Research on Hybrid Communication Networking Protocol Optimization Technology of Ubiquitous Electric Internet of Things

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Abstract. In order to solve the problem of high routing overhead caused by the lack of relay coding in hybrid communication network protocols, this paper studies the optimization technology of hybrid communication network protocols. According to the bandwidth requirement, delay requirement and reliability requirement of communication network, the requirement characteristics of communication network are extracted. Through the establishment of multi-frequency node network, configuration of node white list and agent node selection, the design of hybrid communication network architecture is completed. Design communication packet routing algorithm, according to a certain topology and logical relationship to organize the network nodes. Based on the establishment of hybrid communication network architecture and the design of routing algorithm, the ubiquitous hybrid communication network protocol is optimized. Experimental results show that the total routing overhead of the proposed protocol is 284 packets, 920 packets and 548 packets less than that of the existing protocols, respectively.

Keywords: Ubiquitous electric Internet of Things · Hybrid communication · Hybrid networking · Communication protocol

1 Introduction

At present, major countries in the world have taken the Internet of Things as a major strategy to seize the commanding heights of a new round of economic and scientific and technological development, and China has also taken the Internet of Things as a strategic emerging industry that has risen to the height of national development priorities, and explicitly proposed in the Outline of the 12th Five-Year Plan to promote the research on key technologies of the Internet of Things and the application demonstration in key fields, which has become an important content of the "IOT +" national action plan for development in recent years [1].

Ubiquitous power IOT communication services are characterized by diversification and wide coverage, covering power transmission, transformation, power generation,

S. Wang et al. (Eds.): IoTCare 2021, LNICST 414, pp. 40–52, 2022.
https://doi.org/10.1007/978-3-030-94185-7_4

dispatch and other power grid links. In addition to the information services of the original smart grid, a variety of new services, including photovoltaic cloud network, energy storage cloud, vehicle network, new energy cloud, financial media cloud, comprehensive energy application platform, multi-station integration, data center, and source network charge interaction system, have been introduced, and new requirements have been put forward for the development of the existing power communication network, no matter from the service mode or the mode of networking [2]. In this context, the scientific information development technology model is taken as the standard to pay attention to the overall development and construction needs of the electric power industry, and the necessary information and system applications are implemented in combination with the actual monitoring model of the power Internet of Things network, and the standards of information exchange and communication protocols are defined.

Therefore, this paper studies the hybrid communication network protocol optimization technology of ubiquitous power Internet of Things to improve the efficiency and reliability of hybrid communication network.

2 Hybrid Communication Networking Protocol Optimization Technology for Ubiquitous Power Internet of Things

2.1 Extract Characteristics of Communication Networking Requirements

At present, the main business of ubiquitous power IOT can be divided into internal business and external business. Since there is little change in the mode of communication networking and carrying of ubiquitous power IOT, this paper focuses on the future external business needs of ubiquitous power IOT. In external services, this paper mainly considers three aspects of communication network bandwidth demand, delay demand and reliability demand, and refines them according to the collection demand and control demand [3]. In power IoT, bandwidth is used to describe the capacity of a link to transmit service data, the maximum amount of data that a particular link in a distribution network can carry in a unit time. The maximum data transfer rate generally satisfies the second theorem of fragrance, and the expression of the function is as follows:

