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An Applied Research on the Algorithm by which Gateway Device Plans the Message Path in the Wireless Network

Xunfang LIU[1], Shuguang WU[2]
[1]Hunan City University, Hunan Yiyang 413000, China
[2]Modern Education Technology Center, Hunan University of Technology, Zhuzhou, Hunan, China

Abstract: In the traditional industrial wireless network, the algorithm to plan the massage path in property diagnosing will appear such situations as message jamming , interference and communication capability depression when routing node seeks for the massage path .This article will show a algorithm by which gateway device plans the message path in the wireless network, and analyze the shortcomings the traditional routing node has when it runs the algorithm , as well as the law of the industrial wireless network communication data .To fully consider the indexes of time lapse, energy consume , reliable transmission and load balancing , it simplifies the algorithm process of the message path , also shows the specific steps of the algorithm by which gateway device plans the message path. Finally, we conduct the comparative experiments emulation twice to compare it with AODV in the aspects of dropped packets number, throughput as well as the time lapse .The experiment manifests that the algorithm in this thesis is more useful in the industrial wireless network path planning than AODV.

Keywords: Routing Node; Running Algorithm; Gateway Device; Communications Volume

1. Introduction

Industrial wireless technology is another hot technology after site bus line in the industrial control field. It is the revolutionary technology that can cut down the cost and enlarge the applied range of industrial measure and control system. It is a new increasing point of industrial automation products in the few years [1-3].It is a burgeoning technology in the early century, aiming at short journey and low-rate information exchange. It is good to use in the bad industrial scene with the features of strong anti-jamming capability, minimum energy consume, real-time communication and so on. It is the function spread and technology innovation of the existing wireless technology in the industrial application field, finally converting into the new standards of wireless technology [4-6].
It develops from the rising wireless sensor network technology which has the feature of application dissimilation, aimed at such different areas as military affairs, medical treatment, families and so on, but the implementation technique of the both is different. Industrial wireless technology is a kind of wireless sensor network technology which can meet such special needs as reliable industrial application, low energy consume, good real time and so on [7-9].
As semiconductor microelectronics, communication and computer technology are developing rapidly, wireless sensor network technology has achieved great improvement. Wireless sensor network technology can get various objective physical information, thus to be applied in military affairs, national defense , industrial and agricultural control , city administration , biological medical treatment, environment monitor, emergency and disaster dealing and many other fields, especially in the industrial field apparatus monitor in a bad environment [10-14].
In the wireless sensor network, routing protocol will transmit the data group to the aimed node through the source node [15-18]. The key point of routing is to find the smaller communication delay path from the source node to the aimed node, thus to increase the utilization ratio of the whole network, prevent communication jamming and balance the network discharge. The realization of routing needs network manager’s allocation towards communication resources whose allocative efficiency will influence the every property of the network directly.
With the development of wireless sensor network technology, many routing protocols specially towards wireless sensor network appear, and are applied to industrial wireless technology. According to the different applied targets, these routing protocols can be divided into four types: energy perception routing protocol, inquiry-based routing protocol, geographical position routing protocol and reliable routing protocol.
This article has discussed the following aspects in the widening and innovation:

(1) The traditional algorithm to plan the massage path in property diagnosing will appear such situations as message jamming, interference and communication capability depression when routing node seeks for the massage path. This article will show a algorithm by which gateway device plans the message path and analyze the shortcomings the traditional routing node has when it runs the algorithm , as well as the law of the industrial wireless network communication data .To fully consider the indexes of time lapse, energy consume , reliable transmission and load balancing , it simplifies the algorithm process of the message path , also shows the specific steps of the algorithm by which gateway device plans the message path.

(2)In order to further prove the correctness and effectively of the algorithm by which gateway device plans the message path in this article in the industrial wireless network, we conduct the comparative experiments emulation twice which is conducted by ns2 platform proposed by Lin B etc. to compare it with AODV. We can see from the results that the communication capability of b_r has improved a lot , average delay has decreased 2ms , average throughput has increased 40kbps, reliable transmission rate has increased 7%, on the whole , the algorithm proposed in this article is better than AODV protocol searching path, for its average delay has decreased 2ms , average loading and unloading capacity has increased 30kbps , reliable transmission rate has increased 3%, thus to further improve the whole network property .The experiment testifies that planning path is effective.

