Research Article

Communication MWSN Data Transmission Mechanism Based on a Wireless Sensor Network

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A wireless sensor network (WSN) is considered to have a wide application prospect in a smart distribution network due to its unique low power consumption, fast self-organization, and superior coordination. In order to study the communication MWSN data transmission mechanism based on a wireless sensor network, the difficulty of applying a wireless sensor network to an intelligent distribution network communication is to meet the real-time and reliability requirements of power industry distribution network data communication specifications under the limited network resources. Firstly, the transmission probability is calculated by considering the path loss, the speed of the node, the direction of the node, and the residual energy of the node. In addition, the transmission and replacement order of the message is determined according to the survival time of the data message. Simulation experiments are carried out on MATLAB. The result shows the proposed routing algorithm, compared with the DT algorithm, flooding algorithm, and FAD algorithm, the delivery rate of data messages is increased by at least 6%, and the number of copies is reduced by at least 10% compared with the flooding algorithm and the FAD algorithm. On the basis of satisfying the mobility of sink nodes, the algorithm proposed in this paper can effectively save network energy consumption and prolong the network lifetime.

1. Introduction

Wireless sensor nodes are formed through self-organization and widely used in all walks of life; for example, it is used for monitoring of wild animals, farmland, environment, and infectious diseases. The wireless sensor network is data-centric; however, due to the dynamic changes of the network topology, the wireless link communication quality between nodes is unstable, so design an efficient data transmission algorithm, become a research hotspot of wireless sensor network. A wireless sensor network (WSN) (Figure 1) is a multihop self-organizing network system that deploys a large number of microsensor nodes with computing capability in the monitoring area and forms a short-range wireless low-power communication mode. It integrated the micro-electronic technology, embedded technology, modern network, and wireless communication technology, distributed information processing technology and other advanced technology, can collect the collaborative real-time monitoring, awareness, and network coverage area by monitoring object information, and carries on the processing, after processing the information sent by the wireless way, and in the organization more jump transmission way sent to the observer. It can be seen that the wireless sensor network has the characteristics of dynamic intelligent processing, automatic networking, and cooperative perception.

The main problem of wireless sensor networks is limited node energy and limited storage space, and the network topology changes dynamically. In order to solve the data transmission problem of the wireless sensor network, relevant scholars at home and abroad from different perspectives propose some data transmission mechanisms, in
In order to a certain extent to solve the data transmission problem of the wireless sensor network, but there are still many areas that need to be improved further, such as the calculation formula of node transmission probability and the management of the number of copies [1]. The magnitude of the signal strength value not only can reflect the relative distance between the node and the sink node but also can reflect the quality of wireless link communication between nodes, so the authors based on the signal strength of the received data message calculate the path loss of the wireless link between two nodes and then consider the remaining energy of the node and the movement speed of the node, so as to calculate the transmission probability of the node [2]. In wireless sensor networks, in order to improve the delivery rate of data messages, most of them use multiple copies for transmission; the impact is redundant copies of data messages in the network, not only occupying the storage space of the sensor node but also consuming a lot of energy, so how to find a balance between the data message delivery rate and energy consumption will become a difficult problem in designing a data transmission mechanism. Based on the analysis of the above problems, the authors propose a simple wireless sensor network-based communication MWSN data transmission mechanism [3].

The hierarchy of the whole Internet of things mainly includes three layers: perception layer, network layer, and application layer. The fusion of the wireless sensor network and mobile communication network is to combine the perception layer and the network layer. The fusion of these two networks will bring many key technologies. Only by solving these key technologies well can the fusion of the two networks be carried out and the development of the Internet of things be advanced.

It can be seen from the above analysis that the path loss caused by obstacles is not taken into account when selecting forwarding nodes based on a node motion model and clustering idea. In mobile wireless sensor networks, the transmission of data messages is realized through wireless channels. The communication quality of wireless channels is unstable due to the movement of nodes and the change of the environment. In order to solve the deficiency of the literature, based on the limited resources of wireless sensor network communications and wireless link quality instability problem, through calculating the path loss to estimate quality of wireless communication link, besides considering the node energy state and the motion characteristics of the selected message delivery capacity greater than itself forward as the candidate nodes, based on the data message replications, the forwarding node is determined from the candidate forwarding node.

