An engineer's guide to Ethernet

Basics for using Ethernet on the plant floor

Ethernet

Answers for industry.

SIEMENS

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No doubt you've heard the buzz about Ethernet networks being employed all over the factory floor – "Ethernet is replacing field bus."

"Ethernet supports determinism." Ethernet works with any vendor's equipment." – but perhaps you're not quite sure what to make of it. After all, field bus and serial network technology has long ruled the plant. Why change now?

Introduction

Well this is one example where the buzz is well-founded. Ethernet is indeed becoming the defacto network standard for factory floor networking, and with good reason. The benefits begin with the ubiquitous nature of Ethernet, which has long been the network of choice in the corporate world. With the industrial version of Ethernet running throughout both your plant and office environments, it becomes far easier to gather plant data and send it to back office applications, to help with capacity planning and ensure maximum productivity. Within the plant, Industrial Ethernet makes it far easier to monitor and troubleshoot various devices, helping to improve overall uptime. And its standards-based, multi-vendor nature means that a single type of network can support your myriad requirements; no more vendor-specific networks that can't easily talk with one another. In short, if you're not on board the Industrial Ethernet train, you may find yourself lagging behind; the Ethernet pioneers long ago left the station.

Before diving in with Industrial Ethernet, however, it's important to understand how it differs from the commercial variety that runs throughout office buildings and consumer homes. Industrial Ethernet adds important capabilities that make Ethernet suitable for the factory floor, including ruggedized equipment, ease of implementation and dramatically improved fault tolerance and performance, to ensure the real-time applications that pervade the plant environment operate without a hitch. Additionally, wireless Ethernet offers a new level of mobility that field bus and serial technologies simply can't match.

History of Ethernet
Ethernet's roots date to the 1970s, when it was created by researchers at Xerox PARC. It came into widespread use in corporate networks in the 1980s, eventually beating out rival standards including ARCNET and IBM's Token-Ring. Beginning in the 1980s, the IEEE began issuing the 802.3 series of standards to define various versions of Ethernet, making it an open protocol that myriad vendors could develop to.

Initial versions of Ethernet used coaxial cable which would run throughout a building, with various computers, printers and other devices hanging off of it. In the mid-1980s, twisted pair Ethernet emerged along with Ethernet hubs. Twisted pair wiring was far less expensive than coaxial cable and the hubs enabled companies to use a hub and spoke topology, rather than a continuous cable run. Hubs also helped overcome Ethernet distance limitations, which were initially about 500 meters.

As companies looked to build ever-larger networks, Ethernet bridges emerged to enable them to link multiple segments together. Still later, switches emerged to provide even greater efficiency, enabling more precise communications with specific devices as compared to the broadcast nature of the hubs and bridges.

While Ethernet initially operated at 10M bit/sec, ever-faster versions have continually emerged. In the mid-1990s, a 100M version, known as Fast Ethernet, was approved as an IEEE standard. At that time, it was common for companies to build 100M Ethernet "backbones" that would support hubs and/or switches connecting desktop devices at 10M. By the end of the 1990s, a standard for Gigabit-speed Ethernet was approved, allowing ever-faster networks. Now companies were connecting desktop devices at 100M bit/sec to Gigabit-speed backbones.

Commercial Ethernet speeds have been going up ever since, into the multi-gigabit range, with continued improvements on the horizon. While Industrial Ethernet equipment generally doesn't require those kinds of speeds, the standards will be firmly in place should the day come when it does.

Wireless Ethernet

Similarly, standards are firmly in place for wireless versions of Ethernet, made possible by radio-frequency technology that is capable of transmitting Ethernet packets.

Wireless versions of Ethernet emerged in the late 1990s, beginning at speeds of 1M or 2M bit/sec but rapidly increasing in speed. The first wireless standard to gain widespread use was ratified in 1999. Known as 802.11b, it operates at about 11M bit/sec. The 802.11g standard approved in 2003 bumps up that speed to 54M bit/sec and is in widespread use today.

Next up is 802.11n, which defines speeds up to 600M bit/sec. Although the standard is not expected to be officially ratified until late 2009, products based on 802.11n are already available, albeit at speeds that typically top out around 450M bit/sec.

Wireless Ethernet has made Ethernet even simpler to deploy, as a legion of home users will attest. And it's now reliable enough for widespread use in business environments. Additionally, laptop and desktop computers now typically come with both wired and wireless adapters, making it easy for businesses to have a mix of both flavors of Ethernet in their environments.

As you can see, Ethernet is an established technology, with some three decades of history behind it. As is typically the case once a technology becomes firmly entrenched, Ethernet has continually become both easier and less expensive to implement, with products available from a wide variety of vendors.

