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DESIGN OF SMART HOME SYSTEM BASED ON WIRELESS SENSOR NETWORK LINK STATUS AWARENESS ALGORITHM

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Abstract. When wireless sensor networks are used in smart homes, the connection state will be unstable due to signal masking attenuation. This will cause low packet rate, high time delay and high cost in the network. In this paper, a network routing algorithm for wireless sensing based on connection conditions is designed. Secondly, the expected number of sends is proposed to evaluate the stability of links. Based on this, the following network signal delivery situation is forecasted in real time and quickly. According to the estimated expected number of transmissions, the path is dynamically corrected to effectively avoid attenuation in the channel and achieve optimal system performance. Experimental results show that the method proposed in this paper can improve the efficiency of message sending and reduce the routing cost under the condition of masking effect.

Key words: Wireless sensor network; Routing; Smart family; Shielding attenuation; Link potential sense

1. Introduction. Due to the particularity of the building structure, it has a solid electromagnetic interference ability and then has a more significant impact on the performance of the smart home wireless sensor network (WSNSH) system. The communication between perceptron's is affected by ground, wall and human movement. Because of the instability of the link connection, the network communication often fails. Some critical alarm information will likely be sent out too late, bringing significant security risks to users.

ZigBee network has been widely used in the practical application of smart home wireless sensor networks. Its default routing algorithm, LEACH, generally adopts flood routing to ensure that efficient routes can be found in the case of attenuation. However, this method also has two problems: First, the flood routing cost of the LEACH method is high; The existing methods do not fully use the wireless transmission characteristics in the environment and cannot accurately estimate the wireless transmission performance. It cannot be dynamically adjusted according to the actual situation. Therefore, its fundamental transmission characteristics in wireless channels, such as wireless SNSH, are not ideal. Second, although link quality indication (LQI) is used to evaluate the link state in the ZigBee node neighbor table and can help routing decisions, LQI needs to determine its value by repeatedly sending and receiving beacon frames. This increases the routing burden. In smart home networking systems, the energy-saving technologies of data communication between data nodes of wireless sensor networks and the whole sensor network mainly revolve around low energy consumption media access control technology, compressed sensing technology, low duty ratio working technology, low energy routing technology and so on. This paper [1] proposes a path selection method to solve the swarm clustering problem.

When the algorithm is used to select the cluster head of WSN in the smart home system network system, a series of factors such as the residual energy of data nodes, the location information of data nodes and the node density of data nodes in WSN should be considered comprehensively. Although this algorithm is reasonable for cluster selection in WSN, it also has a significant defect. Its convergence is poor. This paper studies a WSN path selection method for smart homes. Based on LEACH, the scalable Transmission Count (ETX-SH) is proposed to replace LQI to describe the transmission status of WSNSH under channel conditions [2]. The routing cost is reduced by using the directed routing method. At the same time, a path planning method based on optimal state is proposed.

2. Smart home wireless sensor network. The construction of WSNSH is usually similar to Figure 2.1 (image cited in Wireless Personal Communications, 2018, 101:1019-1055.). The network generally consists

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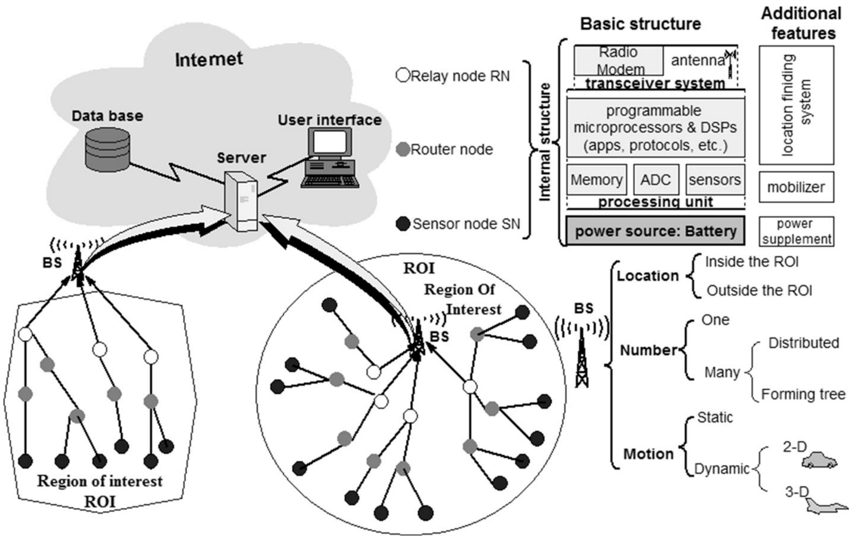

