Exploitation of IP-based Intelligent Networked Measuring and Control Device and System

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Abstract: On the base of network frame and protocol system of Ethernet the networked sensing technology based on Ethernet is studied and the design principles of industrial Ethernet measurement of control system is put forward, and the general structure model is built in the paper. An eight-bit economical MCU scheme is proposed, and a general scheme of distributed intelligent networked measuring and control equipment based on TCP/IP is designed too. A compact TCP/IP protocol stack are successfully implemented in eight-bit MCU. With C51 program language, method of modularized programming is applied in soft design. The problem of in-system modifying measuring and control strategy of its system is solved successfully by assigning memory dynamically and saving parameter with EEPROM, and it makes the intelligent networked measurement and control system can explain and analyses control strategy from PC. Experiment result shows that, the research of intelligent networked measurement and control equipment and system base on TCP/IP is successful, with flexible network, convenient usage, and good commonality.

Keywords: Networked measuring and control, TCP/IP Protocol, Ethernet, Intelligent sensor

1. INTRODUCTION

Intelligent and networked measuring and control technology is already a trend and important study domain of control technology. As the combination of sensor technology, communication technology and computer technology, networked intelligent measuring and control technology is a new kind technology and makes traditional sensor a multifunction sensor which integrate many functions together such as signal detection, signal processing, data communication and etc. It makes sensor's functions progress qualitatively and breaks a new development direction for measuring and control technology. Going through the course from RS232/485-based system to field-bus-based control network, networked intelligent measuring and control technology become more and more mature and is applied broadly in industrial control domain. In recent years, with rapid development of Internet and Ethernet's particular advantage in network application, the study of networked intelligent measuring and control technology is now extending from traditional field-bus to Ethernet-based intelligent measuring and control technology[1-4]. Ethernet-based system has become a focal research point and applied more in distributed control area[5].

Ethernet-based intelligent measuring and control technology is the result of industrial control technology's fusion with Ethernet technology which traditionally is used in commercial or office service. Its predominance is as follows[6]: ①Its communication speed is fairly high and there are many kinds of Ethernet speed such as 10Mbps、100Mbps and1000Mbps. ② Ethernet can meet different requirements of measuring and control system and integrate enterprise information network into measuring and control network. ③ The cost of Ethernet equipment is low. With Ethernet's prevalence, personnel who are capable of maintaining Ethernet is easy to obtain and this reduce the maintaining cost accordingly. ④ Ethernet is easy to be integrated into Internet.

IP-based intelligent measuring and control network fully utilize the prevalence of Ethernet and adopt physical layer and data link layer standard of IEEE802.3 and TCP/IP protocol group, hence, IP-based intelligent measuring and control network can make people easily access control system through Internet and implement remote diagnosis, maintenance and service of measuring and control system.

2. STRUCTURE OF IP-BASED INTELLIGENT NETWORKED MEASURING AND CONTROL SYSTEM

2.1Rapid development of Ethernet technology guarantees its application in measuring and control area

Ethernet as a network technology originally was exploited for commercial and office circumstance. When it is used to construct system frame in measuring and control area, there are several problems to be solved such as non-determinacy, real-time characteristic, security (anti-explosion and etc.), reliability (for instance circumstance applicability) and etc.

①Media Access Control protocol is the main factor which affects data transportation determinacy of LAN. Its characteristic is that each node in network shares the same communication channel and gains required channel resource through competitive mode. When network loads are heavy, the collision which caused by nodes' competition for channel affects data-throughput and transportation time delay of Ethernet and reduces Ethernet performance. One solution to this problem is adopting Ethernet exchanger. From Fig. 1, we can see that each port is an individual collision domain and is separated from each other through exchanger, thus, there are many data channels among different switching ports and

