4 - Networking for Engineering

Networked engineering solutions are witnessing the move from traditional analogue, Programmable Logic Controllers (PLCs) and vendor-based systems to open digitised, integrated and highly robust protocols. There are a range of solutions to suit specific process and manufacturing requirements. However the move to digitisation is, as with other automation protocals, relentless.

The engineering community has previously been fundamental in the planning, commissioning and management of integrated automation systems. With the move to a more “information technology” focus, engineers are required to engage more fully with this technology. There is the opportunity for computer network managers and administrators to work closely with engineers on these systems.

Additionally, instrument technicians and engineers will need to become more familiar with standard networking functionality in order to support and maintain these systems. This move towards digitisation and distributed control devices provides engineers, process control operatives and enterprise management staff with a substantial increase in collected data. The amount of data collected will present new challenges for those involved with management of these systems.

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Current Engineering Networking

Analogue systems (4 – 20 mAO and pneumatics 20-100 kPa) have traditionally been used in the process and manufacturing automation and control industry. However today there is a move towards digital control over the automation systems. Suppliers of instrumentation equipment have utilised the increased power of microprocessors to change instruments from being “dumb” to intelligent and interconnected devices. This has reduced the infrastructure required to design, commission, run and maintain a plant as well as enable greater efficiencies.

Some vendors of instrumentation have followed a path of locking-in clients to their systems with proprietary solutions for process and manufacturing control. This strategy leads to control systems that are able ensure interoperability through “dumb analogue” single-vendor equipment and support. Thus, purchasers of these systems (engineers and management) are able to rely upon the proven performance of these systems. Proven technology reduces risk and the introduction of other systems appears to be unnecessary.

Some observers in process and manufacturing automation/control have commented that Australia’s engineering culture is lagging behind that of the rest of the world. New sites internationally are tending to move away from vendor-based systems and are introducing more open systems that utilise international standards for process control. These new systems provide for enhanced control and measurement capability especially within the fluid process industries and, to a lesser extent, for discrete control and data applications such as in manufacturing.

Unfortunately for the open systems approach, there is some difficulty with backward compatibility in legacy systems. Therefore these new open systems are usually seen as being best suited for “greenfield” sites. While there have been a number of new facilities created, the adoption of these new systems has not yet met with the approval of the majority of the Australian engineering community.

Future Engineering Networks

The next generation of instrumentation provides an increased rate of data flow and this needs to be managed in a number of ways. There is an underlying move in many technology applications covered in this report towards more open systems of control and device connectivity. On many occasions, vendors have led the way with open operating protocols. The success of these protocols and the desire to adopt them as standards has led to international organisations formalising and therefore opening up the availability of these to industry at large.

Apart from providing more real-time control to plant operators, these open systems provide advanced diagnostics for later analysis. This data is able to be transferred to spreadsheets, databases or other applications. Managers of facilities can use this real-time data to examine processes and make improvements. As the data is available to a network, management and maintenance experts are also able to review production data from an Intranet or via the Internet from anywhere in the World. This leads to the opportunity for management of facilities from remote operations rooms or company maintenance focal points.

In this section, a number of open standards will be examined. Some of these standards are imported directly from information and communications technologies. Others have evolved from vendors and engineering enterprises to meet specific needs. The combination of these protocols and systems leads to an open interoperability that has not been realised previously. This also means that many existing engineers and instrument technicians will need to gain the competencies to understand the new networks and incorporation of hybrid systems and legacy analogue systems with digital networks.

Network Architecture and Components

Connection from device to network

Connections from devices to the network have also become standardised. These connections help to reduce the noise, impedance mismatching and other compatibility difficulties. The Electronics Industry Association (EIA) produced a number of recommended standards (RS) to increase the interchange of data. These are commonly known as RS232, RS422, RS423, and RS484 but are more correctly known with an EIA prefix such as EIA232.[1] For simplicity, these standards will be referred to by their common name of “RS.”