Ethernet Timeline

- 1973: Ethernet invented at Xerox PARC
- 1980: Digital Equipment Corp., Intel and Xerox release a standard for 10M bit/sec Ethernet
- 1991: 802.3 10BaseT standard is approved, for 10M Ethernet over twisted pair telephone wire
- 1995: 802.3 100Base-T 100M Ethernet standard is approved
- 1998: 802.3ac Gigabit Ethernet standard is approved
- 1999: 802.11b standard approved, for 11M wireless Ethernet
- 2002: 802.3ae 10G Ethernet standard is approved
- 2003: 802.11g standard approved, for 54M wireless Ethernet
- 2009: 802.11n standard expected to be approved for 600M wireless Ethernet
- 2010: 100G Ethernet expected to be approved

Key: Black text refers to wired Ethernet standards; blue refers to wireless.
SOURCE: Compiled from Directions Magazine and Network World

How it works

Whether wired or wireless, devices on an Ethernet network communicate in the same fashion. Each device has a unique network address. When one PC wants to communicate with another, it creates a data packet that includes the destination PC's address and sends it out onto the network. The packet is broadcast to every other device on the network, although all but the destination PC simply ignore it.

When too many devices try to communicate at the same time, packets can collide with each other. But Ethernet has a built-in mechanism for detecting these collisions and rebroadcasting packets until all are successfully transmitted.

This mechanism does chew up bandwidth, however. Ethernet switches help reduce the effect of the collisions by learning where devices are located. In this fashion, they can isolate collisions to a single segment and only forward packets to the proper destination segment.

In a plant environment, of course, there is no room for risk of collisions that slow traffic. Rather, industrial environments require assurances that instructions sent to a device will get to the device on time, every time. Protocols have been developed that ensure just that in an Industrial Ethernet environment.

Industrial Ethernet

Indeed, while Ethernet equipment on the plant floor uses the same underlying technology as commercial Ethernet, the industrial version has a few capabilities that enable it to meet the more demanding requirements of the plant setting. The differences between Industrial and commercial Ethernet come down to three general categories: environment, ease of implementation and fault tolerance.

Environment

Industrial Ethernet equipment comes in form factors that are more suitable for the plant floor environment than commercial versions. While the exact qualities will differ depending on the type of environment, some common factors that industrial Ethernet equipment must be able to deal with include:

- **Temperature:** Office environments typically have a fairly constant, comfortable temperature, but equipment in a plant may have to withstand temperatures ranging from -4° F to 158° F.
- **Humidity:** Similarly, plant environments are usually far more or less humid than a typical office so industrial Ethernet equipment must be designed to withstand a wide humidity range.
- **Vibration:** Large machines create lots of vibration on a plant floor that doesn't exist in the office environment. Industrial Ethernet equipment is rated for various vibration levels, just as PLCs and control devices are.
- **Noise:** Industrial often have excessive levels of noise in the environment, requiring the use of shielded Ethernet cable to protect noise from interfering with data transmissions.

Implementation

When implemented in an office environment, Ethernet networks are typically administered by the corporate IT department. Given Ethernet's long history, even the most junior IT staff are likely well-versed in how Ethernet works and what's involved in installing and troubleshooting the equipment.

On the plant floor, however, the same engineers who manage existing field bus networks will likely be responsible for installing and maintaining industrial Ethernet equipment. Given the demanding uptime requirements of the plant floor, there is simply no time to call in IT to deal with every network change or glitch.

Industrial Ethernet equipment, therefore, has to be designed to be implemented by plant floor engineers using tools with which they are familiar. That may be the same tools they use to configure or program PLCs, or a simple Web browser interface that allows configuration with a few simple clicks.

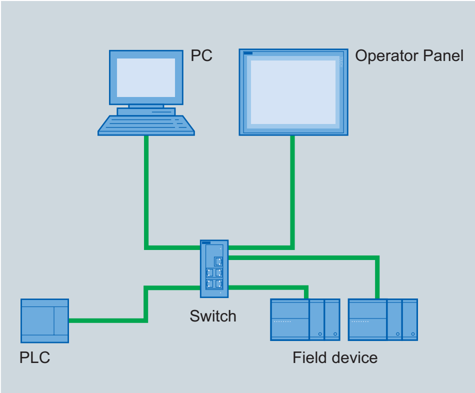
Ethernet to a large extent is a plug and play technology. Once you install an Ethernet switch, you can connect myriad devices to it. And you can connect multiple switches to one another to create ever-larger networks. That's a far different proposition from field bus networks, which are more like self-contained networks that connect PLCs to the components they control, whether sensors, motors, switches or the like.