2. The Shortcomings the Traditional Rout ion Node has when it Runs the Algorithm

This article mainly studies the frequent communication in the industrial wireless network. When the location of the node is stationary, we lay stress on the load balancing and reliable transmission, and plan the message path entirely. When the routing node is running the algorithm, it will seek for the best path with all other conditions limited, but it has certain limitation in time and space, for we only consider the partial situation but forget to find the optimal path entirely. Following are some problems that lead to non- optimal whole network communication owing to the limitation. Industrial wireless network plans the path.

Time limitation figure 1 shows a part of the wireless network structure, the communication lode of the middle node 0 is comparatively large, the remaining energy is small. Message A skips to node 1 through 8 ,the destination is node 4; Message A skips to node 1 through 1 ,the destination is node 4; Only one of the two messages can go through node 0 , there will be two situations:

The first situation, Message A arrives node 1 more quickly than message B, then the path of message A is 1-0-4, the path of message B is $1-2-3-4$ or $1-6-5-4$.

The second situation , Message B arrives node 1 more quickly than message A ,then the path of message B is 1-0-4, the path of message A is $1-2-3-4$ or $1-6-5-4$.

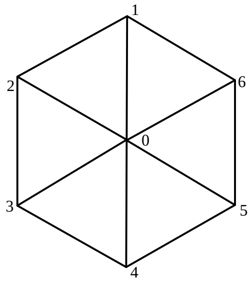

Figure 1. Routing Nodes Distribution Map

Following is the analysis of the communication excellence and inferior of the two situations , the minimum skip number of message A is 10, the minimum skip number of message B is 3; Compare the message path detour degree of the both ((actual skip number – minimum skip number)/ minimum skip number), as the table 1 shows .

Table 1. Detour Degree Comparison under Time Limitation

Message	A	B
Minimum skip number	10	3
Skip number of the first situation	10	4
Detour degree of the first situation	0	0.33
Skip number of the second situation	11	3
Detour degree of the second situation	0.1	0

The detour degree of the message B in the first situation is 0.33, the detour degree of the message A in the second situation is 0.1, then which is more ideal? In the real life, when a person is going to a 1000-meter-far place, he actually walks 1100 meters, he does not walk far; But, when he is going to a 300-meter-far place, he actually walks 400 meters, he walks far. So the detour degree of the message A in the second situation 0.1 is obviously better than the first situation. For the time, routing equipments is not able to make the optimal judgment without knowing the posterior communication situation.

Space limitation table 1 shows a part of the wireless network structure as the question 1, the communication lode of the middle node 0 is comparatively large, the remaining energy is small. Message A skips to node 1 through 8 ,the destination is node 4; Message B skips to node 2 through 1 ,the destination is node 5; Only one of the two messages can go through node 0 , there will be two situations :

The first situation, Message A arrives node 1 more quickly than message B arrives node 2, then the path of message A is 1-0-4, the path of message B is $2-3-4-5$ or $2-1-6-5$.

The second situation, Message B arrives node 2 more quickly than message A arrives node 1, then the path of message B is $2-0-5$, the path of message A is $1-2-3-4$ or $1-6-5-4$.

Following is the analysis of the communication quality of the two situations, the minimum skip number of message A is 10, and the minimum skip number of message B is 3. Compare the message path detour degree of the both, as the chart2 shows.

Table 2. Detour Degree Comparison under Space Limitation

Message	A	B
Minimum skip number	9	3
Skip number of the first situation	9	4
Detour degree of the first situation	0	0.32
Skip number of the second situation	10	4
Detour degree of the second situation	0.12	0

The detour degree of the message B in the first situation is 0.32, the detour degree of the message A in the second situation is 0.12, so the detour degree of the message A in the second situation 0.1 is obviously better than the first situation. For the space, routing equipments is not able to make the optimal judgment without knowing the posterior communication situation

Message jamming the chart 2 shows that in a short time, the path made by the middle nodes 0-6 can deliver numerous messages, some of whom is waiting, some is losing. If a new message goes through node 0, it is inappropriate, if it goes round node 0, it will save time in spite of a longer path. What is more, if the middle nodes send messages frequently, this will lead to interference and influence the communication quality.

