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COMPUTER NETWORK SYSTEMS, INCLUDING MAP, AND THEIR RELEVANCE T0 A SMALL INDUSTRIAL COMPANY

Daniel S. Fowler

Cirrus Reynolds Ltd., Redditch, & Coventry Polytechnic, Coventry

This paper discusses the increasing use of computer networks in industry and why they are needed to help the implementation of factory automation. It also discusses the emergence of the Manufacturing Automation Protocol as a standard for industrial data communications. Finally the paper discusses how the use of industrial networks affects a small company in relation to systems design.

INTRODUCTION

With the advent of Computer Integrated Manufacture and Computer Aided Design (CAD) computer networks now play an important role in industry. That role is increasing in stature as automation widens to incorporate more and more processes. Large manufacturing companies have production lines crowded with robots, machines, automatic jigs and computers, and of course people. Austin Rover at Cowley, Oxford, has spent £100 million on automation over the last three years, with processes linked to a Computervision CAD system. The launch of the Rover 800 car included a further £1.4 million investment in computer integrated planning and control systems [6].

This level of automation requires data communication systems of equal importance to those in the office environment. Office systems provide large computing facilities at desk top level, they are capable of large amounts of information handling. The need to transfer this information between other 'workstations' is important, a large number of commercial computer networks are available for this job, such as IBM's Token Ring or various Ethernet based networks. The computer networks in industry have evolved from these office networks since they also handle information, the programs that control the machinery, communication between different processes, and reporting to managers the state of the factory and production.

INDUSTRIAL COMMUNICATION SYSTEMS

As more and more factories implement automation in an attempt to remain competitive, increasingly so in the large industries such as consumer electronics and car manufacture, the number of microprocessor controlled machines being introduced on to the factory floor is increasing daily, and with increasing complexity. General Motors, GM, of the USA, estimate that they have 20,000 programmable controllers, 2000 robots and 40000 intelligent machines in total in the manufacturing areas. Projected growth of such distributed intelligence is 400-500% over the next five years[4]. All this investment in automation is in order to stay competitive in the marketplace, however, automating for the sake of it is not the solution to cost cutting. Automation brings in new problems that have to be tackled.

In any manufacturing company a two way flow of information occurs between the manufacturing processes and the managers. Production monitoring is a necessary function. Observation of orders coming in, work in progress, control of machinery, and products despatched is a requirement of efficient factory running. The managers provide the processes with the controlling functions, such as manpower and computer programs, and in return the processes provide the management with data on their behaviour. The managers then modify their plans accordingly. This monitoring process has always involved paperwork, information, in several forms, such as invoices, stock records, machine work allocation, and schedules. The very nature of automation increases the amount of information in a factory, due to improved sensing techniques, flexible production methods and employment of 'Just In Time' techniques and CAD. This makes the monitoring task that much more difficult, and that much more costly. Costs that automation was supposed to cut.

A real problem then is the increase in information flow in a factory that results from automation. The need to get that information from the shop floor to the managers and back again is the bottle neck in an automated factory. Without this information the managers cannot run the factory efficiently, this is particularly the case with very large factories. The solution to this dilemma is to improve information flow throughout the factory system and employ effective filtering techniques on the information so that only the necessary information is returned to the managers, in doing so the full benefits of automation can be obtained. An improvement, in information flow can be achieved through the use of the Local Area Network (LAN). LANs in a factory allow almost instant information transfer between the machinery and the management, resulting in improved efficiency, the final objective of automation.

The computers on the LAN can help with the filtering process by taking the generated information and producing graphical output that is easier to understand than pages of figures. The computers can identify problem areas by highlighting, for example, unusual component failures or bottlenecks in a production line. Many software packages are available today which help to present information in a more meaningful way, simulation packages, report generators and expert systems.

Initially the networks in factories are often supplied by equipment manufacturers to allow machines working on a process to communicate. These are localised and specialised, often used in a single area, "islands of automation". For example an assembly line may have several Programmable Logic Controllers (PLCs) communicating to each other to ensure that actuators and machines are turned on and off at the correct times, or if robots are on an assembly line they have to communicate to prevent conflicts. However, if different equipment suppliers are working on the same process how do they get their machines to communicate, for example what if robots and PLCs from different suppliers are on the same assembly line. Also what about getting the production information from all the manufacturing functions to the management? Despite the existence of networking technology these communication problems are not easily overcome.

