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A Switching Subnet Algorithm Based on Industrial Wireless Network Communication Data Change

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Abstract: When the communication data in industrial wireless network changes, the original network topology is not suitable for communication data. It is needed that switching subnet to change the original network topology. The goal of the study is to find a switch combination and to form a new network topology which can get the highest performance comprehensive evaluation in the delay, power consumption, reliable transmission and load balance. Based on the characteristics of industrial wireless networks, this study presents a switching algorithm performed by the gateway device is based on statistical communication data. And then a simulation experiment is designed. The results show that the new topology is better than the old one after switching subnet.

Key words: Industrial wireless network, network topology, switch subnet

INTRODUCTION

Nowadays, WSN (Wireless Sensor Networks) have been applied in industrial production widely. A combination of the WSN and industrial production makes WIA(Wireless Networks for Industrial Automation) having its own characteristics. Industrial production cycle led to its data communication cycle and request of periodic and response of data processing account for about 80% of monitoring data (Liu *et al*., 2009). It is necessary to design an appropriate network topology to improve the real-time performance and reliability.

This study proposes a switching subnet, using the periodic statistical data as the communication data predictive value of the next period of time to switch portion of the terminal node access subnet, so as to the network topology is more reasonable and is more suitable for the change of WSN data. The method takes the energy of the node, the reliable transmission rate of the neighbor nodes, the communication between nodes and the laws of the communication data into account (Zang *et al*., 2011). The main work includes statistical the communication of network, calculate the network performance and implementation of the switching algorithm to find the best handoff scheme.

SWITCHING SUBNET ALGORITHM

If all nodes in WSN are statistics, the message complexity is $O(n^2)$ and n is the quantity of equipments (Fu *et al*., 2009). Moreover, the statistic and router device burden are heavy. In order to reduce the statistics, the field device (sensor) is classified: one, there are two or more router devices as access points in field sensors signal range; the other, there is only one router as an access point in field sensors signal range. As this is a site terminal device switching method, the first field terminal equipment can be switched to different subnets and is called the switched field terminal equipment, which is the focus of statistical object. The second one called the non-switched field terminal equipment.

Calculate the comprehensive performance evaluation as follows:

- The weight indicates the importance of the factors and the values are between 0-1 where, 1 means only consider this factor 0 means that they did not consider this factor. The delay and path costs of each message are directly related to the devices (Guo *et al*., 2011). The dimensionless of the four amounts:

$$q(T) = \begin{cases} \dfrac{T_{max} - T}{T_{max} - T_{min}} & T_{max} - T_{min} \neq 0 \\ 1 & T_{max} - T_{min} = 0 \end{cases} \quad (1)$$

$$q(P) = \begin{cases} \dfrac{P_{max} - P}{P_{max} - P_{min}} & P_{max} - P_{min} \neq 0 \\ 1 & P_{max} - P_{min} = 0 \end{cases} \quad (2)$$

$$q(S) = \begin{cases} \dfrac{S - S_{min}}{S_{max} - S_{min}} & S_{max} - S_{min} \neq 0 \\ 1 & S_{max} - S_{min} = 0 \end{cases} \quad (3)$$

$$q(R) = \begin{cases} \dfrac{\ln(R) - \ln(R_{min})}{\ln(R_{max}) - \ln(R_{min})} & \ln(R_{max}) - \ln(R_{min}) \neq 0 \\ 1 & \ln(R_{max}) - \ln(R_{min}) = 0 \end{cases} \quad (4)$$

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- **The method of boundary value:** if the user asks for a self-defined value, the boundary values is set in accordance with such a request; otherwise, calculate the range to determine the boundary values. Determine the boundary values to the calculate range manually.

Based evaluation function F, the constructed as follows:

$$F = \alpha\times q(T)+\beta\times q(P)+\gamma\times q(S)+\theta\times q(R) \quad (5)$$

$$\alpha+\beta+\gamma+\theta = 1 \quad (6)$$

The value of F can be used for performance comparison between the different topology of the same industrial wireless network.