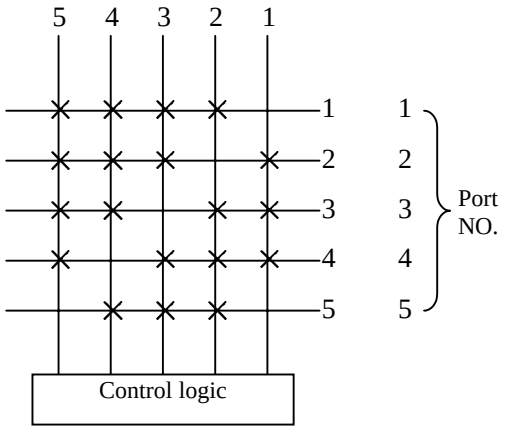

Fig.1 The schematic diagram of Ethernet exchanger

information stream on working ports will not be broadcasted on other ports. Furthermore, combining with full duplex Ethernet technology, communication time delay caused by collision can be restricted in certain range.

② The communication speed have been enhanced to 10M or 100M. At present, kilomega Ethernet has been applied at large. The enhancing of communication speed predicates the improvement of network-loads-capacity and can improve time delay characteristic of measuring and control network.

③ By improving Ethernet equipment, Ethernet of industrial control area can work firmly in such rigor environment as electromagnetic interference, vibration, pressure, high temperature, corrosion and so on. For example, unshielded twisted pair line with antiseptics coat can enhance strength and shielding effect of cable and decrease coupling capacitance at the same time. On account of optical fiber becoming more and more cheap, it has become the optimal choice. It not only can provide more bandwidth and farther transportation distance but also can greatly improve the reliability and accuracy of data transportation. Besides, connection-peg with waterproof and antimagnetic structure can be adopted. All this measures ensure that Ethernet can work steadily in industrial measuring and control environment.

signal to be sent to appointed device.

③Network measuring and control device should be easily connected to network. It should be a plug-and-play device and can be installed, debugged and used conveniently by user. Its using and maintaining cost should be as low as possible.

④Measuring and control device should be able to be configured according to different application situation so as to meet users' different requirement.

⑤Sensing parameters should be able to be set on-line. Device can work under single-machine or networking condition. It will be very flexible that the system operational parameters can be set not only at site but also from remote through Internet.

⑥Field equipment should be at equal position so that they can receive or transmit corresponding data from or to each other.

2.3 General frame of IP-based intelligent measuring and control network

Shown as Fig.2, The whole system include intelligent networked measuring and control device(INMCD), Ethernet exchanger or hub, field-monitoring computer and etc. thereinto,

