Acta Technica *62*, No. 1A/2017, 21–32

The industrial network system design based on PROFINET[1]

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Abstract. With the development of Internet / Intranet technology, the traditional system has been unable to meet the requirements of modern industrial production and management. As a superior model to realize the integration of micro control and macro decision, the industrial network system based on PROFINET has been widely used in industrial process control. Based on the analysis of the layout of the plant and the communication needs, Bus and Ring topology structure was used, hierarchical network design model was designed. And the convergence layer network, access layer network, wireless access network and mobile AGV car terminal network were designed, the system fault treatment and late optimization program were put forward, factory network coverage, real-time monitoring of production data and field conditions were realized. The industrial Ethernet system based on PROFINET has good stability, reliability and expansibility. It improves the ability to withstand and solves the fault, meets the requirements of the production site, and it has a certain directive significance to other applications.

Key words. Industrial network, PROFINET, Ethernet, ring network redundancy.

1. Introduction

The Industrial network mainly meets the exchange of information between various levels of enterprise demands and it is the basic key system in process of the production, manufacture, packaging, etc. In the industrial field, the technology and equipment of commercial network could not be transplanted and reused if it needs to demand the real-time controlling of specific industrial process and the safety request of industrial production. Due to lacking of the international standard, every manufacturer forms an independent production and design according to their own standards of production in order seize market. So the products from different manufacturers cannot be compatible so that the equipment charge is hard to control.

[1]Foundation item: Research and industrialization of high speed precision robot and automatic production line for electronic device assembly (No. 2015BAF10B00).

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It results in great obstacles for the development of industrial automation and the application of new technology.

In 2002, the PROFIBus International Organization (PI) launched an open and automatic Industrial Ethernet standard – PROFINET which is based on Ethernet. It uses the open IT standard. And it is compatible with the Ethernet TCP/IP standard, provides the real-time function, integrates with the existing field bus system, so as to protect the original investment. At present, the PROFINET standard has become a component of IEC 61784 and IEC 61158.

According to the new network architecture pushed out by SIEMENS PROFINET which instead of the original PROFINET has the three major advantages: open, standard, real time, the main solution framework was designed, the current industrial network design was analyzed mainly in the industrial 4 digital chemical plant backbone network for the application background, reflects the high-speed and real-time network demands under the industrial production. Virtual network VLAN, static routing, real time communication, wireless communication and redundant network core technology were designed, the system fault treatment and late optimization program were put forward, factory network coverage, real-time monitoring of production data and field conditions were realized. Therefore, it is a new method to design a hierarchical network based on PROFINET standard. Its theory and model is relatively simple, the evaluation is easily to realize. It can solve the problem that how to monitors industrial networks reliably from a macro perspective, which is the urgent need for the implementation of automation management and access to the Internet in the industrial field.

2. Methodology

2.1. The analysis of design requirements

According to the principle of industrial production rationalization, combined with the actual plant design, the plant area is analyzed by straight line manufacturing process. The first production line is controlled and managed 200 meters outside. The total length of the production line is 1800 m (300 m×6). In this range, the industrial network configuration mode and layout plan are given. And it should need to meet the following requirements:

(1). Integrated monitoring system to monitor the video server and PLC controller; Control center of the PLC control and production line AGV car I/O PLC devices to achieve real-time data communication, real-time data refresh time of 256 milliseconds; IP camera data and video server to achieve data communication.

(2).The convergence layer network and the access layer network realize the wired data communication, and the convergence layer uses the 1000 Mbit/s multi-mode optical fiber, and the access layer uses the 100 Mbit/s multi-mode optical fiber; Wireless overlay network in the full range of real-time seamless switching and data transmission, AP uses an omni-directional antenna and AP between the need to set roaming, and with the AGV car to achieve wireless data communication; From the bottom of the data transmission (AGV car) will be the video signal and control data

sub network isolation.

(3). To fully consider the redundancy of each network layer.

2.2. The design of topology structure

Network topology needs to be set according to the requirements of equipment units in the network which is the spatial structure of the transmission medium. Different network topology has different effects on the network transmission capacity. Network topology structure is composed of three basic topology structures that are Bus, Star and Ring. Blending of the three basic topology structures is completed in the practical project application.

Star topology structure. It refers to each site device is connected to a switch that presents a star distribution. It can be used in the field of high density of equipment, small coverage, and small space expansion, just like large car asked the control area, independent production machines or small automatic workshop. When other devices in the PROFINET network fails, it will not affect the entire network, only the switch failure will cause network communication failure.

Tree topology structure. It is formed by connecting several star topology structures together. It can be divided into several parts of the installation of complex equipment, to communicate as an independent device. Its level is very clear, the network transmission capacity is high and the data has a better security.

