The Industrial Intranet: a Cause For Change

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Most plant data collection applications today use a batch approach, where data is transmitted at the end of the shift or other low usage times of day. New networking technologies are changing this model to real-time, with plant information being continually and automatically collected and analysed - without operator intervention. Plant operations will increasingly be directly connected in a client/server model to host computers and intranet servers. If controllers, PLCs and enterprise resource planning (ERP) systems are able to access any sensor connected to the control and device network, the result will be better information on manufacturing processes.

Imagine the impact of every shop floor worker having the equivalent of a handheld, possibly wireless, network browser at his or her disposal. In real-time, process operations will be able to monitor and fine tune system performance, access plant information and communicate directly with their production line managers. These operational online continuous nodes will be another bandwidth consumer, raising traffic levels significantly.

The industrial intranet will not only supply information internally. Trends towards quick-response, vendor-managed inventory and electronic commerce, are demanding that the manufacturing process, at the centre of the supply chain, be brought online. Customers and suppliers need to be able to look at all points in the supply chain, from initial order placement to raw material consumption to assembly to shipment and delivery.

Decision support systems and data warehousing applications will soon be able to 'mine' massive amounts of data for correlation and trends that call lead to operational improvements. With manufacturing equipment and personnel on the network, higher management can have access to the operational data on the factory floor in unprecedented detail.

Adding these new processes, systems and technologies to today's automation and control communication infrastructure will stress it unbearably. Bottlenecks caused by, typically three, discrete networks

- plant
- control
- device

will need to be removed before networks become a transparent and plant wide utility.

Market forces are dictating Ethernet as the media of choice for next generation industrial intranet. How vendors embrace this tide of change will determine who is seen to lead and who will lag the market.

The road to 'real-time' Ethernet

In the past, there were concerns over Ethernet's ability to deliver the levels of deterministic performance demanded by real-time industrial applications and processes.

The issues that prevented Ethernet from being used formal-time applications and processes in the past are as follows:

- bandwidth is shared not dedicated
- sharing necessitates bus arbitration with no concept of priority
- sharing results in collisions when two or more devices transmit simultaneously
- collisions block the network and prevent all devices from transmitting
- more devices on one segment increases the probability of collisions
- large broadcast domains eat up useable bandwidth
- differentiating between high priority and low priority traffic is not possible
- providing a low delay path for real-time traffic is not possible

In conclusion - a shared Ethernet system can never offer determinism.

Nevertheless, Ethernet has been widely regarded as the logical choice and its technical limitations have been fully evaluated.

How the Ethernet has evolved

To understand the reason why Ethernet has been chosen as the next generation fieldbus, it is necessary to understand some of the milestones that have been achieved in the development of standards based open network design. But first, the goal of the network in its simplest form is to replicate the network characteristics of a communication path between a client and server (or two peers) at a speed dictated by the application.

No complex protocols are required because there is nothing between the source and destination to affect the communication process. The purpose of the network is to maintain these same transmission characteristics but scaled up to serve many hundreds or thousands of networked devices. To achieve this logical connections need to replace physical connections.

Looking at a typical migration strategy for the office automation environment will help us understand the issues as they apply to the industrial community. A simple but effective three phased approach to network upgrade is:

- collapse the backbone
- upgrade server links
- micro-segment the network

The collapsed backbone - more bandwidth

In 1993 the first generation of switched Ethernet devices arrived on the market. With an Ethernet switch in the heart of the network, it became possible to design a network that switched frames from one Ethernet segment to another without affecting devices sending or receiving frames on other switched ports. Very similar to the way a PEX handles voice traffic, an Ethernet switch uses addressing information contained within the header of each Ethernet frame to forward the data. Forwarding either to the device itself a shared LAN segment or the next hop if the device is connected to a remote Ethernet switch.

A switch port is effectively a LAN segment that can support anything from a single to many hundred devices. In 1995, the price per switched port made single device per port connections realistic, but only for servers and very high bandwidth users. A typical first generation Ethernet switch had six switched ports each operating at 10 Mbps giving a potential sixfold boost in basic LAN performance.