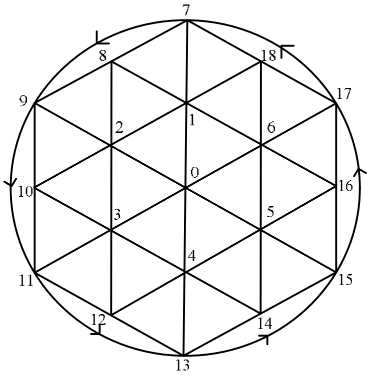

Figure 2. Routing Nodes Distribution Map

As the figure 2 shows , in the part of the wireless network structure , the marginal routing nodes transmit messages to the opposite , if they all go through the central node , the energy consume will be very large , and it will become a disadvantage to load balancing . This also will lead to message jamming because of the frequent communication, which will be likely to happen to the middle nodes 0-6, thus to make messages fail to arrive in time .This is like the transportation of a city, the drivers try to avoid the rode of large car quantity during the peak hour, and arrange suitable transportation route by listening in to the transportation situation. As the chart 2 shows, the message can go round by the way of inverted hour to avoid the middle busy area, but there will be many problems, like what kind of messages should go round, when and how. These problems can not solved by a single routing equipment.

3. The Whole Planning Path of Industrial Wireless Network

3.1. The Characteristics of the Industrial Wireless Network

The industrial communication has its own characteristics compared with the ordinary data network communication. The covering range of the industrial wireless network is limited, data exchange is mostly periodic, the communications volume and periodic time between the field apparatus can be predicted previously .The industrial network data grouping is minor and so is the outburst possibility. There is common property between industrial network and data network, but differences also exist. For example, data network is aimed at maximized throughput and bandwidth utilization, while the industrial network is aimed at time lapse and reliability.

In the industrial wireless network, the node number is relatively settled, the communication fluctuation is not great, so we can plan the message path on the whole. During a industrial production cycle, most is line production, and the everyday industrial communication data is basically the same from the initial stage to the final stage. Therefore it is feasible to make the communication data, node energy and transmission rate in the initial stage as the basis to plan the message path of this production cycle. Then the gateway device will run the algorithm according to the statistics of network communication situation in a period and design the most suitable path for every message, then a routing chart by which every routing node will transmit messages will come into being , thus to make whole network communication achieve the optimum state.

3.2. Network Performance Diagnosis

The industrial wireless sensor network performance diagnosis , i.e. the Study Group13 of ITU-Ｔproposed Ｙ.1540(original : 1.380) advice , including four parameters which define the measurement of IP grouping transmission capability : speed ,accuracy ,dependability , and availability . Also, it defines a series of capability quotas, such as transmission time lapse, time lapse diversification, packet error rate, dropped packet rate, false IP packet rate, packet throughput, bytes throughput etc.

To design for every message path, all situations will make up m programs with n capability quotas .We can get the performance comprehensive diagnostic value by the linear weighted method. The formula is

$$s_i = \sum_{i=1}^{m} t_i r_{ij} \quad (1)$$

In the formula, $1 \leq$ i $\leq$m; y is the j_{th} capability quota of the i_{th} program; w is the weight of the capability quota j , the sum is 1; s_i represents the size of network performance comprehensive diagnostic value, the larger s_i is , the better network performance is ; the smaller s_i is , the worse network performance is.

We estimate the capability quota of each program, including detour degree , reliable transmission , total communications volume and load balancing, they reflect the communication time (with a unblocked network situation , the shorter the path is , the shorter the time is) ,reliability ,energy consume, and network node lifespan .This article diagnoses the excellence and inferior of a program .

3.3. Variable Calculation and Select Programs

In a path grouping program i , first, a vector represents every message path, each component of the vector represents the network routing node, it includes all routing nodes. If the message goes through some routing node, the component value is 1, or it is 0. A vector represents all network routing nodes communications volume. The formula is

$$STV = \sum_{j=1}^{m} mop_j \times mup_i \quad (2)$$

In the formula, STV is the vector representation of communications volume, MPV is a message path vector, MST is the communications volume of a message. N represents the message number (divided by source and object).