$$u = d \cdot \log_2(1 + \alpha) \tag{1}$$

In Eq. (1), u represents the capacity of the channel used for data transmission; d represents the channel bandwidth; α stands for signal-to-noise ratio. Ubiquitous power IOT services mainly focus on bandwidth requirements of more than 2 Mbit/s, with some system stations and clouds having different bandwidth requirements. According to the outline for the construction of ubiquitous power Internet of Things released by China Grid Corporation, the 2 Mbit/s business will be mainly considered, while for the interconnection of cloud platforms or other Internet of Things data platforms, the data traffic is usually convergent traffic, so the granularity is relatively high, and the data will depend on the number of terminals. Delay usually refers to the time spent from the sending end to the receiving end of the power service packet, which is composed of transmission delay, propagation delay, processing delay and queuing delay. Transmission delay and propagation delay are considered in this paper. Transmission delay is composed of the time of collecting and encapsulating data packets, so it is related to the size of data packets, the way of encapsulation and the corresponding hardware. The propagation delay is related to the propagation of data in the communication link, so its size is determined by the propagation distance and the physical medium of the transmission link [4]. In the case of large datagram length, the transmission delay should be considered firstly, while in the case of small datagram length, the propagation delay is the main factor to be considered. Ubiquitous in the power Internet of Things, reliability can be measured by utilization to describe the current network link workload. Network utilization rate describes the weighted average utilization rate of all the links in a distribution communication network. When the network utilization is low, it means that the link has less traffic and does not produce large network delay. However, with the increase of network utilization, network traffic increases, resulting in the need for data in the queue waiting for the receiver to receive data in turn. At this point the network will significantly increase the latency. The relationship between latency and utilization can be expressed in formula:

$$L = \frac{L_0}{1 - \beta} \tag{2}$$

In Eq. (2), L represents the current network delay; L_0 represents the delay of idle network state; β represents the current utilization of the network. According to the demand characteristics of ubiquitous power Internet of Things (IoT) communication networking, a hybrid networking architecture is established to meet the operational requirements of power grids and customers' demand for electricity.

2.2 Establish the Hybrid Communication Networking Architecture of Ubiquitous Power Internet of Things

According to the demand analysis of hybrid communication networking of ubiquitous power Internet of Things, combined with the deficiency of networking scheme of user electricity information collection, the networking architecture is designed from the perspective of dual-mode construction and with reference to the low-voltage power line broadband carrier communication standard. The networking process includes multi-frequency networking, whitelisting of incoming nodes and selection of proxy nodes. Firstly, multi-frequency network is designed to evenly distribute multiple networks in different working frequency points to reduce inter-network interference as much as possible. The new network can quickly grasp the use of frequency points. The overall networking process is shown in Fig. 1.

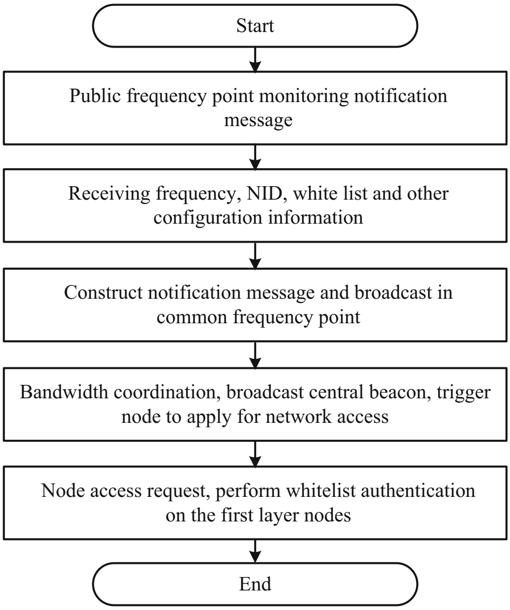


Fig. 1. Overall networking process

A whitelist is stored in the node that has access to the network, and the whitelist is authenticated after receiving the associated request message. In the process of networking, the node that has entered the network does not receive the associated request message for one consecutive beacon period and stops receiving. Whenever the whitelist changes, the network is reorganized. A few nodes in the whitelist change, reorganize the network can increase the network burden. In the hybrid communication network of the Ubiquitous Power Internet of Things, the whitelist is allocated to each node connected to the network, and changes in the whitelist do not necessitate the reconfiguration of the network. This improvement reflects the stability and reliability of the network and enables the network to quickly return to normal operation [5]. The configuration of the white list includes: clearing the white list (deleting the existing white list), replacing the white list (replacing the old white list with the new white list), adding the white list nodes (adding 1 to multiple nodes to the existing white list), deleting the white list nodes (deleting 1 to multiple nodes to the existing white list), and increasing or decreasing the number of white list nodes. Selecting the appropriate proxy node is the key to solve the problem of data transmission. The goal of agent selection is to minimize the number of agents and balance the load as much as possible. Proxy node selection mainly consists of two parts: node selection candidate agent and designated proxy node [6]. In this paper, the node selects candidate agents using three criteria: signal-to-noise ratio, hierarchy and communication success rate. SNR and communication success rate determine the link quality, and the level determines the number of data forwarding. The smaller the level is, the less the number of forwarding is, and the higher transmission efficiency is. In a multi-standard decision, the formula for calculating the comprehensive weight is as follows:

$$q_i = \lambda_\alpha \cdot \alpha_i + \lambda_c \cdot c_i + \lambda_s \cdot s_i \tag{3}$$

In Eq. (3), q_i represents the weight of the monitored node i; α_i represents the link signal-to-noise ratio of the i node monitored; c_i represents the level of the node monitored; s_i represents the success rate of communication between node and node i. During networking, the success rate of communication is the number of beacon frames monitored. $\lambda_\alpha, \lambda_c, \lambda_s$ correspond to weights of α_i, c_i, s_i, respectively. The larger the weight q_i value is, the more suitable it is to be a candidate agent. When the agent node is specified, the candidate agent with the least number of child nodes is selected, and the hierarchy of the candidate agent meets the requirements, then it is designated as the agent node. The multi-standard decision method is used to achieve the goal of designing the hybrid communication network architecture with the minimum number of nodes and load balance.

2.3 Design the Routing Algorithm of Communication Network

For the hybrid communication network ubiquitous in the power internet of things, base station nodes need to manage, collect and maintain the information of all nodes in the network. Adopting appropriate communication group routing algorithm and organizing the nodes in the network according to certain topological structure and logical relationship can greatly facilitate the network management [7, 8].

Ant colony algorithm is used to select routing information in order to optimize the effect of the algorithm before designing the routing algorithm. In order to optimize the route and guarantee the communication efficiency, it is necessary to reset the obstacle avoidance rule. For the obstacle or interference that will not cause great influence on the communication signal, it is set to avoid the problem. When the communication route encounters this kind of obstacle, it is not necessary to replan the other route and reduce the distance of the communication route as far as possible. Multiple path nodes and obstacle nodes in the communication environment are represented by ant colony algorithm, and the optimal path of data transmission and the path after avoiding obstacle are expressed. Then, the ideal optimal path and the actual optimal path can be calculated to analyze the situation of avoiding different obstacles by ant colony algorithm:

$$q = \frac{f(u_x, v_x) - f(u_y, v_y)}{\varepsilon\sqrt{\sigma - 1}} \tag{4}$$

In Eq. (4), q refers to the obstacle identification parameters of ant colony, f refers to the identification function of different nodes, u, v refers to the identification results of coordinates of different nodes, ε refers to the number of key information identified, and σ refers to the total number of node information involved in path identification planning. The ability of the ant colony to recognize obstacles and routes in the environment can be obtained by the above formula. The recognition ability can be obtained by adjusting the obstacle avoidance rules to enhance the pheromone selection ability of ant colony to critical path nodes and important obstacle nodes.

