An IoT Automatic Station for Gradient observation of Microclimate in Mountain Profile

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Abstract: The natural environment and climate of mountain profile are various, and generally have different characteristics of microclimate as the gradient changes, so gradient observation is very significant, especially in the fields of agricultural cultivation and ecological environment. In this paper, an IoT(internet of things) automatic station solution based on LoRa is proposed to solve the problem of gradient difference, wide coverage area, poor base station signal, less power supply facilities and high construction difficulty in microclimate gradient observation of mountain profile. The system adopts the distributed architecture, using the node equipment to do multi-point encryption observation of the crops at different gradients, and transmitting data through the WSN network. In order to realize long distance communication in complex environment, using the wireless spread spectrum modulation technology of LoRa in communication unit which has the advantages of strong anti-interference ability and high sensitivity. This paper introduces the integrated design method of node equipment in integration of sensor, power supply unit, acquisition unit, communication unit, and also introduces the key technologies such as WSN wireless ad hoc network, low power consumption management and attitude recognition. Through the use of the scene about coffee base in Baoshan City, Yunnan Province which is a complex mountain profile environment with a vertical gradient of 1000 m, the experimental data showed that the IoT automatic station equipment is stable and reliable, and the packet loss rate in wireless communications is less than 1%. In addition, it also has the characteristics of easy installation, wide coverage, solar power supply, dumping alarm and so on.

Keywords: IoT; LoRa; WSN; Gradient observation; Automatic Station

Introduction

Mountainous terrain accounts for 69% of the total land area in China. This vast mountainous terrain has a wealth of use, including: agriculture, forestry, the mining of minerals and the development of tourism. For example, in parts of the Yunnan Province, coffee is the main local cash crops which is suitable for planting in the mountains. Coffee is a kind of shade-requiring plant, which is difficult to grow fruit at high temperature and easy to be frozen to death at low temperature. It can be said that the yield of coffee is closely related to the climatic conditions of growing environment. Therefore, in the mountain, management of crop agricultural activities must be targeted, planned and based on climate conditions and local conditions. Because of the vertical gradient of mountainous terrain, with the change of altitude, the climatic conditions of the mountain environment have a greater difference, and are easy to form a local microclimate environment. Therefore, the observation of climate in whole range of mountain is very important, especially for microclimate gradient observation of mountain profile [1].

The traditional automatic weather station mode has more strict requirements on the observation site and the infrastructure, but the complicated terrain and environment of mountain are not conducive to the transportation of large-scale equipment and the construction of infrastructure such as electric power and communication. Therefore, in the mountain environment, the traditional weather station is more difficult to deploy and the automatic weather station equipment that has been deployed have common problems such as low observation density and insufficient data representation.

The IoT(internet of things) automatic station modes based on ZigBee, WiFi or GPRS and other conventional communication technology are also difficult to meet the low-power and long-distance communication performance requirements in mountain environment, such as ZigBee network communication distance is usually within 100 meters, the distance is too short; WiFi technology can achieve long-distance communication by setting up high-gain antenna and power amplifier, but the power consumption and volume will increase a lot, and this technology is not easy to implement; and GPRS technology is limited by the signal coverage of base station and can't guarantee smooth communication in some special terrain of the mountain environment. Besides, a large number of operators flow cards are also very difficult to facilitate the late maintenance of equipment.

In this paper, an IoT(internet of things) automatic station solution based on wireless spread spectrum modulation technology of LoRa is proposed to solve the problem of microclimate gradient observation of mountain profile, such as large gradient difference, wide coverage area, poor signal of base station, less power supply facilities and high difficulty of construction. The system adopts the distributed architecture, using the node equipment to do multi-point encryption observation of the crops at different gradients, and transmitting data through the WSN network. Based on LoRa's strong anti-interference ability and high receiving sensitivity, it can realize long-distance communication in complex environment.

1. System architecture

1.1 Characteristics of microclimate gradient observation of mountain profile

Microclimate gradient observation of mountain profile belongs to the field of agricultural meteorological observation.