The formula of the total communications volume of the whole network routing nodes is

$$sp = \sum_{i=1}^{n} stvc_i \quad (3)$$

In the formula, ST is represents the communications volume, STVC represents the component of communications volume vector, n represents the routing node number. The formula of the actual path-length is

$$APL = NMPVC - 1 \quad (4)$$

In the formula, APL represents the actual $path-length$, NMPVC represents the number of the component whose medium value of message path vector is 1. The formula of the message detour degree is

$$MDT = (APL - PL_{\min}) / PL\min \quad (5)$$

In the formula, MDE represents the message detour degree, APL represents the actual path-length, $PL\min$ represents the minimal path-length. The formula of the total message detour degree is

$$SMDE = \sum_{i=1}^{m} MDE_i \times mn_i \quad (6)$$

In the formula, SMDE represents the total message detour degree, MN represents the message communication times, the minimal total message detour degree value is 0. When the detour degree transforms into the path capability quota, it means that the present path is close to the shortest path degree, the formula is

$$PI = (SMDT_{\max} - CADE) / SMDT_{\max} \quad (7)$$

In the formula, PI represents the path quota, $SMDT_{\max}$ represents the maximum total message detour degree, CSMD represents the present total message detour degree.

Reliable transmission quota means the present reliable transmission rate is near to the maximum reliable transmission rate degree .The formula is

$$RUI = (InCRT - InRu\min) / (InRs_{\max} - InRu_{\min}) \quad (8)$$

In the formula, RTI represents the reliable transmission quota, CRT represents the present reliable transmission rate, Ru_{nin} represents the maximum reliable transmission rate, Ru_{nin} represents the minimal reliable transmission rate.

Energy consume means that the present energy consume is near to the minimal energy consume degree. The formula is

$$YTE = (SP_{\max} - CRT) / (SP_{\max} - SP_{\min}) \quad (9)$$

In the formula, YTE represents the energy consume quota, CST represents the present total communication volume, SP_{nin} represents the maximum total communication volume, SP_{nin} represents the minimal total communication volume.

In order to make the lifespan of the network nodes longer, the routing nodes whose remaining energy is larger should bear more communication volume, this kind of match is the most ideal. The formula of the matching degree is

$$CD = \sum_{j=1}^{k} NPE \times MT \quad (10)$$

In the formula, NRE represents the remaining energy of the nodes, NT represents the communication volume of the nodes.

Load balancing quota means that the present load is near to the optional matching degree, the formula is

$$PST = (CRT - SP_{\min}) / (SP_{MAX} - SP_{\min}) \quad (11)$$

In the formula, LBI represents the load balancing quota, CMD represents the matching value, SP_{nin} represents the maximum matching value, $SP_{\max}$ represents the minimal matching value.

Finally, calculate the comprehensive diagnostic value of the program:

$$TP = u_j \times pt + u \times TSP + u_2 \times RST \quad (12)$$

The sum of weight is 1, each is allocated according to the specific production situation. For example , the equipment nodes in the automobile manufacturing plant are convenient to change batteries and don't rely on energy strongly , so we can take a small weight, as long as we make sure that the node energy can satisfy the needs of a production cycle .

To calculate the diagnostic value of each path grouping program and avoid the frequent occupation of one path at the same time is likely to start up message jamming. The biggest program of the comprehensive diagnostic value is the optional, thus to produce a routing list stored to every routing node. Comprehensively diagnosing the second and the third program also produces a routing list for reservation.

3.4. Simplify the Algorithm

If all the message path situations are taken into consideration, the program number is too large and the algorithm is too complicated. Following is how to decrease the program number and simplify the algorithm.

First, select the messages .Find out the messages which have the limitation previously mentioned according to the calculated statistics and plan them again, the others which don't have the limitation remain the original routing protocol.

Second, the messages with large communication volume are the key point. If such message path changes, it will influence the network a lot. So plan the message path with large communication volume first and then the message path with small communication volume.

The short distance message path has less selections, and one more path skip will be quite evident to the increase of the detour degree. The long distance message path has more selections, and one more path skip will be not so evident to the increase of the detour degree. Therefore, plan the short distance message path first and then plan the long distance message path.

The detour degree can be limited below 40%, take the situation of chart 2 as the example, the remaining energy of the middle nodes is small. The messages are divided by the source and the objects , the returning message goes the same path . The shortest path distance is message 1 , i.e. the message whose source and object is adjacent, so the shortest path won't change .There are 33 messages whose shortest path distance is message 2, so it is the shortest path. There are 12 messages whose shortest path distance is message 3, so the path distance is 3 or 4, and try to avoid the central nodes 0-6, there are 2 ˆ 6 ＊3 ˆ 6 kinds of grouping situations . There are 3 messages whose shortest path distance is message 4, so the path distance is 4,5 or 6, there are 5 ˆ 3 kinds of grouping situations .This is the simplified algorithm according to the distribution of nodes .

