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Cloud Service Quality Estimation Using Meta-Analysis

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Abstract: Cloud computing has led a paradigm shift from 'own' to 'rent'. Through cloud computing, end-users can get the services of storing data and running an application as a service. Since the impact of low quality service is very critical to companies or end user, it is essential to assure the service quality of cloud computing. Previous studies mostly consider visible quality factors, i.e., service availability. Our approach includes latent factors as well as visible factors. The primary objective of the research is to develop quantitative measurement techniques for estimating and predicting the quality of cloud service. Firstly, deep factors and visible factors affecting the QoS (Quality of Service) of cloud system will be analyzed. Secondly, through meta-analysis method, quantitative measurement techniques to predict and estimate QoS of cloud system will be developed. When companies consider the adoption of cloud computing, this research can give a guideline for high quality cloud service by measuring QoS quantitatively.

Keywords: Cloud Service, QoS, Quantitative Service Measurement, Quality Factor, Meta-Analysis

1. Introduction

Cloud computing can provide IT infrastructure and environment to run services on demand. Through cloud computing, end-users can get the services of storing data and running an application as a service. Cloud computing has noticeable advantages. The cost of the initial IT infrastructure is not required. Users only pay by consumption. Its capacity is scalable on demand. Productivity is enhanced because it is easy to use and time-to-market is reduced. Recently, the market of cloud computing has been growing rapidly. According to IDC report, international market size will become $72.9 billion in 2015. However, a lot of companies are still reluctant to introduce the cloud computing. They are worried about the security of corporate data and quality of service. Since the impact of low quality of service is critical to companies, it is essential to assure the service quality of cloud computing. Previous studies mostly focused on the limited aspect of the cloud service, i.e., service availability. As such, it is required to analyze the latent factors affecting the service quality of cloud computing. On the basis of the analysis, the methodologies for measuring service quality should be studied.

The primary objective of the research is to develop quantitative measurement techniques for estimating and predicting the quality of cloud service. Firstly, deep factors and visible factors affecting the QoS (Quality of Service) of cloud system will be analyzed. Secondly, through meta-analysis method, quantitative measurement techniques to predict and estimate QoS of cloud system will be developed. When companies consider the adoption of cloud computing, this research can give a guideline for high quality cloud service by measuring QoS quantitatively.

By quantifying cloud service quality, guides for standards of QoS between service providers and users can be proposed. For instance, through the estimation of QoS, cloud service provider can estimate the maximum subscribers that the cloud system can afford. In addition, cloud service provider can decide when the equipment for cloud service should be installed additionally.

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2. Background

2.1 Cloud Computing

Cloud computing delivers computing and storage capacity as a service to end-users. Three types of cloud computing are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). In IaaS model, as physical or virtual machines, computers are provided. In PaaS model, a computing platform is offered by cloud providers. It includes operating system, programming language execution environment, database, and web server. In SaaS model, application software and database are installed and operated by service providers. They can be rented by service users. Through a web browser, a desktop, or mobile applications, cloud applications are accessed. Benefits of cloud computing include no cost of the initial IT infrastructure, pay by consumption, scalable capacity on demand, reduced time-to-market, minimum maintenance cost, and etc [1].

2.2 Quality Factors

Web service quality factors are represented by functional and non-functional properties [2]. They consist of business value quality, service level measurement quality, interoperability quality, business processing quality, manageability quality and security quality. Such factors should be considered for achieving the high cloud service quality.

The deep factors are defined as the factors affecting the growth of economy underlying over long periods of time [3]. Their origins lie in geography, climate, culture, politics, and historical accident. In terms of cloud service quality, the deep factors can be taken into consideration. Cloud service quality can be affected when the cloud service provider and the service user are in the geographically different locations. Population or educational level of the service location can affect the cloud service quality. Law and regulations or economic factors occurred due to change of business environment should be considered as well. More various, latent and macroscopic factors, i.e., deep factors, should be analyzed. The deep factors, as factors to improve the future cloud service quality, are the basis for the metrics which can measure the service quality

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quantitatively.

2.3 Meta-Analysis

A meta-analysis can be described as a method contrasting and combining results from different studies. It aims to identify patterns among study results or other interesting relationships [4]. It is composed of five steps: 1) formulating research questions 2) defining inclusion and exclusion criteria 3) literature search and study selection 4) study quality assessment and data extraction 5) statistical analysis and result presentation [5]. Through meta-analysis, cloud service quality can be measured based on the analysis of previous study results.

3. Related Work

The studies about the cloud service quality were mainly carried out in two ways. One type is to define the service quality factors and then present success and failure causes of the service based on quality factors. The other type applies quality measurement models based on quality theories to cloud service quality.

