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Research on Evaluation of the MANET System Survivability

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Abstract

Through the limitations of current evaluation about the MANET system survivability, a quantitative evaluation method based on grey relation analysis is proposed. First, the typical grey relation analysis method has been improved and the quantitative evaluation model base on the network entropy difference was established. Then the change of every key service's survivability situation is assessed by using the network entropy difference. At last the MANET system is simulated to test method of grey relation analysis, and the calculating result indicates that the proposed method can effectively evaluate the actual survivability of the MANET system.

Key words: MANET, survivability, entropy difference, grey relation analysis

1. Introduction

The research on the survivability of network system is an emerging area both at home and abroad, which also can be a hot area in the current study of survivability. Taking a panoramic view of research in network system, the majority put emphasis on the reliability, security issues, and so on. Few scholars to do comprehensive investigation on the entire survivability of MANET system [1-5], and the quantitative evaluation study of the survivability is even less. There are no systematic evaluation model and realization mechanisms in the MANET system survivability. This paper focuses on the survivability evaluation of the MANET system and the grey relation analysis based on information entropy difference

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was proposed. The MANET system may make a quantitative evaluation of survivability by taking full advantage of grey relation analysis evaluation model based on information entropy difference.

2. The grey relation analysis method based on information entropy difference

Grey relation analysis is a method which describe the strength or the size or the order of the relationship between factors by using the sequence of grey relation grade (also called the grey relation order), which can analyze and determine the influence between the factors or the extent of contribution to the system through the grey relation grade [6]. Grey relation analysis does not require excessive number of sample and the typical distribution, which can acquire ideal result through less calculation. These results are consistent with the results of the qualitative analysis. By using the factors data, the grey relation coefficient and the grey relation grade, the grey relation model could derive the merits of system behaviour by associated sequencing. The model can apply to the MANET system with the further improvement.

2.1. Improved grey relation analysis method

- The establishment of MANET system survivability evaluation model.

The situation evaluation process based on grey relation analysis is divided into three levels: index layer, service layer and system layer. The changes of key services in the survivability of the situation can be identified through the associated analysis of the performance index, and eventually the system situation evolution is got. Under normal circumstances the assumption that the network can provide a services set for S = {S1, S2… Sn}; network performance evaluation indexes or attributes set A = {A1, A2… Am}. Based on the requirement of MANET system survivability evaluation, services set and indexes set are established.

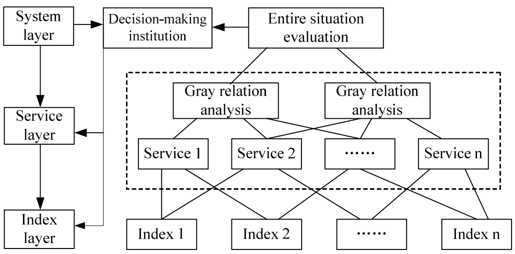

Fig 1 System Survivability Model of Situation Evaluation

- The definition of the best and the worst services indexes in evaluation.

Although these two indexes in the assessment could not exist (otherwise there is no need to do the assessment), but as the optimal and the worst starting point, the two indexes can be used to measure the degree of relationship between other services and them.

- In order to achieve the quantitative evaluation, the paper introduced the information entropy. Information entropy difference can be used in survivability evaluation of the MANET system. Information entropy is a network security performance description. The smaller (but not negative) the entropy value is, the less the understanding of the network system will be, which indicating the network system would be more stability. That means, the smaller the entropy value is, the better its survivability will be indicated; the greater the entropy value is, the poorer its survivability will be.