The RS232 was originally developed in the early 1960s to overcome problems of networking using a digital-to-analogue conversion process for data transfer.[2] This initial standard was established for slow data rates (20 Kbs) and short distances (16 m) and was designed for single-ended data transmissions. The RS423 is also single-ended but provides for 100 Kbs and runs to a distance of 1.3 kms.

The other data transmission type is termed “differential” and provides for greater performance by nullifying the effects of ground shifts and induced noise signals that can appear as common mode voltages on a network. The RS422 can run at 100 Kbs and travel 1.3 kms. The RS485 provides similar performance but is able to be used in a multi-point network and have 32 drivers and 32 receivers on a single two-wire bus network.

Ethernet

Ethernet is the predominant Local Area Network (LAN) technology for computer networks as it is easy to implement, manage, maintain and is very flexible. It is also an international standard from the Institute of Electrical and Electronic Engineers (IEEE) known as IEEE 802.3.[3] This technology will become more visible in engineering as more devices and networks move to open standards based systems.

Traditional wiring for engineering is to have one wire per device running from the device to the control room. This method worked well for analogue signals but has a number of limitations with the main one being the lack of interconnectivity and interoperability with the newer digitally-based devices. The solution is to use the Ethernet architecture that is used in computer networks. Ethernet is able to use multiple types of physical connection media and use different types of communication protocols. This provides Ethernet with much more flexibility than previous networks.[4]

The use of the IEEE 802.3 standard brings with it some changes in the way data is passed between devices. One of the overarching models is the Open Systems Interconnection (OSI) and defines the process by which data is physically transmitted to the computer application in a device (See below for more information). This commonality in data transmissions allows for greater interconnectivity of devices as each is sending data that is able to be understood by another.

Another benefit of using Ethernet is that it allows for a single cable to be connected to a number of devices. This reduces the initial cost of commissioning infrastructure. One of the main cabling architectures is the “bus” topology. In this arrangement, one cable can provide for all the data transmissions between devices instead of having one cable per device. Conflicts in sending the data frames are resolved through the OSI and Carrier Sense Multiple Access/Collision Detect (CSMA/CD) and a limit to the total cable length of the network. There are three speeds of Ethernet available and are shown in Table 4.1.

Table 4.1 – Ethernet Characteristics[5]

Version	Code	Symbol Rate (Mbps)	Min. Cabling	Shielded
Ethernet	10Base-T	10	2 pair Cat 3	No
Fast	100Base-TX	125	2 pair Cat 5	No
Fast	100Base-T4	33	4 pair Cat 3	No
Fast	100Base-T2	25	2 pair Cat 3	No
Gigabit	1000Base-T	1000	4 pair Cat 5	No
Gigabit	1000Base-X	1250	2 pair Cat 5	Yes

The use of Ethernet in process automation has been limited and proven reliability remains a concern of some engineering operatives. However with increasing bandwidth and increasing data to and from smart devices, Ethernet is becoming a solution that is able to provide real-time data to process workers and management.[6]

Transmission Control Protocol over Internet Protocol (TCP/IP)

This technology was developed by the US Defence Advanced Research Projects Agency (DARPA) for the 1969 ARPANET that has become the basis for today’s Internet. Transmission Control Protocol (TCP – an acronym one should commit to memory) is connection-oriented and accomplishes the transmission of data packets between computers and checks to ensure that all data arrives at the intended location. Internet Protocol (IP) routes the data packets and provides reporting of errors and manages the fragmentation and reassembly of large information units.[7]

As this is a standard method of communication within information technology, the adoption of Internet-based transmission is a likely solution for future engineering networks. Additionally, this type of network construction can lead to more remote control and data dissemination than has previously existed. The combination of all the technologies listed above leads to a more robust, interconnected and resilient network for process and manufacturing automation.

