

Network Systems in CIM Environment*

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Abstract: This paper discusses the architecture, protocol standards, and the design strategy of network systems in the CIM environment. The first part describes problems in standardizing communication protocols, analyses communication attributes in the CIM environment, and explains our strategies. The second part presents the design of the CIMS/ERC network system and its traffic statistics.

Key words: CIM; protocol standard; enterprise network; LAN; TCP/IP

Introduction

In a Computer Integrated Manufacturing (CIM) system, the various automated technologies, such as CAD, CAPP, CAM, FMS, MRP-II, etc., should be linked together in a coordinated manner. CIM is an integrated system including design, planning, manufacturing, selling and marketing. Therefore, an open enterprise network system appropriate to automated manufacturing and management is a fundamental requirement for the system.

The enterprise network system is usually built using interconnected LANs. LANs can be interconnected by repeaters, bridges, or routers, and can now also be interconnected by switching hubs which support multiple LAN segments on a 1 Gbps backplane. Such a switched internetwork uses a star topology and can have an uplink to FDDI. Further, it will support asynchronous transfer mode (ATM) in the near future. The broadband integrated services digital network (B-ISDN) based on ATM switching technology will provide wide area real-time multimedia communication services.

Since the computers and devices in an enterprise network system have to conform to a common communication protocol suite for their internetworking and interoperation, the complex problem of standardizing communication protocols cannot be avoided. Currently, there is no consensus about communica-

tion protocol standards in the scientific world. For example, the two protocol suits, TCP/IP and OSI, are both open networking protocol standards and other proprietary systems have been widely used, particularly within LANs. Therefore, the first problem confronting the design of a network system for CIM is how to standardize the communication protocols.

1 Problems in Communication Protocol Standardization

The standardization of communication protocols has been a controversial topic for many years. Since 1983, computers connected to ARPANET all adopted TCP/IP which is an open protocol suite based on the internet protocol (IP) and the transmission control protocol (TCP). ARPANET has been extended as the world-wide Internet and TCP/IP has also been called internet protocol suite (IPS).

The international standardization procedure for computer communication protocols began in the 1980's. The ISO proposed the OSI reference model with protocol standards for 7 layers. At that time, the IEEE computer society developed standards for the lowest two layers. Specifically, the IEEE 802 committee developed a set of standards for LANs with IEEE802.3, 802.4, and 802.5 as protocol standards for CSMA/CD, token bus and token ring, respectively. These standards were also accepted as international standards by ISO. Based on the OSI model, General Motors and Boeing proposed the manufacturing automation protocol (MAP) and technical and office protocol (TOP) standards. The lower layer protocols of MAP and TOP are

Manuscript received: 1995-08-30

* Supported by the National High-Tech Development Program of China

IEEE802.4 and IEEE802.3 respectively. The OSI connectionless network protocol (CLNP), transport protocol class 4 (TP4), session protocol, and presentation protocol are their third to sixth layer protocols. Manufacturing message service (MMS) is the MAP application layer. The TOP application layer includes FTAM for file transfer, VT for virtual terminal, X.400 for electronic mail handling, etc. However, seven protocol layers have been perceived as unnecessary complex. Therefore, the Mini-MAP architecture was proposed with gateways to interconnect Mini-MAP, MAP and TOP.

OSI products began to appear in the mid-1980s with vendors promising to develop OSI products and governments and industries planning to adopt the OSI standards. In 1988, the U. S. Federal Government adopted government open systems interconnection profile (GOSIP) which is based on the OSI protocol suite and is a joint standardization program of ISO and ITU. The GOSIP standards were expected to replace the TCP/IP and other proprietary protocols. For a time, OSI standards attracted more and more attention around the world and many people believed that OSI would be the best system for networking.

However, OSI products have been very slow coming to market and are difficult to integrate while the Internet has grown rapidly. Although in February, 1986, the Internet had only 328 registered networks^[1], by the end of 1994, the Internet had grown into a huge international infrastructure of over 40 000 interconnected networks. TCP/IP products are now widely used not only in the Internet, but also in LANs and in private networks. In addition, some proprietary "non standard" LANs are still in progress and are playing an important role, e. g. Novell's Netware and Microsoft's NetBEUI.

