it difficult for a person interested in applying QoS attributes to find the exact information that he or she is looking for. Therefore, we created a new classification scheme where each category under this scheme can point to the information needed for successful application of QoS attributes. The following are some beneficial uses of these new categories.

The consumer category of QoS attributes provides a framework for selection of the best-matched service for one's intended purpose. The provider category provides a framework for creation of checklist of all components pertaining to the capacity of the web service, which is very useful for projection of a future expansion. The developer category provides a framework for creation of checklist of all components pertaining to service design and development, which is vital for successful implementation of web service. The security category provides a framework for evaluation and discussion of the security issue between service partners. Finally, the service run-time and network infrastructure categories provide a framework for assessing hardware performance and drafting an agreement of use of network infrastructure.

We hope that this initiative will serve as a starting point for any researchers beginning to investigate the body of knowledge on these topics and as an aid for further development of new attributes, measures, categorization, and ways to apply them.

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