Chapter 6

Networking

Early methods of remote monitoring or "communicating" between two distant points relied on single pneumatic tubes or low voltage electronic circuits to relay information. During the 1970's scanners were used with multiple systems to simultaneously transmit two or more messages on a single channel electronically, however, response time was slow and if the central processor failed, the entire system was down.

Also during the 1970's, data communications companies, realizing that obsolescence had overtaken conventional computer networks having one large central computer with several remote terminals connected to it by telephone lines, determined that distributed data processing was shown to be a more efficient way to do the job.

Distributed processing, in brief, replaces the one large central computer with multiple smaller computers, or microprocessors, geographically or functionally separated, which cooperate in the support of user requirements. Connection between the multiple microprocessor and the other devices in the network is through various common carriers or private transmission methods.

Today, in the HVAC-EMS business, the transition from centralized EMSs to distributed networks, enters the data communications world. Data Communications—the transmission of words or symbols from a source to a destination—is no longer exclusive to the business world. Its pervasive impact is now being felt in the HVAC-EMS profession. Understanding the explanations of bits, bytes, baud rate, LAN, ARCNET, token ring network, IBM-PS/2, modems, RS-485, peer-to-peer, as well as a host of other communications terms will assist the EMS user to understand their EMS.

LAN (LOCAL AREA NETWORK) TOPOLOGY

During recent years, EMS manufacturers have been using explanations to describe their systems such as:

> "The System "X" Facility Management System utilizes a unique tiered LAN architecture and a family of intelligent Distributed Control Units … System "X" is based around the use of multiple "token passing" LANs functioning in a tiered environment. This open-ended architecture allows the system … (1988-Control Systems International, Carrollton, Texas).

> "A built-in RS-485 communication trunk is provided … a second RS-485 trunk is provided to control universal points … high speed 64 kilobits per second peer-to-peer LAN option enables fast system-wide response to …" (1989-Barber-Colman, Loves Park, Illinois).

> "The LAN selected uses industry standard ARCNET, which is a token bus network transmitting at 2.5 Megabits to all devices called nodes which … a second bus is based on RS-485 and Opto-22's "Optomux" protocol, which uses a baseband, 9600 baud, ASII character for its signaling method and … "(1990-Johnson Controls, Inc., Milwaukee, Wisconsin).

> "Network protocol is IBM SDLC operating at a speed of 1,000,000 Baud … communication ports consist of (2) RS232C smart controllers with (1) optional RS232/RS485 port for …" (1989-Delta Controls, Inc., Surrey, British Columbia, Canada).

LAN, in its most basic form, is a data communication facility providing high-speed switched connections between processors, peripherals, and terminals within a single building or between buildings.

The ideal LAN would be an information distribution system that is as easy to use as the conventional AC power distribution system in a building. Thus, adding a data terminal, processor, or peripheral to a local area network should require nothing more than plugging it into a conveniently located access port. Once plugged in, it should communicate intelligently with any other device on the network. This ideal system is summarized by the features that make the AC power system so easy to use:

1. One-time installation.
2. Widespread access.
3. Application independence.
4. Excess capacity.
5. Easy maintenance and administration.

If an information distribution system were available with all the desirable properties listed above, it would mean that telephones, data terminals, printers, and storage devices could be moved as easily as unplugging and plugging in a lamp. Moreover, the equipment could be supplied by a variety of vendors. Although, such an ideal system does not now exist, local area networks of several forms represent some of the first steps in the development of such a system.

There are four major obstacles that must be overcome in the development of the ideal LAN:

No Single Standard

Due to the continually changing status of LANs and competitive nature of the vendors, a variety of local area network standards exist — both official and de facto. The situation is improving, however, because even the dominant suppliers who have been protecting their proprietary interfaces are being pressured by a maturing market to release interface specifications.

Diverse Requirements

The communications needs of a modern office building include voice, video, high-speed data, low-speed data, energy management, fire alarm, security, electronic mail, etc. These systems present transmission requirements that vary greatly in terms of data rates, acceptable delivery delays, reliability requirements, and error rate tolerance.

Costly Transmission Media

Being able to deliver tens of megabits per second to one device and only a few bits per second to another implies that the lower rate devices are burdened with a costly transmission media. The best economic solution must involve a hierarchical network design (one with stepped levels of capacity) that allows twisted pair connections for low and medium data rate devices (a low step) feeding into a backbone high bandwidth transmission system (a higher step) such as coaxial cable or optical fibers. However, one must be careful so that the cost of active components used for getting on and off the network does not outweigh the lower fiber costs.

