Vnet/IP REAL-TIME PLANT NETWORK SYSTEM

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The Vnet/IP is a real-time plant network system for process automation based on the 1-Gbps Ethernet communications system. The Vnet/IP system implements transport protocols optimized for process automation on top of the UDP protocol, simultaneously realizing real-time operability and a high degree of reliability and usability. This system will be used as the core network for CENTUM distributed control systems and has been put forward to the International Electrotechnical Commission (IEC) for approval as a new international standard.

INTRODUCTION

In today's global economy, competition is intense and the business environment is continuously changing. Efficient production methods and rapid adaptation to market trends are thus prerequisites for the survival of any company in the production industry. Companies therefore require a production system that can offer 1) information integration that enables real-time response to market information, 2) flexibility to adjust to changes in business climate for efficient production, 3) reliability to ensure product and service quality, minimum cost, and on-time delivery, and 4) the ability to grow in a changing business climate. One key component of the production system is DCS, and network technologies for DCS systems need to be improved.

Regarding information and communication technologies, the Internet and Ethernet have become widespread, while low-cost, high-speed communications have become available for the general public. Thus, we are already in a ubiquitous society, where we can easily access various types of information regardless of location. Recently in the upper communication layer, technologies such as Web services, XML and standard function blocks are used, and they realize openness for logical information sharing. In the lower communication layer, technologies such as HTTP, TCP, UDP, IPv4/v6 and high-speed Ethernet realize openness for information transmission. In addition, field communications are becoming open due to digitization, the widespread use of intelligent devices, and the like.

Plant system developers have been providing proprietary network systems to achieve real-time response and high reliability required for stable plant operation. To meet the demand for higher speed and openness, Ethernet-based plant networks have emerged in recent years. Unfortunately, introducing such networks has compromised plant stability. However, Ethernet is already in widespread use and affords very low-cost communications. In addition, Ethernet is advancing rapidly as Internet technologies are improved, and is much more promising than other data communication systems. With this background, there have been high hopes for an industrial Ethernet which can be reliably used for production systems.

The switching hub technology has solved the collision problem, which has hindered real-time operation of Ethernet. The increase in speed of Ethernet to 100 Mbps has also fueled the development of a full-fledged Ethernet system for industrial applications.

Yokogawa has developed Vnet/IP, an Ethernet-based plant network system that offers real-time response, high reliability, and openness. This system is now being reviewed as an international IEC standard for real-time Ethernet for factory automation.

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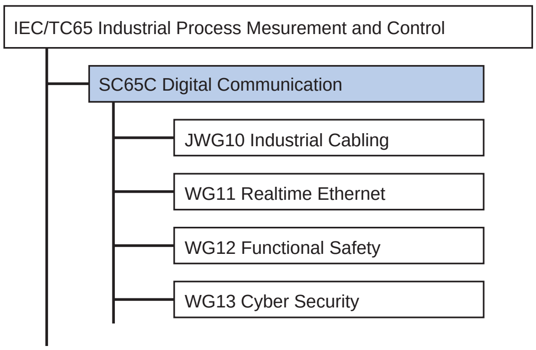

Figure 1 IEC's organizations for RTE standardization

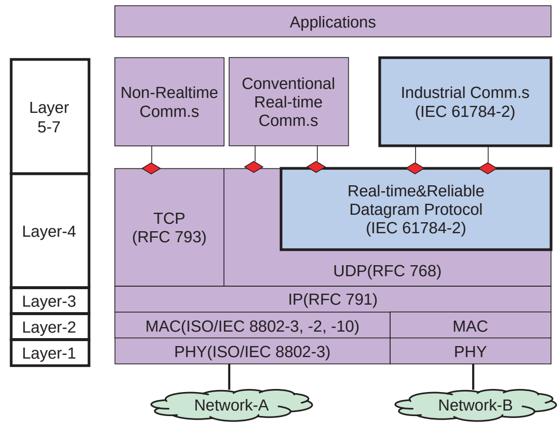

Figure 2 Vnet/IP protocol profile

TRENDS OF INDUSTRIAL ETHERNET

The original purpose of Ethernet was to transmit large volumes of data regardless of transmission duration. Due to constraints in real-time response, Ethernet cannot be used for production systems as is. Also, no Ethernet-related standards have been developed to ensure reliability (e.g. redundancy) of production systems. So, existing Ethernet-based systems cannot satisfy the requirements for stable operation.

In view of the above, automation suppliers of many countries set up a consortium to develop a de facto standard, while international standards organizations, such as IEC and ISO, have launched an effort to establish a de jure Ethernet standard. The TC65 of IEC, which is in charge of the standardization of industrial process measurement and control (Figure 1), has started work on establishing a standard for industrial Ethernet. This standardization effort is considered the next most important topic since an international standard was established for field bus systems. IEC aims to establish the international standard by 2007.

FEATURES OF Vnet/IP

Through IEC's efforts to standardize Real-time Ethernet (RTE), more than 10 systems have been proposed. However, most of them are data communication systems for discrete process, such as a motion control system. No existing RTE systems fulfill the requirements for communication systems for continuous process control.

