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Fuzzy AHP를 적용한 클라우드 컴퓨팅 환경에서 보안 속성의 상대적 중요도 평가

Relative priority evaluation of security attributes in cloud computing using fuzzy AHP

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요 약

클라우드 컴퓨팅의 장점에도 불구하고 보안성에 대한 문제들이 많은 사용자들의 선택에 장애가 되고 있다. 본 논문에서는 클라우드 컴퓨팅의 보안성에 대한 ISO 7498-2 표준의 관련 속성들이 전체 보안 품질에 미치는 상대적 영향도를 평가하였다. 많은 요인들의 영향도를 객관적으로 평가하기 위하여 Fuzzy AHP(Analytic hierarchical process)를 적용하였다. 본 연구는 클라우드 컴퓨팅 서비스의 보안 관련 각 속성들의 상대적 중요성을 구체적으로 수치화 할 수 있었고, 클라우드 컴퓨팅 서비스의 효율적인 선택 및 개발에 필요한 관리 방법을 제시할 수 있었다.

Abstract

In spite of many advantages of cloud computing, security concerns are a barrier in users' adopting the cloud service. In this paper, we evaluate relative priorities between security attributes of ISO 7498-2 standards affecting overall security quality in cloud computing. For an objective evaluation, the fuzzy AHP(Analytic hierarchical process) is applied. The evaluation results represented the relative priority with concrete number can be an effective management method to choose and develop the cloud computing service.

Key words : 클라우드 컴퓨팅(cloud computing), 보안 관계(security concerns), ISO 7498-2, 퍼지 AHP(fuzzy AHP), 상대적 중요성(Relative priority)

Ⅰ. Introduction

Cloud computing has recently raised an intensive interest in various fields, but it is still an evolving paradigm that incorporates the evolutionary development of many existing computing technologies such as distributed services, applications, information and infrastructure consisting of pools of computers, networks, information and storage resources [1]. It has shown tremendous potential to enhance collaboration, agility, scale, availability-although its definitions, issues, underlying technologies, risks, and values need to be refined. Despite the advantage and value that the cloud presents for users, several surveys of potential cloud adopters in-

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dicate that security and privacy are the number one concern delaying its adoption and it will continue to keep some users out of cloud computing[2, 3, 15].

In this paper, by evaluating relative priorities between various security-related attributes we verify the first consideration to solve the security concerns.

The evaluation of relative priorities between security attributes is potentially very complex due to the multitude of variables that influence the decision process. Determining the most important influences on security in cloud environments is crucial and helps cloud providers focus on factors with the highest weight and identify the best policy to improve security quality. How to evaluate the relative importance of these factors thus can be considered as a multiple-attribute decision-making problem. Analytic hierarchy process (AHP) is an appropriate method for solving multiple-attribute decision-making problems[4]. However, human judgment on the importance of alternatives or criteria is always subjective and imprecise. To make up for this deficiency in AHP, several researchers integrate fuzzy theory with AHP to determine the criteria weights from subjective judgments of decision makers[5, 6]. Consequently, this study applies a fuzzy AHP approach to determine the relative priorities of security attributes in cloud computing environment.

Ⅱ. Related research

2-1. Security concerns and related researches in cloud computing

The US National Institute of Standards and Technology (NIST) defines cloud as follows: “Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three delivery models, and four deployment models.”[7]. In spite of advantages, the security concerns are barriers to apply cloud computing services. In minimizing potential security trust issues as well as adhering to governance issues facing Cloud computing, a prerequisite control measure is to ensure that a concrete Cloud computing Service Level Agreement (SLA) is put in place and maintained when dealing with outsourced cloud service providers and specialized cloud vendors[8].

The Gartner Group lists seven security issues, privileged access, regulatory compliance, data location, data segregation, recovery, investigative support, long-term viability, data availability, which one should discuss with a cloud-computing vendor. The following list shows security issues highlighted by Gartner[2]. By considering the above mentioned cloud issues, executives can gain a comprehensive understanding as well as measure the feasibility of employing Cloud computing solutions to best match their Cloud strategy.

