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Cloud Computing System Risk Assessment Model Based on Fuzzy Matrix

Yongli Tang, Yan Jin and Lihua Wang
College of Computer Science and Technology, Henan Polytechnic University,
454000, JiaoZuo, China

Abstract: The application of the cloud computing system brings convenience to users which potentially exists many risks of system security. It is one of the difficulties and current researches to assess the risks of cloud computing system correctly and objectively. Through analyzing the security risk which exists in the cloud computing system, the article presents a kind of risk analysis model based on the fuzzy matrix which makes a modeled analysis algorithm to security risk of cloud computing system and simulates the feasibility and availability of the model through a example which proves the validity of the model.

Key words: Cloud computing system, risk assessment model, fuzzy matrix

INTRODUCTION

Cloud computing is an emerging Internet computing model which is proposed by Google first, currently it is the hot topic in the IT field. Many enterprises have been paying much attention to cloud computing since its being propounded with its powerful processing capabilities, customizable services and relatively low price. However, it can not be overlooked that cloud computing security problems have been exposing gradually, for example, the risk of enterprise applications, data security and privacy and so on. Cloud computing security issues, affecting the application and popularization of cloud computing, are vitally important in the research of cloud computing.

In the cloud computing environment, the data of the businesses themselves are all in the cloud, whereas, the structure of the cloud itself is opaque, so then it produces a distrust of psychological state. This is not only a pure technical problem, but also a business problem, of which referring to various aspects of factors like credibility and integrity, laws and regulations and so on (Jamil and Zaki, 2011). Thus, to ensure the users really feel comfortable to use cloud computing service, it requires to solve the problem of security from both technical and non-technical aspects (Foster *et al*., 2008).

Our study proposed a risk assessment model for cloud computing system with the combination of traditional information security risk assessment ideological and cloud computing system risk assessment. The model is applied to some complex systems in which complex problems can be separated to several simple ones, besides, it can come out the evaluation result by the form of the quantitative data, so the evaluation result could be objective and reasonable.

This study has an important significance which can reduce the security-related incidents of cloud computing system, ensure information security and to enhance the user's confidence in the use of cloud computing services. For promoting the development of cloud computing, the wealth of information security risk assessment methodology appeared.

The following will discuss security risks which the enterprises face when they deploy cloud computing and evaluate the risk of cloud computing services.

THE RISKS OF CLOUD COMPUTING

Physical risk

Unexpected Event: Unexpected event is the things that people can not foresee which are natural disasters or not. for example: thunder and lightning, fire and water, sudden power lost and so on. something that can not be predictable. So the cloud computing system should do better measures to preventing emergencies.

Human factor: Human factor is one of the most important factors that affects whether the cloud computing system can operate normally. For example, when a cloud computing system is damaged by the lawless, its server suddenly loses power which influences system's operation, or when the user's confidential data are stealed by internal employee. Therefore, it is very important to prevent the destruction of the outlaws.

Corresponding Author: Yan Jin, College of Computer Science and Technology, Henan Polytechnic University, 454000, JiaoZuo, China

Systemic risk

Operating system damage prevention measures: If the business operating system is insecure in a cloud computing environment, then the system administrator will have overtopped authority and can freely access the user's data which affects the privacy protection seriously.

Application software damage prevention measures: As the cloud computing services are implemented through a variety of software modules, as well as Web Services to integrate. So once the software has security events, it will have a huge impact.

Database system damage prevention measures: Now, cloud computing database market mainly includes Google's Bigtable, Amazon's SimpleDB, AppJe's AppJet database and the new model databases like Oracle open source Berkeley DB and so on. These databases are already quite mature, but there are still some problems, for example: the traditional division of security zone is invalid; unauthorized access; data integrity and confidentiality and so on.

Data risk

Users' privacy information being leaked: In the process of using cloud computing services, the user's privacy information may be leaked, while the attacker often analyzes based on the computational tasks submitted by the user and then reveals some private information of the user (Wang and Fan, 2012).