In the field of agricultural meteorological observation, the observation object includes the physical elements and biological elements in the crop growth environment. The physical elements are divided into meteorological elements and soil elements [2]. This paper mainly discusses the meteorological elements. These meteorological elements can be divided into two categories, one is the meteorological element with regional representations and the other is the meteorological element with obvious regional microclimate characteristics.

The meteorological element with regional representations has six conventional weather elements (temperature, air pressure, environment humidity, wind direction and speed, rainfall), total solar radiation, sunshine duration, root mean square of photosynthetic and so on. This kind of meteorological data has a high consistency in the larger spatial scale, and is irrelevant to environmental factors such as crop species and planting distribution, and is suitable for single point unified observation.

The meteorological element with regional microclimate characteristics mainly include the inter-crop temperature and humidity of different height, and this meteorological element has large differences in space, and are closely related to the crop species, the height and density of plant. So this meteorological element is suitable for multi-point encryption observation.

1.2 The design of system architecture

The IOT (internet of things) automatic station described in this paper adopt the distributed system architecture, it consists of a master station equipment and a number of inter-crop meteorological instruments. The master station equipment is used to observe regional meteorological elements. The inter-crop meteorological instruments are for observation of the meteorological elements with regional microclimate characteristics. The communication between master station equipment and the inter-crop meteorological instruments adopts wireless networking technology, and the master station equipment carries on the network collaborative management to the inter-crop meteorological instruments in the station.Fig1 is a schematic diagram of a distributed architecture.

The master station can interact with the remote software platform through the operator's network.

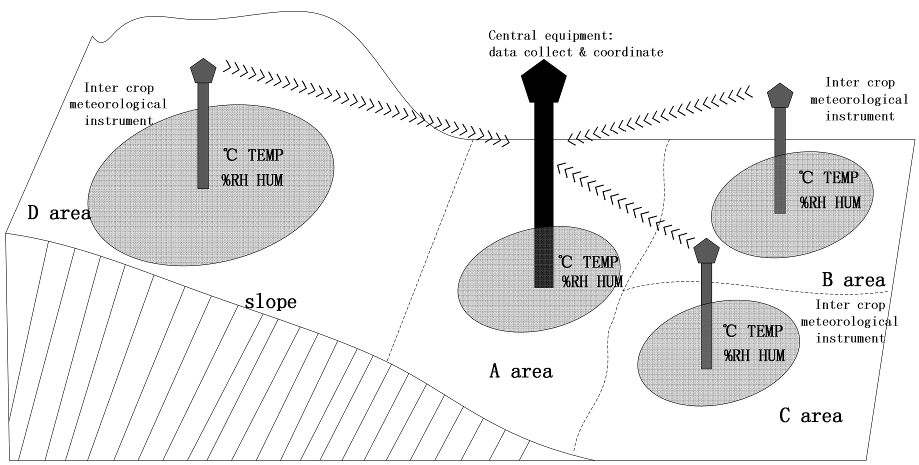

Fig1. A distributed architecture

2. The design of inter-crop meteorological instrument

The inter-crop meteorological instrument is mainly aimed at observation of crop layer with regional microclimate characteristics. The observation elements include temperature, humidity, and naked temperature and so on between the plants of different heights. The observation data is transmitted to the master station through the wireless network. This instrument can achieve plug and play of field observation.

2.1 The overall design of inter-crop meteorological instrument

The instrument adopts a structural integration design method on the architecture and highly integrates solar panels, batteries, sensors and hardware circuits and other components. Fig2 is a block diagram of hardware circuits, Fig3 and Fig4 are schematic diagrams of structures.

The hardware circuit part is the core of the whole inter-crop meteorological instrument, and achieves acquisition, computing, storage and communication function of the sensor data.

The inter-crop meteorological instrument with integrated structure has many portable features such as easy installation, deployment, self power supplying, ad hoc network, mobility and so on, which is very suitable for observation in complex environments such as mountains and farmlands.

