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An Industrial Internet Cloud Gateway Design Based on Cloud Platform

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Abstract. *Aiming at improving the cloud gateway characteristics, e.g., low economic benefits, serious energy consumption caused by the complexity of the communication protocol of on-site production data, and insufficient mining of production data, this paper suggests an industrial cloud gateway design scheme with effective energy management. The functions include aggregation, analysis, storage, conversion, edge computing, uploading industrial data, and realizing unified integration of production data carried out by the gateway. As the multi-task parallel processing mechanism and edge computing function are proposed based on the integrated data and transmitted to the cloud server to ensure the high efficiency of processing data. The function of continuous breakpoint transmission is used to ensure the stability and reliability of data transmission. The suggested architecture gateway with the NB-IoT module is designed and implemented by a combination of software and hardware to conduct multiple encryption processing and cloud account authentications on data to ensure the safety and reliability of data transmission. The experimental results show that the suggested gateway can cope well with the complex field environment and achieve the above functions.*
Keywords: Multi protocol, Data gateway, Cloud platform, Data encryption, Data aggregation.

1. Introduction.

In recent years, with the rapid development of the Internet industry, the realization of the industrial Internet has gradually become the core of industrial enterprises [1]. It combines the traditional sector with the internet cloud platform, cloud computing, big data analysis, and other information technologies [2] and takes the cloud platform as the carrier to break the traditional industrial mode and form a new industrial manufacturing mode [3], namely the industrial Internet mode [4]. This new type of networked industrial manufacturing service mode is based on the appropriate underlying industrial equipment [5]. Through the cloud platform, it realizes the integration of the physical and virtual digital worlds, the informatization and intelligence of industrial data [6]. It effectively improves the balanced development of industrial production and social needs. The industrial Internet cloud gateway is the key to achieving industrial interconnection [7]. In

contrast, the traditional gateway connects with the field device through the interface, then collects the data to the gateway node [8], analyzes and processes the collected data using the protocol converter embedded in the gateway, and transmits the parsed data to the cloud platform through TCP / IP and other Internet of things protocols [9]. This kind of gateway has problems such as small data processing capacity, low processing efficiency, and single processing protocol, which greatly inconveniences the process of actual field use [10]. When the data protocol processed is changed due to the replacement of the equipment connected to the gateway, the gateway needs to be redeveloped, resulting in a serious waste of workforce and material resources [11]. Therefore, because of this situation, it is essential to design a gateway that supports multiple data protocols, improves the real-time reliability of data processing, and realizes the convenience of data storage and the ability of deep data mining using the cloud [12].

2. **Industrial Internet Gateway Based on the Cloud Platform.**

The purpose of the industrial Internet is based on the realization of large-scale mining of industrial data [13]. It refers to the realization of networked connection of people, machines, objects, systems, etc., and the construction of a brand-new manufacturing mode covering the whole industrial chain [14], which provides an implementation way for the development of industrial digitalization, networking and intelligence [15]. There are two situations between underlying industrial devices: physical heterogeneity and communication protocol heterogeneity, which lead to inconvenient communication between devices which makes it difficult for cloud platforms to integrate industrial data of different protocols quickly [16]. The industrial Internet cloud gateway is the central hub to realize the convergence and interaction of data between physical layer heterogeneous networks and heterogeneous protocol industrial devices and the deep mining of industrial data by remote cloud platforms, and it is the critical node to realize the transformation from traditional industry to information industry [17].

The industrial cloud Internet architecture based on cloud platform services collects and analyzes relevant data of industrial devices supporting different protocols through gateways to provide data sources for the application layer of the cloud platform; On the cloud side, the converged multi-protocol data is parsed and converted into unified standard protocol data (HTTP protocol) through the gateway, and the integrated protocol data is transmitted to the remote cloud server using NB-IoT, Ethernet and other communication technologies, to achieve comprehensive processing and analysis of the data on the cloud platform [14]. The industrial Internet gateway architecture based on cloud platforms is shown in Figure 1.

In the physical layer, the gateway reserves eight serial ports (485 interface and 232 interface), 1 USB interface, and two can interfaces; In the protocol conversion module of the functional layer, industrial devices containing different protocols are connected through the gateway, and different protocols are analyzed and converted into unified protocols and uploaded to the cloud to realize the analysis and conversion of heterogeneous protocols [18]. In order to ensure the real-time reliability of data transmission, the gateway has the function of local data caching, which temporarily stores the data of the underlying industrial equipment in the gateway after being parsed, providing data caching capability [19]. At the same time, the reliability of data transmission is ensured by using the functions of TCP communication and breakpoint continuation after uploading data fails [20]; In order to improve the security of data transmission, hardware encryption and software encryption are used to ensure the security of data transmission; In the uploaded layer, the communication module NB-IoT/Ethernet is used to upload the industrial data converted into HTTP protocol to the cloud platform [20].

