Review on Key Technologies of Wireless Monitoring of Pump Group Based on Internet of Things

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***Abstract*—In this paper, Internet of Things (IoT) technology is applied to wireless monitoring field of pumps. The structure of wireless sensor network nodes in the perception layer of the IoT, as well as the division and function of each part of the wireless monitoring system in the process of signal acquisition and transmission are analyzed. The characteristics of several wireless monitoring technologies and their best applicable working environment are introduced. LoRa wireless communication technology is selected to monitor the pump group, taking LoRa technology as an example, the role and technical advantages of IoT in the whole wireless monitoring system are elaborated. At the same time, some problems of wireless monitoring technology are pointed out.**

Keywords-Pump group; Internet of Things (IoT); Wireless monitoring; Wireless communication technology

I. INTRODUCTION

Pump group is widely used in petrochemical industry. Due to the large number of pumps, poor working environment, long running cycle and other factors, the probability of pump failure is relatively large. Therefore, monitoring the operating state of the pump to discover and eliminate faults in a timely manner is of great significance to the continuous and efficient operation of the equipment, safeguarding the interests of enterprises and ensuring the safety of staff. The traditional monitoring scheme uses wired method to transmit the data of pump group operation status, which has the shortcomings of high cost and poor flexibility. Under some harsh working conditions, it will lead to cable damage, and maintenance is difficult. With the development of the Internet of Things (IoT) and wireless communication technology, wireless sensor network based on wireless communication technology as the perception layer of the IoT for data transmission has a series of advantages such as low cost, convenient maintenance and high flexibility. It can effectively solve a series of problems such as cost and complex wiring caused by wired monitoring, which is of great significance to production practice.

II. DEVELOPMENT STATUS AT HOME AND ABROAD

A. *The Development Status of Internet of Things at Home and Abroad*

In the 1990s, the concept of the IoT was put forward by the Massachusetts institute of technology of the United States. After the concept of the IoT was formally defined in the "ITU Internet report 2005: The Internet of Things" published by the international telecommunication union (ITU), experts and scholars from all countries paid attention to it, and governments of all countries also increased the capital investment in the industry of the IoT [1]. As a leader in the IoT technology, the United States had built a smart digital power grid using the IoT technology. The system can automatically locate and upload the location of faults, so as to quickly restore power supply. In addition, the "A Smarter Planet" project proposed by the United States has accelerated the research and development of the IoT technology. The European Union, Japan and Korea also attach great importance to the IoT industry. In order to speed up the pace of information construction, they had deployed the development strategy of the IoT successively.

Domestic research on the IoT began in 1999. Through the construction of some practical sensor networks, the IoT industry had gradually developed in China. The proposal of the "Perception of China" strategic concept and the release of the "Twelfth Five-Year Development Plan of the Internet of Things" had greatly promoted the development of China's IoT technology. Nowadays, IoT technology has become a part of the national development strategy, and it has been gradually applied to the industrial field.

B. *Current Situation of Condition Monitoring at Home and Abroad*

The research on condition monitoring has appeared very early abroad. In 1997, the first Internet-based industrial remote diagnosis seminar was held in the United States, which promoted the rapid development of this field. Companies such as Bently had developed condition monitoring systems and began to apply them to the industrial sector. With the emergence of wireless integrated network development

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platform system, more and more wireless monitoring systems are applied to the condition monitoring of rotating machinery.

III. DESIGN OF WIRELESS MONITORING SYSTEM FOR PUMP GROUP

A. Structure of The Wireless Sensor Network Node

In the wireless monitoring system of pump group based on IoT, the signal acquisition of pump group's running state is realized by wireless sensor network [2]. Fig. 1 shows the structure of a wireless sensor network node. The wireless sensor network node is generally composed of sensor module, processor module, wireless communication module and power module.