In January, 1994, the U. S. national institute of standards and technology (NIST) established the federal internetworking requirements panel (FIRP) to reassess the GOSIP policy. As a result of their discussions, FIRP suggested that the current GOSIP policy be modified to recognize both OSI and IPS protocols and hybrid stacks as acceptable internetworking standards^[2]. This result shows that no single protocol suite can meet the full range of today's and tomorrow's international communication requirements. At the time when OSI was proposed, the current high-speed transmission rate and the challenge of real-time multimedia applications had not been foreseen. Furthermore, people could not ignore the

fact that some proprietary non-standard systems play an important role, particularly within LAN's. Taking into account that there is no single standard protocol suite available, the network system designer has to study how to integrate multiple protocol stacks and how to select the existing network technologies for meeting today's and tomorrow's automation requirements.

2 Communication Attributes in the CIM Environment

Because of the current multiplicity of protocol standards, the CIM computer network system must be a heterogeneous internetwork. Thus, the communication attributes must first be analyzed then the selection criteria for network technologies to meet CIM requirements can be discussed.

The main data flow in the CIM environment is the data required for product design and manufacturing, i. e. the data generated and shared by CAD, CAPP and CAM. There are a number of standards for product data exchange including initial graphics exchange specification (IGES) and standard for exchange of product model data (STEP). IGES is designed to allow CAD data to be exchanged between design systems, while STEP specifies how to establish a complete computer definition of the physical and functional characteristics of a product through its life cycle. STEP defines the product geometric features, its construction information, i. e. the materials and assembly, its tolerances and quality constraints, etc. STEP is more ambitious and sophisticated. IGES data is shared in the form of files while in STEP the principle technique for exchanging data will be the shared database although in the first STEP implementation data may be exchanged using files. In either standard, data flows among CAD, CAPP, and CAM through files and shared database transactions. The amount of data exchange is very large but less sensitive to delay since there is no real-time requirement.

The manufacturing shop floor has different kinds of data flows, including production order data and machine commands for controlling the machine tools. After the production orders and commands are completed, the machine status, alarms and feedback are returned. Therefore, the data transfer is manufacturing messages and database retrieval. At the shop floor level, the amount of data is not large but the delay must not exceed some bound.

An MIS/Office network is mainly concerned

about managerial activities and financial planning and, therefore, does not require deterministic delays. However, the geographical coverage of the network will be greatly expanded in the near future. In addition, the type of information will extend from text data to multimedia data, and the requirement for high bandwidth will continue to grow.

Computer networks in the CIM environment are usually interconnected LANs with an uplink to the public data network. A possible solution is the Ethernet/802.3 with unshielded twisted pair media for the integration of CAD, CAPP, CAM, and the office automation system. However, the unshielded twisted pair media is not suitable for the shop floor environment because of electromagnetic interference. Switched internetworking is now suggested for enterprise network systems. A switched LAN is based on switching hubs and supports multiple LAN segments and different media types. Each segment can handle 10 Mbps traffic simultaneously. It supports the high-speed uplink to FDDI and can evolve to ATM technology in the future. The ATM Forum is also considering the LAN emulation service on an ATM network to provide adequate internetworking with legacy LANs^[3].

In the upper layers of the communication protocols, multiple protocol suites will continue to coexist in the enterprise network. Recently, more and more vendors are using TCP/IP as their native communication protocol suite or as a built-in protocol stack coexisting with their proprietary ones. However, TCP/IP is now facing the challenges of exhausted IP address space, the QoS requirement of real-time multimedia communication, etc. Therefore, TCP/IP must be extended^[4-6] and new protocol architecture and new generation protocols will be needed for the ATM environment^[1-3]. The internet engineering task force (IETF) is focusing its attention on running IP over ATM while the ATM forum is working on multiprotocol support over ATM^[7]. Since TCP/IP is widely used and its new applications, such as world wide web (WWW), Gopher, wide area information servers (WAIS), are being rapidly developed, we believe that TCP/IP will be a reliable and practical technology to integrate heterogeneous systems today and in the near future. When new generation protocols are developed, they will be compatible with the old ones and good transition mechanisms will likely be introduced.