2.2. The grey relation analysis method based on information entropy difference

Analytical method can be divided into the following steps:

step1: The establishment of the original data matrix

After the MANET systems run services S_i over a period of time, the value X_{ij} of indexes A_j can be gained within the sampling time. The indexes set A matrix of decision-making will be achieved:

$$X = \begin{vmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{vmatrix}$$

In the survivability situation assessment of MANET systems, indexes set A can generally be classified into the cost-based type and efficiency type. The bigger the efficiency index value is, the better it will be; the smaller cost-based index value is, the better it will be. We assumed that O_1 represent efficiency index set and O_2 represent cost-based index set, then $O_1 \cup O_2$={A1,A2, …,Am}, and $O_1 \cap O_2$=§.

step2: The standardization of the decision-making matrix

As the indexes set having different dimension, the need for the original decision-making matrix to deal with non-dimensional regularization is to ensure that the comparability of indexes between the same factors. The raw data were treated as the standardization of non-dimensional by using the formula (1) or formula (2).

If the A index is the efficiency type, then

$$r_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}, i = 1,2,\cdots,n; j \in o_1 \qquad (1)$$

If the A index is the cost-based type, then

$$r_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}}, i = 1,2,\cdots,n; j \in o_2 \qquad (2)$$

It is clear that $r_{ij} \in [0,1], (i = 1,2,\cdots,n; j = 1,2,\cdots,m)$, and the standardization matrix $R = \left[r_{ij}\right]_{n\times m}$ will be achieved.

step3: The definition of the best and the worst indexes

Let $r_i^+ = \max_j r_{ij}$, $i = 1,\cdots, m; j = 1,\cdots, n$, then $r^+ = (r_1^+, r_2^+, \cdots r_m^+)$ was defined the best index and called as excellent vector index G.

Let $r_i^- = \min_j r_{ij}$, $i = 1,\cdots, m; j = 1,\cdots, n$, then $r^- = (r_1^-, r_2^-, \cdots r_m^-)$ was defined the worst index and called as sub-vector B.

step4: The calculation of grey relation coefficient

The assumption that the weight vector of each indicator is as follows: $W = (w_1, w_2, \cdots, w_m), w_i > 0, (i = 1,2,\cdots,m)$, and $\sum_{i=1}^{m} w_i = 1$. By the analysis of grey relation, the relation coefficient between arbitrary line vector $R_j = (r_{j1}, r_{j2}, \cdots, r_{jm})^T$ in the standardization decision-making matrix and vector G and vector B are:

$$\xi_{R_j,G}(k) = \frac{\min_j \min_k \left|r_{jk} - g_k\right| + \rho \max_j \max_k \left|r_{jk} - g_k\right|}{\left|r_{jk} - g_k\right| + \rho \max_j \max_k \left|r_{jk} - g_k\right|}$$

$$\xi_{R_j,B}(k) = \frac{\min_j \min_k \left|r_{jk} - b_k\right| + \rho \max_j \max_k \left|r_{jk} - b_k\right|}{\left|r_{jk} - b_k\right| + \rho \max_j \max_k \left|r_{jk} - b_k\right|} \qquad (3)$$

ρ represent distinguish coefficient and ρ∈ [0,1] (General value is 0.5). The weighting relation grade between the services Rj and the excellent vector G and sub-vector B are: $\gamma(R_j, G) = \sum_{k=1}^{m} w_k \xi_{R_j,G}(k)$ and $\gamma(R_j, B) = \sum_{k=1}^{m} w_k \xi_{R_j,B}(k)$, w_k represent the weights of each index.

step5: The achievement of quantitative evaluation to the services

According degree of the relation grade between the services indexes and system optimal vector and the worst vector, the survivability of services could be evaluated [7]. Assessment factor C_i is defined as follows:

$$C_i = \gamma_i(R_j, G) \Big/ \left(\gamma_i(R_j, G) + \gamma_i(R_j, B)\right), 0 < C_i < 1, (i = 1,2,\cdots,n)$$

The bigger the Ci is, the better the survivability of services will be.

step6: The determination of the services optimal subordination

If γ (R_j, G) is bigger, it means that the system service and the optimal vector G get a closer relation, and the service is in better situation. If γ (R_j, B) is bigger, it means that the system service and the worst vector B get a closer relation, and the service is in worse situation. In order to find the optimal solution vector of system: u = (u1, u2…un), the Lagrange function was established in accordance with the least square method.