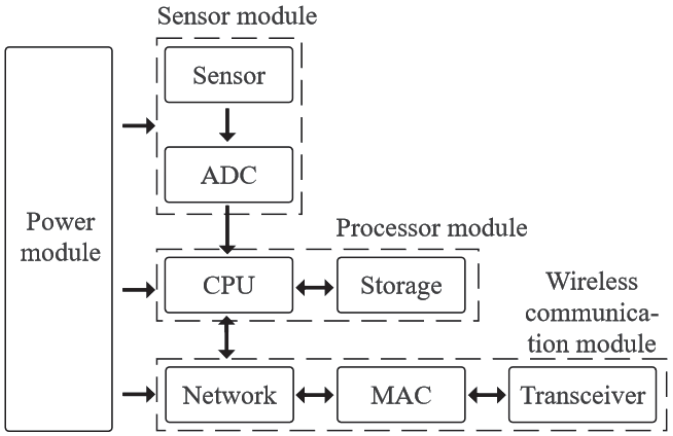

Figure 1. Structure of node

Sensor module is mainly composed of sensor and Analog-to-Digital Converter (ADC), which is responsible for data collection and processing. Through the analysis of the vibration and temperature signals of the pump, the current operating state of the pump can be evaluated effectively. Therefore, the vibration and temperature sensors are two indispensable sensors for monitoring the pump. Vibration and temperature sensors acquire the vibration and temperature signals of the pump, the signals are filtered and amplified by the circuit in the sensor module and then transmitted to the ADC. The ADC converts the analog signals into digital signals that can be transmitted wirelessly, and then transmits the digital signals to the processor module of the node.

The processor module is mainly composed of Central Processing Unit (CPU) and memory, which controls the operation of the whole node and is the core module of the whole node. The CPU receives the digital signal processed by the sensor module and sends the signal to the wireless communication module of the node after storage in the memory.

The wireless communication module is responsible for the sending and receiving of signals of the whole node. The wireless communication module receives the signals transmitted by the processor module, and transmits the signals collected by the node to the gateway through wireless communication technology to complete the uplink transmission of data. The wireless communication module can also receive the instructions sent by the gateway and transmit them to the processor module. The CPU receiving signal control node executes the instructions sent by the gateway and completes the data downlink transmission.

The power module provides sufficient power for the entire network node and ensures the normal operation of each module [3].

B. Comparison of Several Wireless Communication Technologies

Wireless communication technology has been widely used in industry and developed rapidly due to its advantages of low cost and low power consumption. At present, relatively mature wireless communication technologies include Bluetooth, Wi-Fi, ZigBee, LoRa, NB-IoT, etc. In the wireless monitoring system of the pump group, the node transmits the device status information collected by the sensor to the gateway through wireless communication technology, Therefore, choosing the appropriate wireless communication technology is the basis of ensuring the secure and efficient communication between nodes and gateways.

TABLE I. COMPARISON OF SEVERAL WIRELESS COMMUNICATION TECHNOLOGIES

Parameter	Wireless communication technology				
	Bluetooth	***Wi-Fi***	***ZigBee***	***LoRa***	***NB-IoT***
Transmission distance	10m	100m	75m	20Km	15Km
Communication frequency	2.4GHz	2.4GHz	2.4GHz	433/470/868/915 MHz	800-900MHz
Transmission rate	2Mbps	54Mbps	250kbps	37.5kbps	250kbps
Maximum energy consumption	100mW	100mW	1mW	100mW	200mW
Network node	7	255	65535	65535	About 100000

As shown in Table I, Bluetooth technology is a short-range wireless communication technology. Bluetooth technology has a high bandwidth, the maximum transmission rate can reach 2Mbps, which can complete a large amount of data transmission in a short time, but its maximum network capacity is only 7 transmission nodes, the network size is small. The maximum transmission distance is only 10m, the coverage is narrow, and the chip cost is high. To sum up, due to the technical characteristics of Bluetooth technology, it is rarely used in the field of industrial wireless monitoring.

Wi-Fi technology has a maximum network capacity of 255 and a communication distance of 100m. Its greatest advantage is that its maximum transmission rate can reach 54Mbps, which is tens of times that of Bluetooth. However, when it achieves a larger transmission rate, it is accompanied by the increase of node energy consumption. Under the condition of battery power supply, higher data acquisition frequency and fast transmission rate often accompany with the shrinkage of battery life. Therefore, Wi-Fi technology is suitable for wireless monitoring occasions where the number of pumps is

small, the distribution range is relatively centralized and a large amount of data transmission is required.

