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Application of Multi-attribute Cloud Decision Method in Congestion Control

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Abstract

In the process of congestion control decision, there are two main problems. One is how to solve the uncertainty of attributes. The other is how to solve the operation between qualitative and quantitative. So, the paper uses cloud model, and proposes a fuzzy multi-attribute cloud decision method. By simulation experiment, it can effectively solve the uncertainty of attributes evaluated, especially coexistence of randomness and fuzzyness, and the operation between linguistic evaluation value and evaluation data. It can easily be used to solve the multi-attribute decision-making or evaluation problem with uncertainty in various fields.

Keywords: *Multi-attribute, cloud model, congestion control, decision*

1. Introduction

In real life and practical application, evaluation and decision is a very common problem. Evaluation is often used as the basis and foundation of the decision, and it is always multi-attribute problems, namely multi-attribute decision. Due to the popularity and importance, the multi-attribute decision theory and method play a prominent role in many areas and have great social value and broad application prospects.

In fact, many problems of the real world is complex and difficult to quantize, and there is uncertainty with randomness and fuzziness being main features, which increases the difficulty to evaluate and decision. In previous studies, probability theory for the random uncertainty and fuzzy set theory is mainly used to discuss the fuzzy uncertainty[1-5]. However, randomness and fuzzyness often coexist in the actual system .It is a very important issue, how to resolve this uncertainty in more reasonable and comprehensive way to support the objective and accurate evaluation.

The evaluation of congestion control is important and necessary to insure network transferring quality, but it is complex too. In the evaluation processing of congestion control, attribute considered is not single, and many factors should be involved, including delay, throughput and drop loss rate and so on. Moreover, the procedure of getparms has certain randomicity, and sometimes attribute evaluation information with language. So the evaluation information of congestion control has objective randomicity and subjective fuzzyness. Actually, the evaluation of congestion control is the multi-attribute evaluation problem with uncertainty, and there are two important problems as follow. Firstly, how to solve the uncertainty of attributes, especially coexistence of fuzzyness and randomness? Secondly, how to solve the conversion of linguistic evaluation information and evaluation parameters to get final evaluation result of congestion control.

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Based on above problems, we consulted many excellent research achievements. By studying, cloud model by De-yi Li academician is one and only, and it can solve not only uncertainty of information but also conversion between qualitative and quantitative. Therefore, we researched deeply cloud model and proposed a multi-attribute cloud decision method for congestion control.

The paper is organized as follow. Firstly, it introduces the background of the research, and points out two main existent problems in congestion control evaluation. Then, cloud model is introduced. Thirdly, multi-attribute cloud decision method is proposed. Finally, we use it to evaluate a congestion control scheme, and introduce in detail its whole operation process.

2. Background of Research

2.1 Overview of Cloud Model

The cloud model is a tool for qualitative and quantitative transforming and solving uncertainty problem proposed by De-yi Li. In the model, a cloud consists of many disordered cloud drops, each of which is defined as a element in quantitative domain with exact number expressing a random realization of qualitative conception on the domain, and certainty degree of its realization is a random number with stable tendency valued in the closed interval [0, 1]. The certainty degree of cloud drop is a random number, and reflects fuzziness, so it can express the relationship between randomness and fuzziness. And the distribution of cloud drop in the quantitative domain is called the cloud[6-8]. The overall shape of the cloud reflects important characteristics of qualitative concept and cloud droplets is Quantitative description of qualitative concept. The generation process of cloud droplets, which means mapping between the uncertainty qualitative concept and quantitative values.

The cloud expresses a conception with three digital characteristics, Ex (expected value), En (entropy), and He (hyper entropy)[9-10]. Here, Ex is the distribution expectation of a cloud drop in the quantitative domain, and En can measure the uncertainty of a qualitative conception, and He expresses the uncertainty of the entropy. The normal cloud is the most important cloud model, and its definition is as follows.