Protocols for Process and Manufacturing Automation

Open Systems Interconnection (OSI)

The OSI reference model was developed by the International Organisation for Standardization (ISO) in 1984. This is the primary model for computer networking and plays a significant role in interoperability. The model describes how information passes from one computer software application through to another computer's application.

The model lists seven layers that provide for specific network functions. Each of these layers provides for a specific task to be completed independent of other layers.[8] The layers are as follows and are in reverse numerical order to match Figure 4.1:

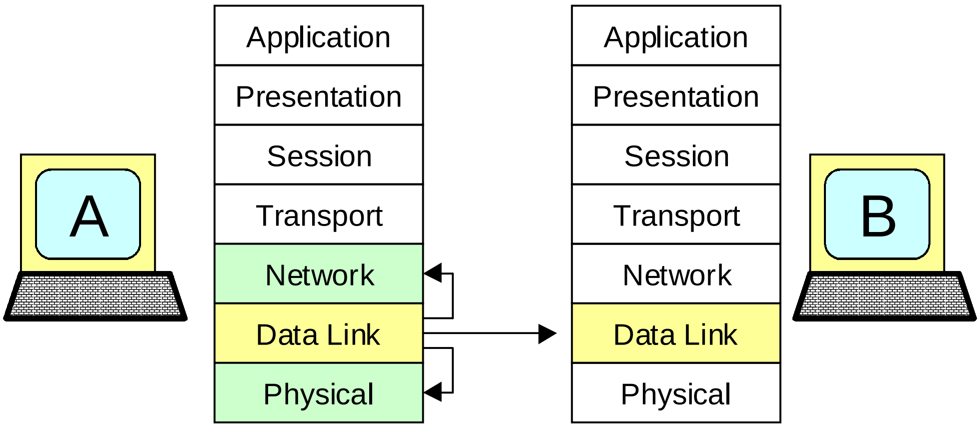
> **Layer 7 Application** – This is the layer that provides application software with communications. The actual software application is not contained in the OSI model. It is at this level that the File Transfer Protocol (FTP) and Simple Mail Transfer Protocol (SMTP) operate.
>
> **Layer 6 Presentation** – This layer provides for the coding and conversion of data and ensures that the exchange is understandable. This layer also provides for the exchange of data from one application to another through common data formats such as ASCII for text and Graphics Interchange Format (GIF). This layer also provides for data encryption and compression.
>
> **Layer 5 Session** – This layer establishes, manages and disconnects the communication session between computers. This layer also ensures that data is sent and retrieved from other computers. The Zone Information Protocol (ZIP) and Session Control Protocol (SCP) operate within this layer.
>
> **Layer 4 Transport** – This layer manages the traffic across the network to another computer and ensures that the packets arriving are not coming too quickly, out of order or if they are missing. The Transport Control Protocol (TCP) included in this layer ensures that the data is received correctly.
>
> **Layer 3 Network** – This layer prepares the address for the destination. It is at this layer that the network addresses are attached to the data packets and allow for data to be passed between different physical networks. The data can be sent through the same path (connection-oriented) or allow for each packet to take differing routes (connectionless). See Box 4.1 for more information.
>
> **Layer 2 Data Link** – This layer formats and frames network packets. At this layer, a Media Access Control (MAC) sub-layer defines the way the network manages the data flow between multiple devices that are sending data simultaneously. At this layer, network characteristics are assigned, physical addresses are attached, error notification is made and flow control of data is managed. The network topology is also defined that consists of the data link layer specifications and how devices on the network are to be connected. The Institute of Electrical and Electronics Engineers (IEEE) has

subdivided this layer into the Logical Link Control (LLC) and Media Access Control (MAC).

Layer 1 Physical – This layer defines the electrical, mechanical, procedural and functional specification for physically transferring data between computers and devices on the network. It is at this layer that voltage, timing of voltages changes, physical data rates, setting of maximum transmission distance and physical connectors occurs.

