Eight popular open architecture fieldbuses:

Part 2 – The guide to the pros and cons for users and OEMs

By Perry Sink

If your hardware/software projects have anything to do with industrial automation or process control, then you know that open industrial networks (fieldbuses such as DeviceNet and Profibus) are being considered and specified more and more all the time.

Robots, material handling systems, process control installations, assembly and packaging machines can have dozens to thousands of sensors and intelligent devices. There are three ways you can interconnect those devices: 1) hardwire each device individually; 2) use a 'proprietary' network such as Modbus Plus, Remote I/O or Genius I/O; or 3) use an open architecture network.

Just by using a network, you gain tremendous advantages in larger systems: faster wiring time; lower installation cost; modularity; and the potential for very powerful diagnostics. I won't go into all of the arguments for networking here, as I believe that most engineers can recognize the benefits of this.

In Part I of this article, published in February 2000 (See articles at www.pc104-embedded-solns.com), I presented the major features and attributes of Profibus, DeviceNet, CANopen, Interbus, and AS-I.

In Part II of this article, I cover the major features and attributes of ControlNet, Foundation Fieldbus, and Industrial Ethernet.

Industrial Ethernet overview and application summary

- Ethernet: The Worldwide Defacto Standard for Business and PC Networking
- Origin: Digital Equipment Corporation, Intel and Xerox, 1976
- Implemented on Multitudes of chips produced by many vendors. Based on IEEE 802.3
- Formats: 10 Base 2, 10 Base T and 100 Base T, 100 Base FX, 1 Gigabit; Copper (Twisted Pair / Thin Coax) and Fiber
- Connectors: RJ45 or Coaxial
- Maximum Number of Nodes: 1024, Expandable with Routers
- Distance: 100M (10 Base T) to 50 KM (Mono mode, Fiber with Switches)
- Baudrate: 10M to 100M Bit/sec
- Message size: 46 to 1500 bytes
- Messaging format: Peer-to-Peer
- Supporting Trade Organization: Industrial Ethernet Association (www.IndustrialEthernet.com) and IAONA ( ).
- Typical Applications: Nearly universal in office / business Local Area Networks. Widely used also in PC to PC, PLC to PLC and supervisory control applications. Gradually working its way toward the "sensor level" in plant floor applications.
- Advantages: Ethernet is the most widely accepted international networking standard. Nearly universal worldwide. Ethernet can handle large amounts of data at high speed and serve the needs of large installations.
- Disadvantages: High overhead to message ratio for small amounts of data; No power on the bus; Physically vulnerable connectors and greater susceptibility to EMI/RFI than most fieldbuses; Confusion based on multiple open and proprietary standards for process data.

The networking of millions of PC's in offices and the proliferation of the Internet across the world has made Ethernet a universal networking standard. Ethernet hardware and related software has evolved to the point where even inexperienced users can build simple networks and connect computers together.

Ethernet hardware is "dirt cheap" and can be purchased in office supply stores, computer stores and e-commerce sites everywhere.

In contrast to the perception that the popular fieldbuses are expensive, difficult to use, and that there are too many of them vying for market dominance, Ethernet appears to be a panacea. Furthermore, a study by a Big Three automotive manufacturer showed that Ethernet could potentially serve up to 70% of plant floor networking applications.

Reality may be somewhat different, however – at least right now. There are at least three major issues, which must be addressed satisfactorily for Ethernet to become a viable, popular, plant-floor fieldbus:

1. A common "Application Layer" must be established. When your device receives a packet of data, what format is that data in? Is it a string of I/O values, a text document or a spreadsheet? Is it a series of parameters for a Variable Frequency Drive? How is that data arranged? There are several competing standards. More about this below.

2. Industrial grade connectors will be necessary for many applications. Cheap plastic "Telephone Connectors" don't cut it on the plant floor, and the RJ45 connectors aren't up to the task. An industrial strength connector will be a great benefit.

3. Many users desire 24 Volt power on the Bus. This is advantageous from a practical standpoint – it reduces wiring and power supply problems – but it adds cost and introduces noise and other technical problems.

4. Some applications require determinism. Ethernet as it is typically used is not deterministic or repeatable; in other words, throughput rates are not guaranteed. However, methods exist for architecting deterministic Ethernet systems. Note that, in reality, most people who think they need determinism really just need speed.

Ethernet doesn't guarantee interoperability

Ethernet is just a physical layer standard, in much the same way an RS232, or for that matter, a telephone line, is. Having a physical connection means that messages can be transmitted, but it does not assure successful communication. Just because

you can make a telephone ring in Shanghai doesn't mean you can speak Mandarin.

