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QoS Routing Algorithm Based on Entropy Granularity in the Network Transmission

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Abstract**:** *With the rapid development of computer networks, more hosts are connected to the Internet where they could communicate with each other. The need for network service has exceeded the service capacity of the network, and the Quality of Service* (*QoS*) *is gradually declining. Based on existing Shortest Path First* (*SPF*) *algorithm, this paper proposes a new QoS required transmission path approach by considering the overhead balance of network resources. This paper uses the entropy granularity as the main line in the application of routing protocols. Firstly, it researches the optimization of routing algorithms for network load balancing resources, routing algorithms based on link traffic distributing weights, link weight optimization based on adaptive genetic algorithm and computational intelligence based on entropy granularity theory. This research proposes a method to apply entropy granularity to Open Shortest Path First* (*OSPF*) *routing, including the implementation of the method. After that, a case study is presented by using some examples.*

Keywords**:** *Quality of Service* (*QoS*), *routing, entropy, granularity, network communication.*

1. Introduction

In recent years, the total bandwidth of Internet lines and the number of users have increased rapidly [1]. The formulation of network protocols and the submission of draft standards require participation and support from the basic research of the network. Nowadays, it is difficult to put forward new agreements or drafts for only learning the existing protocols. With the rapid development of computer networks, more hosts are connected to the Internet. The need for network service has exceeded the service capacity of the network, and the Quality of Service (QoS) is gradually declining [2]. The purpose of optimizing network resources is to make full use of the resources under the premise of satisfying the quality requirements of the service and to avoid the situation where some resources are not fully utilized [3-7]. The traditional

Shortest Path First (SPF) algorithm (such as Dijkstra's algorithm) mainly focuses on how to find a best path to meet the request or have the largest possibility to meet the request path [8, 9]. However, it may ignore the overall network resources and cause low comprehensive utilization. There may even be some problems such as network congestion, which may cause the decreasing in the overall number of requests and affect the performance of the network [10].

Bellman-Ford algorithm considering two variables (path bandwidth, link transmission delay) was proposed to solve the QoS routing problem [11]. This algorithm makes assumptions about the network model, assuming that a node-based router adopts a rate-based scheduling algorithm. From the calculation formula of the maximum end-to-end delay of the scheduling algorithm, the factors that determine the path delay including link transmission delay and path bandwidth can be identified. Therefore, the network topology maps based on different bandwidths was introduced to calculate the shortest path according to the link length on different topological maps [12]. The algorithm maximizes the use of network resources at the time and satisfies a certain QoS request at that time. However, the algorithm does not consider the cost paid by the network. For example, when the available network topology map is constructed to meet a traffic request, some bandwidth is insufficient, and the link is pruned [13, 14]. When there are more requests, especially in the cast of heavy network load, subsequent requests may not be satisfied because of the previous occupancy of bandwidth, which may lead to a decrease in overall reception rate [15]. In addition, if the load balancing algorithm pursues the greatest degree of balanced use of network resources, not only delay sensitive services cannot accept the computational delay caused by complex calculations, but also it is not necessary to achieve the absolute equilibrium state of the network.

Based on existing SPF algorithms (such as Dijkstra's algorithm), this paper proposes a new QoS required transmission path approach by considering the overhead balance of network resources. First of all, it considers the optimization of routing algorithms for network load balancing resources. Routing algorithms based on link traffic distributing weights, link weight optimization based on adaptive genetic algorithm and computational intelligence based on entropy granularity theory are integrated secondly. Thirdly, this approach specifically applies entropy granularity to Open Shortest Path First (OSPF) routing, including the implementation of the approach. By doing this, it avoids heavily occupied bottleneck links. Compared with the existing SPF algorithm, this algorithm can effectively use network resources and can improve the request acceptance rate of the network.

