Development of Low-Power Wide-Area Communication Gateway for Power Data Transmission

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Abstract. With the rapid development and maturity of communication technology, integrated computer technology and sensor technology, small sensors with sensing, computing and communication capabilities have begun to appear all over the world. The sensor network composed of these small sensors has received a lot of attention. This paper studies the low-power wide-area communication gateway for power data transmission. Based on the analysis of the energy consumption strategy of the power data transmission process, the low-power wide-area communication gateway for power data transmission is developed, and the developed gateway was tested. According to the peer test results of the gateway, the packet loss rate of the gateway within 100m is relatively good. Therefore, when arranging network nodes, try to control the transmission distance of the gateway within 100m. The energy consumption test shows that the energy consumption of the gateway is basically in an ideal state.

Keywords: Power Data, Data Transmission, Wide Area Communication, Gateway Development

1. Introductions
Wireless sensor network mainly refers to a multi-node, independent network system formed by a large number of digital sensor nodes in a specific area through wireless communication [1-2]. The design purpose of wireless sensor network is mainly to identify, collect, analyze and process various types of information of monitored objects in the area covered by the network, and send it to observers for other corresponding inspections and processing in a timely manner [3-4]. With the continuous progress and development of mobile communication network technology, wireless sensors and Internet networks have developed rapidly, with strong survivability, and strong real-time performance, which have expanded their broad application prospects [5-6], and are widely used in power data monitoring, military, ecological monitoring, medical treatment, sanitation and other fields [7-8].

For the research of low-power wide-area communication, some researchers have proposed a multi-channel MEMS-based low-power gateway, which combines LoRa and NB. The method is to use multi-channel LoRa and NB-IoT gateway (M-CLNIG), and multiple wireless MEMS-based LoRa nodes (WMLN) to construct an LPWAN for factory machine vibration monitoring, and experimental verification of the proposed method. The experimental results show that the multi-channel LPWAN monitoring method proposed in this paper has high-precision data synchronization acquisition, big data storage and data streaming upload capabilities [9]. Some researchers have suggested that most IoT
devices today use personal gateway devices, such as smart phones or home WiFi access points. The necessity of configuring and maintaining these gateways has brought additional burdens to users and developers of IoT applications. Therefore, to address this problem, the development of a crowdsourced low-power wide area network (csLPWAN) is used to eliminate the need for personal gateways, to reduce the consumption of data transmission [10]. Some researchers have proposed that low-power wide area networks (LPWAN) have been used to support low-cost and mobile two-way communication in the Internet of Things (IoT), smart cities, and various industrial applications. However, in this process, LPWAN technology is one of the main security the problem is to prevent attacks on legitimate communications between nodes, resulting in packet loss, packet arrival delay, and packet skew arriving at the reporting gateway. Therefore, LoRa technology is proposed for this phenomenon to reduce the packet loss rate of data transmission [11]. In summary, there are many research results for low-power wide-area communications, but there are relatively few developments on gateways.

This paper conducts research on low-power wide-area communication gateways for power data transmission, summarizes the energy consumption composition of power data transmission on the basis of relevant literature data, and then analyzes the energy consumption by strategy. The gateway is developed, and the developed gateway is tested, and relevant conclusions can be drawn from the test results.

2. Research on Low-Power Wide-Area Communication Gateway

2.1. Energy Consumption Composition of Power Data Transmission

The energy loss of power data transmission can be divided into three main parts: perception, processing and data transmission [12]. Among them, data transmission is the main part of energy consumption. Therefore, many studies ignore the energy consumption of perception and data processing when calculating node energy consumption, and use the energy consumption of transmission to estimate the energy consumption of sensor nodes.

2.2. Low-Power Wide-Area Communication Strategy

(1) If the sensor node is already idle, the system will not be able to provide corresponding services. Especially for persistent queries based on service configuration, the routing for the first query is likely to cause failure, because the service node is inactive for a period of time. Therefore, it is necessary to update and introduce a new service model within a certain period of time. However, there will be a large number of data packets to be exchanged during the switching process, so the switching between the combined path between the new service and the old service will generate a certain amount of time and energy consumption. The continuity routing of synthetic planning query based on service provision is designed to meet the needs of applications, and to minimize the energy consumption and loss of synthetic planning routing provided by the service, while taking into account the sleep scheduling mechanism of service supply nodes.

(2) In our traditional method, the data is updated manually, that is, the updated source code is directly written into the node of each sensor via a computer or software. However, with the development and rapid growth of the Internet, such a one-to-one mass data update method has become more and more possible. In addition, some sensor nodes are likely to be located in remote areas, and the sensor nodes cannot be reached directly. Therefore, it is very necessary to design the data update mechanism on the automatic sensor network.

