UDC 681.3.093:044.3
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APPLICATION OF THE HOT-SPOT EVALUATION METHOD FOR MONITORING OF DATA CENTER NETWORK

Denis Olegovich Zuev, Kropachev Artemii Vasilyevich, Usov Aleksey Yevgenyevich, Roman Gorshunov.Application of the hot-spot evaluation method for monitoring of data center network. Abstract. Network monitoring methodology development was considered as important stage of data center infrastructure organizing due to requirements of services efficiency and stability. It was mentioned that construction of adaptive and scaled algorithm of data processing in real time regime is a nontrivial task for developers. Process of hot-spot evaluation of the network data indexes was shown as a part of monitoring technique includes obtaining of subjective weight and objective weight of each index which could be used to get the comprehensive evaluating index. It was demonstrated that optimal relative value represents degree of relativeness to optimal one up to the attributes of fixed type, range type, cost type and efficiency type. Triangular fuzzy numbers were used to form the fuzzy judgment matrix which includes uncertainty of subjective judgment experts. Comparative judgment matrix forming method which implies obtained of weighted values by using of the fuzzy number comparison size theory was analyzed. It was noticed that based on the hot-spot comprehensive evaluation value, hot-spot degrees of all monitoring point can be ordered and hierarchy will be obtained during the sorting process. First stage of this algorithm includes getting hot-spot degree evaluation index system's original index grade by experts' judgment method. Second stage refers to determination of value for each level as monitoring original data. At the next stage hot-spot degree should be evaluated as the same ordinary monitoring points. Final stage includes achieving corresponding comprehensive evaluation value based on every level value. Hot-spot degree range of each monitoring point was obtained as result of forming hot-spot comprehensive evaluation values' uniformly ranking of all levels. Finally, hot-spot level of each monitoring point was correspondingly obtained and hot judgment of the monitoring was received with the level of data center rules in advance.
Keywords: data center, virtual machine, hot-spot, fuzzy analytic hierarchy process. triangular fuzzy number, relative value, type attribute.

Зуев Д. О., Кропачев А. В., Усов Д.М., Горшунов Р. Применение метода оценки «горячей точки» для мониторинга сетей центров обработки данных. Разработка методологии сетевого мониторинга рассмотрена как важный этап организации инфраструктуры центров обработки данных, в соответствии с возросшими требованиями по эффективности и стабильности услуг данных сервисов. Процесс оценки «горячих точек» индексов сетевых данных был показан как часть метода мониторинга, включающий получение субъективного веса и объективного веса каждого индекса, который можно использовать для получения всестороннего оценочного индекса. Было продемонстрировано, что оптимальное относительное значение представляет степень соответствия атрибутов к оптимальному значению. Метод нечеткой треугольных чисел рассмотрен для формирования матрицы нечетких суждений, которая включает экспертную оценку. Проанализирован метод формирования матрицы сравнительных оценок, который подразумевает получение взвешенных значений с использованием теории размера сравнения нечетких чисел. Было отмечено, что на основе методологии оценки «горячих точек» можно упорядочить степени «горячей точки» мониторинга и получить иерархию во время процесса сортировки. Первый этап этого алгоритма включает в себя получение исходного индекса оценки степени готовности, который базируется на экспертной оценке. Второй этап относится к определению значения для каждого уровня мониторинга исходных данных. Заключительный этап включает достижение соответствующей комплексной оценки на основе каждого значения уровня. Классификация контрольных горячих точек должна быть получена в результате формирования однородных ранговых оценок всех уровней.
Ключевые слова: центр обработки данных, виртуальная машина, горячая точка, процесс нечеткой аналитической иерархии. нечеткие треугольные числа, относительное значение, атрибут типа.