2. Literature Review

In response to this research question, Feng and others proposed that in the spray phase, copy the data message to the meeting node whose transmission probability value is greater than itself [4]. Zhang et al. proposed a dynamic
prediction algorithm DPMQ based on multiqueue management and divide the storage queues of nodes into three categories, so as to determine the principle of inserting and discarding data messages [5]. Adam et al. proposed the use of a heuristic and approximation algorithm and solve the multiconstrained QoS-MCMP routing algorithm for wireless sensor networks [6]. Wang et al. proposed an improved LQ-AODV routing algorithm based on link quality; this strategy only occurs after link failure and congestion and will reselect the routing path [7]. In order to reduce the energy consumption of the network, Lin et al. in a network with overlapping clusters find nodes in multiple clusters and use this type of node to forward data messages, effectively improving the performance of the network, in order to balance the energy consumption of the network [8]. Kim et al. assumed that the cluster head node can be the member node which is fixed, proposed a routing algorithm MCHCA, which is based on the size of the network and the communication radius of the node, determined the number of cluster head nodes, and collected data messages when the cluster head node moves to the communication range of each member node in the cluster; finally, the data messages of all member nodes are merged and transmitted to the sink node [9]. Therefore, Al-Mekhlaﬁ et al. believe that in-depth study on the new characteristics brought by the combination of the wireless sensor network and mobile communication network explores the design of a new wireless sensor network in line with the development trend of a ubiquitous network in the future and its inﬂuence on the future mobile communication network from terminal to network and even business development [10].

On the basis of the current research, propose a communication MWSN data transmission mechanism based on the wireless sensor network, propose a routing algorithm LDM, according to the current position of the node and the next movement direction, calculate the transmission probability of the node, and select the next hop sending node according to the calculated transmission probability; at the same time, it manages the storage queue of the node and improves the performance of the network. The results show the proposed routing algorithm, compared with the DT algorithm, flooding algorithm, and FAD algorithm, the delivery rate of data messages is increased by at least 6%, and the number of copies is reduced by at least 10% compared with that of the flooding algorithm and FAD algorithm [11–13].

3. Methods

3.1. Network Model and Energy Model. The network monitoring area is set as a square area with side length of $M$, and $n$ sensor nodes move randomly in this area. The node uses the positioning algorithm to determine the initial position of the movement [14] and randomly determines the destination of the movement and moves uniformly in a straight line toward the destination at a speed of $[v_{min}, v_{max}]$ (see Figures 1 and 2).

The energy model uses a simple wireless communication energy consumption model. Since the energy consumption of the communication module is the largest, for the sake of simplicity, only consider the energy consumption of nodes when sending and receiving data messages.

The energy consumption of the node when sending data messages, determined by the size of the data message $L$ and the transmission distance $d$, satisfies the formula.

$$E_{TX}(L, d) = \begin{cases} LE_{elec} + LE_{amp} d^4, & d < d_0, \\ LE_{elec} + LE_{amp} d^4, & d \geq d_0. \end{cases}$$

(1)

In the formula, $E_{elec}$ is the energy consumption of transmission and $e_{fs}$ and $e_{amp}$ are the energy consumption coefficients of the power amplification part.

The energy consumption when the node receives data messages, determined by the size $L$ of the data message, satisfies the formula.

$$E_{RX}(L) = E_{RX-elec}(L) = LE_{elec}.$$  

(2)

Assuming that the communication radius $R$ of the node is smaller than $d_0$, when two nodes meet and when a node sends a data message of length $L$, the energy consumption is

$$E_{TX}(L) = LE_{elec} + LE_{fs} d^2.$$  

(3)

The energy consumption of a node receiving a data message of length $L$ is

$$E_{RX}(L) = LE_{elec}.$$  

(4)

After the node sends and receives the data message of length $L$, the remaining energy is

$$E_{residual} = E_{initial} - (2E_{elec} + LE_{fs} d^2).$$  

(5)

