A Data Fusion System for Multi-Protocol Internet of Things

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Abstract. Due to the heterogeneity of various communication protocols in the Internet of Things (IoT) system, there is no unified communication interface standard for IoT devices. Multi-protocol IoT data fusion system was designed in this paper, which can be applied to the environmental detection of smart community. This system is based on the idea of layered design model. Firstly, various sensors are used in the sensing layer to collect environmental information in the community. Then, four wireless communication protocols, WiFi, ZigBee, LoRa and Bluetooth, are used in the wireless transmission layer to transmit the data in the sensing layer to the next layer. Secondly, protocol adaptation layer is added between wireless transport layer and application layer. In the protocol adaptation layer, a unified communication frame format is formulated. Finally, in the application layer, we developed the upper computer software through QT, and the gateway completes the data interaction with the application layer through TCP/IP protocol. The test results show that the system can support the data acquisition of multiple types of sensors and transmit the data through the above four wireless communication technologies. This system can complete the unified conversion of data format in the protocol adaptation layer and also has a strong data transmission stability, in line with the application requirements.

Keywords: Wireless Communication, Internet of Things, Data Fusion, Multi-Protocol

1. INTRODUCTION

With the rapid development of the Internet of Things [1], "smart factory [2]", "smart community [3]" and other new applications began to enter our production and life, in addition to the continuous progress of sensor technology, the demands also accelerated the construction of the Internet of things system. However, there are many protocols applied in the Internet of Things, and it does not have the unified standard for the communication interface.Nowadays,the various productions do not have good compatibility, which brings great limitations to the applliccation. Therefore, the key to solve this problem is to develop an IOT data fusion system that can support multiple communication protocols [4].

At present, researches on the Internet of Things are mainly dedicated gateways that support a single protocol. This kind of gateways only support a single communication protocol and do not have the ability to extend the protocol. The single application scenario cannot be well applied to the current Internet of Things where multiple communication protocols coexist. In addition, technology companies such as Xiaomi and Huawei have also launched smart gateway products. However, the compatibility of products needs to be improved. At present, only the products of domestic manufacturers can be accessed, which limits the choice of consumers. The intelligent gateway system proposed in this paper allows the access of multiple protocols and has no restriction on the products of different manufacturers.

The main work of this paper are as follows:

1)This paper takes intelligent community environmental detection as the experimental scenario, and completes the collection of multiple types of environmental data in the community ;

2)Four wireless communication protocols to complete the upward transmission of environmental data were used ;

3) A unified data transmission format was developed;

4) The upper computer software is written to complete the display of data .

2. OVERALL SYSTEM ARCHITECTURE

The overall structure of the system adopts the hierarchical design idea to complete, which is divided into four layers. As shown in "**Fig. 1**", the sensing layer, wireless transmission layer, protocol adaptation layer, and application layer are displayed from bottom to top.

The perception layer is the lowest level of the IOT system structure. The most important function at this level is perception. That is, through a variety of sensor technology to achieve the collection of community environmental data. In the wireless transmission layer, we use four wireless communication protocols to transmit all kinds of environmental data collected in the sensing layer upward. The third layer is the protocol adaptation layer. The function of this layer is to shield the heterogeneity of various protocols in the wireless transmission layer. By designing a unified communication format, we can realize the macro unity of all nodes in different protocols. In order to see the real-time data collected by each node in the sensing layer more intuitively, we use QT to build a TCP/IP client host computer in the application layer to receive the data collected in the sensing layer in real time.