(3) The main advantage of Zigbee technology over other short-range wireless communication technologies lies in its low power consumption. Especially in the field of wireless sensor networks, achieving low power consumption on terminal nodes can significantly reduce battery power consumption, extend the life of network nodes, and extend the life of the entire network. There are many ways to achieve low node power consumption, but they can be considered in terms of hardware selection and software design.
2.3. Power Control Algorithm

The core of the existing power control model is to find the functional relationship between the quality of the connecting cable and the transmitting power, and to dynamically adjust it according to the relationship between these functions. Algorithm optimization is mainly based on changes in the relationship between connection quality characterization parameters and the effects of attitudes. However, whether it is the static function relationship at startup or the dynamic function relationship according to the selected environment during operation, it can no longer simply express the complex correlation between the connection quality and the transmission power. To dynamically adjust a power value to an appropriate level, a technology that relies on the strength of the signal received by the node to adjust the power feedback is needed. So to improve it, the improvement method is as follows:

In the strategy iteration, the corresponding return $V(s)$ after the strategy $\pi$ is adopted in the states. The specific iterative process is shown in formulas (1) and (2). Among them, $r$ is the discount coefficient. When the system has only a limited number of states and actions, it can ensure that the algorithm converges to the optimal strategy within a limited number of steps. It can be seen that the object of strategy iteration is strategy, and the goal is to make it converge to the optimal strategy.

\begin{align}
Q_\pi(s, a) &= U(s, a) + \gamma \sum_{s' \in S} p(s, a, s') V_\pi(s') \\
\pi'(s) &= \arg \max_{a \in A} Q_\pi(s, a)
\end{align}

3. Development of a Low-Power Wide-Area Communication Gateway for Power Data Transmission

3.1. Development and Analysis of Communication Gateway

The power and energy required to detect power are generally determined according to application requirements. In many occasions, compared with the local data processing or sensor node communication function, the power required to detect this function is almost completely negligible. However, in some specific cases, the energy consumed when detecting an arithmetic unit can even be compared with the energy consumed when communicating data. Therefore, two main energy-saving methods are usually used. 1) Manage the frequency and energy in the design process of the network subsystem or network protocol; 2) Manage the frequency of the detected network subsystem or each node of the sensor.

3.2. Network Node

The wireless sensor logically divides the entire network node into two parts. That is to say, the functional logic part related to the node application (for example, sensors or micromotors, thyristors and other actuators that collect information such as voltage and current in pollution control equipment) and wireless communication parts.

Divide the system into two parts. It is not only a sub-platform of a sensor and an actuator, but also a sub-platform of wireless communication. In this way, these two modules can be designed and run independently, and can be debugged and distributed development. This greatly reduces the development cost of the gateway and the cycle of network operation management, as well as the cost management and maintenance costs of the network operator after using the gateway. In addition, the logic function part and the wireless function part of the node itself can also be separated independently. The realization of the gateway is no longer necessary, it requires a lot of manpower and financial resources to be invested in wireless communication to design and manufacture how to realize the entire gateway communication system, only need to follow a standardized software and hardware based on the wireless communication platform Interface, so that different signals, sensors and actuators from various pollution monitoring and control devices can be easily connected.
3.3. Communication Gateway Hardware Design

3.3.1. MCN. The model processor MSP430F5438 is mainly used for the selection of the main control chip, and the responsible manufacturer is Texas Instruments. After the alarm signal is sent out, the various functions are switched smoothly, and it only takes 5 seconds to ensure the normal operation of the processor. This flexible operation mode keeps the power consumption of the main control system at a very low level. If you want to ensure basic functions, you need to configure four interfaces to effectively control each communication unit.

3.3.2. Circuit. This article selects ADI blackfin53x processing chip series, MSP430F5438 model processor belongs to the Blackfin product line fusion Analog Devices/Intel's micro signal architecture (MSA). The Blackfin processor architecture combines the advantages of the most advanced dual MAC signal processor, simple RISC microprocessor instruction set, and command multimedia multimedia capabilities (SIMD) capabilities to form a unique instruction set structure.

3.4. Communication Gateway Software Design

3.4.1. Micro-power wireless module. The short-distance wireless communication between the three phases of the communication terminal generally requires a wider transmission bandwidth, but the time and power consumption should be as low as possible. This is the reason why the wireless micro-power unit of the device uses ZigBee technology, which can realize short-distance, low-power, low-speed, and low-cost two-way wireless communication. At the same time, the main controller monitors the sleep/wake-up of the ZigBee module and only maintains the normal operation of the ZigBee module when necessary, which can further reduce the power consumption of the communication terminal.

3.4.2. Communication module. The GPRS communication unit is responsible for receiving all control commands, and the fault detection function forwards them to their respective processing equipment. In this design process, Motorola G24 was selected as the key to the communication unit.