This paper is then organized as follows. Section 2 gives the definition of two measurements using the mathematic manner. Section 3 reports on the QoS routing algorithm based on the hypothesis and analysis of the complexity from theoretical point of view. Section 4 talks about the improved algorithm using entropy granularity concept. The entropy space model and entropy granularity are introduced. Section 5 illustrates the implementation of the algorithm and measurement through an example. Conclusions and future research directions are talked on Section 6.

2. Definition of two measurements

The purpose of optimizing the use of network resources is to maintain the resource utilization in a state of equilibrium while ensuring the quality of QoS services [16]. So the acceptance rate of request for the network should be as high as possible. This section introduces two measures of network load balancing and request acceptance and their mathematical descriptions.

A network can be represented as a directed graph $G = \langle V, E \rangle$, where V represents a set of router nodes in the network and E represents a set of links between routers. Assuming that the number of network link is m, that is $|E| = m$, and the bandwidth of link l is C_l and the remaining bandwidth of the link is R_l, then the resource idle rate of link l is

(1) $$B_l = \frac{R_l}{C_l}.$$

In this way, the mean value $E(B)$ of the resource idle rate of the link in the network can be obtained:

(2) $$E(B) = \frac{\sum_{l=1}^{m} B_l}{m}.$$

Network load balancing is used to characterize the degree of deviation of the resource idle rate of each link [17, 18]. It is recorded as DU. The smaller the value of DU, the more balanced the network resource usage will be. The mathematical formula is as follows:

(3) $$\mathrm{DU} = \frac{\sum_{l=1}^{m} (B_l - E(B))^2}{m}.$$

The request acceptance rate is used to measure the network's ability to accept business requests, denoted as AP, which can be described as:

(4) $$\mathrm{AP} = \frac{C_a}{C_r},$$

where c_a is the number of service requests that have been received, and c_r is the total number of service requests at a certain time. For the entire network, under the premising QoS service, if the load of each link tends to be consistent, the higher the request receiving rate means the network resources are optimized and utilized.

3. QoS Routing Algorithm

3.1. Network model hypothesis

Assume that the state information published by the network is accurate. In this environment, the following assumptions about the network model are given:

(1) The remaining bandwidth published per link is accurate, P_{st}^k represents the number of *k* shortest path from the source node *s* to the target node *t*, and q_{st}^k represents the data traffic on the *k* path.

(2) A special scheduler using a Weighted Fair Queuing Scheduler or a Rate Controlled Earlist Deadline First Scheduler [19] is used at all nodes of the network to ensure that the end-to-end time delay of the path *p* is as follows:

$$D(P) = \frac{\sigma}{\rho} + \frac{cn}{\rho} + \sum_{l \in P} dl, \tag{5}$$

where σ is the flow's burst, *c* is the maximum packet size of the stream, *dl* is the static delay, which is the propagation delay on link *l*, and ρ is the reserved bandwidth rate; *n* is for the number of path link segments, *P* is the selected transmission path.

The problem description could be translated into: for the network $G = \langle V, E\rangle$, there is a request $R = (s, t, \rho', D')$, looking for one or several paths from the ingress node *s* to the target node *t*, so that the remaining bandwidth of the path or the remainder of several paths or the sum of the bandwidths is not less than ρ', and their delays are not greater than D'.

3.2. QoS routing algorithm based on the network utilization

According to the resource request of the upper section traffic, the routing algorithm is used to calculate the number of different link hops and the transmission path satisfying the path delay requirement. It calculates the load balance degree for each path with remaining bandwidth, and selects the minimum load balance degree path as an optional route [20, 21]. If the remaining bandwidth of the selected path is insufficient, the re-routing strategy is used to select the path of the second minimum load balance as the selected route, and the occupied bandwidth is the bandwidth request bandwidth minus the bandwidth allocated to the previous path. The path chosen is not necessarily the least delay, but it can balance the network load. The specific algorithm description is as follows:

Step 1. When the traffic request occurs, obtain the bandwidth request ρ' and the delay request D' that needs to be reserved.

