Research on network integration technology of observation stations

ZHAN Yanjun[1*], MA Shangchang[1], ZHUANG Ting[2], ZHANG Sujuan[1]

(1. *Chengdu University of Information Technology*, *Chengdu* 610225; 2. *Tianjin Binhai Meteorological Bureau*, *Tianjin* 300457)

Abstract: According to the phenomenon of "four more" and "four low" problems in the observation stations, the surface-based meteorological observing system can't adapt to the change of the adaptive observation equipment and reduce of business intensification. A station integrated system is proposed, which can be configured, connected and extended to all kinds of observation equipment. And the integrated processor is designed, supporting a variety of communication interface standards. Flexible configuration, connection and expansion between conventional and new type of meteorological observation equipment are supported. It is capable for online calibration and maintenance of observation equipment. The effectiveness of automatic observation equipment is totally achieved to provide basic information support for disaster prevention and mitigation and national economic development.

Key words: station network integration; serial device sever; quality contro; data communication; linux

1 Introduction

With the development of the meteorological observation technology and the automation of surface-based observation, especially in recent years, the new type of observation equipment on cloud, visibility andweather phenomenon has been established in meteorological observation stations. The kind of equipment is numerous which has caused many problems while improving the ability of surface-based observation. 1) Communication lines, terminals, software systems and data standards are the problem of "four more". Surface meteorological sensors or observation equipment are connected with communication cables to each terminal according to different interfaces and connections. 2) System reliability, utilization, maintainability and scalability are the problem of "four low". One device corresponds to one communication line and one terminal, which reduces the reliability of the entire integrated meteorological observation system. Each kind of system works with their respective machine timing, resulting in the inconsistency of acquisition time and low utilization rate of each terminal and data. Plenty of data standards are difficult to be unified and the scalability of the system is reduced. A large number of complex software systems not only increases the labor intensity of the staff, but also reduces the maintainability of the service system. The phenomenon of "four more" and "four low" problems caused bad adaption to observation equipment changes, poor automatic observation ability, reduction of business intensive degree, increase of station maintenance work and the lack of comprehensive data quality control. To establish a system with flexible configuration, connection and expansion for all kinds of observation equipment interfaces, the "four more" and "four low" problems are solved. And it also meets the demand of improving the quality of observation data and developing of future surface-based meteorological observation.

2 System design

In this system, a new idea of network integration technology ofobservation[1] station is constructed based on the integrated processor. The system block diagram is shown in Fig 1.

The sensor and integrated processor of theobservation station are connected by wireless Zigbee. However, according to the actual practice, it is also

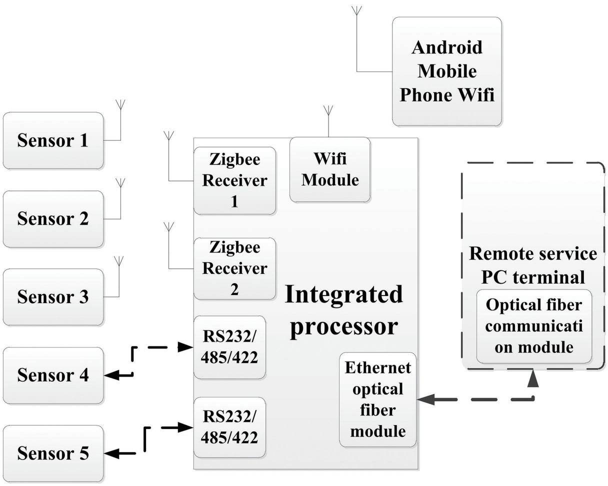

Fig. 1 Systemblock diagram

connected through the serial port (RS-232/485/422) or optical fiber wired communication to ensure that integration between the processor and the sensor is seamless. The data collected by the integrated processor is obtained access to the Ethernet via the Ethernet optical fiber communication module and the remote terminal is received through the network. With the addition of network communication, the data volume of communication has broken the bottleneck of the amount by the serial communication. At the same time[2], optical fiber communicationcan avoid the electronic interference and the influence of the temperature and humidity of environment, realize the insulation protection and not be affected by the short circuit, the sudden wave or the static electricity. It can effectively improve the anti-interference ability and reliability of the system. The main function of the Wifi module is to realize the data visualization of the integrated processor when the current observation equipment has no liquid crystal display interface. The maintenance of this equipment has brought a lot of difficulties. Due to the long distance of the operational terminal from meteorological observation field, the workers can't check the device state in real time to bring great distress for maintenance[3]. With the Wifi module added, the workers only need to download the integrated processor APP with a mobile phone, and then connect to the device to display the status of the device information. What's more, the mobile phone can be used as the real-time display terminal, such as the current temperature, humidity, wind direction and other meteorological elements[4].