In this paper, the steps of designing a hybrid network routing algorithm for ubiquitous power Internet of Things are as follows: (1) Sending network broadcasts from the base station node to the surrounding, and initiating the networking process. Assuming that a total of A nodes receive netting packets from the base station node, the A node replies to the base station node in turn [9, 10]. The base station node receives a reply from the A node, indicating that the A node successfully joins the logical layer. (2) The A node that has joined the network shall be granted the authority of networking in turn, and shall send network broadcasting. Nodes that receive networked broadcasts may: A. be in the same logical layer as the sending node (logical layer 1); B. be in the next logical layer (i.e. have not joined the network); and C. be in the logical layer above. The specific processing process is as follows: if the receiving node and the sending node are located at the same layer, the receiving party shall record the corresponding receiving quality, and select two (at most two) nodes with the lowest receiving quality as its neighbor nodes, which shall be recorded in the local routing table. If the receiving node is in the next logical layer, the node sends a reply to the sender, joins the cluster with the sender node as the central node, and becomes a member of the cluster. After receiving the reply, the central node records the ID of the cluster-node in the local routing table, and reports the access information of the new node to the base station node [11]. If the receiving node is above the sending node, it is not processed. Node processing is completed with some delay until all nodes in Logical Layer 1 have sent their networked broadcasts. (3) Repeat step (2) until there is no receiving node at the next level (not yet joined the network). In the hybrid communication network of ubiquitous power Internet of Things, due to its time-varying topology, the channel quality may be degraded in the process of network operation, resulting in link failure and direct communication [12]. In order to ensure the reliability and stability of communication, it is necessary to adopt an effective link failure recovery mechanism by enabling the alternate path to restore communication. If an uplink failure occurs, the source node can select one of its neighbors as a temporary relay node to allow communication to proceed normally. If downlink failure occurs, the source node needs to add a failure flag to the original packet to notify it of downlink failure with the destination node. The node that receives the packet checks to see if it is the neighbor of the destination node [13, 14]. If so, the failure flag is removed and the packet is sent to the destination node. Conversely, the destination node returns the packet to the source node through the neighbor node after it receives the packet. At this point, all nodes have joined the network, ubiquitous IOT hybrid communication group network routing strategy is completed.

2.4 Set up the Hybrid Networking Communication Protocol

Although the communication protocol based on PRIME standard has been well designed and has been applied in Europe and America, its popularity in our country is limited to a certain extent because it is based on the European power line communication industry standard, and its content and system are complicated, and the requirements for computing capacity and storage space of nodes are higher [15]. On the basis of establishing hybrid communication network architecture and designing routing algorithm, the hybrid communication network protocol of ubiquitous power Internet of Things is optimized. Existing communication protocols are mainly used for local switching, without considering the coding mechanism of relay forwarding. Therefore, some fields such as relay routing table and hops are added to the data frame. This paper adopts CSMA/CA competition mechanism based on binary exponential backoff algorithm which is widely used in IEEE802.15.4 protocol to design the MAC layer protocol. The basic principle of the algorithm is: when the node has data to send, it first random backoff for a period of time, and then listen to the channel. If it is found that the channel is idle, it sends data; if it is found that the channel is busy, it will be randomly evaded for a period of time, repeat the previous step. If the number of retreats exceeds, the communication fails and the packet is dropped. The specific steps are as follows: (1) Initialize the parameters before sending the data by the node; (2) Randomly delay $0 \sim$ (2i-1) the evasion period (i is the minimum evasion index); (3) Detect whether the channel is idle, and if it is idle, send the data; otherwise, proceed to the next step; (4) Add 1 to the value of the evasion order, and set the minimum evasion index; and (5) Check whether the value of the evasion order is greater than the maximum evasion index, and if so, determine that the channel access fails and the packet is dropped; otherwise, go to step (2). The standard data frame is mainly composed of frame header, control code, source node, destination node, layer number, hop number, relay routing table, data length field, data field, check code and frame tail. Due to the strong attenuation, high noise and time-varying load impedance of power line, the length of data frame should not exceed 63 bytes in order to ensure the reliability of communication. The broadcast process is initiated by a base station node sending a data frame, and the node receiving the broadcast frame continues to broadcast the frame to its children until it traverses the network. The unicast process is initiated by a unicast data frame sent by a base station node to a specified destination node [16–18]. The base station node searches for the main route in the routing table of the base station node, and writes it into the relay routing table domain, and sets the number of hops as the number of node IDs. If a node finds itself in the first node address position in the relay routing table domain after receiving a data frame, it sets the source node to a MAC ID, deletes the first node address stored in the relay routing table domain, subtracts the number of path hops by 1, forms a new data frame, and sends it. This continues until the data frame reaches the destination node. After receiving the data frame, the destination node decides whether to reply to the base station according to the need. Based on the above process, this paper finishes the optimization design of hybrid communication network protocol for ubiquitous power Internet of Things.