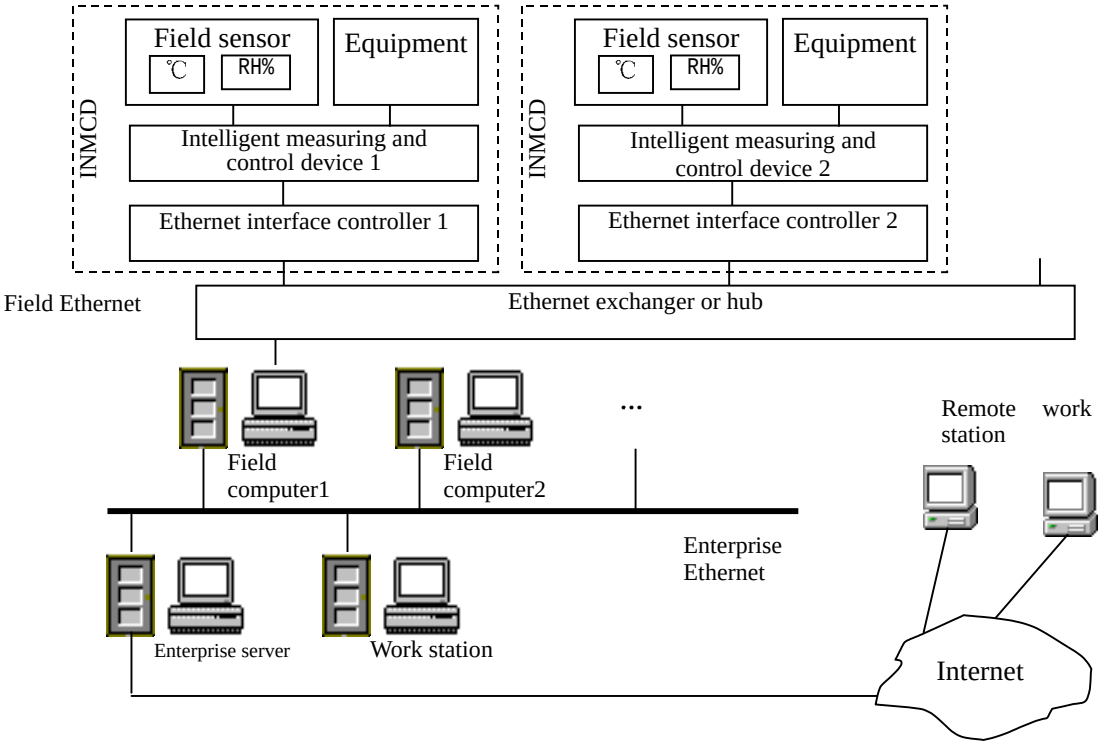

Fig.2 The gross structure diagram of networked measurement and control platform

2.2 Applying Ethernet to field networked industrial measuring and control system should follow some design principles:

①It is the basic requirement of measuring and control system to ensure the stabilization and credibility of data transportation.

②Real-time characteristic is also necessary to system, especially to some emergency data such as alarm signal. Corresponding strategy must be adopted to ensure this kind of

intelligent networked measuring and control device is composed of Ethernet interface controller and other sensors and equipments. In succession, we mainly discuss measuring and control platform.

① Sensor is used for collecting field data and pass them to intelligent measuring and control device to process. Field measuring and control device implement control function by passing control instruction to controlled equipment. The measuring and control strategy of each device can be modified on-line on field computer and transmitted to field measuring and control device through Ethernet interface controller. Owing

to having its own measuring and control strategy, field intelligent networked measuring and control device can cooperate with each other even field computer is shut down or is in failure.

② Network interface controller as a intelligent equipment is the core of networked measuring and control device. It has output scheduling (such as choosing remote output or local output).

Communication module can transmit local data to remote and receive remote control instruction. Network interface adapter is the core of IP-based intelligent measuring and control network. The hardware structure of Ethernet communication controller is shown in Fig.3. thereinto, we

