Research and Design of Adaptive Networking Method Based on LoRa

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Abstract. An adaptive networking method based on LoRa (Long Range) technology is proposed. The data transmission of wireless sensor networks widely used in the Internet of things is studied. A star network composed of LoRa wireless transmission technology is designed to build an adaptive data transmission network. The design process of network topology, hardware and adaptive networking method of adaptive networking are introduced. Aiming at solving the problems of limited node capacity, adjacent frequency interference, and unreasonable channel resource allocation in the LoRa network, an adaptive frequency hopping mechanism is used for networking. The system uses I.MX6ULL as the main control and integrates 8 LoRa modules at the same time, which greatly improves the node capacity of the gateway. The server can realize real-time viewing and monitoring of node equipment, and real-time evaluation of channel communication quality.

1. Introduction

There are many types of wireless technologies in IoT applications, which can be divided into two categories in terms of transmission distance: (1) Short-distance communication technologies, including ZigBee, WiFi, Bluetooth, etc.; (2) Long-distance wireless communication technologies, including wireless WAN and low-power WAN, etc. Low-power WAN technology is a revolutionary Internet of Things access technology in the world in recent years, and LoRa belongs to this technical field. LoRa[1,2] is based on chirp spread spectrum modulation, which maintains the same low-power characteristics as frequency-shift keying (FSK) modulation and significantly increases the communication distance, changing the previous compromise between transmission distance and power consumption. The user provides a simple way to realize long-distance communication.

The research on the LoRa network is mainly for the LoRaWAN network. Haxhibeqiri and others pointed out that the number of terminal devices and their throughput have an impact on the performance of the LoRaWAN network[3]. The scalability of the number of terminal devices in each gateway in a single-gateway LoRaWAN deployment is studied. Lim analyzed the average packet success probability (PSP) of the LoRa system under the slotless ALOHA random access protocol[4]. By appropriately allocating an SF for each transmission data, the system PSP can be maximized, which also maximizes the connectivity of the nodes. Abeele used a different analysis model in which the LoRa error model was constructed from a wide range of complex baseband error rate simulations and used as an interference model[5]. This interference model is used in combination with the LoRaWAN MAC model in ns-3 to study a multi-channel spreading factor multi-gateway two-way LoRaWAN network with thousands of terminal devices. Using the LoRaWAN ns-3 model to analyze the scalability of LoRaWAN,
the results show that the downstream traffic has an adverse effect on the upstream traffic transmission rate. Increasing the gateway density can improve but cannot eliminate this effect. Aoudia proposed a high-efficiency and energy-saving architecture that combines a long-distance communication receiver with an ultra-low-power short-distance wake-up receiver to achieve high energy efficiency and low-latency communication in a long-distance network[6]. The hardware architecture and software protocol are designed. Experimental measurement and analysis comparison show that the proposed method does not require a trade-off between power consumption and delay.

Due to the above-mentioned problems of the LoRaWAN network protocol, its cost is high, and the capacity of the LoRa gateway node is limited and it is impossible to online real-time monitoring and optimization. This paper proposes an adaptive networking method based on LoRa, considering transmission efficiency and network coverage, using a star network architecture, adding adaptive algorithms for channel evaluation, improving network node capacity and communication reliability, optimizing energy efficiency and reducing nodes Power consumption.

2. Analysis of common networking methods
The networking design of a wireless network determines its network performance and lifetime, which specifically involves the network topology, multiple access technology, and channel sharing.

2.1. Network topology
The network topology is the connection method of various devices. The general wireless network topology includes star structure, tree structure, mesh structure, honeycomb structure, etc. Different topologies are suitable for different communication technologies and application scenarios. This topology has its own advantages and disadvantages, and the choice of topology directly determines the performance of the entire wireless network[7].

Among them, the child nodes of the star topology structure are only connected with the central node, and the child nodes only communicate with the central node. The structure is simple, there are only two devices in the network, the connection is convenient, the connection method is single, the management and maintenance are relatively easy, and the scalability is strong. The stability of the network is high, and the central node determines whether the entire network is working normally, regardless of the child nodes. LoRa communication itself has the characteristics of long transmission distance, and generally does not need relay or routing to expand the coverage. The star network is suitable for the simple structure of LoRa network.

