Research on "Six in One" Campus Security System Based on Multi- node Data Feedback

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Abstract. In terms of the current incompatibility of various campus monitoring networks and the difficulty of timely sharing as well as the unified storage and management of heterogeneous data in heterogeneous networks, a security monitoring system for multi- node heterogeneous data is designed in the paper, in which the data communication format, sensor encapsulation protocol, gateway design and implementation, database design and monitoring platform construction are studied, realizing the collection and forwarding of heterogeneous network data. Moreover, the data exchange format uses a lightweight format to facilitate the transmission and storage of data, and the sensor protocol is encapsulated to solve the heterogeneous problem caused by the difference in data conversion formulas and meanings between different sensor networks. Furthermore, simulation experiments have proved that the system can efficiently and reliably collect, store and process heterogeneous data in a heterogeneous network in real time, and the built monitoring platform can centrally display and manage campus monitoring information in real time.

1. Introduction
The multi- node heterogeneous data access scheme is one of the key issues discussed in the system, and the smooth access of heterogeneous data is the prerequisite for realizing the intercommunication among heterogeneous networks and the sharing of heterogeneous data [1]. Besides, relying on the existing three sensor networks of LoRa, NB-IoT, and ZigBee on the campus, the system is equipped with sensors such as temperature and humidity, PM2.5, and SO2 on its nodes. Additionally, combustible gas and toxic gas sensors are included as well. Through the monitoring of these data, security risks such as fires and toxic gas leakage can be prevented, which reduces the loss of life and property safety of teachers and students. In addition, it can be linked with campus cameras to quickly lock the alarm area according to the sensor alarm position for monitoring, reducing false alarms and finally realizing the "six in one" campus safety management [2-4].

The communication data format is mainly unified in the paper, and JSON format is applied to structure the data description so as to realize the encapsulation and data analysis of the three sensor network protocols. What is more, a gateway is established based on the Raspberry Pi to realize the collection and forwarding of various data, and the server obtains the data uploaded by the gateway through real-time monitoring of the network. Meanwhile, the data stream is parsed and stored in the MySQL database according to the encapsulated sensor protocol configuration file, which provides an interface for the upper layer to use [5].
2. Unified Communication Data Format

Due to the different network protocols of LoRa, NB-IoT and ZigBee, the hardware structures, drivers and operating systems of the collection equipment and gateways are also different, and these distributed heterogeneous characteristics make the collected data heterogeneous too, which is not conducive to data storage and interaction [6-8]. Therefore, it is necessary to define a unified communication data format, which is used to specify the form of data upload, while ensuring the integrity of the data. Moreover, since the transmission protocols of the three types of sensors are also different, it is required to define the protocols among different sensors, such as the definition of the bytes number of sensor data, the number of bytes, the offset and the conversion multiple, so that subsequent protocol encapsulation and data analysis can be facilitated[9].

The communication data format defined by the system is shown in Figure 1.

| Start | Network identification number | Node identification number | Data flow | End |
|-------|-------------------------------|---------------------------|-----------|-----|
| #S    | A*/D*/C*                      | a*/b*/···                 | #E        |

Figure.1 Communication Data Format

It is specifically defined by the program, including start and end characters, network identification number, collection unit identification number, data flow 4 parts. The start and end characters are used to judge the integrity of the data and directly determine whether the data can be parsed by the server, and the network identification number is applied to identify which network the uploaded data belongs to. Besides, the definition of the unit identification number is that as there are multiple collection nodes among each network, and the location of each node is different, it is necessary to define a specific unit identification number to determine the location of the node. Data stream is the data information collected by each network node, including sensor data such as temperature and humidity, wind speed, SO2 and PM2.5. [10].

In addition, since the conversion relationship among the data to be uploaded and the actual data is defined, the uploaded data itself is meaningless, which not only maintains the flexibility and autonomy of various heterogeneous networks, and decouples the upper-layer applications from the lower-layer monitoring terminals, but also gives full play to the server's scheduling function and strong processing capabilities, and optimizes resource allocation. What is more, the network identification number and unit identification number are defined by the administrator. The identification number of the ZigBee network is defined as 11 in the system proposed in the paper and the identification number of the acquisition unit as A. The identification number of the LoRa network is 12 and the identification number of the acquisition unit is set as B. Meanwhile, the identification number of the NB-IoT network is 13, and the identification number of the collection unit is C[11].