3 Experimental Study

In order to test the application effect of the proposed hybrid communication networking protocol optimization technology for ubiquitous electric Internet of Things, a simulation experiment was designed to verify the performance of the communication protocol.

3.1 Experimental Preparation

This experiment mainly uses MATLAB TrueTime network simulation toolbox to carry out simulation experiment verification and result analysis. In order to compare the routing performance of different communication protocols, the same node distribution and physical layer parameters are used in the simulation process. Set in the 100 m100 m network, there are a total of 15 randomly distributed nodes, among which node 1 is the base station node. The transmission rate is 128.6 kbps. The location distribution of each node in the network is shown in Fig. 2.

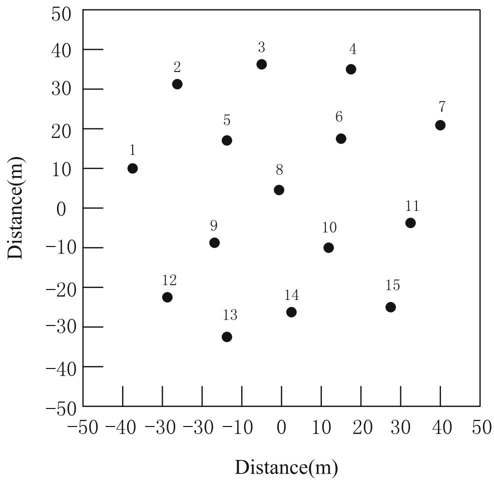
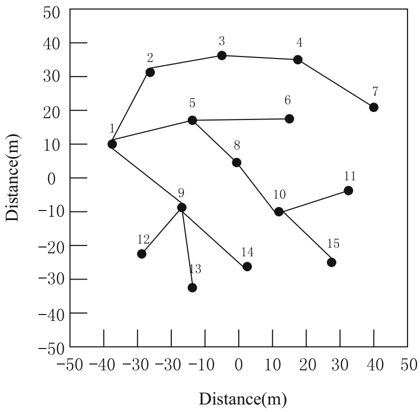


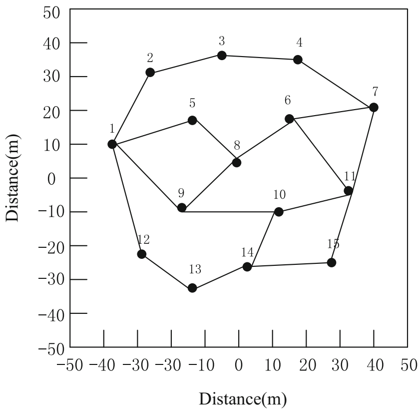
Fig. 2. Distribution of nodes

3.2 Communication Protocol Routing Overhead Test

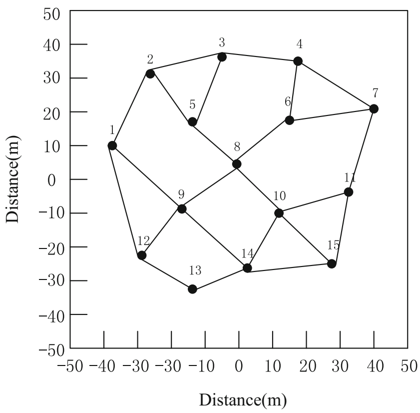
In this experiment, the optimized technology communication protocol proposed in this paper was set as the experimental group, and the networking communication protocol based on PRIME standard and the improved PRIME communication protocol were selected as the control group to conduct a comparative experiment. The three communication protocols were used to form the network respectively, and the logical topology of the network nodes finally formed was shown in Fig. 3.



(a) Prime Agreement



(b) Improvement of the PRIME agreement



(c) This paper designs a communication protocol

Fig. 3. Communication protocol networking structure

As can be seen from Fig. 3, the network structure composed of PRIME communication protocol is a tree type, while the improved PRIME communication protocol and the communication protocol designed in this paper form a mesh topology structure with chordal connection. In order to comprehensively compare the performance of the above communication protocols, the routing cost is selected as the evaluation index. Routing overhead refers to the number of all control packets transmitted in the network during networking and maintenance. It reflects the effective transmission efficiency of the network. The routing overhead of each node of the three communication protocols is compared, and the comparison results are shown in Table 1.