Layers 5 to 7 are known as the "upper layers" and deal with application issues through software. Some software application providers refer to the upper layer as their own software as is in the case of Foundation Fieldbus. The layers below, 1 to 4, are predictably described as the "lower layers" and primarily deal with data transport.

Figure 4.1 – OSI layers



BOX 4.1 – CONNECTION-ORIENTED AND CONNECTIONLESS NETWORKS[9]

A connection-oriented network is a packet-switched network where no pre-established connection is necessary between sending and receiving stations. The data packets follow a prescribed set path with the data packets arriving in the same order in which they were sent. Frame relay and Asynchronous Transfer Mode (ATM) are examples of this type of network and are similar to a circuit-switched network.

A connectionless network is also a packet-switched network but there is no pre-established connection between the sending and receiving stations. The data packets are given the source and destination address and how the data packets get to the destination is determined by the network based upon traffic on the network. Internet Protocol (IP) is an example of a connectionless network and is similar to a packet-switched network.

Object Linking and Embedding for Process Control (OPC)

This open system provides a solution to the interoperability issue of multiple vendor protocols. OPC is a series of standards' specifications. The first standard (originally called simply the OPC Specification and now called the Data Access Specification) resulted from the collaboration of a number of leading Worldwide automation suppliers working in cooperation with Microsoft. The OPC Foundation has nearly 300 members with Fisher-Rosemount, Rockwell Software, Opto 22, Intellution, and Intuitive Technology as members of the original working group in 1996.[10]

Originally based on Microsoft's Object Linking and Embedding (OLE) Component Object Model (COM) and Distributed Component Object Model (DCOM) technologies, the specification defined a standard set of objects, interfaces and methods for use in process control and manufacturing automation applications to facilitate interoperability.[11] Object Linking and Embedding has been renamed ActiveX.[12]

The OPC Foundation has taken the same approach toward interoperability as was taken with printer drivers. Instead of having each manufacturer write a driver for each software application, an operating-systems concentric approach was taken. In this way, a printer manufacturer would only write a driver for the operating system rather than for each application. By using a standard way of configuring computer hardware and software interfaces, a device will easily connect to another without lengthy installation (plug-and-play).

The OPC enables companies to build robust and durable automation solutions quickly, choosing the right components for their specific requirements. It decreases the up-front costs and reduces long-term costs of automation and control systems. The OPC uses a Component Object Model (COM) as a standard interface and inter-component communication protocol. This allows manufacturers to reuse component-based software and provides for the use of a variety of programming languages. ActiveX is an object-based platform that is open and allows for integration by software developers to create web-based applications.

The advantages of this approach is that it allows vendors to focus on adding value to their products without preparing interfaces for new devices or applications. Users are able to have available a wider range of devices and suppliers from which to choose the best solution. The focus on this is the "plug-and-play" capabilities, interoperability and web-based access and control.

Supervisory Control and Data Acquisition (SCADA)

Supervisory Control and Data Acquisition (SCADA) is the generic term given to a range of software application programs that are used in process control. These systems provide for the collection of data in real time from remote locations for the control of equipment and conditions. SCADA has applications for power plants, oil and gas refining, telecommunications, transportation, and water and waste control.

Using the technologies described above, SCADA systems are able to collect data and provide the data for use by other devices, display at a control centre or as data for other applications. The offerings from vendors are increasing in scale with some reporting up to one-million devices being connected to a system.[13] These systems provide for a range of alarm functions including interconnectivity to email and mobile communications,[14] Internet connectivity, reporting and trend display.[15]

Fieldbus Technologies

“Fieldbus” is a generic term given to networking technologies which define how data is to be directed through a network in process and manufacturing automation. These technologies have been developed to provide an alternative for the analogue standard. Nearly all of these technologies have been developed for manufacturing automation, building automation and other discrete types of automation. The levels of data communication and interconnectivity between devices and the network depend upon the scope of the original creators of the particular fieldbus. Some have open systems and others are proprietary.[16]