Fault Tolerance

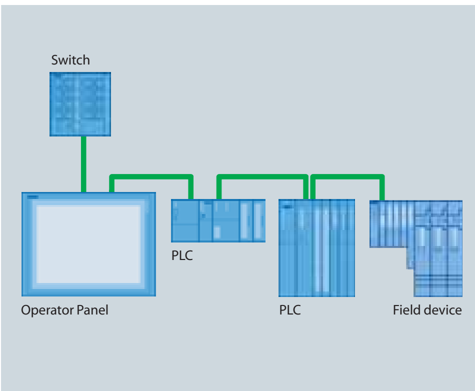
Industrial Ethernet also adds features that make it more reliable than traditional Ethernet.

Topology

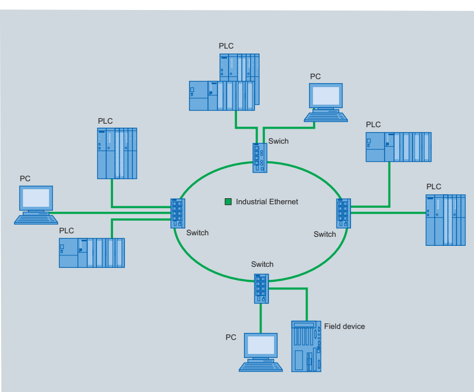
As with speeds, Ethernet topologies have advanced over the years. As noted above, Ethernet was originally implemented in a line topology, with multiple devices sharing a single cable. In such a topology, any cable break or fault disrupts communications for all devices.



Star Topology



Line Topology



Ring Topology

A step up in terms of reliability is the star topology, in which devices link point-to-point with a central hub or switch. For larger networks, multiple stars are configured in a hierarchical fashion, also known as a tree topology, with segments continually feeding up in the pyramid. In either, the effect of any failure is limited to a single network segment.

Industrial Ethernet takes the topology picture up yet another notch, using a ring topology to further protect against failure. Any single device failure effects only that device and any others connected directly to it. And if the cable itself should break, traffic can be routed around the break in the opposite direction to its destination. In short, with a ring topology, no single point of failure can cause a loss of network communication.

Protocol enhancements

As noted above, the broadcast nature of commercial Ethernet results in packets colliding with one another and having to be retransmitted, resulting in delays. While it’s acceptable for an email message to be delayed a few seconds in an office environment, such delays are not acceptable on the plant floor, where the idea of repeatability is paramount. Messages intended to start or stop an operation have to arrive on time. Delays of even a few milliseconds can destroy entire production runs or injure workers.

Over the past few years, a number of protocols have been developed to address this need for repeatability, and to address the shortcomings in TCP/IP, the main protocol used in office Ethernet environments. TCP/IP has an addressing scheme that makes it possible for any two devices to find one another, whether they are located in the same room or on different continents. It also includes mechanisms for resending packets in case they don't get to their destination on the first try.

While TCP/IP works well for the kind of communications typical of business applications such as email, it includes many functions that simply aren't necessary on a factory floor. For example, factory devices are relatively close together, so much of the overhead inherent in the TCP/IP addressing scheme isn't necessary, allowing for a much more efficient protocol. On the other hand, TCP/IP does not include some capabilities that are crucial on the factory floor, such as assurances that data will get from Point A to Point B within a well-defined timeframe, usually milliseconds.

Protocols designed for Industrial Ethernet use address all of these areas, enabling true real-time communications over Ethernet on the factory floor. That means when an operator sends an instruction for a machine to perform a certain function, he can be assured the instruction will be performed on time – every time.

It's also important to remember that Ethernet is simply a transport mechanism; multiple protocols can simultaneously ride on top of it. So the same network that carries real-time I/O traffic among devices on the factory floor can be used to carry TCP/IP traffic supporting the exchange of Excel spreadsheet documents between plant floor engineers and back office manager.

Monitoring

Ethernet's ability to connect multiple types of devices also gives plant engineers a great deal of choice in terms of how they choose to monitor devices on the plant floor. Industrial Ethernet devices include mechanisms to provide diagnostic data to plant engineers in various formats. Some may choose to receive it on the same HMI device they use to monitor PLCs. Many devices now come with embedded Web servers, enabling engineers to get diagnostic data from a Web browser on any laptop or desktop PC connected to the Ethernet network — even when they're outside the plant.

Users can also mix and match management technologies. SNMP (Simple Network Management Protocol), for example, is a standard protocol routinely used to manage devices attached to commercial Ethernet networks, while OPC and SCADA are common monitoring and control standards in the industrial world. With Ethernet, any or all of those protocols can all share the same network, enabling engineers to use the management protocol best-suited for each device.

Replacement

Industrial Ethernet devices are also designed to be easy to replace should the need arise. If a switch fails at 2 a.m., the plant engineer has to be able to quickly swap it out, without waiting for help from IT. Many devices come with memory cards that store the switch configuration. Installing a new device is as simple as removing the memory card from the failed one and loading it into the new.