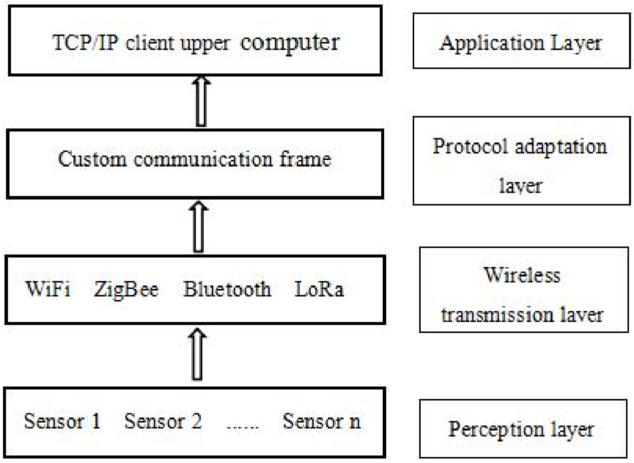

Fig. 1 Overall system architecture.

3. SYSTEM LAYERED DESIGN SCHEME

3.1. Perception Layer

In the sensing layer, we use meteorological sensor, wind speed sensor, PM2.5 sensor, and MQ series gas detection sensor to complete the collection of community temperature, humidity, atmospheric pressure, altitude, wind speed, PM2.5, PM10 and other data.The following describes the sensors used.

3.1.1. Meteorological Sensor

The model of meteorological sensor adopted in this paper is GY-39.This is a sensor module that can measure atmospheric pressure, temperature and humidity. Operating voltage 3-5V, low power consumption, easy installation.Its working principle is that the sensor MCU collects various sensor data, processes it uniformly, and outputs the measurement results in a certain data format using serial port directly.The baud rate of the serial port can be 9600 bps or 115200 bps.There are two ways of continuous data and query output, and the Settings can be saved after power failure. After we perceive that the node has received the data, we need to convert it into standard data according to its corresponding data format.
Data format parsing examples:

< 5A-5A-45-0a-0b-2D-00-97-C4-3F-12-77-00-9c-FA >

i. $T = (0x0b << 8) \mid 0x2d = 2861$.

$Temperature = 2861/100 = 28.61\ (℃)$.

ii. $P = (0x00 << 24) \mid (0x97 << 16) \mid (C4 << 8) \mid 3f = 9946175$.

$Air\ pressure = 9946175/100 = 99461.75\ (pa)$.

iii. $Hum = (0x12 << 8) \mid 77 = 4727$.

$Humidity = 4727/100 = 47.27\ (\%)$.

iv. $Elevation = (0x00 << 8) \mid 0x9c = 156\ (m)$.

3.1.2. Wind speed Sensor

The wind speed sensor adopted in this paper is assembled by a small dc brush motor and a three-cup rotating wind cup. Its working principle is that when there is horizontal flow wind in the environment, the rotating wind cup can generate rotation and drive the small motor to generate voltage. The relation between voltage and rotation speed is shown in "**Fig.2**"Using this signal voltage, the ambient wind speed can be measured.

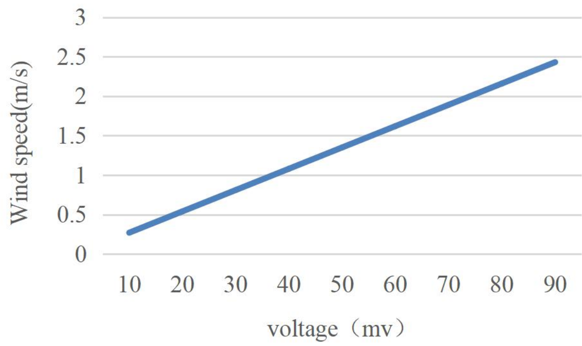

Fig. 2 Diagram of voltage and wind speed.

At the sensing node, we use ADC channel to collect the voltage signal generated by the sensor.Through the relation between voltage and wind speed, the actual wind speed data is calculated.

3.1.3. PM2.5 Sensor

The MODEL of PM2.5 sensor adopted in this paper is DSL-04.It is a laser digital PM2.5 sensor.Built-in laser and photoelectric receiving module, using the principle of light scattering, the laser produces scattered light on the particulate matter, which is converted into electrical signal by the photoelectric receiving device, and then the mass concentration of PM2.5 and PM10 can be calculated through a specific algorithm.The sensor adopts asynchronous serial communication (UART), communication interface configuration: baud rate 9600;Data bit:8 ;Stop bit:1 ;Check bit:None.There are two communication modes: question answering and continuous, and the choice of this paper is question answering mode.

