Research on Routing Algorithm in Intelligent Meter Reading

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Abstract. The introduction to broadband micro-power wireless technology in the national network intelligent meter reading system can increase the bandwidth, improve the meter reading performance, and make up for the narrow bandwidth and low speed in narrow-band micro-power wireless and PLC technology. In the smart meter reading network, the generation and maintenance of routes are the key. This paper improves the AODVjr algorithm and improves it from full-network broadcasting to semi-directional directed broadcasting, calculating channel quality based on weight, making it suitable for real-time routing repair in broadband micro-power wireless intelligent meter reading. The improved algorithm minimizes route repair time and routing overhead while ensuring communication success rate. The simulation results show that with the increase of the number of nodes, the semi-directional broadcast has much better performance in routing request packet transmission success rate, average hop count, communication success rate, and route repair delay than the whole network broadcast.

1. Introduction

In the more than 100 years of power grid development, based on the initial power generation, transmission and distribution functions, the communication technology, network technology and control technology have been continuously combined to make the power grid gradually become intelligent and digital. Smart grid is a basic application of NB-IoT, and smart meter reading technology is also widely used in smart grid [1-3]. Power line carrier (PLC) technology is the earliest application in smart meter reading because of the existing power line transmission medium, but it is greatly affected by random impulse noise. There may be a short distance between two nodes but the distance of the information transmission line is longer. In order to solve the problems of PLC, the industry has developed research of narrow-band micro-power wireless. Because of its low power consumption and flexible network deployment, it is widely used to develop dual-mode communication technology combined with PLC [4]. However, due to its narrow bandwidth, low data transmission rate and weak anti-interference ability, state grid is now studying broadband micro-power wireless communication technology [5]. Its wide bandwidth, including the chirp modulation bandwidth up to 3.6mhz, has strong anti-interference ability and large channel capacity, which largely improves the shortcomings of narrow-band micro-power wireless and PLC.

In the intelligent meter reading communication network, route planning and repair are a major problem in the intelligent meter reading network. The efficient routing algorithm can greatly reduce the routing overhead and improve the communication success rate. Literature [6] evaluated a series of intelligent algorithm-based routing protocols, such as reinforcement learning (RL), ant colony algorithm (ACO), genetic algorithm (GA), etc, and further pointed out its application scenarios. In literature [7], a Q-routing model based on Q-learning is proposed. The Q-value is continuously
updated according to the state-actor pair, and then the next hop node is selected according to the minimum Q-value. In literature [8], the cluster is used to divide the network into multiple sub-networks. The improved AODVjr algorithm is used between the sub-networks, and the tree routing algorithm is used in the sub-network to find the destination node. Literature [9] proposes an F-AODVjr algorithm to determine whether to forward RREQ packets based on the remaining energy of the nodes. In literature [10], in the tree routing algorithm, the next hop route is selected by means of the node neighbor table, and the invalid nodes in the neighbor table are deleted in the plan to reduce invalid forwarding. There are also many studies based on game theory, LoRa and other technologies to optimize routing, improve efficiency, increase transmission distance, and extend network life [11-15].

This paper improves an AODVjr algorithm for real-time routing repair of broadband micro-power wireless intelligent meter reading network. In the tree network topology, the improved AODVjr algorithm is oriented half-direction broadcasting, and the tree distance $d(u, v)$ is used to determine the forwarding radius of the data packet. Each time the data packet is forwarded, the forwarding radius is reduced by 1, and $r = 0$ is no longer forward. At the same time, relay node recalculates the tree distance. If $r >= d(u, v)$, node continue forwards to find the destination node, otherwise discard.

During the forwarding process, the link quality is updated according to the weight. The improved algorithm (AODVjr-Pro) and the algorithms in [8] and [9] show that the former has better performance.

The structure of this paper is as follows: The first part describes the intelligent meter reading network topology model, the second part describes the classical AODVjr algorithm and points out its inadequacies, the third part proposes an improved algorithm for the inadequacies of the AODVjr algorithm and applies it to the broadband micro-power wireless intelligent meter reading network, the fourth part analyzes the proposed improved algorithm in the network scenario of meter reading, the fifth part summarizes the paper.