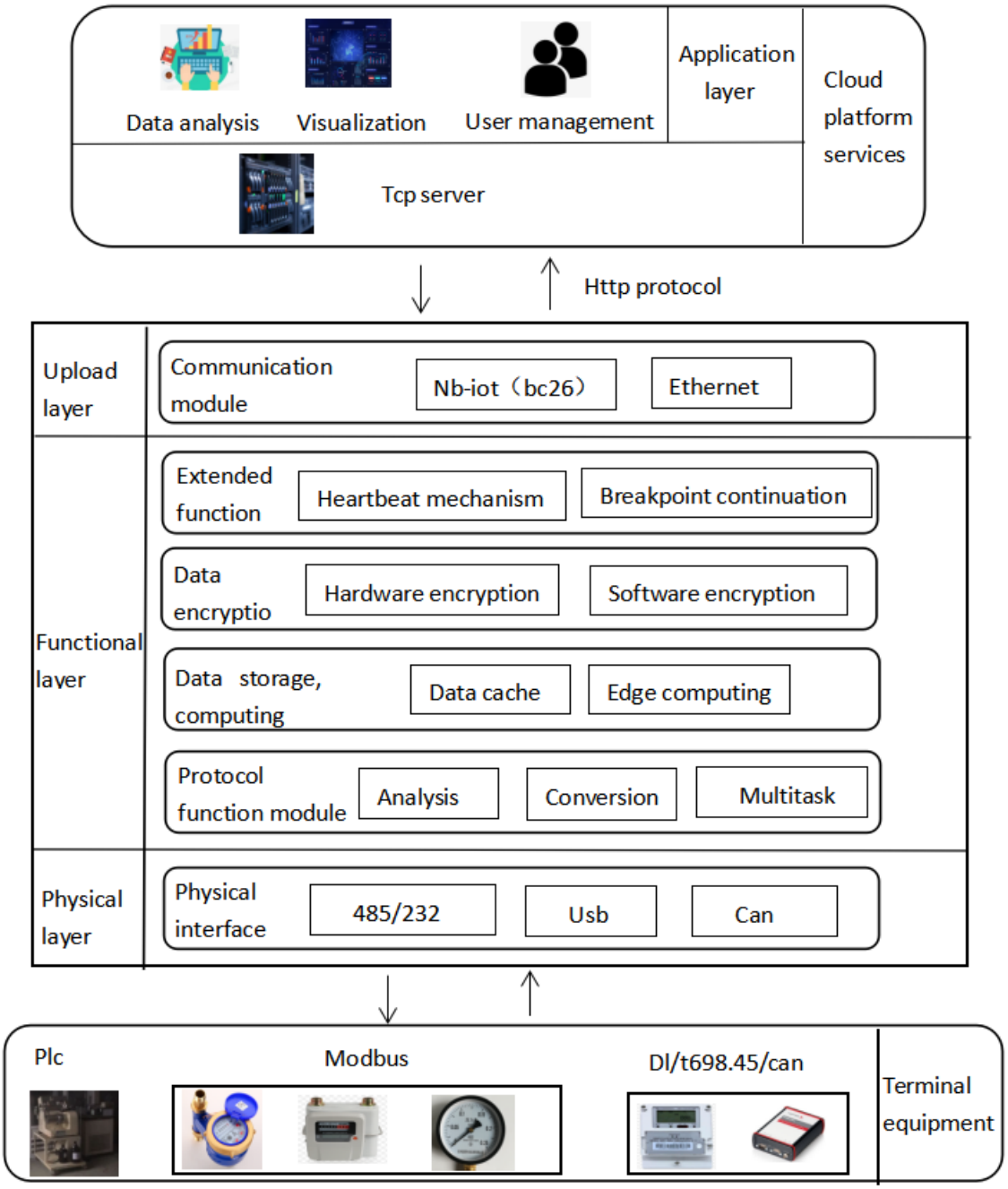

FIGURE 1. Industrial Internet gateway architecture based on cloud platform

3. Gateway Hardware Design.

The gateway takes the $stm32f429igt6$ chip as the core and other basic modules such as NB-IoT module to realize the hardware system design of the gateway [20, 4]. The chip integrates FPU and DSP instructions, with several equipment e.g., 256KB SRAM, 1024KB flash, 12: $16bit$ timers, 2: $32-bit$ timers, 2: full duplex I2S, 3 IICS, 8 serial ports, 2: USB (supporting host / slave), 2: can, 3: $12bit$ ADCs, 2: $12bit$ DACs, 1: RTC (with calendar function), 1: $SDIO$ interface, 1: FMC interface, 1: $TFTLCD$ controller (ltdc), 1: $10/100MB$ Ethernet MAC controller One hardware random number generator, and 140 general-purpose IO ports. The gateway is developed based on uCOS II operating system and provides 6-way RS485 communication interface, 2-way RS232 interface, 1-way can

interface and Ethernet interface. The gateway cooperates with NB-IoT communication module BC26, clock module, power supply module and other relevant basic modules to realize the overall function of the gateway [21]. As shown in Figure 2 are the physical pictures of STM32 chip and relevant pins.