Definition: set U as a domain comprising accurate number, whose accorded qualitative concept is C, for any given element x in domain, if x meets the following conditions: x ~ N（Ex, En’2）, En’ ~ N（En, He2）, and the certainty degree of x for C meets (1), the distribution of x in domain U is called normal cloud model[6].

$$\mu = e^{-\frac{(x\text{-}Ex)^2}{2(\mathrm{En}')^2}} \tag{1}$$

Normal cloud is a cloud model used widely, because of its universality based on normal distribution and normal membership function.

2.2 Analysis of the Characteristics of the Cloud

- The generation of cloud

For popular one-dimensional normal cloud, it can generated drops needed by follow algorithm.

(1) Generates normal random number x with Ex as expected value and En as variance;
(2) Generates normal random number En’ with En as expected value and He as variance;
(3) Calculates y= $\exp[-(x-Ex)^2 / 2\times En^2]$;
(4) Combinates (x,y) to form a cloud drop.
(5) Repeat steps (1) to (4) until a required number of cloud droplets.

The algorithm is also suitable domain space with two-dimensional or higher dimensional case.

The algorithm uses twice the normal random number, and a random number is basis of one, namely multiplexed relationship, which is the key to the algorithm.

- Analysis of digital characteristics

(Expected Value)Ex: Representative value of qualitative concept, the number of domain space to reflect the concept of cloud droplets of the center position of the group. It presents the information center values of the corresponding fuzzy concept.

(Entropy)En: Entropy is used to measure ambiguity and probability of qualitative concept, which reflects the uncertainty of the qualitative concept and also reveals relevance of fuzziness to randomness simultaneously. Entropy can also be used to indicate granularity of qualitative concept.

(Hyper Entropy)He: The hyper entropy is measurement of entropy' uncertainty, namely the entropy of entropy, which reflects coherence all points' uncertainty representing of the qualitative in domain space. The size of entropy describe indirectly the degree of dispersion and thickness of the cloud.

Based on digital characteristics above-mentioned, Figure 1(a、b、c) show cloud model as setting different value.

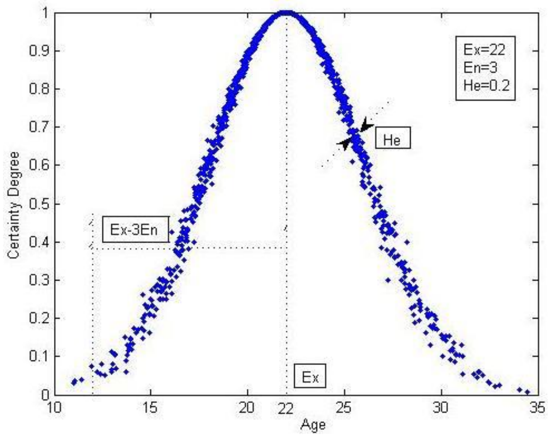

Figure 1 (a). Cloud Model of "Youth"

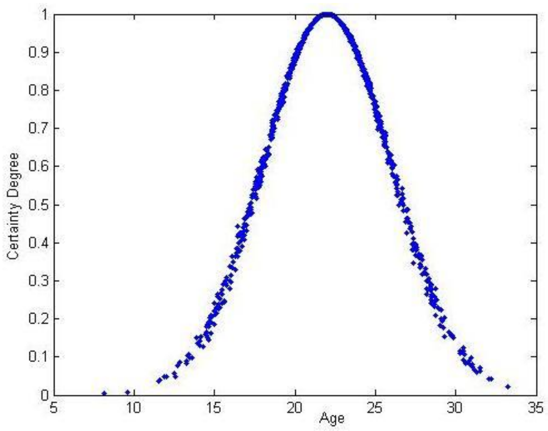

Figure 1 (b). Cloud Graphics of"Ex=22,En=3,He=0.7"