Sophisticated Functional Requirements

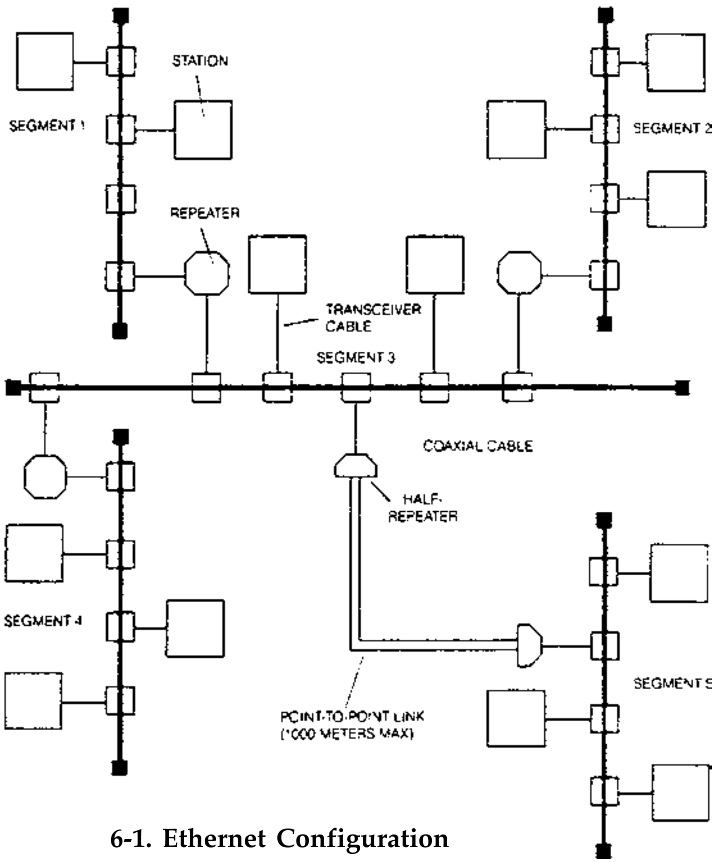
Providing a network with the desired data rates and distances is only one item that must be considered in the data communications problem. Before one data device can communicate intelligently with another, numerous higher level communications functions must be compatible. These include codes, formats, error control, addressing, routing, flow control, access control, configuration management, and cost allocations.

The first, most important non-proprietary data communications network to technically qualify as a LAN was Ethernet (a trademark of Xerox Corp.). The coaxial cable used in Ethernet can handle transmissions at 10 Mbs over one channel. A channel is defined as a physically independent direct pathway between two devices or separate carrier frequency on the same path.

The Ethernet architecture is based in concept on a system that allows multiple distributed devices to communicate with each other over a single radio channel using a satellite as a transponder. One station communicates with another by waiting until the radio channel is idle (determined by carrier sensing) and then sending a packet of data with a destination address, source address, and redundant check bits to detect transmission errors. All idle stations continuously monitor incoming data and accept those packets with their address and valid check sums. Whenever a station receives a new packet, the receiving station returns and acknowledgment to the source. If an originating station receives no acknowledgment within a specified time interval, it retransmits the packet under the assumption that the previous packet was interfered with by noise or by a transmission from another station at the same time. (The latter situation is referred to as a collision, which is overcome by networks using a baseband protocol called CSMA/CE Carrier Sensed Multiple Access/Collision Detection.) The Ethernet employs the same basic system concept using coaxial cable distribution throughout a building or between multiple buildings. See Figure 6-1.

Because access to the Ethernet involves a certain amount of contention (competition) between stations trying to send a message at the same time, the behavior of the network must be analyzed and controlled in a statistical manner. *Token passing networks*, on the other hand, provide a different access procedure. Access is determined by which station has the token; that is, only one station at a time, the one with the token, is given the opportunity to seize the channel. The token is passed from one idle station to another until a station with a pending message receives it. After the message is sent, the token is passed to the next station. In essence, a token passing network is a distributed polling network.

Two basic topologies (configurations or arrangements) exist for token passing networks: *Token Passing Rings* and *Token Passing Buses*. In a token passing ring, shown in Figure 6-2, the closed loop topology



6-1. Ethernet Configuration

defines the logical topology (that is, the order in which the token is circulated). A token passing bus, shown in Figure 6-3, has more operational flexibility because the token passing order is defined by tables in each station. If a station (for example, a printer) never originates communications, it will be a terminate-only station and need not be in the polling sequence. If a station needs a high priority, it can appear more than once in the polling sequence.