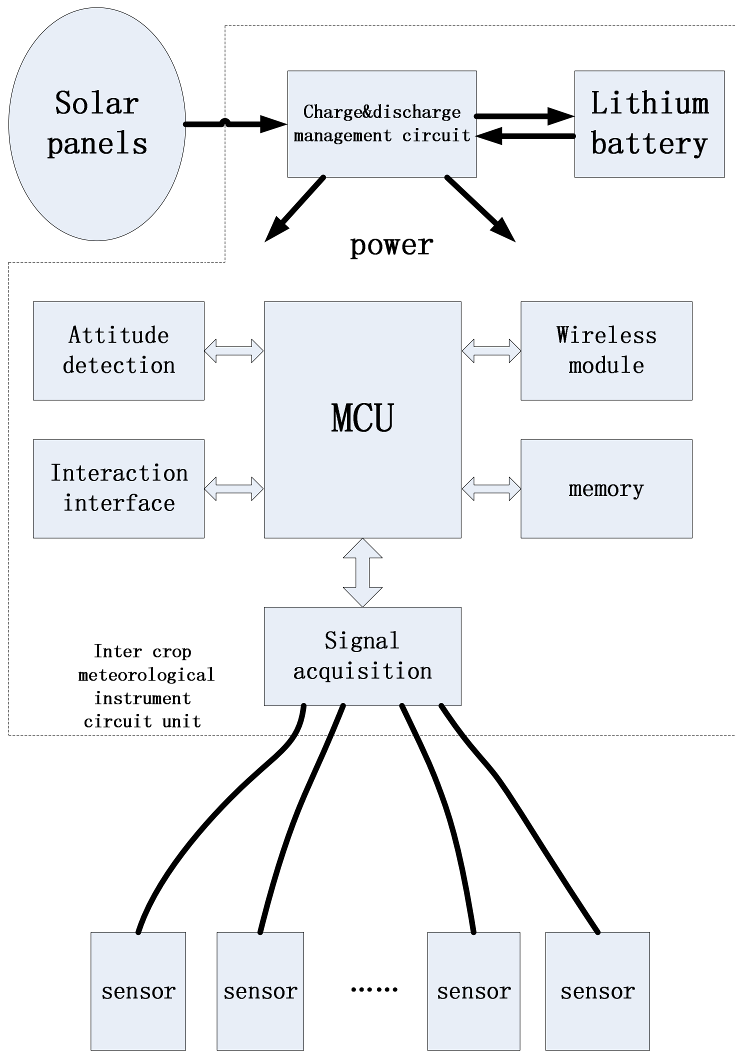

Fig2. Hardware circuit

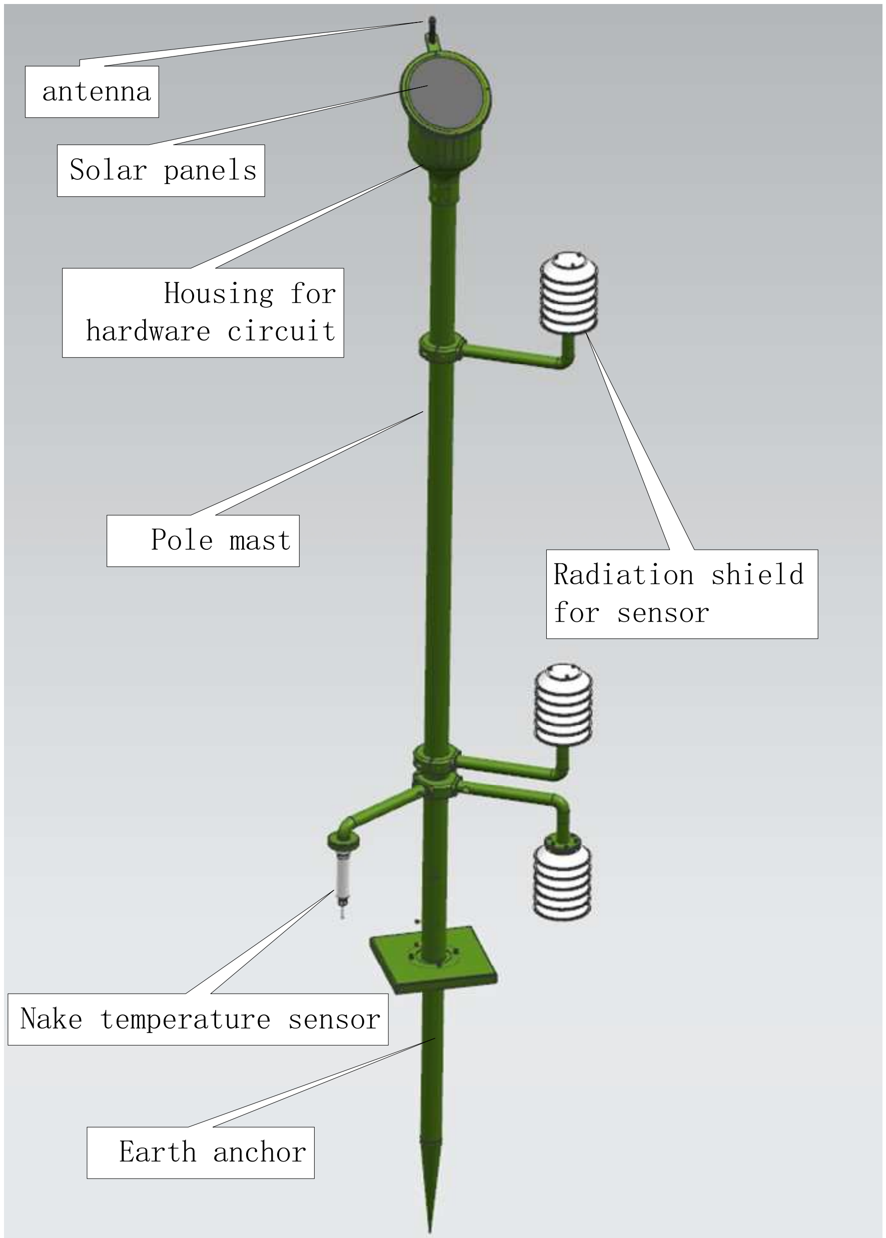

Fig3. The inter-crop meteorological instrument

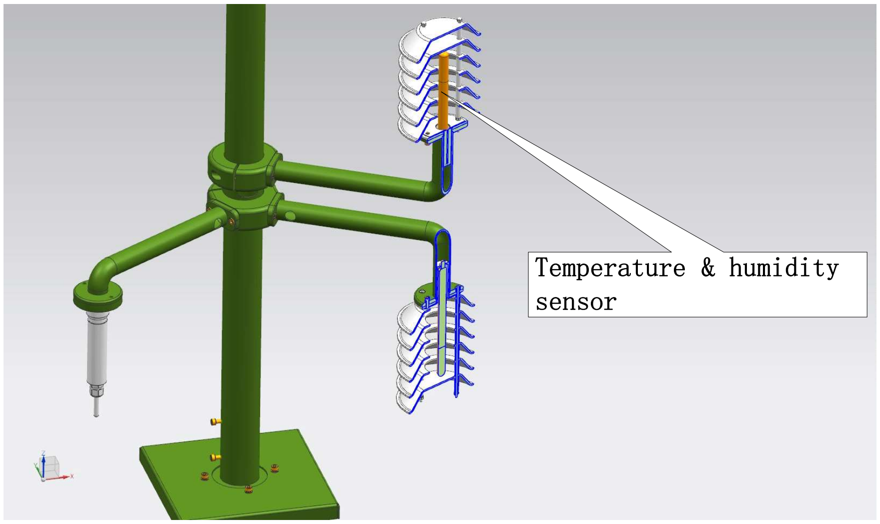

Fig4. Structural installation of temperature and humidity sensor

2.2 Sensor

The inter-crop meteorological instrument has two types of sensors, naked temperature sensors and air temperature and humidity sensors. The naked temperature sensor adopts the current more mature PT100 platinum resistor. Considering range, accuracy, size and power consumption and other factors of sensor, the EE060 sensor from E+E Company is selected for the air temperature and humidity sensor.