Vnet/IP was developed for DCS to enhance continuous and batch process control for mid- and large-size plants. It is optimized to flexibly transfer large amounts of data distributed within the plant with real-time capability, or at about 100 ms. However, the performance realized for very large systems is also effective for stable operation of small- and mid-size plants. An extra capacity is provided to address the increase in data traffic volumes in order to boost the productivity of such plants.

Vnet/IP is a plant network based on 1-Gbps Ethernet, with which R3.05 of the CENTUM CS 3000 was the first to be made compatible. It can be seamlessly connected with a traditional Vnet system, and it will be an infrastructure for a current DCS system to grow into a new production system.

ARCHITECTURE OF Vnet/IP

Until recently, plant networks employed a parallel architecture, in which the control network and the information network are separated. Not only was such architecture costly, but also it hindered the integration of control data with engineering and maintenance data on intelligent field devices installed over a wide area, control devices, and the like.

To integrate control and information networks, each of them must be able to execute its own tasks without interference from the other. It is essential to ensure that non-critical communications that do not directly relate to control will not affect critical communications that directly relate to control. Specifically, it is required: 1) to ensure that real-time response is not affected by other traffic control, 2) to ensure that the reliability is not compromised by redundancy and environmental resistance technology, and 3) to ensure that security needs to be provided against cyber attacks and other network-related threats.

(1) Protocol profile

In the profile of the Vnet/IP protocol stack, a new highly-reliable real-time transport layer lying above the layer of standard protocols, such as Ethernet and UDP/IP, is implemented. In the upper layer, international formats, such as OPC and SOAP, and the proprietary process data access protocol for CENTUM system can be implemented together (Figure 2). The implementation of the CENTUM process data access protocol allows for the use of data from past CENTUM systems.

(2) Real-time response

For real-time operation, Vnet/IP adopts technologies for transmission scheduling, priority control, and high-speed response.

Transmission scheduling is performed when a large amount of packets is transmitted by multiple transmitting stations at one time, in order to prevent delays in the data being transmitted to receiving stations as well as delays of transmission retry due to packet loss. Even when a 1-Gbps collision-free switching hub is used, the internal buffer overflows if a large amount of packets is transmitted by multiple ports at one time, eventually resulting in packet loss and delay. Vnet/IP divides a macrocycle of 100 ms into time slots of 1 ms, each of which is assigned to different transmitting stations. Each time slot contains specific types of data for different categories of communication.

The Type of Service (ToS) field of the IP protocol is used to assign a priority order (1– 4) to packets. Each communication station has transmitting/receiving buffers, where bypass processing is executed according to the priority order. This priority assignment is applicable to network devices such as switching hubs. In order to recover quickly from transient communication errors, the UDP/IP stack is adopted. Because the UDP/IP stack has a protocol for quick error response and minimizes memory copy, it enables data transmission with high reliability and speeds that cannot be matched by the TCP or the UDP. In case of large-volume data transmission or in a network for a wide area, the throughput of the system can be reduced by response delays. To prevent such throughput reduction, confirmation is made for a specified number of packets as necessary.

(3) High reliability

Thanks to its fault tolerant and fault avoidance capabilities as well as maintainability, Vnet/IP offers high reliability.

The network configuration is dual redundant, with the two networks independent from each other. When the main network goes down due to a failure or abnormality, the other one is immediately activated by network switching for real-time operation. All routes between stations in the network are constantly monitored by the exchange of diagnostic packets. Even an abnormality in routes that are rarely used can be immediately detected. When switching of CPU control right is performed for the dual-redundant controller of the pair-spare architecture, destinations of data being transmitted are automatically changed so that normal operation can continue.

(4) Openness

Vnet/IP can simultaneously perform communications using TCP-based standard protocols, such as FTP and HTTP, and control communications. The standard-protocol communications handle engineering data, and maintenance data. And control communications handle information which requires real-time response and high reliability. Ethernet-compatible devices of various vendors can be connected to form a multi-vendor network. In addition to bandwidth control and distributed communication processing, cyber security measures have been implemented, not only to ensure the real-time response and high reliability required for control communications, but also to enable simultaneous performance of control communications and open communications.

In communication stations, the physical layer and the MAC layer are made dual-redundant for network connection. These layers are shared by the stack for control communications and the data link service function for open communications. The protocol processing function for open communications is implemented in a CPU other than the one in which the processing function for control communications is implemented. The protocol processing is thus separated from the processing function for control communications, so that the former does not adversely affect the latter. In addition, the data link service function for open communications is implemented with a bandwidth control function that prevents excessively heavy traffic of open communications from interfering with control communications.

A security function using a public encryption key is implemented in the transport protocol for control communications. This security function protects against cyber attacks by falsification, masquerading, and the like.

Compact controller (AFV10)

Interface card (VI701)

Vnet router (AVR10)

Figure 3 Hardware components of Vnet/IP

SYSTEM CONFIGURATION OF Vnet/IP

(1) Hardware

Three devices recently developed for Vnet/IP are the interface card VI701, the compact controller AFV10, and the Vnet router AVR10 (Figure 3). The VI701 is designed to be mounted on a PC, and the AVR10 connects Vnet/IP with Vnet. The Vnet/IP control ASIC, which is used in all three devices, allows for compactness and high reliability.