3.1.4. MQ series Sensors

MQ series sensor MQ series sensor is a kind of gas leak detection device used in the community, the factory, with a wide detection range, high sensitivity and fast response and other characteristics.Suitable for the detection of liquefied gas, butane, propane, methane, alcohol, hydrogen, smoke, etc.Table 1 shows the gas detection types of MQ sensors.

Table.1 MQ series Sensors.

Type	**MQ-2**	**MQ-3**	**MQ-4**	**MQ-7**	**MQ-8**
Gas	Smog	Alcohol	Natural gas	CO	H_2

The output of MQ series sensors is a switching signal. In normal state, the sensor generates a low level signal; when the gas concentration exceeds the threshold, it generates a high level signal.We receive the output signal of the sensor through the IO port of STM32F103 microcontroller, so as to realize the detection of the community gas environment.

3.2. Wireless Transmission Layer

3.2.1 Communication Protocol Comparison

The mainstream protocols used in the Internet of Things today can be divided into wired protocols and wireless protocols.The cable protocol has the characteristics of stable transmission and fast speed, but it also leads to the difficulties in wiring and high cost.In recent years, the rapid development of wireless communication protocols, transmission stability and speed can also be guaranteed, so this paper chooses wireless protocols in the transport layer to support.At present, wireless communication protocols mainly include WiFi [5], Bluetooth [6], ZigBee [7] and Infrared [8], which are four commonly used short-range protocols.There are two remote wireless protocols, LoRaWan [9] and NB-IOT [10].The six communication protocols are compared in various aspects, as shown in Table 2.

Table. 2 Comparison of wireless communication technologies

Kind	Transmission Distance	Number of Nodes	Transmission Rate
ZigBee	100m	65535	250kb/s
WiFi	50m	24	10Mb/S
Bluetooth	30m	15	1Mb/S
Infrared	5m	1	4Mb/S
LoRa	3km	65535	19.2kb/s
NB-LOT	3km	65535	200kb/s

WiFi and Bluetooth belong to the most used and the most familiar wireless communication protocols, and the transmission rate and performance are guaranteed, this system selected to support WiFi and Bluetooth.Infrared communication can only be single - to - single, does not meet the application requirements, will not be considered.ZigBee is a widely used short-distance communication protocol, and ZigBee has the advantages of simple networking and low power consumption. With more and more intelligent devices, convenient networking will become a huge advantage, so it should be supported.With the emergence of smart home, smart city and other applications, for short distance communication protocols, there are short transmission distance, coverage is not wide enough and other shortcomings.Then the new long-distance protocol is more in line with the application needs.Between LoRaWan and NB-LOT, the two commonly used long-distance communication protocols, the frequency band of NB-LOT is a toll band, while the cost of LoRaWan is relatively low. Therefore, the LoRaWan protocol is supported.To sum up, this system chooses WiFi, Bluetooth, ZigBee and LoRaWAN wireless communication protocols for support, these four protocols can ensure the compatibility of the system, but not to make the system too complex.

3.2.2. Hardware Implementation

The implementation of wireless communication protocol in this paper is completed through the development of existing modules.The model of WiFi module is usr-WIFI232-B2 module, which has strong transmission stability.A subnet allows 24 nodes to be connected.This system selects CC2640, which is a low power Bluetooth chip with high cost performance. It supports one master and multiple slave mode, which meets the networking requirements of the Internet of Things.TI CC2530 is selected as the Zigbee module, which is perfectly compatible with the Z-Stack protocol Stack provided by TI.At present CC2530+Z-Stack is the mainstream solution of ZigBee protocol.The LoRa protocol uses the ATK-LORA-01 module, which uses the efficient ISM frequency band SX1278 spread spectrum chip and supports 32 channels.Each channel can access 65535 nodes.The communication distance can reach 3km.