In the ISO 7498-2 standard [3], produced by The International Standards Organization (ISO), Information Security should cover a number of suggested themes. Cloud computing security should also be guided in this regard in order to become an effective and secure technology solution.

Therefore by exploring the information security requirements at each of the various cloud deployment and delivery models set out by the ISO, vendors and organizations can become confident in promoting a highly protected safe and sound cloud framework.

In this paper, we apply fuzzy AHP to security attributes defined by ISO 7498 to calculate relative priorities between security-related attributes and figure out the first consideration to solve the security concerns.

2-2. AHP and Fuzzy AHP

Analytic hierarchy process (AHP) is a useful method for solving complex decision-making problems involving subjective judgment (Saaty, 1990)[4]. In AHP, the mul-

ti-attribute weight measurement is calculated via pairwise comparison of the relative importance of two factors. Assuming there are N number of decision elements, denoted as (W1, . . . , Wi, . . . , Wn), its judgment matrix would be A = [aij], in which aij represents the relative importance of Wi and Wj. Then, by using the row vector average normalization proposed by Saaty (1980), the weight of Wi is calculated as:

$$w_i = \frac{(\Pi_{j-1}^{n} a_{ij})^{\frac{1}{n}}}{\Sigma_{i=1}^{n} (\Pi_{j-1}^{n} a_{ij})^{\frac{1}{n}}}, \quad i,j = 1, 2, \ldots, n \quad (1)$$

where wi denoted the weight of the ith decision element, and weight vector w = (wi), i = 1, ..., n.

Though AHP is designed to capture decision-maker knowledge, the conventional AHP does not fully reflect human thinking style[9]. However, it is well recognized that human judgments for qualitative items are represented by linguistic and imprecise patterns. Linguistic and imprecise descriptions were difficult to solve using AHP until the recent development in fuzzy decision-making. Fuzzy set theory resembles human reasoning in its use of approximate information and uncertainty in decision generation. A major contribution of fuzzy set theory is its capability to represent vagueness. Meanwhile, AHP was developed to solve the multiple-attribute decision-making problem. By incorporating fuzzy set theory with AHP, fuzzy AHP enables a more accurate description of the multiple-attribute decision-making process[10, 14].

Therefore, in this study, we use the fuzzy AHP approach since this approach is adequate to explicitly capture the importance assessment for human imprecise judgments.

To convert fuzzy value into crisp value, we applied CFCS(converting fuzzy data into crisp scores) method developed by Opricovic and Tzeng (2003)[11]. While the center of gravity method is too complicated in its process, the CSCF method can clearly express fuzzy perception, which is based on the procedure of determining the lower and upper scores by fuzzy min and fuzzy max, and the total score is determined as a weighted average according to the membership functions.

Ⅲ. Priority weight evaluation process and security attributes

The process of applying the fuzzy AHP comprise of the following main steps:

Step 1. Regarding the evaluation goal, configure a hierarchical attribute structure influencing security.
Step 2. Construct a pairwise comparison matrix of the attributes with fuzzy ratio judgments.
Step 3. Limit the matrix by raising it to a sufficiently large power (where is an arbitrarily large number) until it converges into a stable matrix.
Step 4. Defuzzify the fuzzy set in the converged matrix.
Step 5. Derive relative priorities from the matrix

We apply fuzzy AHP to security attributes defined in ISO 7498-2 as Fig. 1. Explanations about each attribute are as follows:

A. Identification & authentication: this process is targeting at verifying and validating individual cloud users by employing usernames and passwords protections to their cloud profiles.
B. Authorization: authorization is an important information security requirement in Cloud computing to ensure referential integrity is maintained. It follows on in exerting control and privileges over process flows within Cloud computing.
C. Confidentiality: in Cloud computing, confidentiality plays a major part especially in maintaining control over organizations' data situated across multiple distributed databases.
D. Integrity: the integrity requirement lies in applying the due diligence within the cloud domain mainly when accessing data.

