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A Multi-Path DSDV-Based Routing Protocol for WIA-PA Network

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Abstract
WIA-PA is a kind of wireless network for industrial process automation, which has a high requirement for the real-time and reliability of the data transmission. Based on the deficiency of the existing routing protocols, this paper puts forward a new kind of WIA-PA routing protocol - MWD. The protocol chooses the stablest link in the routing table as the optimal route, and then based on the node disjoint strategy, determines a route as the backup route, which disjoints with the optimal routing node. When the node needs to transmit data, it can search the local routing table and choose the optimal route to transmit data. If the optimal route fails sometime, it can transmit data through backup route. The simulation results show that MWD protocol can enhance the real-time and reliability of the WIA-PA significantly.
Key words: WIA-PA NETWORK, MULTI-PATH ROUTING PROTOCOL, HIGH RELIABILITY, HARD REAL-TIME

1. Introduction

Industrial wireless network technology is a new emerging kind of special wireless sensor network technology which is facing the information interaction between devices, and is suitable for harsh industrial field, and has a strong anti-interference, low power consumption, high real-time performance and high reliability. WIA-PA (Wireless Networks for Industrial Automation-Process Automation), which is used for the industrial automation process, is the specification for industrial wireless networks researched and developed independently by China and became the IEC international standard in October 2008. It adopts the two layers of network topology combined with star and MESH [1]. The network routing protocol is the important support and guarantee for the high quality node network communication. However, up to now, this kind of network doesn't have an efficient, stable and mature routing protocol.

There are a lot of routing protocols concerning wireless networks. However different specific applications have different requirements. For the WIA - PA

industrial environment applications, the key of its reliability lies in a reliable routing protocol. In industrial application, the death of one or several nodes will make one or more routes inaccessible, so that the industry key data cannot be transmitted to the gateway, which will lead to a local network or even the entire network paralyze. Single path routing protocol can not satisfy the high reliability of the WIA-PA network [2]. Therefore, it is necessary to choose multi-path route. In industrial field environment, most of the intelligent instruments are fixed on the relevant equipment. Most of the nodes are relatively static except some of the nodes move slightly while in motion. So the network topology of the WIA-PA network is relatively stable. Therefore, table driven routing protocol is more suitable for WIA - PA network. DSDV [3] (Destination-Sequenced Distance-Vector routing) protocol is a kind of table driven protocol. Howe- ver, DSDV is a kind of single-path routing protocol and can not satisfy the requirement of WIA-PA network for high reliability. DSDVM [4] (DSDV-based Multi-path routing) protocol is the multi-path routing protocol based on the DSDV. It can find a number of node disjoint paths from the source node to destination node and obtain and maintain a number of shortest paths. In data transmission, it can choose the minimum hop path as the optimal path from the source node to the destination node [5]. But it is hard to avoid the optimal path which contains nodes on the verge of death. If so, the life cycle of this optimal path is very short and the reliability and stability of the routing protocol is greatly reduced.

This paper, on the basis of routing protocol, puts forward a multi-path WIA-PA routing protocol based on the link stability - MDW(Multi-path DSDV-based Routing Protocol for WIA-PA). It uses node sending signal strength method to forecast the stability of the link and then chooses the most stable one as the optimal routing path to transmit data. Meanwhile, it chooses a path that does not intersect with the main route as the backup route based on the node disjoint path strategy. Finally, through the NS-2 simulation, at the expense of less energy consumption, the average delay of MDW at data packet delivery rate and data packet port to port is improved compared with those of DSDV and DSDVM. Thus, it satisfies the hard real-time and high reliability requirements of WIA-PA network.

2. The proposing of the MDW protocol

WIA - PA is the wireless network system based on IEEE802.15.4 standard for process measurement, monitoring and control [6]. It is a short-range, low rate information interaction wireless communication standard for equipment. It covers the technology of spread spectrum and narrow band, multichannel communication, Star-MESH two layers topology, TDMA/CSMA mixed access mode. And it has the technology feature: strong anti-interference ability, hard real-time property and high reliability. It is suitable for harsh industrial environment and the areas that people can not be reached. WIA-PA adopts the two layers of network topology combined with star and MESH [7], which is illustrated in figure 1.

