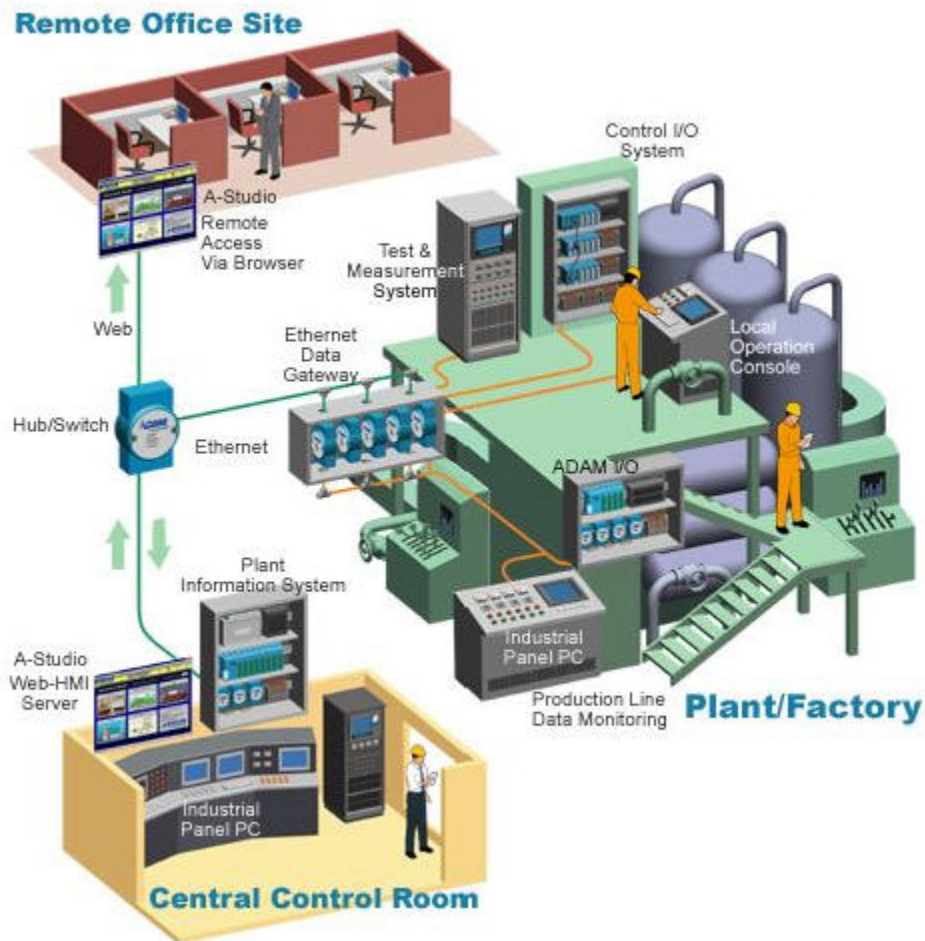


Gigabit Ethernet: Meeting the Future with Increased Bandwidth

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Ethernet Takes the Enterprise

Much has been written about the use of Ethernet in manufacturing. Ethernet has been around a long time. For computers and networking, it has been around practically forever. One of the great benefits of this fact is the time-tested and de-bugged nature of the Ethernet protocol for networking. Since the mid-1990s, Ethernet networks have become ubiquitous. They are used in offices, in homes, in workplaces, in building automation, and with increasing dominance, not just frequency, on the factory floor.



The biggest reason for the dominance of Ethernet as a networking protocol is the fact that it is used exclusively by Enterprise IT departments within the enterprises they network. Most offices in most buildings built after 1990 are pre-wired for Ethernet, with multiple Cat-5 cables pulled into each office, ready to hook up. Because Ethernet is such a widely used protocol, large numbers of technicians and programmers understand it, and can work with it. Microsoft Windows is designed to work easily with Ethernet local area networks in the enterprise. The availability of Internet connections and TCP/IP over Ethernet makes it possible to connect local networks to other networks creating an enterprise-wide WAN. On the factory floor, Ethernet is vendor-neutral, able to

carry many different types of communications over the same cable, unlike the proprietary protocols like Modbus, DeviceNet or Profibus (all of which have been converted to run over Ethernet).

The Value of COTS Going Forward

Industrial networking has actually been around longer than IT networking. The first industrial networks were highly proprietary systems produced by the DCS manufacturers for early distributed control systems. These networks were and are, highly secure, proprietary, and quite expensive. Ethernet, on the other hand, has become “commercial, off the shelf” and highly commoditized, and on the factory floor, can piggyback on top of existing corporate Ethernet and IP infrastructure. There is even a new standard, Ipv6-LoWPan, which produces IP enabled, Ethernet ready radios on a chip.