Therefore ACID (atomicity, consistency, isolation

표 1. 퍼지 집합에 의한 대쌍 비교 행렬
Table 1. Pairwise comparison results by fuzzy set

Security	Identification & authentication	Authorisation	Confidentiality	Integrity	Non-repudiation	Availability
Identification & authentication	(1.0000, 1.0000, 1.0000)	(0.4167, 0.3333, 0.2778)	(0.3125, 0.2500, 0.2778)	(4.0000, 5.0000, 6.0000)	(4.0000, 5.0000, 6.0000)	(4.8000, 6.0000, 7.2000)
Authorisation	(2.4000, 3.0000, 3.6000)	(1.0000, 1.0000, 1.0000)	(0.6250, 0.5000, 0.4167)	(4.8000, 6.0000, 7.2000)	(4.8000, 6.0000, 7.2000)	(5.6000, 7.0000, 8.4000)
Confidentiality	(3.2000, 4.0000, 6.0000)	(1.6000, 2.0000, 2.4000)	(1.0000, 1.0000, 1.0000)	(5.6000, 7.0000, 8.4000)	(5.6000, 7.0000, 8.4000)	(7.2000, 9.0000, 10.800)
Integrity	(0.2500, 0.2000, 0.1667)	(0.2083, 0.1667, 0.1389)	(0.1786, 0.1429, 0.1190)	(1.0000, 1.0000, 1.0000)	(1.6000, 2.0000, 2.4000)	(2.4000, 3.0000, 3.6000)
Non-repudiation	(0.2500, 0.2000, 0.1667)	(0.2083, 0.1667, 0.1389)	(0.1786, 0.1429, 0.1190)	(0.6250, 0.5000, 0.4167)	(1.0000, 1.0000, 1.0000)	(2.4000, 3.0000, 3.6000)
Availability	(0.2083, 0.1667, 0.1389)	(0.1786, 0.1429, 0.1190)	(0.1389, 0.1111, 0.0926)	(0.4167, 0.3333, 0.2778)	(0.4167, 0.3333, 0.2778)	(1.0000, 1.0000, 1.0000)

and durability) properties of the cloud's data should without a doubt be robustly imposed across all Cloud computing deliver models.

E. Non-repudiation: non-repudiation in Cloud computing can be obtained by applying the traditional e-commerce security protocols and token provisioning to data transmission within cloud applications such as digital signatures, timestamps and confirmation receipts services (digital receipting of messages confirming data sent/received).

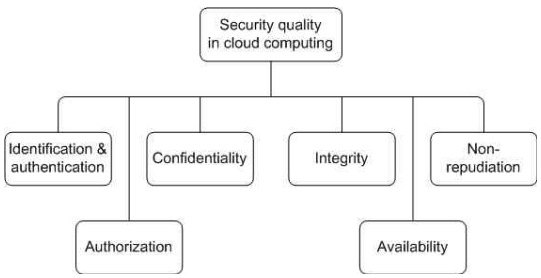

그림 1. 보안관련 속성의 계층적 구조
Fig. 1. Hierarchical structure of security attributes

F. Availability: availability is the critical information security requirements in Cloud computing because it is a key decision factor when deciding among private, public or hybrid cloud vendors as well as in the delivery models.

This study applied fuzzy AHP to above 6 attributes.

Ⅳ. Evaluating relative priority weights

The AHP method provides a structured framework for setting priorities on each level of the hierarchy using pair-wise comparisons that are quantified using a 1-9 scale. Instead of a crisp value, fuzzy AHP applies a range of values to incorporate the decision maker's uncertainly. In this method, the fuzzy conversion scale is as in [12, 13].