In 1999 we saw backbone Ethernet switches with performances in the order of terabits/second And due to the massive reduction in cost for switched ports, it will not only be feasible but highly recommended to give all users a dedicated port.

More speed - removing the bottlenecks!

As has been the case with all network topologies, Ethernet has needed to address the scalability issue. It was all very well having a high performance box, but when you run out of ports you need to add a second and third box. Linking these boxes together at even 20 Mbps, with full-duplex, still resulted in many ingress ports contending for a single egress or uplink port - the classic network bottleneck!

A similar issue arose with the paradigm shift from standalone to client server computing where many clients contended for relatively few servers. A further shift is upon us today with the intranet computing model. In this model every PC has the potential to become a server, they can pop up anywhere on the network creating non-uniform traffic patterns.

The need for more speed resulted in Fast Ethernet .... again standard Ethernet but now operating at 100 or 200 Mbps in full-duplex mode - ten times faster than standard 10 Mbps Ethernet. Initially Fast Ethernet was used for inter-switch links and server connections. More recently, auto-sensing 10/100 Ethernet is becoming the standard Ethernet interface for users. With regard to future scalability issues, when the desktop evolves to 100 Mbps, the recently standardised Gigabit Ethernet will provide the bandwidth to move data around the enterprise removing bottlenecks to servers and between Ethernet switches.

Micro-segment - full-duplex port switching

Ethernet is a scalable technology, micro-segmenting the network to give users the bandwidth they require is a simple way to balance the needs of all network users and devices. It allows for a single device to have its own Ethernet segment. Alternatively, users or devices can be grouped to operate in the traditional shared mode.

Connecting a single device per port has two significant benefits:

- first it is now possible to switch off bus arbitration and operate in full-duplex mode. With arbitration disabled, a device can transmit and receive at wire speed and at any instant in time. This removes collisions and the resultant impact on network performance
- secondly, by providing separate paths for transmit and receive, full-duplex effectively doubles the available bandwidth of Ethernet from 10 to 20 Mbps or from 100 to 200 Mbps in the case of Fast Ethernet. This gives a significant boost to performance to any dedicated switch port user. In the early days this was typically the server connection or inter-switch link. Today, any device requiring real-time or bandwidth intensive network access should be connected with full-duplex.

Market segmentation

During 1997 all the major issues that once prevented an Ethernet transmission system from addressing the needs of the real-time industrial automation network had been overcome. It was vendor implementation issues that separated switches that were capable of delivering real-time capabilities on a repeatable basis and those that were not.

Ethernet in automation evolution not revolution

A typical industrial implementation is shown in Figure 1, where the control room, the fieldbus and the control domain are shown.

Remembering back to the issues that prevented an Ethernet network from meeting the needs of real-time industrial automation applications and processes, it can be seen that through evolution not revolution Ethernet has become a high performance deterministic network service.

