IoT Terminal Communication and Status Management System Based on LoRa Technology

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Abstract: This article discusses the basic content and application advantages of LoRa technology, combined with the key points of the establishment of the Internet of Things terminal communication and state management system. The content of this article includes system architecture analysis, communication connection mode, terminal registration phase, data transmission phase and terminal cancellation phase. The author studied the simulated environment test, communication distance test, energy consumption monitoring test and other contents. The purpose of this article is to improve the security of the IoT terminal communication environment, speed up signal transmission, and improve signal transmission quality.

1. Introduction
In the context of the continuous improvement of the technological sophistication of the Internet of Things, the communication between the underlying Internet of Things devices and the cloud will also become more frequent. At the same time, the masses' requirements for system communication performance are constantly improving. As a low-power wide-area network technology, LoRa technology has great advantages when applied to the construction of IoT terminal communication and status management systems. It can not only optimize the original performance of the system, but also has a positive meaning for reducing system operating power consumption and improving resource utilization.

2. Overview of LoRa Technology Related Content

2.1 Basic Discourse
LoRa technology is a long-distance communication scheme based on LoRa spread spectrum modulation technology. It was first launched in 2013 by SemTech of the United States. LoRa technology is different from traditional wireless technology in that it is based on linear Chip spread spectrum modulation (CSS) demodulation technology. Its effective transmission distance has far surpassed the current wireless systems using FSK and OOK modulation technologies. Compared with other wireless communication technologies in the current Sub-GHz frequency band, LoRa technology has higher sensitivity, which effectively extends the distance of wireless communication.
2.2 Application Advantage

| Technical Characteristics | LoRa                  | NB-IoT                  | Sigfox                |
|----------------------------|-----------------------|-------------------------|-----------------------|
| Network Deployment         | Independent Network Construction | Cellular Base Station Multiplexing | SigFox Net          |
| Transmission distance rate | Long Distance         | Long Distance           | Long Distance         |
| RF bandwidth               | 0.3-50kbps            | < 100kbps               | < 100kbps             |
| Receiving sensitivity      | > 148dBm              | Same as Cellular Network| > 126dBm              |
| Battery Life               | About 10 Years        | About 10 Years          | About 20 Years        |
| Frequency band             | Unlicensed Band       | Licensed Frequency Band | Unlicensed Band       |

As shown in Figure 1, the working frequency band of LoRa is below 1GHz, which includes 433MHz, 470Mhz, 868MHz, 915MHz and so on. LoRa has low requirements for signal-to-noise ratio, low power spectral density, and low signal power. Therefore, it has strong energy saving. Secondly, the transmission rate of LoRa is very low, the amount of transmitted data is small, and the energy consumption is reduced, and its receiving current is only 10mA. The network capacity of LoRa is very large. A LoRa gateway can connect to millions of LoRa nodes, and it supports parallel processing of multiple channels and multiple data rates. Because of its large system capacity, it exceeds the current industry capacity requirements for LPWAN technology. Its network communication cost is extremely low, and it supports narrowband data transmission. In addition, LoRa technology has higher signal reception sensitivity than other application technologies, which is also conducive to the stable transmission of long-distance signals. Moreover, it has a strong link budget function in the signal transmission process. This effectively reduces the power loss during link operation.

3. Key Points for Establishing IoT Terminal Communication and Status Management System

3.1 System Architecture Analysis
As shown in Figure 2, the design of the system architecture mainly includes the terminal layer, gateway layer, server layer, and application layer. Next, let's start with a detailed discussion on it.

3.1.1 Terminal Layer
As shown in Figure 2, in the design process of the management system, there are many terminal devices to meet the conventional requirements for stable operation of the system. In the specific application process, the terminal layer contains many types of equipment. In addition to sensor equipment, mobile equipment, and institutional equipment, conventional servers can also be used as a terminal layer structure for applications. Its main work content is the collection of original data during the operation of the system and the execution of instructions after the system is issued. At the same time, it maintains close contact with the gateway layer to ensure the smooth completion of communication. Besides, terminal layer devices all have UART communication functions in applications, which also improves the compatibility of terminal devices. It allows many systems to be smoothly connected to the network, thereby improving the applicability of the system itself [1].

3.1.2 Gateway Layer
As shown in Figure 2, the gateway layer of the system is also composed of many gateway nodes in the application. These gateway nodes come from different application areas. Meanwhile, they will also radiate to the outside with the node as the center, forming a star-shaped network covering regional communications. Moreover, we also need to maintain the communication function between servers during the application process. In the specific work process, the main work content of the gateway layer is to perform protocol conversion. In addition, we should also supervise and manage the operation of the router to improve the stability of the node's working status. Furthermore, the gateway layer also shoulders the related work of edge computing, which can maximize the use of computing resources, thereby improving the stability of the system's operating state [2].

3.1.3 Server Layer
As shown in Figure 2, compared to the total amount of equipment at the gateway layer and terminal layer, the number of equipment required by the server layer is relatively small. When the amount of processing information is small, one server can meet the requirements, and it can adjust the number of servers as the amount of data processing increases. The server layer will directly connect with the gateway layer, and its main job content is to maintain the operating status of the system. Simultaneously, supervise the running status of the system router. Otherwise, it will work with the gateway layer to complete the established distributed computing work. The calculation results will also be summarized by the server to meet the normal application requirements of the application layer [3].