3 Block diagram of integrated processor

Integrated processor is the core of observation station network integration. The location in the surface-based meteorological observation integrated system and its internal block diagram are shown in Fig 2.

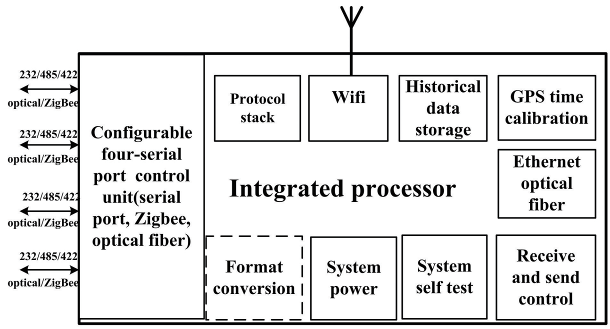

Fig. 2 Integrated processor system block diagram

High performance embedded microprocessor ARM9 is regarded as the core that is the overall design of the system. Considering system power consumption and the number of serial port, the ARM9 of Atmel is used in this system[5]. The main function of configurable four serial port management unit (serial port, Zigbee, optical fiber) is to provide a configurable unit for the device access mode of the field. And the plug-in design is used in the module, containing 232/422/485 communication module, Zigbee communication module and optical fiber communication module. The user can insert corresponding module according to the interface requirements of the front-end sensor, and then achieve compatibility of many access methods through the configuration between the mobile phone APP and software. The design solves the problem of access to new and old equipment. GPS time module guarantees the accuracy of integrated processor's time. The current meteorological data transmission mode uses minute data, namely a packet of data is passed every minute, and the accuracy of time is particularly important[6]. And the system clock can also be provided to historical data storage module. Historical data is stored in historical data storage, which is convenient for data reconciliation and query. Meanwhile, it ensures data integrity when the terminal computer system is maintaining, upgrading and short time interruption of communication link. Data format conversion module is design to match the active module which supports online upgrade, mainly ensuring the effective access of foreign importing new meteorological observation equipment. The system self-test module is used to realize the remote maintenance of the system. And the self-test circuit is mainly a collection of working voltage and temperature[7]. Then, the voltage and temperature are transmitted through network to facilitate the remote maintenance for the station staff. All communication modules are controlled by transceiver control module with communication protocol module, to achieve optical fiber communication among communication control system, meteorological observation equipment and terminal business software system.

3.1 Network interface design

DM9000C is one of the DM9000 series industrial products. With DM 9000's 100 pins, DM9000C only has 48 pins and relatively low consumption. The external general processor interface is easy to be connected with the processor and the internal MAC layer and PHY layer function can be achieved. The processing speed can reach 100 Mbps, which is compatible with the DM 9000C's software and hardware. It has adequate reference design material and the best price versus performance ratio[8].

Fig 3 is a network interface circuit diagram for the system.

DM9000's 16 data linessequentially connect to the lower 16 bit data lines of ARM9. In the 16-bit operation mode, enable pin of the chip links the nGCS0of ARM9 and the extended network card locates in the processor's BANK4 storage area. It is