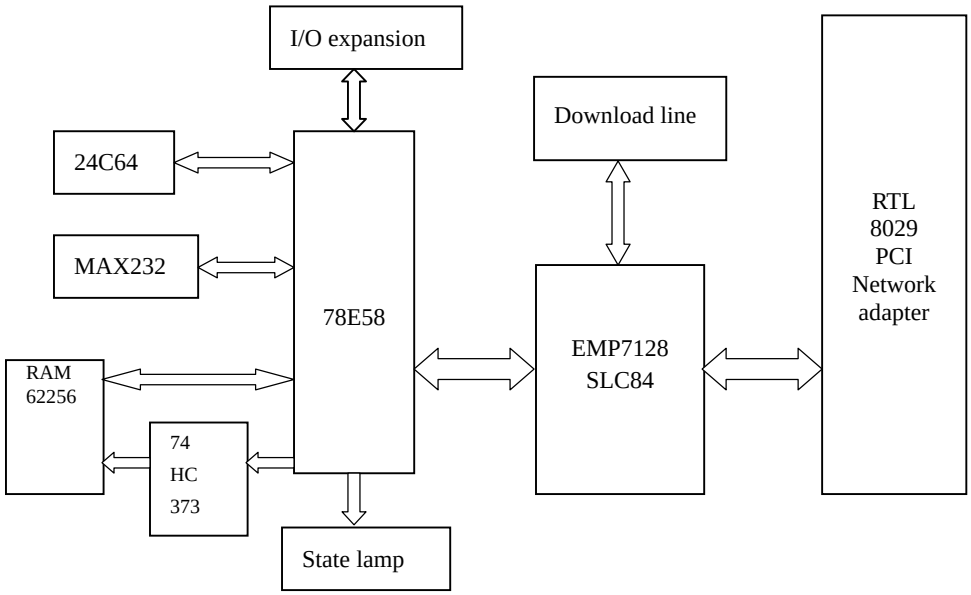

Fig.3 The hardware structure diagram of Ethernet communication controller

standard Ethernet interface and acts as the access from device to network. In it TCP/IP protocol is embedded for the need of communication. It can also integrate traditional sensors and equipments which can not communicate through Ethernet into new measuring and control system based on Ethernet communication technology. It also acts as transforming interface between RS232/485 and Ethernet. It realizes the communication among different field devices and field measuring and control computers.

③ Field measuring and control computer mainly manage and schedule whole field Ethernet as gateway of field Ethernet and enterprise Ethernet. It integrates equipment of field Ethernet into information management system of enterprise Ethernet and blocks unauthorized access to sensors and equipment in field Ethernet from exterior.

3. IP-BASED INTELLIGENT NETWORKED MEASURING AND CONTROL DEVICE

3.1 Hardware structure of IP-based intelligent networked measuring and control device

IP-based intelligent networked measuring and control device is divided into 5 parts: sensor module, signal process module, Ethernet communication module, keyboard module and LCD display module.

Sensor input module consists of analog quantity input, digital quantity input and switching value. Input of analog quantities are implemented by some sensing units such as humiture sensing unit, photosensitive sensing unit and gas sensitive unit.

Signal process module's core is MCU and mainly realizes A/D conversion, digital signal processing (for example digital filter, nonlinear compensation and self-diagnosis) and data

select a 8-bit MCU, 78E58B, as central controller to drive network adapter with 8029 chip. A compact TCP/IP protocol, which include ICMP、IP、ARP、TCP、UDP and etc., is run in the MCU. Electrically erasable ROM (EEPROM) need not complicated circuit structure and can be expanded with flexibility. Even the power source is shut down, can the data in it be preserved for a long time. As exterior memory, it is used to preserve some parameter setting and system control strategy configuration, and it has high reliability. With it, we successfully solve the problem of modifying network measuring and control strategy of system on-line. When the intelligent networked measuring and control device receives strategy from superior computer, it dynamically add or decrease variables according to strategies of different complexity and save the diagnosis and explanation result into EEPROM. This make each networked measuring and control device has individual measuring and control scheme. All devices in system can cooperate with each other to complete integrated function. The logic design of CPLD chip is custom-built according to 8029 network adapter in order to drive PCI network adapter. With customized CPLD, MCU can access RTL8029AS network adapter through PCI-bus using only little I/O and control chip foot.

Keyboard module mainly provides setting at site function of system parameters. It works under interrupt mode. Whole keyboard has 4 individual function keys and a reset key.

LCD display module consists of LCD screen, LCD controller and display memory. It connects to MCU with indirect interface. As control center of display system, LCD controller receive control instruction from measuring and control computer, analyze those instructions and control each part in system cooperate with each other to accomplish instruction.

3.2 Protocol and soft structure of IP-based intelligent networked measuring and control device

TCP/IP hierarchical model is based on 4 layers structure, as shown in Fig.4. Whole TCP/IP protocol system is very huge