The forerunner of token passing networks in the U.S. is the Attached Resource Computer Network, *ARCNet*, developed by Datapoint Corporation. Initially, the network and protocol were kept proprietary, but the data link protocol, interface specs, and even integrated circuits were made publicly available in 1982. Functionally, the

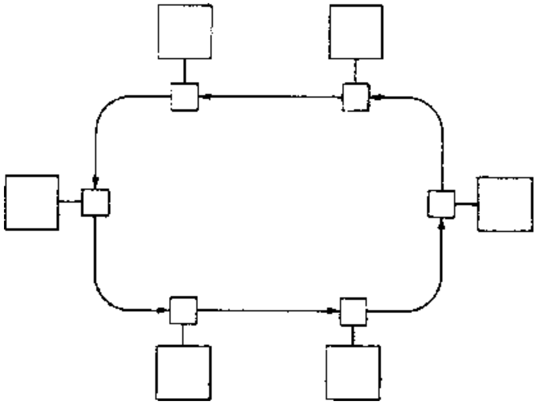


Figure 6-2. Token Passing Ring

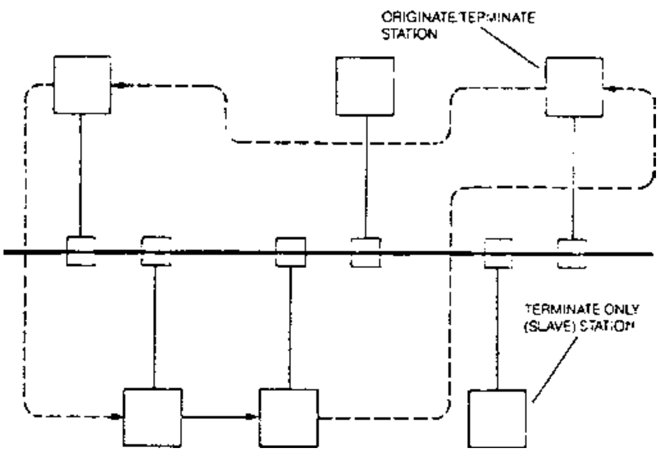


Figure 6-3. Token Passing Bus

ARCNet is a token passing bus, but the physical topology, shown in Figure 6-4, is a hybrid bus/star. Rather than distribute taps along a linear bus as suggested in Figure 6-3, the ARCNet uses hubs with individual ports to connect Resource Interface Modules (RIMS) to the transmission media.

The hub based architecture is an effective means of controlling the signal quality because the hub isolates each RIM port from the main coaxial cable. Unidirectional (one-way) amplifiers in the hubs provide zero insertion loss and suppress reflections because only one direction of transmission is enabled at a time. Amplifier switching is possible because a token passing network only transmits in one direction at a time.

The ARCNet interconnects the hubs and RIMs with RG62 coaxial cable using baseband transmission at 2.5 Mbps (baseband vs. broadband: limits on baseband include less than 10 Mbps, low frequency, twisted pair/coax less than 2 miles; limits on broadband include greater

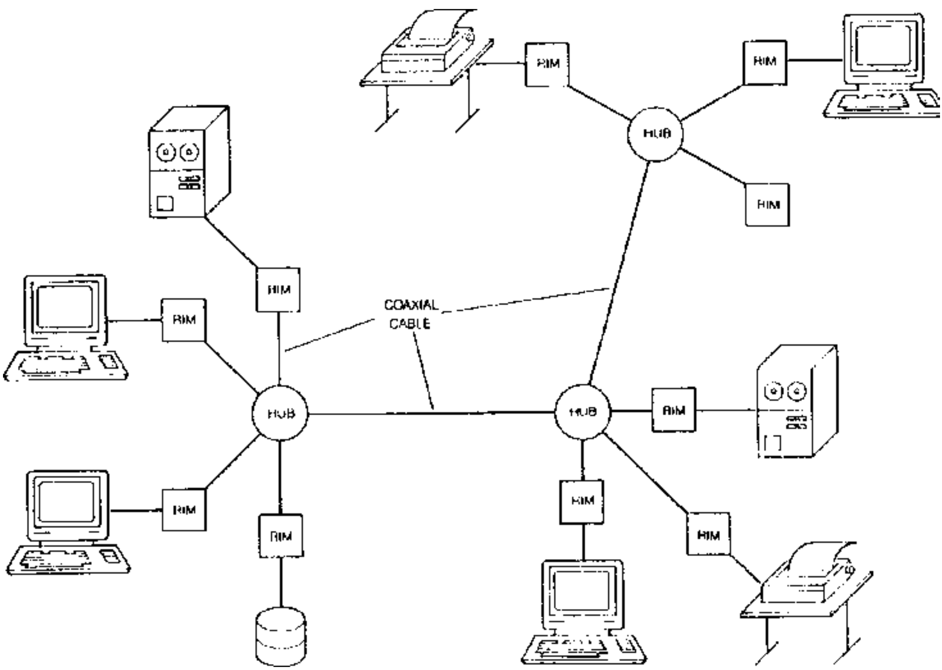


Figure 6-4. ARCNET Configuration

than 10 Mbps, digital and analog, and long distances). Although 2.5 Mbps is a relatively low data rate, ARCNet uses inexpensive coax and can be configured (laid out) with as much as four miles between stations. The cable length between a hub and a RIM is limited to 2000 feet, but a four-mile span can have up to a maximum of ten hubs in a series path.