Lists have been compiled that provide a comparison between various fieldbuses and involve data transmission rates, message lengths or the number of devices allowed on a segment.[17] In nearly all of these systems the data is transferred only to a control centre and not between the devices themselves. It is not appropriate in this review to examine each of the available fieldbuses as there are reports on over 100 fieldbus styled offerings. In the following paragraphs there are a few fieldbus technologies that are mentioned for completeness with a more lengthy look at Foundation Fieldbus. Interestingly there is lively debate among engineers as to which fieldbus is superior and it is sometimes difficult to objectively assess these offerings.

Controller Area Network (CAN)

The CAN protocol is an international standard defined in ISO 11898 and ISO 16845. CAN uses a broadcast communication using message oriented transmission protocol and only defines the message. CAN is able to achieve a high degree of system and configuration flexibility and it is very easy to add stations to an existing CAN network as the new stations are purely receivers. This allows the concept of modular electronics and also permits multiple reception and the synchronization of distributed processes. CAN is a highly reliable technology and is used in automotive applications for mission critical systems.[18]

CANopen

CANopen is a CAN-based higher layer protocol originally developed for industrial control systems and is based on the OSI (see above). The family of specifications includes different device profiles as well as frameworks for specific applications. The flexible application layer optional features suit tailored networks. CANopen was originally developed as a standardized embedded network with highly flexible configuration capabilities. It was pre-developed in an Esprit project under the chairmanship of Bosch. In 1995, the CANopen specification was managed by CAN in Automation (CiA).[19]

DeviceNet

This system is based on the Controller Area Network technology. This technology provides for a low cost, high reliability network and is able to satisfy much of the common wiring requirments with power for the devices coming through the network. DeviceNet is able to work as a smart network but suffers from a limited bandwidth and small message sizes with a maximum of 64 nodes. This technology can be thought of as the application that sits on top of the CAN using the OSI model.[20]

ControlNet

This fieldbus is a mission-critical, high-performance application with the ability to work between multiple computers, programmable logic controllers and other sub-networks. ControlNet uses low bandwidth and provides for greater redundancy options than the TCP/IP networks as it can provide 100 percent reliability. This reliability comes at a price with few vendors suppling products for this technology.[21]

Profibus

This is the most widely accepted international networking standard in industrial automation. This fieldbus is able to process large amounts of high-speed data within large organisations and this is its main feature. Profibus periodically interrogates each device for its status thereby ensuring that the network is operating correctly and reliably. This technology provides for device-to-device communication (peer-to-peer) with up to 126 nodes.[22]

Foundation Field Bus

The technology began to evolve in 1984 through the International Electrotechnical Commission (IEC) and the International Society for Measurement and Control (ISA). The primary objective was to define a digital and serial link that would communicate between the primary automated devices and higher-level devices in a production control room. The focus of the activity centred on process automation that involved fluid processes (known as H1) and manufacturing (known as H2) automation for discrete control and data collection.[23]

The H1 fieldbus was required to power the devices from a single shielded twisted pair and communicate on a cable 1.9 kms in length without repeaters (9.2kms with repeaters) and in electrically noisy environments. H1 sends data using the Manchester encoded signal at 31.25 Kbps and can use High Speed Ethernet (HSE) connections. Up to 32 instruments can be multi-dropped with each device has its own TCP/IP address, it is able to be contacted directly through a web-based application.[24]

The main features that set Foundation Fieldbus apart from other fieldbuses is its ability for bi-directional (plug and play) communications where the device identifies itself, enables control in the field, has single loop integrity for continued operation during host failure and for sophisticated diagnostics.