Bus topology structure. PROFINET network structure is similar to the Profibus bus structure, all communications equipment is a serial connection, the application of the switch is installed in the PROFINET network, to achieve PROFINET bus topology structure. Bus topology structure is realized by the switch switch which is close to the connecting terminal, it can be applied in the need to extend the structure of the bus system towel, also gives priority to the use of the best delivery systems, assembly lines and other equipment. In order to reduce the cable weight, the bus configuration can be selected. It is cabling saving, easy maintenance and maintain.

Ring topology structure. All sites are connected by an annular cable to form a ring topology structure. When the system has high availability of network components, it can be used to prevent the occurrence of a broken cable or a fault. In order to increase the effectiveness, Ring topology structure with redundancy can be selected. The advantages of ring topology in dealing with network component failures easily.

Therefore, the factory network can be divided into the aggregation layer network (including the control center, the production line main switch), the access layer network (to connect the wireless access point AP equipment), wireless coverage access network and mobile AGV car terminal network.

2.3. The design of topology structure

The internal network topology structure of the car adopts the Bus and Ring topology structures. It realizes the video data collection by IP camera, control data monitoring by PROFINET IO devices and uses SCALANCE W721 as a wireless

client and upper network (wireless access network covering layer) for wireless communications. It uses SCALANCE X310 as the car switches, IP camera, PROFINET IO devices and wireless client are connected via industrial Ethernet cable and switch.

However, considering the transmission distance of 5 GHz is lower than 2.4 GHz and the interference of the same frequency is small. According to the linear production line of the factory, the wireless coverage into the network and the need to meet the real-time transmission of video data and other specific circumstances, in order to avoid the same frequency interference, to ensure the transmission rate and relatively long-distance transmission, the program used 5 GHz band.

Using the PLC S7-1200 as the PROFINET I/O controller and the PROFINET I/O device, the PROFINET I/O controller is placed in the control center and the PROFINET I/O device is configured in each AGV car. Through the integrated monitoring system using the map software on the PROFINET I/O controller to operate, to achieve each AGV car control data monitoring and control, real-time communication data refresh time is set to 256 milliseconds.

Since five cars are in the lowest level of the network, and the small car wireless client has the same role. This layer switches can be divided in the same subnet; similarly, five IP cameras and five PROFINET I/O devices at the same time. As the network terminal, it is divided into the same subnet. According to the terminal equipment connected with the port must be in the same subnet, the gateway can get the switch ports. And five AGV cars were named AGV1, AGV2, AGV3, AGV4 and AGV5, as shown in Table 1. Now the wireless client is connected to port 2 of the switch, the IP camera is connected to port 3 of the switch, the PROFINET I/O device is connected to the switch of port, as shown in Table 2.

2.4. The design of wireless access network

Wireless access network layer is the main equipment of the wireless access point AP, W761 SCALANCE is selected. According to the technical requirements, an AP should be placed place, so as to complete the network coverage in the AGV car running track. Due to the lateral coverage of the AP omnidirectional antenna is circular, the AP should be set in the first production line and the first six production line tail in order to avoid dead ends. It is 19 AP totally. In the full range, real-time seamless video and data delivery ensure that the AGV car seamlessly switches in the high-speed mobile, the method that configure AP roaming is used to solve the technical requirements.

Table 1. VLAN division

VLAN ID Switch	AGV1's Switch	AGV2's Switch	AGV3's Switch	AGV4's Switch	AGV5's Switch
201	P1.3	P1.3	P1.3	P1.3	P1.3
202	P1.4	P1.4	P1.4	P1.4	P1.4
Note: This table is a single trunk VLAN trunk connection label settings, and the remaining trolley settings and this exactly the same.					

When VLAN is used for data isolation, the data in different VLAN needs to be transmitted at the same time on the trunk line. The VLAN connection of the switch to the switch (trunk trunk) must contain the VLAN tag. So the trunk connection should be to M for each VLAN ID, which is shown as Table 3.

Table 2. IP planning of mobile AGV car terminal network layer

	AGV1	AGV2	AGV3	AGV4	AGV5
Wireless client	192.168.25.1/21	192.168.25/21	192.168.25.3/21	192.168.25.4/21	192.168.25.5/21
IP camera	192.168.25.6/21	192.168.25.7/21	192.168.25.8/21	192.168.25.9/21	192.168.25.10/21
PROFINET I/O Device	192.168.25.11/21	192.168.25.12/21	192.168.25.13/21	192.168.25.14/21	192.168.25.15/21
P1.2	192.168.25.16/21	192.168.25.17/21	192.168.25.18/21	192.168.25.19/21	192.168.250/21
P1.3	192.168.251/21	192.168.252/21	192.168.253/21	192.168.254/21	192.168.255/21
P1.4	192.168.256/21	192.168.257/21	192.168.258/21	192.168.259/21	192.168.25.30/21

Note: Taking into account the number of IP needed for the upper layer equipment and ensure that the system can easily upgrade the network, and in order to facilitate the management of network equipment at all levels, The first 21 bits are selected as the primary network number. The rest of the layers are taken this method, the following will not repeat them.