Consider the optimization of the industrial wireless network otherwise. Which message is the node remaining energy, and whose service is better.

The first step, set off the messages whose path won't change, they will consume a part of energy, which is inevitable.

The second step, among the remaining messages, set off the message with the shortest path distance, because the path of the shortest distance message changes a little, the detour time and the path cost is relatively huge, so find out the shortest distance message path first. The other messages can be regarded as a large message, so the remaining energy is divided by the two messages. It is easy to find the path situation of the small message, while the path situation of the large one will be quite complicated .The component value range of the large message path vector is defined like this. First, the shortest path combination of each message is the lower limit, the longest path combination of each message is the upper limit. Second, as the routing node serves the least messages, the component gets the minimal value. As the routing node serves the most messages, the component gets the minimum value. Then, the combination formed by each component value change which is in the range of the lower limit and the upper limit is the path situation of the large message. Finally, those defined path messages should also be taken into consideration, and some path should avoided frequent occupation, i.e. the path which is occupied too frequently should be abandoned. With the help of comprehensive diagnosing method, those defined path messages and the previous two messages will be calculated together, and the small message path is defined.

The third step, if the message path has defined, the optional program will emerge; Or continue to run the second step .

The fourth step, generate the routing list on the basis of the optional path combination program. Only one routing list can be produced by this simplified algorithm. There is no spare routing list, but the routing list made up by the shortest path can be regarded as the spare routing list.

4. Experimental Results

Conduct the simulation experiment with the platform ns2 proposed by Lin B. The nodes layout is shown in the chart 3. In order to highlight the experimental results, the network is designed into a wireless network of partial frequent communication, the nodes energy and reliable transmission rate are the same. Conduct the experiment twice , define the message path with AODV protocol searching path and gateway device planning path separately and test the dropped packets number (calculate the dropped packets rate) , throughput and time lapse . Chart 3 is the experimental environment arrangement.

Design two connections: build a connection between node 3 and node 3, and mark this connection as *cbr* . Build a connection between node 0and node 1 2, and mark this connection as table l.

In the first experiment, use the AODV protocol to search the path, use *tcp* to connect path 0-5-6-11-12. The dropped packet number, throughput and time lapse are listed in chart 4, the arranged results are listed in table 4.

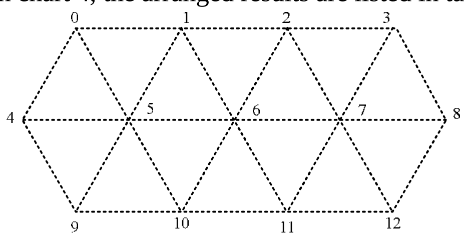

Figure 3. Routing Nodes Distribution Map

Table3. Simulation parameters

parameter	value
Network area	600m ×600m
Routing node number	13
Nodes space	150m
Transmission radius	200m
MAC protocol	802.11
Routing protocol	AODV
Simulation time	80s

Table 4. Data chart of the first experiment results

Message	*cbrl*	*cbr*	Gross
Average time lapse (ms)	23.06	77.78	35.29
Average throughput (bps)	378318	109789	488120
Total dropped packet number	1167	3663	4835
Received packet number	3779	1101	4884
dropped packet rate	0.25	0.78	0.53

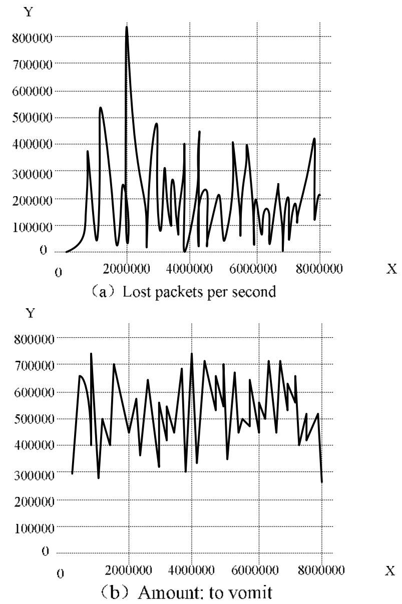

Figure 4. The First Experiment Results

It can be seen from the first experiment results, the two messages are mutually interferential. *cbr* is a short message of large communication volume and its path has only one skip, so its path doesn't change. *cbrl* is a long message of small communication volume and its path has numerous skips , so its path should be planned again . In consideration of the network property, the path of *cbrl* in the second experiment is designed as $0-5-10-11-12$, the total communication volume doesn't increase, the load balancing doesn't change without the detour. The dropped packet number, throughput and time lapse in the second experiment are listed in table 5, the arranged results are listed in table 5.