Based on the service quality theory, the effects of SaaS' flexibility and customizability on the service quality and the satisfaction of SaaS' users are analyzed [6]. By analyzing related studies, properties of cloud computing service are classified into 7 features, i.e., Security, Reliability, Availability, Inter-operating, Economic, and Intellectual Property [7]. CSQM (Cloud Service Quality Model) supporting communications between cloud services and end users was presented by [8]. CSQM contains five quality factors, i.e., service level quality, integration quality, security quality, usage manageability, and metering quality. Quality of Experience (QoE) as perceived by users can be considered as the latent factor for managing cloud service quality. Based on QoE, service quality is measured quantitatively [9]. Masayuki et al. studied the security requirements of cloud computing. Access control, authentication and ID management, and security visualization were described as important themes in light of the nature of cloud computing [10]. Vouk suggested that optimization, portability, security, and ROI(Return On Investment) and TCO (Total Cost of Ownership) be important research issues of cloud computing [11]. Parasuraman et al. defined service quality as a comparison between expectations and performance. Service quality was described to contain the process delivering the service as well as the result of the service [12].

The previous researchers analyzed quality factors affecting the cloud computing service focusing on IT. To improve the service quality diversely and broadly, it is necessary to analyze deep factors which are latent from economy, society, culture as well as IT. Competitiveness of global cloud computing is closely related to the establishment of effective laws and policies. Various latent factors should be taken into consideration to achieve the high quality of cloud service.

4. Our Approach

In order to attain high quality cloud service, service quality should be estimated. For that purpose, we present an estimation technique after analyzing quality factors using Meta-Analysis.

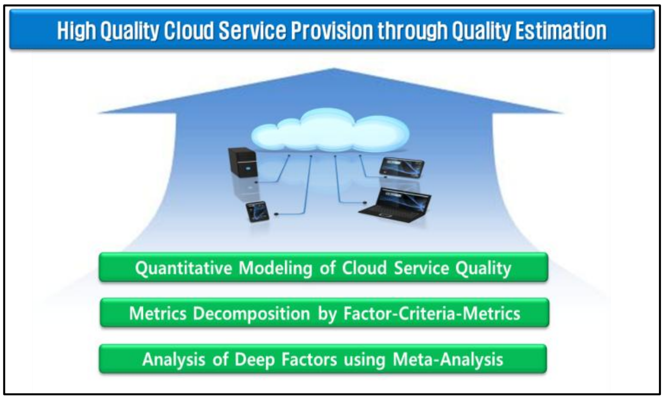

Figure 1. Overall Approach

4.1 Analysis of Deep Factors of Cloud service

Users should be protected from service interruption due to the service provider's bankruptcy. The cloud computing deposit system can be used for that purpose. It can assure that the business operations of companies using the service are stable. In the case of service interruption, the deposit agency carries out the functions of the service provider temporarily with the duplicated system and data of the service provider. During the temporary service by the deposit agency, the service users can find a new service provider and prohibit the loss of data [13].

Temporary service interruptions can occur due to the system malfunctions of the service provider. Cloud service users should be protected from them. Since cloud computing is a new computing service, the concepts of cloud computing should be considered in the law and regulations. As such, the definition, type and service provider classification of cloud computing should be reflected in the existing law. Substantial protection to users in the event of temporary service interruption should be provided by the law.

Security and information leakage are big concerns of cloud computing service. Particularly, when the physical location of the data is changed, data protection and privacy protection should be fully taken into account. Additionally, if the physical location securing the data is an overseas country, it is unclear how to apply the regulation about inspecting the provider's physical facilities. The necessary law for these matters should be established.

The quality of cloud computing services can be secured through the Service Level Agreement (SLA) guidelines. Standard SLA guidelines for cloud computing should be set up and diffused. The quality properties should be presented in the SLA guidelines in detail including MTBF (Mean Time Between Failure), MTTR (Mean Time To Repair), and MTTF (Mean Time To Failure).

If the interoperability of cloud computing cannot be guaranteed, data lock-in can occur. Service users become dependent on the service of a specific service provider. To ensure the interoperability of cloud computing, functions of cloud service should be implemented by adopting related standards. Standard adoptability can be calculated by the ratio of functions implemented by adopting related standards. Standard

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conformability can be depicted as the degree of conformability of cloud services. Relative proofness implies that exchanging and using the information between two specific system platforms in cloud services are successful [2].

The popularity of various devices, i.e., netbooks and smart phones, has increased enormously. It is expected to expand the scope of the cloud computing market by supporting such devices. The communication support among service users is considered as an important factor for applying the cloud service. Interactions between the end user and the cloud, i.e., human-computer-interaction, are important as well.