Fig. 2.1: Topology of smart home wireless sensor network.

of terminal, routing, and coordinator nodes. In a network, nodes are usually stationary [3]. In these sensors, the end nodes often collect data from sensors such as temperature, humidity, combustible gases, and infrared monitoring. The routing node is used to transmit data to the partner point. The coordinator node completes the network and data summary of the whole system.

3. LEACH algorithm. Classical LEACH is a hierarchical network structure control scheme based on the "wheel." Establishing a cluster head in each cycle and the information transfer between nodes in the cluster is the essential work of WSN. In the classical LEACH method, when the cluster head is selected, each node in WSN will generate a corresponding random sequence [4]. This random number is on a scale of 0 to 1. Compare this random number with the threshold $S(m)$ determined by formula (1) and determine whether this data node can serve as the cluster head.

$$S_j(m) = \begin{cases} \dfrac{q}{1 - q[d^* \bmod (\frac{1}{q})]}, m \in R \\ 0, m \notin R \end{cases} \tag{3.1}$$

The number of clusters in WSN that currently have several votes in the cluster is d. A cluster head algorithm based on cluster theory is proposed. The ratio of cluster heads to the number of data nodes in the wireless sensor network is represented by q. R is a cluster of nodes without cluster heads.

3.1. Improvement of LEACH algorithm.

3.1.1. Classification method of "hot area" and "non-hot area.". In the organizational structure of smart homes, the central node is generally the core to complete the control of the entire WSN. There must be a central node. Nodes need to have two main functions to realize the control of each node through the control terminal: one is to be able to carry out information transfer, and the other is to be able to carry out a network connection. Secondly, there must be adequate data collection capabilities [5]. The central node broadcasts a message to the object monitoring area. The monitored objects are partitioned according to the relationship between them and the central node and are divided into "hot areas." The subregions far from the central node are collectively called "non-hot areas" based on the information received. Each node divides its location into a "hot zone" and a "non-hot zone." The upper and lower bounds of the subzone j are:

$$W_j = c_{\min} + j \times \frac{c_{\max} - c_{\min}}{v}, j = 1, 2, \cdots v \tag{3.2}$$

$$LB_j = c_{\min} + (j-1) \times \frac{c_{\max} - c_{\min}}{v}, j = 1, 2, \cdots v \tag{3.3}$$

$c_{\max}$ represents the maximum distance from the central node. $c_{\min}$ represents the shortest distance from the data child node to the central node. v is the number of "hot zones" and "non-hot zones" in the target area.

3.1.2. Dynamic regulation principle of cluster radius. The number of nodes in each cluster in the "hot zone" and "non-hot zone" depends on two essential factors: monitoring range

$$D$$

and node density

$$\varphi$$

. The following formula can calculate the number of nodes in a cluster:

$$v = \pi D^2 \varphi \tag{3.4}$$

In WSN, each cluster selection process will generate the corresponding node energy consumption. The energy consumption of the cluster head is calculated according to the following formula:

$$Y_{total} = Y_{rec} + Y_t {=} \pi D^2 \varphi \times t + s) \times Y_e + \sigma \times (Y_e + \delta_{amp} c^2) \tag{3.5}$$