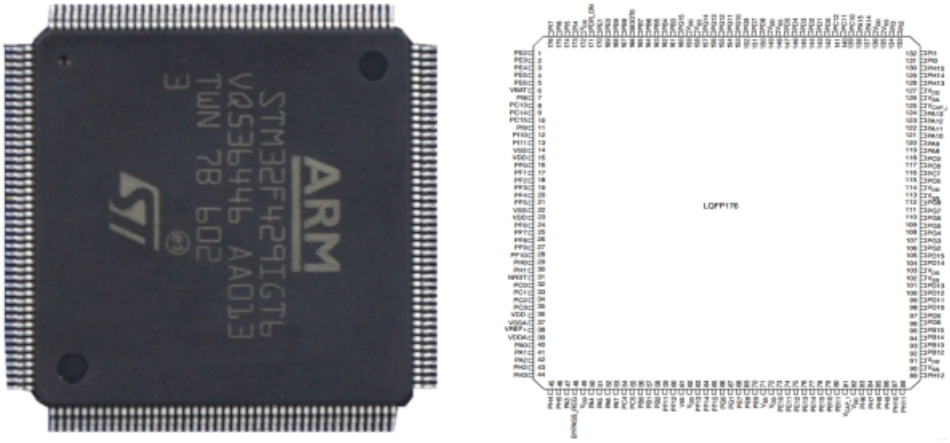

FIGURE 2. STM32 chip physical diagram and pin diagram

3.1. **Design of Power Supply Module.**

The power supply module includes a group of 3.3V power input and output pins (2 * 3) (Vout1) and a group of 5V power input and output pins (2 * 3) (vout2). Through these two groups of pins, 3.3v/5.5v power can be provided to the outside, or 3.3v/5.5v power can be connected to the module from the outside. As shown in Figure 3, the circuit pins and schematic diagram of the power supply module [22].

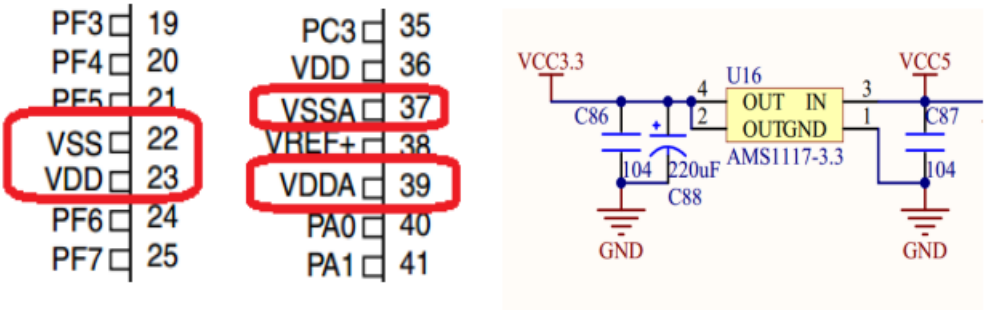

FIGURE 3. Pin diagram and schematic diagram of power supply module

3.2. **Clock Module Design.**

The clock module is the pulse of a single chip. When we use any peripheral, we must turn on the corresponding clock and turn off the unused peripheral clock in time. This can reduce the system's power consumption, save energy and achieve the effect of low power consumption [17] [22]. Every clock ticks, the system will process one step of data to achieve stable operation of the system. Figure 4 is a schematic diagram of the clock module.

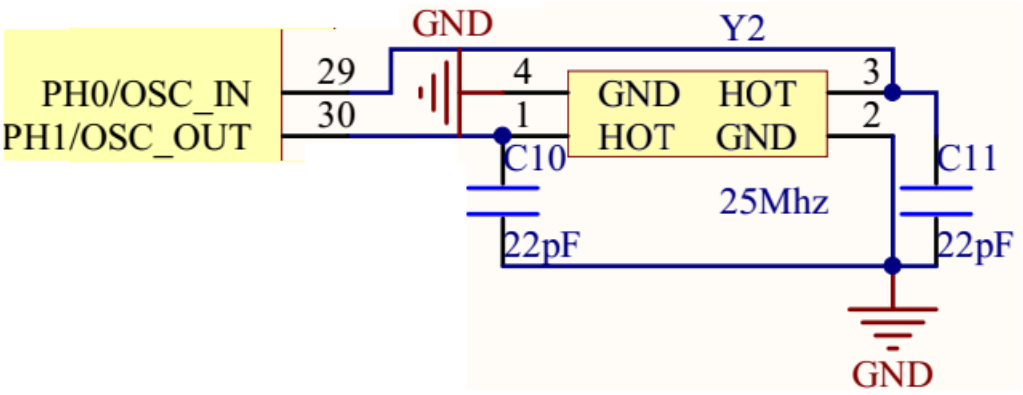

FIGURE 4. A schematic diagram of clock module

3.3. **Communication Module Design.**

The NB-IoT communication module adopted by the gateway is BC26. NB-IoT is widely used in various scenarios due to its advantages of low cost, low power consumption, wide coverage area and support of tens of thousands of connections. Based on this advantage, the gateway decides to use BC26 module to realize cloud processing of data [19]. As shown in Figure 5, NB-IoT module (BC26) is a physical diagram and pin diagram [22].