Related technical indicators of temperature and humidity sensor are as follows:

Table 1 Temperature and humidity sensor performance parameter

	EE060&Temperature	EE060&Humidity
Range	-40~60℃	0～100%RH
Accuracy	0.3℃ /20℃	2.5%/20℃
Power Consumption	1mA/12V	

2.3 The design of communication

According to Shannon's information theory formula,

$$C = B \bullet log_2\left(1 + \frac{S}{N}\right)$$

The C is the signal transmission rate, the B is the signal bandwidth, S / N is the signal-to-noise ratio. From the formula itself, when C is certain, if B is increased, S / N will decrease accordingly. In theory, when B increases to a certain extent, S / N can be less than 1, which means that if the bandwidth B is large enough during transmission, the power of the signal can even be lower than the noise power, so that the signal can be hidden in the noise for transmission.

Due to vertical gradient of mountain profile, the climate is changeable, the content of water molecules in the air is very large, the fog is often formed, and the mountain lush vegetations have a certain occlusion to wireless signals. The space environment causes the electromagnetic wave have great attenuation, and requirements for signal-to-noise ratio will be higher, especially in the case of long distance.

LoRa is a wireless spread spectrum modulation technology with a maximum spreading factor of 12. In other words, the amount of information will be increased in the modulation process and is 12 times more than before. Spreading spectrum is equivalent to increasing bandwidth, which has very low requirements of signal-to-noise ratio in the low-rate communication conditions, also has a strong ability of anti-interference, and is very suitable for distance wireless communications in mountain environments [3] [4] [5].

The inter-crop meteorological instrument uses SX1278 RF chip from Semtech Company to achieve wireless communication based on LoRa. Combined with inter-crop meteorological instrument's requirements of the maximum amount of data that needs to be transferred, maximum transmission distance and system latency, the LoRa wireless communication parameters are set as follows:

Table 2 LoRa RF parameters

parameter name	Value	Remarks
Spreading factor	9	Max:12
Signal bandwidth	125KHz	7.8KHz～500KHz
Band	433MHz	
Transmit power	18dBm	

Through the parameter setting of Table 2, the final coupling loss is 148dB and the receiving sensitivity is -120dBm. After measured outdoors by this configuration, the distance of point-to-point communication is up to 3km in an unobstructed environment. More detailed parameter setting is shown in Fig5.

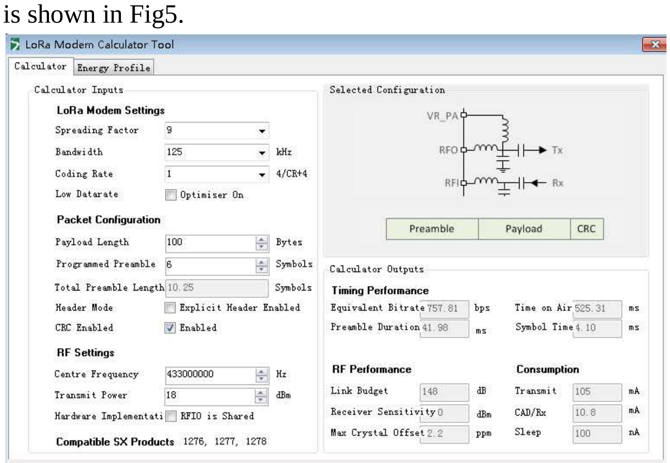

Fig5. Parameter setting of LoRa

2.4 The design of power supply

The inter-crop meteorological instrument adopts solar power supply, but the integrated and miniaturized design of structure also indirectly limits the solar panel power and the capacity of energy storage battery, so during power supply design process, the charging efficiency and equipment's own power consumption should be considered fully.

This paper adopts LTC4121 charge and discharge management chip to manage charge and discharge of solar and lithium battery. LTC4121 chip has the function of MPPT (maximum power point tracking) and can ensure that the solar panels continue to run in the best condition[6][7].

At the same time, this system uses dormancy, power management, removing redundancy and other technical means to realize the integrated control of the whole power consumption of inter-crop meteorological instrument.