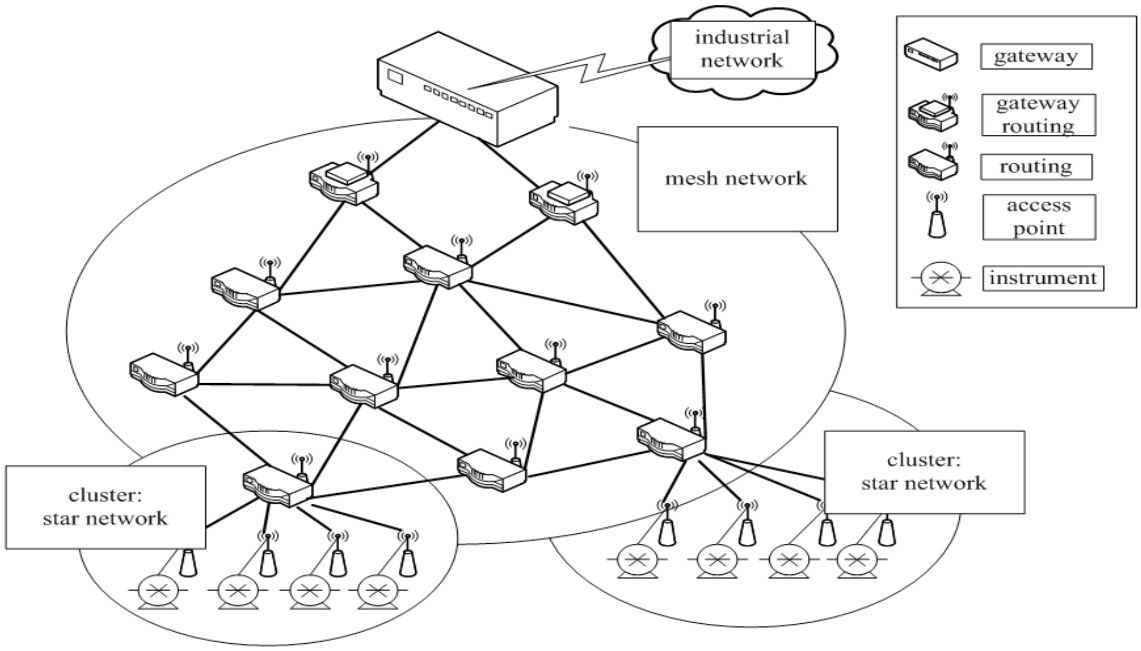

Figure 1. The network topology of WIA-PA

For MESH network, the route is necessary. For the industrial applications of WIA-PA, all the routing nodes in the MESH network can receive and send data stably and in real time. So it is very important for the design of the WIA-PA routing protocol.

The research of MANET routing protocol is an important research field of Ad-Hoc network. The Ad-Hoc network route consists of Table-driven route, On-demand route and Hybrid route. Table driven route has high real-time and the routing delay is small. Meanwhile, the requirements for the routing node processing ability are high. Besides, it needs regular routing maintenance and energy consumption is relatively large. However, these characters are very suitable for the requirements for the high stability of the WIA-PA network. On-demand route is a kind of route, when there is a need to send data, a routing request is made. For industrial frequent data transmission in real time, this kind of route is too complicated and the network delay is big. Meanwhile, it is not conducive to implement its high real-time for the WIA-PA network whose topological structure is relatively stable. Therefore, this paper chooses table-driven route protocol DSDV. Based on DSDV, this paper puts forward multi-path routing MDW as the WIA-PA network routing protocol. The WIA-PA routing nodes adopt the dual-core processors and large-capacity industrial batteries (1 to 3 years of life span), which provides sufficient conditions for the use of table-driven route. Hence, MDW can satisfy the requirements of the WIA-PA network for high real-time and high reliability.

3. The research of MDW protocol

3.1. Some explanations of MDW

The first one: in WIA-PA network, all the intelligent instruments send data to gateway. In the routing table of each node, only the routing entries which are the gateway routing of the destination nodes are maintained. In doing so, the routing table is greatly simplified and the cost of the route discovery and maintenance is saved. And it is beneficial to the improvement of the network life cycle.

The second one: set a new routing table entry - LS (Link Stability). The routing stability is indicated by a responded figure. The greater the LS value is, the higher this path stability is, and the greater the reliability is.

The third one: the node neighbor table is introduced into MDW. The neighbor table consists of two routing entries: Neighbor ID and $P_r(d)$ ($P_r(d)$ represents the node received power of the sending signal from the neighbor node.), which are used for calculating each path's LS entry of the routing table.