THE OSI NETWORK MODEL AND CLOSED SYSTEMS

The problem with networks supplied by equipment manufacturers is that they are 'closed'. They are dedicated to their own machines and often cannot communicate to other manufacturers machinery. Thus for the robots made by one manufacturer to communicate to the PLCs of another manufacturer special equipment is needed. This custom equipment is often expensive and with high software overheads. Similarly networks to obtain information from the whole factory are either none existent, in which case information is collected on paper, or adaption of office networks.

To illustrate these problems it is possible to look at GMs case. Of their 40000 intelligent devices only 15% are able to communicate with each other, and when communication does take place it uses up to 50% of the automation installation costs, due to cabling, custom hardware and software[4]. (Cabling to industrial standards, £5.00 per metre plus cost of manpower to install cable. Design, manufacture and production of specialised hardware to interface between different systems. Cost of software development, very labour intensive.)

International standards are being developed to overcome the problem of closed data communications. By considering the processes involved in transferring information a set of rules can be built up with which a network can be designed. One definition of these processes has been defined by the International Standards Organisation (ISO). The Open Systems Interconnection, OSI, model (on which practical implementations of the processes can be based) states that seven processes, or layers, required to communicate over a network. All seven layers work to effect user to user communication without the user realising that a complex communications system exists. The OSI model is discussed in any good computer networking book.

The OSI model can be used for both localised exchange of data, which is often restricted to a single building or small area within a building using a LAN, or for much larger areas of data exchange, country or continent wide systems, referred to as Wide Area Networks (WAN). Each layer of the OSI model follows set rules when transmitting the given data through it, these rules are known as a protocol. At the physical level three main protocols have emerged for networks. For LANs Carrier Sense Multiple Access with Collision Detection (CMSA/CD) and Token Passing are the main protocols, of which there are many variants. CSMA/CD allows any node to transmit at anytime, this can lead to corrupt data as two nodes transmit simultaneously. If this occurs the network is cleared and the nodes have another chance to try again, after waiting a certain time (which increases on each collision). In token passing each node takes turns to transmit its information, when it receives a 'token'. For WANS X.25 is growing in importance, also Integrated Services Digital Networks (ISDNs) hold a lot of promise for the future for the simultaneous transmission of voice and data over telephone systems.

The big advantage of the 0SI model is that it provides an architecture for communications that is "open". In other words if the manufacturers follow the standards set out by ISO for OSI then networks from various sources will no longer be incompatible. This was one aim of the new Manufacturing Automation Protocol (MAP).

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MAP - A UNIVERSAL INDUSTRIAL COMMUNICATIONS PROTOCOL

General Motors saw the need for a standard communications protocol for industry back in 1982. They initiated Manufacturing Automation Protocol, MAP, and published the first specification. Since that first document MAP has been taken up by the large manufacturing industries in general as the de facto industrial communications standard. By the end of 1988 General Motors expect all their suppliers of intelligent devices to provide MAP compatibility. It is logical to assume that all companies that implement MAP will request the same. General Motors have thus opened up communications for the modern factory, using the OSI model as a basis. The move away from closed systems is beneficial to all of industry, especially when it comes to equipment costs. A supplier is unable to inflate prices if other companies are manufacturing systems that achieve the same communications aims.

MAP implements a 10Mb/s Broadband Token Passing protocol, IEEE 802.4, to cope with industrial needs. The response time is predictable. MAP has full error protection, network recovery and data security built in. It is fast reliable and suitable for industrial environments. However, it is very complex, as an indication the latest MAP 3.0 Specification runs to well over 500 A4 pages. MAP's complexity brings a number of disadvantages. Firstly, manufacturers of MAP equipment find that it is difficult to conform to the standard, this increases product development times and costs. It is difficult to understand. It is also very expensive, costing many thousands of pounds per node. This is currently its major disadvantage. As with a lot of new technology the first uses are costly until it becomes popular. Finally its performance for industrial control purposes is limited due to high processing overhead of the seven layers, hence the development of the Enhanced Performance Architecture, or MAP EPA. However, the full protocol is adequate for the general factory network.