Data isolation technology: In the cloud computing system, all users' data are located in a shared environment, all the data will not be able to use once the encryption system arise problems. Therefore, it is also important that the cloud computing providers can isolate some data. For example: many exams are conducted online now. It is necessary that take isolation measures to question bank and the answers. If the exam with answers is not in place then the safety of the papers will not be guaranteed.

Data backup and recovery: As the user can not know the specific location of the data stored in the process of cloud computing. so if the data and reference program are not backed up the unexpected events, such as a sudden power loses. It will not be able to protect the security of users' data so far as to the data can not be restored. Therefore, the backup of the data is essential.

Related security regulation

Security audit measures: Some cloud computing service providers usually refuse to accept external audit and security certification, while traditional service providers must pass this external audit services. For this provider, the users need to take on more obligations and responsibilities owing to not audit the result of the operation.

Related rules and regulations: In cloud computing environment, traditional illegal activities aiming at particular users will be difficult to achieve, because the data from multiple users may be stored together and may be transferred between multiple hosts or data centers. At the same time, the illegal activities for unparticular users' data will increase if the ISP does not have measures in this regard. when the illegal activities occur, the national public security departments will be unable to start which will make illegal events further increased in the cloud computing environment (Karabacak and Sogukpinar, 2005).

Geographical impact to system: The information security laws and regulations exists regional difference, at present, if the multiple servers for cloud computing are placed in different countries, the IT regulatory policies they face will be different. For example, some countries have the authorization to view the data stored in the data center, while others are strict to ensure the users' data information privacy. so when the users and the enterprises use cloud computing services, they can present personalized needs according to their own situation (Wei, 2011).

Relevant safety technology

Encrypt the saved files: Encryption technology can encrypt files which only the password only can be decrypted. Encryption allows you to protect the data, even if the data are uploaded to the others at a distant data center. The PGP or the corresponding open source product such as True Crypt program provides strong enough encryption function, as long as you use the password can not be cracked, then in addition to you, no one can access your sensitive information.

The use of filters: Vontu, Websense and Vericept and other companies provide a system to monitor what data leave your network, thereby automatically prevent sensitive data. For example, the social security number has a unique digital arrangement, so that different users in a same company enjoy various degree of freedom when exporting data.

Anti-hacking measures: In the cloud computing environment, the hacker spread zombie codes in the form of the virtual machines by cloud computing resources, the

affected users are difficult to detect these zombie codes in the virtual machine running in a computer. At the same time, the hackers hide their true identity through rented virtual machine.

In the way, when virtual machines' operation is closed, of which the state information will disappear, this greatly increase the chance to access the network crime evidence in the virtual machine (Liang and Luan, 2012).

FUZZY COMPREHENSIVE EVALUATION METHOD

Basic idea: On the basis of determining the evaluation factors, the factor evaluation standard and weight can applies fuzzy set transform principle. For using degree of membership to describe the factors and its fuzzy boundaries which can constructs the fuzzy evaluation matrix and determines the evaluation objects belong to which classes ultimately through the multilayer composite operation. so the key point is the fuzzy evaluation matrix.

Evaluation process: Information security risk assessment is a complicated process determined by many factors, among factors there are hierarchical distinction, this kind of problem is multi-level problem, For multi-level problem, first, it needs to evaluate hierarchically, according to the category the evaluation factors belonged to, then to evaluate from the overall which is the multi-level fuzzy comprehensive evaluation (Hu and He, 2008).

Establishing the system evaluation index system: Establishing the guiding ideology the system of system evaluation index is: index system to truly reflect performance of the system.

Determined factors set: Based on the established evaluation index system, the factor sets is $U = \{u_1, u_2, ..., u_m\}$. Because there are different levels of factors, cannot be equal to treat, treated by their respective levels (Kandel, 1986).

