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Research on Underground Sewage Monitoring System Based on Intelligent Algorithm

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ABSTRACT

Using 4G network intelligence as the data transmission channel of field and monitoring centre, a sewage treatment monitoring system with simple structure, stable performance, fast transmission rate and high accuracy is established. In this paper, USR-G780 DTU is selected as the transceiver of network equipment. PLC was initialized through ladder diagram programming, and information such as water quality parameters in sewage treatment and online operation status of each equipment was transmitted to the monitoring centre, and remote connection between S7-1200 and the monitoring centre was completed. In addition, Modbus RTU communication protocol is used to complete the communication between the field PLC and the slave station, as well as TCP/IP to complete the data network transmission, and finally complete the design of the whole communication process. The experiment proves that the data based on 4G intelligence is more accurate, the transmission efficiency is greatly improved, and the feasibility, accuracy and security of the system design scheme are also verified.

INTRODUCTION

As a wireless data transmission link, 4G network transmits the detection data from each sewage treatment plant site in villages and towns to the monitoring centre for real-time monitoring and strengthening the supervision (Samkaria et al. 2018). The original sewage treatment control system is mainly used for the control of related pumps and valves in the drainage buffer pool, aeration pool, lifting pump room and clearing pool. In order to strengthen the monitoring of effluent quality, the environmental protection bureau increased the detection of COD value, BOD value, NH_3N, dissolved oxygen content and other related data of inlet and outlet water (Song et al. 2017). Due to the limited economic conditions of villages and towns, most of the sewage treatment plant sites are in remote locations, the terrain is complex and the manual field operation is difficult. The original wired mode is adopted to arrange the wiring of the new equipment, which extends the construction cycle and construction cost of the system to a certain extent.

Therefore, the research and design of remote monitoring system based on 4G intelligent technology not only solves the access problem of new equipment in sewage treatment stations, but also speeds up the efficient transmission of data.

The innovation of this paper is that the traditional sewage treatment monitoring system is optimized to wireless remote monitoring by integrating communication technology, computer technology and power electronic technology on the basis of not changing the traditional original monitoring equipment, which reduces the cost, simplifies the control strategy reasonably and makes the remote area sewage monitoring possible.

PAST STUDIES

A study developed the intelligent distribution network remote monitoring system on the basis of 4G network, which ensures the reliability of power supply and improves the automation level of distribution network system information (Cao et al. 2017). In order to avoid disputes arising from law enforcement in some key urban areas, Rong et al. (2017) proposed a remote on-board monitoring system under 4G network, which improved the efficiency and management of law enforcement. In order to better manage vehicle information, Li & Kai (2018) used the advantages of 4G network to put forward a wireless vehicle monitoring system to lock vehicle location information and realize the process of real-time information transmission to the remote server. Through scientific and technological progress, the monitoring system based on 4G intelligent technology has been constantly improved and has been applied in different fields.

Design of Remote Monitoring System for Sewage Treatment

Remote monitoring system structure of sewage treatment: The traditional sewage treatment monitoring system realizes the effective connection between the monitoring centre and the field control layer through laying cable, which is mainly

composed of test instruments, control equipment, PLC and industrial personal computer (Guo et al. 2018). Considering that most of the existing villages and towns are located in a relatively remote location and complex problems, the more remote monitoring is no longer applicable to the existing industrial environment. This paper designed a remote monitoring system for sewage treatment based on 4G network, which is mainly composed of field control layer, 4G wireless communication network and monitoring centre. It has the functions of environmental monitoring, real-time data transmission and remote control, and realizes the informatization, automation and intellectualization of the remote monitoring system for sewage treatment.

It can be seen from the structure diagram (Fig. 1) of optimized remote monitoring system for sewage treatment that the field control layer mainly consists of test instruments, electrical equipment, PLC station and DTU. Firstly, PLC is responsible for collecting analog quantity of field-testing instrument and switch quantity of valve and pump, and realizing control and parameter adjustment of related equipment by writing internal program of PLC.