2. Intelligent meter reading network topology model
In the broadband micro-power wireless intelligent meter reading network, in order to realize dual mode in combination with broadband PLC, the tree network topology specified in the broadband PLC protocol is adopted. As shown in Figure 1, the connection represents the communication link.

The nodes in Figure 1 have three roles: the central coordinator (CCO) controls the data transmission and network status of the entire network; the proxy coordinator (PCO) is the relay node, which has simple data processing functions to forward data; station (STA) is a terminal smart meter.

![Figure 1. Broadband micro-power wireless smart meter reading network topology](image)

3. AODVjr routing algorithm
The AODVjr algorithm is a lightweight and on-demand routing algorithm that is improved by the AODV algorithm. In the AODVjr algorithm, three messages are involved: a route request message (RREQ), a route reply message (RREP), and a route error message (RERR). It removes the serial
number, hello message and predecessor list in the AODV algorithm. Since there is no predecessor list, so only the destination node can send the RREQ packet, and the destination node directly processes the first RREQ packet that received.

The AODVjr routing algorithm is divided into two phases: the route discovery phase and the route repair phase. In the route discovery phase, it is assumed that the route from node S to node D in Figure 1 is disconnected, 1) the source node S generates an RREQ packet to broadcast over the entire network; 2) After the next node receives it, it is judged by the process shown in Figure 2; 3) Repeat the steps of 2) until the destination node D is found.

Start
The node receives the RREQ packet
Update the path cost in the routing table
Is the destination node?
Forward RREQ packet
The routing table is full?
Is the same RREQ packet of the same source node?
Is the path cost in RREQ larger than in the routing table?
Y
Y
Y
N
N
N
Generate a new route insert into the route table
Generate RREP and send
Update the path cost in the routing table
Forward RREQ packet
End

Figure 2. AODVjr algorithm route discovery process

In the route repair phase, the link state between the two nodes is determined at the MAC layer, and the result is uploaded to the network layer. Route repair is a full-network broadcast of RREQ packet, and the routing overhead is large, so it is necessary to judge whether the link is actually disconnected or temporarily disconnected due to accidental interference. In ZigBee, the node sets a counter to count the number of failed information transmissions. When the number reaches the threshold, the link is considered to be disconnected and the repair process is initiated.

AODVjr algorithm routing repair is a full-network broadcast of RREQ packet, which is easy to cause broadcast storms, increase routing overhead and even network congestion. In addition, the route repair is transparent to the source node that send information, and the source node sends the data packet normally. If the route repairing initiating node S has no storage capacity or insufficient storage capacity, the packet loss rate is increased.

4. AODVjr routing algorithm improvement

4.1. Tree distance

In the broadband micro-power wireless intelligent meter reading network, making some improvement based on the shortcomings of AODVjr algorithm, and an AODVjr-Pro algorithm is proposed to improve the communication success rate, shorten the route repair time and reduce the routing overhead.

The broadband micro-power intelligent meter reading network adopts a tree network topology to form a distributed route. Based on the relationship of size of the tree distance d(u, v) and the routing request packet forwarding radius r, we improve the whole network broadcast to a half direction
forward. The tree distance $d(u, v)$ represents the minimum hops between two nodes $(u, v)$, and the formula is expressed as:

$$d(u, v) = depth(u) + depth(v) - 2depth(lca(u, v))$$  \hspace{1cm} (1)

Where $depth(u)$ represents the depth of the route repair initiating node $u$, $depth(v)$ represents the depth of the destination node $v$, and the common parent node (generally node $u$) represented by $lca(u, v)$.

The route repair initiating node $u$ calculates $d(u, v)$ and set up $r = d(u, v)$. Each time the route request message is forwarded, its radius $r$ is decremented by 1, and when $r = 0$, it is not forwarded; At the same time, the node recalculates $d(u, v)$ once it receives the route request message. If $r >= d(u, v)$, it continues to forward the route request message to find the destination node $v$, otherwise it is discarded and not be processed.

