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Wireless Sensor Environment Monitoring System for Chemical Industrial Areas Based on Path Selection Routing Algorithm

Ziqing Xie

Zhejiang Industry Polytechnic College, Zhejiang 312000,China
ziqingxie2091@zjipc.com

To solve such defects as scattered monitoring points, difficult wiring and poor real-time capability of the current environment monitoring, a kind of remote real-time monitoring system for the air environment of chemical industrial areas based on wireless sensor network (WSN) is designed in this paper. Main functions of this system are as follows: the sensor nodes distributed in chemical industrial areas can collect air environment parameters, the data can be transmitted to data centre of the central control room via base station for real-time processing and analysis, remote terminal users can give round-the-clock real-time monitoring to the air quality through the internet, it can also give real-time alarm as to air environment of the areas affected by such emergencies as pollution and the dramatic change of environment, and it could provide decision support as to prevention of air environment pollution. It is proved by the experimental results that wireless sensor network can not only overcome the problem of low reliability of the traditional environment monitoring system but also increase new monitoring function. Thus, it can be concluded that the wireless sensor monitoring system based on path algorithm can solve the problem of real-time monitoring on the environment of chemical industrial areas effectively, and it shows the great application value in the unmanned environment monitoring in harsh conditions and in the event tracking.

1. Introduction

Appearance of chemical production is the sign for promotion of social development, scientific and technological progress and human civilization to a certain degree, the important area of modern production, and the important embodiment of the developed industry currently. Along with rapid growth of the economy of our country, chemical industry develops at full speed, and the accompanying thing is continuous increment of the frequency of chemical accidents which could cause numerous casualties, serious economic loss and even adverse political influence (Movassaghi et al., 2014). Chemical industry has huge promotion and acceleration effects on social economy and living standard of the people on the one hand, and great threat to life and property safety of the masses on the other hand.

By aiming at the hidden dangers and disadvantages of the monitoring system for chemical industrial areas, it is imperative to research and develop the modern, safe, reliable, efficient and cheap air environment monitoring system. The research on the environment monitoring system for chemical industrial areas based on wireless sensor network can effectively solve the problem of difficult environment monitoring in chemical industrial areas and obtain the real-time effective data, the monitoring method is safe, simple and reliable, and environment monitoring personnel does not need to arrive at the chemical industrial areas personally for monitoring, which are the reasons for our research and development on this environment monitoring system (Mansou et al., 2014). Moreover, research and development on this monitoring system shall play an increasingly important role in the environment monitoring in chemical industrial areas.

This paper designed difficult wiring and poor real-time capability of the current environment monitoring, a kind of remote real-time monitoring system for the air environment of chemical industrial areas based on wireless sensor network (WSN) To solve such defects as scattered monitoring points. Main functions of this system are as follows: the sensor nodes distributed in chemical industrial areas can collect air environment parameters,

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the data can be transmitted to data centre of the central control room via base station for real-time processing and analysis, remote terminal users can give round-the-clock real-time monitoring to the air quality through the internet, it can also give real-time alarm as to air environment of the areas affected by such emergencies as pollution and the dramatic change of environment, and it could provide decision support as to prevention of air environment pollution. It is proved by the experimental results that wireless sensor network can not only overcome the problem of low reliability of the traditional environment monitoring system but also increase new monitoring function.

2. Clustering Algorithm Based on the Maximum Energy Path Selection

The wireless sensor network not only overcomes low reliability problem of the traditional environment monitoring system effectively, but also increases new monitoring function, so it can better solve the problem of real-time environment monitoring in chemical industrial areas (Sangeethaa et al., 2015). Most of the current WSN are composed of some sensor nodes with battery (Yang et al., 2015), and these data collection nodes in wireless sensor network are powered by battery, while the battery cannot be changed or charged timely in special and complex environment, so it needs to design the algorithm which could reduce power consumption of the network to prolong use time of the monitoring network (Weng et al., 2013).

2.1 Clustering algorithm based on the maximum energy path selection

Formula (1) is the classical wireless sensor network energy consumption formula. It supposes the energy of bit loss of transmission b as E_T; the magnified power loss is divided into free space model ($d<d_0$) and multi-path attenuation model ($d>d_0$) according to the positions of source node and destination node.

$$E_T = \begin{cases} b \times E_{elec} + b \times \xi_{fs} \times d^2, d < d_0 \\ b \times E_{elec} + b \times \xi_{mp} \times d^4, d \geq d_0 \end{cases} \quad (1)$$

In the formula, E_{elec} refers to the used energy value of transmission circuit, ξ_{fs} refers to the magnified power energy value of the free space channel model, and ξ_{mp} refers to the magnified power energy value of the multi-path attenuation channel model. It can be seen from formula (1) that the energy loss shall be smaller along with the transmission approaching to node during the process of transmitting data to relay node via cluster head and finally to base station. The distance from cluster head to member node shall be much shorter than the distance from cluster head to relay node or gateway, and the power of network is mainly used in inter-cluster transmission. By optimizing the performance, all power consumptions of network can e reduced.