All kinds of sensors and communication modules mentioned above are connected to the DEVELOPMENT board of STM32F103 to achieve corresponding functions.Table 3 shows the comparison between sensors and communication protocols.

Table. 3 Protocol and sensor comparison table.

Protocol	LoRa	WiFi	Bluetooth	ZigBee
Sensor	Meteorological Sensor	MQ Sensor	PM2.5 Sensor	Wind speed Sensor

3.3. Protocol Adaptation Layer

In this paper, four wireless communication protocols are used to transmit the data collected in the sensing layer upward.But because different wireless communication protocols have their own data transmission format.Therefore, in order to mask the heterogeneity of wireless communication protocols, all nodes in different protocols are unified .We had to design our own data communication format on top of the wireless protocol.In addition, we use our own communication format to benefit the security of the system.

In the data communication format, we need one byte to distinguish the communication protocol.We use the four character“L”, “W”, “B” and “Z” to represent LoRa, WiFi, Bluetooth and ZigBee communication protocols respectively.Secondly, this system supports multiple subnets of the same protocol. We use two ASCII codes to represent the subnet number.The maximum number of nodes allowed under the same subnet varies for each of the four communication protocols.Zigbee and LoRa can access up to 65535 nodes.So we need 2 bytes to represent the number of nodes on the same subnet under the same protocol.Then there is the specific collection of data at each node.Finally, we add the frame header and the frame tail for each frame data to form our complete data communication format.Table 4 shows our complete data format.

Table. 4 Communication frame format.

Number of Bytes	Frame Format	Example
2	Frame Header	57(H) 47(H)
1	protocol type	L(A)
2	Subnet Number	01(A)
2	Node Number	0001(H)
Indefinite	Data	26.62(A)
2	Frame Tail	57(H) 47(H)
A —— ASCII H —— Hexadecimal		

3.4. The Application Layer

After the gateway receives the data of the awareness layer, in order to make the data more intuitive display and use.We need to move data up to the application layer.This article uses familiar TCP/IP protocol to complete this function.TCP/IP protocol we use socket programming.The gateway serves as the server and the upper computer serves as the client "**Fig. 3**" shows the workflow of the client and server.

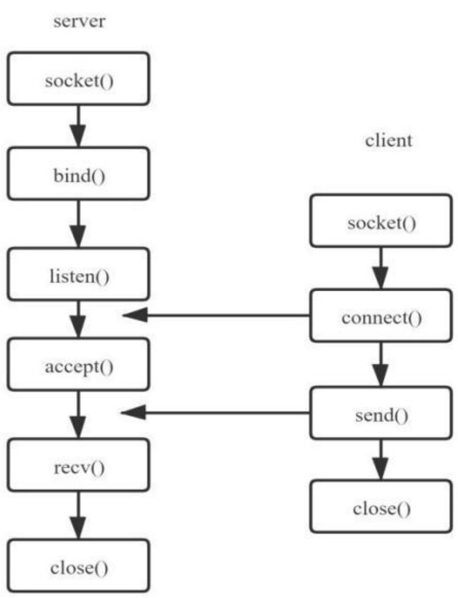

Fig. 3 Socket communication process.

The gateway uses STM32F407 development board in hardware.Socket programming is realized by using LWIP protocol on the development board.We use QT to write a host computer client software to receive the gateway through TCP/IP protocol transmission of the environment information collected by each node.We can through the intuitive graphical interface to observe the data of each sensor.We set the address of the server as: 115.25.46.137 and the port number as: 8088 on the upper computer.The server was successfully connected.Then we receive the data sent by the server as shown in "Fig 4".