3.2. Calculation of Transmission Probability Value. In wireless sensor networks, sink nodes have unlimited energy, strong computing power, and large storage space and can control the transmission power. According to the literature, the sink node periodically broadcasts detection data packets; it has little impact on the transmission of data messages by sensor nodes in the network [15]. After the sensor node receives the lightweight detection packet sent by the sink node, the path loss can be calculated as follows. After the sensor node $i$ receives the lightweight detection data packet sent by the sink node, the calculation formula of path loss is

$$LS_i = LS_0 + \omega \ln \left( \frac{d_i}{d_0} \right),$$  

(6)

where $d_i$ is the relative distance between the sensor node $i$ and sink; $d_0$ is the selected reference relative distance, and the author takes $1m$; $\omega$ is the path loss rate, and the size of the value is related to the environment (take 3); $LS_0$ is the corresponding path loss value when the distance is $d_0$. 


For sensor node $i$, calculate the direction of movement of the node according to the last and current path loss; the formula is

$$mv_i = LS_{it} - LS_{it'} = \begin{cases} 
1, & \text{if } LS_{it} - LS_{it'} < 0, \\
0, & \text{if } LS_{it} - LS_{it'} = 0, \\
-1, & \text{if } LS_{it} - LS_{it'} > 0,
\end{cases}$$

(7)

In the formula, $LS_{it}$ means the calculated path loss after the detection packet was received last time and $LS_{it'}$ represents the path loss currently calculated. After the sink node sends the detection data packet, some nodes will not receive due to link conflicts and other reasons [16], in order to calculate the movement direction of the node more accurately.

Let the transmission probability of sensor node $i$ be $P_i$, which is related to the current path loss of the sensor node, the node’s own movement direction, the remaining energy of the node, and the speed of the node. $P_i$ calculation formula is

$$P_i = a \cdot \frac{1}{LS_i} \cdot \frac{mv_i \cdot |v|}{v_{max}} + \gamma \cdot \frac{E_{res} \cdot |E_{ini}|}{E_{ini}}$$

(8)

In the formula, the values of $a$, $\beta$, and $\gamma$ can be selected according to different applications, in order to determine the focus of the above three factors; the authors focus on the third factor, the energy state of the node; the values in the simulation experiment are $a = 0.3$, $\beta = 0.2$, and $\gamma = 0.5$, respectively.

### 3.3. Management of the Number of Copies

Transmission of data messages adopts the “storage-carry-forward” approach. In order to increase the delivery rate of data messages, reduce the delay of data message transmission and adopt multiple copies of management. However, the redundancy of data messages will consume more energy [17]; therefore, controlling the number of copies of a data message is the key to designing a data transmission mechanism.

Without loss of generality, assuming that node $i$ senses and generates a new data message $k$, the transmission probability of node $i$ is $P_i$; let the number of copies of the data message $k$ be $m$. With any copy of data message $k$, when the probability of being successfully received by the sink node is $\theta$, $m$ is the number of copies of data message $k$. The determination of the value of $\theta$ will affect the number of copies of the data message; the larger the value of $\theta$, the more the copies and vice versa [18].

With any copy of data message $k$ transmitted by sensor node $i$, the probability of being successfully received by the sink node is

$$1 - (1 - P_i)^m.$$  

(9)

According to the above analysis, then $1 - (1 - P_i)^m = \theta$; then, there is

$$m = \begin{cases} 
\log_{1-P_i}(1-\theta), & P_i < \theta, \\
1, & \text{other.}
\end{cases}$$

(10)

Since the sensor node is moving, its transmission probability value changes dynamically. It can be seen from formula (10), the number of copies is determined by the node’s transmission probability values $P_i$ and $\theta$, so when the change of $P_i$ is greater than a given threshold, the number of copies should be updated in due course.

Assuming that $e$ copies of the data message have been transmitted and $n_{new}$ copies need to be transmitted, the calculation formula is

$$1 - (1 - P_i)^{e+n_{new}} = \theta,$$

(11)

$$n_{new} = \log_{1-P_i}(1-P_i^e) - e.$$  

(12)

### 3.4. Transmission of Data Messages

After the sensor nodes in the network meet, send inquiry packets to each other; thereby, the transmission probability value of the encountering node is obtained [19]. Put the data message dynamics, copy transmission to the node whose probability value is greater than itself, and modify the number of copies of the data message. When the number of candidate forwarding nodes is greater than the number of copies of the data message that needs to be transmitted, the data message is copied
and transmitted to several nodes with higher probability values. The pseudo-code of the algorithm is shown in Figure 3.

