IoT Gateway with Edge Computing Function

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Abstract. With the development of cloud computing, distributed IoT systems are also constantly evolving. Due to the different requirements for data collection in different scenarios, the functions of edge IoT systems are also different. Some of the Internet of Things(IoT) data collection load is heavy, but the amount of data that needs to be uploaded is not large. Some IoT needs to prioritize the collected data or filter some private data. For this reason, the gateway built between the IoT and the Internet should have certain functions of calculation and data concentration. This article uses RK3399 as a platform to transplant an embedded operating system, and uses a custom data frame to convert data from sensor network coordinators into a unified format such as Zigbee, WIFI, Lora, etc. According to different attributes such as type, source, authority, priority, the data is classified, stored, filtered, and calculated. Finally, the saved data is forwarded to the network in the form of a file by the TCP/IP protocol to realize remote data monitoring. Performing certain calculations and classification processing in advance through the gateway reduces the load of the access network and the pressure of data processing for the data aggregation center. In addition, the local data storage function of the gateway not only reduces the risk of data loss, but also provides the possibility for repeated queries. At the same time, the gateway also reserves a corresponding server thread for the access control of the local area network.

Keywords: Internet of Things(IoT), data processing, edge Smart Gateways, Edge calculation

1. INTRODUCTION

Under the premise of continuous enhancement of computer performance, continuous increase of Internet of Things devices, continuous optimization of Internet distributed technology, and continuous development of artificial intelligence and big data. The concept of smart city has changed from theory to an important direction of current global urban development [1]. The deployment of smart cities is currently based on a continuously topological star structure with cloud computing and storage centers as the core ,the model is shown in "**Fig. 1** " [2].

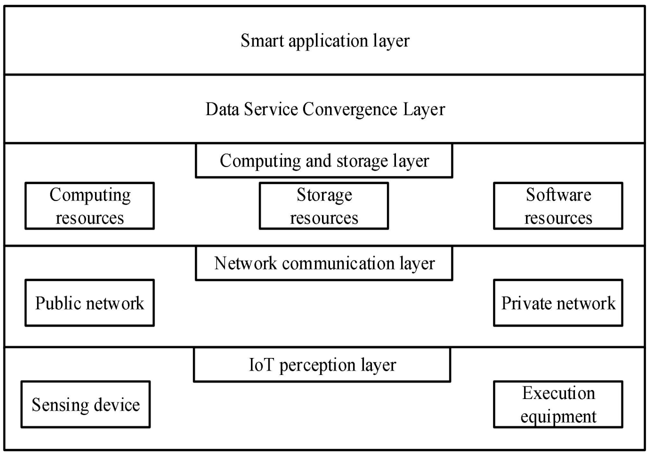


Fig. 1 Smart city technology model

A smart city can be roughly divided into five layers: smart application layer, data and service integration layer, computing and storage layer, network communication layer, and IoT perception layer. As the bottom layer of the smart city structure, the IoT perception layer should have the ability to perceive the environment intelligently [3]. It can collect, identify, detect and control information in the direction of urban infrastructure, environment, and security through perception devices and sensor networks.

Due to different application scenarios, the functions of edge IoT network systems are also different. Some edge IoT subnets have a large amount of data collection, but only some key data needs to be uploaded, and some networks need to filter some private information. In addition, with the development of Internet of Things technology, the number of Internet of Things devices is also expanding. According to Gartner's estimates, the total number of IoT devices will reach 25.2 billion by 2025. The increase of edge devices and data streams of the Internet of Things has put a lot of pressure on cloud computing centers and urban data networks [4].

Combining fog computing [5] with edge gateways is a key means to solve these problems. The edge computing gateway serves as a key device connecting the perception layer and the network communication layer. By using distributed local storage, providing edge data processing interfaces, and timely monitoring and responding to edge network information, the efficiency of data processing is improved, the load of the transmission network is reduced, and the burden of computing and storage of cloud servers is decreased [6]. At the same time, it also improves the real-time performance and reliability of data processing on the edge [7].