$$F(u_j) = \sum_{j=1}^{m} \left\{ \left[(1-u_j)\gamma(R_j, G)\right]^2 + \left[u_j \gamma(R_j, B)\right]^2 \right\} \qquad (4)$$

By using the formula (4) and $\frac{\partial F(u_j)}{\partial u_j} = 0$, it can be concluded $u_j = \left\{1 + \left[\gamma(R_j, B)/\gamma(R_j, G)\right]^2\right\}^{-1} (j = 1,2,\cdots,n)$. u_j Represent the optimal service subordinate degrees of Sj to the system.

step7: The realization of system quantitative evaluation

First of all, the definition is given in the following:

Definition 1: The survivability probability of service can be defined as: $P(u_j \mid u_j \geq \delta) = \frac{u_j}{u_{\max}}$, (j = 1, 2, , n), u_j represent the subordinate degree of service S_j to the system optimal vector; u_{max} represent the maximum degree of subordination; δ represent system subordination threshold (General value is 0.4). If $u_j<\delta$, the service is unavailable.

Definition 2: we assumed the survivability probability of services S_j is P1 before the evaluation, the survivability probability of service S_j is P2 after the evaluation, and then the entropy difference $\Delta P = -\log_2\left(P_2 / P_1\right)$ can be used to describe the survivability changes of service S_j.

According to the definition 1 and definition 2, if △P≤t (t is a constant less than 1, called as the survival threshold, in general t≤0.9), it indicate that the system can provide the normal services; if △P>t, it mean that the system can not provide the normal service. In order to characterize the survival changes trend of key service in detail, it is generally used the following Table 1 to describe the form of classification [8].

Table 1 classification of survival situation levels

△P range	＜0.1	0.1～0.9	0.9～1.7	1.7～3	＞3
grade	better	normal	bad	worse	worst
Performance decline	＜3%	3%～8%	8%～20%	20%～50%	＞50%

Definition 3: It was assumed that H1 represent the network entropy difference before the evaluation and H2 represent the network entropy difference after the evaluation, then $\Delta H = H_2 - H_1 = \sum_{i=1}^{n} w_i' P_i^{(2)} - \sum_{i=1}^{n} w_i' P_i^{(1)} = \sum_{i=1}^{n} w_i' \Delta P_i, (i = 1,2,\cdots,n)$.

w_i represent the weight of service S_i relative to the whole services of the MANET system, and the value was specified by the system administrator. The survivability situation of entire MANET system can be described by the value △H in the assessment. If △H get greater value, it means that the system survivability is in worse situation, or the system's ability to provide key services is decline.

3. Simulation of the MANET system

3.1. Setting up the experimental environment

OPNET Modeler [9] was used in the simulation. The parameters which were set for simulation are shown in Table 2. In order to have meaningful comparisons, each simulation experiment was run for five different seed value and all timers were set to 3 seconds. In the MANET system, node mobility and the number of nodes would have impact on the survivability of the system. Therefore, the simulations will be run under two cases: different mobility and different members.

Test 1: member = 5, 10, 20, 30, 40; Test 2: mobility = 0, 5, 10, 15, 20; (m / s)

Table 2 Terms of parameters in simulation

Simulator	OPNET Modeler 11.0
Total Nodes	50
Simulation Time	100s
Simulation Area	1000m×1000m
Node Placement	Random
Mobility	Random Way-point
Pause Time	10s
Min-Max Vel.	0 – 20m/s
Transmission Power	15dbm
Channel Capacity	2Mbps
Mac Protocol	IEEE 802.11

3.2. Indexes data collection

The survivability of the system can be analyzed by testing the ability of the system to provide essential services and secondary services in testing process. The services set in simulation were Video multicast、Web、Telnet and Ftp。The types of services could be specified by the requirements of users.