TCP/IP doesn't guarantee interoperability, either!

There are many transmission protocols that can be used on Ethernet; the most popular, and the one used on the World Wide Web, is TCP/IP, which stands for Transmission Control Protocol/Internet Protocol.

When you download a file from the web, you can see the speed of the transmission speed up and slow down as network traffic levels change. TCP/IP is the mechanism that breaks the downloaded file into any number of bits and pieces and re-assembles them at the other side. TCP/IP was developed at Stanford University in the 1970's as a "handshaking" mechanism that would assure that 'the message would always eventually get through.' It does seem a bit miraculous that those files usually come across perfectly, with every single bit intact, wouldn't you say?

To carry the Web example a bit further, we've all had the experience of downloading a large file, only to discover that our PC "cannot find an associated application for this file type." So you end up downloading a plug-in like Shockwave or RealAudio or Winamp or Adobe Acrobat Reader so you can open the file.

The exact same problem applies to industrial controls. You can send any file or piece of process data you want to over Ethernet or the Internet, but the receiving end has to know what to do with the data. TCP/IP doesn't assure you of opening the file; it just guarantees that it will arrive.

Fieldbuses, school buses, and flatbed trucks

To an extent, you can think of the current popular fieldbuses – DeviceNet, Profibus, Interbus – as being like a school bus. The school children (bits or bytes of data) file into the bus and sit down in their respective seats, in a predefined arrangement. The popular fieldbuses have profiles (arrived at over years and years of laborious committee meetings) for the most common devices: Analog and digital I/O, drives, controllers, etc. – and the data comes in prescribed formats.

Well, if Profibus is like an orderly school bus, then Ethernet and TCP/IP are like a flatbed truck. You can put anything you want on the back of the truck and send it. But it may be a mess for the guy on the other side who's trying to unload it. Back to our school children, if you put a bunch of kids on the back of a truck, you'd have chaos.

The approach that is used, then, is "strapping the school bus on the back of the flatbed truck." You put the children, lunchboxes in hand, on the bus, put the bus on the truck, transport it at high speed, then take the bus off the truck. The children can exit the same way they got in.

Similarly, data can be packaged into an existing fieldbus format, and then transported on TCP/IP. This is the likely direction the industry will take.

Existing fieldbuses on Ethernet

The next frontier for the established fieldbus organizations is to produce Ethernet TCP/IP application layers of their protocols. Presently, there are three major contenders: Modbus/TCP (Modbus protocol on TCP/IP), EtherNet/IP (the ControlNet/DeviceNet objects on TCP/IP) and Profibus on Ethernet.

One could propose an infinite number of potential application layer protocols, and in fact right now there are, in addition to the above protocols, a myriad of other, proprietary standards from various vendors. But there are several significant advantages to employing the existing bus architectures:

- Profiles for many devices have already been defined, and can be transferred to Ethernet with relatively little effort.
- In systems which use, for example, Profibus as an I/O level network, and Profibus on Ethernet at the supervisory level, the relationship between the two networks is relatively transparent. Data can be transferred between the upper and lower network fairly easily.
- Many developers and users are familiar with these existing protocols, and this speeds the process of product development and adoption.

To go into the details of Modbus/TCP, EtherNet/IP and Profibus/Ethernet is beyond the scope of this article. But for more information, see the following links:

Modbus/TCP

http://www.modicon.com/openmbus/

If there is currently a defacto standard for Ethernet on the plant floor, this is it. Takes advantage of the simplicity and availability of Modbus. However, the limitations of Modbus also apply; it has limited ability to transmit complex sets of parameter data between devices.

Ethernet/IP

http://216.10.36.18/10_2/02_news/02_ethernet-ip-release.htm

This specification has strong possibilities but is just now being released. Example code and the specification itself will be available from ODVA, ControlNet International and Industrial Ethernet Association.

Profibus on Ethernet

http://www.profibus.com/data/articles/2868.html

This specification is, as of this writing, still unreleased. However, with the worldwide acceptance of Profibus, it has strong likelihood of commercial success.

A final note about "Application Layer" protocols: *They can co-exist on the same network.* You could have all three of the above protocols on the same wire, running simultaneously, just like you pass Word documents, HTML files and .exe's all on the same office LAN. However, this is bound to create added confusion and expense as well.