Pressure from customers as long as twenty years ago caused many suppliers to abandon their proprietary network protocols in favor of Ethernet, at least from the controller to the main process control computer. Finally, the growth of embedded computing in industrial applications with the use of programmable automation controllers or PACs with built in Ethernet networking made it a foregone conclusion that Ethernet would be used in the plant floor environment.



ADAM-5550KW (8 Slot Programmable Automation Computer)



ADAM-4577 (1-port Universal Serial Device Gateway)

But it was on the plant floor that Ethernet first stumbled. Originally, Ethernet had been designed as a “sharing” network, and packets banged around the network more or less at will, and the higher the level of traffic, the slower the packets ran. So if there was a mission critical packet, and the traffic was low, the packet would be received by its intended computer in a very short time. If the traffic was high, on the other hand, the packet might take quite a while to reach its recipient. For years, the discussion was all about determinism. Determinism is the ability to send a piece of information to a receiver in a predictable amount of time, and receive a response, also in a predictable amount of time. Early Ethernet was not deterministic. Many industrial networking experts believed that this would make it impossible to use Ethernet on the plant floor at the controller level. In addition, most controllers were devices with serial I/O. There were a number of serial communications protocols common on the factory floor: DeviceNet, ControlNet, and Modbus. It was necessary to provide serial-to-Ethernet protocol converters. Once these converters became available, suppliers began to provide versions of these protocols that operated over Ethernet networks as well. ModbusTCP/IP, and CIP (the Common Industrial Protocol) are examples. So, too, the industrial networking standards, Profibus and Foundation Fieldbus and HART, were made available in Ethernet environment versions: Profinet, Fieldbus HSE, and HART over Profibus, and the new WirelessHART, intended to operate wirelessly to an Ethernet-enabled gateway to the plant Ethernet LAN.

The Role of Switches in Ethernet networks

What changed was the development, first, of bridges and hubs, and then of switches. If the network was more intelligent, it could determine where a packet needed to go and get it there in a predictable amount of time. As network traffic increased, it became important to regulate that traffic. The first devices were called hubs. Hubs simply isolate impedances and forward data to all the devices on the same domain. This did not lessen packet congestion. Networking engineers then developed bridges. These connected one LAN (local area network) to another. This helped by keeping traffic from one network from migrating to another network where it did not belong. But it became quickly apparent that this wasn't good enough. Even intelligent bridges, which can learn over time which messages to forward and which not, did not do enough to reduce the congestion in networks, and thus the networks continued to be substantially less deterministic than necessary for the industrial plant floor.

The Ethernet switch was the answer. This device provided enough bandwidth to ensure that each device was on its own virtual network, and permits data to be sent to only the device to which it is addressed. Basically, switches take a network shared by many devices, as described above, and segment it into small pieces comprised of only the devices that require being in communication with one another. Thus communication with one group of devices does not interrupt or interfere with that of another group that doesn't require the information.



EKI-2525 (5-port Industrial Unmanaged Ethernet Switch)

The Need for Managed Switches

The drive for bigger, better, more deterministic networks produced first, high availability network topologies, and then smarter switches. These switches, called “managed Ethernet switches” provided hardware, firmware, and software capabilities that early hubs and switches did not have. First, and most important, these devices contained built-in network traffic management firmware, including provision for rate limiting and network management. These switches use SNMP (simple network management protocol) for remote monitoring of conditions in the network, and provide rate limiting to eliminate broadcast storms. Managed switches provide IGMP snooping, which determines which devices need to be sent certain types of information, without sending the information to devices that do not require it. They provide troubleshooting capability, with real-time diagnostics and statistics. They also have built-in access control, MAC address filtering, and provide the ability to produce VLANs wherever required. In addition, some managed switches use high availability redundant X-ring topology.

The unplanned manual scram (shutdown) of the Browns Ferry, Alabama, Nuclear Power Plant in August of 2006 due to a broadcast storm illustrates the reason that protection from this problem is mandatory. Managed switches provide this. Ethernet permits a message (called a frame) to be sent to all LAN devices using a broadcast message, or a range of devices using a multicast message. During normal operation broadcast/multicast frames are forwarded to all ports except the source port. If the number of broadcast/multicast frames exceeds a specified rate (number of frames per time period), the switch will discard broadcast frames above the threshold and after the time period has elapsed, the switch will resume forwarding broadcast frames.



EKI-7659C (8-port/2-port Gigabit Industrial Managed Redundant Ethernet Switch)

Industrial Ethernet switches are quite different in design from commercial switches, even though they share the same COTS background, and many components and accessories. Industrial switches are more robust, built to be used on the factory floor and in adverse environments.