Step 2. Based on the adjacency matrix *A* of the available bandwidth in order to satisfying the delay requirement from the entry node *s* to the exit node *t*, calculate the shortest path p_{st}^1, the second shortest path p_{st}^2, the third shortest path p_{st}^3, ..., the *m*-th shortest path p_{st}^m.

Step 3. If the calculated available path set is empty, then the traffic request will be rejected and go to Step 6. If the available path set is not empty, calculate the different load balance paths $\mathrm{DU}_1, \mathrm{DU}_2, ..., \mathrm{DU}_m$, which is recorded as $\mathrm{TDU} = \{\mathrm{DU}_i, 1 \le i \le m\}$.

Step 4. Choose the minimum network load balance.

$$\mathrm{DU}_k = \min \mathrm{TDU}.$$

The corresponding path is p_{st}^m,

$$q_{st}^k = \min\{\rho', \min_{l \in p_{st}^k}\{R_l\}\},$$

$$\rho' = \max\{0, \rho' - q_{st}^k\},$$

$$R_l = R_l - q_{st}^k, \quad l \in p_{st}^k.$$

Step 5. If ρ' is not equal to 0, $\text{TDU} = \text{TDU} - \{\text{DU}_k\}$ then go to Step 4; if ρ' is equal to 0, then move to Step 6.

Step 6. Return and algorithm finish.

3.3. Analysis of complexity

The key step of the algorithm is to calculate the shortest path between the pair of ingress and egress nodes, the second shortest path, and the *m* shortest path, as can be seen from the literature. Complexity of calculating the shortest path in the network is $O(n^3)$, the complexity of calculating the second shortest path is $O(n^4)$, and the complexity of calculating the *m*-th shortest path is $O(n^{m+2})$. If $m = 1$, this algorithm is the classic SPF routing model.

4. The improved algorithm using entropy granularity

In computer networks, traditional shortest path routing often causes network congestion and increases latency, while links on longer paths are not fully utilized. Even if the network is expanded, it will not solve the problem fundamentally and cause waste of resources. QoS routing can be solved under certain network resources. The QoS requirements of a single stream such as bandwidth, delay, time jitter, etc. [22]. It should be noted that the QoS constraint considered in the routing is only the bandwidth requirement. This is because other QoS requirements such as delay and packet loss rate can be converted into equivalent bandwidth, and many real-time applications have bandwidth strict requirements [23].

4.1. Entropy space model

The routing network could be expressed as a weighted graph $G(X, E)$. X is the finite set of nodes and E is the set of edges. $w: E \to R^+$, $w(e) \in [0, d]$ is the weight of edge e. Let all the weight follows $\{d_1 > d_2 > ... > d_k\}$, we can define an equity relation $R(d_i)$: $x \sim y \Leftrightarrow \exists x = x_1, x_2, ..., x_m = y$, $w(x_j, x_{j+1}) \geq d_i$, $j = 1, 2, ..., m-1$, $i = 1, 2, ..., k$. We can define the entropy space for $R(d_i)$ as $X_i = \{x_1^i, x_2^i, ..., x_{n_1}^i\}$, $i = 1, 2, ..., k$. Mark $X = X_0$, x_i^0 is the element from X and will be presented by hierarchical structure. Assume $z \in X$, $z = (z_0, z_1, ..., z_k)$, $p_i: X \to X_i$ is the mapping which is defined as natural projection. Let $p_i(z) = x_i^i$, the number i coordinates of x is $z_i = t$. That means the number of t element of z in X_i. The edge set of X $E_0 : e = (x_j^0, x_i^0)$, $w((x_j^0, x_i^0)) \geq d_1$. We can get (X_0, E_0), $e(x_j^0, x_i^0) = (x_j^0, x_i^0)$. For X_1, we can define edge set $E_1 : (x_j^1, x_i^1) \in E_1 \Leftrightarrow \exists x_j^0, x_i^0 \in X, x_j^0 \in x_j^1, x_i^0 \in x_i^1$, $w((x_j^0, x_i^0)) \geq d_2$. And the edge should meet the following condition:

$$e(x_j^1, x_i^1) = \{((x_j^0, p_1(x_j^0)), ((x_i^0, p_1(x_j^0))), \forall x_j^0, x_i^0 \in X, x_j^0 \in x_j^1, x_i^0 \in x_i^1, w((x_j^0, x_i^0)) \geq d_2\},$$

$$e(x_j^1, x_i^1)$$

is the edge set of X, labeled as e_{ji}^1. Then, we can get the entropy space is (X_i, E_i).

We can define E_i for X_i:

$$E_1 : (x_j^i, x_i^i) \in E_i \Leftrightarrow \exists x_j^0 \in x_j^i, x_i^0 \in x_i^i, w((x_j^0, x_i^0)) \geq d_{i+1},$$

$$e(x_j^i, x_i^i) = \{((x_j^0, p_1(x_j^0)), ..., p_i(x_j^0) = x_j^i, ((x_i^0, p_1(x_i^0)), ..., p_i(x_i^0) = x_i^i))$$

$$\forall x_j^0 \in x_j^i, \ x_i^0 \in x_i^i, \ w((x_j^0, x_i^0)) \geq d_{i+1}.$$

The entropy space is (X_i, E_i), $i = 0, 1, ..., k-1$.

Based on that, we can give the following definitions:

Definition 1. $\forall x, y \in X, d_i$, x, y is connected by $d_i \Leftrightarrow$ in X, there is a path with the weight $w \geq d_i$ from x to y.

Definition 2. $\forall x = (x_0, x_1, ..., x_k)$, $y = (y_0, y_1, ..., y_k) \in X$, d_i, x, y is connected by $d_i \Leftrightarrow$ $x_i = y_i$, where $x = (x_0, x_1, ..., x_k)$, $y = (y_0, y_1, ..., y_k)$, are presented by hierarchical structure.

Proof: Let $x_i = y_i$, x, y are the connection of X_i. Thus, $p_{i-1}(x)$ and $p_{i-1}(y)$ will be connected via d_i on (X_{i-1}, E_{i-1}). Additionally, $p_{i-2}(x)$ and $p_{i-2}(y)$ will be connected via d_{i-1}. Therefore, on (X_{i-2}, E_{i-2}), they are connected. Using the same principle, we can get x, y are connected via d_i on X.

Let x, y be connected on X through d_i. Then $p_i(x) = p_i(y)$, thus, $x_i = y_i$.■

4.2. Entropy granularity

For each element x_m^i in (X_i, E_i), a matrix MT_m^i could be established. Let x_m^i has s elements from X_{i-1}, thus, $m = 1, 2, ..., n_i$,

$$\mathrm{MT}_m^i(tj) = \begin{cases} e((x_t^{i-1}, x_j^{i-1})) & \text{if} \quad (x_t^{i-1}, x_j^{i-1}) \in E_{i-1}, \\ \varnothing \quad \text{otherwise}. \end{cases} \tag{6}$$

The granularity could be expressed as $\{\mathrm{MT}_j^i,\ j = 1, 2, ..., m\}$.

Assume that an element x_m^i is from X_i which is consisted by a set of nodes from X_{i-1}. When there is an edge connecting x_t^{i-1} and x_k^{i-1}, there are some nodes x_t^{i-2} and x_k^{i-2} from X_{i-2} which are connected. Thus, the granularity of the entropy could be used for some network transmission to examine the QoS routing problem.

The most significant contribution by using the entropy granularity is as follows. In the first place, the weighted connection (edges) in the network could be sequenced when considering the communication among different hosts. So that, the prioritized request will be dealt with first so as to improve the QoS. Secondly, the entropy granularity based on the route connection is used for examining the routing. The connection for transmission will be quantitatively examined through the granularity matrixes which are formed by the elements in the network.