Determine the fuzzy weight sets: In the actual evaluation work, commonly used methods to determine the weight are: statistical experiment method, analysis inference method, expert evaluation method and analytic hierarchy process. When determine the weights between relevant factors of each layer, obtain the fuzzy weighted set A (Xie and Liu, 2000).

Determine evaluation set: Evaluation set is a set which composed by the various general evaluation result of evaluated object might make for. To determinate the evaluation set will be according to actual needs to be, the division of general level is between 3-7, namely evaluation sets $V = \{v_1, v_2, ..., v_n\} (3 \le n \le 7)$.

Establish fuzzy evaluation matrix: First, fill in the evaluation card by experts, according to the specific circumstances of evaluation factors, given the corresponding level; Second, According to the statistics of the evaluation, list the evaluation result Tables; Third, According to the evaluation result Tables, get the factors belonging to membership of different rank evaluation, get fuzzy evaluation matrix R (Wang, 2011).

Calculation comprehensive evaluation result: The factors which to be considered can not exist dependencies in the layers, that the same layer is independent of each other. The evaluation algorithm of each layer is the same, that fuzzy comprehensive evaluation model is:

$$B = A \circ R$$

Among, "$\circ$" is fuzzy factor, it has multiple of computing ways, this article will use "multiply and operator".

Through layers of fuzzy operation, the fuzzy sets is $B = \{b_1, b_2, ..., b_n\}$, normalized $B' = \{b'_1, b'_2, ..., b'_n\}$, among:

$$b'_j = \frac{b_j}{\sum_{i=1}^{n} b_i}, (j = 1, 2, ..., m)$$

Give evaluation report: The final assessment conclusion can determined by the overall evaluation B and certain principle of evaluation, the commonly used principle of evaluation the principle of confidence, the minimum cost principle, the maximum membership degree principle, scoring principles (Chen *et al*., 2008).

The significance of the model: The model evaluates cloud computing system more effectually, to improve the confidence of the users to use cloud computing, more users start using cloud computing, in order to achieve a virtuous cycle of cloud computing and sustainable development.

THE RISK EVALUATION MODEL OF CLOUD COMPUTING

Determining factors set: The factors set of determine should be given the evaluation index system of the organization, given the security level model of cloud computing, based on the commonly level model of

Table 1: Evaluation object set of level division table

First level	Second level
System risk status (U)	
Physical risk (u1)	Unexpected event (u11)
	Human factor (u12)
Systemic risk (u2) (u21)	Operation system damage prevention measures
	Application software damage prevention measures (u22)
	Database system damage prevention measures (u23)
Data risk (u3)	Users' privacy information being leaked (u31)
	Data Isolation technology (u32)
	Data backup and recovery (u33)
Related security regulation (u4)	Security audit measures (u41)
	Related rules and regulations (u42)
	Geographical impact to system (u43)
Relevant safety technology (u5)	Encrypt the saved files (u51)
	The use of filters (u52)
	Anti-hacking measures (u53)

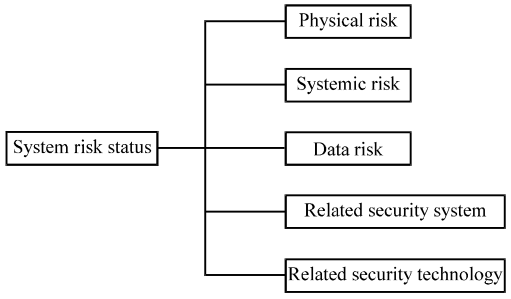

Fig. 1: The security level model of cloud computing

information security, as Fig. 1 shown. Each contains multiple indicators, determined the factors set U as shown in Table 1.

Determine the weight set: Hierarchy analytical process was proposed by the famous American operations research expert A.L.Saaty to determine the index weights. This process just given the comparison of relative importance between indexes by this method, can be calculated the weights, so can be avoided experts' subjective factors.