Openness

It is important to note that Ethernet or Industrial Ethernet by itself does not guarantee that any two devices can communicate with one another. Think of Ethernet as a telephone line, capable of carrying conversations between any two people. If those two people don't speak the same language, however, they will not be able to communicate.

With Ethernet, the protocol that rides on top of the network provides the language that enables communication between and among devices. In terms of Industrial Ethernet, you'll want to choose a protocol that offers an open architecture, one that is supported by numerous companies that make equipment deployed on the plant floor. PROFINET, for example, is one such protocol, defined by some 50 working groups representing 70 companies.

Benefits of Ethernet

The benefits of using Ethernet on the plant floor include both those that are technical in nature, such as more advanced troubleshooting and greater visibility of diagnostic data, as well as practical business benefits that stem from the ability to more easily exchange data between the plant and office environments.

Cost

Cost, of course, is a primary business benefit of Ethernet. Many plants likely have various types of field bus networks in place, and must train personnel on how to operate each of them. Using Ethernet as the sole network technology means engineers need to learn only one network technology, reducing the need for specialized expertise.

Additionally, field bus technology requires special, dedicated interface cards for the computers and the devices they control. With Ethernet, a single low-cost interface can support all kinds of communications with myriad devices. Additionally, with field bus technology, passing data from the plant floor to back office systems requires gateways to perform a translation between the network media types. In addition to the initial cost of the buying and installing the gateways, they also require ongoing maintenance. An all-Ethernet environment eliminates those costs.

Remote diagnostics and troubleshooting

Most of the technical benefits of Ethernet on the plant floor stem from the ability to make data more easily accessible. As noted above, with Ethernet running throughout the plant environment, an engineer can now get more advanced diagnostic data on PLCs, sensors and other devices in any number of ways, wherever the engineer may be.

That is a significant step forward as compared to traditional ways of diagnosing and troubleshooting problems. Diagnosing a broken wire on an I/O device, for example, would require the automation controller to recognize there was a problem with one of the I/O devices on its dedicated field bus. The controller would send an alarm to an HMI over another network to notify the machine operator, who would alert maintenance staff. Maintenance would have to physically travel to the fault location and plug a programming device directly into the automation controller and its field bus to investigate.

With all devices connected to an Ethernet network, the scenario is far simpler. When a wire on the I/O device breaks, the device itself could send an alert out over the network. That alert could be picked up by various devices, including an HMI to alert the machine operator and a SCADA tool, which may push the data up the chain to an ERP system that records the alert into its database for historical reporting. Maintenance staff could be alerted on a central management tool, or even by email or text message. They can then collect additional diagnostic data from the device over the network, with no need to physically travel to the device. In short, Ethernet allows repairs to be completed far more quickly, keeping the plant running at peak efficiency.

Dispelling Industrial Ethernet myths

Industrial Ethernet is too new to be trusted on the plant floor.
Ethernet has been around for more than 30 years. Industrial Ethernet builds on that foundation, adding capabilities that give Ethernet the determinism, reliability and ease of use required for the plant floor.

Industrial Ethernet is too expensive as compared to field bus technology.
Industrial Ethernet uses most of the same components as field bus, including a PLC, I/O, cables and connectors. What changes is you use an Ethernet switch instead of a field bus node, in the process gaining a common infrastructure that will support most any device you want to connect. Initial implementation costs are about the same but in the long run, that common infrastructure will likely drive down your total cost of ownership because you will no longer need specialists for each type of field bus in use. Ethernet also allows for more effective monitoring tools.

Industrial Ethernet products are proprietary, not open, resulting in vendor lock-in.
While official Industrial Ethernet standards are still in the works, vendor groups have coalesced around different specifications. PROFINET, for example, is backed by some fifty working groups representing seventy companies. Commercial Ethernet followed much the same path before the IEEE formally approved the first Ethernet standard.

Plant engineers are used to field bus and serial network technology. Industrial Ethernet is too complex for them.
Engineers who have been managing field bus and serial networks for years understand how networks operate. While they will have to learn about the specifics of Industrial Ethernet, the technology is no more complex than what they already know. They can also use their familiar automation engineering tools, such as Siemens STEP 7, to configure their Ethernet networks. And given that Ethernet has a well-defined future growth path, the knowledge they acquire will serve them well for years to come.

Device-to-device communications

With its ability to connect virtually any kind of device to the same network, Ethernet makes it simpler for devices on the plant floor to communicate directly with each other. Such device-to-device communication is becoming increasingly common as engineers determine how to utilize data without taking time for humans to review it.

Field bus systems must be hard-wired to communicate with one another, or programmers must figure out the various commands each device responds to and write complex programs to enable devices to communicate. But Ethernet opens the door to the use of graphical engineering tools that make fostering communications between devices a simple matter of drawing a line between them on a GUI. Behind the scenes, the tool determines how the devices should communicate and Ethernet carries the data traffic.