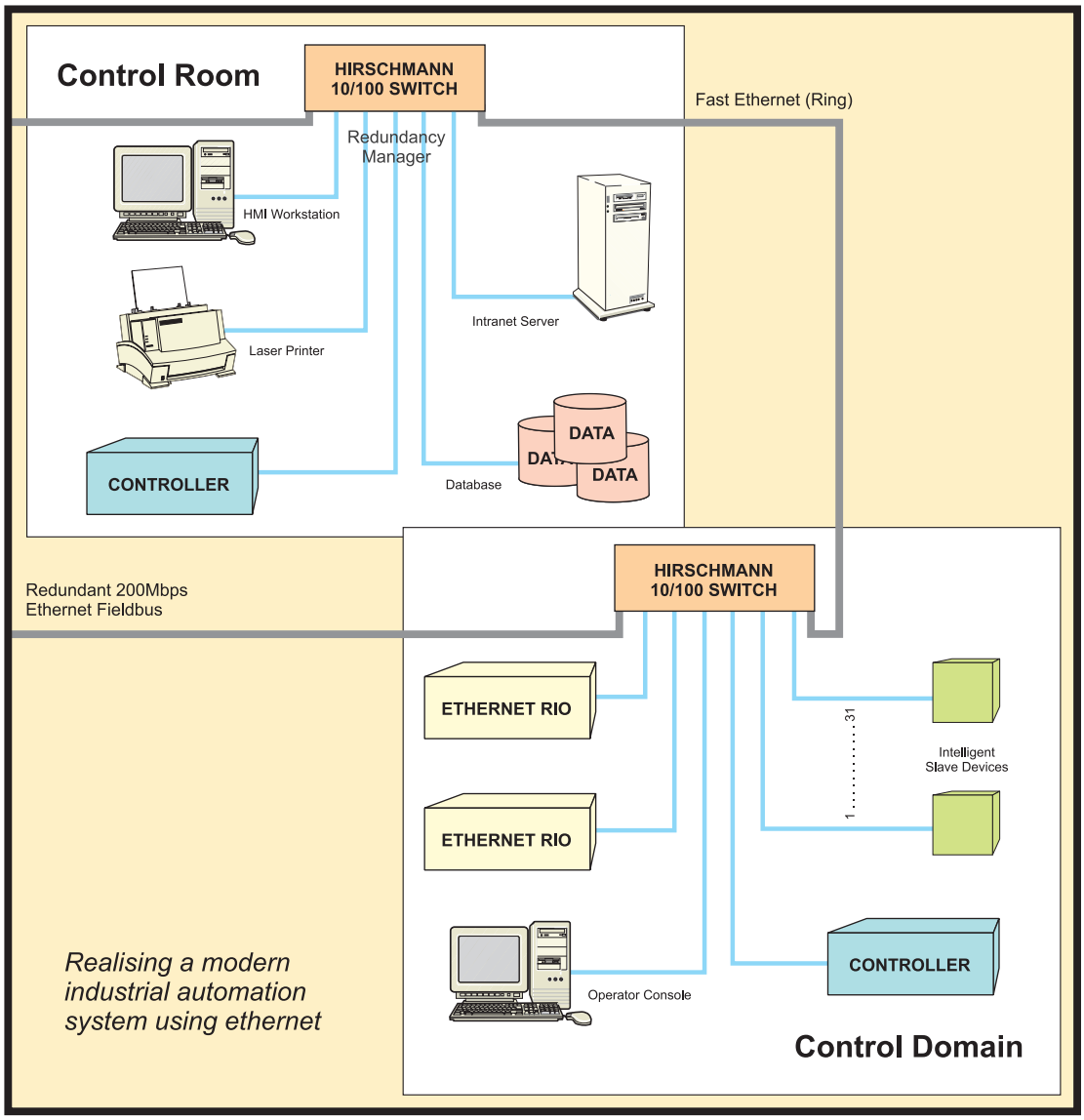

Figure 1
Realising a modern industrial automation system using Ethernet.

Conclusion

Ethernet is well established. Furthermore, all the developments that have allowed it to evolve with market needs are underwritten by international standards bodies, making Ethernet a truly open solution that is cost-effective and can be deployed throughout office automation and industrial automation networks. Bandwidth is dedicated, although it can still be shared.

- port switching overcomes the need for bus arbitration
- full 10 or 100 Mbps per device
- the IEEE802.1 p/Q standards deliver priority and QoS fields to the standard Ethernet frame format
- full-duplex eliminates collisions
- bandwidth is scalable, ie more users = more bandwidth
- fast Ethernet provides 200 Mbps of bandwidth in the backbone
- micro-segmentation and VLAN keeps broadcast domains small
- RSVP, ISSLL, 802.1 p/Q provide explicit techniques for requesting granularity of QoS
- data prioritisation and multiple queues for data ensure real-time traffic is given the fastest path through the network.

Take Note
Market forces are dictating Ethernet as the media of choice for industrial intranets. It cuts right across the present three networks

- plant
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- device

and offers a truly open solution underwritten by international standards bodies.

Resume

Gary Graham has 16 years experience in the industrial measurement and control industry. He is currently business manager of Industrial Control and Automation at Schneider Electric South Africa. His special interests lie in the field of web technologies in the integration of plant floor and automation systems to the enterprise, the transparent factory philosophy.