Design and implementation of a security system based on ADSL access technology

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Abstract. Taking the network switching equipment and the microcontroller as the core, a security system based on ADSL access technology is designed with the embedded method. The structure and communication mode of the security system are studied from three aspects: network switching equipment configurations, network communication module design of uplink equipment and communication module design of ADSL access equipment. The system can establish security monitoring points on existing telephone lines, which can not only meet the security protection requirements of high bandwidth, long transmission distance and information security, but can also reach the level of several kilometres. Furthermore, it can greatly reduce construction costs and operation costs of security system, and effectively realize the logistic support ability of security system.

1. Introduction

The safety protection of each computer room in the measurement and control area is an important guarantee for the safe and stable operation of the measurement and control equipment. At present, the existing safety protection systems on the market are generally suitable for short-distance or small-scale office areas, computer rooms and other places, and are not appropriate for long-distance, widely distributed measurement and control areas. For areas with coverage of kilometers, there are currently two common security network management approaches to establish the system: One is relying on the telecommunication providers such as China Mobile or China Telecom with a wide distribution range [1], which has a risk of leaking secrets and high maintenance costs later; The second is adopting the optical fiber networking technology for network management [2], which requires higher construction costs [3], and fiber has not yet been popularized at each location in the measurement and control area. Due to various restrictions mentioned above, the security guarantee of the measurement and control area had always depended on traditional methods such as manual inspection and telephone alarms, which were labor-intensive, complicated, and non-real-time. So, it is particularly urgent to study convenient and reliable security systems.

Because of the wired telephone lines equipped in each computer room, it is feasible research direction to design a security system relying on them. The full name of ADSL is Asymmetric Digital Subscriber Line, which divides ordinary telephone lines into three independent channels: data uplink, data downlink and telephone data through frequency division and multiplexing technology. ADSL access technology can guarantee no interference between the fixed telephone service and high-speed data transmission, and have a long transmission distance and simple access. Due to the above characteristics, ADSL access technology has been widely used. Taking the field of monitoring and security as an example, the researchers have studied and realized the centralized supervision of heating
data [4], petroleum data collection network [5], boiler data collection network [6]. But if the above schemes are applied to the measurement and control area directly, it is necessary to modify the existing communication cable and network equipment, thus it will affect the reliability of the measurement and control network services, which is not allowed. This paper designs a security system based on ADSL access technology, which can not only meet the requirements of coverage, data bandwidth, transmission distance, and information security, but can be also erected and managed without changing the existing communication cable layout.

2. Overall design of security system

2.1. Security system composition

The security system based on ADSL access technology includes three major parts: uplink equipment, network switching equipment and ADSL access equipment, as shown in Figure 1.

![Figure 1. The structure connection diagram of the security system.](image)

The uplink equipment acts as a server. It communicates with each ADSL access equipment through network switching equipment, and receives real-time working conditions of each computer room in the measurement and control area.

The network switching equipment is the communication hub of the whole security system, which includes ZXDSL9806H [7], TL-SF1008L and some modems. ZXDSL9806H is broadband access equipment and TL-SF1008L is a two-layer network switch. The configuration of network switching equipment will directly affect the network data transfer.

The ADSL access equipment serves as clients, which includes system terminal boxes, a monitoring computer and network cameras. ADSL access equipment can receive the latest GPS time information from the uplink equipment. It also reports the link monitoring data and the current working state data of the monitoring points to the uplink equipment.

Each piece of ADSL access equipment can send out alarms, issue voices and take videos.

2.2. The access method of ADSL equipment

Each computer room in the measurement and control area is equipped with landline phones and telephone lines. With a telephone separator, two landline phones can share the same telephone line at least. One of the landline phones can be replaced with a piece of ADSL access equipment, then they can transmit telephone voices and network information at the same time without mutual interference.

All of the ADSL access equipment can be connected to the security system in this way, which enables network communication with the uplink equipment.

3. Network configuration of security system

3.1. Network device connection

ZXDSL9806H, TL-SF1008L and modems work together to configure two VLAN networks for the system. They can achieve data communication between the uplink equipment and system terminal.
boxes, network cameras and the monitoring computer. Figure 2 is the connection diagram of network equipment of the security system.

![Figure 2](image_url)

**Figure 2.** The connection diagram of network equipment of the security system.

The alarm voice information transmitted among the uplink equipment and system terminal boxes is non-real-time with small amount of data, it should belong to low-speed network services. While the surveillance video information transmitted between each network camera and the monitoring computer is always real-time with large amount of data, so it should belong to high-speed network services.

### 3.2. ZXDSL9806H network configuration

In order to transmit the above two types of network data quickly and efficiently, the alarm voice information and the surveillance video information should be separated into two VLANs when configuring the ZXDSL9806H. The configuration includes four parts: VLAN network configuration, Ports isolation settings, ADSL user access configuration and multicast configuration.