Consider a bottling line, for example, where multiple machines must work together to get the job done. A bottle washer, capper, labeler, filler and so on all carefully coordinate their activities to fill bottles without waste or breakage. With Ethernet and some graphical tools, it’s a simple matter to forge real-time communications among the devices and create a truly automated line, where if one component is having a problem it can immediately tell the others to slow down, for example.

Bandwidth

Ethernet also supports far more network bandwidth than existing field bus networks, enabling it to carry traffic from sophisticated devices like motion controllers, cameras and automated vision systems that generate a significant amount of traffic. With gigabit speed, Ethernet offers a path to the future that field bus technology simply does not. Ethernet is also capable of supporting thousands of network addresses, so there is no practical limit to the number of devices that can be attached to the same network.

Mobility

Wireless Ethernet offers a new level of mobility for the plant floor. Consider environments that employ automatic guided vehicles (AGVs), for example. To foster communications among moving devices, slip-ring technology is typically used, with devices tethered to a central controller. Because of its mechanical nature, slip-ring technology is prone to failure, bringing increased maintenance costs. Wireless Ethernet provides more freedom of movement along with more reliable communications for AGVs and other mobile applications.

Business value

Perhaps most important, the any-to-any connectivity that Ethernet provides means the business can more easily get the information it needs to make better, more informed decisions.

In most plant environments, answering simple questions like, "How many parts did we ship today?" requires manual reporting. Perhaps a manager pulls data from various machines or an intermediary server to generate a report, then sends it to the business office at the end of the day. Similarly, the business sends orders to the plant for it to fulfill, taking its best guess as to what kind of capacity the plant can handle on any given day.

By making it simple to connect the factory floor to back office systems, Ethernet enables the business to easily gather more accurate, up-to-date data at any point in time. An executive could be in a meeting in China, and quickly determine whether his U.S. plant has the capacity to meet an order he's about to take. Others at the plant can easily determine whether downtime is going to put an order off-schedule and alert the customer accordingly. Or perhaps there's excess capacity so the business can send another order to the plant, thereby improving utilization.

Conclusion

In short, the buzz about Industrial Ethernet is well-founded. Building on Ethernet's 30-year history, Industrial Ethernet offers a low-cost, high bandwidth, open network infrastructure that offers ease of installation and maintenance while still meeting the performance needs of the factory environment. It also greatly simplifies connectivity not only among factory floor devices but between the factory and back office systems. That can bring tangible business benefits, ranging from improved factory productivity and more accurate production timetables to, ultimately, increased profitability.

There's no reason to go any longer without the benefits Ethernet can bring. Check out the "Getting Started" section to learn more about the next steps you can take to bring Industrial Ethernet to your plant environment.

Getting Started

Learn more about industrial Ethernet from these resources:

- The Industrial Ethernet Advisory Group, a resource and community that covers all aspects of Industrial Ethernet, including a forum for technical support and queries, news and events, articles and product information. www.industrial-ethernet.org
- An explanation of Industrial Ethernet and its various components from Siemens, a major Industrial Ethernet supplier: http://tinyurl.com/ddo93u
- Industrial Ethernet, 2nd Edition, by Perry S. Marshall and John S. Rinaldi, a book that serves as a reference tool on installation and troubleshooting of Industrial Ethernet networks. The book is intended to help readers "prepare to plan industrial Ethernet installations with realistic expectations, make knowledgeable purchasing decisions, and identify and prevent common causes of failure." Available at Amazon.com and other major booksellers.
- Industrial Ethernet on the Plant Floor: A Planning and Installation Guide, by Robert Lounsbury, also provides guidance on how to plan an Industrial Ethernet network, including a discussion of network architectures, components, product selection and the basics of noise, including how to abate it. Available at Amazon.com and other major booksellers.

An Ethernet Checklist

Here are the basic components you need to get started with Industrial Ethernet

Ethernet enabled controllers: PLCs with integrated Ethernet Interface that support TCP/IP, ETHERNET I/O (PROFINET), peer-to-peer communications, machine safety, motion control and communications to higher level systems.

Ethernet switch: The foundation of an Ethernet network is the switch, which shuttles traffic among devices connected to it and to other switches. Switches come in various forms and sizes, but the two basic types are managed and unmanaged. Unmanaged, or “dumb” switches require no configuration. Simply connect devices to them and they can talk to one another. But, as the name implies, they cannot be monitored or configured from a remote management station. That requires a managed switch, which typically come with various features that make for easy monitoring, configuration and network optimization.