Зуєв Д. О., Карпачова А. В., Усов Д.М., Горшунов Р. Застосування методу оцінки «гарячої точки» для моніторингу мереж центрів обробки даних. Розробка методології моніторингу мережі розглянута як важливий етап організації інфраструктури центрів обробки даних, відповідно до зрослими вимогами по ефективності і стабільності послуг даних сервісів. Процес оцінки «гарячих точок» індексів мережевих даних був показаний як частина методу моніторингу, що включає отримання суб'єктивного ваги і об'єктивного ваги кожного індексу, який можна використовувати для отримання всебічного оціночного індексу. Було продемонстровано, що оптимальне відносне значення представляє ступінь відповідності атрибутів до оптимального значення. Метод нечіткої трикутних чисел розглянуто для формування матриці нечітких суджень, яка включає експертну оцінку. Проаналізовано метод формування матриці порівняльних оцінок, який має на увазі отримання зважених значень з використанням теорії розміру порівняння нечітких чисел. Було відзначено, що на основі методології оцінки «гарячих точок» можна впорядкувати ступеня «гарячої точки» моніторингу та отримати ієрархію під час процесу сортування. Перший етап цього алгоритму включає в себе отримання вихідного індексу оцінки ступеня готовності, який базується на експертній оцінці. Другий етап відноситься до визначення значення для кожного рівня моніторингу вихідних даних. Заключний етап включає досягнення відповідної комплексної оцінки на основі кожного значення рівня. Класифікація контрольних гарячих точок повинна бути отримана в результаті формування однорідних рангових оцінок всіх рівнів.

Ключові слова: центр обробки даних, віртуальна машина, гаряча точка, процес нечіткої аналітичної ієрархії. нечіткі трикутні числа, відносне значення, атрибут типу.

1. Introduction

Nowadays requirements to data center services efficiency and stability have significantly grown. Hereby reliability of the network has become one of the most attention performances and server performance monitoring system becomes main tool of providing reliable network services. Organizing of data processing in real time regime is a serious task for developers while efficient monitoring system ought to be adaptive and scaled.

It should be noticed that due to virtualization of modern data center servers monitoring system functional nodes also should not be considered as physical elements. Up to the virtual machine (VM) life cycle phase the system should be divided into further main modules [1-4].

- VM monitor;
- monitoring data integration;
- cluster data integration;
- node information gathering.
- VM monitor provides transfer of significant data (e.g., CPU or RAM usage) to the monitoring system by VM-scripts. Monitoring data integrator collects significant network data and stores it in the database, while cluster data integrator gathers other data blocks for the next VM layer. gathers different local information on a cloud node according to specific demands. The node information gathering module gathers local VMs information on the network nodes. There are also should be mentioned monitoring tool server, configuration generator, user interface and database module which used to retrieves information from database (e.g., configuration data), receive monitoring data and perform actions and stores information.

Due to virtualization paradigm it possible to develop universal data center monitoring technique based on mathematical model which could be implemented to different server platforms. Among the different methods hot-spot evaluation technique is proved to be most efficient one and should be properly considered.

2. Classification of index target type

According to the hot-spot evaluation of the network data indexes it has to be calculated the subjective weight and objective weight of each index to get the comprehensive evaluating index of hot-spot degree.

Subjective weight which represents each index influencing hot degree, could be determined by its triangular fuzzy number [5] up to FAHP technique (HAHP: Fuzzy Analytic Hierarchy Process) is deployed to determine the of each index influencing hot degree. Triangular Fuzzy Number is a triplet which includes smallest likely value, the most probable value and largest possible value of fuzzy event. Objective weight could be defined by the multi-objective decision-making method which includes determination of the index target type. Thereby basic algorithm includes further stages (Fig. 1):

- subjective weight determination (FAHP technique);
- multi-objective decision-making method;
- dimensionless processing (to gain optimal size of index and its matrix):
- maximizing deviation method; (determination the objective weight of index);
- combining and comparison of subjective weights and objective weights;
- receiving of the hierarchy of VM monitored spots.