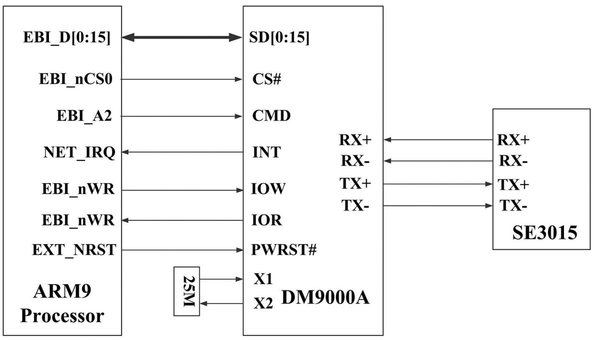

Fig. 3 Network interface of integrated hardware control system

said in the DM9000C data sheet that DM9000C is not like some other processor expansion chip having address bus pin. But it is connected to the ARM9's third address bus through the CMD pin of the chip. This is because DM9000C relies on the CMD input signal to distinguish the scanty of two addressing ports, DATA and INDEX. INDEX distinguishes the internal register address of DM9000C and DATA is reading/writing data for the register [9]. When the processor works on the DM9000C, the INDEX firstly selects the address and then writes the data to the register or reads the data from register. If the content of the data bus belongs to INDEX or DATA, it depends on the CMD signal. The interrupt request pin of DM9000 is joined by external interrupt 7, and the processor can respond to the interrupt request generated by the network chip in time. DM9000C read and write request signal directly links the processor read and write control signal without other processing. The operation of ARM9 can keep synchronization with DM9000C. The DM9000C reduction pin is connected with the ARM9 system reset circuit, which ensures that the chip can be synchronized with the processor. External clock input is used in DM9000C with the external 25M oscillator to provide the necessary clock for DM9000C. In addition, the three pins of EECS, EESK and EEDIO are utilized for MAC address information of the external EEPROM storage card. It is often used in this way to set up the MAC address of the network card in practical design. The

EECS pin should be connected to the low level to select the 16-bit operating mode of EECK, and EECK can be used to choose that the DM9000C interruption begins in which way. 10BASE-T/100BASE-TX interface of system network interface uses SE3015 optical module.

3.2 RS-232/485/422 configurable communication module

RS-232/RS-485/RS-422 configurable communication module uses the serial communication module of SP339. Inthe procedure of the system hardware circuit design, the characteristics of the serial transceiver interface of Atmel SAM9G20 are fully utilized. The TTL serial port of main control chip is converted into RS-232/RS-485/RS-422 by the external SP339. And by controlling the level of MODE1 and MODE0 of SP339, the output signal is selected from three kinds of serial signals RS-232/RS-485/RS-422. The two pins only need to connect to the ARM9 IO port, and three ways of communication can be achieved through the high or low level of the ARM9 IO port. LED1 and LED2 indicate that if the data is sent or received. When TXD or RXD appears a series of pulses, the LED is clearly flashing and transistor of T1 is used to switch sending or receiving communication. This circuit can effectively reduce the number of components used for external connection and the cost of the product. Especially, the hardware circuit design is greatly simplified. The hardware circuit design is based on the serial communication module of SP339, as shown in Fig 4.

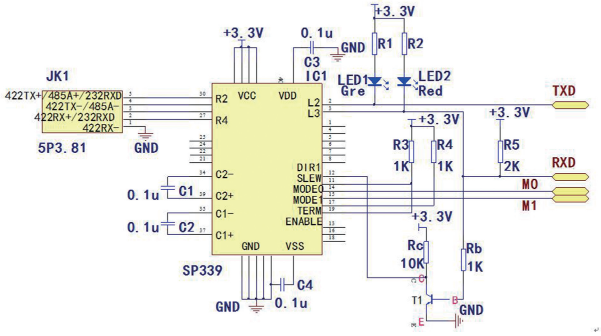

Fig. 4 Serial communication module based on SP339

3.3 Wifi module design

At present, the main interface of Wifi is serial or USB port. Considering the requirements of the speed, this design uses the Wifi module with USB interface. UN5885-IPEX is specially designed for the wireless LAN communication of embedded system, which is a Wifi module for long-distance communication. With this module, the wireless communication function of WLAN can be expanded efficiently from the host USB interface of the embedded hardware. The communication function of LAN is realized by RT3070WMAC/BB of Ralink[10]. The sending and receiving function is achieved by RT3070. The IEEE802.11/b/g/n standard is fully implemented, and the maximum communication rate is up to 150Mbps. At the same time, the high gain power amplifier is integrated with three poles. The distance is further and the penetration is stronger.

3.4 GPS time-calibration module

GPS time-calibration module adopts low power consumption MAX7Q ofUblox. The connection between this chip and ARM9 is the serial port. The system uses 3.3V power supply. In order to improve the sensitivity of signal, the signal is received by active antenna. There is no FLASH in the module, and the power must be reconfigured.

4 System software design

4.1 Integrated processor software design

The software structure of integrated processor is shown in Fig6. The software structure of embedded Linux can be divided into system boot layer, kernel layer and application layer [11]. When the system starts up, the kernel boot code is firstly executed to set relevant hardware information and prepare the required software environment for the Linux operation. If the Boot loader code execution is completed, the program jumps to the entrance of the Linux system to start running the kernel. For the compressed image format kernel, the first step is to extract the kernel. Then the boot process mainly includes the implementation of the code associated with architecture, the establishment of MMU, page table and structure related variables. The driver is loaded, the console is initialized and the initial process is started. After the start of system, the various customized applications automatically run. The applications are based on C function library, the kernel function API, system calls, file system and kinds of protocols for completing the functions of the system. The work of the drive contains industrial Ethernet DM9000C driver transplantation, serial port driver extension, 18B20 temperature sensor driver, ADC driver and key device driver. The application design mainly includes the serial program, the network application program, the system state self-testing program, the system process monitoring program, the sending and receiving data cache program, data format conversion program.

