The Future of Ethernet in the Manufacturing Environment

Frances Monk
fmonk@ra.rockwell.com
Rockwell Automation, Milton Keynes, MK11 3DR, England

***Abstract* - Ethernet's worldwide acceptance in commercial environments has created an eagerness to expand its responsibilities on the plant floor. The network's performance capabilities make it ideal for tasks such as data monitoring, trending, and program maintenance. However, many predict that recent technological advancements in Ethernet, including Fast Ethernet, Gigabit Ethernet and switch technology, will also enable it to handle mission-critical control responsibilities currently being managed by existing industrial automation networks. Meanwhile, others contend that Ethernet has a long way to go before it can assume an expanded role in the manufacturing environment. This article provides an overview of Ethernet, describes how Ethernet networks are implemented in manufacturing today, and discusses a number of practical and important considerations regarding their implementation in the future.**

I. COMMUNICATIONS PROTOCOLS USED WITH ETHERNET

Ethernet technology by itself provides a set of physical media definitions, a scheme for sharing that physical media (CSMA/CD) and a simple frame format and addressing scheme for moving packets of data between devices on a LAN. In addition, all installed Ethernet networks support one or more *communications protocols* that run on top of Ethernet and provide sophisticated data transfer and network management functionality. It is the communications protocol that determines what level of functionality is supported by the network, what types of devices may be connected to the network, and how devices interoperate on the network.

Some of the protocols that have been implemented over Ethernet are DECnet™, Novell IPX™, MAP™, TOP, the OSI stack, AppleTalk™, and TCP/IP. Of these, *TCP/IP* is receiving the most attention due to the emergence of the global *Internet* (including the World Wide Web) and the corporate *intranets* that are transforming how corporations distribute information internally. TCP/IP is the protocol of the Internet. Although TCP/IP will run on physical media other than Ethernet, and Ethernet supports other communications protocols, the two have become increasingly linked due to the desire of organizations to seamlessly integrate their internal intranets with the global Internet. It is safe to say that TCP/IP is now the dominant protocol running on Ethernet networks on the factory floor as well.

TCP/IP is a layered protocol that can be mapped approximately to the OSI 7-layer network model. Fig. 1 shows the OSI network model. On this diagram, Ethernet represents Layers 1 (Physical) and 2 (Data Link). The Internet Protocol (IP) maps to Layer 3 (Network). The TCP transport maps to Layer 4 (Transport). The user services commonly associated with TCP/IP networks map to Layer 7 (Application). Some examples are http, SNMP, and FTP. (The TCP/IP protocol suite has no specific mapping to Layers 5 and 6 of the model).

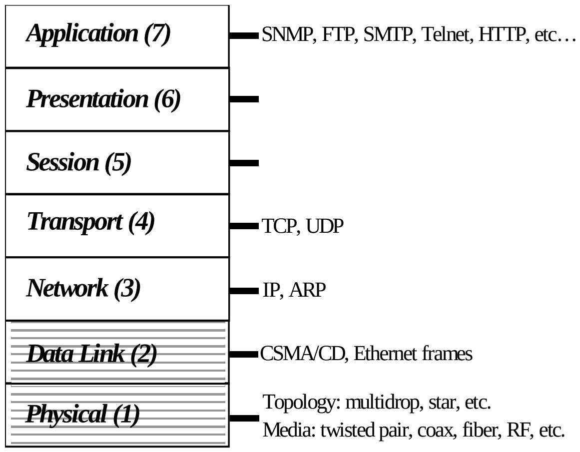


Fig. 1 - OSI 7-Layer Network Model.