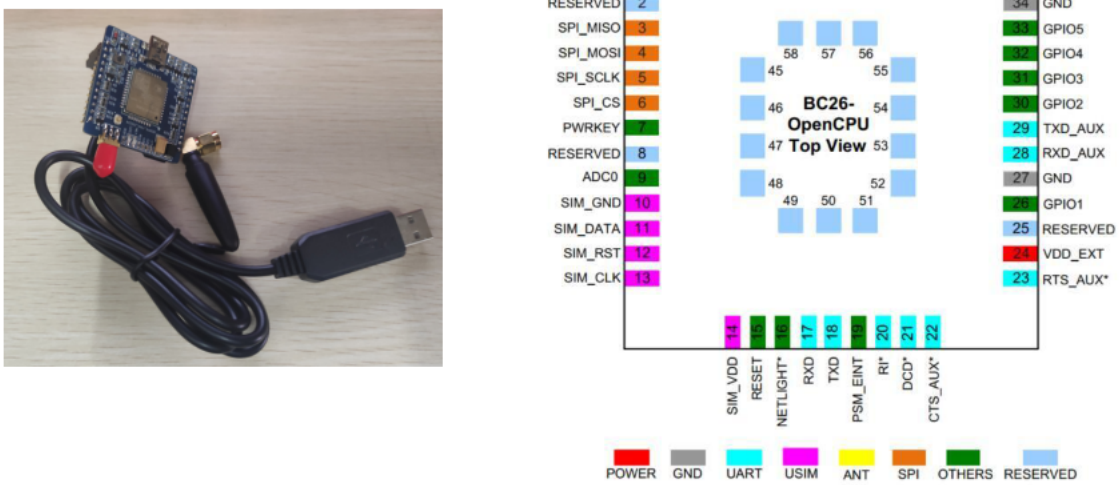

FIGURE 5. NB-IoT physical diagram and pin diagram

The gateway is connected to the underlying industrial equipment through RS485, RS232, can and other physical interfaces. The gateway realizes the analysis and conversion of industrial data gathered to the gateway through the multi-protocol conversion function of the gateway, and then uploads the data converted into a unified protocol to the remote server of the cloud platform through the function module.

4. **Gateway Software Design.**

In the software design of the industrial Internet cloud gateway, the embedded development of the gateway function module is realized through the embedded development program keil5. The main function of the gateway is to recognize the rapid analysis, conversion, encryption, upload of aggregated data, cache of uploaded data, and storage of historical data [23]. UCOS II is used as the operating system of the gateway to coordinate and coordinate the various functional modules of the gateway so as to ensure the rapid processing and response of the converged multi-protocol data and the safe and reliable operation of the gateway [24]. Figure 6 is a functional diagram of the gateway.

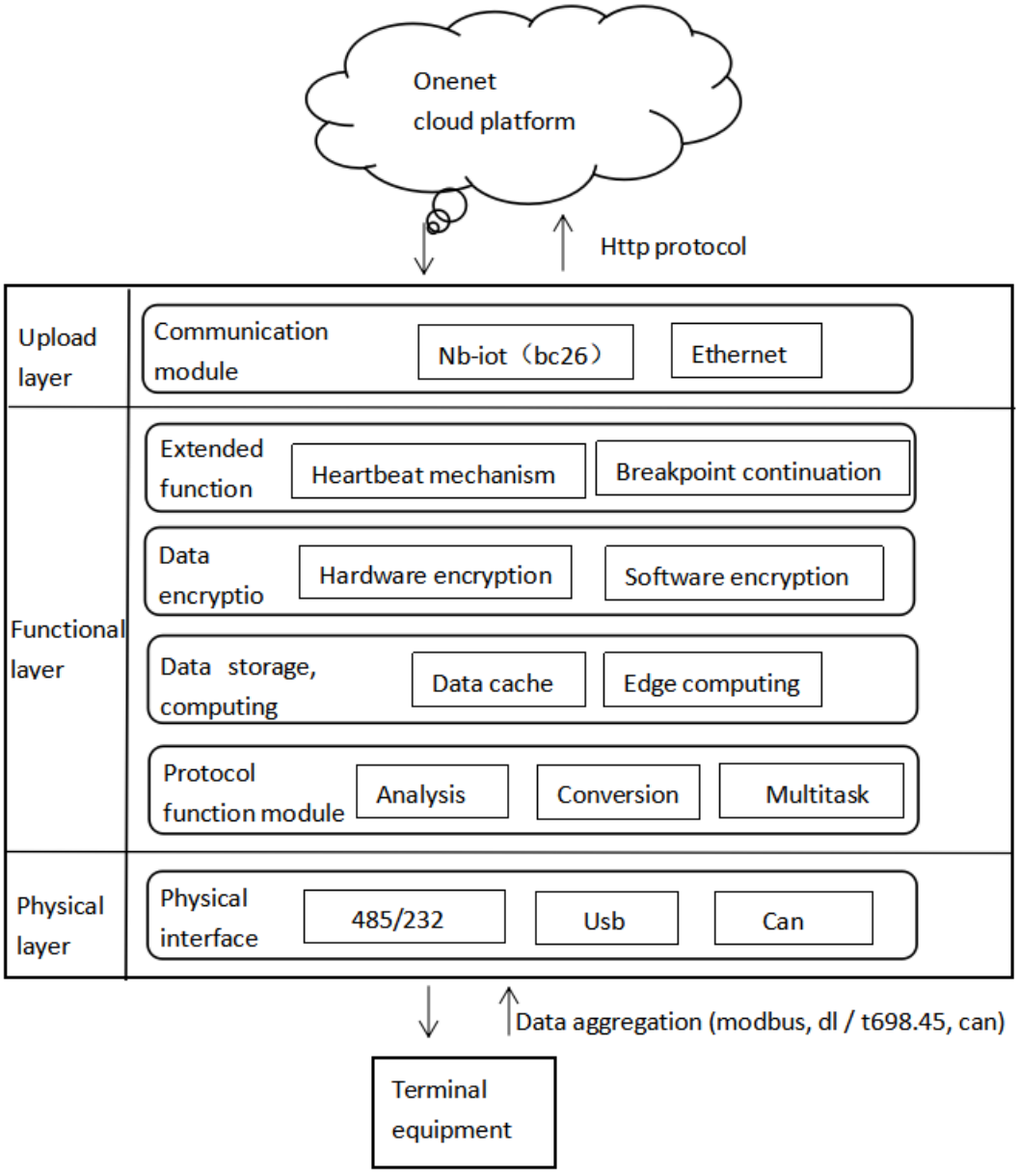

FIGURE 6. A structure layers of Gateway functions

In the gateway software system, it includes functions such as multi-protocol device data acquisition module, industrial protocol driver module, protocol data analysis, and conversion module, HTTP client, and other gateway parameter settings so as to realize the interaction between industrial data unified as HTTP protocol and cloud platform through the gateway [25].