The rationality experimental results of various scale methods of Saaty made show that using the 1~7 ratio scale method expressed the relative important degree between any two indexes is reasonable. The method show survey results by 1~7, according to hierarchical analysis principle can structure judgment matrix. Using square root method to find the weight of each index and normalizing, calculating consistency check, but if the weights do not meet the consistency requirements, to adjust determine matrix, until meet the requirements (He, 1995).

Ultimately determine the results is the first level fuzzy weight set A = (0.1, 0.2, 0.2, 0.3), the second level fuzzy weight set A_1 = (0.4, 0.6), A_2 = (0.2, 0.3, 0.5), A_3 = (0.4, 0.3, 0.3), A_4 = (0.2, 0.5, 0.3), A_5 = (0.4, 0.3, 0.3).

Table 2: The cloud computing system evaluation results table

	Rank				
Factor	Very safe	Safe	Safe in general	risk	very risk
u11	25	5	0	0	0
u12	20	5	5	0	0
u21	20	5	5	0	0
u22	15	5	10	0	0
u23	10	10	5	5	0
u31	15	10	5	0	0
U32	5	10	10	5	0
U41	5	5	10	5	5
U42	5	10	5	5	5
U43	15	10	5	0	0
U51	10	10	0	5	5
U52	10	10	10	0	0
U53	10	5	10	5	0

Determine reviews set: Making V = (V_1, V_2, V_3, V_4, V_5) represented {very safe, safe, safe in general, risk, very risk}, they expressed safety degree of factors form high to low.

Determine the fuzzy comprehensive assessment matrix: Inviting 30 experts, according to the divided five levels respectively evaluate to the factors of the end of level which listed in Table 1, namely u_{11}, u_{12}, u_{21}, u_{22}, u_{23}, u_{31}, u_{32}, u_{33}, u_{41}, u_{42}, u_{43}, u_{51}, u_{52}, u_{53} this 14 factors and their layer factors can be calculated through their evaluation results and the corresponding weights. The statistics of the evaluation results of the eight factors shown in Table 2.

After experts evaluated and separately calculated the membership of factors. For example with u_{11}, in 30 experts, 25 person think that it is very safe, 5 person think that it is safe. So the membership of u_{11} in very safe is 5/6; the membership of u_{11} in safe is 1/6; the membership of u_{11} in safe in general is 0; the membership of u_{11} in risk is 0; the membership of u_{11} in very risk is 0. So the assessment of u_{11} is u_{11} = (5/6, 1/6, 0, 0, 0,).
Similarly:

$$u_{12} = (2/3, 1/6, 1/6, 0, 0)$$

$$u_{21} = (2/3, 1/6, 1/6, 0, 0)$$

$$u_{22} = (1/2, 1/6, 1/3, 0, 0)$$

$$u_{23} = (1/3, 1/3, 1/6, 1/6, 0)$$

$$u_{31} = (1/2, 1/3, 1/6, 0, 0)$$

$$u_{32} = (1/6, 1/3, 1/3, 1/6, 0)$$

$$u_{33} = (1/6, 1/6, 1/3, 1/6, 1/6)$$

$$u_{41} = (1/6, 1/6, 1/3, 1/6, 1/6)$$

$$u_{42} = (1/6, 1/3, 1/6, 1/6, 1/6)$$

$$u_{43} = (1/2, 1/3, 1/6, 0, 0)$$

$$u_{51} = (1/3, 1/3, 0, 1/6, 1/6)$$

$$u_{52} = (1/3, 1/3, 1/3, 0, 0)$$

$$u_{53} = (1/3, 1/6, 1/3, 1/6, 0)$$

Fuzzy comprehensive assessment: Evaluating starts from the lowest level. Evaluation algorithm is based on the comprehensive evaluation model: B = A∘R, and, "∘" presents "multiplication and sum" which is common matrix multiplication.

