A Routing Method Based on Wireless Sensor Network for Smart Meter Reading System

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Abstract. Smart meter reading system is the core of advanced metering infrastructure for Smart Grid. Wireless sensor network is an important means to realize the power information collection. Based on hierarchical strategy, this article proposed a method to establish routing in wireless smart meter reading system. This method provides reliable two-way communication routing, but also greatly reduces the collision probability of network communications. In order to verify the feasibility of the approach, a large number of simulation experiments were carried out. This idea has been applied in actual engineering practice.

Introduction

Smart Grid has the attention of the world. Domestic and foreign research institutions are also racing to develop smart grid technology[1-3]. Through the advanced metering infrastructure (AMI), grid operation data can be achieved for analysis and mining. Thus operators can optimize the entire power system operation management[4-6]. AMI Provides a flexible and interactive information exchange platform for users and power companies. Smart meter reading system is the core of advanced metering infrastructure for Smart Grid.

Currently, wireless sensor network technology has got more and more attention and related core technology was a major breakthrough[7]. Wireless sensor network technology is applied to the power information collection network is the trend of the technology. A routing establishing method based on hierarchical strategy for wireless sensor network was proposed in this article. By this method, can establish bidirectional reliable communication path between smart meters and concentrator.

Power Information Collection Network Architecture

The power information collection system based on wireless sensor network includes: concentrator, collectors and user-side smart meters (referred to as the terminal node). All nodes in the power information collection network are equipped with wireless communication capabilities. The concentrator and master complete information exchange through the uplink communications network. The power information collecting is done through the local communication network between the concentrator and the terminal nodes. The architecture is shown in Fig.1.

In the local network, the interactive information only occur between the concentrator and the terminal nodes. There are no information interaction between the terminal nodes. In a typical residential area, the number of nodes usually up to nearly thousand points. Thus, large-scale network routing establishing method become research focus and technical challenges of the power information collection network[8].
Routing establishing method based on hierarchical policy

The local network is composed by a large number of terminal nodes. As far as possible to avoid communication conflicts, improve the reliability of communication between the terminal nodes and the concentrator, a large-scale wireless sensor network is divided into multiple logical levels based on the hierarchical thinking. The purpose of reducing communication conflicts between the terminal nodes can be achieved by reducing the size of the nodes on each level. The division of the network hierarchy is automatically realized through a hierarchical policy-based routing establishing mode.

A. Network hierarchical strategy

The routing establishing is initiated by the concentrator in the local communication network. This procedure is shown in Fig.2.

![Figure 2. Procedure of routing establishing](image)

At the moment T0, the concentrator sends a routing establishing request to all nodes in the local network. Obviously, only those who are close to the concentrator nodes can receive this request. For the convenience of description, these nodes are named as HS(1).

On receipt of the routing establishing request, the nodes within HS(1) can join the local network through sending routing establishing response to the concentrator. Because they are the first nodes to join the network, so they constitute the first level of the network. In order to form an ordered network level, they join the network must be completed within the interval T1, which is also outlined in Fig.2.

Next, they need to forward the routing establishing request to other nodes which can not receive the request directly from the concentrator. This procedure should be completed within the time interval T2.

Those nodes who received the forwarded request are named as HS (2). Within the time interval T2, the nodes within HS(2) do nothing but record the address of forwarding nodes. After the interval T2, they can send routing establishing response to the concentrator by those nodes within HS(1). Should be noted that they must complete this operation within the time interval T3.

By performing the above process, a structured communication network is formed.

B. The first layer routing establishing procedure

The concentrator will periodically send routing establishing request to the local network for maintaining network. The node A should listen to the local network to determine the existence of the network. If find, it should wait for the routing establishing request.

For a network which has no routing between the concentrator and the terminal nodes, The first layer routing establishing procedure is shown in Fig.3.

First, the concentrator send routing establishing request to nodes exist in the local network, as shown by dotted line 1 in Fig.3.

The distance between the node A and the concentrator is recent, so the node A can receive the request from the concentrator. Within the interval T1, the node A record the address of the concentrator into its routing table as its parent node. So the node A has a uplink path to the concentrator. At the same time, the terminal node A prepare a routing establishing response. Within the interval T1, it sends the response to the concentrator at a random time, as shown by solid line 2 in Fig.3.