Table 3. VLAN trunk connection settings

VLAN ID	P1.1	P1.2	P1.3	P1.4
1	U	-	-	-
201	-	M	U	-
202	-	M	-	U

Note: This table is a single trunk VLAN trunk connection label settings, and the remaining trolley settings and this exactly the same.

There are six main steps to build a wireless roaming network with multiple AP.

(1) Each AP set a different IP address to avoid the IP address conflict;

(2) Each AP sets the same SSID in the same data channel and sets the different SSID in the different data channel;

(3) Adjacent APs are placed in different frequency bands and are separated by more than 5 frequency bands to avoid mutual interference;

(4) The same encryption and authentication mode is set for each AP;

(5) Each AP sets the same password, and different AP in different data channels set different passwords;

(6) Each AP sets the same management channel.

The iPCF function is enabled on each AP. The AP are connected to their clients in turn in a fixed order. Each client takes about 2ms to transmit data. After

each client's communication, the polling interval. There is a short time slot, and a broadcast packet can be sent at this time, if necessary. Since there is no priority level for packets in the transmission buffer in the task request, the non-PNIO mode is used.

AP set from left to right is 1 to 19, which is shown as Table 4.

Table 4. AP roaming settings and wireless coverage Access network IP planning

AP	IP	SSID	Channel	Encryption	password
1	192.168.26.1/21	SiemensAPLine12	1	WPA2-PSK	SiemensCupLine1
2	192.168.26.2/21		6		
3	192.168.26.3/21		11		
4	192.168.26.4/21		1		
5	192.168.26.5/21	SiemensAPLine2	6		SiemensCupLine2
6	192.168.26.6/21		11		
7	192.168.26.7/21		1		
8	192.168.26.8/21	SiemensAPLine3	6		SiemensCupLine3
9	192.168.26.9/21		11		
10	192.168.26.10/21		1		
11	192.168.26.11/21	SiemensAPLine4	6		SiemensCupLine4
12	192.168.26.12/21		11		
13	192.168.26.13/21		1		
14	192.168.26.14/21	SiemensAPLine5	6		SiemensCupLine5
15	192.168.26.15/21		11		
16	192.168.26.16/21		1		
17	192.168.26.17/21	SiemensAPLine6	6		SiemensCupLine6
18	192.168.26.18/21		11		
19	192.168.26.19/21		1		

Note: Encryption Authentication Select the WPA2-PSK mode that is currently the most secure.

2.5. The design of access layer network

The access layer network mainly consists of 7 work switches and 3 redundant switches. 7 work switches are connected 2-3 wireless access points, and constitute a ring structure, to achieve single-loop redundancy. In order to make the access layer more stable and safe, and taking into account the cost, decided to add three redundant standby heat engine to form a ring, and three redundant switches with their own closest to a work switch connected to form Double ring redundancy. Double-loop redundancy can greatly reduce the network equipment failure and network

connection failure caused by the loss, when a single failure does not require staff to rescue, in a very short time (5-10 ms) to resume communication. The access layer network is connected through 100 Mbit/s multi-mode optical fiber, and the farthest transmission distance is 2000 m, which meets the requirement of dual-ring redundant transmission in the access layer of the scheme.

2.6. The design of convergence layer network

The convergence layer network consists of eight two-layer Switches and a three-layer Switch. The switches are connected with 1000 Mbit/s multimode fiber. The three-layer Switch is deployed in the control center as the last level of the entire network to the control center, distributing the data to the video server and the PROFINET I/O controller. Due to the ring protocol has many good characteristics such as the availability, high reliability, short recovery time, this solution meets the requirements of the related technology. At the same time, an increase of 2 Layer 2 switches to form a loop to achieve ring redundancy.

MRP can effectively guarantee the high availability of Association Network firewall in user network applications. It supports dual-system hot backup based on automatic detection and supports active load balancing, session protection and takeover, and active configuration synchronization. In a transparent, routing, mixed mode and other work load balancing, support up to 2 to 8 sets of equipment, and HRP in many ways not as good as MRP, so in the convergence layer of redundancy protocol selection, the choice of MRP protocol.

3. Result analysis and discussion

3.1. The analysis of feasibility

The design of the industrial network system based on PROFINET meets 13 technical requirements of the network, the sub network isolation uses VLAN technology. Network redundancy in the convergence layer using MRP redundancy protocol and in the access layer using a double loop structure. AVG car high speed mobile seamless switching using AP roaming technology. From the design and analysis of mobile AGV car terminal network, wireless coverage access network, access layer network and convergence layer network, many innovations are done to make the network program having more feasibility and innovation.