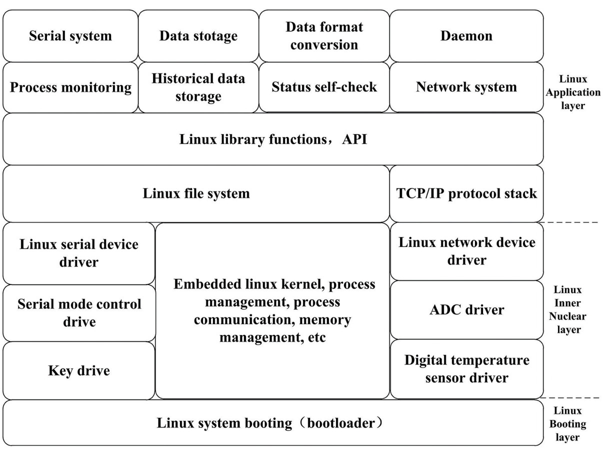

Fig. 5 Linux program structure of integrated processor

4.2 Data quality control algorithm

In order to guarantee the quality of observed data, the meteorological data should be carried on data quality control. The control algorithm is realized in the embedded system. In view of the observation elements of the current observation station, the five major categories of observation elements are selected for quality control, as shown in table 1.

Table 1 The list of quality control elements

Quality control elements	Quality control object
Temperature	Temperature per minute, the highest and lowest temperature per hour
Humidity	Humidity per minute, minimum humidity per hour
Wind direction and wind speed	Wind direction, wind speed per minute, the maximum wind speed and wind direction per hour
Air pressure	Air pressure per minute, the highest and lowest pressure per hour
Rainfall	Cumulative rainfall per hour

4.2.1 Climate limits check

For the Climatology, the maximum value of each climate element is regarded as climate limit values. If the detected data is out of the range, the data is wrong. the control algorithm is as follows:

- Temperature: $T_{MIN} < T < T_{MAX}$

$T_{MAX} = 40℃$, $T_{MIN} = -55℃$ January, February, October, December and November of every year;

$T_{MAX} = 45℃$, $T_{MIN} = -50℃$ March, April of every year;

$T_{MAX} = 50℃$, $T_{MIN} = -25℃$ May, June, July, August and September of every year;

- Humidity: $0\% < H < 100\%$;
- Wind direction: $0° < W_D < 360°$;
- Wind speed: $0m/s < W_S < 65m/s$;
- Air pressure: $520hPa < P < 1080hPa$;
- Cumulative rainfall per hour: $0mm < R < 150mm$。

4.2.2 Station boundary value check

Each observation station has the maximum and minimum value recordfor observation elements[12], and interface is programmed for a reservation. From Integrated controller to station, the observation of meteorological data should be ensured in a specific range of changes [X1, X2] to do the appropriate configuration. The X should meet the requirements as follows:

$$X \in [X1, X2] \quad (1)$$

4.2.3 Change rate check

Some meteorological elements have "stablity", and it is not easy to "change"[13]. The test of change is to verify the change rate of the instantaneous meteorological value, and check out the impractical spike signal or jump value, as well as the the dead measurement area caused by the sensor faults. Such as:

- The temperature change rate is less than 2℃/min;
- The humidity change rate is less than 5%/min;
- Wind speed change rate 20m/s;
- The pressure change rate is less than 0.3hPa/min.

4.2.4 Internal consistency check

For the examination of different factors, whether there is a physical connection is called internal consistency check. The basic algorithm to check the consistency of the data is based on the relationship between the two meteorological variables.

- The dew point temperature td≤t (temperature);
- The wind speed is WS = 00, then WD direction willnot change ;
- The wind speed WS ≠ 00, then WD direction willchange ;
- Maximum wind speed per minute is bigger than or the same with the average wind speed of 2 min and 10 min;
- The extreme value and its time should be corresponding with the corresponding period instantaneous value between meteorological factors;
- All cumulative amount should be corresponding with the corresponding period instantaneous value between meteorological factors[14].