II. THE APPLICATION LAYER AND SERVICES REQUIRED FOR AUTOMATION

Automation architectures must provide users with three primary services. The first, Control, is the most important. Control services involve the exchange of mission-critical data between controlling devices such as PLC's and I/O devices such as variable-speed drives, sensors and actuators. Networks that are tasked with the transmission of this data must provide some level of priority setting and/or interrupt capabilities. Second, networks must provide the user Configuration capabilities to set-up and maintain their automation systems. This functionality typically involves the use of a personal computer (PC) or equivalent tool for programming of various devices in the system. This can be performed at commission, and also during run-time, such as recipe management in batch operations. Lastly, an automation architecture must allow for Collection of data for the purposes of display in MMI stations, analysis and trending, and/or troubleshooting and maintenance. Networks that can provide all three services – Control, Configuration, and Collection of data – deliver the greatest amount of flexibility and efficiency for better overall system performance.

Networks that are based on the Producer/Consumer model – where data is identified, rather than tied to explicit source and destination addresses – can support Control, Configuration, and Collection of data services.

III. THE APPLICATION LAYER AND INTEROPERABILITY

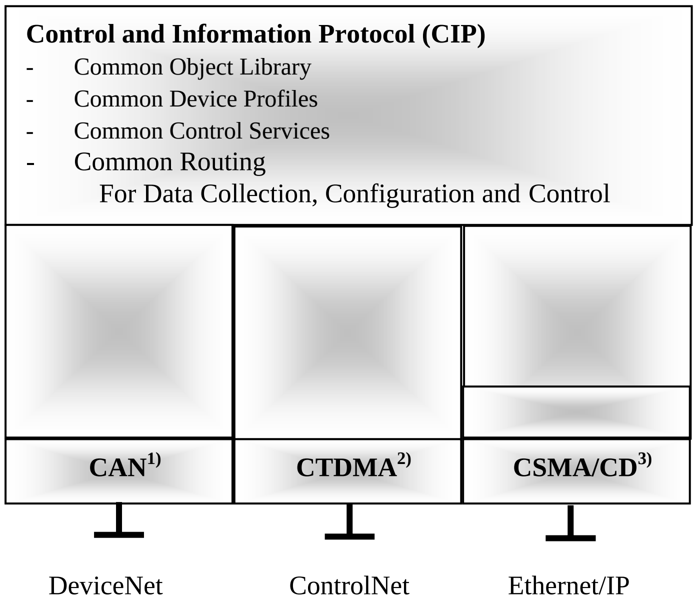
The TCP/IP protocol suite provides a set of services that two devices may use to communicate with each other over an Ethernet LAN, or over a wide-area network that spans the globe. However, using TCP/IP alone does not guarantee that the two devices can communicate effectively, if at all; it only guarantees that messages will be successfully transferred between the two devices. Compatible application software is also required. This means that the applications in both devices must understand the attributes and services provided by the other, and that they use a common messaging scheme to communicate over TCP/IP. This ability for devices from different vendors to communicate up through the Application Layer is called *interoperability*.

Today, vendors of automation devices that connect to Ethernet-TCP/IP have implemented their own Application Layer protocols. As a result, equipment from different automation vendors connected to the same plant floor Ethernet can physically coexist on the LAN but cannot interoperate.

PLC’s from one vendor cannot readily share information with PLC’s from another vendor, nor can vendor A’s software download programming or configuration information into vendor B’s device. This lack of interoperability makes it difficult for customers to integrate Ethernet-based automation equipment from different vendors on the same Ethernet network.

Protocols like MMS have in the past been promoted as “open” automation application protocols for TCP/IP, but their acceptance by the industry has been inconsistent. Currently, there are multiple initiatives underway to define a common application layer protocol for TCP/IP in the Industrial Automation industry. For example, the Fieldbus Foundation recently has announced an initiative to replace their planned H2 high-speed network with Fast Ethernet. By porting portions of the Fieldbus Foundation communication protocol stack to run as an application layer on TCP/IP, for process applications. Another approach for industrial applications is supported by multiple organisations, including the Open DeviceNet Vendor Association, ControlNet International and the Industrial EtherNet Association. These independent organizations promote EtherNet/IP (Industrial Protocol), which uses the object-orientated Control and Information Protocol (CIP) (Figure 2) as the application layer over TCP/UDP/IP. The tremendous advantage of this approach is the seamless network integration from Ethernet to ControlNet and DeviceNet, because DeviceNet and ControlNet already use CIP.