4.2. Signal to noise ratio

In order to enhance the communication success rate, we use the signal-to-noise ratio (RSN) to measure the link quality. The threshold of RSN is -3.8dB. If the link quality is greater than this threshold, it will be used as the communication link. Otherwise, the communication link will be discarded.

The value of SNR threshold needs to be based on the size of bit error rate (BER). The simulation conditions of SNR are described as follows:

- Channel environment: band limited AWGN channel
- Modulation method: 1/2Turbo
- Sample rate: 78MHz
- Simulation frame number and symbol length: 8000 frames / 128 symbols
- Related simulation rates and bandwidth: 76.17Kbps/3.65625MHz, 152.34Kbps/3.65625MHz, 304.69Kbps/3.65625MHz, 609.375Kbps/3.65625MHz

Here, the simulation rate of 600Kbps is mainly taken, and the BER-SNR relationship corresponding to different sampling points is compared. The simulation rate formula is expressed as follows:

$$rate = \frac{\text{sampling rate}}{\text{sampling points}}$$  \hspace{1cm} (2)

Figure 3 shows the relationship between bit error rate (BER) and signal to noise ratio (SNR):
When the bit error rate reaches $10^{-3}$, the signal-to-noise ratio threshold of 600Kbps is -3.8dB. When receiving the same route request packet from the same source node, to avoid accidental interference, update the link quality by weight. The formula is as follows:

$$R_{SN} = i \cdot old\_SN + j \cdot new\_SN$$  \hspace{1cm} (3)

Where $i$, $j$ represents the weight, and $i + j = 1$. old\_RSN represents the stored RSN, and new\_RSN represents the RSN calculated from the received message.

4.3. AODVjr-Pro algorithm steps

The specific steps of the algorithm are described as follows:

First step: When the PCO forwards the service data packet, the route repair process is triggered when the periodic evaluation route is invalid or there is no route. First, the route repair initiating node calculates the tree distance $d(u, v)$ according to formula (1), and assigns the value to the message forwarding radius $r = d(u, v)$. The routing repair initiating node generates a routing request packet, broadcasts in a half direction, and searches for the destination node.

Second step: After receiving the route request message, the intermediate node determines whether forwarding is required according to the process of Figure 4. Specific steps are as follows:

Table 1. Relay node forwarding step.

| Step1 | After receiving the route request packet, first evaluate whether the RSN meets the threshold. If yes, go to step 2; otherwise, discard the message. |
|-------|----------------------------------------------------------------------------------------------------------------------------------------|
| Step2 | Judging whether the node is the destination node. If yes, generate a route reply message and send it; otherwise, go to step 3. |
| Step3 | Judging whether the message is from the same source node. If yes, update the RSN according to formula (3); otherwise, go to step 4. |
| Step4 | Reducing the forwarding radius $r$ by 1, and then Judging whether $r$ is zero. If yes, discard it and do not forward it; otherwise, go to step 5. |
| Step5 | Recalculating $d(u, v)$ and then compare the size of $d(u, v)$ and $r$. If $r \geq d(u, v)$, a new route is added to the routing entry, the value of the RSN is stored, and the route request packet is forwarded; otherwise, the packet is discarded. |
Third step: Repeat the process of the second step until the destination node is found. When repeating the second step to forward the route request message step by step, a distributed route to the route repair initiating node is formed.

The fourth step: After receiving the first route request packet, the destination node starts the timer for monitoring for a period of time, selects a proxy node with the best link quality, and generates a route reply message to be sent to the route repair initiator node through the selected proxy node. During this transmission, a distributed route to the destination node is formed.

The fifth step: After receiving the route reply packet, the route repair initiating node sends a route response packet to the destination node, and sets the route status to the available status. If no route reply packet is received within the specified time, a routing error packet is sent to the data sending source node.

5. Simulation results and analysis
There are a variety of network simulation platforms, such as NS2, OPNET, OMNeT++, NS3, etc. This paper chooses the NS3 network simulation platform for simulation. Based on the shared PLC NS3 Module of the University of British Columbia, some functional codes are modified to conform to the application scenarios of broadband micro-power wireless smart meter reading. The real-time route repair algorithm proposed in this paper is simulated on the built platform.