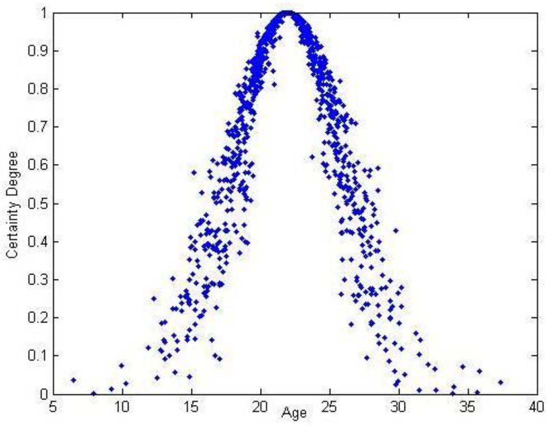

Figure 1(c). Cloud Graphics of"Ex=22,En=3,He=0.1"

- Analysis of graphic characteristics

In the cloud model, each certainty degree of quantitative value to qualitative concept is a random number meeting normal distribution, but not the only value. This feature reflects the uncertainty mapping qualitative and quantitative variables.

The thickness of the cloud is uneven, which reflects the randomness of certainty degree and evaluation' overall regularity.

Mapping results between quantitative and qualitative value always have subtle changes, but fluctuating within a certain range, not violently impacting to the overall characteristics of the cloud.

From the above, cloud model fully integrates configurative fuzziness and randomness existing in qualitative and quantitative mapping and study universal rules for inherent uncertainty, which makes possible that range and distribution rule of quantitative data are gotten from qualitative information, and vice versa. Therefore, the multi-attribute decision based on cloud model of is feasible.

2.3 Problematic Presentation

To analyze and evaluate one complex phenomenon, many attributes of the phenomenon will be thought, and the evaluating values of the attributes will be given by several experts or multiple simulation to form a decision alternatives set, then completing the selection of the optimal solution, which is known as multi-attribute decision problems. As the analysis mentioned, the uncertainty in the evaluation factors is key to affect the evaluation results, so it is focus and difficulty that uncertainty problem is solved effectively during multi-attribute evaluation.

Based on the previous analysis of the characteristics of the cloud model, the cloud decision method is proposed in this article to solve this problem [11-15].

3. Overview of the Algorithm

The proposed method can be organized into four steps.

1) Setting one phenomenon or thing is denoted as S, and it is evaluated with n attributes, and the set of attributes is denoted as A, A={a1,a2,⋯⋯,an}, n≥ 1, ai is the ist attribute, 1 ≤ i ≤ n; alternatives set M proposed by experts or simulation,M={m1,m2,⋯..,mk},k≥ 2,mj is the jst solution, 1≤ j≤ k, and each solution is evaluated by n attributes.Then it evaluation matrix can be expressed as follows:

$$S = \begin{array}{c|ccc} & m_1 & m_2 \;\cdots & mk \\ a_1 & a_{11} & a_{12} & a_{1k} \\ a_2 & a_{21} & a_{22} & a_{2k} \\ \cdots & \cdots & \cdots & \cdots \\ a_4 & a_{n1} & a_{n2} & a_{nk} \end{array}$$

2) Determining set of evaluation of each property based on the actual situation, and establishing corresponding evaluation cloud for each evaluation set (see the algorithm 1) .Real evaluation always uses fuzzy natural language or numerical range, so to establish evaluation cloud by the one-dimensional normal cloud, of course semi-cloud according to actual conditions, to be an evaluation cloud set.

3) For alternatives, each actual property is calculated separately certainty degree $\mu(i)$ with equation 2 by evaluation cloud, and then carry out a comprehensive evaluation degree, and final decision obtained by comprehensive certainty degree, its calculation method shown as equation 3.

$$\mu_i = \exp[-(A_i - Ex)^2 / 2\times En^2] \tag{2}$$

$$Ex \in C_i, En \in C_i, C_i \in \{C_{a1}, C_{a2}, ..., C_{an}\}$$

$$g_i = \sum_{i=1}^{n} (\mu(i) * P(i)) \tag{3}$$

4) At last, evaluation result is to elect scheme with max certainty degree, as equation 4.

$$g = \max\{g_1, g_2, ..., g_n\} \tag{4}$$

Algorithm 1 is descried as follow:

CG(Ex,En,He,n) representing for forward normal cloud generator, Digital characteristics (Ex,En,He) and the number of cloud drops as input, cloud drop and its certainty degree as output afterwards.