Local area network standards (as with other communication standards) get established in two ways: by dominant manufacturers who attract plug compatible competitors, and by official standards organizations. The leading official standards organization for LANs in the U.S. is the IEEE 802 Standards Committee. This committee has several working groups responsible or establishing these LAN standards:

1. 802.1 — Coordinating the interface between OSI Levels 1 & 2 with the five higher level layers.
2. 802.2 — Logical data link standard similar to HDLC and ADCCP.
3. 802.3 — CSMA/CS standard similar to Ethernet.
4. 802.4 — Token Bus standard.
5. 802.5 — Token Ring standard.

Each of the LAN system architectures presented previously have unique technical and operational advantages and disadvantages.

No presently available single LAN system architecture can economically satisfy the needs of all communications within a building or between multiple buildings. Nor is it likely that one system will ever evolve to economically fulfill these needs. Thus, there will always be a need for either separate systems tailored to specific applications or possibly hybrid systems employing the best features of selected individual architectures.

EMS manufacturers that apply these hybrid-type systems will be one step ahead of the competition. (See Figure 6-5 and 6-6).

MEDIA/TRANSMISSION METHODS

Transmission Methods—General

A number of different transmission systems and media can be used in an EMS for communications between the field panels and Central operator station. These transmission systems include twisted pairs, voice grade telephone lines, coaxial cables, electrical power lines, radio frequency, and fiber optics. (See Figure 6-7).

Twisted pairs

A twisted pair consists of two insulated conductors twisted together to minimize interference by unwanted signals.

Twisted pairs can carry information over a wide range of speeds depending on line characteristics. To maintain a particular data communication rate, the line bandwidth or the signal to noise ratio may require adjustment by conditioning the line. Twisted pairs are permanently hardwired lines between the equipment sending and receiving data, or switched lines routed through the telephone network. Switched lines have signaling noise, such as ring signals within the data bandwidth, that can cause impulse noise resulting in data errors.

The nominal bandwidth of unconditioned twisted pairs is between 300 and 3000 Hz. For each Hz of available bandwidth, 2 bps can be transmitted. A twisted pair with a bandwidth of 2400 Hz can support a 4800 bps data rate.

Hardwired twisted pairs must be conditioned in order to obtain operating speeds up to 9600 bps. Data transmission in twisted pairs, in most cases, is limited to 1200 bps or less.

Voice Grade Lines

Voice grade lines used for data transmission are twisted pair circuits defined as type 3002 in the Bell Telephone Company publication standard BSP 41004. The 3002 type line can be used for data transmission up to 9600 bps with the proper line conditioning. The most common voice grade line used for data communication is the unconditioned type 3002 that allows transmission rates up to 1200 bps. Voice grade lines must be used with the same constraints and guidelines as for twisted pairs.

Coaxial Cable

Coaxial cable consists of a center conductor surrounded by a shield. The center conductor is separated from the shield by a dielectric. The shield protects against electromagnetic interference. Coaxial cables can operate at data transmission rates in the megabits per second range. Attenuation becomes greater as the data transmission rate increases. The