Hot-spot evaluation is handled through optimal relative and classification of index target type, the comprehensive weight calculation, the hot-spot degree comprehensive evaluation value determination and hot-spot sorting. Optimal relative value represents degree of relativeness to optimal, which is similar to the concept of membership degree. It should be determined up to the target type. Main types of attributes are:

- fixed type attribute;
- range type attribute;
- cost type attribute;
- efficiency type attribute.

Fixed type attribute F_{ij} represents stabilizing at a fixed value as a target of indexes analysis:

$$F_{ij} = \begin{cases} 1 - \frac{|a_{ij} - a_i^o|}{max_n\{a_{ij} - a_i^o\}} & for\ a_{ij} \neq a_i^o \\ 1 & for\ a_{ij} = a_i^o \end{cases}, \tag{1}$$

where a_{ij} is the measured value of i index of j VM and a_i^o is the optimal value of a_{ij}. To simplify equation (1) it should be used absolute differences maximum among n observed spot:

$$\sigma_i = max_n\{a_{ij} - a_i^o\}. \tag{2}$$

Thereby equation (1) can be simplified as:

$$F_{ij} = \begin{cases} 1 - \frac{|a_{ij} - a_i^o|}{\sigma_i} & for\ a_{ij} \neq a_i^o \\ 1 & for\ a_{ij} = a_i^o \end{cases}. \tag{3}$$