Table 1. Deep Factors of Cloud Service

Factor	Criteria	Metrics
Law / Regulation	Service interruption by provider's bankruptcy	E * T, where E = 1 if cloud escrow service is used, E = 0 otherwise, T = 1 if full escrow type is used, T = 0.75 if standard escrow type not including experts support of agency is used, T = 0.5 if only data escrow service is used.
	Temporary service interruption by system malfunctions of provider	P * (S + V), where P = 1 if legal policy exists, P = 0 otherwise, S = 0.5 if system error is covered, S = 0 otherwise, V = 0.5 if virus infection is covered, V = 0 otherwise
	Information security	P * (S + M), where P = 1 if legal policy exists, P = 0 otherwise, S = 0.5 if safety inspection policy exists, S = 0 otherwise, M = 0.5 if management system exists, M = 0 otherwise
Standard	Standard adoptability	$\sum_{i=1}^{n} f(x_i)$ / total # of functions of cloud service, where $f(x_i)$ = 1 if function x_i is implemented by adopting of related standards, 0 otherwise
	Standard Conformability	$\sum_{i=1}^{m} g(x_i)$ / # of functions implemented by adopting related standards, where $g(x_i)$ = 1 if function x_i conforms all adopted standards, 0 otherwise
	Relative Proofness	{VPI_1, VPI_2, …, VPI_n}, where n is # of platforms verified, VPI (Verified Platform Information)
Social trend focusing on end user value	Multiple device support	# of Supported devices / total # of devices
	Human-to-human communication	C * T where C = 1 if collaboration is supported, C = 0 otherwise, T = 1 if full option is used, T = 0.5 if standard option is used.
	Human-computer-interaction	user success rate = the percentage of tasks that users complete correctly
Availability	MTBF	Execution time / # of failure
	MTTR	$\sum_{i=1}^{n} R_i$ / # of repair, where R_i is ith repair time
	MTTF	MTBF = MTTF + MTTR

Table 1 describes deep factors, criteria, and metrics identified by using FCM(Factor-Criteria-Metrics) decomposition approach. FCM is a hierarchical model. High level quality factors are set. Each quality factor consists of lower-level criteria. The criteria are easier to measure than the factors. Then actual metrics are suggested for the criteria. Since the relevant relationships between factors and their dependent criteria are described by the tree, the factors can be measured from the viewpoint of the dependent criteria measures. By using the metrics obtained through the FCM approach, you can evaluate the cloud service quality under specific project as following statistical model;

$$QoCS = \sum_{i=1}^{n}(w_i * (\prod_{j=1}^{m} M_{ij})) \qquad (1)$$

QoCS(Quality of Cloud Service) is the value which is evaluated the quality of cloud service. *M* is the metric of criteria C_i and *m* is the number of metric in criteria C_i. We assume that individual metric(*M*) is an exclusive relation with each other. The metric is greater than 0 and less than 1. $\prod_{j=1}^{m} M_{ij}$ represents the quality of the selected criteria C_i under the specific project. w_i is the weight of Criteria *i* under a project. Therefore, equation (1) represents the quality of target cloud service.

4.2 Applying to Meta-Analysis

Among deep factors, critical factors to cloud service quality are identified through Meta-Analysis. It was helpful for identifying patterns and relationships from various factors. Meta-analysis consists of five steps. Firstly, formulating research questions should be carried out. Our research question is to identify the techniques applicable for estimating cloud service quality. Secondly, defining inclusion and exclusion criteria should be performed. Not only accepted papers but also reports from public research institutes are taken into account. The contents of the previous studies should include the factors enhancing the cloud service quality. The research period of the papers are constrained between 2008 and 2012 to reflect the latest research results. In addition, languages used in the research are restricted to English and Korean. Thirdly, literature search and study selection should be done. Both Google scholar search engine and Google web search engine are used for retrieving research papers and reports by using the specific keywords, i.e., "cloud computing quality", and "service level agreement". Among total 22 studies, 6 of them are selected after applying inclusion and exclusion criteria. Fourthly, study quality assessment and data extraction are performed. From selected studies, the factors affecting cloud service quality are identified. They include availability, standards closely related to interoperability, law/regulation, and social trends focusing the end user value. Lastly, statistical analysis and result presentation

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should be carried out. The factors identified from previous studies are shown in the Table 2. The number in the table indicates the number of reference. All studies included availability as important factors, but indirect factors, i.e., law/regulation, standard are not considered much. The main reason is that service availability can be easily quantified. Since metrics of latent factors are not explicitly described in the previous studies, particular attributes including types and characteristics based on the criteria are used for forming the metrics.

Table 2. Factors described in previous studies

No	Law/Regulation	Standard	Social trend	Availability
2		O		O
6			O	O
7		O	O	O
8		O	O	O
9			O	O
13	O	O	O	O

5. Conclusion and Future work

In this paper, techniques for estimating cloud service quality are presented. By employing Meta-Analysis, factors affecting cloud service quality are identified. Those factors include latent factors as well as IT factors. Identified quality factors include law/regulation, standards, social trends focusing on end user value, and availability. For each factor, metrics are decomposed by using Factor-Criteria-Metrics method. Each metric can be used for estimating cloud service quantitatively. Since the deep factors are analyzed, it is possible to study which countries are effective for locating the data center providing cloud service. Since QoS of cloud systems can be measured quantitatively, quality can be assured more precisely through various quality metrics including legal policy, availability, etc.

Future works of this research can include the development of a tool evaluating for cloud service quality. According to identified service quality factors, metrics can be defined and then visualized. The quantitatively evaluated results of service quality can be described by using dashboard functionalities.

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