In this section, the improved AODVjr-Pro algorithm is simulated and compared with the NCLZHR algorithm in literature [8] and the F-AODVjr algorithm in literature [9]. With the number of nodes changes, Comparing and analyzing the success rate of routing request message transmission, average hops, communication success rate, and route repair delay, It can be seen that this algorithm has certain superiority. The range of the number of nodes is from 10 to 100.

The main simulation parameters as shown in Table 2:
Table 2. Main simulation parameters.

| Parameter                | Value                           |
|--------------------------|---------------------------------|
| network range            | 100m * 100m                     |
| node distance            | 10m                             |
| packet size              | 256Byte                         |
| simulation time          | 100s                            |
| data transfer rate       | 600Kbps                         |
| signal to noise ratio threshold | -3.8dB                     |
| old_RSN weight (i)       | 0.6                             |
| new_RSN weight (j)       | 0.4                             |

Figure 5 describe the distribution of the success rate of routing request message transmissions in the three algorithms as the number of nodes increases.

The success rate of routing request packet transmission reflects the size of the routing overhead. It can be seen from the figure that the success rate of the routing request message decreases with the increase of the number of nodes. When there are fewer nodes, there will be fewer forwarding times, and more routing request messages will reach the destination node, so the success rate of routing request messages reaching the destination node will be higher. The more nodes, the more packets are forwarded, the larger the routing cost, and the lower the success rate of route request packets. The simulation results show that the success rate of routing request message transmission in the AODVjr-Pro algorithm proposed in this paper is higher than that of the other two algorithms. That is to say, in the case of routing failure with the same number of nodes, this algorithm can make the network complete the routing repair process faster and resume normal communication.

Figure 6 describe the distribution of the average hops among the three algorithms as the number of nodes increases.

The hops refers to the forwarding times of route request message from source node to destination node, and the average hops refers to the average forwarding times of route request message in simulation time. The average hops is a key indicator of network overhead. As the number of nodes increases, the number of network layers increases. Because the hops is closely related to the number of layers, the more times the route request message is forwarded. As can be seen from the figure, the average hops of the AODVjr-Pro algorithm proposed in this paper is smaller than the other two algorithms. Especially when the node is greater than 60, the average hops growth in this algorithm is relatively flat. In contrast, this algorithm has fewer forwarding times and less routing overhead.
Figure 6. Average hops

Figure 7 describe the distribution of communication success rate among the three algorithms as the number of nodes increases.

The communication success rate of data transmission reflects the stable reliability of network routing and self-repair ability after routing failure. As can be seen from the figure, the communication success rate presents a downward trend with the increase of the number of nodes. When the number of nodes is greater than 70, the AODVjr-Pro algorithm of this paper has a flatter trend compared with the other two algorithms. And under the same number of nodes, the communication success rate of this algorithm is slightly higher than the other two algorithms. The algorithm is more suitable for the real-time routing repair process of broadband micro-power wireless intelligent meter reading.

Figure 7. Communication success rate

Figure 8 describe the distribution of route repair delays in the three algorithms as the number of nodes increases.

As can be seen from the figure, the route repair delay increases with the number of nodes, but the number of nodes increases from 10 to 100, and the delay change is only a few milliseconds. According to the figure, the AODVjr-Pro algorithm proposed in this paper has a smaller delay, which is lower than the other two algorithms. This shows that in the process of routing repair, the algorithm in this paper makes one-way broadcast of routing request message, which greatly reduces the routing overhead, shortens the time of routing repair and makes the routing repair more efficient.
Figure 8. Route repair delay

6. Conclusion
In this paper, when designing the real-time routing repair process of broadband micro-power wireless intelligent meter reading network, the AODVjr algorithm is improved. The request message is improved to directional half-direction broadcast from whole-network broadcast, and the link quality is updated according to the weight. This article first elaborates AODVjr algorithm and points out the deficiencies that in the entire network broadcast. Then, the improved algorithm is put forward and simulated in the broadband micro-power wireless intelligent meter reading network scenarios. The simulation result shows that with the increase of the number of nodes, the AODVjr-Pro algorithm in this paper has better performance than the other two algorithms, the routing overhead is smaller, higher communication success rate, less routing repair delay.

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