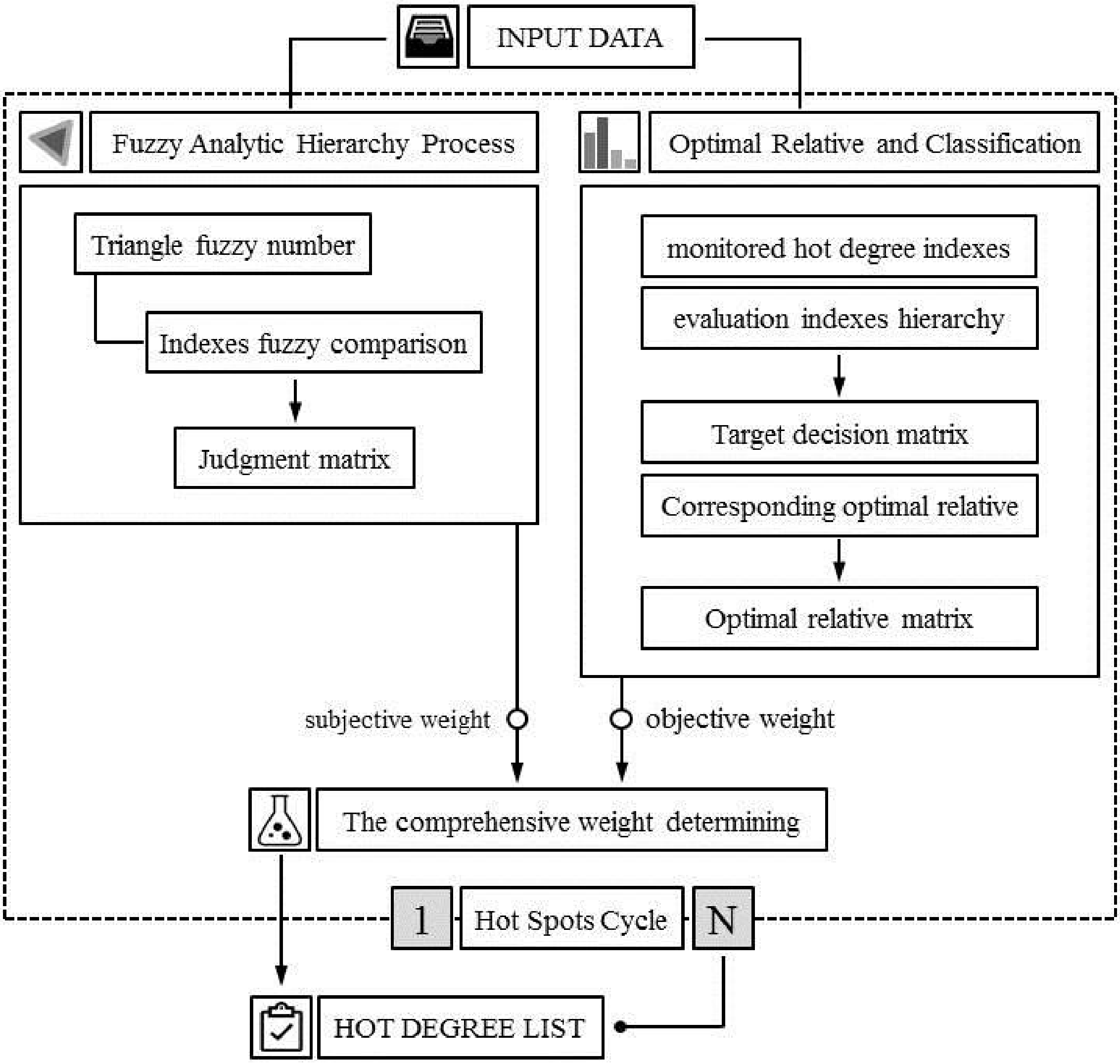

Fig. 2. Hot-spot comprehensive evaluation algorithm.

Range type attribute in other hand represents property values falling in a fixed interval as a target type of indexes.

$$R_{ij}=\begin{cases}1-\frac{a_i^L-a_{ij}}{max\{a_i^L-a_i^{min},a_i^{max}-a_i^U\}} & for\ a_{ij}<a_i^L\\ 1-\frac{a_{ij}-a_i^U}{max\{a_i^L-a_i^{min},a_i^{max}-a_i^U\}} & for\ a_{ij}>a_i^U\\ 1 & for\ a_{ij}\in[a_i^L,a_i^U]\end{cases},\qquad(4)$$

where a_i^L is best lower bound, a_i^U is best upper bound, a_i^{min} is minimum of measured values of a_i index and a_i^{max} is maximum one. To simplify equation (4) it should be used absolute maximum of a_{ij} deviating the optimal range:

$$\eta=max\{a_i^L-a_i^{min},a_i^{max}-a_i^U\}.\qquad(5)$$

Thereby equation (4) can be simplified as:

$$R_{ij}=\begin{cases}1-\frac{a_i^L-a_{ij}}{\eta} & for\ a_{ij}<a_i^L\\ 1-\frac{a_{ij}-a_i^U}{\eta} & for\ a_{ij}>a_i^U\\ 1 & for\ a_{ij}\in[a_i^L,a_i^U]\end{cases}.\qquad(6)$$

In other hand cost type attribute C_{ij} represents smallest attribute value as the best index and efficiency type attribute E_{ij} represents biggest attribute value as the best index, contrary to the cost type attribute:

$$\begin{cases}C_{ij}=\frac{1-a_{ij}}{a_i^{min}+a_i^{max}}\\ E_{ij}=\frac{a_{ij}}{a_i^{min}+a_i^{max}}\end{cases}.\qquad(7)$$

Thereby to evaluate m hot degree spots of n monitored spots, it should be formed target decision matrix A of the measured values a_{ij} and target decision matrix that converts to optimal relative matrix:

$$A=\begin{bmatrix}a_{11} & \dots & a_{1n}\\ \dots & \dots & \dots\\ a_{m1} & \dots & a_{mn}\end{bmatrix};F=\begin{bmatrix}f_{11} & \dots & f_{1n}\\ \dots & \dots & \dots\\ f_{m1} & \dots & f_{mn}\end{bmatrix}.\qquad(8)$$