The network transmission rate of ZigBee technology is only 250kbps, and it shares 2.4GHz communication frequency band with Bluetooth technology and Wi-Fi technology. To a certain extent, it will affect its security and reliability. Because it works in 2.4GHz frequency band, its ability to cross the wall is also poor. However, its network capacity is large and power consumption is small, the maximum energy consumption is only 1mW, and the maximum network capacity reaches 65535 nodes. It can realize wireless monitoring of a large number of pumps. It can also expand the wireless communication distance by constructing star, tree or mesh topology [4]. Therefore, ZigBee technology is more suitable for broader wireless monitoring occasions with more pumps and a distribution range of about 100 meters. Because of its technical advantages, ZigBee is also widely used in the field of industrial wireless monitoring.

NB-IoT technology is a long-distance wireless communication technology. The transmission distance of signals in open areas can reach 15Km, and the transmission distance in towns can reach 1~2km. The maximum transmission rate of NB-IoT can reach 250kbps, which can provide users with high-quality communication services. Compared with other wireless communication technologies, although the maximum energy consumption of NB-IoT reaches 200mW, but most of the time NB-IoT is in the Power Save Mode (PSM) when there is no uplink and downlink data, and the energy consumption is only about 15μw, which greatly improves the battery life of NB-IoT terminals. The disadvantage of NB-IoT technology is that it works in authorized frequency band below 1 GHz, and carriers provide communication services. However, in some relatively remote areas, the signal is difficult to cover. Compared with other wireless communication schemes, it can't form a relatively independent network, and the NB-IoT band authorization fee is high, which increases the cost of network deployment. Therefore, NB-IoT technology is suitable for wireless monitoring occasions with large number of pumps, wide distribution, high quality data transmission and operator signal coverage.

LoRa communication technology is also a kind of long-distance wireless communication technology. The most remarkable feature of LoRa communication technology is that the communication distance is farther than other communication methods under the same power consumption. The transmission distance of signal in open area can reach 20Km, and it can reach 2Km to 5Km in dense areas of towns or other buildings. The maximum network capacity has reached 65535 nodes, which can effectively monitor industrial production areas with large number of pumps. Due to its low power consumption and long-distance transmission design, LoRa technology can only reach the transmission rate of about 37.5 Kbps in general, so LoRa communication technology is suitable for wireless monitoring occasions where the number of pumps is large and the distribution range is wide and the communication speed requirement is not too high.

Each of the five wireless communication technologies described above has its own application in wireless monitoring of pump groups. For the wireless monitoring system of the pump group studied in this paper, because the number of pumps in the pump group is large and the distribution range is relatively large, this requires that the selected communication technology can meet the requirements of a long communication distance and a large number of access nodes. LoRa and NB-IoT technologies can meet the above requirements. Considering that in practical industrial applications, the pump group is often distributed in remote places, considering the cost and other issues, this paper uses LoRa technology as the communication mode of wireless monitoring of pumps

C. Wireless Monitoring System of Pump Group Based on Internet of Things

IoT is an information technology based on the Internet, which integrates and applies various advanced technologies in various ways to realize the interconnection of all things. The overall framework of wireless monitoring of pumps using IoT technology is shown in Fig. 2. The IoT is mainly composed of three layers: perception layer, network layer and application layer [5].

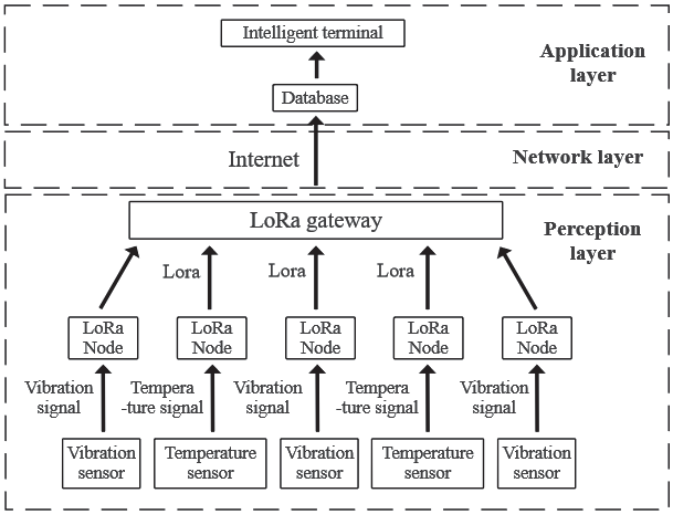

Figure 2. Overall Scheme of Wireless Monitoring System for Pumping Station

The perception layer is mainly composed of wireless sensor networks. Data acquisition is the main task in the IoT system. The vibration and temperature sensors installed in the pumping station acquire the vibration and temperature signals of the pumping station, the data are processed and converted by LoRa nodes, the signals are transmitted to the LoRa gateway through wireless communication through LoRa technology, the signals are transmitted to the network layer of the IoT through the gateway. Complete the data acquisition of the perception layer of the IoT.