After the concentrator received the response from the terminal node A, it should record the address of the terminal node A into its routing table as its child node. So the concentrator established
the down link to the node A. Now, the node A join the local network as the first level node. Other nodes, like node B, as the first hop node execute similar process with the terminal node A to join the local network.

Through this process, all terminal nodes around the concentrator form the first level of the local network.

C. The second layer routing establishing procedure

The second layer routing establishing procedure is shown in Fig.4.

As far from the concentrator, the routing establishing request from the concentrator can not reach the node C. So those nodes joined the local network should forward the request. After the terminal node A joined the local network, it will forward the routing establishing request to other nodes within the interval T2, as shown in Fig.2 and also shown by dotted line 2 in Fig.4.

Within the interval T2, the node C will receive many routing establishing request frames from the first level nodes. It should select a node which has the best link quality as its parent node. The rest operation is recording its parent’s address into routing table.

The node C should prepare a routing response and send it to the concentrator within the interval T3. It should send the response to its parent node, as shown by solid line 3 in Fig.4. The parent forwards the response to the concentrator, as shown by solid line 4 in Fig.4.

The node A, as the parent node of the node C, records the address of the node C into its routing table as its child node. The concentrator records the address of node C into routing table as its grandson node. Then the node C established a uplink path to the concentrator and the concentrator established a downlink path to the node C. As shown in Fig.4, the node C, D, and E constitute the second level of the local network.

D. Network maintenance procedures

After establishing communication link, the local network should have fast network self-healing ability. A node communication failure can not affect the normal network communication. For achieving the purpose of rapid network self-healing, each node must periodically monitors its parent node is working properly or not. This process can be completed through the normal application data interactive. It can also be achieved by periodically sending query commands to its parent node. As shown in Fig.5.

The node D can not receive data form its original parent, the node A. This result suggests that the communication connection has been lost with its parent. The node D issues a searching command to the local network again. The node B may receive its request to join. By executing the same kind network joining process, the node D re-joined the local network by the node B again. In the process of re-joining the network, the child nodes of node D do not need to perform any operation to re-join the network. The failure resulted by the communication link lost between the node D and its original parent node is repaired quickly.
Conflict avoidance mechanism in routing establishing process

In order to reduce the collision probability in the routing establishing process and improve the success rate of routing establishment, the max node number of each layer must be considered, named as $M$. Hashed is used to compute the random jitter time of node in each layer[9]. By configuring the random jitter time in communication process, the success rate of routing establishment can be greatly improved. \( J = \text{hashed}(M) \) \( (1) \)

Assumed that $N$ is the number of nodes with the same hops in the local network, the collision probability $\delta$ in the routing establishing process can be computed as in (2) and (3).

\[
\theta = \frac{M \times (M-1) \times \ldots \times (M-N+1)}{M^N} = A_M^N \cdot \frac{1}{M^N} \tag{2}
\]

\[
\delta = 1 - \theta = 1 - \frac{A_M^N}{M^N} \tag{3}
\]

For a local network with 200 nodes, a large number of simulation experiments were carried out based on OPNET simulation platform. The success rate of routing establishment with different value of $M$ is shown in Tab.1.

<table>
<thead>
<tr>
<th>M</th>
<th>Success rate of routing establishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>77.8%</td>
</tr>
<tr>
<td>5</td>
<td>84.3%</td>
</tr>
<tr>
<td>9</td>
<td>100%</td>
</tr>
<tr>
<td>10</td>
<td>100%</td>
</tr>
</tbody>
</table>

By the simulation results, in order to improve the success rate of routing establishment, may be appropriate to increase the value of M.

Conclusion

For the proposed wireless sensor network routing establishing method based on hierarchical strategy, author and team members have developed a wireless communication protocol for power information collection system. It has been successfully applied to on-site engineering. Currently, the demonstration system covering 20,000 low-voltage power users has been established in Shenbei high-tech development district of Shenyang, China. The data collection success rate of entire system reached 100%.

References

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