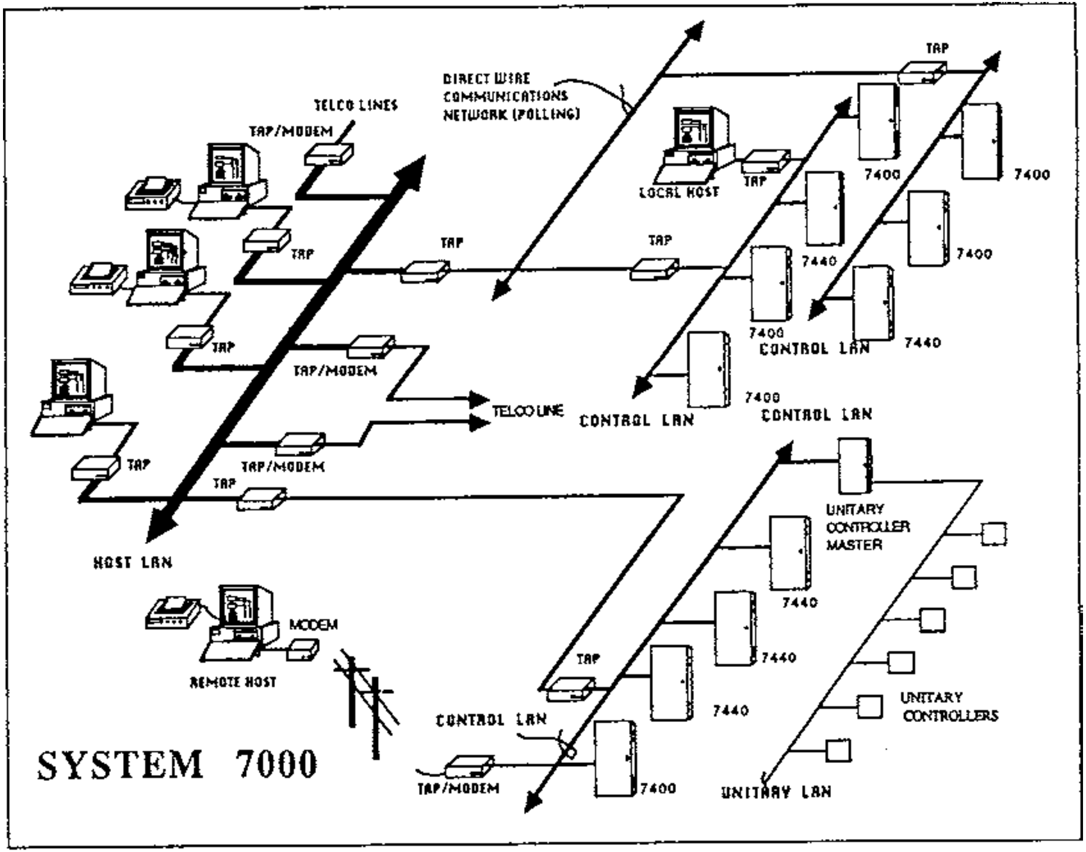


Figure 6-5. C.S.I.—LAN

INTRODUCTION

The System 7000 Facility Management System utilizes a unique tiered Local Area Network (LAN) architecture and a family of intelligent Distributed Control Units (DCUs) to provide a control network of as few as 100 points or as many as 100,000 points. This allows for centralized command and control of many widely distributed processes with unprecedented reliability and speed.

OVERVIEW

The System 7000 is based around the use of multiple "token passing" LANs functioning in a tiered environment. This open ended architecture allows the system to support hundreds of terminal work stations and tens of thousands of points with response times not found in today's systems.

HOST LAN

At the top of this tiered LAN architecture is one or more Host LANs. A single host LAN can support a single PC work station or as many as eight (8) PC work stations. All work stations are communicating over a single pair of wires on the Host LAN in a multi-tasking/multi-user environment with one or more controller LANs.

Utilizing the Host LAN structure, one or more work stations may communicate with over 1,000 remote controller LANs, each capable of supporting 63 Distributed Control Units.

The Host LAN, as well as the controller LAN utilizes a CSI proprietary protocol for LAN communications. Equipment not designed for direct communication with the LAN must utilize a "gateway" or TAP into the LAN. These firmware specific TAPs provide for messaging, protocol conversion, AA/AD (Auto Answer/Auto Dial) and much more.