Practical applications and the future of Ethernet on the plant floor

I wrote this without the help of seers, soothsayers, astrologists or palm readers. But here's what I see in my crystal ball:

- It will be difficult and expensive to get Ethernet to the sensor level. Using Ethernet to turn a valve on or off, or to connect a node to a photo eye or prox switch, is kind of like putting five-foot monster tires on a Ford Escort. However, it will do well for "Racks" and clusters of I/O tying into a single node.
- Ethernet will not necessarily be "dirt cheap" in industrial applications, and overall may prove to be *more* expensive.
  - Ethernet PC cards cost 1/10th as much as, for example, DeviceNet cards, for several reasons. Obviously, they're made by the millions. They don't have a processor: they're passive, meaning that the PC does most of the work. DeviceNet cards usually have a processor on board that handles all communication. Also, long term availability is a real problem with consumer computer products. Product life cycles are measured in *days*, not years! Finally, the quality of cards you buy at an office supply store may be lacking, certainly not for professional, industrial use. (This is why Synergetic makes industrial grade Ethernet NIC cards for PC/ISA and PC/104.)

  - Ethernet in embedded applications is much more expensive than CAN. CAN chips cost $1 or less; Ethernet chips are much more. So devices themselves with Ethernet built in will definitely have a cost factor. I expect Ethernet to have costs similar to Profibus, which has more expensive ASICs.
  - Industrial grade cables and connectors will drive the cost up as well.
- Not only are Ethernet ASICs more expensive than CAN chips, running a TCP/IP stack takes more horsepower than your usual 8051 can supply. The processors will cost more, too.
- A TCP/IP packet has 68 bytes of overhead. For short messages, corresponding to typical industrial I/O products, that's a lot of overhead. So 10Mbits may not be as fast as it sounds.
- The promise of fiber optic, 100M and 1000Mbit Ethernet is certainly exciting, and potentially overcomes most people's speed issues. However, the cost associated with these enhancements may be substantial.

The bottom Line

Ethernet will establish itself among the popular fieldbuses as a legitimate and attractive option. I do not believe it will replace them, but for some applications it will be the clear winner.

Foundation Fieldbus

- Foundation Fieldbus: The Open International Standard for Mission Critical, Process Control and Intrinsically Safe Environments
- Origin: ISA, 1998
- Implemented on chips produced by multiple vendors.
- "H1" Intrinsically Safe, 31.25Kbit/sec; "HSE" High Speed Ethernet, 100Mbit/sec. Based on ISA SP50/IEC 61158
- Maximum Number of Nodes: 240 per segment; 65,000 possible segments.
- Distance: 1900M for H1
- Baudrate: 31.25K and 100M Bit/sec
- Message size: 128 Octets
- Messaging format: Client/Server, Publisher/Subscriber, Event Notification
- Supporting Trade Organization: Fieldbus Foundation (www.fieldbus.org)
- Typical Applications: Distributed Control Systems; Continuous process control, Batching, Oil and Gas
- Advantages: Flexible, sophisticated protocol with many capabilities; Intrinsically safe; Integrated device level/plant level approach; Very strong contender as future process industry standard.
- Disadvantages: "Process Industry" centric; limited availability of compatible devices; *s-l-o-w* process of standardization and industry adoption.

Foundation Fieldbus has finally come into its own and is rapidly establishing itself as the future standard for process industry networking.

Since its official introduction in 1997, many DCS vendors have been embracing Foundation Fieldbus, developing and certifying devices. Foundation Fieldbus contends with Modbus, HART and Profibus PA as a standard.

The unique requirements of the process industry

Process industry installations tend to be "campus wide": much larger than the cell-level and "production line" sized applications more typical of the automation industry. Upgrades and changes tend to be done much less often and are more expensive. (When process vendors find a customer, they usually put out press releases and have big parties, because these projects are typically very large.)

The process industry is very, very cautious about new technology. These installations can be extremely hazardous and there's no room for error. So the Fieldbus Foundation's objective of developing the "ultimate" networking standard, that would please everybody, was an ambitious one and it did not come about easily.

Sophisticated fieldbus

What was produced, however, is a sophisticated, object-oriented protocol, which uses multiple messaging formats and allows a controller to recognize a rich set of configuration and parameter information ("Device Description") from devices which have been plugged into the bus. Foundation Fieldbus even allows a device to transmit parameters relating to the estimated reliability of a particular piece of data.

