Research on Cloud Security Risk Assessment based on Fuzzy Entropy Weight Model

Jun Liu, Zuhua Guo

Department of Computer Science and Technology of Henan Institute of Technology, Xinxiang, 453003, Henan province, China
{Jun.Liu} ddnt@163.com

Abstract. A method of cloud security risk assessment based on fuzzy entropy weight is proposed. In this framework, seven aspects of cloud security risk assessment indicators are set up, include the virtualization, data security, infrastructure, applications, soft environment, cloud services and security management. The simulation results show that the fuzzy entropy weight method is effective for the cloud security risk assessment, and the execution speed is fast.

Keywords: Cloud computing, risk assessment, fuzzy entropy weight, membership matrix

1 Introduction

"Network is the computer" is one of the main ideas reflected by the cloud computing. A large number of storage, computing and software resources are linked together, forming a large-scale IT resource pool of shared resources [1,2]. Economy, convenience, and high scalability are the advantages of cloud computing. With these advantages, more and more enterprises focus on Cloud Computing.

Nowadays, many key issues are accompanied by the rapid development of cloud computing and gradually emerged, especially the issue of cloud security [3]. With the continuous expansion of the application field of cloud computing, the importance of security issues has become more and more significant, which has seriously hindered the popularization of cloud computing technology. In recent years, frequent cloud security incidents further aggravated people's concerns. In 2009, Microsoft's cloud computing platform stopped running for about 22 hours. Google has also experienced a large number of user file leak events. Moreover, there was a large downtime in Amazon's services in 2011. The occurrence of this series of cloud security events illustrates that the security situation the cloud computing faced has been very serious [4]. A survey report on the problem of cloud computing model in the Internet Data Center shows that security, usability and performance are the three major challenges faced by cloud computing services [5]. It can be seen that cloud security is the impact of cloud computing is the primary reason for the normal development. Only study and
solve cloud security issues, the sustainable development of cloud computing can be guaranteed [6].

There are so many types of risk assessment methods and models. A lot of scholars have carried out its analysis and research. Duncan pointed out the possible security risks in cloud environment by analyzing the structure of cloud computing system and data storage and transmission mode under cloud computing environment. And on this basis, he put forward the cloud computing-based information system security risk assessment method [7]. The concept of network resource availability risk was proposed by Sari, and the risk assessment and prediction of the probability of availability of resources and statistical methods were performed [8]. Joseph validated the uncertainty and risk from different perspectives and used the relevant theory to propose new models of uncertainty and risk modeling [9].

In this paper, we propose a risk evaluation method based on fuzzy entropy weight. This method can improve the accuracy and efficiency of cloud security risk assessment on the basis of previous research results.

## 2 The Construction of Fuzzy Entropy Weight Model

First, establish a set of security risk factors. Let $B = \{b_1, b_2, \cdots, b_n\}$, where $n$ is the number of factors. Then, according to the classification of assets, threats and vulnerabilities, construct their corresponding evaluation set $C = \{c_1, c_2, \cdots, c_M\}$, where $M$ is the number of elements in the corresponding evaluation set. Thirdly, the risk factors are subjectively evaluated according to the evaluation set $C$, and construct the fuzzy function $b_i \rightarrow g(b_i) = (q_{i1}, q_{i2}, \cdots, q_{im}) \in G(C)$. Where $G(C)$ is the set of fuzzy sets on $C$, and $g$ is the degree of support of factor $b_i$ on each evaluation set.

The membership vector of factor $b_i$ to the set $C$ is $Q_i = (q_{i1}, q_{i2}, \cdots, q_{im})$, so the membership matrix is

$$Q = \begin{bmatrix}
q_{11} & q_{12} & \cdots & q_{1m} \\
q_{21} & q_{22} & \cdots & q_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
q_{n1} & q_{n2} & \cdots & q_{nm}
\end{bmatrix} \tag{1}$$