4.1. **Protocol Conversion Function.**

Based on the heterogeneity of data protocols of industrial devices in the physical layer, the functional modules proposed to realize the conversion of various protocols are shown in Figure 7. This function module can realize the data analysis of heterogeneous devices, and convert the aggregated industrial data into the data format of HTTP protocol through the multi protocol conversion module and transmit it to the cloud server.

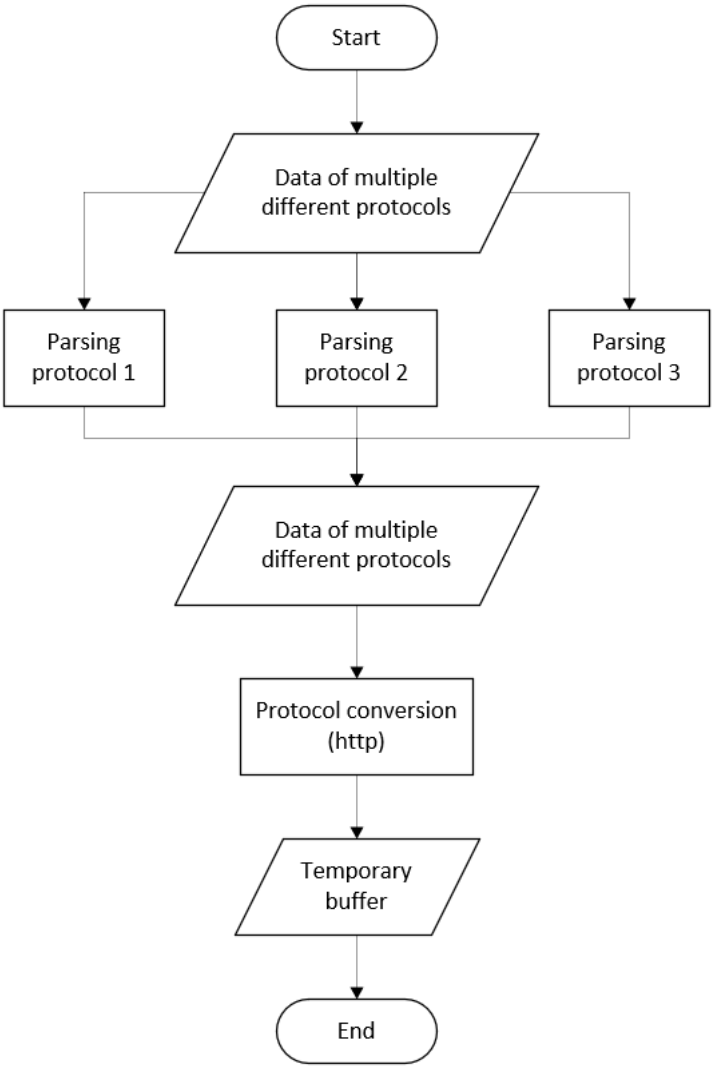

FIGURE 7. A flowchart of multi protocol conversion

The multi protocol conversion function module is connected to the industrial equipment through the physical data interface of the gateway downward, aggregates the data of different industrial equipment into the data cache, parses and converts the data of different protocols gathered in the cache into a unified protocol (HTTP protocol) by calling the protocol conversion module, and interacts with NB-IoT, Ethernet and other communication modules upward to transmit the converted data to the onenet cloud platform [25].

4.2. **Multi Task Processing Mechanism.**

The simultaneous analysis and conversion of multiple data protocols are realized for converged multiple industrial data. The data protocol conversion task is divided into individual sub tasks according to different protocol data. The time slice rotation scheduling

feature of the uCOS operating system is used to process multiple protocol conversion data in parallel. The parallel processing task mechanism is realized to ensure the real-time data processing performance. The operating principle of this mechanism is as follows: taking advantage of the time slice rotation system of uCOS system processing tasks, the gateway stores the industrial data of different protocols received by the physical interface in the memory cache area, uses the efficiency of its operation as the processing center of multi-protocol conversion tasks, splits the multi-protocol conversion tasks to be performed by the gateway into multiple protocol conversion tasks, and distributes them to multiple threads for parallel processing, After completing the protocol conversion task, store the processed data in the storage area of the flash chip and wait for the upload module to upload the data to the cloud. As shown in Figure 8.

