Research on New Generation Power Information Acquisition Technology Based on BPLC and Bluetooth5.0 Technology

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Abstract. With the continuous development of wireless communication technology, more and more applications are used in industry and home. As the bluetooth 5.0 technical specification put forward, Bluetooth Low Energy has a great improvement in communication performance and power consumption. In this paper, the broadband power line carrier (BPLC) was taken as the main trunk channel, and creatively integrated an information acquisition scheme with the Bluetooth Mesh as the network extension. Besides, the Dijkstra algorithm based on speed factor was used to complete the system routing planning, and a new generation of power information acquisition scheme was proposed.

1. Introduction

The development plan of “Strong Smart Grid” proposed by State Grid Corporation of China has reached the end of the third stage, and it is planned that a unified “Strong Smart Grid” will be fully built by 2020. As one of the key components of the smart grid, the reliability and accuracy of the technical scheme selection of the power information acquisition system has become an important factor to measure the safe and efficient operation of the smart grid[1].

The application of broadband power line carrier (BPLC) provides a better performance information collection method for solving the problems of slow transmission speed and large channel interference exposed by traditional power line carrier(PLC)[2][3]. With the development of Bluetooth 5.0 technology, the communication performance of low-power Bluetooth technology has been greatly improved[4]. In this paper, Bluetooth 5.0 technology is creatively used as the power information acquisition system scheme. On the basis of supporting BPLC as the main channel, the feasibility and performance characteristics of this new power acquisition scheme are studied.
2. Broadband power line carrier and bluetooth 5.0

2.1. Broadband power line carrier (BPLC)
Power line carrier (PLC) is a communication method that transmits data or voice through power line [5]. The biggest advantage of this communication method is that it does not need to set up an extra network. Only the existing power line is needed, and the signal can be transmitted to the data or voice through the carrier wave at high speed.

Aiming at the disadvantages of low carrier frequency and large radio-frequency interference in narrowband power line carrier communication, broadband power line carrier (BPLC) has been developed and applied [6][7]. The biggest advantage of the BPLC communication method is that the channel bandwidth is wide, the transmission rate is fast, and it is less interfered by the external network. Therefore, it is a power information collection method with better performance [8].

2.2. Bluetooth 5.0 and mesh network
The Bluetooth 5.0 protocol specification released by the Bluetooth Technology Alliance (SIG) once again improves Bluetooth performance in terms of transmission rate and coverage. For Bluetooth Low Energy (BLE), the 5.0 communication protocol supports two data transmission rates of 1m/s and 2m/s at the physical layer, with an effective transmission distance of up to 300 meters, which is better suitable for the communication environment of the Internet of things, smart home, etc.

Mesh network is a communication technology based on mesh topology type, which uses flooding routing algorithm to effectively expand the communication coverage. In July 2017, SIG officially released the first version of the Bluetooth mesh network specification. On the basis of affirming the Mesh network architecture, it better integrates the characteristics of BLE and provides a more robust solution.

3. A new power information acquisition scheme

3.1. Dual mode scheme of power information acquisition
This paper proposes a dual-mode acquisition communication scheme which integrates BPLC and Bluetooth 5.0. The main channel of this communication scheme is BPLC, while the branch channel of the system is Bluetooth 5.0. In practical application, the uplink and downlink channels of power consumption data between meter boxes in the station area support BPLC, while the meter box uses Bluetooth module to collect power consumption information and send it to the dual-mode module through Bluetooth mesh network. The communication architecture is shown in figure 1.

![Diagram of power information acquisition system](image-url)
3.2. Composition of relay module

Figure 2. Dual-mode relay module incorporating BPLC and Bluetooth 5.0

In order to realize the data interaction between the two communication modes of BPLC and Bluetooth 5.0, two MCUs with stable and efficient performance are selected to build a dual-mode relay module. Among them, the BPLC chip adopts the high-speed carrier power line carrier communication chip ssc1667 of EASTSOFT company, the Bluetooth chip adopts chip nrf52840 of Nordic company which supports Bluetooth 5.0 protocol, and the nRF52840 module is used as the power collection device in the meter box. Figure 2 shows the physical model of a dual-mode relay module incorporating BPLC and Bluetooth 5.0.

4. Route planning of power information acquisition

In this paper, according to the characteristics of station routing, the system routing algorithm uses a single source shortest path algorithm-Dijkstra algorithm[9][10]. Dijkstra algorithm is an algorithm to find the optimal path from one vertex to other points. It can be used to solve the optimal path problem in directed graphs. The main feature of the algorithm is to use the breadth first search method, to expand the search layer by layer with the starting point as the center, until the end point. The algorithm can traverse all nodes and has strong stability.