The algorithm used in the normal random number generation, and a random number is basis for another random number. This is also the key to the algorithm. CG can be realized by a computer through a specific program, Concrete realization from[6].

The process of multi-attribute cloud decision method see Fig.2, the identifier described in detail above.

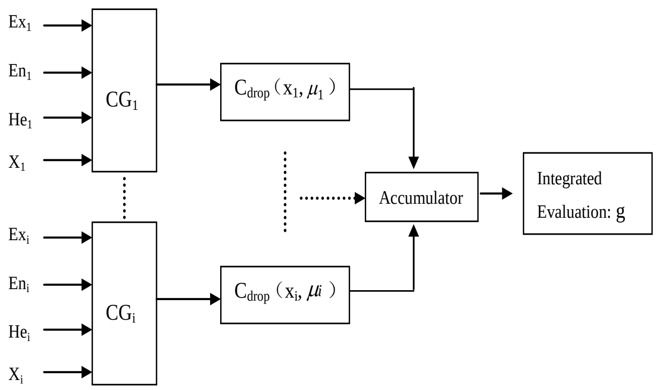

Figure 2. The Evaluation Process based on Cloud Decision

4. Application Example on Evaluation of Network Congestion Control

4.1 Case Description

There are a variety of schemes for network congestion control and the scheme performance required for different types of business are not the same. The paper selects the network delay, delay jitter and packet loss rate as performance evaluation references to [16].

Case data are obtained using NS2. Simulation topology and parameters are shown in Figure 3, S_1, S_2, D_1, D_2 as host nodes and R_1, R_2 as router.

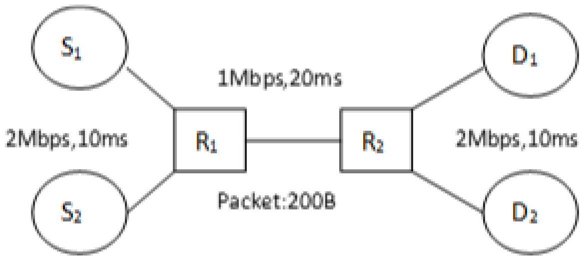

Figure 3. Simulation Topology Scenario

S_1 and S_2 respectively send data with constant tcp data to D_1 and D_2 .Bottleneck Link R_1 to R_2 existed, two data stream will content bandwidth under different load conditions. During simulation, we keep one rate 100kbps constant and another start from 500kbps to 950kbps gradually. In order to ensure performance fairness, we set evenly light and heavy load scenes.

Delay jitter is a key actor to evaluate performance of network. Some different simulation scene data show in table 1.

Table 1. Dalay Jitter Simulation Data

Simulation Rate（kb/s）	Delay Jitter (ms)		
	Solution 1	Solution 2	Solution 3
500	1.82	2.03	1.76
600	2.07	2.16	1.93
650	2.79	2.37	2.52
700	2.01	2.34	2.48
750	3.88	3.24	2.97
800	5.21	5.04	4.36
850	6.79	5.43	5.04
900	14.86	15.07	12.14
920	11.71	16.13	13.07
940	12.50	11.80	12.70
950	12.03	13.45	12.10

We can see the change of parameter ,also by figure to contrast on different scene among solutions, reference to Figure 4.