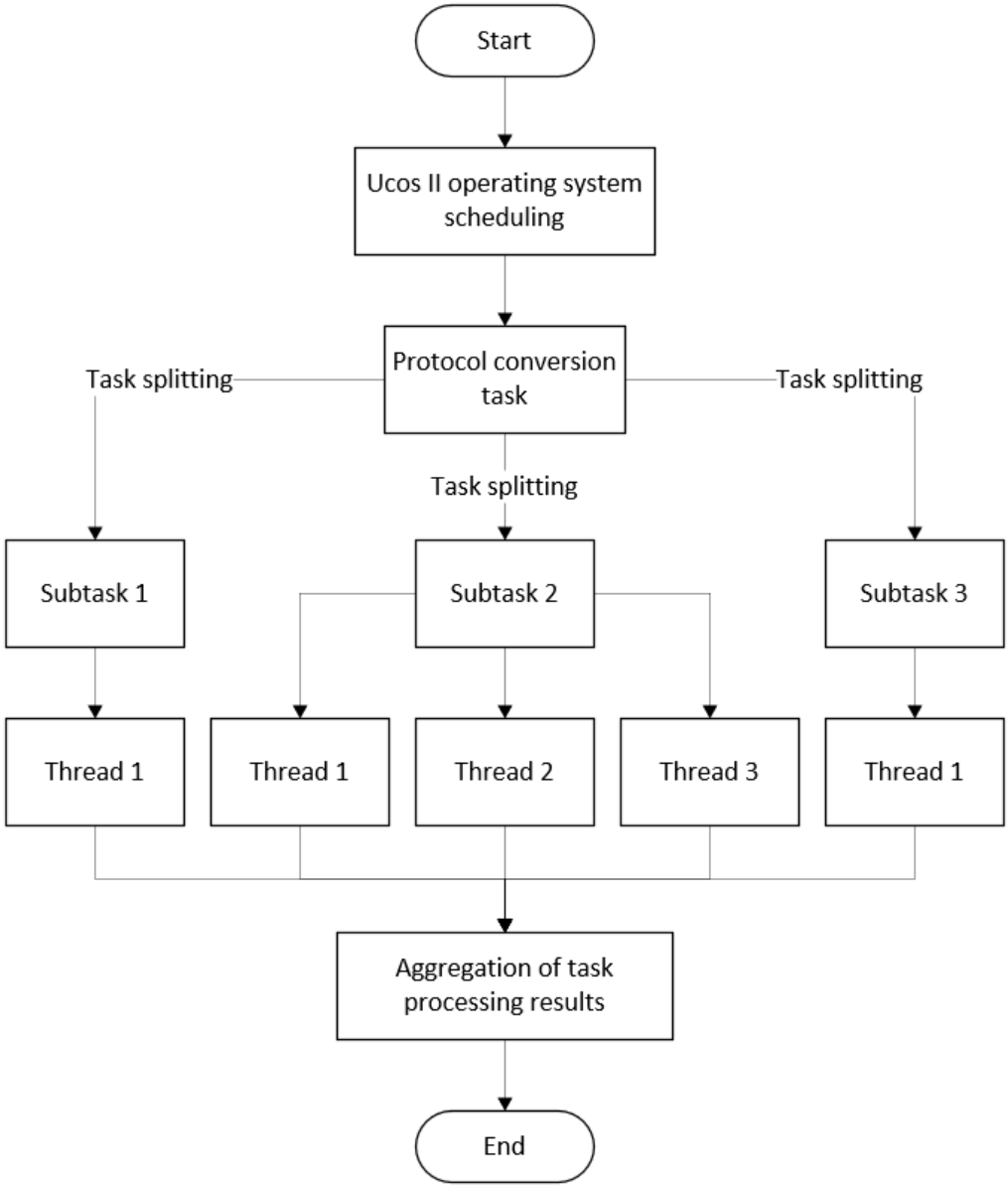

FIGURE 8. A flowchart of multi protocol conversion

4.3. **Edge Computing.**

For the gateway to collect the same type of data, if it only analyzes and uploads the data and operates on the cloud, it will bring a lot of inconveniences. In order to fully exploit the performance of the gateway, the simple addition and subtraction of the unified type of data is processed locally on the gateway and uploaded to the cloud after the data is processed, which can more effectively save the computing power of the cloud and the efficient and flexible processing of data. Code the data formula to be calculated in advance to generate the edge computing configuration file. After the gateway runs, read the configuration file into the program and wait for the call. After the gateway collects the data of the lower-level devices, it calculates the data according to the formula after protocol conversion according to the configuration file prepared in advance and stores the calculated data and other data that needs to be uploaded to the cloud in a unified manner, to facilitate the subsequent upload function module to call the data [26].

4.4. **Data Storage.**

The gateway parses and converts the gathered industrial data through the protocol conversion module and then stores the converted data in a unified format in the gateway's database. On the one hand, the gateway realizes the function of continuous transmission at breakpoints, on the other hand, it makes a historical backup of the gathered data, and on the other hand, it makes a secondary view in the future [28]. The data stored in the gateway can be locally exported to the computer through the Ethernet interface for a secondary backup.

4.5. **Data Encryption.**

In terms of hardware, the commercial encryption chip n32s032 is used to encrypt the uploaded data to ensure the security of data transmission. This chip adopts the SM4 symmetric algorithm, which is a grouping algorithm with a packet length of 128 bits and a key length of 128 bits. Both the encryption algorithm and the key expansion algorithm adopt a 32-round nonlinear iterative structure. The decryption algorithm has the same structure as the encryption algorithm, except that the round key is used in the reverse order, and the decryption round key is the reverse order of the encryption round key.

In terms of software, after the gateway establishes a communication connection with the cloud platform, users can log in to their own accounts through the cloud platform. The cloud platform server authenticates the gateway device through the product ID, user ID and master API key, so as to verify the authority of the industrial Internet cloud gateway; Algorithms encrypt the data transmitted by the gateway and cloud platform to avoid the leakage of relevant data caused by interception and cracking of data by a third party during transmission [27].