2.2 Maximum energy path selection mechanism

In the wireless sensor network, sensor node has a limited spreading scope, and node treatment and storage functions and the energy resource are also limited (Zuo et al., 2013). We plan to select the optimal path transmission data packet all the time, and maximize the network life cycle. In this program, we shall give energy estimation, use threshold value, and select the optimal path according to the subsequent average energy value and the maximum energy plan.

In the ECME algorithm, the path with the maximum energy in the multiple data transmission paths is selected by adopting the maximum energy path selection technology, and it is used in communication. This technology is that: it supposes that multiple routing paths have been established between transmitting terminal of source node and receiving terminal of destination node, and then one shall give comparison to total energy value of these replaceable paths, select the path with the maximum integrated power value, and take it as the optimal path for data transmission (Guo and Zhang, 2014).

2.3 ECME algorithm simulation and performance analysis

It gives simulation analysis to ECME algorithm, AODV based on average energy and AODV with threshold value by virtue of Gnuplot simulation software. Gnuplot is a graphing tool by using commands, namely that user can give graphing by inputting corresponding commands in software and can give modification by giving commands. Thus, we can give intuitive analysis by virtue of graph.

Throughput rate analysis: throughput rate refers to the maximum receiving and transmitting rates borne by equipment at the time of no frame loss, and it is mainly used in measuring network performance. It also refers to the data volume transmitted in network within 1s, or the number of requests for data processing within 1s. It is the important indicator for network performance measurement, and it is measured by “number of bytes/second” generally. Actually, one request and one page all refer to the data transmitted in network essentially, and unit of the data is number of bytes. Figure 1 shows the simulation analysis of throughput rate.

It is known from the figure that: after the time reaches to 50s, throughput rate of ECME algorithm is still very high; throughput rate of EAODV begins to show attenuation somewhat after 20s; AODV with threshold value shows attenuation substantially after 50s, and it rises to some extent when approaching to 70s. According to the comprehensive analysis, throughput rate of ECME algorithm is higher than that of EAODV based on average energy and that of AODV with threshold value. This means that throughput rate of the proposed algorithm is more superior to that of the other two algorithms.

Data packet transfer rate: it refers to proportion of the data packet transmitted by source node and the data received by receiving terminal, and this parameter is very important for the network performance test. Figure 2 shows the analysis on data packet transfer rates of the several algorithm protocols by means of simulation.

It is known from the figure that ECME energy algorithm can reach the data transmission close to 96% by simulation and after giving comparison to data packet delivery rates of the three energy algorithm technologies in wireless sensor network.

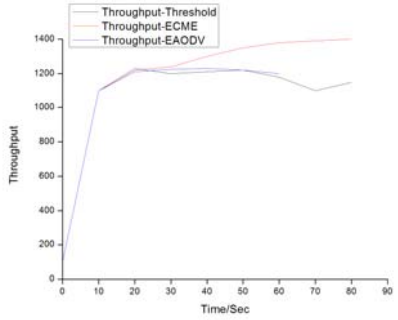

Figure 1: Throughput analysis

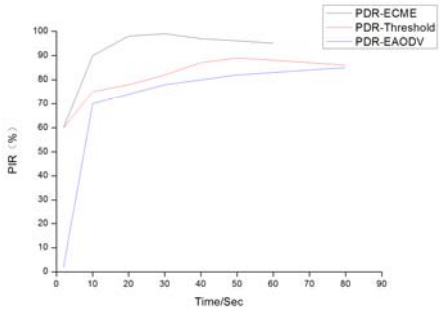

Figure 2: Packet delivery ratio analysis

UDP data packet loss analysis: UDP is a kind of transport layer protocol without direct correlation, it is used in the transmission when data arrives not by sequence, it can provide a relatively better information transfer service, and the specification is IETF RFC 768. Figure 3 shows UDP information packet loss analysis of the several algorithms.