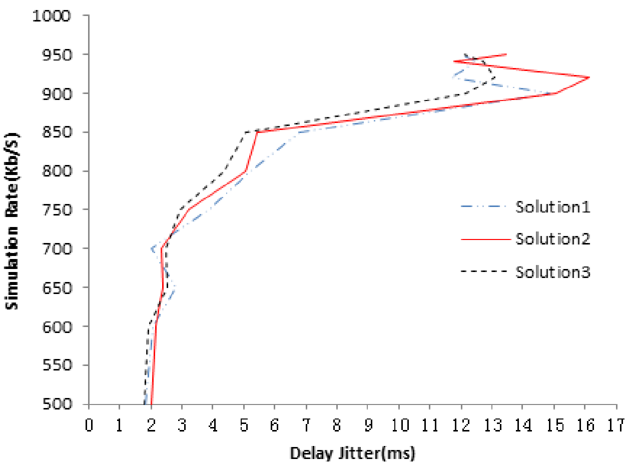

Figure 4. Daly Jitter Chart for Different Solutions

Intuitively viewing from the figure, when entering high load state, three congestion control solution for delay jitter all play some role. But it is difficult to objectively evaluate what better solution using traditional method, the same as other evaluation factors. To complete a comprehensive and objective assessment is more difficult. Generally we evaluate solution using linguistic assessment information based some experimental data or experts's experience. Here using cloud decision method presented, we can obtain the certain degree to ideal state and change trend. The information will help us to find out detailed relation between network load and performance and to provide basis for adjustment and control strategy.

4.2 Simulation Analysis

We quote the level of network performance and the corresponding interval from [17](see Table 2).

Table 2. Evaluating Factor and Grade

grade	Delay/ms	Delay Jitter/ms	Drop Loss Rate/%
Excellent	0≤X≤150	0≤X≤50	0≤X≤3
Good	150<X≤400	50<X≤80	3<X≤10
Poor	X>400	X>80	X>10

Assuming there are three alternative to improve network performance, by simulation, and finally simulation results of the three performance evaluation factors were given. How to evaluate the three alternative? For traditional decision method, we can only evaluate by single factor according to the simulation data, unless each factor 'simulation results very good or bad. Otherwise it is difficult to give a comprehensive evaluation on multi-attribute, of course, to make decision.

Under different simulation circumstances, the average network delay, jitter, and packet loss rate are gotten for each solution. In order to prove the method simple and effective, the paper does test under uniform circumstances. Assuming, transferring as 940Kbit/s, the network performance values of the three solutions is shown in Table 3.

Table 3. Network Performance under 940Kbit/s

Solution	Delay/ms	Delay Jitter/ms	Drop Loss Rate/%
1	77	12.5	8.57
2	89	11.8	9.72
3	69	12.7	8.36

Under above mentioned circumstances, each plan can evaluate on single factor to use language rank description, but it is difficult to evaluate on multi-attribute, not to mention decision. Next, we use the method proposed by this paper to solve the problem above.

First, building evaluating cloud according to the figure characteristics provided in Table 1, separately delay evaluation cloud Cdelay, delay jitter evaluation cloud Cjitter and drop loss rate evaluation cloud Cdrop.,each cloud can construct rank cloud according to data in Table1.Here the rank clouds sees figure 4-6 and are expressed as follows.

According to attribute evaluation set, network delay rank evaluation cloud is expressed as follows, and its cloud graph see Fig.5

$$C_{delayexcelent} = \begin{cases} 1 & x < 0 \\ C(0,42,0.05) & x \in [0,150] \end{cases}$$

$$C_{delaygood} = C(275,43,0.05) \quad x \in (150,400]$$

$$C_{delaybad} = \begin{cases} C(400,5,0.05) & \\ 1 & x \in (400,\infty) \end{cases}$$

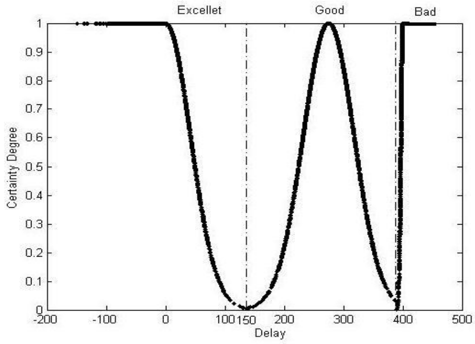

Figure 5. Delay Rank Evaluation Cloud

The expression of delay jitter cloud evaluation is listed below and its cloud graph see Figure 6.