In recent years, many scholars have devoted themselves to studying the framework of the edge-side gateway system of the Internet of Things and the design scheme of the edge-side gateway. Gawali [8] proposed an intelligent irrigation system based on the Internet of Things. In this system, sensor nodes collect the temperature and liquid level of the water tank, and forward the data to the cloud via the gateway through the Zigbee protocol. The cloud platform runs data processing and sends control commands. Ke Han designed a temperature alarm system based on Modbus communication protocol, and forwarded data through MQTT [9]. T. Nguyen Gia [10] and others stored the sensor data collected by Lora as image data with loss of accuracy, and then forwarded the edge data transmission scheme through the network. Cristian puts forward an edge computing architecture that covers a single IoT device, edge intelligent gateway and cloud infrastructure based on λ-CoAP[11]. However, the above design schemes are all applied to a single communication protocol or data format, and the gateway is only used as a data forwarding center without the ability to work offline and store locally.

A smart IoT gateway design with edge computing capabilities was proposed in this paper. As a device between the data acquisition system and the network communication layer applied to the edge of the Internet of Things, the gateway has the following characteristics:

(1) Converge data which is collected by multiple wireless transmission protocol coordinators.

(2) Data in different formats can be stored locally, processed by calculation, and forwarded remotely.

(3) The gateway software has better platform compatibility and portability.

2. ARCHITECTURAL LAYOUT

The overall structure of the edge computing gateway system includes the following five parts: data acquisition and access unit, data fusion and processing unit, data storage and management unit, gateway internal data computing unit, and edge assist computing unit,the Gateway structure is shown in "**Fig. 2**".

The specific functions of each part of the gateway are as follows:

(1) Data collection access unit:

Deploying sensors to collect data such as air pressure, temperature, and images. Uploading the data to the corresponding receiving module of the gateway by Zigbee, Bluetooth and other protocols.

(2) Data fusion and transmission unit

The gateway reads the data of the receiving module from the buffer through a unified data interface, unifies the format, and then classifies the data according to the type of data and sends it to different functional modules for processing. At the same time, this unit will also help the gateway to establish a stable transmission channel on the network.

(3) Data storage and management unit:

The collected data and calculated and processed data are stored in different formats according to actual types and requirements, and visually displayed.

(4) The internal data calculation unit of the gateway

Located inside the gateway, it uses the gateway's own computing resources to filter some simple, relatively stable, and less important data, or simply fill in missing values.

(5) Edge assist computing unit

Located outside the gateway, it can communicate with the gateway stably on the edge side, and is mainly used to implement relatively complex data processing functions.

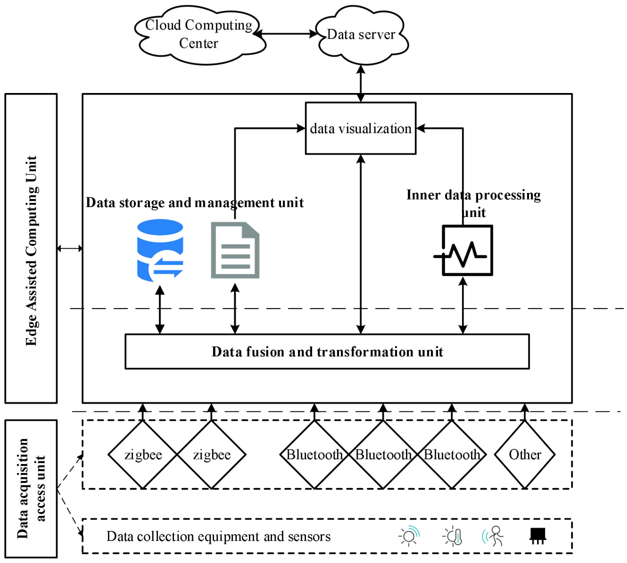


Fig. 2 Gateway structure diagram.