2.2. Multiple access technology
In a real communication area, multiple nodes need to share limited wireless spectrum resources. Therefore, it is necessary to effectively allocate broadband resources to multiple nodes to improve system capacity. In a wireless communication system, multiple terminals communicate with the same base station at the same time, and different users and base stations must be assigned different characteristics[8]. In order to make full use of channel resources, reduce communication conflicts, and increase system capacity, a variety of multiple access technologies have been developed. Multiple access technologies are generally divided into frequency division multiple access (FDMA), time division multiple access (TDMA), and code division multiple access (CDMA), Space Division Multiple Access (SDMA).

TDMA divides time into non-overlapping time slots. Each user in the network allocates independent time slots for data transmission and reception. Under the condition of timing and synchronization, each terminal communicates with the base station in independent time. In the gap without interfering with each other. TDMA data is not sent continuously, so it can enter a low-power mode when the transmitter is not working, reducing the power consumption of the system. The TDMA technology transmitter and receiver need to maintain time synchronization, which requires high synchronization consumption. Considering the characteristics and application scenarios of LoRa technology, nodes can adopt TDMA mode.
2.3. Channel sharing
In wireless communication networks, although multiple access technology can solve some communication conflict problems, a single user occupies a channel will cause a waste of resources; channel resources are limited, and when the number of users is large, channel resources will be insufficiently allocated. Therefore, the same channel will be provided to multiple users for common use. When multiple users send data at the same time, conflicts will occur, resulting in data transmission failure. In order to solve the problem of channel sharing conflicts, there are three types of solutions: random access, controlled access, and channel multiplexing.

Random access means that all users can occupy the channel randomly. When concurrent data exists on the shared channel, channel conflicts are caused, which will cause the user's data transmission to fail. CSMA is a typical random access technology. CSMA means that the user needs to check whether the current channel is free before sending data. If it is free, the channel will be occupied and the data will be sent directly; otherwise, it will not be detected until the channel is free. The CSMA principle is relatively simple and easy to implement, and does not require centralized control. However, when the network data volume increases, the channel load is large, which causes the transmission time to be prolonged, and the transmission efficiency drops sharply. CSMA avoids collisions in the following three ways: channel idle detection, request to send (RTS) and permission to send (CTS), and ACK confirmation. On the basis of the TDMA mode used by the node, the CSMA access mode can be used when accessing the network to allocate channels to reduce communication conflicts.

3. Adaptive networking design
LoRa-based adaptive networking is mainly composed of temperature nodes, communication gateway and server.

In the entire communication network, the node is responsible for data collection and then wirelessly transmits it to the sub-gateway through LoRa. The gateway integrates 8 sub-gateways, one of which is used as a control gateway to select communication channels for node communication parameter configuration, and the remaining 7 sub-gateways work in different communication channels and are responsible for receiving node temperature information. The gateway MCU packs the data and sends it to the server through the TCP protocol, and at the same time performs local calculations on the data, carries out channel quality assessment and communication parameter modification. The server can view the information of each node in real time, as well as the issuance of control instructions. The overall system structure diagram is shown in figure 1.

![System structure diagram](image)

Figure 1. System structure diagram

3.1. Node program design
The LoRa node equipment mainly samples the temperature data and sends the collected information to the sub-gateway through the radio frequency module SX1276. Before the node enters periodic sampling, it first sends an allocation request to the control channel, and the gateway allocates a communication channel to the node through an adaptive algorithm. After receiving the allocation request, the node resets the communication parameters, sends a network access request to the sub-gateway where it is located, and starts normal operation after receiving the network access permission.
The network access request is for synchronizing with the system time of the sub-gateway, in order to increase the channel capacity, avoid communication conflicts, and integrate various networking methods. I have adopted TDMA and CSMA access methods. The TDMA method requires high time synchronization. The RTC clock synchronization error of STM32L053R8 is about 10ms. Therefore, the length of the fixed time slot must consider the length of the sent data and a certain time redundancy. Taking into account the time drift, nodes need to re-enter the network after a certain period of time, and resynchronize the RTC clocks of each node. When the communication quality of the node is poor, after sending the network access request next time, the node receives a frequency hopping instruction to switch the communication channel of the node. The node program flow chart is shown in figure 2.