Switch subnets to the field devices of frequent communication and do not need switch subnet to the occasional communications equipment. In order to the field devices of frequent communication be able to access to the appropriate subnet, the occasional communications equipment switch to other subnets, because too many devices in the subnet are also a great burden on the access point router equipment.

Definition 1: The network accessing subnet field equipment is known as a topology state.

Definition 2: Frequent communication can switch over the site terminal equipment is about switching subnet object. In Table 1, each equipment several alternative access point and a current access point, the equipment switching form combination, is called replacing combination. Each kind of replacing combination forms a kind of topological state.

Definition 3: Switching combination is conveyed by vector. Setting the frequent switching communication terminal equipment have k, each switch combination is corresponded to a k dimension vector X, each component is the value of access points i equipment, can switch over the site terminal equipment list.

Table 1: Performance and optimization purpose

Performance factor	Quantify	Optimization purpose	Weights
Time	Average delay T	Small	α
Energy consumption	Communication volume of data	Small	β
Load balancing	Matching degree S	High	γ
Reliable transmission	Reliable transmission rate R	High	θ

The specific procedure of switching algorithm is as follows:

Step 1: Calculate T, P, S, R in Table 1

Step 2: Judge all switching over to the terminal equipment whether it is worth of frequent switching equipment i. In statistics search of equipment i for the news (i, j) of the source address and equipment I for the purpose of news (i, j). In this time the device send and receive messages for n(i). Set a constant c, when n >c and think it is frequenting communication, fitting into the switch object, the news for the other side form objective collection J1 and j source collection J2; Otherwise think equipment i occasionally communication, not worth switching, ignore it. Find out the frequent change of communication equipment forming the collection

Step 3: Frequent communication equipment according with switch condition is number of k, the equipment Numbers are for s, $0 < s < k+1$. Each of them has l_s optional equipment access points and a former access points, so the total replacing combination have:

$$\prod_{s=1}^{k}(l_s+1)$$

types:

$$\prod_{s=1}^{k}(l_s+1)$$

switching combination vector, every vector is x_t:

$$0 \le t < \prod_{s=1}^{k}(l_s+1)$$

Step 4: Initial value t = 0

Step 5: Generates a data sheet for switching combination vector x_t, the initial value equals temporary Table 1. From the first component to the k component, the initial value s = 1

Step 6: For x_t, the s component, if component value is 0, it maintains the original access point and go to Step 11; Otherwise go to step 7

Step 7: Estimate the data after switching. Equipment i switches to alternative route equipment subnet. Construct statistics data in x_t sheets, fill optional routing device address in the routing equipment address

Step 8: Adjust for the j execution in J1 and J2: If alternative route equipment subnet and equipment j in the subnet communicate, it go to step 9; Otherwise, go to step 10

Step 9: Duplicate communication of the data between the equipment i and j according to the full path. Add hop, delay, previous hop, next hop to the x_t data sheet's new statistics column. Nodes on the path of the receiving data of the increasing is consistent, calculate the increasing the send data according to predict communication data quantity and delete the original news (i, j) from the data in the Table x_t. Go to Step 11

Step 10: New subnet sends a test message to j, carrying the hop, time and the data of the path node. fill the data into the new data sheet, fill messages times and the communication data in accordance with the path of reliable transfer rate between equipment i and j news data into the new data sheet (if not, reliable transfer rate is default value of 1) and delete the original data from sheet

Step 11: If J1 or J2 have j who don't implement adjustment of the data, go to steps 8; If all j is implemented, then can get equipment i under switching data communication, the x_t data sheet is updated

Step 12: s = s+1, if s>k, it go to step 13; otherwise go to step 6

Step 13: At this time, the data switching combination x_t sheet is got, the sheet is estimated and is not the actual statistics. In order to determine whether to take such a switch, x_t sheet and temporary sheet 2 add to temporary sheet 3. Calculate average delay T, communication total quantity P, the matching degree of loading S and reliable transfer rate R basing on temporary sheet 3