Combined, these organisations have more than 500 members and are also addressing multi-vendor compatibility issues with independent conformance test labs.



1. **CAN** (Controller Area Network)- originally developed by the automotive industry for vehicle networking, later adopted for other uses, including Industrial Automation
2. **CTDMA** (Concurrent Time Domain Multiple Access) - Data Link Layer that gives ControlNet its unique deterministic scheduled I/O capability
3. **CSMA/CD** (Carrier Sense Multiple Access with Collision Detection) – Data Link Layer used by Ethernet

Fig. 2 - Seamless Communication model.

IV. OTHER PRACTICAL CONSIDERATIONS FOR ETHERNET IN THE MANUFACTURING ENVIRONMENT

There are still a number of important user considerations to be addressed by ethernet if it is to gain true acceptance as a real-time control network in the manufacturing environment. These include, but are not limited to, environmental, cost, security and ownership.

The huge diversity of industrial applications can require the physical components of an industrial automation system to be exposed to climatic changes, air born pollutants, shock and vibration extremes, and wash-down environments. They can also be located in an electrically-noisy or hazardous environment.

The availability of different media options, such as fiber optic cabling, help in some applications. However, the lack of a standardised, industrial standard connector for high-class protection is one area where connecting and wiring technology for ethernet needs improvement to withstand the rigors of an industrial environment.

The use of industrial grade products to increase availability and reliability also means additional costs. Industrial hubs and switches are still more expensive than office grade components and are typically not required in other industrial automation network architectures. The restriction of 100 meters on the cable length from a switch to a device often requires additional switches to be designed into the network architecture – resulting in more cost.

As ethernet finds its way out of the office and down on to the shop floor there are growing concerns over the question of who actually owns the network. In the office environment the IT department specifies the equipment, assigns the IP addresses, maintains the networks and manages the security. Who owns these tasks on the shop floor, the Control Engineers, IT or both?

The specification of ethernet equipment for use in the industrial environment requires an in-depth understanding of the control system, its environment and the process it is controlling, the typical domain of the control engineer.

Adding a new device to the control system will require the IT department to assign an IP address, if this is required urgently will IT respond in time?

With existing industrial networks such as DeviceNet or Profibus the node address can be set via dipswitches on the device. Should this be an option for the IP address on the ethernet node and if so who would set it?

Security of the network is a major topic to consider. Who should own and manage this activity?

Great care must be taken to safe guard critical configuration data from being changed that could affect the safety of the whole control system.

Individual companies are starting to find their way around these issues but a lot of time is still spent in detailed debate with some issues still not resolved.

V. HELPING TO PROMOTE ETHERNET IN AUTOMATION IN EUROPE

IAONA (Industrial Automation Open Network Association) is an alliance of leading international manufactures and users of automation systems with the goal to establish Ethernet as an open solution in industry. The alliance has several working groups, some of which are focusing on:

1. Standards and technologies for the Layer 7 protocols
2. Connecting and wiring technologies for Ethernet for industrial purposes
3. Intrinsic safety with ethernet
4. Safety technology

Founded in November 1999 the group now has more than 100 member companies.

VI. CONCLUSION

The global acceptance of Ethernet-TCP/IP has made it a popular choice for many end users and for a wide variety of network applications. It offers an abundance of compatible products, high data throughput, and commercially available components at relatively low costs. The future paradigm for Ethernet is one of distributed objects communicating in a peer-to-peer fashion, within corporate intranets and across the Internet. In this environment, plant-floor Ethernet devices will be required to interoperate with corporate information applications, as well as support control, often on the same network. Customers will require that devices from different vendors interoperate on the same network.

The adoption of a standard application layer, supported by multiple vendors with interoperability testing that allows the user to Control, Configure and Collect data via industrially rated media, is critical if ethernet TCP/UDP/IP is to be accepted as a realistic option to the existing industrial automation networks implemented in manufacturing today.