By using a commercial encryption chip as the hardware encryption method combined with cloud platform user authentication and account authentication in the application layer of data transmission, not only the stability and reliability of data transmission between the gateway and the cloud platform are ensured, but also the occupation of CPU resources is saved to a great extent, and the operation efficiency of the gateway is improved [30].

4.6. **Heartbeat Mechanism and Breakpoint Continuation.**

After the gateway is connected to the cloud, to ensure the network connection's stability and find problems in time, the gateway is designed to send heartbeat data packets to the cloud through a timer according to a certain time. The cloud receives JSON format data in the form of HTTP protocol . After verifying that the data is correct, the cloud returns OK. After receiving OK, the gateway confirms that the network connection between the gateway and the cloud is normal. The retransmission mechanism is triggered if the

gateway fails to receive the OK returned by the server in time. After three times, if the server still does not respond, it is judged that the network is disconnected, and the gateway initiates a request to reconnect with the server [31].

In order to ensure the stability and reliability of data upload, a communication exception detection mechanism is designed to realize the function of data breakpoint continuous transmission and ensure the reliability of data in the transmission process. The continuous transmission process of cloud network relationship system breakpoints is shown in Figure 9.

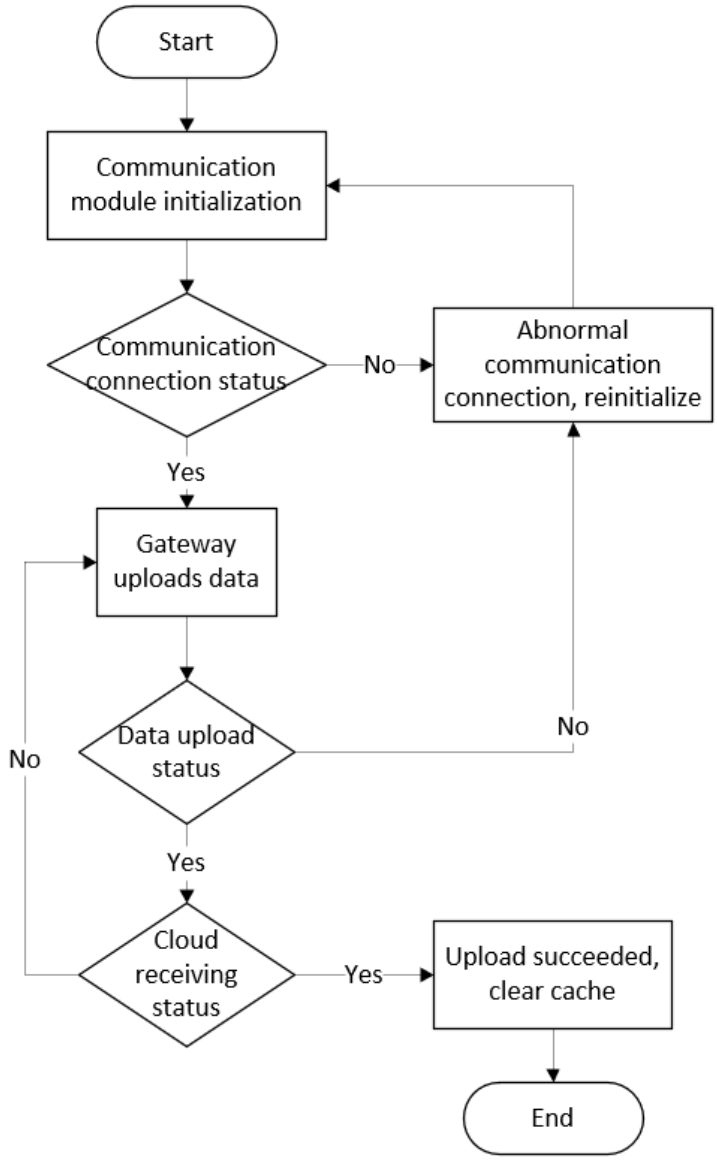

FIGURE 9. Function diagram of breakpoint continuous transmission

5. **Experimental Verification.**

Building an industrial scene simulation platform to test the performance of the gateway, according to the envisaged industrial Internet cloud gateway architecture and software and hardware design scheme, a gateway physical object is made to verify the effectiveness of the design scheme. As shown in Figure 10, the gateway and the simulated industrial scene replace the corresponding industrial equipment with industrial water and electricity

meters; The one net cloud platform is used as the application platform in the cloud, and the overall test environment is built through the gateway.