4G network Hardware Design

Working principle of DTU: DTU is the Data Transfer Unit. Using the public network of mobile operators, it is a wireless terminal device specially used to convert serial data into IP data or IP data into serial data and provide users with wireless data transmission through wireless communication network (Qiang et al. 2017). DTU module does not need the support of other computers. It only uses the network's characteristics of "always online, fast access speed and data flow billing", and has incomparable advantages in cost performance. In the initial stage of DTU software development, the TCP/IP protocol stack will also be included. Users need to understand the principle of communication protocol before programming, which increases the complexity of module use. With the rapid development of electronic technology, software technology and mobile communication technology, after 2008, the DTU module is generally embedded with TCP/IP protocol. It mainly adopts hardware method to encapsulate the collected data through its internal embedded processor into the network protocol and then send it to the data centre through the network, lowering the technical threshold (Razak et al. 2017). It has the advantages of wide network coverage, rapid and flexible networking, short construction cycle, billing by flow, low user cost and good security and confidentiality. DTU is widely used in traffic, environmental protection, water, electricity, gas automatic meter reading and remote monitoring and other data acquisition, data transmission and other industries. The basic working principle of DTU is to login into the mobile operator's 4G network through the SIM card, obtain the dynamic IP address of the mobile intranet after initialization, and then encapsulate the signal collected on the spot through the internal integration of TCP/IP protocol of DTU, and finally transmit it to the monitoring centre through the 4G network, and vice versa (Biglari et al. 2018). Data terminals are typically PCS, sensors, or other embedded devices. Its data processing process mainly includes five stages: (1) when DTU is powered on, open the serial port to read out the working parameters saved in internal FLASH. (2) insert SIM card into the DTU module, log in the 4G network for PPP dialling, and the network centre assigns dynamic IP address to 4G DTU. (3) as the network environment of 4G DTU is internal network, it needs to reacquire and allocate dynamic IP address for connection every time it communicates with the data centre (Ghiasi & Mozafari 2018). In order to save the tedious configuration parameters each time, the monitoring centre can use fixed IP or dynamic IP address plus domain name resolution. Communication will continue as long as the two sides establish a connection. (4) 4G DTU is always in an active position when communicating with the data centre. When the data centre receives the TCP/UDP communication request sent by 4G DTU and gives a response, it indicates that the handshake is successful. Its essence is to establish socket connection between DTU and monitoring centre as socket client and server (Harada & Yanbe 2018). The request packet is then sent over the network to the internet under a uniform protocol. After receiving the request, the server software of the monitoring centre establishes a connection and sends a reply message. (5) after the communication connection is normal, DTU ACTS as the data packaging between the site and the monitoring centre, and encapsulates the data collected from the site in a TCP/UDP packet through the serial port and sends it to the monitoring centre (Borja 2018). Conversely, when DTU receives the monitoring centre data packet, it takes out the data content through the serial port and sends it to the executing device.

4G DTU model selection: The design scheme of the monitoring system requires that the communication module can communicate with Siemens S7-1200, and the sewage treatment site has been covered by the 4G network. In order to ensure the transmission stability of the 4G network, this paper plans to use the USR-G780 DTU as the 4G wireless data transmission terminal in combination with the project design requirements, resources, skills, costs and other factors. The hardware part is mainly composed of CPU control module, 4G wireless communication module and power module, as shown in the diagram of its internal hardware structure.