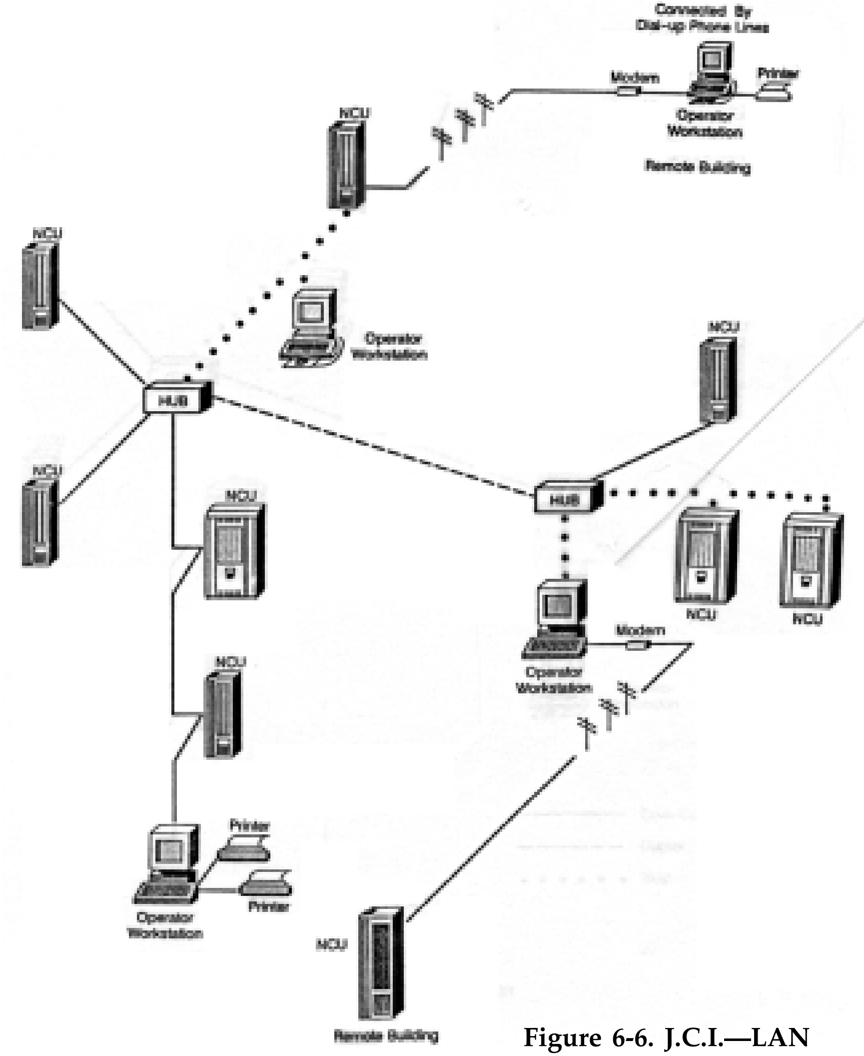


Figure 6-6. J.C.I.—LAN

INDUSTRY STANDARD ARCNET

ARCNET is a token bus network Initially developed by Datapoint Corporation as a very fast, 2.5 Megabit communications link for computer-to-computer connections. The technology was licensed to third party electronics firms to manufacture ARCNET control chips, making low cost token passing networks readily available to many industries. It wasn't long before ARCNET moved from the office to the shop, as system integrators realized that the network's reliability, noise immunity, predictability, and low cost were perfect for allowing automated machines to communicate with each other on the factory floor. Growth in demand led to second sourcing of the control chips, and the development of new configuration and cabling options. As many more manufacturers adopted the use

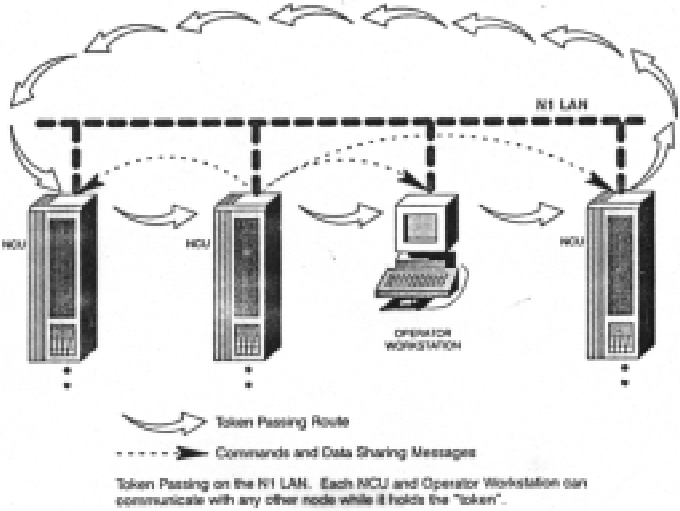


Figure 6-6. J.C.I.—LAN (*Continued*)

of ARCNET in their systems, the ARCNET Trade Association was formed to provide a user forum for maintaining standards, coordinating connectivity issues, and charting future growth. ARCNET has now become a de facto industry standard, with over 1,000,000 connected devices worldwide.

TOKEN BUS

In ARCNET, devices connected to the network are called nodes, which are addressed from 1 to 255. Access to the network is controlled by a "token" which is passed around the network, going from each node to the node with the next address. When a node has the token, it may broadcast a message to any other node before passing the token on. This message is received simultaneously by all other nodes, but only responded to by the node to which the message was addressed. This scheme allows all devices on the network to operate on a peer-to-peer basis, which means the network is not dependent on any single device for nodes to share information. Token passing is also deterministic, which means that the maximum amount of time it takes for a message to be sent from one node to another is predictable, even under heavy communication traffic conditions. It also guarantees that every node has access to the network on an equal basis.

ARCNET is self-configuring. If a node should fail, it is automatically removed from the token passing sequence so that communication is maintained uninterrupted among the remaining nodes. When a new node is added, or a failed node recovers, ARCNET immediately recognizes the node and adds it into the token passing sequence. Should the communication trunk be severed, both halves of the network are automatically reconfigured Into two separate networks, each with the ability to maintain peer-to-peer communications among the connected nodes.

Network Control Units and Operator Workstations are ARCNET nodes in Metasys. NCUs optionally have an ARCNET communication circuit integrated within the Network Control Module. For an Operator Workstation, an ARCNET communication card is installed in a PC to allow the computer access to the network. ARCNET cards are manufactured by both Johnson Controls and other vendors.