σ represents the amount of data owned by each member node in the cluster. s represents the amount of data passed by other cluster heads. According to formula (3.6), the relationship between each data node's competition radius and the group head's position is determined.

$$D = (1 - \alpha \times \frac{c_{\max} - c}{c_{\max} - c_{\min})} \times D_0 \tag{3.6}$$

c is the distance between the head of the cluster and the central node. α represents the influence of the distance between cluster heads and central nodes in the "hot zone" and "non-hot zone" on their competition radius [6]. The competition radius of "hot zone" and "non-hot zone" is shown in formulas (3.7) and (3.8).

$$D_{hot} = [\delta_1 \times (1 - \alpha \times \frac{c(S_j, BS) - c_{\min}}{c_{\max} - c_{\min}} + \delta_2 \times \frac{Y_{res}}{Y_{init}}] \tag{3.7}$$

$$\begin{aligned} D_{unhot} &= [1 - \alpha \times \frac{c_{\max} - c(S_j, BS)}{c_{\max} - c_{\min}}] \times D_0 \\ &+ [\lambda_1 \times sgn(Y_{res} - Y_{ave} + \lambda_2) \times \frac{x}{v}] \times \Delta D \end{aligned} \tag{3.8}$$

Y_{res} indicates the residual power of the node. Y_{ave} is the average value of the remaining node energy of the two adjacent data nodes. $c(S_j, BS)$ represents the distance between the node S_j and the central node. ΔD represents the competitive radius adjustment value of "hot zone" and "non-hot zone." x and v indicate the number of nodes in an area and an entire area, respectively.

3.2. Cluster Header Selection. Each node generates a random number when selecting the cluster head under initial conditions [7]. This random number is between 0 and 1. Compare the random number to the new threshold $S(m)$ calculated from the formula (3.9). If the random number is lower than the new threshold, it will be played in the whole network, and the new threshold$S(m)$ is determined to be the new cluster head.

$$S(m) = \begin{cases} \frac{q}{1 - q^*(d^* \bmod \frac{1}{q})} \cdot \left(\mu_1 \frac{Y_{cur}(m)}{Y_{init}} + \mu_2 (1 - \frac{c_{ctos}}{c_{\max}} \right) m \in R \\ 0, m \notin R \end{cases} \tag{3.9}$$

An improved LEACH method is proposed, which introduces parameters $Y_{cur}(m), Y_{init}$ and c_{ctos}. It allows for better consideration of cluster selection. $Y_{cur}(m)$ represents the energy left at the current data node. Then $Y_{init}$is the initial amount of energy for that data point. c_{ctos}represents the distance between the current node and the Sink node [8]. Two methods μ_1 and μ_2 are used to reduce the weight of each parameter in the network. Where $\mu_1 + \mu_2 = 1, \mu_1 \geq 0, \mu_2 \geq 0$.

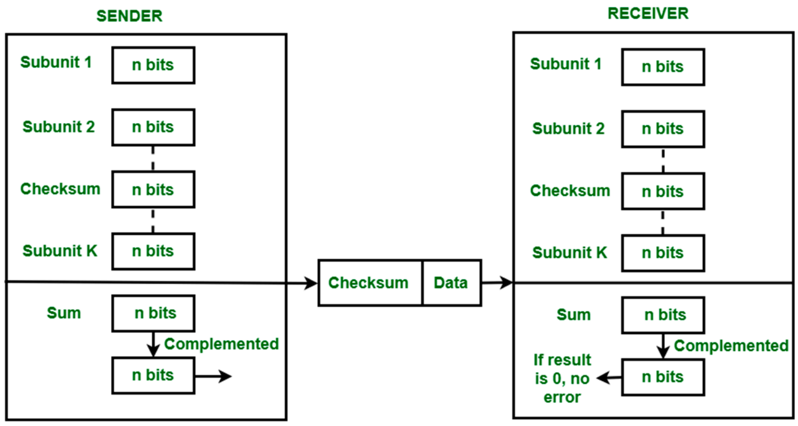

Fig. 3.1: Schematic diagram of node fault correction.