3.2. The economic analysis

The industrial network system based on PROFINET meets the technical requirements and ensures the availability of network systems under the premise of full account of the economy. Personnel cost budget related to the implementation, installation and maintenance of the industrial network project in order to achieve the balance between system performance and cost (as shown in Table 5).

Considering the transmission distance of 1000 Mbit/s multimode optical fiber

between the aggregation layer switches in the aggregation layer network, it is decided to add only two Layer 2 aggregation layers for redundancy to meet the requirements of Part A Switch to form a reliable ring network structure. Compared to every other switch to add a redundant device, greatly reducing the cost of equipment.

In the access layer network, taking full account of the access layer network as a link between the convergence layer network and the wireless coverage access network, in the case of higher importance in the system, choose to use 10 access layer switches Constitute a dual-ring network structure, in which seven access layer switches constitute the outer ring, used to connect the wireless AP, the remaining three constitute the inner ring, for the full realization of redundancy. In the original access to each AP access layer switch without a dual-ring redundancy, based on the reduction of nine switches and to achieve a double-loop redundancy.

Table 5. Hardware cost table

	Quantity (sets) / Length (m)
Wireless AP	19
Wireless client	5
IP camera	5
PLC	10
Layer 3 switches	1
Layer 2 switches	18
1000 MBit/s Multimode fiber	4000
100 MBit/s Multimode fiber	About 7500
Industrial Ethernet cable	About 400

3.3. The optimization of the system

When the plant area needs to expand the scope, you can use the atomic topology shown in Figure 1 to expand. Plant expansion is divided into horizontal and vertical two ways. Horizontal, at the end of the sixth line to continue to build production lines, consistent with the previous production line, this expansion plan is easy to achieve, directly in the corresponding network layer in accordance with the original design principles to add equipment, connection lines and configuration can be. Vertical expansion can be multiplied production line, with the original production line form U-shaped, this expansion in addition to the original topology to build again, the need to dock with the original network system.

The scheme is designed to ensure the feasibility of horizontal expansion and vertical expansion. In terms of hardware, the vertical expansion only need half of the original equipment; software, leaving enough IP addresses and VLAN number. It needs to expand the access layer, wireless overlay network layer and AGV, and expand beyond three times of the horizontal expansion, which needs to be extended uniformly.

As a result of using the ring redundancy technology, the network expansion and expansion of the need to expand the "loop" and "chain" operation, that is, the

original part of the original ring topology and other parts off, in accordance with the original design principles and methods section by section to add. And finally the original part of the ring on the top of the new network. Lateral expansion not only need to access the network layer and wireless coverage access network expansion, also need to aggre-layer network and AGV car expands exponentially. In practice, it is necessary to simultaneously expand and expand the horizontal and vertical, to build a stable, safe and reliable network system.

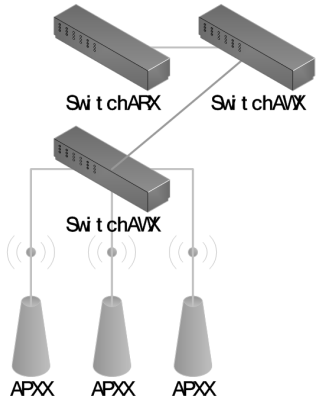

Fig. 1. Extended topological map

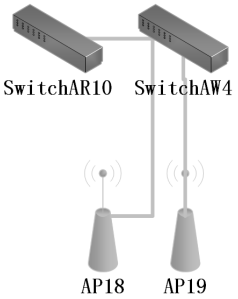

Fig. 2. Ring port part

4. Conclusion

As a strategic technology innovation, PROFINET provides a complete network solution for the automation communication field. The design of industrial network based on PROFINET is the accurate analysis and planning of the design object and it is an important means to make the traditional industrial production workshop covering network monitoring. It can realize remote control by combining the In-

ternet effectively and realize the network monitoring management of the industrial production line, production workshop, automated warehouse, intelligent workshop and so on. And it provides design ideas for the network architecture of industrial production line, assembly line and workshop.

The general design of SIEMENS PROFINET open standards based on industrial network was studied, the key technologies such as real-time industrial Ethernet was analyzed, the design principles and methods of industrial Ethernet were given, and the convergence layer network, access layer network, wireless access network and mobile AGV car terminal network are designed in detail. Through the analysis of the system performance and the solution of the factory in the all unexpected situations were quantified, the solution was put forward. The results show that the industrial system based on PROFINET has good innovation and practicability, good economic performance, and strong reliability of monitoring data communication. PROFINET bus communication provides a reliable guarantee for the complex system of large capacity data exchange. It will have a good application prospects. But there are still a lot of key technologies to be resolved, the positive research work will contribute to its rapid application, and produce good economic benefits.

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Received April 23, 2017