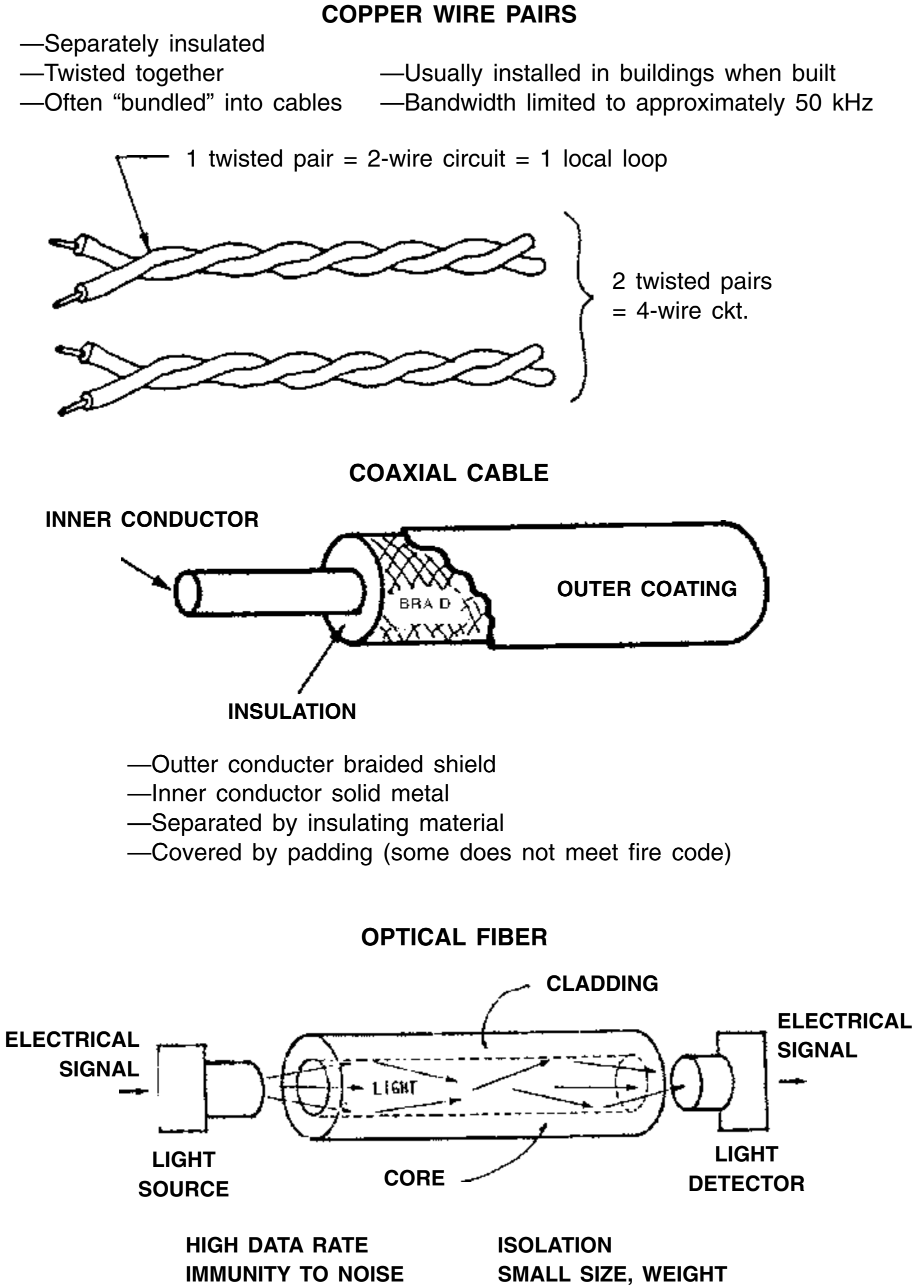


Figure 6-7. Transmission Media

transmission rates are limited by the data transmission equipment and not by the cable. Regenerative repeaters are required at specific intervals depending on the data rate, nominally every 2000 feet to maintain the signal at usable levels.

Power Lines

Data can be transmitted to remote locations over electric power system lines using carrier current transmission that superimposes a low power RF signal, typically 100 kHz, onto the 60 Hz power distribution system. Since the RF carrier signal cannot operate across transformers, all communicating devices must be connected to the same power circuit (same transformer secondary and phase) unless RF couplers are installed across transformers and phases permitting the transmitters and receivers to be connected over a wider area of the power system.

RF

Modulated RF can be used as a data transmission method with the installation of radio receivers and transmitters. The use of RF must be coordinated with the communications department to avoid interference with other facility RF systems. MODEMS must be provided at each receiver-transmitter location. FM is used in most cases because it is not susceptible to amplitude related interference.