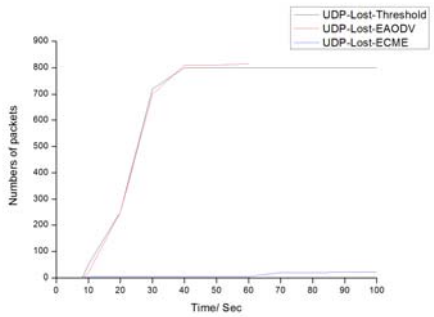

Figure 3: UDP packets lost analysis

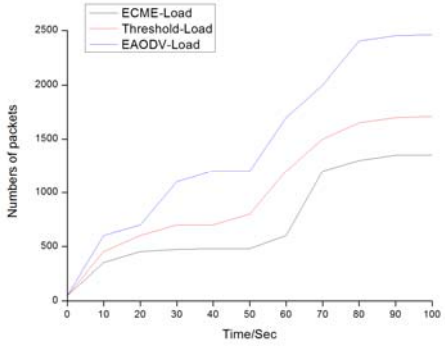

Figure 4: Routing load analysis

It is known from the figure that the packet loss rate of ECME algorithm is far smaller than the other two corresponding programs during the whole process after transmitting data packet successfully. The program proposed in this paper merely show loss of 30 packets during data transmission process, while the protocol based on average energy and the AODV protocol with threshold value show loss of 800 packets and 840 packets respectively, which indicates that many nodes of this network all play roles fully.

Routing load analysis: routing load refers to the total routing packet exceeding actual data packet of the network, and the greater load may cause the weaker network performance. Size of the part exceeding network information packet is used in judging quality of the protocol. Thus, Figure 4 gives routing load simulation analysis to the three protocols of ECME, AODV based on average energy and AODV with threshold value.

It is known from the figure that: quantity of the routings in ECME energy program is merely 1,200 packets when reaching 85s, while results of AODV based on average energy and AODV with threshold value are 2,800 packets and 1,600 packets respectively at the same time point. Moreover, it can be seen intuitively from the simulation curve in figure that: the quantity of routing overloads and the energy consumption of routing packet in broadcasting of the ECME energy program are all much smaller than those of the other two programs.

It is indicated from the simulation in the aforementioned several aspects that: ECME algorithm possesses the higher transmission efficiency by comparing with AODV based on average energy, AODV protocol with threshold value and even other existed technology based on data routing cluster, and effective use of the network energy occupies a relatively high proportion.

3. Practical Application Design of the Chemical Production Environment Monitoring Network

3.1 Chemical production environment monitoring system structure design

The environment monitoring system for chemical industrial areas based on wireless sensor network adopts multi innovative designs, and it provides the basis for expansion of the work of the environmental protection department by establishing a stereo monitoring network in chemical industrial area, which plays a great role in environmental protection. This project adopts wireless sensor network technology which integrates microelectronic technology, built-in computer technology, modern network, wireless communication technology and distributed information processing technology, etc. and can give real-time monitoring and collection to information of the various environment monitoring objects in network coverage areas by coordination of the advanced technologies and then give processing, and the processed information can be transmitted to terminal equipment by means of wireless transmission. Sensor can ensure the accurate data collection, and wireless communication technology can ensure reliable and timely data transmission, so this technology can well solve environment monitoring problem of the chemical industrial areas currently.

3.2 Simulation results analysis

The design determined by aiming at the chemical production environment monitoring system gives analog simulation to power usage of the deployment nodes by utilizing MATLAB 6.0 simulation environment. Table 1 shows the simulation value setting, and table 2 shows the data generated by simulation.

Table 1: Simulation parameters

Correlation parameter	Numerical value (unit)
Number of network sensor nodes	1200
Initial energy of sensor node	250 mAh
Network coverage area	150
Node coverage rate	90%
Node sleeping time	15 min
Maximum communication distance of nodes	25 m
Transceiver speed	11400 bps

Table 2: Simulation Result

Correlation parameter	Numerical value
Hop node number	121
Maximum hop count	22
Coverage rate	90%
The occupancy rate of the surviving nodes after the failure of network's normal working mode	6.3%
Network life cycle	25 months

It can be seen from the two tables above that: when the maximum communication distance of the nodes deployed in chemical plant is 25m and the receiving-transmitting rate is 11400 bps, the network can give continuous work for 25 months; after failure of the normal working mode of the network, there are only 6.3 nodes survived in network, which indicates that power of various nodes in the network is consumed evenly, thus real time of the data of the areas monitored and long-time operation of the network can be ensured.