3.3. Data communication mode. The data communication mode is mainly optimized according to the "hot area" and "non-hot area" divisions. The process is as follows.

1) If the cluster head node S_j is in the "hot zone," then this node does not need to exchange data with other cluster nodes. The data information between the front-end data node and the central node is exchanged to realize the energy saving of the node.

2) If the location of the group head node S_j is in the "hot zone" that has not been determined in advance, then a group head group near the group head node must be reconstructed with it. The network transmission mechanism is proposed. This mechanism uses the cost function of network transmission information to find the minor network transmission node S_j. Repeat the above steps until you find the data to transfer to the central node. Formula (3.10) represents an expression used to calculate the cost function for data communication.

$$\psi = \omega \times \frac{c^2(S_i, S_j) + c^2(S_j, BS)}{c^2(S_j, BS)} - \upsilon \times \frac{Y_{res}}{Y_{init}} + \psi \times \frac{N_{member}}{N} \tag{3.10}$$

3.4. Network organization self-recovery mechanism. Even if a small number of wireless communication nodes fail in a smart home, it will not affect the essential characteristics of the entire home network [9]. According to the characteristics of the smart home, the local repair is carried out in four states: node failure, adding, deleting and moving.

3.4.1. Node fails. Network failure occurs when the communication node encounters a short circuit or power consumption in the power system. Communication lines need to be repaired. The patching process is shown in Figure 3.1.

If data node 01 is faulty, links 00-01, 01-05, and 01-08 are also faulty. Data node 01 that fails without data transfer will not be immediately detected. Communication was cut off until 01's data node was asked to transmit data. In this case, the link must be repaired [10]. The detailed repair process for node data transmission is as follows. 1) If central node A wishes to send data to node 09, the information should be sent at 00-01-05-07-09 according to the original path. When node 01 cannot be found when data is transmitted through node 01, node 00 sends a command to the control terminal. This means that node 01 has failed and needs to be maintained. At this moment, you need to check whether node 05 is the neighbor of node 00 according to the route information recorded during the networking.

3.4.2. Adding Nodes. According to the existing routing information, a new node is added to the existing network [11]. Each node has its route information. When a new data node sends a request to its neighbor to join the neighbor cluster, the smart home network usually responds to the response of another data node. At the same time, the intermediate node can be found according to the path of other data nodes.

Table 4.1: Simulation scenario parameters.

Parameter	Value
Nodal area	(0,0) ~(20,10) m
Total inductor node	10, 20, 30, 40
Fading link | Fading link	8
Arc of oriented conduit	2m
Link attenuation threshold	1.651×10^5
Smoothness coefficient α	0.7

3.4.3. Node shift. The methods of solving the two types of nodes of motion data and motion alone are also different. When a large number of data nodes are migrated, the central node is used to reissue new networking instructions to realize the reconstruction of the whole networking process. When the movement of a single data node is low, insert a new data node again [12]. In this case, the central node does not need another significant network restart.

4. Algorithm simulation. MATLAB software simulates the method's effectiveness in the WSNSH environment. This paper compares and analyzes the improved LEACH algorithm, LEACH algorithm, and multipath routing algorithm AOMDV. In this way, the characteristics of different methods can be shown from different angles.

4.1. Setting of simulation scenarios and parameters. The simulated smart home network area is 20*10 square meters [13]. A wireless SNSH scheme based on WSNSH is proposed in this paper. Real applications were simulated using between 10 and 40 different nodes. The channel attenuation threshold is determined based on the nominal transmit-receive energy ratio of TI's CC2530 chip. The simulation parameters are listed in Table 4.1.

4.2. Simulation performance index. The paper evaluated three performance indicators to compare the effects of the above three methods in WSNSH during the simulation process:

(1) Message transfer rate: the ratio between the number of messages received by the target node and the number of messages sent from the source node. This value can be used to describe the probability of success of packet sending.