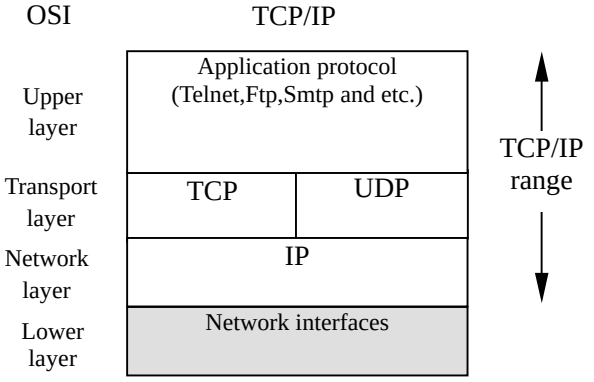

Fig.4 The architecture of TCP/IP

and need to engage a great of hardware resource, so it is impossible to implement in ordinary 8-bit MCU. In fact, it is not necessary to use whole function of TCP/IP, so we only use a compact protocol. Thereinto, IP layer's main function is network routing and it is also the base of Internet. Transport layer provide peer-to-peer connection-oriented service or unconnected data packet service. Superior to transport layer, there is application layer. In application layer, users can exploit all kinds of application-based control program.

Whole system program consists of 5 modules and several sub-modules, as shown in Fig.5. Data acquisition and process module mainly accomplish analog signal acquisition and process, digital signal acquisition and process and switching signal acquisition and process. Series port communication module is used as system debugging and parameter setting port. Ethernet communication module mainly implements Ethernet data packing, unpacking and other data receiving/transmitting functions. Man-machine interactive module is the interface of keyboard process and display parameter setting. Measuring and control strategy analysis and execution module mainly analyse strategy from superior computer, store, call and execute measuring and control strategy to drive PLC, signal lamp and etc.

We design application program with C51 language. With structure and union these two data structure of C language, we encapsulate the format of TCP, IP and Ethernet frame packet. For high-level language has superiority in processing complicated data structure, the program is more standard and legible. Traditional MCU system is a single task system whereas in our system, one equipment may communicate with several equipments through Ethernet. In order to make system be more flexible and meet requirement of complicated system, we adopt the RTX51 Tiny, a multitask real-time operation system designed for 8051 processor. Each module is programmed into corresponding sub-task. Using time slice loop scheduling method, each sub-task is allocated a time slice of same length and access CPU separately in its own time slice. Thus, microscopic rotation running appears concurrence running on macroscopy.