The related indicators of power supply design are as follows:

Table3 Parameters of power supply

Solar panel power	2W
Lithium battery capacity	8.4V/10AH
power consumption of inter-crop meteorological instrument	0.17W
Working days without interruption during continuous rainy days	15 days

2.5 The design of toppling alarm

Mountain soil relaxation after rain may lead to toppling of inter-crop meteorological instrument and affect data accuracy, in order to prevent this possibility from occurring, the system design a toppling alarm based on 3D posture detection technology. This alarm system obtains angle of inclination and swing amplitude by monitoring inter-crop meteorological instrument's 3D posture data in real-time and calculation. The excessive angle of inclination or swing amplitude will trigger the alarm immediately. The alarm information will be sent to the main node via the wireless network, and then the main node will notify the software monitoring platform.

The core device of posture detection is MPU6050 six-axis sensor.

3. Network collaboration

In the process of wireless communication between the inter-crop meteorological instruments and the master nodes, the channel of the wireless network is unique. Therefore, in the case of networks containing multiple inter-crop meteorological instruments, some concurrent phenomena such as wireless data transmission conflicts and so on will become more serious as the increase in number of network nodes. In order to ensure that all nodes can work together and eliminate network conflict, network collaboration technology should be adopted, mainly including: slot mechanism, synchronization technology and retransmission compensation mechanism.

The periods of communication between the inter-crop meteorological instruments and master nodes are divided into active upload time slot, time synchronization slot, interaction time slot and several safety time slots shown in Fig6.

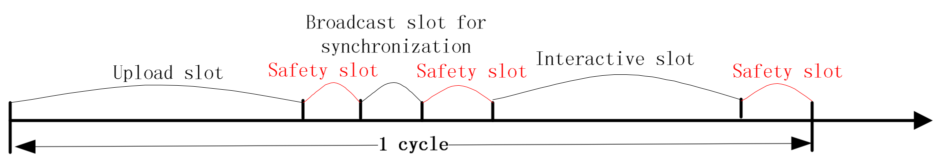

Fig6. Allocation of time slots

In the active upload time slot, the inter-crop meteorological instrument will further subdivide the active upload time slot in order and upload the data in its own time slot space to reduce the possibility that multiple nodes send data simultaneously. And the nodes can be allowed to active retransmit in their own time slot space.

In the time synchronization slot, the master node downlink transmits broadcasts of time to perform network time synchronization. And the time compensation algorithm is adopted to eliminate the error of the synchronization time caused by transmission of wireless data, and improve accuracy of time slot.

In the interaction time slot, the inter-crop meteorological instruments interact with the master node to realize the process of ad hoc network and self-negotiation, and complete the division of time slot. At the same time, the master node can compensate data from inter-crop meteorological instruments. Adopting data compensation mechanism can improve the reliability of data transmissions to deal with environmental interference and other special circumstances.

The safety time slot is used to ensure that cross phenomenon between the slots caused by delay errors will not happen.

By proving the active upload time slot, when there are four inter-crop meteorological instruments in the network, the active upload time series of the four inter-crop meteorological instruments can meet the time slot requirements after network self-negotiation. After the network self-negotiation is set up in the experiment, the inter-crop meteorological instrument will send data every 20 seconds in one minute. The four inter-crop meteorological instruments which ID numbers are 001 to 004 will upload data in strict order respectively in 0s ~ 3s, 21s ~ 23s, 40s ~ 43s, and the validation messages of active upload time slot test show in Fig7.

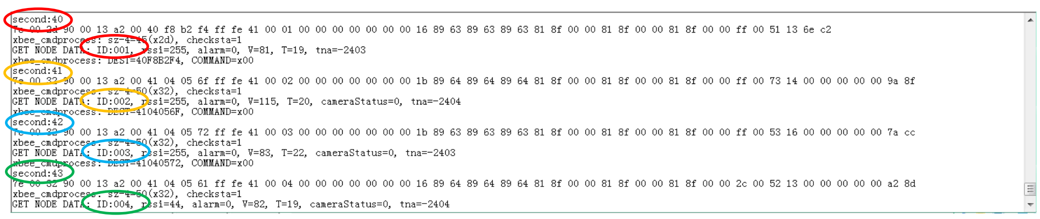

Fig7. Validation messages of active upload time slot test

4. Analysis of operation in the outfield

The IoT(internet of things) automatic station based on LoRa in this paper is installed and filed tested verification in coffee base in Baoshan City, Yunnan Province.