In accordance with the survivability index of MANET system, the data need to collect include: the reliability index (reliability A1), the integrity indicator (checksum intensity A2), and the availability index (packet loss rate A3, Delay A4, the average response time A5, throughout A6、Channel utilization A7), the confidentiality index (denial of access level A8, unauthorized access level A9). A1 is relative with MTBF. The parameters can be acquired directly from the device parameters table. A8 and A9 is tested to score by the administrator, which value ranging from 1 (best) to 4 (worst). Based on the actual business applications characteristics and needs, the value of A8 and A9 were defined in Table 3:

Table 3 the definition of A8 and A9 in MANET system

Service	confidentiality	
	denial of access level A8	unauthorized access level A9
S1	3	3
S2	2	2
S3	3	3
S4	2	2

Four different types of service will be loaded to the system in the test process. As the system provides the services, the random data sampling would be executed. According to various indexes that could be affecting the survivability, we could given the weight of the following indexes{0.1,0.1,0.15,0.2,0.12,0.1,0.08,0.05,0.1}, and given the weight of various services {0.35,0.3,0.15,0.2}.

4. The quantitative evaluation of MANET system survivability

In the experiment, the indicators data is collected under different environmental. MANET systems survivability can be evaluated from four aspects of system: reliability, integrity, availability and confidentiality through the sampling data.

According to the improved grey relation method, service index set construct the original matrix with the data of sampling. The result acquired by the grey relation method base on entropy difference is in line with the actual situation. The quantitative calculation of the various services is as follow:

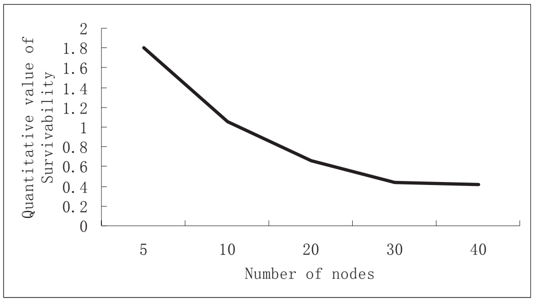

Fig 2 Survivability with different number of nodes

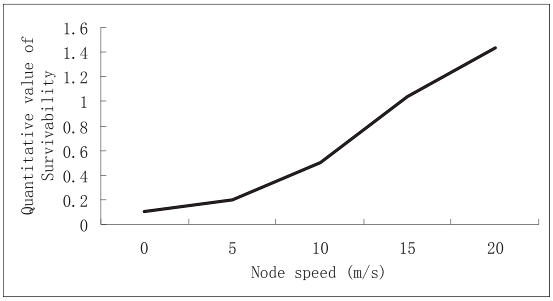

Fig 3 Survivability with different speed

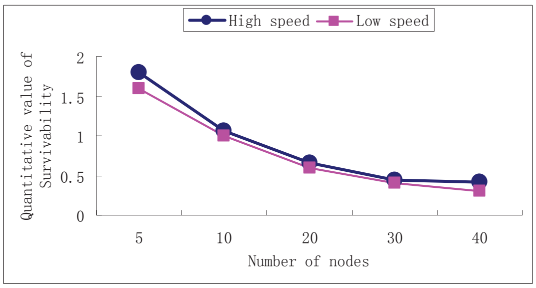

Fig 4 Survivability comparison with different speeds

The following conclusions can be drawn through the experiments and results:

From the Figure 2 and Figure 3, we can see that MANET system survivability increased with the increased number of nodes, and decreased with increasing velocity. The results of qualitative analysis were consistent with the results of quantitative analysis basing on the grey relation algorithm. Figure 4 shows the survivability of service was changed in different numbers and mobile speed, which could to be able to compare systems in different situation for survival of quantitative analysis. The results coincide with the actual situation.

5. Conclusion

The grey relation method based on entropy difference, not only to accurate quantitative analysis the survivability of MANET systems and describe survivability situation, but also to provide the quantitative value used in comparison between different systems or system in different times. MANET system survivability research is still at the initial stage, the majority of existing research is the theoretical basis study, and there is no complete theory and architecture at the present time.

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