At the same way range type attribute matrix, cost type attribute matrix, efficiency type attribute matrix could be determined:

$$R=\begin{bmatrix}r_{11} & \dots & r_{1n}\\ \dots & \dots & \dots\\ r_{m1} & \dots & r_{mn}\end{bmatrix};C=\begin{bmatrix}c_{11} & \dots & c_{1n}\\ \dots & \dots & \dots\\ c_{m1} & \dots & c_{mn}\end{bmatrix};E=\begin{bmatrix}e_{11} & \dots & e_{1n}\\ \dots & \dots & \dots\\ e_{m1} & \dots & e_{mn}\end{bmatrix}.\qquad(9)$$

The judgment matrix thereby represents the relative importance of an upper layer element and other layer element. Importance scale is proved to be good digital measurement method in compassion to index importance.

2. The comprehensive weight determining algorithm

Triangular fuzzy numbers FAHP technique based on the index hierarchy (Fig. 2) is developed to build the fuzzy judgment matrix. Judgment matrix includes uncertainty of subjective judgment experts and can be used to form comparative judgment matrix [6] where weighted values are obtained by using the theory of fuzzy number comparison size. For n hot-spots massive comprehensive evaluation index of the layer which is related to upper layer consists from set $X(x_1, x_2 \dots x_n)$. Thus triangular fuzzy number could be obtained as importance fuzzy judgment of index i relative to index j (determined by experts): $y_{ij} = [l_{ij}, m_{ij}, u_{ij}]$. Up to the triangular fuzzy numbers definition l_{ij} and u_{ij} represent the fuzzy extent of judgment, so $(u_{ij} - l_{ij})$ value shows comparative fuzzy degree.

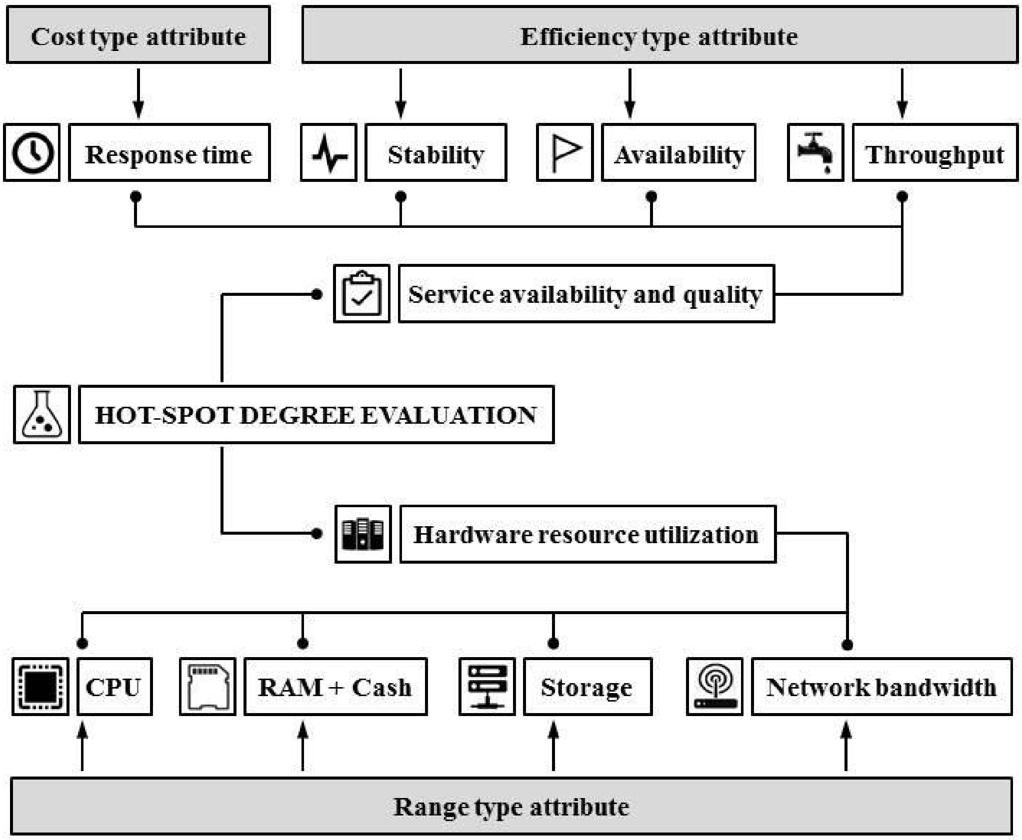

Fig. 2. The hot-spot evaluation indexes hierarchy structure.