(2) Average: The average number of path nodes that must pass when transmitting information groups from the source node to the target node [14]. This value describes the time it takes for a packet to be sent. It's proportional to the time delay.

(3) Routing cost: the number of instruction groups in routing processing. This value can be used to describe the characteristics of network congestion. It's proportional to the time delay.

4.3. Experimental Results.

4.3.1. Packet Sending Rate. The more nodes there are, the more links are available. Compared with the LEACH method, the improved LEACH algorithm has a higher submission rate when the number of nodes is the same. Since the LEACH method cannot control the link state effectively in the transmission process, the possibility of packet loss is very high, so this paper proposes an improved LEACH method based on ETX-SH. The expected number of links between nodes in the network is calculated, and the optimal path is selected to minimize the ETX-SH in the network [15]. Determine the most stable path on the link for sending packets. In a sense, this is also a way to improve the delivery success rate. When the number of nodes is small, the recurrence rate of AOMDV is not high. However, its delivery rate increases rapidly with the number of knot points, consistent with the improved LEACH method. This is because small networks do not take full advantage of multiple paths. The AOMDV method will generate more backup chains as the network scale increases. When the primary link fails to be sent, it can be transferred to the secondary link and sent again in time [16]. In wireless SNSH, multipath transmission technology reduces channel influence on system performance. Figure 4.1 shows the simulation comparison of packet delivery rates of the three algorithms.

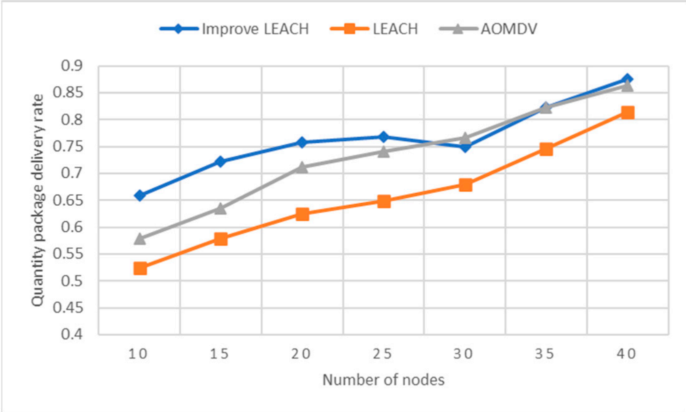

Fig. 4.1: Comparison of packet transmission rate simulations.

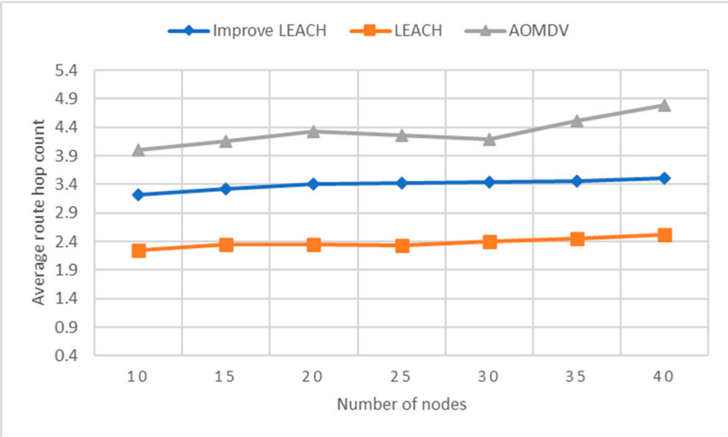

Fig. 4.2: Comparison of the average number of paths jumps under different algorithms.