4.2.5 Spatial consistency check

The spatial consistency is checkedfor the spatial distribution of meteorological data. The method can be used to determine when the integrated processor is connected to more than one meteorological data. The main space quality control method for the integrated processor is the Madsen-Allerupt. It is a kind of spatial quality control method that Madsen and Allerupt found[15]. The basic principle is based on the hypothesis that the spatial distribution of the elements in a certain space is assumed to be uniform. Then an ascending sort for the observation value at the same time of sensors is needed. So the statistics T^{it} is calculated for 1/4, 2/4, 3/4 values.

$$T^{it} = (X^{it} - q^{t,1/4}) / (q^{t,3/4} - q^{t,1/4}) \qquad (2)$$

The X^{it} is the observation value at the time t, qt,1/4、qt,2/4、qt,3/4 are the 1/4, 2/4, 3/4 bit value of the approaching sensor at the time t. When $|T^{it}|$ exceeds the specified value, the tested elements is wrong at the time t.

5 System test

After the system design is finished, the practical operation of the system is carried out in the observation field of Chengdu University of Information Technology to test the practical effect. The four serial ports separately access visibility meter, new type automatic station and radiation meter. Fig 6 is a picture of an integrated processor in the observation field , Fig 7 is the integrated processor System test diagram ,Fig 8 is the Computer terminal data test, Fig 9 is the Mobile phone Test data.

Fig. 6 Integrated processor in the observation field

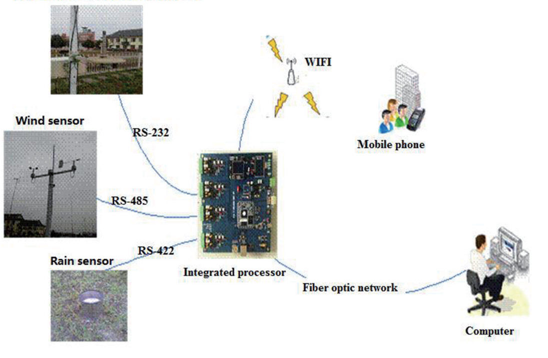

Fig. 7 System test diagram

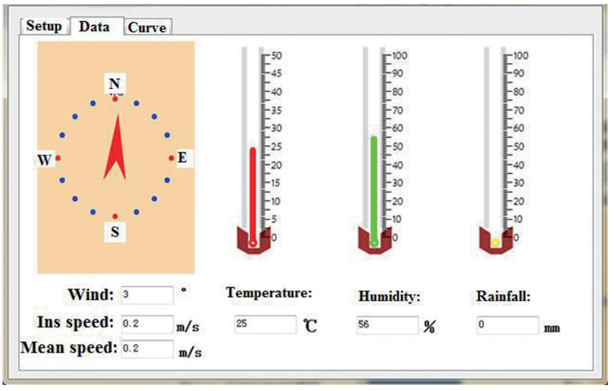

Fig. 8 Computer terminal data test

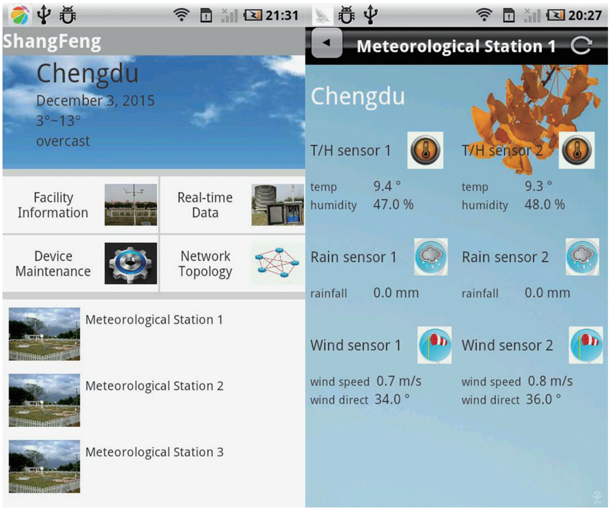

Fig. 9 Mobile phone data test

6 Conlusion

The system realizes the collection, transmission and storage of conventional surface meteorological observation data, and supports the Ethernet optical fiber connection with observation terminals. The way of connecting with observation device and sensors chooses from the RS-232/422/485 protocol. And the remote on-line update is convenient. The problem that current surface meteorological observation system cannot be adaptive to the change of equipment has been solved, as well as low degree of intensity service. The experimental results prove the system works stably and a good application prospect.

Acknowledgement

This work was supported by Meteorological Industry Research Projects (2013): Development and Application of Key Integration Technologies for Surface-based Meteorological Observation.

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Authors' Biographies

ZHAN Yanjun, born in 1980. Now is a lecturer in Chengdu University of Information Technology. Her research interests include atmospheric sounding technology and application, Signal processing.

Tel: +86-028-85966005
E-mail: angela-zhan@cuit.edu.cn