Fiber Optics

Fiber optics uses the wideband properties of infrared light traveling through transparent fibers. Fiber optics is a reliable communications media which is rapidly becoming cost competitive when compared to other high speed transmission methods. It is best suited for point-to-point high speed data transmission.

The bandwidth of this media is virtually unlimited, and extremely high data transmission rates can be obtained. The signal attenuation of high quality fiber optic cable is far lower than the best coaxial cables. Repeaters required nominally every 2000 feet for coaxial cable, are 3 to 6 miles apart in fiber optic systems. Fiber optics must be carefully installed and cannot be bent at 90° right angles. Additional benefits include features such as space savings in conduits and freedom from EMI interference. However, on the other hand, splicing is difficult and there is the requirement of convertors to get off the fiber optic network.

See Table 6-1 for a comparison of transmission methods.

Table 6-1. Transmissions Methods—Comparison

Method	*First Cost*	*Scan Rates*	*Reliability*	*Maint. Effort*	*Expandability*	*Compatibility With Future Requirements*
Coaxial	high	fast	excellent	min.	unlimited	unlimited
Twisted pair	high	med.	very good	min.	unlimited	limited
RF	med.	fast but limited	low	high	very limited	very limited
Microwave	very high	very fast	excellent	high	unlimited	unlimited
Telephone	very low	slow	low to high	min.	limited	limited
Fiber optics	high	very fast	excellent	min.	unlimited	unlimited

MODEM is an acronym for modulator/demodulator. The MODEM is analogous to a telephone set, which converts the voice to an electric signal at one end of a wire and converts the signal back to sound at the other end of the wire. MODEMs can communicate between field panels and controllers when the controller is separate from the field panel. MODEMS are also used to communicate with an EMS from a remote location. Upon receiving a signal from a sensor or controller, the MODEM imposes the information in binary form onto carrier waves. These waves convey information over communication links known as data transmission media. The information is imposed on the wave by altering, or modulating, the wave form; it is then extracted from the wave by demodulating. In the case of a digital signal from a sensor this process is straightforward. Analog signals from sensors require analog/digital converters to condition the signal prior to modulation, MODEMs are characterized by transmission speed and the way in which modulation is accomplished.

There are two basic modulation classifications—baseband and broadband. Baseband MODEMs convert data into binary form using differential current impulses for transmission. However, baseband is not true modulation because a carrier wave is not modulated. At any point in time, data transmission along an individual communication link is limited to a single signal and one direction. Baseband MODEMs are also known as line drivers, local MODEMs, short-distance MODEMs short-haul MODEMs, or digital line adapters. They are 50 to 90% less costly than broadband and are ideal for short-range work. In addition, they can operate at higher speeds, have fewer internal parts, and are not subject to errors common in true modulation techniques.

Baseband MODEMs are limited to ranges of two to three miles. When used with dedicated lines, the lines must have dc continuity -and cannot have loading coils. In addition, baseband modulation is highly susceptible to interference when used with existing communication lines.

In broadband modulation, the frequency, amplitude, or phase characteristics of the carrier wave are modulated. Frequency shift key (FSK) modulation is most often used with an EMS. In FSK, carrier wave frequency is increased to represent a binary “one” and decreased to represent a binary “zero.” Similarly, in amplitude modification (AM) and in phase modulation (PM), the amplitude and the phase, respectively, are increased or decreased accordingly. The amount of data coded on the signal can be increased by selecting four or eight values (or more) for the characteristic being modulated; this is not generally done with FSK. With broadband modulation more than one signal can be sent at one time and data can be transmitted in both directions simultaneously.

EMS terminology also includes pulse width modulation (PWM). PWM is a means of directly transmitting digital information; the information is never coded in binary form and MODEMs are not involved. PWM is used with direct digital control systems and is discussed under Chapter 5.

The speed of data transmission is measured in bits per second, which are single binary digits, or in bauds. For EMS applications, one baud is one bit per second, and speeds of 300, 1200, and 9600 baud are used. High-speed MODEMs (9600 baud) are normally used when transmission is confined to one building. Lower speeds are used between buildings; 1200 baud is the prevalent speed.

To summarize, by modulating and demodulating the characteristics of a carrier wave, MODEMs impose and extract data onto and from wave forms transmitted over the data transmission media. There are two classes of modulation: baseband, used to transmit minimum amounts of data short distances; and broadband, used for longer distances and larger amounts of data. While there are three types of broadband modulation, the one most often used with EMS is frequency shift keying. Data transmission speeds can also vary; the speeds most common for EMS application are 9600 baud within buildings and 1200 baud between buildings.