4. Wide Area Communication Gateway Detection

4.1. Communication Reliability Design and Testing

For the wide-area communication gateway developed in this article, the communication reliability test is carried out. After data collection using three different sensors, the collected data is sent to the gateway, and the distance between the two is set to 10 meters, 60 meters, and 100 meters. At 150 meters, each sensor sent a total of 100 data packets, and recorded the number of packets lost by the gateway. The related data results are shown in Table 1:

| Distance (m) | Sensor 1 | Sensor 2 | Sensor 3 |
|-------------|----------|----------|----------|
| 10          | 0        | 1        | 1        |
| 60          | 30       | 24       | 25       |
| 100         | 45       | 43       | 45       |
| 150         | 78       | 79       | 80       |

Table 1. Communication reliability results.
Figure 1. Communication reliability results.

It can be seen from Figure 1 that the packet loss rate of the wide area communication gateway developed in this article is still relatively good, and the packet loss rate control within 100m is better.

4.2. Energy Consumption Detection

For the wide-area communication gateway developed in this article for energy consumption detection, under normal circumstances, the MSP430F5438 operating frequency is 4k, the sampling is continuous sampling, and the GPS module works, and the corresponding value is 1. When the main monitoring station sends out relevant instructions and is instructed to download data, and then send it to the communication terminal and information, the ZigBee communication module works. The communication terminal and A, B, and C all pass through the ZigBee module. It interacts with each other, and the corresponding value is 2. One stage is responsible for receiving instructions and sending relevant data and information. Next, the GPRS module is started, and the corresponding working mode is 3. By calculating the energy consumption of the gateway to transmit data in these 3 working states, the relevant data is shown in Table 2.

| Working status 1(mw) | Working status 2(mw) | Working status 3(mw) |
|----------------------|----------------------|----------------------|
| 1                    | 210                  | 340                  | 984                  |
| 2                    | 211                  | 342                  | 985                  |
| 3                    | 212                  | 343                  | 986                  |
Figure 2. Energy consumption test results.

It can be seen from Figure 2 that the total power consumption of the gateway in three working states is ideal. In working state 1, two working modules are activated, and the energy consumption is 210mw, which is higher than the power consumption under one working module can be less.

5. Conclusions
This article focuses on the research of low-power wide-area communication gateways for power data transmission. After understanding some related theories, the main purpose is to understand the energy consumption of the data transmission process, and analyze the corresponding strategies to reduce energy consumption. And on the basis of these, the wide-area communication gateway is developed, and the developed gateway is tested. The test results show that the energy consumption of the gateway developed in this paper can meet the ideal energy consumption state, but in the research process there are still some shortcomings, mainly because the experiment was not carried out in the actual circuit, so the experimental data is relatively ideal, and the actual situation of the circuit is not considered.

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References
[1] Barrachina-Munoz S, Bellalta B, Adame T, et al. Multi-hop Communication in the Uplink for LPWANs [J]. Computer Networks, 2016, 123(aug.4):153-168.
[2] Cui S, Joe I. Collision prediction for a low power wide area network using deep learning methods
[3] Sela Y. Mobile Telephone Gateway Apparatus, Communication System, and Gateway Operating System [J]. Gondwana Research, 2017, 23(2):661-665.
[4] Keller J. Northrop Grumman to operate BACN voice and data gateway for airborne communications [J]. Military & Aerospace Electronics, 2019, 30(2):25-26.
[5] Yamada T, Ninagawa C. Analysis on burst packet buffering of communication gateway between fast IP network and slow facility fieldbus [J]. IEEJ Transactions on Electrical and Electronic Engineering, 2016, 11(4):508-515.
[6] Haxhibeqiri J, Karaagac A, Moerman I, et al. Seamless roaming and guaranteed communication using a synchronized single-hop multi-gateway 802.15.4e TSCH network [J]. Ad hoc networks, 2019, 86(APR.):1-14.
[7] Lei, Du, Wenbin, et al. Design and Implementation of Smart Home Gateway Based on 433MHz Radio-Frequency Communication [J]. Recent Advances in Electrical & Electronic Engineering (Formerly Recent Patents on Electrical & Electronic Engineering), 2018, 11(1):80-87.
[8] Chambers, Mary. Interpersonal relationships and communication as a gateway to patient and public involvement and engagement [J]. Health Expectations an International Journal of Public Participation in Health Care & Health Policy, 2018, 21(2):407-408.
[9] Alistair, Hookway. Communications: Remote management gateway offers a constant ear to the ground [J]. Panel building and system integration, 2017(Jul.):20-21.
[10] Prouty A M, Fischer J, Ann Purdom.... Spiritual Coping: A Gateway to Enhancing Family Communication during Cancer Treatment [J]. J Relig Health, 2016, 55(1):269-287.
[11] Tamura T. Gateway apparatus, communication system, and communication method [J]. Physics Experimentation, 2017, 13(4):311-8.
[12] Qin H, Cao B, He J, et al. Cross-Interface Scheduling Toward Energy-Efficient Device-to-Gateway Communications in IoT [J]. IEEE Internet of Things Journal, 2020, 7(3):2247-2262.