Network interface cards (NICs): The Ethernet NIC connects the Ethernet cable to the device you want to put on the network. Most any new PC you buy, whether laptop or desktop, comes standard with two Ethernet NICs: one wired, one wireless. Similarly, factory floor equipment now often comes standard with an Ethernet NIC and most of the equipment you’ve already got probably either has an Ethernet NIC or can be adapted to accept an Ethernet cable.

Cable: Industrial Ethernet requires a shielded Ethernet cable that can protect it from the noise and, in some cases, radio frequency waves that are common on plant floors.

Wireless access points: Wireless Ethernet requires wireless access points (WAPs or APs) to be strategically placed throughout the plant. Each AP can communicate with a number of wireless devices, with the exact number and range depending on the specific AP model. APs typical connect to one another via a wired Ethernet connection.

Glossary of Industrial Ethernet Terms

10BASE-T – 10 Mbps Ethernet system based on Manchester signal encoding transmitted over Category 3 or better twisted-pair cable.

10BASE2 – 10 Mbps Ethernet system based on Manchester signal encoding transmitted over thin coaxial cable. Also called Cheapernet or ThinNet.

10BASE5 – Original 10 Mbps Ethernet system based on Manchester signal encoding transmitted over thick coaxial cable. Also called ThickNet.

10BASE-F – 10 Mbps Ethernet system based on Manchester signal encoding transmitted over fiber optic cable. This is a base standard for three fiber optic implementations.

10BASE-FP – 10 Mbps passive MAU fiber optic implementation which is not popular.

10BASE-FB – 10 Mbps backbone MAU fiber optic implementation which is not popular.

10BASE-FL – Popular 10 Mbps link fiber optic implementation which replaces the older FOIRL implementation.

100BASE-FX – 100 Mbps Fast Ethernet system based on 4B/5B signal encoding transmitted over fiber optic cable.

100BASE-T – Term used for the entire 100 Mbps Fast Ethernet system, including both twisted-pair and fiber optic media types.

100BASE-T2 –100 Mbps Fast Ethernet system designed to use two pairs of Category 3 twisted-pair cable. Not a popular technology.

100BASE-T4 — 100 Mbps Fast Ethernet system designed for four pairs of Category 3 twisted-pair cable. Not a popular technology.

100BASE-TX – 100 Mbps Fast Ethernet system based on 4B/5B signal encoding transmitted over two pairs.

100BASE-X – Term used when referring to any Fast Ethernet media system based on 4B/5B block encoding. Includes 100BASE-TX and 100BASE-FX media systems.

4B/5B – A block encoding scheme used to send Fast Ethernet data. In this signal encoding scheme, 4 bits of data are turned into 5-bit code symbols for transmission over the media system.

802.2 – IEEE Working Group for Logical Link Control (LLC).

802.3 – IEEE Working Group for CSMA/CD LANs (local area networks).

Auto-Negotiation – A protocol defined in the Ethernet standard that allows devices at either end of a link segment to advertise and negotiate modes of operation such as the speed of the link, flow control or half-or full-duplex operation.

Backbone – A network used as a primary path for transporting traffic between network segments. A backbone network is often based on higher capacity technology, to provide enough bandwidth to accommodate the traffic of all segments linked to the backbone.

Bandwidth – The maximum capacity of a network channel. Usually expressed in bits per second (bps). Ethernet channels have a bandwidth of 10-, 100-, and 1000 Mbps.

Baud – A baud is a unit of signaling speed representing the number of discrete signal events per second and depending upon the encoding can differ from the bit rate.

Bit – A binary digit. The smallest unit of data, either a zero or a one.

Bit Rate – The amount of bits that can be sent per second. Usually described in units of kbps or Mbps and frequently referred to as the data rate.

Block Encoding – Block encoding is a system whereby a group of data bits are encoded into a larger set of code bits. Block encoding is used in Fast Ethernet.

BNC – A bayonet locking connector used on 10BASE2 thin coaxial cable segments and is commonly found in communication systems.

Bridge – A device that connects two or more networks at the data link layer (layer 2 of the OSI model).

Broadcast – A transmission initiated by one station to all stations on a network.

Broadcast Domain – The set of all stations in a network that will receive each other's broadcast frames. A single segment or set of segments connected with a repeater or switches are included in a broadcast domain.

Bus – A shared connection for multiple devices over a cable or backplane.

Category 3 – Twisted-pair cable with electrical characteristics suitable for carrying 10BASE-T. Not recommended for new installations.

Category 5 – Twisted-pair cable with electrical characteristics suitable for all twisted-pair Ethernet media systems, including 10BASE-T and 100BASE-TX. Category 5 and Category 5e cable are the preferred cable types for structured cabling systems.

Category 5e – An enhanced version of Category 5 cable, developed to improve certain cable characteristics important to Gigabit Ethernet operation. It is recommended that all new structured cabling systems be based on Category 5e cable; however, this cable may not be the best for use in industrial installations because of noise susceptibility.