1. **VLAN network configuration:** It is mainly used to set up VLAN1 for the low-speed network service and VLAN2 for the high-speed network service. The 24 ports of ZXDSL9806H are available to 24 users. When assigning ports, the ports 1-12 are assigned to VLAN1 users as input and output of alarm voice information. The ports 13-24 are assigned to VLAN2 users to transfer surveillance video information. Aiming at receiving surveillance video information, port 1 is configured to the monitoring computer. Therefore, port 1 belongs to VLAN1 and VLAN2 respectively. The uplink ports FE1, FE2 and the ports 1-24 should be assigned to different network services. The uplink ports FE1 and FE2 (with “tag” mode) and ports 1-12 (with “untag” mode) are added to VLAN1. The ports 13-24 (with “untag” mode) and the port 1 are added to VLAN2.

2. **Ports isolation settings:** By default, ZXDSL9806H 1-24 ports are isolated from each other and cannot be accessed, but the isolation relationship can be released through network configuration commands. For the low-speed service VLAN1, alarm data information exists between the system terminal boxes and the uplink equipment. It does not require the mutual communication between the ports in VLAN1, so the default state of the ports 1-24 is maintained. However, for the high-speed service VLAN2, the surveillance video information of the ports 13-24 is sent to the TL-SF1008L through port 1, so VLAN2 ports need to be deisolated to communicate with each other. In addition, both low-speed and high-speed services use multicast protocols to communicate.

3. **ADSL user access configuration:** ADSL users access configuration is mainly used to set the virtual path and channel parameters of user ports. It need create a ADSL line configuration file and an alarm line file, and enable ADSL ports.
(4) Multicast configuration: Multicast configuration is set for low-speed VLAN1 network and high-speed VLAN2 network, including multicast numbers, multicast IP, multicast source IP, multicast source ports and destination ports.

3.3. TL-SF1008L network configuration
ZXDSL9806H uplink ports FE1 and FE2 only receive “tag” data packets, and discard all packets marked as “untag”. The TL-SF1008L should implement two functions: firstly, it receives data packets marked as “tag” from the ZXDSL9806H ports, then removes “tag” and sends them to the upper equipment; secondly, it receives packets marked as “untag” from the upper equipment, then adds “tag” to them and sends them to the ZXDSL9806H. Therefore, for the network configuration of the TL-SF1008L, it is only necessary to set "Insert VLAN Tag" to the ZXDSL9806H uplink port and "Remove VLAN Tag" to the uplink equipment. "VLAN ID" settings are the same for TL-SF1008L and ZXDSL9806H.

4. Software and hardware design of network communication of security system

4.1. Software and hardware design of the network communication modules of uplink equipment
The uplink equipment includes the GPS acquisition module, network communication module and voice alarm module. The communication of network data mainly includes two aspects: one is to receive the link monitoring data and real-time voice alarm data from each piece of ADSL access equipment, the other one is to send the latest GPS time data and the real-time voice alarm data of the ADSL access equipment to the others. The uplink equipment works in full-duplex mode. It forwards the two types of data on the network, using unicast and multicast communication respectively.

The system sends and receives data through a microcontroller and a network interface module. The microcontroller adopts Microchip's PIC24FJ256GA108 [8] and the network interface module adopts the ethernet controller W5300 [9]. W5300 uses 8-bit direct address mode addressing registers. In order to reduce the network data forwarding conflicts during the communication process, W5300 selects the port register SOCKET0-3 to communication. SOCKET0 is used to send time data. SOCKET2 is used to receive time data. SOCKET1 is used to send real-time voice data and alarm data, and SOCKET3 is used to receive real-time voice data and alarm data.

![Figure 3. The network communication process of W5300.](image)

The network communication process of W5300 is shown in Figure 3. After the SOCKET ports finish their initialization, the system starts to judge whether to send data. Two flags “gps_mark” and
“receive_voice_n” (n represents different pieces of access equipment) are set in program code, indicating that whether GPS time data and real-time voice alarm data is received respectively. When their value is "1", it means that the corresponding data has been received. When their value is "0", it means that the data has not been received. For example, if the uplink equipment queries “gps_mark=1”, it means that the uplink equipment has collected the latest GPS time, then the uplink equipment will send GPS time data to the ADSL access equipment in multicast mode; If the uplink equipment queries “receive_voice_n=0”, it means that no real-time voice and alarm data is received, then the next GPS time will be sent.

At the same time, the ADSL access equipment reports the current link monitoring data of the terminal at a rate of 10 seconds per frame. The uplink equipment will check whether the terminal network data is correct. A flag “receive_time_n” is also set in the program code. If the uplink equipment checks that “receive_time_n=0” and “receive_voice_n=0”, it shows that time data and voice alarm data of the ADSL access equipment has not been received, the uplink equipment will ascertain that which ADSL access equipment it is by acquiring the port number.