The Basics of Gigabit Ethernet

One of the things that makes Ethernet work is the basic “speed limit.” Most Ethernet networks today are a mixture of 10 Mbit and 100 Mbit nodes. As time passes, fewer and fewer 10 Mbit nodes are used, and switches and servers have needed more and more bandwidth as more desktops and in the industrial environment, more field controllers and even some devices on the plant floor have been produced as 100 Mbit nodes.

In 1998, IEEE produced the first of several standards that, essentially, raised the “speed limit” to 1000 Mbit, or 1 Gigabit. Originally, it was believed that gigabit speeds would require fiber optic cabling, but it is now common that standard CAT-5e or CAT-6 copper cable can be used in Gigabit Ethernet networking applications. For high reliability networking, CAT-6 cable is preferred. As the cost of fiber optics continues to go down, and as more industrial plants are being re-configured, Gigabit Ethernet over Fiber (1000Base-SX or –LX) is beginning to compete quite well with 1000Base-CX and 1000Base-T copper wiring.

Gigabit Ethernet in Manufacturing

The drive to higher and higher bandwidth is being driven by the need to provide networking capability for converging information delivery sources. The sheer number of connected devices in a manufacturing enterprise is enormous, and bandwidth must be provided. In addition, more data is being demanded from the devices on the factory floor itself. With the growth of Profinet, CIP and FF HSE, it is now possible to reach directly down to the sensor level to obtain diagnostics and asset management data which must use the factory Ethernet LAN to reach its intended storage

and manipulation. Without the use of Gigabit Ethernet, the infrastructure itself can be a huge bottleneck when considering adding VoIP (voice over Internet Protocol) and other “bandwidth hogs” like security cameras, vision monitoring systems, streaming video for training and quality, and other applications on the horizon.

There is even a convergence between the enterprise itself (ERP, MRP and supply chain management systems) and the plant floor using new technologies like RFID, bar-coding, and other location-specific transmitters. Now many plant floors have wirelessly-enabled manufacturing cells, and even sensors. Facility security is requiring the ability to provide bandwidth for VoIP communications and live video for surveillance and even personnel monitoring and training. As 1 Gbit Ethernet rapidly pervades manufacturing enterprises for backbones, high availability networks, and video, 10 Gbit Gigabit Ethernet is on the horizon.

Industrially Hardening Gigabit Ethernet

Even though the components are the same, COTS devices that function quite well in the enterprise may not survive the factory floor. It is often necessary to “harden” these devices and re-package them for use in the industrial enterprise. Packaging differences may include DIN rail mounting, panel mounting in enclosures that are rated for use in industrial environments. Properly packaged switches provide the availability of low voltage (24V) DC power via terminal block, rather than by the ubiquitous “wall wart” type power converter, as well as additional power supply filtering and surge protection, as well as ESD protection on Ethernet. Industrial grade switches need to be protected against EMI and RFI that simply doesn’t occur in the office or home environment, like arcs, high voltage transients, and dirty power supplies. In addition, the temperature specifications of industrial grade managed switches need to be far wider than COTS standard. Temperature ranges, and therefore operation vary from -10 to +60 degrees C and -40 to +75 degrees C.

Ethernet from the Boardroom to the Sensor?

No proprietary network can rival the ubiquity and utility of Ethernet, both Fast (100 Mbit) and Gigabit (1000 Mbit). These networks have pervaded the entire enterprise, with the exception of the sensor level itself, right down on the plant floor.

This too is changing. Even sensors are being connected directly to Ethernet networks via CIP, Profinet and Foundation Fieldbus HSE and other protocols.

The proliferation of COTS embedded computers used for operator workstations, calibration devices, and even for field transmitters themselves has made it possible to see a future where Fast Ethernet, rapidly followed by Gigabit Ethernet may be available directly from the sensor electronics themselves.



UNO-2171 (Intel® Pentium® M Embedded Automation Computer)

The U. S. Food and Drug Administration (FDA) has mandated a Process Analyzer Technology push, which is taking formerly lab devices and putting them out in the process plant and on the production line. Process Analyzers typically report a high bandwidth data stream rather than the bit or byte data or analog values that simpler field sensors report. Since many of these analyzers are built using COTS embedded computers, it is easy to see a future where Ethernet will be as pervasive on the factory floor as it is in the rest of the enterprise. Adding to this the machine vision applications, RFID sensors, and collaborative engineering software that is being rolled out on the plant floor makes the installation of Gigabit Ethernet on the plant floor mandatory for economic competitiveness in the future. It may even be that wireless Ethernet will also pervade the industrial plant. Sensor design packages have become available with 802.15.4 LoPAN radios embedded on the board, and with IPv6 Ethernet stacks natively installed as firmware on the radios.

Gigabit Ethernet switches provides room for future growth and expansion, while providing backward compatibility with 10M and 100M devices. The future of the manufacturing enterprise is firmly centered on Ethernet, and Gigabit Ethernet is the future of networking.

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