Table 5. Data chart of the second experiment results

Message	*cbrl*	*cbr*	Gross
Average time lapse (ms)	20.90	85.95	33.45
Average throughput (bps)	419570	99894	519452
Total dropped packet number	840	3742	4584
Received packet number	4198	999	5201
dropped packet rate	0.18	0.80	0.48

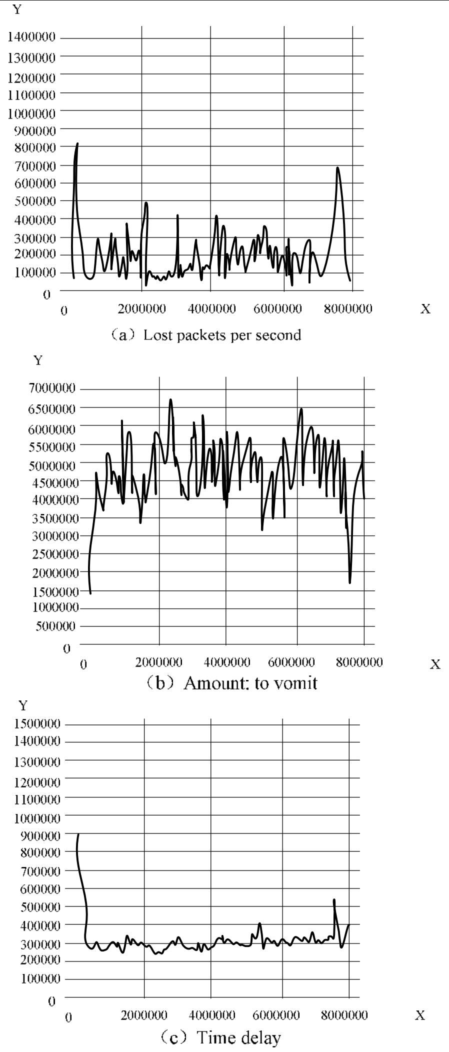

Figure 5. The Second Experiment Results

Judging from the two messages independently, the communication capability of *cbrl* has decreased slightly, the average time lapse has increased 8ms, the average throughput has reduced 10kbps, the reliable transmission rate has decreased 2%; The communication capability of *cbr* has improved a lot, the average time lapse has decreased 2(ms), the average throughput has increased 40kbps, the reliable transmission rate has increased 7%. This meets the original intention that the little benefit should be abandoned so as to get the big one. On the whole, compared with AODV protocol searched path, the average time lapse of the planned path has decreased 2ms, the average throughput has increased about 30kbps, the reliable transmission rate has increased 3%, and then the comprehensive performance of the network has improved. The experiment indicates that planning the path is effective.

Conclusion

To plan the path is carried out by gateway device. Overall planning all the message path of the industrial wireless network in a period and breaking the limitation of the routing nodes searching the path can not only prolong the nodes surviving time but also avoid the message jamming and interference and increase the reliable transmission rate. The data which the algorithm needs is computed by the routing nodes, the collected message times, data volume and the generated routing list are the most reasonable arrangement for the message path in the last period. Simultaneously, it is of certain timeliness to regard the routing list as the reference of the message path in the next period. Therefore, it is a key question to arrange statistic time reasonably. If it takes too long, the routing list will not indicate the optional message path correctly; If it takes too short, the frequent updating of the routing list will be a huge computational load and such problem may happen, in the last short period, a certain message doesn't appear, but it appears in the next period, thus to contribute to the inaccuracy of the routing list. In the industrial wireless network, the nodes and messages are relatively stable. When the statistic samples become more and more, the rules will be mastered more correctly. To arrange the suitable length of time and predict the future communication situation reasonably can help to produce a more accurate routing list.

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