5. Implementation and discussions

5.1. Problem statements

Given a network $G(X, E)$, there are two sets: $x = (x_0, x_1, ..., x_k)$, $y = (y_0, y_1, ..., y_k)$, assume that $x_i = y_i$, $x_j \neq y_j$, $j < i$. Find a connected route from *x* to *y* where the entropy granularity is of minimum value. The mean value $E(B)$ and DU are minimized. The solution follows several steps:

1) Initiate $x = (p_0(x), p_1(x), ..., p_k(x))$, $p_i : X \to X_i$, $i = 1, 2, ..., k$, $X = X_0$.

2) The start set $x = (x_0, x_1, ..., x_k)$, $y = (y_0, y_1, ..., y_k)$, let $x_k = y_k$, then they are connected in (X_{k-1}, E_{k-1}). That means they are equal in X_k.

a. Get $p_{x_k}^k$, the path $e(x_{k-1}, y_{y-1})$ presents the node x_{k-1} to y_{y-1}. The path includes some nodes a_k which are inserted into *x* to *y*. Then, we can get a node set N_s including $a_k + 2$ elements. In N_s, from number 2*i* node to 2*i* + 1, there is a d_k edge for connecting the nodes. There is no edge for connecting number $2i - 1$ node and 2*i*. However, the coordinates of *k* – 1 are the same. Thus, they are connected in (X_{k-2}, E_{k-2}), $i = 1, 2, ..., a_k + 1$. Let $k \leftarrow k - 1$, go to Step 1.

b. When the coordinates of numbers $2i - 1$ and 2*i* nodes are the same, we can get a node set N_s.

c. Calculate MT, $\mathrm{MT} = \ln \sum e((x_i, y_j))$.

d. Calculate $E(N_s) = \dfrac{\sum_{i=1}^{a_k+1} B_i}{k}$.

e. Calculate $\text{DU} = \frac{\sum_{i=1}^{a_{k+1}} (B_i - E(N_s))^2}{k+1}$.

As $x = (x_0, x_1, ..., x_k)$ is the starting set, and $y = (y_0, y_1, ..., y_k)$ is the destination, let $x_k = y_k$, then the connection for (x_{k-1}, y_{k-1}) in (X_{k-1}, E_{k-1}) is $e(x_{k-1}, y_{y-1})$. Then we can get:

(7) $$x^1 = (x_0^1, x_1^1, ..., x_{k-1}^1 = x_{k-1}),$$

(8) $$x^2 = (x_0^2, x_1^2, ..., x_{k-1}^2 = y_{k-1}).$$

Put (7) and (8) into N_s, we can get $N_s = (x, x^1, x^2, y)$. Since the coordinates of x and x^1, x^2 and y have the same coordinates of $k - 1$, we can figure out the connection in (X_{k-2}, E_{k-2}). Therefore, we can find the minimum value of $E(B)$ and DU.

5.2. An experimental case

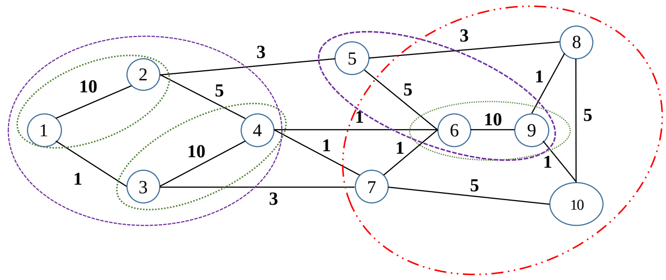

Fig. 1. Entropy granularity topological network

This section takes an example to demonstrate the feasibility of the proposed algorithm. Fig. 1 show the entropy granularity topological network which includes 10 nodes $\text{Node} = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}$. The weight set for each connection is $w = (10, 1, 5, 10, 3, 3, 1, 1, 1, 5, 5, 3, 1, 1, 5)$. Assume that (X_0, E_0) has 10 elements:

(9) $$(X_0, E_0) \quad x_1^0 \to x_2^0, x_3^0 \to x_4^0 x_6^0 \to x_9^0, x_5^0, x_7^0, x_8^0, x_{10}^0.$$

We can get the entropy set for $R(10)$ is

(10) $$X_1 = \{x_1^1 = (1, 2), x_2^1 = (3, 4), x_3^1 = (5), x_4^1 = (6, 9), x_5^1 = (7), x_6^1 = (8), x_7^1 = (10)\}.$$

The seven elements have the granularity matrices:

(11) $$P_1^1 = \begin{pmatrix} 1 & (1, 2) \\ & 1 \end{pmatrix}, \ P_2^1 = \begin{pmatrix} 1 & (3, 4) \\ & 1 \end{pmatrix}, \ P_3^1 = \begin{pmatrix} 1 & (6, 9) \\ & 1 \end{pmatrix}, \ P_4^1 = P_5^1 = P_6^1 = P_7^1 = (1).$$

Based on the granularity matrix, the entropy space is shown in Fig. 2.

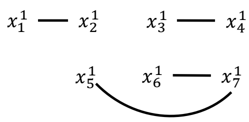

Fig. 2. Granularity space topology for $R(10)$

For $R(5)$, using the same steps from the proposed algorithm, we can get the entropy set $X_2 = \{x_1^2 = (1, 2, 3, 4), x_2^2 = (5, 6, 9), x_3^2 = (7, 8, 10)\}$. There are three elements and the granularity matrixes for them are as follows:

(12) $$P_1^2 = \begin{pmatrix} 1 & ((2,1),(4,2)) \\ & 1 \end{pmatrix},\ P_2^2 = \begin{pmatrix} 1 & ((6,3),(9,4)) \\ & 1 \end{pmatrix},$$

$$P_3^2 = \begin{pmatrix} 1 & 0 & ((7,5),(10,7)) \\ & 1 & ((8,6),(10,7)) \\ & & 1 \end{pmatrix}.$$

The entropy space of (X_2, E_2) is shown in Fig. 3.

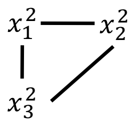

Fig. 3. Granularity space topology for *R*(5)

For $R(3)$, there is only one element $x_1^3 = (1, 2, 3, 4, 5, 6, 7, 8, 9, 10)$, the matrix is then as follows:

(13) $$P_1^3 = \begin{pmatrix} 1 & ((2,1,1),(5,3,2) & ((3,2,1),(7,5,3)) \\ & 1 & ((5,3,2),(8,6,3)) \\ & & 1 \end{pmatrix}.$$

5.3. Discussions

From the matrix, it could be observed that $p_{tj}^i = (a, b)$ then $p_{jt}^i = (b, a)$. We can have the 10 sets for the QoS routing,

$$N_1 = (1,1,1,1),\ N_2 = (2,1,1,1),\ N_3 = (3,2,1,1),\ N_4 = (4,2,1,1),\ N_5 = (5,3,2,1),$$
$$N_6 = (6,4,2,1),\ N_7 = (7,5,3,1),\ N_8 = (8,6,3,1),\ N_9 = (9,4,2,1),\ N_{10} = (10,7,3,1).$$

Let the starting set is $x = N_1 = (1,1,1,1)$ and the destination is $y = N_{10} = (10,7,3,1)$. As $x_3 = y_3$, the maximum path capacity is $d_3 = 3$.

We can get the $N_s = ((1,1,1,1),(10,7,3,1))$, as $x_3 = y_3 = 1$, the connection from P_1^3 could be extracted for inserting to N_s = ((3, 2, 1), (7, 5, 3)) will be used and the following result could be obtained:

$$N_s = ((1,1,1,1),((3,2,1),(7,5,3)),(10,7,3,1)) \Rightarrow [3,7],$$

Since the second coordinates for (1, 1, 1, 1), ((3, 2, 1) and (7, 5, 3)), (10, 7, 3, 1) are the same, the connections could be calculated from P_1^2 and P_3^2. We can get the following matrix and insert into N_s.