Coaxial Cable – A cable with an outer conductor, surrounding an inner conductor. Coaxial cables are used for 10BASE5 and 10BASE2 Ethernet systems.

Collision – The result of having two or more simultaneous transmissions on a common signal channel such as halfduplex Ethernet or shared Ethernet.

Collision Domain – The set of all stations and repeaters connected to a network where faithful detection of a collision can occur. A collision domain terminates at switch ports.

CRC – Cyclic Redundancy Check. An error checking technique used to ensure the accuracy of transmitted data.

Crossover Cable – A twisted-pair patch cable wired in such a way as to route the transmit signals from one piece of equipment to the receive signals of another piece of equipment, and vice versa. This allows communication between two DTEs or two DCEs. The opposite of a crossover cable is the straight-through cable.

CSMA/CD – Carrier Sense Multiple Access/ Collision Detect. The medium access control (MAC) protocol used in Ethernet.

Data Link Layer – Layer 2 of the OSI reference model. This layer takes data from the network layer and passes it on to the physical layer. The data link layer is responsible for transmitting and receiving frames. It usually includes both the media access control (MAC) protocol and logical link control (LLC) layers.

DCE – Data Communications Equipment. Any equipment that connects to Data Terminal Equipment (DTE) to allow data transmissions between DTEs. DCEs are not considered end devices or stations.

DTE – Data Terminal Equipment. Any piece of equipment at which a communication path begins or ends. A station (computer or host) on the network is capable of initiating or receiving data.

Encoding – A means of combining clock and data information into a self- synchronizing stream of signals.

Error Detection – A method that detects errors in received data by examining cyclic redundancy checks (CRC) or checksum.

Ethernet – A popular local area networking (LAN) technology first standardized by DEC, Intel, and Xerox (or DIX) and subsequently standardized by the IEEE through the 802.3 committee.

Fast Ethernet – A version of Ethernet that operates at 100 Mbps. Although 100 Mbps is not considered fast, this reference is still used.

Fast Link Pulse – A link pulse that encodes information used in the Auto-Negotiation protocol. Fast link pulses consist of bursts of the normal link pulses used in 10BASE-T.

FDDI – Fiber Distributed Data Interface. An ANSI standard (ANSI X3T12) for a 100 Mbps token passing network (Token Ring) based on fiber-optic and twisted-pair cable. Some of this technology is used in the Fast Ethernet standard.

Fiber Optic Cable – A cable with a glass or plastic filament which transmits digital signals in the form of light pulses.

Flow Control – The process of controlling data transmission at the sender to avoid overfilling buffers and loss of data at the receiver.

Forwarding – The process of moving frames from one port to another in a switching hub.

Frame – The fundamental unit of transmission at the data link layer of the OSI mode.

Full-Duplex Operation – A communications method that allows for the simultaneous transmission and reception of data.

Gigabit Ethernet – A version of Ethernet that operates at 1000 Mbps.

Half-Duplex Operation – A communications method in which transmissions and receptions can occur in either direction but not at the same time.

Hub – A device with three or more ports at the center of a star topology network. Hubs can usually be cascaded with a hub-to-hub connection. Frequently this name is used to mean repeating hub.

IEEE – Institute of Electrical and Electronics Engineers. A professional organization and standards body.

Interframe Gap – An idle time between frames, also called the *interpacket gap*.

Intranet – The Internet is the worldwide collection of networks based on the use of TCP/ IP network protocols.

Late Collision – A failure of the network in which the collision indication arrives too late in the frame transmission to be automatically dealt with by the medium access control (MAC) protocol. The defective frame may not be detected by all stations requiring that the application layer detect and retransmit the lost frame, resulting in greatly reduced throughput.

Link Layer – Short for Data Link Layer. This is layer 2 on the OSI model.

Link Light – An optional status light on a DTE or DCE that indicates the status of the link integrity test. If this light is lit on both ends of the link, it indicates that the link is passing the link integrity test.

Link Pulse – A test pulse sent between transceivers on a 10BASE-T link segment during periods of no traffic, to test the signal integrity of the link.

Link Segment – A point-to-point segment that connects only two devices and is "capable" of supporting full-duplex operation.

LLC – Logical Link Control. A standardized protocol and service interface provided at the data link layer and independent of any specific LAN technology. Specified in the IEEE 802.2 standard.

MAC – Medium Access Control. A protocol operating at the data link layer used to manage a station's access to the communication channel.

MAC Address – A unique address assigned to a station interface, identifying that station on the network. With Ethernet, this is the unique 48-bit station address. Same as the physical address.