According to the degree of the influence of assets, the frequency of threat and the severity of vulnerability, the factors of risk evaluation index system are classified into $Q_t$, $Q_r$, $Q_f$. Assume that the corresponding weight vector of each factor is $\varphi = \{\varphi_1, \varphi_2, \cdots, \varphi_n\}$. When calculating the impact of assets, the frequency of threats and the severity of vulnerability, the weights of the different evaluation sets are given by the expert evaluation method. Then we can get weights.
vector \( V = (v_1, v_2, \cdots, v_n) \) in asset impact assessment set, weight vector \( W = (w_1, w_2, \cdots, w_n) \) of threat frequency, weight vector \( X = (x_1, x_2, \cdots, x_n) \) of the degree of vulnerability. Where \( n_1 \) is the number of elements in the asset impact assessment set, \( n_2 \) is the number of elements in the threat frequency set, \( n_3 \) is the number of elements of the degree of vulnerability set. Finally, the severity of vulnerability, vulnerability and vulnerability of the assets are respectively:

\[
\begin{align*}
S_e &= \phi Q e V^T \\
S_i &= \phi Q t W^T \\
S_f &= \phi Q c X^T
\end{align*}
\]

Entropy is used in information theory to represent the uncertainty of things, and entropy is used as a measure of uncertainty. Suppose the system may be in the following \( n \) different states: \( T_1, T_2, \cdots, T_n \). \( Q_i \) denotes the probability that the system is in the state \( T_i, 0 \leq Q_i \leq 1 \), then the entropy can be expressed as:

\[
H(q_1, q_2, \cdots, q_n) = -k \sum_{i=1}^{n} q_i \ln q_i
\]

This entropy satisfies the following conditions:

\[
H(q_1, q_2, \cdots, q_n) \leq H\left(\frac{1}{n}, \frac{1}{n}, \cdots, \frac{1}{n}\right)
\]

\[
H(q_1, q_2, \cdots, q_n) = H(q_1, q_2, \cdots, q_n, 0)
\]

\[
H(BC) = H(B) + H\left(\frac{C}{B}\right)
\]

When these three conditions are satisfied at the same time, there is a unique form:

\[
H(q_1, q_2, \cdots, q_n) = -\sum_{i=1}^{n} q_i \ln q_i
\]
3 Experimental Results and Analysis of Cloud Security Risk Assessment

In order to verify the effectiveness of the proposed fuzzy entropy weight method for the evaluation of the risk of cloud security, we simulated the cloud with server scale of 50 in the CloudSim platform. After randomly setting the indexes, the risk evaluation of cloud security was carried out.

In this paper, because the cloud security risk involves seven aspects, e.g. virtualization $M_1$, data security $M_2$, infrastructure $M_3$, application $M_4$, soft environment $M_5$, cloud services $M_6$ and security management $M_7$. First, take the security management $M_7$ as an example to carry out risk assessment. The security management $M_7$ consists of error operation, inadequate regulatory mechanisms, not uniform standards, internal threats and improper protection. The results are shown in Figure 1.

![Fig.1. Three membership matrices](image-url)
Further, we can get the weight vector corresponding to each factor as follows:

\[ \varphi_i = (0.12, 0.30, 0.19, 0.19, 0.20) \]
\[ \varphi_t = (0.18, 0.13, 0.26, 0.24, 0.19) \]
\[ \varphi_j = (0.25, 0.25, 0.22, 0.23, 0.05) \]

Further calculation, evaluation of the weight of each indicator, as follows:

\[ V = (0.13, 0.13, 0.20, 0.20, 0.34) \]
\[ W = (0.13, 0.13, 0.20, 0.20, 0.34) \]
\[ X = (0.13, 0.13, 0.20, 0.20, 0.34) \]

The risk value of \( M_7 \) is further calculated as follows:

\[ S_c = 0.17 \]
\[ S_j = 0.18 \]
\[ S_f = 0.16 \]
\[ S_{M_7} = 0.17 \]

Similarly, the seven aspects of cloud risk assessment can be calculated as follows:

\[ S_{M_1} = 0.15 \]
\[ S_{M_2} = 0.14 \]
\[ S_{M_3} = 0.15 \]
\[ S_{M_4} = 0.14 \]
\[ S_{M_5} = 0.13 \]
\[ S_{M_6} = 0.16 \]

If these seven aspects of the total security risk for the cloud set to the same weight, we can get the overall cloud security risk assessment score:

\[ S = \frac{\sum_{i=1}^{7} S_{M_i}}{7} = 0.15 \]

The results of the above evaluation show that, for the cloud modeled in this paper, the security risk score is 0.15, which is between 0 and 0.2. The level of security risk for the first level, e.g. the low level. This indicates that the cloud modeled in this paper is...
in a safe state. The above process also confirms the effectiveness of the fuzzy entropy method proposed in this paper for cloud security risk assessment.

4 Conclusions

A method of cloud security risk assessment based on fuzzy entropy weight model is proposed in the framework of fuzzy evaluation theory for the risk assessment of cloud security.

References