((2, 1), (4, 2)), ((7, 5), (10, 7)),

$$N_s = ((1,1,1,1),(2,1),(4,2),(3,2,1),(7,5,3),(7,5),(10,7),(10,7,3,1)) \Rightarrow [2,4][3,7][7,10].$$

Since the first coordinate of

$$((1,1,1,1),(2,1)),\ ((4,2),(3,2,1)),\ ((7,5,3),(7,5)),\ ((10,7),(10,7,3,1)),$$

the connections could be obtained from $P_1^1,\ P_2^1, P_7^1$:

$$(1, 2), (3, 4), (7, 7), (10, 10).$$

Then we can get the updated N_s

$$N_s = ((1,1,1,1),(1,2),(2,1),(4,2),(3,4),(3,2,1),(7,5,3),(7,7),(7,5),(10,7),(10,10),(10,7,3,1)) \Rightarrow$$

$$\Rightarrow [1,2][2,4][4,3][3,7][7,7][7,10][10,10].$$

Thus, we can finally get

$$(1,2,4,3,7,10).$$

We can calculate the following measurement:

Calculate MT, MT = $\ln \sum e((x_i, y_j))$ =ln(10+5+10+3+5)=3.49.

Calculate $E(N_s) = \dfrac{\sum_{i=1}^{a_k+1} B_i}{k}$ =(10+5+10+3+5)/5=6.6.

Calculate DU = $\dfrac{\sum_{i=1}^{a_k+1} (B_i - E(N_s))^2}{k+1}$ =6.87.

Finally, the acceptance rate AP could be calculated.

From this case, it could be observed that, the optimization from different iterations could be achieved. The network routing could be converted into the establishment of entropy space. From the space, the network routes could be obtained based on the objective functions such as the mean value $E(B)$ of the resource idle rate and acceptance rate AP. Compared with traditionally QoS routing approach with the AP of 29.41% [24], this proposed algorithm has higher ratio.

$$\mathrm{AP} = \frac{C_a}{C_r} = \frac{5}{6} \times 100\% = 83.33\%.$$

From this case, some contributions could be summarized from the following aspects. Firstly, two measurements are defined in this paper to evaluate the routing results. They could be used for quantitatively examining the service acceptance ratio and network reliability. Secondly, entropy granularity is defined for hierarchical examination of the routes. A set of nodes will be established through iteration of the paths. The routing problem is converted into entropy space which could be linked with the QoS. The proposed algorithm has higher network reliability ratio than typical routing approaches using fuzzy logic methods. The objective function using the resource idle rate for evaluating the network QoS which could be improved by comparing different granularity matrixes.

6. Conclusion and future work

This paper uses the computational intelligence based on entropy granularity as the core in the application of routing protocols. Firstly, it researches the optimization of routing algorithms for network load balancing resources, routing algorithms based on link traffic distributing weights, link weight optimization based on adaptive genetic algorithm and computational intelligence based on entropy granularity theory. This research proposes a method to apply entropy granularity to Open Shortest Path First (OSPF) routing. After the implementation of the method, experimental results are presented by using simulation studies. Finally, the significance and practical application of entropy granularity in the network transmission of OSPF routing are discussed.

Future research direction will be conducted in the following aspects. In the first place, how to consider more impact factors from the network so that to evaluate the reliability of QoS will be further studied. For different networks, several models containing different mechanisms could be considered. Moreover, the type of data in the network will be extended. The performance of packet loss rate, round-trip time and receiver advertised window could be examined by using Markov chain approach. Finally, a prototype system will be established for testing the feasibility of the proposed approach. More quantitative analysis will be given to improve this research in the near future.

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