Foundation Fieldbus is able to bring in from a variety of devices, data for archival, trend analysis, process optimisation study and report generation. The access to accurate and high-level data enables processes to be fine-tuned for better manufacturing throughput and reduced downtime. Foundation Fieldbus is also able to assist in planned and unplanned maintenance tasks with advanced notice of device failure rather than using the vendor's recommended replacement that is based on an average of device failures.[25]

This technology is able to become the dominant fieldbus for the process industry, however adoption by existing technicians and engineers is believed to be too slow. This is due to a lack of knowledge, skills and competencies at managerial, engineer and technician levels. This technology is best suited to a "greenfields" site but some Foundation Fieldbus sub-networks on other networks are possible on "brownfield" sites.[26]

Software

Software applications for process and manufacturing automation will be the main drivers of the next generation of industrial automation. The data collected from these systems needs to be able to be read through web-based applications. This move will require the use of a range of software programming languages to enter new areas where engineering, information technology and software developers will cooperate on new projects.

The International Engineering Consortium has attempted to promote an "open systems" approach to programming. This standard, IEC61131, provides for this standardisation. Some of the features of this includes structured text, ladder diagram, and sequential function charts. One feature is that this standard allows for graphical programming tools.

IMPLICATIONS FOR THE SHARED TECHNOLOGY INDUSTRIES

Automotive

The move towards "fly-by-wire" automotive management systems will draw upon these fundamentals of engineering and network integration. The network and original equipment will be fixed in terms of a service and maintenance technicians, problem solving will be critical for the success of the future automotive service person and an understanding of networking protocols more important. Additionally, retro-fitting of devices will become more of a concern in order to ensure the integrity of the mission-critical aspects of the vehicle.

Building and Construction

Issues relating to this industry have been more completely covered in Chapter 3 – Networking for Automated Buildings.

Engineering

As this chapter has dealt exclusively with engineering, this industry area will be greatly affected by the next generation of networking technologies. Legacy facilities will continue to operate and large vendors will continue to provide proprietary systems into process and manufacturing automation. These vendors will need to continually revise product offerings to ensure that they are matching the flexibility and interoperability of the open systems approach. Conservative decisions regarding new process engineering facilities in recent times have not permitted the adoption of newer fieldbus technologies to be demonstrated. Continued attention needs to be paid to this area.

Electrical

The cabling infrastructure for process and manufacturing automation is moving towards high-speed Ethernet and will require greater care and up-skilling in new cabling technologies. Electrical and instrument technicians will also need to understand the particular requirements of the network protocol to be installed to ensure that maximum data speeds are able to be realised.

Electronics

The interoperability of devices connected to the process and manufacturing automation networks will require additional problems to be solved. As these devices are to connected to an Internet-based network, electronics technicians and instrument technicians will need to understand these issues. Not only will data be collected for control purposes but also for management information. This will create new pressures for real-time data to be used in different ways and by different individuals and will create new challenges for electronics and instrumentation technicians.

Information Technology

Information technology operatives will play an increasing large role in the implementation of industrial automation. This includes network management, database management and software development.

Network management and administration will become central to these new systems. Enterprises supplying TCP/IP networks are managing the introduction through teams of engineering and information technology staff. As each discipline requires specialist operatives, the combination of both of these skill areas is unlikely to be found in one person. Information technology staff will find the installation of the new networks very familiar to well established computer local area networks but will also need to understand electrical principles.

Database management will become of increasing importance to the success of industrial automation. As the data is more easily captured, there is a tendency by some managers to ask for all available data to be archived for later use. This places increasing demands on database managers with billions of records being collected and stored.

Software applications will continue to drive the value of these new networks. Compared to previous technology where one person was able to manage a set number of controls, new systems will only alert the operator if a process is failing by utilising a “management by exception” approach. Software and smart devices will monitor, adjust and supervise operations without the need for human control and will use graphic descriptions of real-time data rather than numerical output.

Telecommunications

Little new technology will be employed in this area as many of the SCADA systems are already using wireless and wireline technologies. Please also see Chapter 7 – Wireless Local Area Networks for more information.

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