3.2. Route discovery process

In WIA-PA networking phase or the period of new nodes joining in the network, the node informs other nodes the existing of itself by broadcasting Hello packet which includes gateway assigned ID and its neighbor table. Meanwhile, it can also receive the neighbor table and routing table of other nodes' broadcasting. After the neighbor nodes receive the newly joined nodes' packet, they will recalculate the routing LS value from the routing table to gateway route. And then they will update the routing table and send the new routing table to the neighbor nodes. After a period of time, each node can create a complete routing table and neighbor table. The entry of routing table is illustrated in table 1 and the entry of neighbor table is illustrated in table 2.

Table 1. The entry of the routing table

The entry of the routing table	Description
Destination	The destination address, especially for the gateway route in WIA-PA
Next Hop	The first routing node address to the destination node
Number of Hops	The hops to the destination node
Sequence Number	The routing sequence number, which is used for marking the routing degree of the new and the old and updating the route
LS	The link stability of the route, which is used for marking the stability degree of the routing path
Install Time	Time in setting up the route

Table 2. The entry of the neighbor table

The entry of the routing	Description
Neighbor ID	The neighbor node of the marked node
$P_r(d)$	The node received power of the sending signal from the neighbor node

Taking link stability as the criterion for choosing route can improve the quality and reliability of the route. The link stability of a route is showed by the received signal power of the node. The link stability of a routing path is the minimum received power value of all the intermediate nodes that compose this routing path, LS=min{$P_r(d)_1$, $P_r(d)_2$, ……$P_r(d)_{NoH}$}, $P_r(d)_1$ represents the received signal power of the source node from the first node, which shows the link quality and the stability from the source node to the first node. The link stability of the route is the minimum value of all the link stability between two nodes. LS is used to represent the link stability of this routing path. In the calculation of $P_r(d)$, Two-ray Ground Reflection Wireless Channel Transmission Model is adopted. Compared with Free Space Transmission Model, the ground reflection path is taken into consideration as well as the straight line propagation path in the Two-ray Ground Reflection Model [8]. The received signal power is illustrated in formula 1:

$$P_r(d) = \begin{cases} \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} & d < d_r \\ \frac{P_t G_t G_r {h_t}^2 {h_r}^2}{d^4 L} & d \geq d_r \end{cases} \quad (1)$$

In the above formula, d represents the distance between the sender and receiver; P_t represents the emission signal power; G_t and G_r represent antenna gain of the sender and the receiver respectively; L(L⩾1) represents the system loss; λ represents wavelength, which is the system loss; h_t and h_r represent the height of the sending antenna and the receiving antenna respectively; d_c is a defined distance d_c=(4π*h_t*h_r)/λ. When the distance is less than d_c, the data transmission between nodes is the short distance data transmission and the radio wave can be considered as straight line propagation mode; however, when the distance is more than the d_c, it is the Two-ray Ground Reflection Radio model and the height of the antenna and the signal reflection from the ground should be taken into account [9].

The node disjoint strategy refers to the method that the node chooses the path that does not meet with the optimal path as the backup routing path in the routing table. The node disjoint path is also called completely disjoint path. That is to say, there are a number of paths from the source node to destination node and there are no common node except the source node and the destination node [10]. In figure 2, we choose the first routing path as the optimal path. For the LS value of the routing path 1 is the biggest. The routing path 2 is taken as the backup routing path. The probability of multi-path disconnect is related to the number of the intermediate nodes and the path disjoint. The node disjoint multi-path strategy reduces the probability of data transmission interruption caused by node breakdown in the network and ensures the continuity and real time of the WIA-PA network data transmission.