Step 14: t = t+1, if

$$t=\prod_{s=1}^{k}(l_s+1)$$

go to step 15; otherwise go to step 5

Step 15: Of all the network switching equipment have been counted and all kinds of switching combination also be considered. Calculate the average delay of all replacing combination T, communication total quantity P, the matching degree of loading S and reliable transfer rate R and choose the maximum and the minimum of T, P, S, R of as boundary value (user don't request). If the user has special requirements, the values require adjustment. Finally calculate evaluation function F value in each combination of state and find out the switch combination when F is the maximum. That is each equipment's switching plan

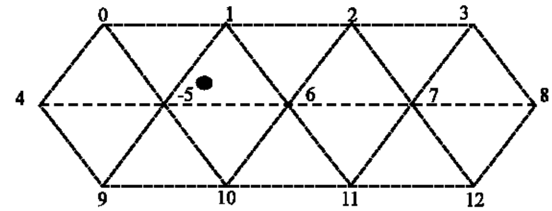

Fig. 1: Router nodes distribution diagram

Table 2: Experimental results data table of No. 1 access node

Msg	AD (ms)	AT (bps)	TPLN	TPRN	PLD
cbr1	70.43	116512	493	1128	0.30
cbr2	83.34	99469	703	963	0.42
cbr3	61.75	135372	358	1294	0.22
Sum	70.78	351353	1554	3385	0.31

Table 3: Experimental results data table of No. 6 access node

Msg	AD (ms)	AT (bps)	TPLN	TPRN	PLD
cbr1	59.55	137997	260	1336	0.16
cbr2	61.27	134382	358	1301	0.22
cbr3	64.29	134898	445	1306	0.25
Sum	61.69	407277	1063	3943	0.21

Simulation: Figure 1 is the layout of an industrial wireless network with 13 router nodes. A terminal node is among the Node 1, 5 and 6 .Its access points are also node 1, 5 and 6. Now its access point is node 5. Statistical data in a period of time shows that it communicates with node 3,4,12 frequently. And three kinds of messages send in turn with uniform occupancy time and about the same amount of communication.

On the hand of energy consumption and delay, the current access point is node 5 and the sum of paths is 7. If the access point is node 1, the sum of paths will be 7. If the access point is node 1, the sum of paths will be 6. So node 6 should be the access point. Simulation experiments are made with NS2 to test the three cases.

Calculate the packet loss rate in 80s according to the packet loss number and the experimental results are in Table 2. Msg stands for Message, AD stands for Average Delay, AT stands for Average Throughput, TPLN stands for Total Packet Loss Number, TRPN stands for Total Received Packet Number, PLD stands for Packet Loss Date.

When the terminal node is accessed node 6, calculate the packet loss rate according to the packet loss number and the experimental results are in Table 3. It can be seen that the effect of three kinds of messaging are good, except cbr1 has some delay jitter.

In Table 2 and 3, experimental results show that No. 6 access node is better than the other two cases at delay, throughput and the packet loss date totally. From the experimental Screenshot, it can be seen that finding the message paths made network performance poor early in the experiment and then the network communication is relatively stable.

CONCLUSION

In the way of switching subnet, the purpose is to optimize the network with the means of finding a suitable access point and statistical communication data is the foundation (Lin *et al*., 2011). The data included the number of messages and traffic is collected by the router nodes, in order to estimate the next phase of communications data. The network topology after switching subnet has a certain timeliness so that the time of reasonable arrangements for statistical data and implementing the switching algorithm is also a key issue. The switching subnet algorithm doesn't change the original topology of the network subject and only switch a small number of terminal nodes effectively. It can meet the industrial wireless network communication data and achieve the network topology optimization. Through long-term statistical sampling can make the more accurate estimation of the future communications data and the more accurate calculation of the performance evaluation of the switching portfolio, which is of great significance to improve the effectiveness of the algorithm.

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