4.1. Principle of dijkstra algorithm

The idea of Dijkstra's algorithm is to take G = (V, E) as a weighted directed graph, where V represents the set of all nodes and E represents the set of weighted paths. All node sets V are divided into two groups, one is the node set of the solved optimal path (the initial value is only one of the source nodes), which is represented by S; and the other is the node set of the determined optimal path to be solved, which is represented by U. The algorithm increases in the order of the shortest path length, so the nodes in the set U are added to the S set one by one. The constraint is that the shortest path length from the source node to each vertex in the set S is less than the shortest path length from the source node to any vertex in the set U, and the stop condition is until all nodes in the set U are added to the set S. Finally the optimal path from all nodes to the source node is solved.

4.2. Application of algorithms in power information acquisition system

According to the principle of Dijkstra's algorithm, it is not difficult to see that the algorithm only plans and optimizes the path, but it does not consider the influence of the speed factor, so that the actual arrival time is quite different when the weight of the path is the same. In this paper, according to the characteristics of power line carrier and bluetooth environment of power information acquisition system, the speed factor is added as a limiting factor to Dijkstra's algorithm, and based on this, the optimal path planning from the source node to other nodes is carried out.

The specific implementation steps of the algorithm are as follows:

- Taking \( S(m) \) as the set of analytic optimal paths, where \( m \) is the number resolved, and \( m=1 \) at the initial state.
- \( U(n) \) is the set of nodes to be solved for the optimal path, and \( (m+n) \) is the total number of nodes.
- Let \( D(i,j) \) be the weight of the path distance from node \( i \) to node \( j \), and \( D(i,j) \) can be expressed as:
Let the transmission rate between any two nodes \( i \) and \( j \) be \( V_{ij} \), and the speed of nodes that are not directly connected be 0.

Take \( T_{ij} \) as the realization time between nodes \( i \) and \( j \), and \( T_{ij} \) satisfies the formula (2)

\[
T_{ij} = \frac{D(i, j)}{V_{ij}}
\]

 Traverse the value of set \( T_{ij} \) and get the minimum time from node \( j \) to the source node in set \( U(n) \), that is, the value of \( \min[T(1, j), T(1, i) + T(i, j)] \) to determine the best path.

Repeat Step 6 until all \( U(n) \) nodes are added to \( S(m) \).

In this paper, the concentrator is used as the source node of remote meter reading, the dual-mode module is used as the relay node, and the Bluetooth module in the meter box is used as the terminal node to build a power data collection system. Taking figure 3 as the running chart of the simulation system, the implementation process of Dijkstra algorithm used in this paper is studied.

![Figure 3. Undirected weighted simulation diagram](image)

In figure 3, node A is the source node (concentrator), node B and C are the relay nodes (dual mode module), node D–J are the terminal nodes (Bluetooth module), and the link value represents the distance weight \( D(i, j) \) According to the instructions in the dotted block diagram, B, D, E, and F are the nodes in meter box 1, and C, H, I, and J are the nodes in meter box 2.

Using the adjacency matrix \( D(i, j) \) to express the distance weight is shown in Equation 3.

\[
D(i, j) = \begin{cases} 
0 & 100 & 70 & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
100 & 0 & 50 & 10 & 15 & \infty & \infty & \infty & \infty & \infty \\
70 & 50 & 0 & \infty & 20 & \infty & 15 & \infty & 25 & \infty \\
\infty & 10 & \infty & 0 & 5 & 20 & \infty & \infty & \infty & \infty \\
\infty & 15 & 20 & 5 & 0 & 10 & 10 & \infty & \infty & \infty \\
\infty & \infty & 20 & 10 & 0 & \infty & \infty & \infty & \infty & \infty \\
\infty & \infty & 15 & \infty & 10 & \infty & 0 & 15 & 10 & \infty \\
\infty & \infty & \infty & \infty & \infty & \infty & 15 & 0 & 20 & \infty \\
\infty & \infty & 25 & \infty & \infty & 10 & 20 & 0 & \infty & \infty 
\end{cases}
\] (3)

According to the field application scenario and the principle of unified reference, the speed of broadband carrier is set to 100, the speed of Bluetooth in the same meter box is set to 50, the speed of Bluetooth in different meter boxes (affected by the shell) is set to 10, and the speed adjacency matrix \( V(i, j) \) is shown in Equation 4.
Solve the time set $T(i,j)$ according to Step 6 of Dijkstra's algorithm as shown in Equation 5.

$$V(i,j) = \begin{bmatrix}
\infty & 100 & 100 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
100 & \infty & 100 & 50 & 50 & 0 & 0 & 0 & 0 & 0 \\
100 & 100 & \infty & 0 & 10 & 0 & 50 & 0 & 50 & 0 \\
0 & 50 & 0 & \infty & 50 & 50 & 0 & 0 & 0 & 0 \\
0 & 50 & 10 & 50 & \infty & 50 & 10 & 0 & 0 & 0 \\
0 & 10 & 0 & 50 & 50 & \infty & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 50 & \infty & 50 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 50 & \infty & 50 \\
0 & 0 & 50 & 0 & 0 & 0 & 0 & 50 & 50 & \infty
\end{bmatrix}$$