3.2. Adaptive method
The realization of the adaptive frequency hopping mechanism is through the gateway's analysis and evaluation of the communication physical layer parameters RSSI and SNR and the data layer PRR. The gateway's adaptive allocation algorithm for device nodes includes two stages, one is that the node has just been added to the network, and the other is that the node has collected data in the network. The gateway program flow chart is shown in figure 3.

In the first stage, the communication parameter list of the 8-way sub-gateway is constructed, and the Elman neural network is used to find the mapping relationship between the RSSI, SNR, and PRR values. Judge the node distance according to the RSSI and SNR of the sub-gateway, use the mapping relationship model to predict the PRR, and assign channels to the nodes according to different weights.
Record the channel where the node is located. When the channel reaches full capacity, assign the node to the next channel according to the parameter list. When a node's network access request is received, different time slice serial numbers are assigned to the node and recorded in a two-dimensional array. First, query whether the node allocates time slices on other channels, and if so, release the time slice serial numbers it has occupied.

In the second stage, when a node is collecting data, it records the packet reception of each node. When receiving the network access request of the node, calculate the PRR of the node in the entire data transmission stage and the PRR predicted by the mapping relationship model, and compare the error between the two. When the error is large, the communication quality of the node at the moment is poor. According to the first phase method re-allocates the channel, but it cannot be on the same channel as the previous cycle. If it is, it is allocated to the next channel and the frequency hopping instruction is sent to the node. Evaluate the PRR of the entire channel in real time. If it is greater than the maximum threshold, you can modify the transmit power in the communication parameter list in a stepwise decreasing manner. If it is less than the minimum threshold, in a stepwise increase manner, the transmit power has upper and lower limits. When the PRR of the channel is less than a certain threshold, it can be judged that the quality of the entire communication channel is poor, and the nodes on this channel are hopped to other channels according to the first phase method. After all nodes under the channel are re-allocated, modify the frequency in the communication parameter list and reset the channel. The server can view the communication status of each node online, and can manually modify the parameter list and specify the frequency hopping instruction of the node.

4. Network test
The designed self-adaptive networking method is tested through the server platform developed in the laboratory. The platform stores and displays the uploaded temperature data, and checks the communication status of each node in real time. You can also run the Linux gateway program through the SecureCRT connection, and print out the running status of the adaptive networking.

The equipment capacity of the entire network is determined by the time slice and the data collection cycle. Considering the limited equipment of the laboratory node, the upload cycle is shortened as much as possible, and the full capacity of the channel is small, which is convenient for testing. A small number of node devices can be used to detect whether the design of the adaptive networking method is reasonable.

The command sending page is simple. The sending window only supports sending HEX command frames. After the sending is successful, a message will be displayed to send to the device. Since the parameter list of each sub-gateway is stored in the gateway program, the sent instruction can modify the parameter list, or directly issue a frequency hopping instruction to the node to switch the communication channel of the node. The test shows that the system successfully realizes the online setting of the sub-gateway parameters. The entire communication network is reliable under long-term operation, and nodes can realize adaptive frequency hopping according to the communication quality.

5. Conclusions
The test results meet the design requirements of adaptive networking. Through the 8-way sub-gateway, the node capacity of the network is greatly improved, and the realization of the adaptive mechanism greatly improves the communication reliability and stability of the network. The realization of the adaptive algorithm can evaluate the communication quality of the node well. The online modification of gateway parameters and the realization of viewing of the information of each node meet the requirements of actual users. The local data processing of the gateway reduces the delay of communication and improves the intelligence of the gateway.

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