It demonstrates the technique of the fuzzy comparison judgment matrix determination method:

$$Y = \begin{bmatrix} [l_{11}, m_{11}, u_{11}] & \dots & [l_{1n}, m_{1n}, u_{1n}] \\ \dots & \dots & \dots \\ [l_{n1}, m_{n1}, u_{n1}] & \dots & [l_{nn}, m_{nn}, u_{nn}] \end{bmatrix}. \tag{10}$$

Fuzzy comparison judgment matrix of layers as relative ones to this one could be formed at the same way. Thus, the fuzzy relative weight of index i compared with other index in this layer shoul be determined as:

$$Q_i(l_i, m_i, u_i) = \left[\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} l_{ij}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} m_{ij}}, \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} u_{ij}} \right]. \tag{11}$$

It should be noticed that each triangle fuzzy number in the fuzzy relative weight vector is required to be clarified before stage of sorting the current layer index.

The corresponding subjective weight w_i and objective weight v_i [7–10] of Q_i can be determined as:

$$\begin{cases} w_i = (l_i + 2m_i + u_i)/4 \\ v_i = \frac{\sum_{j=1}^{n} \sum_{k=1}^{n} |F_{ij} - F_{ik}|}{\sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{n} |F_{ij} - F_{ik}|} \end{cases}, \quad (12)$$

where j and k indicate different monitoring spots, and thus $|F_{ij} - F_{ik}|$ corresponds to the absolute value of the membership degree. Finally the comprehensive weight is obtained by values the subjective weight and objective weight.

$$S_i = \frac{w_i \cdot v_i}{\sum_{i=1}^{n} w_i \cdot v_i}. \quad (13)$$

The combination of the index evaluation value reflects the quality of comprehensive index and thus comprehensive evaluation value is not qualified when any of the indicators of evaluation value stays unqualified. Standard of being qualified is usually refers to actual situation.

3. Conclusions

Network monitoring strategy is a one of the key task of data center development due to requirements of services efficiency and stability. It should be noticed that organizing of adaptive and scaled algorithm of data processing in real time regime is a serious task for developers. Hot-spot evaluation of the network data indexes as a part of monitoring technique includes obtaining of subjective weight and objective weight of each index which could be used to get the comprehensive evaluating index. Optimal relative value represents degree of relativeness to optimal one up to the attributes of fixed type, range type, cost type and efficiency type.

Triangular fuzzy numbers based on the index hierarchy is used to form the fuzzy judgment matrix which includes uncertainty of subjective judgment experts. It has to be used to form comparative judgment matrix where weighted values are obtained by using the theory of fuzzy number comparison size. Based on the hot-spot comprehensive evaluation value, hot-spot degrees of all monitoring point can be ordered and hierarchy will be obtained during the sorting process. First stage includes getting hot-spot degree evaluation index system's original index grade by experts' judgment method. Next stage refers to determination of value for each level as monitoring original data. Hot-spot degree should be evaluated as the same ordinary monitoring points. Final step is achieving corresponding comprehensive evaluation value based on every level value. Hot-spot degree range of each monitoring point can be obtained as result of forming hot-spot comprehensive evaluation values' uniformly ranking of all levels. Hot-spot level of each monitoring point has to be correspondingly obtained and hot judgment of the monitoring will be received with the level of data center rules in advance.

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