4.2. Software and hardware design of network communication modules for the ADSL access equipment

ADSL access equipment includes network cameras, the monitoring computer and system terminal boxes. The network cameras and monitoring computer can be directly connected to the network switching equipment, without the need to design a separate network communication module. The microcontroller adopts PIC24FJ256GA108 and the network communication module adopts W5500.

![Figure 4. The circuit composition of the terminal box of the alarm system.](image)

The circuit composition of each system terminal box includes a single chip microcomputer circuit, a network interface circuit, an alarm and a fixed voice playing circuit, a real-time voice acquisition circuit, an audio amplification circuit and an operation display circuit. Figure 4 shows the composition of the terminal box of the alarm system.

There are three types of signal sources for voice alarms: the manual switch alarm, the environmental induction alarm, and the real-time voice alarm.

The manual switch sends alarms in the form of “terminal box number + alarm”, and the alarm sent by manual voice can be freely expressed. In the event of environmental induction alarm, the alarm signal is transmitted in the form of "terminal box number + type of alarm information". When the sensors for smoke, water immersion, motion detection, temperature and humidity connected to the terminal box sense the change of the environment, they send alarm signals to the PIC24FJ256GA108 through the RS485 interface. Then the signal-to-speech conversion is achieved through the voice processing circuit.

The system terminal boxes contain the network communication module and the voice alarm module. Both of them operate under the control of the PIC24FJ256GA108. The system terminal boxes receive the latest GPS time data and voice alarm data from the uplink equipment, report the link monitoring data and the local real-time voice alarm data to the uplink equipment.

W5500 is controlled by SPI data frames when it communicates with PIC24FJ256GA108. A SPI data frame includes three parts: the address segment, the control terminal and the data segment. The
address segment specifies a 16-bit offset address for W5500 registers. The value of the offset address is transmitted from the highest flag bit to the lowest flag bit. The control terminal is represented by 8 bits, which are used to select registers, and can specify the attribution, read/write access mode and SPI operation mode of offset area set by the address segment. The data segment can be set to any length or fixed length, such as 1 byte, 2 bytes or 4 bytes. The system adopts different byte lengths for the data segments depending on the data forwarded.

The data reading and writing of the SOCKET register is followed by the SPI frame format. During the read operation, the value of the read/write control bit (RWB) is "0" and the value of the operating mode bit (OM [1: 0]) is "00" in the SPI control segment. During the write operation, the value of the read/write control bit (RWB) is "1" and the value of the working mode bit (OM [1: 0]) is "00" in the SPI control segment. The network communication flow of W5500 in ADSL access equipment is shown in Figure 5. The size of these two types of data will affect the network data sending, so the data field length is set to 256 bytes during the software design.

![Diagram](image_url)

**Figure 5.** The network communication process of W5500.

### 5. System implementation

The uplink equipment, ZXDSL9806H and TL-SF1008L were mounted on the overall wiring rack of the wired telephone in the area, where the security system was located. A terminal box of the ADSL access equipment is shown in Figure 6. The separators, ADSL modem, and the terminal boxes were installed in the security system monitoring points, such as computer rooms.

The results show that the terminal boxes can function properly within 5 km. They have correct and responsive information display, stable and reliable system operation. The operation of the security system does not affect telephone conversations.

The advantages of the entire security system are as follows:

1. There are many kinds of security alarm information. In addition to switch alarm and artificial voice alarm, it can also realize automatic alarm of smoke, water immersion, temperature and humidity overruns;
2. The alarm voice changes according to the alarm event, any security terminal can receive the alarm information within 10 seconds. Furthermore, the voice automatically loops, which is very intuitive and clear;
3. The monitoring information is various. The terminal box can display the online status of other access equipment. Besides the above functions, the monitoring computer can display the video surveillance of each computer room in real time;
4. Any terminal box can carry out voice of the whole network or special line, and can give an alarm or talk in real time.

In summary, the established security system not only has a low cost, but also meets the security network management needs of each computer room in the measurement and control area. Finally, it provides a stable and reliable security guarantee for the measurement and control area.
6. Conclusions
For the measurement and control area, a security system based on ADSL access technology is designed by using the existing cable telephone lines. The network communication module of the uplink equipment and ADSL access equipment of the security system are studied. It realizes a variety of environment-sensing automatic alarms, voice broadcast and terminal distributed linkages. The validated results show that the system can establish monitoring points on the existing telephone lines. Even in the places where there is no existing cable telephone line, the cost of setting up new telephone cable is very low. So it can reduce the construction cost and operation cost of the security system. Ultimately, it matches security requirements of the measurement and control area, with high bandwidth, long transmission distance and information security.

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