A master node is set on a hillside at an altitude of about 1,600 meters, and there are two inter-crop meteorological instruments deployed around the master node, respectively at the altitude of 1,200 meters and 1400 meters. The maximum linear distance between the inter-crop meteorological instrument and the master node is about 2 km. Fig8 is a picture of the scene.

Fig8. Experiment equipment in the outfield

This IoT(internet of things) automatic station has been running for about 5 months by the time this paper was written. The equipment was running well in the five months. By the data statistics, the data reporting ratio attained to 100%. One of these successful communication ratios attained to 98.3%. Software platform shown in Fig9 shows the data of temperature and humidity from the inter-crop meteorological instruments. Fig10 shows the statistics about the ratio which inter-crop meteorological instruments report data to the master node.

	观测时间	到报时间	温度1(℃)	温度2(℃)	温度3(℃)	温度4(℃)	湿度1(%)	湿度2(%)	湿度3(%)	湿度4(%)	温度13(℃)
1	2017-08-23 11:35	2017-08-23 11:34:26	30	29.9	29.5	29.3	67	65	65	64	30.5
2	2017-08-23 11:30	2017-08-23 11:29:26	30.2	30	29.6	29.3	64	64	65	65	30.6
3	2017-08-23 11:25	2017-08-23 11:24:27	30.5	30.3	29.7	29.3	65	64	65	65	30.9
4	2017-08-23 11:20	2017-08-23 11:19:26	31	30.7	30	29.5	64	62	65	65	31.5
5	2017-08-23 11:15	2017-08-23 11:14:26	31.5	31.2	30.3	29.7	62	61	64	65	32
6	2017-08-23 11:10	2017-08-23 11:09:27	32.6	32	30.9	29.9	61	61	63	65	33
7	2017-08-23 11:05	2017-08-23 11:04:27	33.6	32.9	31.8	30.5	58	58	61	63	34.3
8	2017-08-23 11:00	2017-08-23 10:59:26	33.8	33.1	32	30.7	57	57	59	62	34.7
9	2017-08-23 10:55	2017-08-23 10:54:26	33.2	33	32	30.9	60	59	60	62	34.5

Fig9. Software platform data display

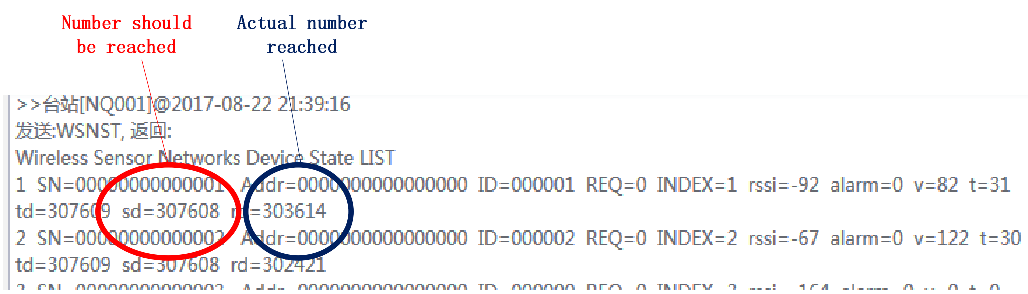

Fig10. A statistic about data reporting ratio

5. Conclusion

The IoT(internet of things) automatic station based on LoRa in this paper has stable and reliable performance, and this automatic station's reporting ratio is not less than 99.9%. The inter-crop meteorological instrument with integrated structure has many portable features such as easy installation, deployment, self power supplying, ad hoc network, mobility and so on, which is very suitable for microclimate gradient observation of mountain profile and the crop observation in complex environments. The overall structure design of inter-crop meteorological instrument has a certain universal applicability and reference.

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