(4)

$$T(i,j) = \begin{bmatrix}
0 & 1 & 0.7 & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
1 & 0 & 0.5 & 0.2 & 0.3 & \infty & \infty & \infty & \infty & \infty \\
0.7 & 0.5 & 0 & \infty & 2 & \infty & 0.3 & \infty & 0.5 & \infty \\
\infty & 0.2 & \infty & 0 & 0.1 & 0.4 & \infty & \infty & \infty & \infty \\
\infty & 0.3 & 0.2 & 0 & 0.1 & 0.2 & 0 & \infty & \infty & \infty \\
\infty & \infty & 0.4 & 0.2 & 0 & 0 & \infty & 0.3 & 0.2 & \infty \\
\infty & \infty & \infty & 0.3 & 0 & 0 & \infty & 0.4 & \infty & \infty \\
\infty & \infty & \infty & \infty & 0.2 & 0.4 & \infty & \infty & \infty & \infty \\
\infty & \infty & \infty & \infty & \infty & 0 & \infty & \infty & \infty & \infty
\end{bmatrix}$$

(5)

According to the adjacency matrix, a new weighted digraph is constructed, and the weight is time. As shown in figure 4.

Figure 4. Directed weighted simulation graph processed by Dijkstra algorithm

This paper compares the results of the two optimization paths based on whether the speed factor is considered in the Dijkstra algorithm. Table 1 shows the optimization path and the duration under the distance weight, and table 2 shows the optimization path and the duration under the time weight.

Table 1. Optimization path and duration under the distance weight

| node | optimization path | duration |
|------|-------------------|----------|
| A    | A-A               | 0        |
| B    | A-B               | 1        |
| C    | A-C               | 0.7      |
| D    | A-C-E-D           | 2.8      |
| E    | A-C-E             | 2.7      |
| F    | A-C-E-F           | 2.9      |
| H    | A-C-H             | 1.0      |
| I    | A-C-H-I           | 1.3      |
| J    | A-C-J             | 1.2      |
Table 2. Optimization path and duration under the time weight

| node | Optimization path | Duration |
|------|-------------------|----------|
| A    | A-A               | 0        |
| B    | A-B               | 1        |
| C    | A-C               | 0.7      |
| D    | A-B-D             | 1.2      |
| E    | A-B-E             | 1.3      |
| F    | A-B-E-F           | 1.5      |
| H    | A-C-H             | 1.0      |
| I    | A-C-H-I           | 1.3      |
| J    | A-C-J             | 1.2      |

According to the results of Tables 1 and 2, the optimal path determined by time weights takes less time to implement nodes D, E, and F, which can better meet the real-time requirements of the system and have better performance.

5. Experiment and test

Based on a new power acquisition system that integrates BPLC and Bluetooth 5.0 technology (hereinafter referred to as BPLC + BLE) and the routing algorithm used in this paper, a laboratory test environment is built to test the feasibility and performance of the system. Figure 5 shows the test environment built by the laboratory.

![Simulated environments](image)

(a) Simulate the test environment between meter boxes

(b) Simulate the test environment in the meter box

Figure 5. Laboratory simulation test environment

In order to objectively analyze the performance of the new power information acquisition system proposed in this paper, a comparative experimental group was established by using the narrowband carrier module ssc1655 and the broadband carrier module ssc1667 of EASTSOFT Company, and the three system nodes were traversed 100 times respectively. The statistical point reading success rate and traversal time are shown in Table 3.

Table 3. Performance test table of power acquisition system

| System       | Point reading success rate | Traversal time(s) |
|--------------|----------------------------|-------------------|
| Narrowband PLC | 100%                       | 1030.5            |
| Broadband PLC  | 100%                       | 320.1             |
According to the test results of table 3, it can be concluded that the three power collection systems operate stably and the success rate of the point reading is 100%. The new power collection system that integrates BPLC and Bluetooth 5.0 technology proposed in this paper is weaker than the broadband PLC in communication rate, but it has been greatly improved compared with the narrowband PLC, and the Bluetooth device has low cost and superior performance. Therefore, it has certain practical value and promotion significance.

6. Conclusions
With the introduction of Bluetooth 5.0 technical specifications, low-power Bluetooth has greatly improved the transmission performance and power consumption. This paper innovatively applies Bluetooth technology to the power information acquisition system. On the premise of ensuring the BPLC as the main channel for collecting electrical information, BLE Mesh is used as the system network extension, and the Dijkstra algorithm based on the speed factor is used to complete the route planning. According to the experimental test results, the system runs stably, which is a high-performance and low-cost power consumption collection scheme.

Acknowledgement
Project supported by State Grid Technology Project (5216AB180007)

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