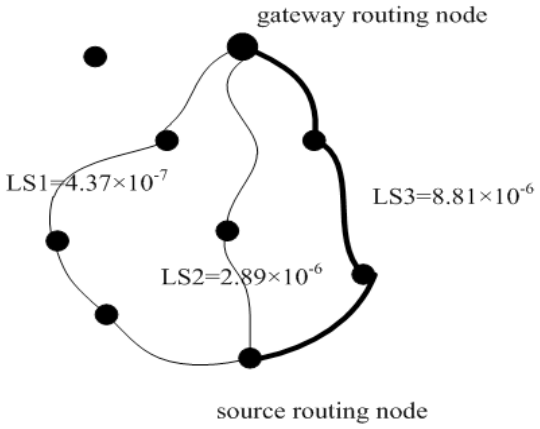

Figure 2. The node disjoint strategy

3.3. The maintenance of the route

MDW routing protocol maintains its routing table through broadcasting routing updated packets among nodes. Each node broadcasts the updated packets to all the nodes in the network periodically and then sends the whole routing information to the neighbor nodes. Just as DSDV, no matter whether the network topology of the WIA-PA network changes, this periodic broadcasting continues. For specific industrial field, the broadcast period can be adjusted to reduce the energy consumption and the use of the bandwidth of the network. When the network topology changes or a new node joins in, the received information power of the node and its neighbor nodes will also changes. Then the routing table and the neighbor table of the nodes around will be updated and the updated packets will also be broadcasted. The nodes which receive the updated information will update their route and choose the stablest routing path as the first-choice route. If there are several paths that have the same LS, it will choose the largest sequence number route as the optimal route. The generation of the Sequence Number is inherited from DSDV algorithm, which can help nodes distinguish the effective and expired routing information. The routing information with greater sequence number will always be received.

The routing updating packets have two forms: Full Dump and Incremental. The full dump includes all the routing table entries of the node; the incremental only includes the updated route. The incremental is adopted to update packets usually. It is suitable for the

WIA-PA network which the network topology is relatively stable and the routing information changes less.

The routing table also needs to be maintained while the link is disconnected. Link failure can lead to the suspension of message transmission. Especially in industrial application, the loss of some important message will lead to industrial control fault and failure. Therefore, the timely link failure detection and recovery are an important part of the routing maintenance. There are two ways of detecting the link fai-lure. One is communication hardware detection; the other is to infer through time, that is to say, after the setting time, the node still does not receive the information from the previous node. Then the link failure is inferred. Number of Hops of the disconnected link equals ∞. At this moment, the gateway routing node which detects the disconnection of the link will offer an updated packet. This information has a new sequence number which is generated by adding an odd number to it and the number of hops are set as ∞, which will lead to the update of the routing table. The new route will be set up if and only if the node receives the missing routing node information again. The update of the neighbor table is accompanying with the broadcasting of the routing table. The joining of the new node and the node breakdown is maintained and updated by the updating of the packets.

4. Simulation test

The simulation test uses NS-2Version 2.33 network simulation software. The evaluation is based on the performance evaluation criterion proposed by literature. Simulation scenario parameter settings are shown in table 3.

Table 3. Simulation scenario parameter settings

Parameter	Value
wireless transmission distance	250m
the wireless channel bandwidth	2Mbps
node distribution area	1000m * 1000m
node deployment	random
number of nodes	20, 40, 60, 80, 100, 120, 140, 160
simulation time	500s
the data type	CBR
packets sending rate	20 packets/s
Packet size	128 bytes
MAC protocol	802.15.4
routing protocol	DSDV, DSDVM, MDW

The three routing protocols, DSDV, DSDVM and MDW, show different performance in different network size. The data delivery rate is illustrated in figure 3. In the small size network of 20 to 80 nodes, the data delivery rate of MDW is higher than that of DSDV and DSDVM. Because MDW takes into account of the stability of the routing link, so the data delivery rate is guaranteed. It is suitable for the WIA-PA network which the network topology is relatively stable and the network size is small. The data delivery rate of the multi-path routing protocol is higher than that of single-path DSDV, which tests and verifies the necessity of the multi-path route.

The data packet port to port average delay of the three protocols is illustrated in figure 4 respectively.

In general, the delay of the three is not too big. The delay of DSDV and DSDVM is bigger than that of the MDW, which is because the MDW's survival of routing cycle is relatively long and the influence of updating and maintenance for port to port is reduced. The average remaining energy of the three routes is illustrated in figure 5. The picture shows that after adding neighbor table and multi-path route, the discovery and maintenance of the route consume extra energy. However, the route of MDW is based on the link stability, which reduces the discovery and maintenance times. Compared with DSDV and DSDVM, MDW ensures the improvement of the real-time and reliability of WIA-PA network at the expense of less energy.