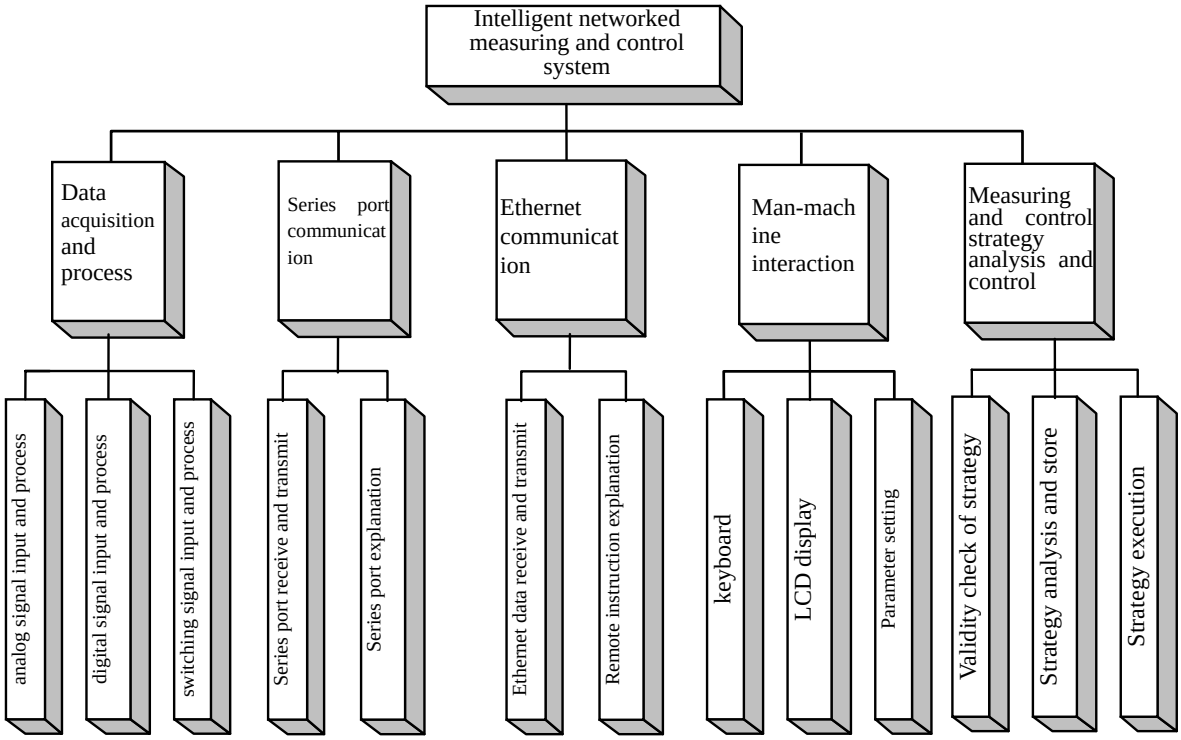

Fig.5 The task frame diagram of intelligent networked measurement and control system

4. APPLICATION IN ENVIRONMENT FACTOR MEASURING AND CONTROL OF IP-BASED INTELLIGENT NETWORKED MEASURING AND CONTROL DEVICE

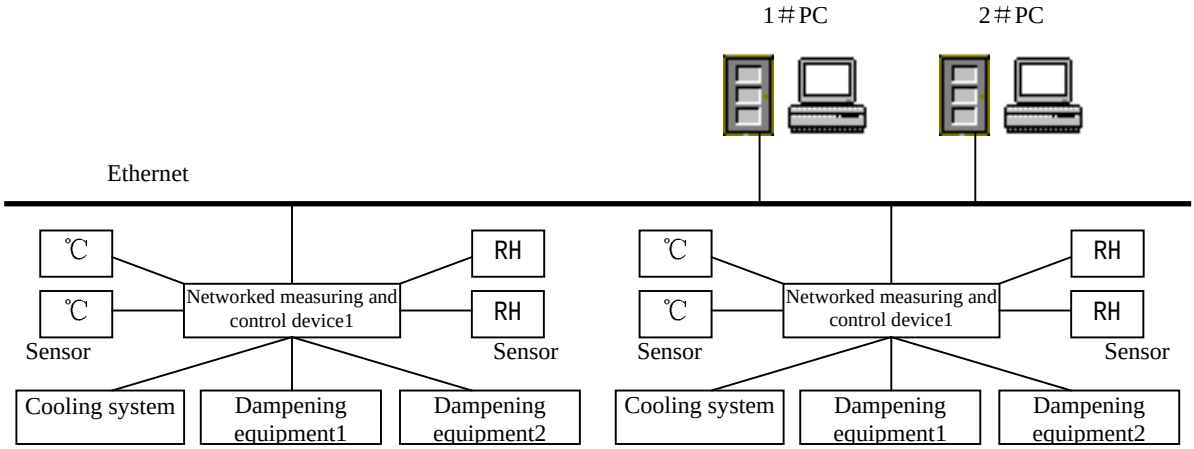

Fig. 6 Connection diagram of experiment equipments

On the base of intelligent networked measuring and control device above, environment factor measuring and control experiment is carried out. The experiment scheme is shown in Fig.6. In experiment, networked measuring and control device is used to collect temperature and humidity states and control cooling system and dampening system according to measuring and control strategy. The microcomputer connected to Ethernet receive data from networked measuring and control device and display running condition on virtual instrument panel through terminal monitoring soft.

After being connected to network and setting the IP of system according to scheme, the system is successfully connected, corresponding humiture is displayed on microcomputer screen and corresponding analog equipment signal is turned on. Experiment result shows that, our networked measuring and control device can successfully be connect to remote host computer through TCP/IP protocol and remote host computer can also implement such tasks as data acquisition, data processing, result display, remote control and etc. through the device. The result proves that the device realizes the function of remote networked measuring and control and meets the anticipated system-designing.

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