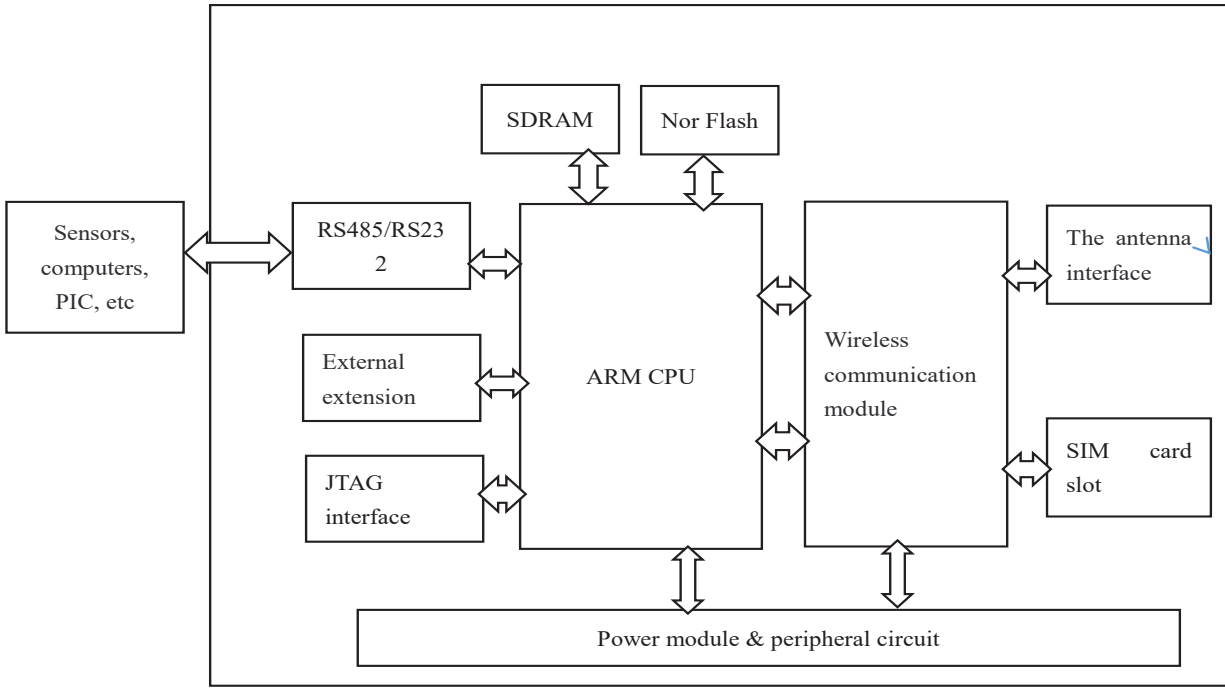

Fig. 1: Internal structure block diagram of USR-G780 DTU.

The USR-G780 industrial-grade 4G DTU is a wireless data remote terminal device designed to meet industrial-grade standards and the needs of industrial users. Based on embedded Linux system development, with a high degree of reliability, comprehensive support for the three major operators, flexible use of interface, support standard RS232/RS485/TLL, I/O interface. Stable performance, compact appearance, high cost performance, standardized interface design, support AT command, voice, SMS, data and other services, support serial communication, suitable for a variety of industrial occasions. Embedded standard TCP/IP protocol stack, 4 centres synchronous data transparent transmission, multi-level data display more intuitive, convenient data centre management, support TCP server function, support to access data centre according to the domain name and IP address. The USR-G780 DTU module includes the design of two-channel analog quantity and three-channel switching quantity, the function of pulse output, pulse count and analog quantity input can be customized, the design of ultra-low power consumption, communication state power consumption <1W, sleep state power consumption < 0.1W, widely used in base station monitoring, industrial automation control, environmental monitoring, water supply and other fields.

Communication Design of Remote Monitoring System for Sewage Treatment

Overall program design of wireless communication system: The programming of data wireless communication system is the process of data transmission after successful communication. Among them, data communication is very important in the system programming, which is divided into two parts: the communication between PLC and DTU and the communication between monitoring centre and DTU. In this way, the data exchange between monitoring centre and field control layer can be truly completed. PLC communication program is mainly used to read and write data of slave station equipment and to set parameters of equipment before operation in the initialization process. The communication between monitoring centre and PLC is established on the transmission module of DTU. The monitoring centre and DTU need to set up the IP address to build a good wireless network platform.

Modbus protocol standard: Modbus is an application-layer message transmission protocol. It does not define the physical layer itself, but only specifies the message structure that can be recognized and applied by the controller. Therefore, it does