The second level fuzzy evaluation:

$$B_1 = A_1 \circ R_{11} = A_1 \circ \begin{bmatrix} u_{11} \\ u_{12} \end{bmatrix} = (0.4,0.6) \circ \begin{bmatrix} \frac{5}{6} & \frac{1}{6} & 0 & 0 & 0 \\ \frac{2}{3} & \frac{1}{6} & \frac{1}{6} & 0 & 0 \end{bmatrix} = (0.733,0.167,0.1,0,0)$$

Similarly:

$$B_2 = (0.45, 0.25, 0.217, 0.083, 0)$$

$$B_3 = (0.3, 0.283, 0.267, 0.1, 0.05)$$

$$B_4 = (0.267, 0.3, 0.2, 0.117, 0.117)$$

$$B_5 = (0.333, 0.283, 0.2, 0.117, 0.067)$$

After respectively normalized were

$$B'_1 = (0.6, 0.167, 0.1, 0, 0)$$

$$B'_2 = (0.45, 0.25, 0.217, 0.083, 0)$$

$$B'_3 = (0.3, 0.283, 0.267, 0.1, 0.05)$$

$$B'_4 = (0.267, 0.3, 0.2, 0.117, 0.117)$$

$$B'_5 = (0.333, 0.283, 0.2, 0.117, 0.067)$$

The first level fuzzy evaluation:

$$B = A \circ R = A \circ \begin{bmatrix} B'_1 \\ B'_2 \\ B'_3 \\ B'_4 \\ B'_5 \end{bmatrix} = (0.1,0.2,0.2,0.2,0.3) \circ \begin{bmatrix} 0.6 & 0.167 & 0.1 & 0 & 0 \\ 0.45 & 0.25 & 0.217 & 0.083 & 0 \\ 0.3 & 0.283 & 0.267 & 0.1 & 0.05 \\ 0.267 & 0.3 & 0.2 & 0.117 & 0.117 \\ 0.333 & 0.283 & 0.2 & 0.117 & 0.067 \end{bmatrix}$$

$$= (0.3633, 0.2682, 0.2068, 0.0951, 0.0535)$$

After normalized it is:

$$B' = (0.3633, 0.2682, 0.2068, 0.0951, 0.0535)$$

Find the optimal solution, given the evaluation report To determine the final evaluation results by using the scoring principles. Scoring principle is change comments set into number which uses a group of appropriate numbers to respectively show comments set and divided science reasonable level and then weighted summate to the evaluation index and then find the conclusion.

In this example, the comment sets is, respectively represent {very safe, safe, safe in general, risk, very risk}, here will be quantified as $V = \{V_1, V_2, V_3, V_4, V_5\} = \{9, 8, 5, 3, 2\}$. For the final results of P, when $P \in [8, 9]$, the corresponding evaluation results is very safe; when $P \in [7, 8]$, the corresponding evaluation results is safe; when $P \in [5, 7]$, the corresponding evaluation results is safe in general; when $P \in [3, 5]$, the corresponding evaluation results is risk; when $P \in [2, 3]$, the corresponding evaluation results is very risk. In this example:

$$P = \sum_{i=1}^{5} b_i \times v_i$$

$$= 0.3633 \times 9 + 0.2682 \times 8 + 0.2068 \times 5 + 0.0951 \times 3 + 0.0535 \times 2$$

$$= 6.8416 \in [5,7]$$

Therefore, the evaluation report is: the security situation of the information system of the organization is safe in general.

CONCLUSION

While the cloud computing provides convenient and efficient services to users, many problems about user's information security also are brought. This article puts a risk assessment model for cloud computing by the multilayer structure fuzzy comprehensive evaluation method. The basic idea is that, stratified the information security problems of the cloud computing and then the top layer of the evaluation results as the evaluation of the input of the next layer. So the complex problems have been decomposed into the relatively simple evaluation factors which make the evaluation results objective and rational, to better reflect the real situation of the system.
The innovative point of this article is to propose an entirely new risk assessment model for cloud computing. Compared with other cloud computing risk assessment model, this model is more suitable to evaluate some of the complexity of the system and can quantify the complex

problem. In this article, some of the technical details not described in detail, the next step will continue to improve.

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