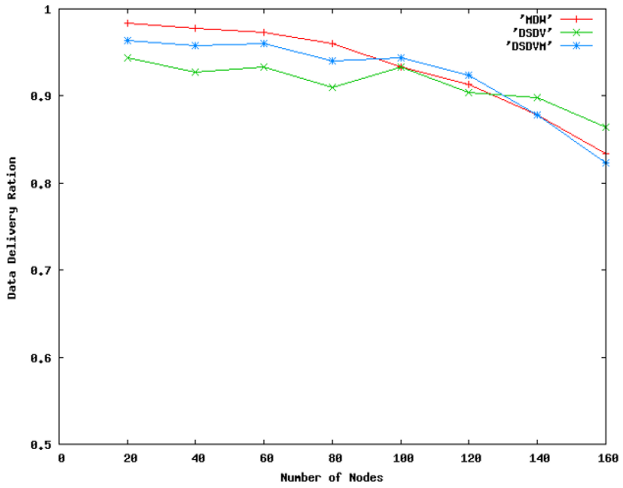

Figure 3. The packet delivery rate under different node size

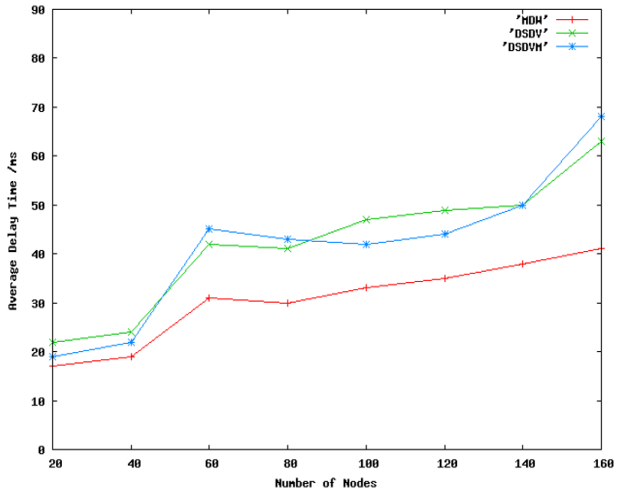

Figure 4. The average delay of port to port in different node size

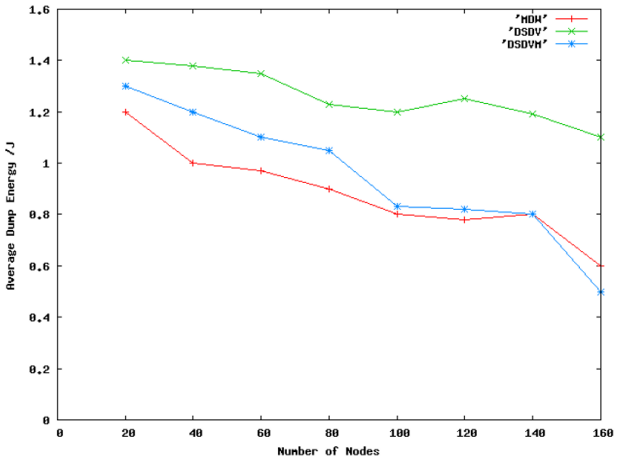

Figure 5. The average remaining energy in different node size

5. Conclusions

The requirement for real-time and reliability of the WIA-PA network data transmission in industrial process automation is strict. The design of the routing protocols is the key technology for ensuring a hard real-time and high reliability WIA-PA network. The MDW routing protocol in this paper is the improvement of the DSDV. It adopts the routing choosing criterion based on the link stability and the node disjoint strategy to choose a high link stability path for transmitting data. Meanwhile, it will choose a relatively stable and disjoint path as backup route to enhance the real-time and reliability of WIA-PA network. Finally, the improvement of MDW on data packet delivery rate, the average delay of port to port and the average remaining energy of the route is tested and verified through NS-2 simulation test.

Acknowledgements

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Data Mining in Medical Quality Supervision Based on Improved BP Neural Network

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Abstract
The current data mining is confronted with many problems in its application in medical quality and safety monitoring based on traditional BP neural network. This paper is aimed at proposing a scheme based on improved BP neural network while providing an analysis of issues concerning data mining based on improved BP neural network in medical quality supervision. For medical quality supervision, the use of improves BP neural network mining, not only improves the level of medical treatment regulation, resulting in medical claims expenses decreased by 8% and infectious disease infection rate decreased by 12%, but exerts positive effects in application as well. In general, in medical quality supervision, the application data mining based on improved BP neural network plays a positive role in two aspects: on the one hand, it can effectively dig out useful data and information; on the other hand, it can guarantee the quality of medical quality supervision.
Keywords: MEDICAL QUALITY SUPERVISION, IMPROVED BP NEURAL NETWORK, DATA MINING