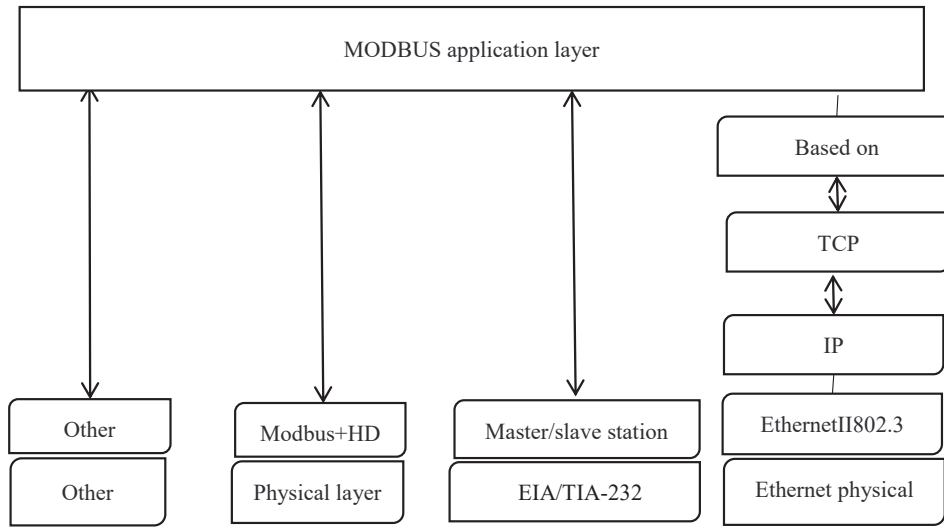

Fig. 2: Modbus communication protocol stack.

not need to consider what kind of network is used for communication. It mainly includes three message types: RTU, ASCII and TCP/IP. Digital and analog data are transmitted in the form of low byte (LSB) and high byte (MSB) respectively. Modbus protocol is a message with specified structure. In Modbus communication, the master station controller must know the address of slave station. The master station finds the slave station equipment through the address to make the corresponding request. When the slave station responds, the master station carries out error detection through a certain verification method, and identifies the message content sent by the slave station, so as to decide what kind of behaviour to produce. When receiving the request from the master station, the corresponding information content will be sent according to the message structure. If the master station is required to respond, it will generate feedback information.

Modbus serial link protocol adopts the master-slave protocol of question and answer mode, which mainly has two modes: (1) ASCII mode: every 8 Bit byte in the information needs 2 ASCII characters, whose advantage is to ensure that the character interval can reach 1s in the transmission process without any error. (2) RTU mode: every 8 Bit byte contains two 4 Bit hexadecimal characters, its advantage is at the same baud rate, can transmit more data, the premise is that each information to ensure uninterrupted data flow transmission. In this paper, Modbus RTU mode is adopted for rs-485 communication between PLC and DTU, so Modbus RTU format is mainly discussed. As can be seen from Fig. 2, the starting bit is the static time. When monitoring the connected devices on the network, the first received by the slave station is the address of the device and it is parsed to determine whether it is its own address. After the last character at the end of the main station is sent, there is a 4-character transmission time, and then the slave station answers back to the main station. If the slave response times out, the master continues to send the next new data.

RESULT ANALYSIS

System structure analysis: With the help of the network equipment 4G DTU, the data collected by PLC can be quickly, accurately and safely sent to the internet network through its internal wireless module. At this time, the monitoring centre will connect to the network through the router and receive the data from the site. The protocol between DTU and the monitoring centre is configured and the communication is set up. The monitoring centre analyses, processes and saves the data from the field through the 4G wireless link. Meanwhile, observe and monitor the normal and orderly operation of on-site sewage treatment through the on-site IPC station.

USR-G780 DTU serial debugging analysis: In order to realize the normal communication between the USR-G780 DTU module and other devices, this paper realizes the one-to-one data sending and receiving process by adding a virtual serial port. The USR-G780 DTU USES the pass-through mode, which means that users do not need to do any data parsing and access devices do not need to make changes to access the remote pass-through data. The transmission cloud management system of USR-G780 DTU is needed here. The transmission cloud is an open platform mainly for solving the communication between devices or upper computers. Two pass-through devices, USR-G780 DTU