CMPR routing algorithm and MP-OLSR routing algorithm are used in indicator difference analysis of the routing performances in different occasions, and the concrete simulation results are as shown in the Figure 5 below:

Figure 5 shows node residual energy variance comparison between CMPR and MP-OLSR in different node movement speeds. It can be seen from the figure that node residual energy variance of CMPR routing algorithm is lower than MP-OLSR routing algorithm in different node movement speeds, and the performance is promoted by 8.1% averagely, which indicates that the node residual energy of wireless mobile network adopting CMPR routing algorithm is more even. The more even node energy consumption can avoid “routing cavity”, thus life cycle of the network can be prolonged greatly.

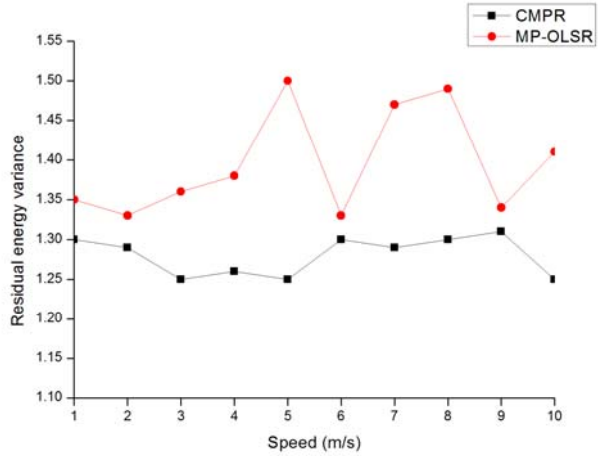

Figure 5: Comparison chart of residual energy variance between CMPR and MP-OLSR

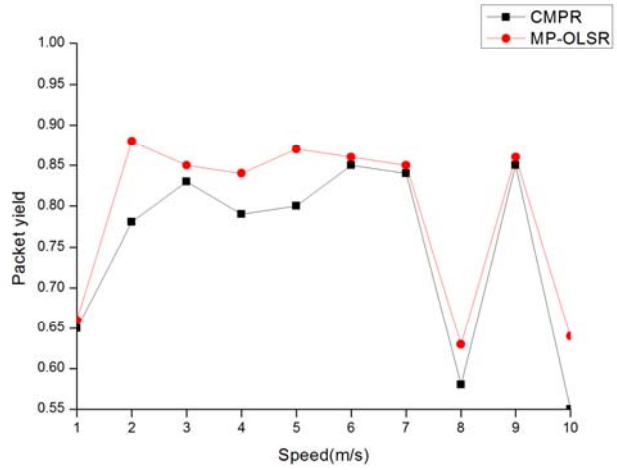

Figure 6: Comparison chart of receiving packets ratio between CMPR and MP-OLSR

Figure 6 shows the packet reception rate comparison between CMPR and MP-OLSR in different node movement speeds. It can be seen from the figure that node packet reception rate of CMPR routing algorithm is slightly higher than MP-OLSR routing algorithm (promoting by 5.7% averagely). The high packet reception

rate can be ensured by taking such measures as establishment of multi non-intersect paths, promotion of the use ratio of buffer area and adoption of the more efficient routing decision algorithm. The mechanisms adopted by CMPR routing algorithm and MP-OLSR routing algorithm are same at the time of constructing multi paths, they all use Dijkstra algorithm in calculating the minimum-cost routing from source node to destination node, and the methods adopted are all the construction of multi non-intersect paths with the aforementioned penalty function. However, in the aspect of buffer area use rate, CMPR routing algorithm possesses the higher efficiency by comparing with MP-OLSR routing algorithm.

4. Conclusions

In this paper, it gives analysis on energy conservation of the wireless sensor network from the two aspects of overall structure and node power consumption of the wireless sensor network. By aiming at energy conservation of the wireless sensor network for environment monitoring, it puts forward the clustering routing algorithm based on the maximum energy path selection, this algorithm adopts the principle of generating the optimal path selection by changing threshold value setting and obtaining the maximum energy, and member nodes of each cluster can give data transmission and algorithm simulation by selecting the minimum load node from adjacent nodes and the maximum energy path. Finally, it gives research on software and hardware systems of the chemical environment monitoring system network, and designs a set of system with low energy consumption by combining with the demand. It is proved by the experiment that: this system possesses strong operability and strong flexibility, and it can adjust power use of the node used effectively, promote use life of the wireless sensor network, ensure chemical plant being monitored continuously and guarantee real time and continuity of monitoring data and the personal and property safety.

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