The development of EPA for MAP is necessary to allow MAP networks to be used in real-time process control systems. It uses only the physical, network and application layers of the seven layer OSI model for networks. The use of three layers of the model allows a much quicker transfer time when getting data through the system. It is estimated that a message packet could travel through the EPA system in 0.5ms as opposed to 40ms for the full protocol.

EPA also is simpler to implement in physical terms, it uses the same standard as the full MAP implementation, IEEE 802.4, however it is the 5MB/s carrierband version. This version is seen as the network for an area of a factory, while the 10MB/s implementation is for the whole factory. Yet EPA MAP is perhaps unnecessary because its objectives can be met by existing networks, also it is not currently available as a commercial product.

A SMALL COMPANY AND INDUSTRIAL NETWORKS

Cirrus Reynolds Limited is a small systems house that produces complex computer test systems and control systems for a variety of customers. The systems produced are often unique highly complex designs. For example a microprocessor controlled piece of test gear to test the anti brake skid (ABS) systems on cars, another system tests the electrical functions of a car facia (dashboard), both these systems, and others, are used on the production lines of motor car manufacturers.

In the past the computer networking requirement of Cirrus has been minimal, however as applications, customer requirements and the computer industry have changed so the importance of computer networks has increased. Cirrus is planning to use a network at its own offices by applying readily available hardware. However, as a component for a system networks are having a more immediate effect and are now very important. So much so that the latest project for the Austin Rover Group (ARG) has a computer network as an important part of its design. The Cirrus Reynolds design philosophy is buy in the various components of a system then assemble them to a design specification. The software for each system is what makes the whole into one homogeneous product.

The ARG project is an engine component test facility. Ten engine component test rigs are each connected to their own computer. Sensors on the rigs, measuring all required parameters, feed analogue to digital converters. Tests are performed on engine components, such as the oil pump, and the results of the tests are given to an analysis computer. The test computers actually step through a 'test sequence' of operations defined in advance by the users of the system. Thus the hardware controlled by the computers steps through whatever actions are necessary to perform a component test. The results can also be uploaded to the ARG Siemens computer, this is used to store information from various engine test facilities. The tests that are performed are programmed by ARG's engineers in a high-level symbolic language developed at Cirrus. This language is suited to the task and far easier to use than a high-level language such as 'Pascal' or 'C'.

The computers are based on the 68020 microprocessor mounted on VME rack systems with an I/O system on a G64 bus. They run the 0S9 multi-tasking, multi-user, operating system and all software is written in 'C'. Each of the ten test computers plus an analysis computer and two programming computers, are connected together via a 1Mbits/sec token passing network. This network is used to transfer all the test results between the various nodes and also for transferring the test programs. The network is inexpensive, at £500 per node, efficient and does the job required with capacity to spare.

The factors in deciding which network to choose for the project were driven by cost effectiveness. Conformance to an international standard was never considered, it would merely have been a bonus if the network had conformed. The network was considered to be just another component the overall system and as such it had to be cost effective in order to keep the cost of the whole system at a reasonable level. Therefore the use of MAP for the system was out of the question, it would have added £100,000 pounds to the costs, that compares to the £6000 for the chosen network. That type of price difference is important for a small company. A small company that has to look carefully at its pricing when quoting for contracts while at the same time making sure that it can make a profit. Similarly the use of an Ethernet system would add another £10,000 to £20,000 on the systems price, not including cabling. While that is only a small percentage of the final quoted price a difference of possibly £14,000 just to buy an international standard network is hard to justify. However as