4.3.2. Average number of hops. Figure 4.2 shows the results of the average number of jumps simulation. When the number of nodes is large, the size of the network will increase, and the number of nodes required for each transmission will also increase. Therefore, the number of paths hops the three methods require to send packets increases. AOMDV has the most significant number of hops when the number of knots is equal [17]. This is because the poor condition of the primary link in the case of channel attenuation leads to multiple transmissions when the AOMDV switches to other links. This will lead to more path jumps. At the same time, improving the LEACH algorithm requires more hops. This is because the improved LEACH algorithm selects lower links to ensure the success rate of data exchange [18]. This attenuation connection can be ignored when the shortest connection is in poor condition. However, the result is that the number of path hops increases relative to the LEACH method.

4.3.3. Route Cost. Figure 4.3 shows the results of the routing load simulation. Network complexity increases as the number of nodes increases, and more command packets must be sent and received during routing [19]. The routing cost of the three methods increases with the number of nodes. The minimum routing cost is obtained by improving the LEACH algorithm when the junction number is constant. There are two reasons for this conclusion. One is to improve the LEACH algorithm to use ETX-SH instead of LQI, thus reducing the cost of repeatedly sending and receiving signals when obtaining LQI. The second is to improve

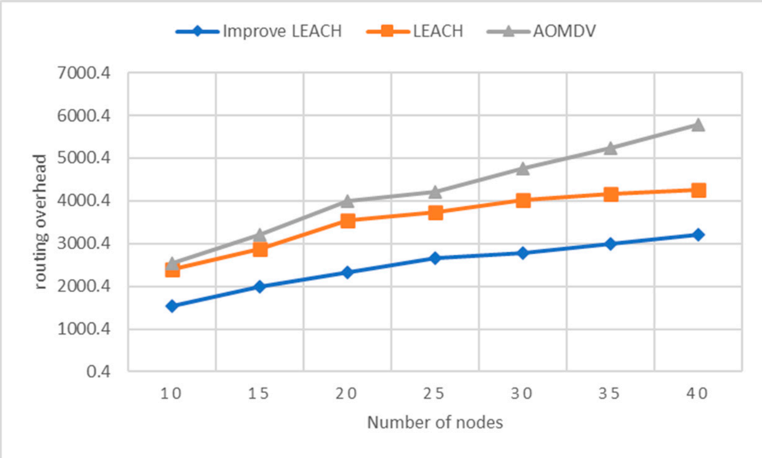

Fig. 4.3: Simulation comparison of path load.

the LEACH algorithm to use the directed route, thus limiting the direction and scope of finding the route. Compared with LEACH and AOMDV global flood forecasting methods, this method can significantly reduce the time needed to find the path. At the same time, AOMDV has a higher routing cost than LEACH. This is mainly due to the large number of instructions AOMDV consumes to construct and maintain routing tables when multipathing is performed.

The improved LEACH algorithm has apparent advantages over LEACH and AOMDV regarding transmission rate and routing cost. This algorithm can improve the success rate of transmission, reduce the additional cost of repeated transmission after transmission failure, and reduce the broadcast storm caused by high transmission costs. It plays a vital role in improving the performance of the network. A new LEACH method is proposed on delay, requiring only an average of 1-2 hops. Because the link is in good condition, the time spent on adding one or two hops is negligible. At the same time, the delay caused by the reduced routing cost is offset by the delay caused by the extra jump. In general, improving the LEACH algorithm and AOMDV can better solve the high-speed and stable data transmission in the case of occlusion.

5. Conclusion. This paper presents an improved LEACH method, which can effectively guarantee the WSNSH system's performance in occlusion. The key is to calculate the ETX-SH value of the link to improve the network performance. Through the analysis of ETX-SH data, the ETX-SH data of the next time point can be obtained to help the user choose the path. Avoid attenuated links as much as possible during the sending process. Select stable links with reasonable expectations during the sending process to ensure the sending rate. Directional routing is used to limit the search scope of the route and further improve the accuracy of the route at a lower cost. The simulation results show that the WSNSH network with channel attenuation has higher transmission efficiency and lower routing cost than the AOMDV network with multipath. This algorithm improves the performance of the WSNSH system well.

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