The storage space of sensor nodes is limited, and the authors manage the storage queue of sensor nodes through the following 3 methods: (1) dynamically update the number of copies of data messages, (2) delete data messages that have been successfully transmitted, and (3) queue the data messages in the node cache queue and determine the transmission and replacement sequence of data messages. The transmission of specific data messages adopts multiple copies, so there is redundancy of data messages in the network; according to the management of the number of copies in the previous article, the number of copies of the data message is calculated by formula (10); update the number of copies by equation (12). In order to save the energy consumption of the network [19], when a copy of the data message is successfully received by the sink node, sensor nodes in the network, by detecting the ID number field of the successfully received data message in the data packet, delete the corresponding data message. The longer the survival time of general data messages, the higher the redundancy and the lower the priority. So the authors based on the survival time of the data message sort the messages in the node storage queue. When the storage queue of the sensor node is full [20], if a new data message arrives, then we need to compare the priority of the data message in the node storage queue with the priority of the new data message and to replace and reorder. Figure 3 shows the data messages in the node storage queue.

4. Results and Analysis

Using the MATLAB7.0 simulation tool, the performance of the data transmission algorithm proposed by the authors is compared with the performance of the other three routing algorithms, and the experiments are shown in Tables 1 and 2.

When the number of nodes is 100, 200, or 300, the change curve of the percentage of dead nodes and the number of rounds tends to be straight; that is, when the number of dead nodes increases, the energy consumption of the medium-density network can maintain a certain balance and its change is close to being linear, which is convenient for predicting the network life cycle and giving early warning.

Four algorithms under default parameters, comparison of simulation results of the network life cycle, average number of copies, and delivery rate of data messages are shown in Table 3.

It can be seen from Table 3 that the number of copies of the direct transmission algorithm DT is always 1, and the life cycle of the network is the shorter, but the delivery rate of data messages is the lowest. This is because after the sensor node generates a data message, carry your own data message campaign, the data message is not transmitted to the sink node until it meets the sink node, and the transmission of data messages does not rely on the help of other sensor nodes. Flooding has the lowest network life cycle, and the average number of copies of data messages is the largest [21, 22]; the delivery rate of data messages is higher than that of DT. This is because the sensor node takes the data message carried by itself; copy to all sensor nodes encountered; however, due to the limited storage space of sensor nodes, the storage queue of the nodes quickly fills up; it no longer receives data messages from other nodes afterwards and only receives data messages generated by the node itself. The authors’ algorithm has a longer network life cycle than the FAD algorithm and flooding algorithm, the average number of copies of data messages has decreased, and the delivery rate of data messages has increased. This is because when the authors’ algorithm selects the forwarding node, the energy state of the node and the direction of movement of the node are taken into account. In addition, the number

| Table 1: Parameter settings. |
|-----------------------------|
| Parameter                   | Value                     |
| Simulation scene (m²)        | (0,500)−(0,500)           |
| Number of nodes             | 75                        |
| Node communication radius (m)| 9                         |
| Packet length (B)           | 2800                      |
| Sink node coordinates       | (300, 300)                |
| Initial energy (J)          | 30                        |

| Table 2: Parameter settings. |
|-----------------------------|
| Parameter                   | Value                     |
| Length of probe data packet (B)| 300                      |
| Data message generation rate (s)| 4                         |
| ε_{up} (pJ/B·m^4)            | 0.014                     |
| ε_{Ed} (pJ/B·m^{-2})         | 26                        |
| E_{elec} (nJ/B)              | 6                         |
| α, β, γ                      | 0.3, 0.2, 0.5             |

Figure 3: Information of the node queue.
Table 3: Simulation experiment results.

| Parameter                        | Algorithm | FAD | DT  | Flooding |
|----------------------------------|-----------|-----|-----|----------|
| Network life cycle (d)           | 7         | 4.5 | 560 | 4        |
| Average number of copies of data message | 6         | 11.0| 1   | 16       |
| Delivery rate (%)                | 80        | 78.3| 56  | 80       |

![Figure 4: Changes in delivery rate under default parameters.](image1)

![Figure 5: Changes in delivery rate under default parameters.](image2)
of copies of the data message is dynamically updated through the set threshold, and delete successfully transmitted data messages to reduce network load and energy consumption [23].