3 CIMS/ERC Network System Design and Traffic Statistics

The CIMS/ERC network system was established in 1988. The network includes two Ethernet segments, the information network and the manufacturing network, installed in two separate buildings. The distance between them is about 1km. The two network segments are connected by optical fibers and bridges to isolate traffic from each other. The information network interconnects computers performing CAD/CAPP/CAM and MRP-II activities using 10BASE5. The manufacturing network integrates a cell controller and other workstations controlling a vertical machine center (VMC), a horizontal machine center (HMC), a turning center, AVG and a warehouse. Since CSMA/CD accessing provides better performance than token passing for time-critical applications on small factory LANs with loads of less than 40%^[8], the CIMS/ERC manufacturing network is also using a baseband coaxial bus which has a high degree of immunity from electromagnetic interference.

TCP/IP is the principle protocol suite in the CIMS/ERC network system. All the computers connected to the CIMS/ERC network system are running TCP/IP with VAX computers running DECnet at the same time. The network system usage is as follows.

1) Resource sharing

Users share resources on the CIMS/ERC network system by using file transfer, remote login, database access based on the client/server model of Oracle DBMS, etc. The communications between the oracle client and server are made using the interprocess communication (IPC) mechanism supported by TCP/IP. The SQL*NET layer above TCP handles the conversion of data and character set representation required by the presence of different computer architectures.

2) Real-time communication

Communications between the cell controller and workstations on the manufacturing network are mainly message exchange through a socket interface based on the IPC mechanism supported by TCP/IP. Real-time communications between workstations and manufacturing devices such as the VMC, HMC, turning center, warehouse, tool presetter, and AGV are implemented using serial line protocols. For example, the NC controller of the turning center is an A950TC, which has two parts: the NC system and

the public interface (PI). PI has a communication protocol stack which handles the communication tasks with remote computers and a manufacturing communication system which does the mapping function from the virtual machine device (VMD) to the NC system. The PI protocol stack is like the Mini-MAP in that it only has physical, data link and application layers. However, it uses RS-232C for the physical layer, RS-484 for the MAC sublayer and IEEE802.2 for the LLC sublayer. Its application layer includes ACSE and MMS. The MMS at the A950TC PI is the MMS server. We developed the RS-484, IEEE802.2, ACSE and MMS client using the RS-232C on a workstation in order to control the turning center NC system^[9].

Traffic on the CIMS/ERC network system has been monitored continuously^[10]. The average and peak data traffic on the CIMS/ERC network system are shown in Table 1 and Table 2 for representative dates.

Table 1 Average data traffic (kb/s)

date	Nov. 9	Nov. 11	Nov. 12
information network	194	119	186
manufacturing network	70	47	67
pass through bridges	49	29	23

Table 2 Peak data traffic (kb/s)

date	Nov. 9	Nov. 11	Nov. 12
information network	2 720	3 720	3 610
manufacturing network	978	1 256	1 511

The statistics show that while there were large amounts of data traffic on the networks, there was only a small amount passing through the bridges. Therefore, the bridges effectively separated the data traffic of each network segment. However, we should note that the peak data load was close to 40%. We are now extending the capacity of the CIMS/ERC network using the switched internet-working technology.

4 Conclusions

In recent years computer networking technologies have progressed rapidly with new technologies appearing frequently. The open architecture and common protocol standards are key issues for inter-connecting heterogeneous devices and for integrating

the management and development of enterprises. However, existing standards should be extended and modified to accommodate present state-of-the-art technologies and new protocol standards will be needed for future technologies.

It is impossible for a single protocol stack to meet the full range of applications. Therefore, organizations cannot pursue a general purpose standardization. Many arguments about the significance of OSI ignore this point. It is difficult to achieve unanimity on new objectives and, at the same time, new technologies are developing so fast that any organization cannot predict all of tomorrow's technologies. The coexistence of many standards and the coexistence of multiple architectures present a complex system that is the focus of the CIMS/ERC development work.

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