The network layer of the IoT is mainly built on the basis of the existing Internet and is mainly responsible for the transmission of information. The network layer receives the data from LoRa gateway in the perception layer, transmits the

signal through twisted pair, coaxial cable, optical fiber or wireless communication, and transfers the operation data of pump station acquired in the perception layer to the application layer safely and efficiently.

The main function of application layer is data storage, and can directly present the information needed by users to users. The application layer is a layer of architecture that users can directly access. Pump group vibration, temperature and other data are collected and transmitted to the application layer through the IoT application layer. After data storage, state analysis, health assessment and fault classification are carried out by database, the assessment of the current running state of each pump in the pump group is sent to the intelligent terminal [6], and the real-time running state of the pump is displayed intuitively to the user through the intelligent terminal, thus realizing the remote monitoring of the pump group, thereby achieving the goal of human-computer interaction in the IoT.

IV. EXISTING PROBLEMS

After years of research and development, wireless monitoring technology has become more and more mature, and has certain applications in the field of industrial production. Wireless monitoring technology has many advantages, but there are also some problems that need to be solved urgently by researchers.

a) Communication distance: Research and comparison of several wireless communication technologies will find that the communication distance between devices is greatly affected by the surrounding environment. When there are many obstacles in the monitoring environment, the effective communication distance between devices will be greatly reduced. How to enhance the transmission distance and communication quality of data in complex environment is an important issue in wireless monitoring.

b) Energy consumption problem: Because of the limitation of wireless monitoring environment, the nodes of wireless sensor networks usually use batteries to supply power. Generally speaking, the size of sensor nodes is relatively small, which leads to the limited power consumption of power module in the nodes [7]. Therefore, on the premise of wireless communication, how to reduce the energy consumption of sensor nodes and prolong the battery life is an important issue of wireless monitoring. At present, there are many schemes to reduce the energy consumption of wireless sensor network nodes, such as reducing communication traffic, reducing the output power of wireless communication module, increasing the sleeping time of wireless sensor nodes, etc. These schemes have achieved the goal of reducing node energy consumption, but how to design sensor nodes with lower energy consumption will be a long-term topic of wireless monitoring technology.

c) Time synchronization: The main purpose of wireless monitoring is to diagnose the faults of the equipment that has already broken down, to assess the health of the equipment that is in normal operation, and to predict the possible faults in the future according to the recent operation status of the equipment, so as to achieve predictive maintenance [8]. For fault diagnosis and prediction of equipment, it is often necessary to arrange different nodes to monitor the equipment at multiple locations of the equipment, so that the information of nodes between different measurement points of the equipment needs to be synchronously transmitted. The typical algorithms include the Reference Broadcast Synchronization (RBS) [9] algorithm and the Timing-Sync Protocol for Sensor Networks (TPSN) [10] algorithm proposed by Ganeriwal et al. Although these algorithms better solve the time synchronization problem between different measuring points of the equipment, they also bring some problems, such as the energy consumption problem caused by the high computational complexity of the RBS algorithm. Similarly, the TPSN algorithm in the process of re-selecting the root node after the root node fails, the energy consumption is also increased. Research on more suitable algorithms will also play a role in promoting the industrial application of wireless monitoring.

V. CONCLUSION

In this paper, the wireless sensor network is used to realize the wireless monitoring of the running status of the pump group through the Lora wireless communication technology. At the same time, after comparing the analyzed information with the IoT technology, the running status of the current pump is transmitted to the user in real time. Thereby remote monitoring of the pump group is achieved. Although wireless monitoring technology has some problems, it still has great advantages compared with traditional wired monitoring. With the maturity and development of IoT technology, wireless monitoring technology based on the IoT will be more and more applied to the industrial field.

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