3. DESIGN AND IMPLEMENTATION OF THE GATEWAY

The edge gateway is based on a chip used in the Big.Little architecture, so that the gateway can seamlessly switch the corresponding processor according to the workload, taking into account high performance and low energy consumption. The sensor and the gateway adopt Zigbee, Bluetooth and other wireless protocol communication methods to realize the data collection function in a certain area. The Android system is transplanted on the gateway, and the universal interface driver is developed through JNI to be compatible with different wireless protocol modules, which provides a solution for the migration of gateway software on different hardware platforms. The three units that undertake the main functions of the gateway are

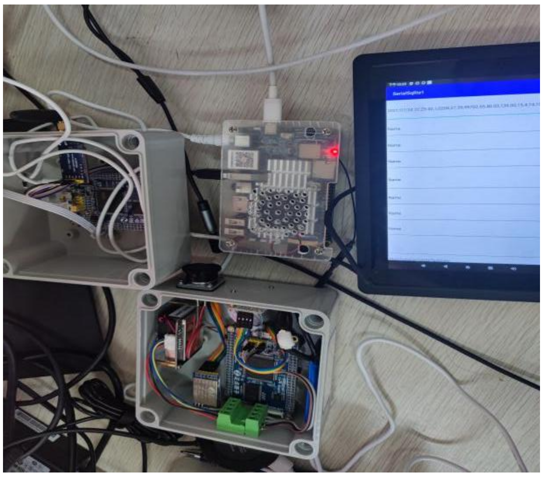


Fig. 3 Hardware connection diagram

mainly introduced .The remaining two units can be implemented relatively simple, this paper will not explain in detail. The hardware connection diagram of the gateway is shown in "**Fig. 3**"

3.1. DATA STORAGE AND MANAGERMENT UNIT

The management part is used to receive the data collected by the perception layer, group the data according to sensitivity and importance, and transmit the insensitive data to the visual interface for real-time display. The storage part stores the image data and text data in bmp and CVS format files respectively. Hand over the corresponding files to different components for corresponding data processing. The processed CVS files are stored in the gateway's local database. The database uses the Room framework to dynamically generate the database, which saves the gateway storage space.

3.2. Computing unit inside the gateway

In the process of high-concurrency data collection, the gateway can use local limited resources to process light-weight data.

When the edge gateway needs to collect data on the edge side during data collection, a small amount of data will be lost due to unstable sensor connections and exhaustion of node energy. At the same time, edge collection nodes usually use data transparent transmission, so important data needs to be encrypted when the gateway interacts with the cloud.

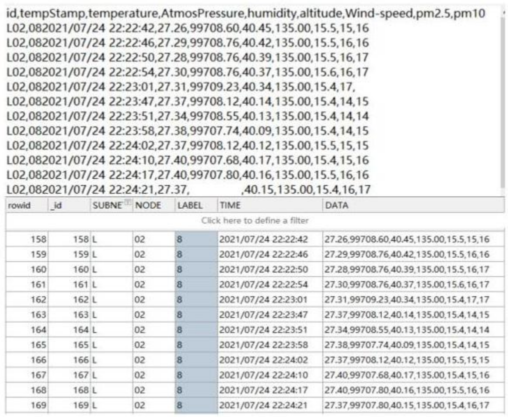
(1) Check whether the internal data of the CVS file is missing.

There are currently three common data missing mechanisms: completely random missing, random missing, non-random and non-ignorable missing.

If there is missing and the data is relatively stable data, such as ambient air pressure, ambient temperature and humidity, etc. Based on the limited computing power of the gateway, a relatively simple mean compensation method can be selected to fill the data.

In order to ensure the reliability of the imputed data, 20 adjacent data including missing items are selected to form a sliding window, and then the mean value is interpolated. After filling, the data is stored in the gateway's local database. "**Fig.4**" shows the CVS file of the original data storage received by the gateway and the database file generated after data processing.. If there is large-scale data, the gateway will send commands to control the sensors to recollect the data or send the files to the edge computing center to process the data using KNN or Bayes [12].

(2) Encryption of data based on sensitivity. Sensitive data files use relatively fast AES symmetric encryption, and asymmetric encryption can be used to transfer the secret key during the network transmission of files. The specific encryption process is shown in "**Fig. 5**".