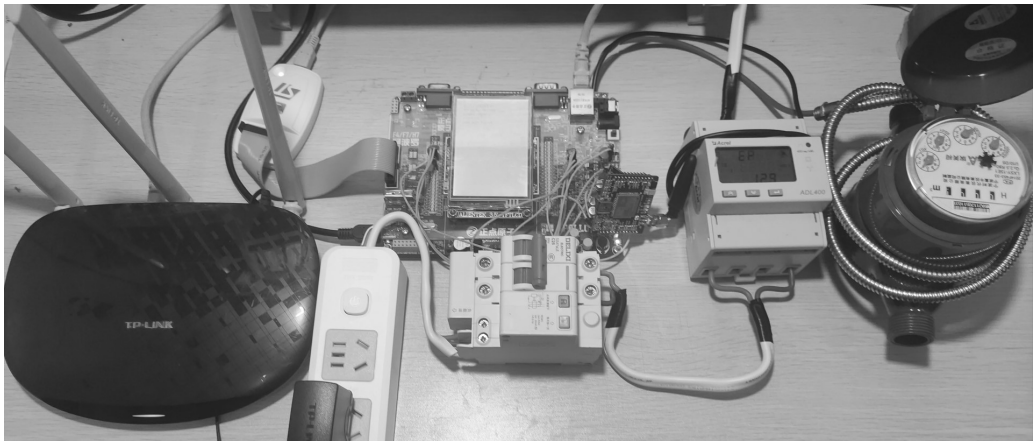

FIGURE 10. Simulation scenario building

5.1. **Cloud Platform Test Results.**

Industrial production data is generated by industrial equipment with different protocols, and is connected with the gateway through the interface to transmit the data to the inside of the gateway for the next step of data processing [28] [29]. In the simulated industrial production environment, we use the data of industrial water and electricity meters (Modbus protocol, DL/t698.45 protocol) to represent the data generated by different protocol devices and interactively process the data with the gateway. We take the onenet cloud platform as the experimental platform, connect the gateway to the cloud platform, and upload the data to the cloud, as shown in figures 11 for data visualization. In the future, we can use the powerful computing power of the cloud to achieve in-depth analysis and mining of data [21].

5.2. **Breakpoint Continuation Function and Historical Data (Local Storage).**

It connects with the underlying industrial equipment through the 485 interfaces, 232 interfaces and can interface of the gateway, converts the aggregated industrial data into a unified protocol data format after analysis, and realizes the breakpoint continuous transmission function and local storage function of data through the breakpoint continuous transmission function module and data storage module [19] [23]. As shown in Figure 12.

5.3. **Gateway Performance Test.**

Under the simulation experimental conditions, the overall performance of the gateway is tested to test the stability and correctness of data transmission after the gateway is connected to the cloud platform [19].

Every 30s, the gateway sends an HTTP protocol data packet to the cloud platform through the communication module. The data packet is the voltage data of the electric meter collected by the gateway in the experimental simulation environment [23]. It is tested continuously for 50 hours to check the data received by the cloud. See Table 1 and Table 2 for details.

6. **Conclusion.** This study presented a design and implementation of an industrial Internet cloud gateway for aggregation, storage, conversion, edge computing, and uploading industrial data. The NB-IoT module used in the gateway processes the integrated collection and processing data and transmits it to the cloud server. The designed and

FIGURE 11. Data visualization

2022/7/25 22:53:17{"zong_power":1.22,"voltage1":237.0,"current1":0.20,"power1":26.0,"power_factor1":0.994,"water1":1}
2022/7/25 22:53:22{"zong_power":1.22,"voltage1":237.0,"current1":0.16,"power1":25.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:53:27{"zong_power":1.22,"voltage1":236.9,"current1":0.16,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:53:32{"zong_power":1.22,"voltage1":236.9,"current1":0.16,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:53:37{"zong_power":1.22,"voltage1":236.9,"current1":0.14,"power1":27.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:53:42{"zong_power":1.22,"voltage1":236.6,"current1":0.15,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:53:47{"zong_power":1.22,"voltage1":236.7,"current1":0.15,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:53:52{"zong_power":1.22,"voltage1":236.7,"current1":0.15,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:53:58{"zong_power":1.22,"voltage1":236.8,"current1":0.18,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:54:03{"zong_power":1.22,"voltage1":236.8,"current1":0.16,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:54:08{"zong_power":1.22,"voltage1":236.8,"current1":0.16,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:54:13{"zong_power":1.22,"voltage1":236.8,"current1":0.17,"power1":26.0,"power_factor1":1.000,"water1":1}
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2022/7/25 22:54:33{"zong_power":1.22,"voltage1":236.8,"current1":0.15,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:54:38{"zong_power":1.22,"voltage1":237.0,"current1":0.15,"power1":26.0,"power_factor1":1.000,"water1":1}
2022/7/25 22:54:43{"zong_power":1.22,"voltage1":237.0,"current1":0.15,"power1":26.0,"power_factor1":0.997,"water1":1}
2022/7/25 22:54:48{"zong_power":1.22,"voltage1":237.0,"current1":0.16,"power1":26.0,"power_factor1":1.000,"water1":1}

FIGURE 12. A cited period paragraph of Data storage

TABLE 1. Packet loss rate and packet error rate test

Communication mode	Number of data sent	Number of data received	Packet loss times	Number of errors	Packet loss rate	Packet error rate
Nb-iot	6000	5887	113	11	1.883%	0.183%
Ethernet	6000	6000	0	7	0%	0.117%

implemented gateway is a combination of software and hardware to conduct multiple encryption processing and cloud account authentications on data to ensure the safety and reliability of data transmission. The function of continuous breakpoint transmission is used to ensure the stability and reliability of data transmission. The suggested gateway

TABLE 2. Data transfer quality

Communication mode	Send heartbeat	Number of data received	Packet loss times	Packet loss rate	Average delay time/ms
Nb-iot	2000	1976	24	1.2%	5874
Ethernet	2000	2000	0	0%	643

architecture design offers options for implementing an industrial Internet gateway from the viewpoints of industrial data collecting, analysis, storage, upload, and security, among other things. The testing results show that the suggested gateway essentially performs the tasks of industrial data aggregation, intelligent communities, and facilitating the subsequent deep mining of industrial data through the big data computing capacity of the cloud.

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