3.1.4 Application Layer
Except to the above three levels, the application layer is also an important part of the system. In a specific application process, the application layer is associated with the cloud service layer, and different cloud service layers are matched according to the type of data information. Moreover, the system will also be abstracted into many unified application nodes during the application process to complete the information interaction with the server. The application layer is also the order issuing unit in the system, it will issue the corresponding adjustment order according to the feedback information, and it is also one of the main control units in the whole system [4].

3.2 Communication Connection Method
In order to ensure the smooth interaction of information, we need to establish a reasonable communication system between all levels. The most commonly used communication system is the internet. First of all, we need to choose a stable and comprehensive TCP as the protocol layer between system operations to meet the communication requirements during system operation. After the system
application selection is completed, its running process is as follows. The gateway layer or application layer will communicate TCP commands to the server layer according to requirements. Secondly, the server layer will verify its identity after receiving the instruction. After the verification is passed, the instruction will be passed to the terminal layer, and then relevant data will be collected and analyzed. Finally, it will feed back the analysis results to the corresponding layer to complete a round of command operations [5].

3.3 Terminal Registration Stage
This layer is a relatively basic content in the system, and its role is to form a solid association with the gateway layer, and the overall smooth access to the system. In this process, Lo Ra technology will serve as an intermediate structure to broadcast content. This stage is also called the invitation stage. This invitation phase will also carry the identity verification information in the gateway layer, so after receiving the signal, the terminal node will perform identity verification on it, thereby forming a stable network structure. It should be noted that the terminal node will not send out a signal before it is connected to the entire network system, which also improves the stability and reliability of the system during operation [6].

3.4 Data Transfer Phase

3.4.1 Collection Node
In the data transmission stage, the main function of the collection node is to complete the smooth collection of conventional information. In the specific application process, the following parts of application content will be involved. (1) Sensor module. It is used for routine collection of data information. Common sensor models include DHT11, BH1750FVI, etc. (2) STM32 microcontroller structure. It is used for the analysis and processing of collected information. The commonly used structure is the Harvard structure, which has the advantages of strong operation stability and fast processing speed. (3) Lo Ra communication module. It is used to coordinate the collected related parameters. After the module is simply processed, it will be passed to the relay node for further processing to meet the requirements of smooth information transmission.

3.4.2 Relay Node
The relay node can regard the relay node in the data transmission layer as a temporary network layer of the system. Its main work content is to receive instructions from the server layer or the gateway layer. In the meantime, it is also an intermediate station for information transmission. Lo Ra communication module and single-chip microcomputer structure will be used in the establishment process. It should be noted that the interface types between the two need to be consistent to meet the requirements of smooth transmission of data information during system operation [7].

3.4.3 Sink Node

Figure 3 Working Diagram of GPRS Module
The information will be temporarily stored at the sink node before being transmitted, and the data will be transmitted through the node after simple processing. In specific applications, the following module structure will be involved. (1) LoRa communication module. It is used to coordinate the collected relevant parameters, and after simple processing by the module, they are passed to the gateway layer. During this period, control information will also be transmitted to meet the basic requirements of the stable operation of the system [8]. (2) GPRS module. It is used for data collection and information exchange. The specific workflow is shown in Figure 3.

3.5 Terminal Logout Phase
When the terminal layer is disconnected from other layers, the system will also enter the logout phase. In the application phase of the system, the terminal will take the initiative to issue a cancellation application instruction to the system. After getting permission, the terminal will temporarily enter the dormant state, and sometimes enter the long-term dormant state according to the actual situation. The system will also issue a logout command to some systems according to the actual operating conditions, so that they will enter the disconnected dormant state, thus ensuring the safety during system operation [9].

4. Analysis of System Test Points

4.1 Simulated Environment Test
In the simulation environment test process, the system can combine its service environment to form a simulation work scenario. For example, three terminals A, B, and C are selected at the terminal layer, one gateway device and one server device. At this time, a retrieval request for an item is issued, and the terminal performs retrieval, aggregation, and transmission. Simultaneously, the terminal also needs content such as the completeness of data collection and transmission efficiency. Compared with the expected design requirements, if the pass rate reaches 100%, then the system test results meet the application requirements [10].

4.2 Communication Distance Test
In the system test process, the communication distance test is also one of the very important contents. The system can be tested through planned experiments, and the packet loss rate and RSSI value are used as system evaluation criteria. The test distance interval can be set to 400m, such as 400m, 800m, 1200m, etc. The terminal layer completes the transmission of data packets, and performs statistics on the packet loss rate. If the packet loss rate is within a reasonable range, the application requirements need to be met. Otherwise, we need to optimize the system until the application requirements are met [11].

4.3 Energy Consumption Monitoring Test
When testing the system, energy consumption monitoring test is also very necessary. When testing it, it is necessary to maintain a certain working state of the system and monitor the power consumption per unit time. In order to verify the stability of the energy consumption of the system, we need to monitor it for a long time. Finally, we need to judge the energy consumption status of the system based on the monitoring results, and provide a reference for subsequent functional system adjustments [12].

5. Conclusion
In summary, LoRa technology has many advantages in the application process, such as low energy consumption and strong stability. Based on the LoRa technology to complete the smooth formation of the system. For one thing, it can optimize the operating state of the system and improve its operating stability. For another, it also has a promotional significance for accelerating the development of the Internet of Things communication system.
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