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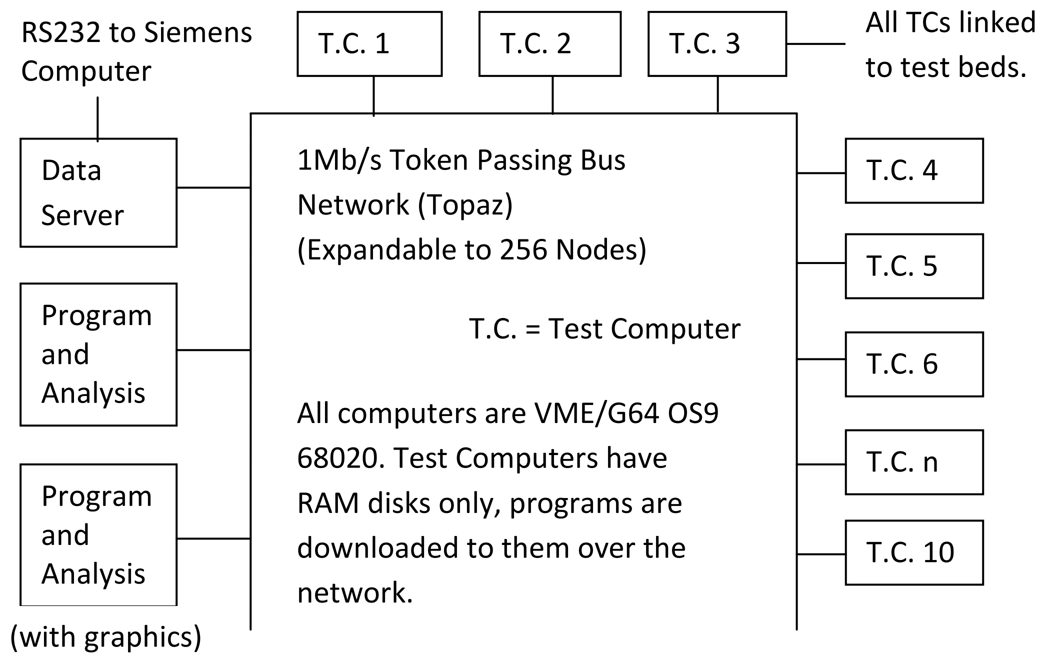
the system is designed it can be quite easily incorporated into a factory network through the use of a gateway. This method is in fact a more effective method of networking than using a complete factory network to handle local communications. It allows our local specialised network to get on with the application it was designed to be used in while any future network has easy access to it. Though it would have been good policy to use an international standard the current pricing of products that support OSI prevented it. In the end the criteria in purchasing the network were:

a. Is the network compatible with the chosen computer systems? (VME OS9)
b. Is the network capable of providing the required performance? (100 kilobytes of data per second on average - real time performance was not required.)
c. Is the network reasonably priced? (Less than one thousand pounds per node.)
d. Is the network easy to use and maintain? (No special expertise required.)
e. Has the network a degree of fault tolerance?
f. Is the network expandable for possible growth in the system?

If the network can accommodate these criteria then it is suitable for use in the Cirrus system. A suitable network was finally chosen. Called Topaz it is based upon a Western Digital 2840 Token Access Controller chip. The cable medium is twisted pair, which is inexpensive, in a multi-drop bus configuration driven by RS 422 drivers with the data Manchester encoded (exclusively ored with the clock signal), distances of up to 1000 meters can be catered for. The network was simple to install and is simple to run, to date no problems have been encountered with it. The simplicity comes from modularity of the system, with the computers being rack based, each element of the system is mounted on separate boards, the network could be changed by changing the network card and networking software. Thus if ARG implemented a complete site wide network the Cirrus system could either be incorporated into it, or more likely, have a gateway onto it. With a gateway one of the other computers would have an additional network board. The operating system then needs only to have another device driver. A gateway to other networks, including MAP, would not be a problem.

Engine Component Test System for ARG



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Fault tolerance in a network is quite import, with large amounts of data being transferred serially it is important that networks can handle errors due to noise and other hazards, such as a cable breaking or computer breaking down. The Topaz network reports when nodes that should be active on the network go down, or when a break in the cable occurs. Transmitted information has to be acknowledged by the receiver. It is also able to reconfigure itself when such an event occurs. The test computers have the ability to store their test results in the RAM disk and wait for the network to become active again if it does go down. Optional backup power supplies are available to deal with mains power loss.

CONCLUSION

Despite the international standards for computer networks Cirrus Reynolds, and possibly other smaller companies, will tend to use existing proprietary networks because they are inexpensive, reliable and effective. The emergence of MAP for industrial communications is beneficial to industry but until its price, and that of other international standards, falls then it will be used mainly by the big industrial corporations. The big corporations have more to gain in using MAP immediately, however, there is still room for the proprietary networks. While MAP is used for the major artery of a factory network the islands of automation, supplied by systems manufacturers, can be equipped with gateways to communicate with it.

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