Foundation Fieldbus uses a scheduler to guarantee the delivery of messages, so issues of determinism and repeatability are solidly addressed. Each segment of the network contains one scheduler. HSE, High Speed Ethernet, is a 100Mbit Ethernet standard which uses the same protocol and objects as FF H1, on TCP/IP. HSE is not commercially available yet, but there are currently some beta sites.

The fieldbus wars and you

With eight different fieldbuses described in this series – with multiple variations within several of them – it's easy to be indecisive and just wait for one standard to "shake out".

You can wait until your teeth fall out, but I can tell you that the emergence of one single fieldbus for everybody is *not* going to happen. No single bus will dominate, because no single but solves all of the problems.

You could make the same arguments for standardizing all automobile engine to a single mounting size, or making all wooden doors the same height and width. But the fact is, the creativity of vendors in the constant race for newer and better technology, and the diverse and growing needs of customers, make it impossible for this to happen.

What you must do is narrow your choices to a few likely options (that's pretty easy) and then research the details and the available vendors for all of the devices you wish to use. Then *do something.* The savings in wiring, the additional diagnostics and functionality that's available in devices, and the lower long-term cost of maintenance are well worth the extra hardware expense.

I also feel comfortable in saying that the established fieldbuses described in this series – particularly Profibus, DeviceNet, Foundation Fieldbus, Interbus, CANopen and AS-I – will be around for a long time. If you choose one of these, the odds are good that you'll still be able to buy products in five years. Industrial Ethernet, however, is still young enough that I wouldn't make any bets that a standard you buy into now will be valid two or three years from now.

Making sure it all works

"End User" plants who want to install new fieldbus technology should seriously consider using a qualified, experienced System Integrator who can guarantee successful operation of the system. This can drastically reduce the risk in exchange for a known up-front cost.

…And some advice for OEMs

If you produce or integrate controls equipment, or develop hardware or software applications, there's no question about it: You need to be fieldbus savvy. When your customers want to buy your product with a fieldbus option, that's not the time to start designing new stuff. Be ready beforehand.

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This is a difficult challenge, because developing a fieldbus interface is an expensive and time-consuming proposition. Most of all, you don't want to do it five times for five different buses. Synergetic's approach to this problem is PC cards and embedded daughter boards, which all have a common hardware and software interface, regardless of the bus. This makes them essentially interchangeable with little or no changes in your software or firmware. A detailed explanation of this common architecture concept is available at www.synergetic.com/oem.

OEMs can use Fieldbus connectivity to differentiate their products in the marketplace. First of all, just having the capability is somewhat distinctive. But taking advantage of the diagnostic and information capabilities is a significant advantage that customers will pay more for. You win both ways.

Networking: The center of new technology development

Networking is obviously a hot topic with the Internet and all of the business and ERP applications out there. And although the Wall Street Journal isn't necessarily doing stories on plant floor connectivity, keep in mind that the general connectivity that's available to citizens everywhere is changing people's expectations. They expect the instant availability of information and results.

Fieldbuses meet this requirement, and quite honestly, most fieldbus users have only begun to tap the true potential of the technology. I encourage you to adopt a fieldbus architecture and squeeze the most performance from it. If you need education, or training, then seek it out. (Hands-on "Boot Camp" classes are available at www.synergetic.com/education).

As you embrace the technology and scale the learning curve, your efforts will be amply rewarded with more productive equipment, more distinctive products, and the ability to attract leading-edge customers.

The value of information

When you buy connectivity, you are really buying information. Let's say you make products for the factory floor, and your control system is installed on a packaging line that seals 500 boxes of cereal per minute.

Using simple calculations, if each box sells for $3, then down time costs $1500 per minute. 15 minutes of down time costs $22,500.

If you design diagnostic features into your controller, which, via a fieldbus, transmit critical data that alerts a maintenance electrician to a potential failure *before* it happens, this is going to save your customer a lot of money. $90,000 per hour, to be exact. Of course automotive plant down time is much more expensive than that – by an order of magnitude. Semiconductor industry down time is yet an order of magnitude more expensive than that. So the cost of what you sell, versus the potential benefits to the customer, is miniscule. Never forget that!

Now of course theory is different than reality. Just because you say it will prevent a problem doesn't make it true. But *if you can* ***prove*** *to your customer that your enhanced device prevents such problems in advance, on a regular, predictable basis,* then your customer will have little resistance to paying a few hundred extra dollars for your device. Remember, when you're selling fieldbus, you're selling information, not wires.

The information your devices provide can be very, very valuable. And that's what's so great about fieldbus technology: Delivering the right information to the right place at the right time, for maximum productivity.

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