Table 1 shows the pairwise comparison results between security attributes. The pairwise comparison is

Table 2. Conversion matrix by power method
표 2. 거듭 제곱법에 의해 얻은 수렴 행렬

Security	Identification & authentication	Authorisation	Confidentiality	Integrity	Non-repudiation	Availability
Identification & authentication	(0.1757, 0.1664, 0.1535)	(0.1757, 0.1664, 0.1535)	(0.1757, 0.1664, 0.1535)	(0.1757, 0.1664, 0.1535)	(0.1757, 0.1664, 0.1535)	(0.1757, 0.1664, 0.1535)
Authorisation	(0.2818, 0.2855, 0.2784)	(0.2818, 0.2855, 0.2784)	(0.2818, 0.2855, 0.2784)	(0.2818, 0.2855, 0.2784)	(0.2818, 0.2855, 0.2784)	(0.2818, 0.2855, 0.2784)
Confidentiality	(0.3803, 0.4142, 0.4567)	(0.3803, 0.4142, 0.4567)	(0.3803, 0.4142, 0.4567)	(0.3803, 0.4142, 0.4567)	(0.3803, 0.4142, 0.4567)	(0.3803, 0.4142, 0.4567)
Integrity	(0.0675, 0.0590, 0.0512)	(0.0675, 0.0590, 0.0512)	(0.0675, 0.0590, 0.0512)	(0.0675, 0.0590, 0.0512)	(0.0675, 0.0590, 0.0512)	(0.0675, 0.0590, 0.0512)
Non-repudiation	(0.0578, 0.0470, 0.0386)	(0.0578, 0.0470, 0.0386)	(0.0578, 0.0470, 0.0386)	(0.0578, 0.0470, 0.0386)	(0.0578, 0.0470, 0.0386)	(0.0578, 0.0470, 0.0386)
Availability	(0.0369, 0.0279, 0.0216)	(0.0369, 0.0279, 0.0216)	(0.0369, 0.0279, 0.0216)	(0.0369, 0.0279, 0.0216)	(0.0369, 0.0279, 0.0216)	(0.0369, 0.0279, 0.0216)

performed with triangular fuzzy set.

For each matrix with fuzzy set, the conversion matrix is obtained by power method as shown in Table 2. Since the conversion matrix is composed with fuzzy set, it needs a defuzzyfication process to get crisp value. The CSCF method was applied in this process.

Table 3 represents the final relative priority between security attributes by crisp values after the defuzzyfication process.

In the evaluation, Confidentiality is the highest priority and is followed by Authorization and Identification & authentication. Integrity and Non-repudiation which are attributes for data management and protection show lower priority relatively and it means that in cloud environments, an access by a person not verified and not certified is considered as the biggest concern.

표 3. 역퍼지화 후의 최종 상대적 우선순위
Table 3. Relative priority calculation results after defuzzyfication

Security	Identification & authentication	Authorisation	Confidentiality	Integrity	Non-repudiation	Availability
Identification & authentication	0.1656	0.1656	0.1656	0.1656	0.1656	0.1656
Authorisation	0.2394	0.2394	0.2394	0.2394	0.2394	0.2394
Confidentiality	0.4161	0.4161	0.4161	0.4161	0.4161	0.4161
Integrity	0.0592	0.0592	0.0592	0.0592	0.0592	0.0592
Non-repudiation	0.0475	0.0475	0.0475	0.0475	0.0475	0.0475
Availability	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285

Ⅴ. Conclusions

Although cloud computing shows many advantages, it is still in its infancy. More than all, since security concerns are delaying its adoption, we need to study and verify factors affecting the security. To set up plans to improve and manage security concerns. it needs to figure out the priority between the security-related factors.
This study applies fuzzy AHP to ISO 7498-2 standards to develop an evaluation method which helps system designers understand the critical factors in implementing cloud computing services with trustful security quality. The analysis results show that a confidentiality attribute should be considered as the most important factor and three attributes, confidentiality, authorization and identification & authentication, come to be more than 82% priorities of all.

However, there are several limitations to this study, requiring further research. This study was conducted with ISO standards only.

More quality standard samples that bring more explanatory power would have allowed more sophisticated evaluation analysis. Also, the study findings thus should be verified with a case study to increase a reliability. To provide more objective information on security concerns and its solutions in cloud environments, future research needs to be undertaken using case studies of particular cloud computing services.

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