It can be seen from the simulation results that the algorithm in this paper can save energy consumption and improve network lifetime to a certain extent and also take into account the influence of mobile sink nodes on network energy consumption. In general, it can meet the needs of general applications. At the same time, for medium-density networks, better energy consumption prediction effect can be achieved. If a data fusion mechanism is added, the life cycle of the network can be better extended.

Under the default simulation parameters, the change of the delivery rate of the four algorithm data messages is shown in Figure 4.

The influence of the communication radius of the node on performance is shown in Figure 5. It can be seen from Figure 5 that as the node communication radius becomes larger, the data message delivery rate curves of the four algorithms are rising. When the communication radius of the node becomes larger, the probability of each sensor node meeting other nodes in the network becomes greater; the possibility of data messages being transmitted to sink nodes will also increase. The data message delivery rate corresponding to the authors’ algorithm is higher than that of the other three algorithms; this is because the authors’ algorithm selects the forwarding node based on the link communication quality of the encountering node, more in line with the actual requirements of wireless communication; in addition, the authors’ algorithm dynamically controls the number of copies of data messages, sorts the data messages in the queue, and effectively manages the node’s queue, thereby improving the delivery rate of data messages.

5. Conclusion

The combination of the wireless sensor network and mobile communication network can make use of the wide-area coverage and transmission capability provided by a mobile communication network to realize the ability of the monitored area to communicate with the remote management node and improve the transmission distance of the existing wireless sensor network. However, due to the differences in the structure of the two networks, it is bound to bring difficulties to the heterogeneous fusion of the network.

The authors explain the communication based on the wireless sensor network and algorithm optimization under the MWSN data transmission mechanism. Wireless sensor network communication is a comprehensive research system and has a lot of technical extension areas; in many aspects, further discussion and research are needed. In order to improve the performance of the network, manage the storage queue of the node; when calculating the transmission probability of a node, comprehensively consider the path loss, the remaining energy of the node, the speed of the node, and the direction of the node. When the transmission probability of a node exceeds a given threshold, the number of copies of the dynamic update message. And according to the received detection data packet, delete the data message that has been successfully received by the sink node in the queue of this node. The next step will consider heterogeneous nodes and diverse data types and how to achieve effective routing of data messages. The authors have a routing protocol for the integration of wireless sensor networks and mobile communication networks; during the research, discuss only from the perspective of energy and single sink node mobility; it does not involve factors such as data fusion, quality of service, congestion control, and multiple aggregation nodes and hybrid aggregation nodes. Finally, research out a report path selection mechanism suitable for the integration of the two networks with a hybrid weighted optimization, and provide an important theoretical basis for the development of the integration of the two networks.

Data Availability

All data shared within the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] Y. Jin, L. Zhou, Q. Wei, K. Bai, and J. F. Li, "Tree-based multi-hop routing method for energy efficiency of wireless sensor networks," Journal of Sensors, vol. 2021, 2021.

[2] L. L. Hung, F. Y. Leu, K. L. Tsai, and C. Y. Ko, "Energy-efficient cooperative routing scheme for heterogeneous wireless sensor networks," IEEE Access, vol. 8, 2020.

[3] B. Liu, R. Yang, M. Xu, and J. Zhou, "A chaotic elite niche evolutionary algorithm for low-power clustering in environment monitoring wireless sensor networks," Journal of Sensors, vol. 2021, no. 3, 2021.

[4] Z. Feng, J. Fu, D. Du, F. Li, and S. Sun, "A new approach of anomaly detection in wireless sensor networks using support vector data description," International Journal of Distributed Sensor Networks, vol. 13, no. 1, 2017.

[5] X. Zhang, D. Li, and Y. Zhang, "Maximum throughput under admission control with unknown queue-length in wireless sensor networks," IEEE Sensors Journal, vol. 20, no. 19, 2020.