After the data format is defined, each sensor network can send sensor data to the gateway through its own transmission protocol. Among them, LoRa and ZigBee collection nodes collect data and communicate with the coordinator according to their respective transmission protocols, and LoRa coordinator is composed of SX1278 receiving module, STM32F407ZET6 control module and power supply module, which communicates with the gateway through the I2C interface of the control module. Besides, ZigBee coordinator is composed of CC2530 receiving module, STM32F103ZET6 control module and power supply module, which communicates with the gateway through the SPI interface of the control module.
3. Design and Implementation of Gateway
The gateway is responsible for data collection, forwarding and communication with the server. The
system proposed in the paper uses embedded devices as the core part of the gateway. Embedded gateways
are of the advantages of small size, high system tailoring, and abundant peripheral resources, which are
very suitable when being used as low-power gateways in sensor networks. In addition, through the
various peripheral interfaces provided by the Raspberry Pi, the gateway can conveniently communicate
with ZigBee, LoRa coordinator and access control terminals. Moreover, the gateway can communicate
with the NB-IoT cloud platform and server via Ethernet. Finally, after collecting all kinds of data through
the hardware interface and the Ethernet port, the data is uploaded to the server background with the help
of TCP protocol. The overall architecture of the gateway is shown in Figure 2.

Among them, the physical layer receives data information from the coordinator through SPI, I2C,
and USART interfaces, and the driver layer is composed of drivers for each interface, which provides a
medium for communication between data. Besides, the system layer is transplanted with the Linux
operating system, which is responsible for task scheduling and resource management. Meanwhile,
network layer supports DHCP, TCP and other protocols, and application layer writes protocol
conversion and data transmission programs to realize data encapsulation and analysis.

4. Data Analysis Based on JSON Format
The gateway collects data and forwards it to the server, and the server is responsible for parsing the data
uploaded by the gateway. With the help of Alibaba Cloud ECS virtual host, the system proposed in the
paper is equipped with a Linux system, and the TCP communication between the server and the gateway
is realized through the TCP protocol interface function of the JAVA language, so that the data collected
and forwarded by the gateway can be received. Moreover, the server monitors the network in real time.
When an interruption occurs, it takes out the data stream and compares the start and end characters
according to the defined data format. After the start and end characters are successfully identified, it
reads the JSON (Java Script Object Notation) configuration file, compares the protocol identifiers, and
judges the network Type and run their respective threads. Additionally, in the thread, with the help of
JSON interface provided by the system, the search is performed byte by byte according to the predefined
data stream format, and the corresponding sensor conversion formula is found according to the network
identification number and unit identification number. Then the true value of the sensor data is obtained through being calculated and converted by the corresponding formula. After the analysis is finished, the database interface is called, and the corresponding value is stored in the MySQL database. Meanwhile, the calling interface is provided for upper-level applications.

In order to facilitate the display of data, the server needs to preprocess the sensor data in the database. Moreover, the server performs averaging processing on the data collected by each sensor every day according to formula 1, and a set of sensor average data are obtained. The average formula is shown in formula 1:

$$\lambda = \sum_{i=1}^{n} \frac{\lambda_i}{n}, \quad (i = 1, 2, \cdots, n)$$

In formula 1, $\lambda_i$ refers to the data of a certain sensor after taking the average value, $\lambda_i$ represents the data of a certain sensor collected by three different collection nodes every day, and $n$ is the number of times collected by each sensor every day.

5. Simulation Test

In the normal network test, the PING command is first used to test the connectivity between the campus network terminal nodes C1 and C2. Then, taking the terminal node C1 as an example, the trace command is adopted to test the access target address 211.68.192.11 /24 and 202.99.96.68 /24 routing process. Finally, the `sh ip route` command is applied to view the routing tables of router R3 and router R4.

After the communication test of the gateway is completed, the three heterogeneous networks of ZigBee, LoRa, and NB-IoT can upload sensor data according to the defined communication data format. Part of the collected data flow collected by the gateway is shown in Table 1:

| Type of data | Byte0 | Byte1 | Byte2 | Byte3~4 | Byte5~6 | Byte7~8 | Byte9~10 |
|--------------|-------|-------|-------|---------|---------|---------|---------|
| Temperature and humidity/NO2 | 11    | A0    | 01    | Air temperature | Air humidity | NO2 | Checksum |
| PM2.5/wind speed | 11    | A1    | Wind speed | PM2.5 | Checksum | -- | -- |
| CO/O3/SO2 | 11    | A2    | 02    | CO concentration | O3 concentration | SO2 concentration | Checksum |

The following conclusions can be obtained after testing:

1. Normal communication can still be realized between multi-node data and the terminal computer to which the network segment belongs.
2. The working status of the campus network core router group has not changed.
3. Campus network users can still access Internet resources normally.

When multi-node data accesses Internet resources, the data stream will be first sent to the active router of the network segment, and then reach the destination address via the border router.

6. Conclusion

An access scheme for heterogeneous data is proposed in the paper, which unifies the communication data format and develops an intelligent gateway to realize the collection and forwarding of heterogeneous network data. Moreover, based on JSON files, the encapsulation of sensor data identification, conversion formula and meaning is realized, which shields the differences between various sensor protocols. Meanwhile, the database is designed according to the actual needs of the system, and the storage of heterogeneous data is completed. Finally, the actual display of the monitoring platform proves that the system proposed in the paper can stably and effectively realize the display and management of campus heterogeneous data monitoring information.
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