The VI701 is a PCI bus card to be mounted on numerous PC-based devices for the CENTUM that is connectable with the existing Vnet. It is used to connect the HIS, which is the HMI of the CENTUM, and all kinds of existing CENTUM devices with Vnet/IP.

The AFV10 is a compact controller for Vnet/IP. Other than the communication interface, the functions of the AFV10 are the same as those of the AFF10, which is an FCS for the existing Vnet. The AFV10 is mounted with dual-redundant communication ports on each of its redundant CPU modules. The high reliability of the AFV10 is attributed to the redundant design of its CPU as well as communication ports. Also, the AFV10 is readily implemented with the SOE function, which uses the time synchronization function of Vnet/IP. The Vnet router is a compact network device of 3-unit height that connects Vnet/IP with the Vnet.

The communication interfaces of these three hardware devices are all mounted with a dedicated ASIC and an MPU for protocol processing (SH-3). Implemented in the dedicated

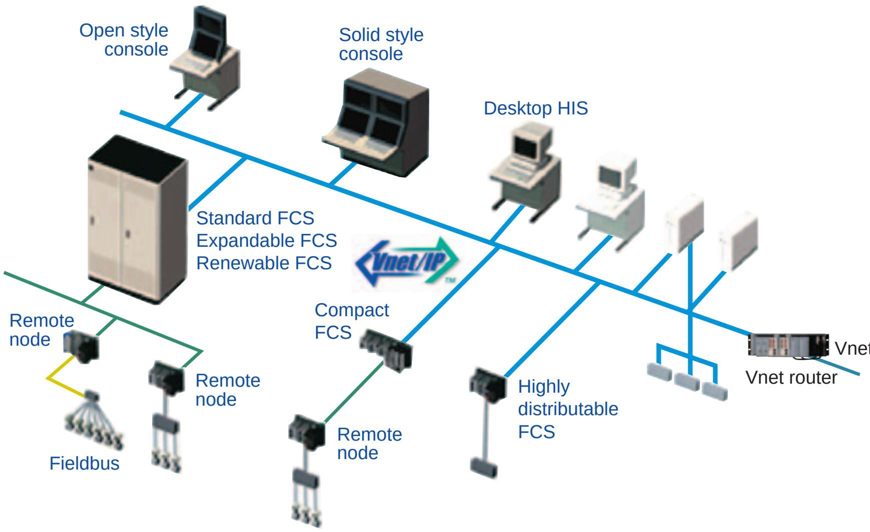

Figure 4 Example system configuration

ASIC are a 1-Gbps dual-redundant MAC function, a buffer control function for priority data transmission and reception, a time synchronization assistance function, a data link function for open communications, and a host-bus interface function.

(2) Communication firmware

Communication firmware is implemented on μITRON, which is an embedded real-time OS, and employs the high-speed UDP/IP protocol stack for an embedded system. The specifications of the host interface are fully compatible with those of Vnet, so existing pieces of Vnet-compatible software can be implemented on new Vnet/IP devices as it is.

(3) Software and engineering

Since any Vnet software interoperates with Vnet/IP, all kinds of existing software as well as engineering data can be migrated to and used in Vnet/IP as is. Between Vnet/IP and Vnet, which are connected via the Vnet router, data can be exchanged seamlessly. Interoperability is not affected by changes in the network environment.

The capability for open communications facilitates connection with another information network and a PLC and the formation of an integrated network.

For network engineering and maintenance purposes, a dedicated utility to monitor all routes in the network and a high-performance alarm system are provided. For network management, SNMP-based general-purpose software is available.

APPLICATION TO CENTUM

Figure 4 presents an example system configuration of a CENTUM with Vnet/IP. The CENTUM can be connected with up to 16 domains, each of which can be connected with 64 communication stations, giving 1024 communication stations. In addition to those stations, up to 124 PCs and Ethernet devices (e.g., PLC) can be normally connected to a domain connected to a CENTUM with Vnet/IP. In a domain, communication stations are connected via general-purpose switching hubs (L2SW) in a tree configuration. Domains are connected via general-purpose routers (L3SW). A Vnet router allows connection with an existing Vnet, and a general-purpose router allows connection with different types of information networks.

The Vnet/IP network is dual-redundant, and in each of the two networks, network devices (L2SW, L3SW, etc.) are used in a pair for connection with general-purpose commercially-available devices. Communication stations and network device are connected by twisted pair cables of 100BaseT or 1000BaseT, or even by fiber optic cables whose transmission speed is 10 Gbps or above. In addition, Vnet/IP is capable of wide-area connection in a redundant configuration using a wireless or remote router.

CONCLUSION

In the future, intelligent field devices and wireless networks of field devices will continue to spread, and the concept of plant maintenance will change accordingly. Eventually, when network security technology has improved, direct access to Internet resources will become possible from a factory or plant site. We consider that Vnet/IP will be a major force for the development of production systems. ◆

REFERENCE

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