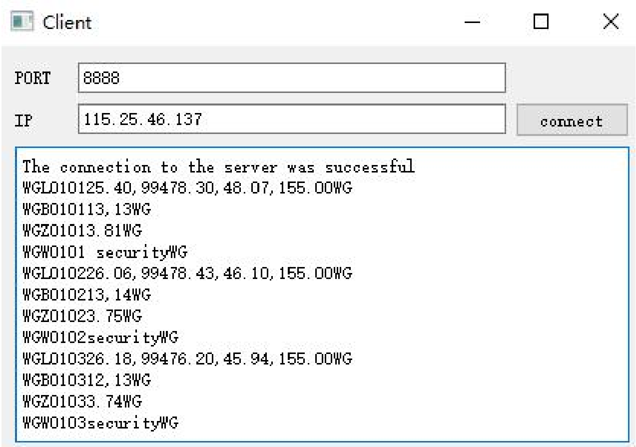

Fig. 4 Data received by the upper computer.

In the upper computer, we received the data sent by the gateway.Below, a brief description of the data received.

(1)WGL010125.40, 99478.30, 48.07, 155.00 the WG.
WG: Frame head.
L0101: Node 01 , subnet 01 of the LoRa network.
25.40: Temperature . Data unit: ° C.
99478.30: Pressure . Data unit: pa.
48.07 : Relative humidity. Data unit: (%).
155.00: Altitude. Data unit: m.
WG: Frame tail.

(2) WGB010113, 13 WG.
WG: Frame head.
B0101: Node 01, subnet 01 of the Bluetooth network.
13: PM2.5 . Data unit: ug/m3.
13: PM10. Data unit: ug/m3.
WG: Frame tail.

(3) WGZ01013.81 WG.
WG: Frame head.
Z0101: Node 01 , subnet 01 of the ZigBee network.
3.81: Wind speed. Data unit: m/s.
WG: Frame tail.

(4) WGW0101securityWG.
WG: Frame head.
W0101: Node 01 , subnet 01 of the WiFi network.
Security: MQ-2 data.
WG: Frame tail.

4. EXPERIMENT AND TEST

4.1. Test Environment

The test of system performance is mainly the transmission efficiency, which can also be considered as the packet loss rate of each communication protocol in the transmission process.Because different test environments have a great impact on test results, we configured our test environments according to our actual application scenarios.The test environment of each protocol is shown in the Table 5.

Table. 5 Test environment Table.

Protocol	Number of Nodes	Distance	Period of Transmission
LoRa	25	1.5km	2s
WiFi	15	15m	2s
Bluetooth	11	12m	2s
ZigBee	20	150m	2s

4.2. Test Results

In the experiment, we tested each protocol 10 times and then averaged it.The experimental results are shown in the table 6.

Table. 6 System test results.

Protocol	Data Sent (times)	Data Received (times)	Packet Loss Probability
LoRa	5000	4933	1.34%
WiFi	5000	4926	1.48%
Bluetooth	5000	4891	2.18%
ZigBee	5000	4932	1.36%

From the table above, we can see that the average packet loss rate of both LoRa network and ZigBee network is about 1.3%, showing strong transmission stability.Both protocols are suitable for large-scale networking.The packet loss rate of WiFi network is only 1.49%, which also has strong stability.The Bluetooth network had the highest packet loss rate, but this was due to the large size of the Bluetooth network and the high concurrency of the nodes in our test environment.When the network size is reduced and the transmission frequency is slowed down, the packet loss rate is significantly reduced.To sum up, the test results of each network are in an acceptable range and meet the application requirements.

5. CONCLUSION

This paper mainly focuses on the research and design of data fusion of various wireless communication protocols.Firstly, multiple kinds of data are collected by using multiple kinds of sensors in the sensing layer.Secondly, in the wireless transmission layer, four common wireless transmission protocols such as LoRa, WiFi, ZigBee and Bluetooth are used to complete the upward transmission of data.In the protocol adaptation layer, the data information uploaded by the terminal nodes of different communication protocols is converted into a unified format to form a macroscopic unity.Finally, through TCP/IP protocol, the data is transmitted to the client host computer built by QT for testing.The test results show that the system can meet the application requirements and has good data transmission stability.

Acknowledgements

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