Table 1. Comparison results of routing overhead of each node

The serial number	Number of packets sent (PCS)		
	PRIME communication protocol	Improve PRIME communication protocol	This paper designs a communication protocol
1	578	235	46
2	574	227	48
3	562	236	45
4	549	242	46
5	563	247	48
6	572	235	47
7	568	238	43
8	570	241	46
9	564	228	47
10	575	236	48
11	572	245	49
12	569	246	43
13	543	241	44
14	572	239	46
15	568	237	48

According to the comparison results of routing overhead among nodes in Table 1, the communication overhead of each node of PRIME communication protocol is 567 data packets, the communication overhead of each node of the improved PRIME communication protocol is 238 data packets, and the communication overhead of each node of the communication protocol designed in this paper is 46 data packets. The total routing overhead of the three communication protocols was further compared, and the simulation time was 200 s. The test results were shown in Fig. 4.

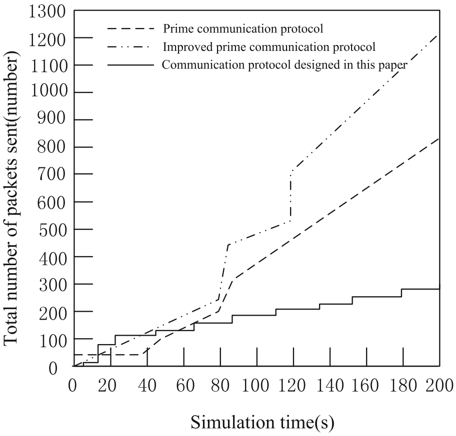


Fig. 4. Test results of total routing cost of communication protocol

According to the test results of total routing cost in Fig. 4, under the condition of simulation time of 200 s, the total routing cost of the communication protocol designed in this paper is 284 packets, which is 920 and 548 packets less than the total routing cost of PRIME communication protocol and improved PRIME communication protocol respectively. The reasons for the above results are as follows: the registration, upgrade and maintenance process of PRIME communication protocol node is complex, which involves the exchange of a large number of data packets, making the total routing overhead high. And the frequency of beacons sent by base station nodes is higher than that of other nodes, which increases the routing overhead of each node. The improved PRIME communication protocol simplifies the node upgrade process and stipulates that the beacon transmission frequency of the base station node and other nodes is the same, thus reducing the total routing overhead and the routing overhead of each node. In the communication protocol designed in this paper, the network entry node has the authority of independent networking, and the child node can join the network directly through the parent node without the permission of the base station node, which greatly simplifies the networking process. The network maintenance mechanism was also removed. Therefore, compared with the previous two, the routing overhead is greatly reduced.

4 Conclusion

This paper studies the optimization technology of hybrid communication networking protocol for ubiquitous power Internet of Things, analyzes and proposes the optimized hybrid networking architecture, and proposes the appropriate communication protocol based on the hybrid networking architecture. The experimental results show that compared with the existing communication protocols, the communication protocol designed in this paper has better performance, can greatly reduce the routing overhead, and has a higher practical value. The optimization of the hybrid communication network protocol can effectively improve the data transmission efficiency of the power communication network, enhance the application effect of the power Internet of Things, and improve the reliable guarantee for the operation efficiency of the power industry. If the hybrid communication network protocol optimization method proposed in this paper is applied to the medical Internet of Things, it can also effectively improve the efficiency of medical information transmission and promote the development of medical digitalization.

However, due to my limited ability, research time and experimental environment conditions, further improvement is needed in future research work. All the research work in this paper relies on the simulation platform to carry out quantitative demonstration on the reliability of the communication network, and lacks specific field experimental data for comparison. Therefore, in future research work, it is necessary to fully compare the test results of field experiments to make the simulation results closer to the actual situation.

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