id,tempStamp,temperature,AtmosPressure,humidity,altitude,Wind-speed,pm2.5,pm10
L02,082021/07/24 22:22:42,27.26,99708.60,40.45,135.00,15.5,15,16
L02,082021/07/24 22:22:46,27.29,99708.76,40.42,135.00,15.5,16,16
L02,082021/07/24 22:22:50,27.28,99708.76,40.39,135.00,15.5,16,17
L02,082021/07/24 22:22:54,27.30,99708.76,40.37,135.00,15.6,16,17
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L02,082021/07/24 22:23:51,27.34,99708.55,40.13,135.00,15.4,14,14
L02,082021/07/24 22:23:58,27.38,99707.74,40.09,135.00,15.4,14,15
L02,082021/07/24 22:24:02,27.37,99708.12,40.12,135.00,15.5,15,15
L02,082021/07/24 22:24:10,27.40,99707.68,40.17,135.00,15.4,15,16
L02,082021/07/24 22:24:17,27.40,99707.80,40.16,135.00,15.5,16,16
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158	158	L	02	8	2021/07/24 22:22:42	27.26,99708.60,40.45,135.00,15.5,15,16
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160	160	L	02	8	2021/07/24 22:22:50	27.28,99708.76,40.39,135.00,15.5,16,17
161	161	L	02	8	2021/07/24 22:22:54	27.30,99708.76,40.37,135.00,15.6,16,17
162	162	L	02	8	2021/07/24 22:23:01	27.31,99709.23,40.34,135.00,15.4,17,17
163	163	L	02	8	2021/07/24 22:23:47	27.37,99708.12,40.14,135.00,15.4,14,15
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165	165	L	02	8	2021/07/24 22:23:58	27.38,99707.74,40.09,135.00,15.4,14,15
166	166	L	02	8	2021/07/24 22:24:02	27.37,99708.12,40.12,135.00,15.5,15,15
167	167	L	02	8	2021/07/24 22:24:10	27.40,99707.68,40.17,135.00,15.4,15,16
168	168	L	02	8	2021/07/24 22:24:17	27.40,99707.80,40.16,135.00,15.5,16,16
169	169	L	02	8	2021/07/24 22:24:21	27.37,99707.80,40.15,135.00,15.4,16,17

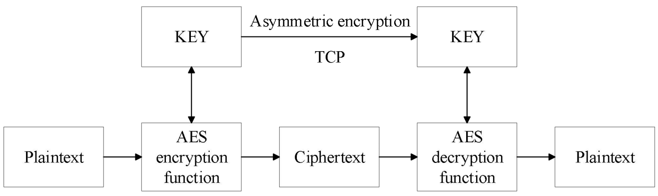

Fig. 5 Encrypted transmission flow chart

3.3. Edge assisted computing unit

In addition to sensor data, video and audio data are often encountered on the edge side. When the gateway performs high-concurrency data collection, the resources are not enough to support complex audio and video processing.

The edge-side assisting computing unit and the gateway can access each other in the same network segment, and assist the gateway to process large-volume data such as video and images.

At present, the JPEG algorithm can be used to compress pictures according to different precisions. On the premise of not losing important features of the image, the size of the image is reduced as much as possible, and the network load and the computing burden of the cloud computing platform are reduced. "**Fig. 6**" shows the size of the original image and the compressed and converted image according to different image quality.

The edge-side assisting computing unit can also perform independent feature extraction. For the character information that is easy to obtain directly, such as license plate and number of people, the picture can be locally based on KNN, template matching OCR and other algorithms to send the extracted character string back to the gateway. The gateway then uploads the data, which greatly reduces the repetitive work of the cloud computing center.

In "Fig.7", the edge assistance computing unit receives the picture sent by the gateway. According to the pre-processing work such as grayscale and normalization. Subsequently, the gradient processing is performed to generate HOG (Histogram of Oriented Gradient), which is combined with the SVM classifier to compare the characteristics of the personnel, and the information of the detected number of people is transmitted back to the gateway.

Fig. 6 Image compression comparison chart

Fig. 7 Number of personnel detection

4. CONCLUSION

Based on the problems of excessive load of cloud service centers and limited access equipment in the existing structure of smart cities, this paper proposes an edge IoT system design framework with edge computing gateway as the core. Based on the system, an edge computing gateway is designed to realize real-time monitoring of sensor data, encryption of sensitive data, interpolation of a small amount of missing values, and local data storage. At the same time, it realizes the functions of data compression and LAN interconnection in combination with the edge meter center. The software-based driver development has also been adopted to solve the problem of compatibility of heterogeneous platforms. In future work, we will add simple image processing inside the gateway, and data compression analysis algorithms will further improve the utilization of the gateway's computing power. At the same time, the design of gateway software is optimized to improve energy utilization efficiency.

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