and virtual serial port, are added to this system, and then the device is exported and added to the device group named "data transmission". Then set the ID and password of the two, the default communication password is 8 bits, or the system default. Select the system automatic generation mode here, and finally save. After completing the above operations of transparent cloud management system, it is necessary to open the "USR-G78x.exe" software again. After opening the serial port, the specific process is as follows: (1) Click "enter configuration state", (2) wait for the device to enter AT command configuration mode. (3) In "select working mode", select "network transmission mode" and set socket A parameters. (4) Enable the registry function. (5) Click "set and save all parameters". Then, a virtual serial port is added with "human virtual serial port software", and its network protocol, target IP and target port settings are: TCP Client, clouddata.usr.cn and 15000, and then, like USR-G780 DTU, the transparent cloud function is enabled. The device number and communication password shall be set according to the transparent cloud management system. After ensuring the connection accuracy of the two, the network status shall be shown as "connected". After setting up the two pass-through devices, it can be observed from the device list that the devices added by the pass-through cloud management system have successfully connected to the pass-through cloud and are online. The serial debugging assistant provided by the USR-G780 DTU module realizes the two-way data receiving and sending with the virtual serial port. When the received data is consistent with the sent data, it indicates that the USR-G780 DTU can normally communicate with other devices and send and receive data accurately. In this paper, the point-to-point transparent data transmission mode is used to realize the process of periodically sending data BB-CC-54-23-75-86-27 from the virtual serial port COM1 to the COM4 port of the USR-G780 DTU, and the corresponding data can be received at the COM4 port. Vice versa, data 01-45-66-ab-c7 are sent to virtual crosstalk COM1 periodically through the COM4 port of USR-G780 DTU, and the same data is received in another device. It shows that the actual received data is consistent with the sent data, which proves the correctness of data transmission.

Analysis of Modbus on TCP/IP protocol: Modbus TCP is the Modbus message transmission protocol running on TCP/IP, and the IP of the network layer and the TCP of the transmission layer jointly constitute the TCP/IP protocol [53,54]. It is by far the most widely used computer communication protocol, but also the most basic internet protocol, are called TCP/IP protocol family. In the industrial instrumentation and automation industry, the port number assigned to it by INNA (Internet Assigned Numbers Authority) is 502. This TCP/IP protocol allows communication between controllers over a network or other device. The model diagram of Modbus TCP/IP protocol is shown in Fig. 3.

Application layer contains all the high-level protocols, such as Hyper Text Transfer Protocol (HTTP), virtual terminal Protocol (Telnet), File Transfer Protocol (FTP) and simple mail Transfer Protocol (SMTP). Transport layer enables peer entities of the source and target nodes to talk, defines the Transport control protocol and the user datagram protocol, and provides end-to-end data channels for applications on both hosts. Internet layer, also known as the Internet Layer, the nodes can be divided into different groups and sent to any node in any other network, and the groups can be transmitted to the target independently (the transmission path may be different). Its packet format and protocol are defined by Internet Layer, namely IP protocol. After routing, Internet Layer also has the ability to interconnect different types of

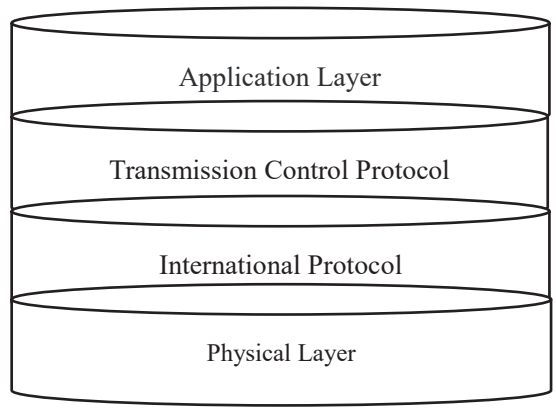

Fig. 3: Modbus TCP/IP protocol model.

networks and congestion control. Compared with Modbus serial link protocol, Modbus TCP/IP applies a special packet header called MBAP packet header to TCP/IP. Because of the existence of this header, Modbus format data is divided into multiple packets for transmission over TCP, and the receiver can also recognize the packet boundary. TCP/IP is used in 93% of the global network, which has become the DE facto standard in the data information industry. As long as Modbus TCP is implemented in the application layer, data exchange of industrial Ethernet can be achieved.

CONCLUSION

This paper, based on the remote monitoring system of 4G intelligent network, realizes the real-time monitoring of sewage treatment, avoids the problem of wired line laying, and studies the remote monitoring system with the combination of practical projects and related technologies, and introduces the importance of wireless communication technology in remote monitoring of sewage treatment. The system is stable, safe and reliable to complete the data transmission at the remote end, which greatly reduces the construction cost and has better system compatibility, and effectively overcomes various problems encountered in the late expansion. In the future, the technology will be more mature, and the detection of underground sewage will be more convenient, which will also be better for the detection and distribution of underground sewage.

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