[6] M. S. Adam, L. Y. Por, M. R. Hussain, N. Khan, and I. Ali, "An adaptive wake-up-interval to enhance receiver-based PS-MAC protocol for wireless sensor networks," Sensors, vol. 19, no. 17, p. 3732, 2019.

[7] R. Prodanovi, D. Rani, I. Vuli, N. Zori, and S. Stankovski, "Wireless sensor network in agriculture: model of cyber security," Sensors, vol. 20, no. 23, p. 6747, 2020.

[8] Z. Lin, H. C. Keh, R. Wu, and D. S. Roy, "Joint data collection and fusion using mobile sink in heterogeneous wireless sensor networks," IEEE Sensors Journal, vol. 21, 2020.

[9] C. M. Kim and S. J. Koh, "Device management and data transport in IoT networks based on visible light communication," Sensors, vol. 18, no. 8, p. 2741, 2018.

[10] Z. G. Al-Mekhlaﬁ, Z. M. Hanapi, and A. Saleh, "Firefly-inspired time synchronization mechanism for self-organizing energy-efficient wireless sensor networks: a survey," IEEE Access, vol. 7, 2019.
[11] D. Loganathan, M. Balasubramani, and R. Sabitha, “Energy aware efficient data aggregation (EAEDAR) with re-scheduling mechanism using clustering techniques in wireless sensor networks,” Wireless Personal Communications, vol. 117, 2020.

[12] C. Kucukkecei and A. Yazici, ”Multilevel object tracking in wireless multimedia sensor networks for surveillance applications using graph-based big data,” IEEE Access, vol. 7, 2019.

[13] D. Rosário, Z. Zhao, A. Santos, T. Braun, and E. Cerqueira, ”A beaconless opportunistic routing based on a cross-layer approach for efficient video dissemination in mobile multimedia IoT applications,” Computer Communications, vol. 45, pp. 21–31, 2014.

[14] W. Abdellatif, O. Youness, H. Abdelkader, and M. Hadhoud, ”Balanced density-based clustering technique based on distributed spatial analysis in wireless sensor network,” International Journal of Wireless Information Networks, vol. 26, no. 2, pp. 96–112, 2019.

[15] M. Katarzyna, W. Michal, and K. Bogdan, ”Secure and time-aware communication of wireless sensors monitoring overhead transmission lines,” Sensors, vol. 17, no. 7, 2017.

[16] R. Maheswar, P. Jayarajan, A. Sampathkumar et al., ”CBPR: a cluster-based backpressure routing for the Internet of things,” Wireless Personal Communications, vol. 118, no. 4, pp. 3167–3185, 2021.

[17] L. Kong, Q. Xiang, X. Liu et al., ”ICP: instantaneous clustering protocol for wireless sensor networks,” Computer networks, vol. 101, pp. 144–157, 2016.

[18] J. L. Guo, Y. Q. Chen, H. D. Yang, C. M. Chen, and Z. Zhang, ”Study on secrecy capacity of wireless sensor networks in Internet of things based on the amplify-and-forward compressed sensing scheme,” IEEE Access, vol. 7, 2019.

[19] B. A. Muzakkari, M. A. Mohamed, M. Kadir, and M. Mamut, ”Queue and priority-aware adaptive duty cycle scheme for energy efficient wireless sensor networks,” IEEE Access, vol. 8, 2020.

[20] S. Kannan, G. Dhiman, Y. Natarajan, A. Sharma, and M. Gheisari, ”Ubiquitous vehicular ad-hoc network computing using deep neural network with IoT-based bat agents for traffic management,” Electronics, vol. 10, no. 7, p. 785, 2021.

[21] Y. Liu, Q. Sun, A. Sharma, A. Sharma, and G. Dhiman, ”Line monitoring and identification based on roadmap towards edge computing,” Wireless Personal Communications, vol. 4, 2021.

[22] A. Sharma, R. Kumar, and P. Kaur, ”Study of issues and challenges of different routing protocols in wireless sensor network,” in 2019 fifth international conference on image information processing (ICIIP), Shimla, India, 2019.

[23] X. Xu, L. Li, and A. Sharma, ”Controlling messy errors in virtual reconstruction of random sports image capture points for complex systems,” International Journal of Systems Assurance Engineering and Management, vol. 1, 2021.