$$C_{jitterexcellent} = \begin{cases} 1 & x < 0 \\ C(0,17,0.05) & x \in [0,50] \end{cases}$$

$$C_{jittergood} = C(68,4,0.05) \quad x \in (50,80]$$

$$C_{jitterbad} = \begin{cases} C(80,1,0.05) & \\ 1 & x \in (80,\infty) \end{cases}$$

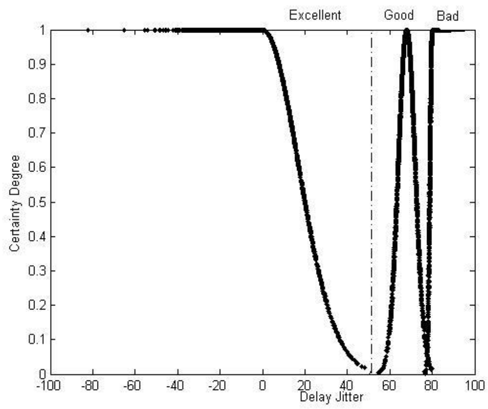

Figure 6. Delay Rank Evaluation Cloud

The expression of drop loss rate cloud evaluation is listed below and its cloud graph see Figure 7.

$$C_{\text{dropxcellent}} = \begin{cases} 1 & x < 0 \\ C(0,1,0.05) & x \in [0,3] \end{cases}$$

$$C_{\text{dropgood}} = C(7,1,0.05) \quad x \in (3,10]$$

$$C_{\text{dropbad}} = \begin{cases} C(10,1,0.05) & \\ 1 & x \in (10,\infty) \end{cases}$$

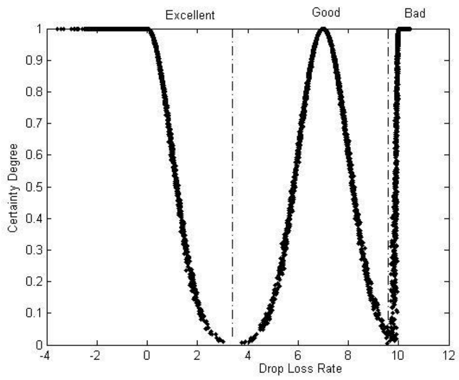

Figure 7. Drop Loss Rate Evaluation Cloud

Secondly, data from Table 2 as inputting to calculate certainty degree with equation 1 based on different evaluation cloud.

Finally, comprehensive certainty degree is obtained with equation 2 as solution's evaluation value, then to select the maximum of evaluation certainty degree as the decision scheme by comparing the evaluation value.

The data above using cloud decision see Table 4.

Table 4. Alternative Solutions Data using Cloud Decision

Solution	Delay Degree	Delay Jitter Degree	Drop Loss Rate Degree	Final Degree
1	0.186	0.763	0.292	1.241
2	0.106	0.786	0.124	1.016
3	0.259	0.757	0.396	1.412

Apparently, 1.412 is the maximum of the three evaluation certainty degree. According to cloud decision method, the final evaluation result solution 3 is best overall performance, its comprehensive certainty degree is 1.412. Actual simulation, we completed experiments on a number of scenes. Here we only select one case and other scenarios method the same.

Above we describe implementation process of multi-attribute cloud decision method based on simulation parameters, and the method can also be applyed based on natural language evaluation information, which is after the conversion natural language qualitative to quantitative, and re-using cloud decision method to make a comprehensive decision.

If we use traditional rank evaluation by simulation data, its result is that the three solutions are all excellent based on performance evaluation factors, whose linguistic evaluation is fuzzy and which can not help us to make decision. By the method presented, we can not only synthetically select strategy, but also to analyse performance parameter detailedly. So the method proposed in the paper is simple and effective.

5. Conclusion

The paper proposes a multi-attribute cloud decision method, and it is used to evaluate the performance of network. The cloud decision method can solve actively the uncertainty problems of system evaluation, and the result of experiment proves the validity and feasibility of the method. Actually, the method is easy to be used widely, and it is apt to solve the multi-attribute decision-making or evaluation problem with uncertainty in various fields. In future, we will study further a more effective method to solve the linguistic evaluation value and linguistic evaluation certainty degree.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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