Manchester Encoding – Signal encoding method used in all 10 Mbps Ethernet media systems. Each bit of information is converted into a "bit symbol" which is divided into two halves. One half is high and the other is low. Manchester encoding results in a 20 Mbaud stream although data is only being sent at 10 Mbps.

MAU – Medium Attachment Unit. The MAU provides the physical and electrical interface between an Ethernet device and the medium system to which it is connected. Also referred to as a transceiver.

MDI – Medium Dependent Interface. The name for the connector used to make a physical and electrical connection between a transceiver and a media segment. For example, the RJ-45-style connector is the MDI for 10BASE-T and 100BASE-TX.

MDI-X – An MDI port on a hub or media converter that implements an internal cross-over function. This means that a "straight-through" patch cable can be used to connect a station to this port, since the signal crossover is performed inside the port.

Media Converter – A device that converts signals from one media type to that of another.

Mixing Segment – A bus segment capable of supporting two or more devices on the same bus. Coaxial cable segments are classified as mixing segments.

Multicast– A transmission initiated by one station to many stations on the network.

Network Layer – Layer 3 of the OSI reference model. At this layer routing of packets between multiple networks occur.

NIC – Network Interface Card. Also called an adapter, network interface module, or interface card. The set of electronics that provides a connection between a computer and a network.

Node – A connection point, either a redistribution point or a communication endpoint. The definition of a node depends on the network and protocol layer referred to. A physical network node is an active electronic device that is attached to a network, and is capable of sending, receiving, or forwarding information over a communications channel.

Octet – Eight bits (also called a byte). This term is typically used in communication protocol descriptions.

OSI – Open Systems Interconnection. A 7-layer reference model for networks, developed by the International Organization for Standardization (ISO). The OSI reference mode is a formal method for describing the interlocking sets of networking hardware and software used to deliver network services. It is a good model to refer to but strict compliance to the model is seldom accomplished.

Packet – A unit of data exchanged at the network layer. This is a much abused definition and the terms frame and packet are frequently interchanged.

Patch Cable – A twisted-pair or fiber optic jumper cable used to make a connection between a network interface on a station or network port on a hub and a media segment, or to directly connect stations and hub ports together.

PHY – Physical Layer Device. The name used for a transceiver in Fast Ethernet and Gigabit Ethernet systems.

Physical Layer – The first layer in the OSI seven layer reference model. This layer is responsible for physical signaling, including the connectors, timing, voltages, and related issues. Data sent over the physical layer are termed symbols.

Plenum Cable – A cable that is rated as having adequate fire resistance and satisfactorily low smoke-producing characteristics for use in plenums (air handling spaces). Air handling spaces are often located below machine room floors, or above suspended ceilings requiring the use of plenum rated cable.

Point-to-Point Technology – A network system composed of point-to-point links. Each point-to-point link connects two and only two devices, one at each end. Devices could be DTEs or DCEs but no more than two can be connected on one link.

Port – A connection point for a cable. Repeater hubs and switching hubs typically provide multiple ports for connecting Ethernet devices.

Propagation Delay – The signal transit time through a cable, network segment, or device. Important in making collision domain calculations.

Protocol – A set of agreed-upon rules and message formats for exchanging information among devices on a network.

Repeater – A physical layer device used to interconnect segments within the same network. An Ethernet repeater can only link Ethernet segments that are all operating in half-duplex mode and at the same speed. Some repeaters can offer media conversion as well.

Repeating Hub – A repeater with more than two ports. This name is frequently shortened to simply hub.

RJ-45 – An 8-pin modular connector used on twisted-pair links.

Router – A device or process based on Layer 3 network protocols used to interconnect networks at the network layer.

Segment – A cable made up of one or more cable sections and connections joined together to produce the equivalent of a continuous cable.

Slot Time – A unit of time used in the medium access control (MAC) protocol for Ethernet.

Star Topology – A network topology in which each station on the network is connected directly to a hub.

Straight-through – Refers to a cable where cable connections at both ends of the cable are pinned the same way. Used to connect a DTE to a DCE.

Station – A unique, addressable device on a network.

Switching Hub – A switching hub is another name for a bridge, which is a device that interconnects network segments at the data link layer. Switching hubs are typically located in the center of a star topology, and provide multiple ports for connections to network stations. Frequently this name is shortened to switch.

Terminator – A resistor used at the end of copper network cables to minimize reflections.

Topology – The physical layout of a network.

Transceiver – A combination of the words transmitter and receiver. A transceiver is the set of electronics that sends and receives signals on a media system. Transceivers may be internal or external. Sometimes called a MAU.

Twisted-Pair Cable – A multiple-conductor cable whose component wires are paired together, twisted, and enclosed in a single jacket. A typical Category 5 twisted-pair segment is composed of a cable with four twisted pairs contained in a single jacket. Each pair consists of two insulated copper wires that are twisted together.

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