LOCAL AREA NETWORKS and CABLE TELEVISION

by

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Transmission of non-entertainment services on CATV facilities has been the theme of numerous "weary prophets" for the last two decades. Although many steps have been taken in this direction, non-entertainment services have not become significant generators of additional cable system revenue. This is not to say that nothing has been done, but simply that the healthy business which was predicted and hoped for has never developed. During this time, however, a whole new segment of communications has evolved within the commercial, industrial and institutional sectors, becoming what we now know as "local area networks", utilizing baseband, broadband and fiber optic transmission media.

We shall briefly examine the development of local area networks and focus upon the kinship of broadband LANs and cable television technology.

EVOLUTION OF THE LAN

Traditional communications such as telephone, telegraph, telex, etc., have been with us for generations, as has the telephone network, which has provided the bulk of communication interconnections. With the advent of the mainframe computer, data volumes began to increase and the business of data communications started its astounding growth. Development of mini- and microcomputers compounded the situation. Computer terminals and peripherals multiplied, not to mention the need for computer-to-computer communication. The computer revolution has been driven by forces from all corners of modern civilization. In industrial, commercial and institutional areas this proliferation required enormous quantities of wire for interconnection and continued changes to keep abreast of the dynamics of the situation. In addition, higher data speeds were needed to efficiently support high density services such as computer graphics.

In short, the data communications, computer and automation industries needed a better way to cope with these dramatic increases, particularly in the areas of concentrated communications such as industrial plants, office buildings, universities, hospitals and the like — hence, the local area network. Designed to carry large volumes of diverse traffic over limited distances, LANs must be compatible with a wide variety of interfaces and data formats and must provide connection to "the outside world". Local area networks are far more sophisticated than the point-to-point and multi-drop circuits traditional in communications of prior years. They allow access to anyone on the network to pass a wide variety of traffic to other points on the network. In effect, all traffic is mixed and each terminal is arranged so that message recipients can sort out their own messages and retrieve them from the mass of other data.

The generalized local area network configurations are STAR, RING, and BUS architectures. A STAR, as the name implies, is configured about a central hub serving terminals with spoke-like connections and is reminiscent of the telephone network. The equivalent of a telephone switch employed in STAR LANs is far more sophisticated than the traditional voice switch. It can handle very high speed data (and may or may not handle voice) and perform extremely rapid switching. Digital PBX's, designed to carry voice and data, are a form of local area network capitalizing on the dual functionality. Some newer digital PBX systems even offer limited video transmission. A STAR network offers dedicated connections to all users, at the expense of somewhat inflexible configuration and a great deal of wire.

Another generalized LAN architecture is called a RING. Here messages are passed serially from terminal to terminal. They are regenerated at each terminal where traffic may also be extracted or added. Users share the network in a time division manner. No master control station is needed since each terminal has the network protocols in its own software. These networks are often implemented with fiber optic technology which lends itself readily to ring operation. One disadvantage of the ring structure lies in the fact that failure of any station on the network will disrupt all traffic which must pass through that station.

A BUS type of architecture is a little more difficult to describe physically. A bus is basically a common transmission path which all stations share on a time division basis similar to the ring. A message from one node need not pass through any other nodes except the one for which it is destined. The network protocols are resident in each terminal unit. This type of distributed architecture boasts high reliability through elimination of common data processing equipment. Failure of a terminal unit affects only traffic which must pass to or from it. Even though broadband networks usually employ a physical tree-and-branch configuration they fall into the BUS category from the data transmission perspective. Broadband networks have achieved widespread popularity due to the proven and straight-forward transmission technology and large bandwidths allowing multiple services, very high capacities and ease in equipment attachment throughout the network. As we all know, broadband networks can readily handle many data paths and configurations plus multiple video channels, and ultimately various types of voice traffic.

There is point of parlance to be noted here. The term "local area network" is used both to describe the entire physical multi-service network, i.e., the broadband local area network in a manufacturing plant, as well as a single group of terminals linked by a specific protocol, several of such groups might be carried on a single physical LAN.

The severest limitation of broadband networks at this time seems to be the lack of equipment to perform the "plain old telephone service". Telephones are almost universally necessary, but require wire other than the coax and hence detract somewhat from the overall attractiveness of the medium. Broadband, however, is being employed in a wide spectrum of LAN service and has been accepted as a standard by major users, such as General Motors, branches of the U.S. Government and many universities and is in use in thousands of locations.

The subject of local area networks cannot be dismissed without some mention of network access methods. Ideally, this type of network should permit random access and provide for all users whether their traffic requirements are large or small. When you consider the range of data rates, interfaces, protocols, etc., this is a big order. The general solution is to care for the interface, data rate and buffering requirements in the terminal unit (often called Bus Interface Unit or Network Interface Unit). Assuming these requirements have been accomplished the next step is to gain access for the traffic to the main data stream. Since the STAR network is basically a collection of point-to-point circuits controlled by a switch, the following comments do not directly apply, however, there are many similarities in the operation of the switch. The RING and BUS architectures operate with a common data stream for all users, so that the protocol that we speak about is basically that set of rules that governs access of a given terminal to the main data stream.

Multiple stations have been very successfully controlled by multi-drop and polling techniques. Polling protocols have been used which are very efficient and dependable. Polling systems, however have the disadvantage of requiring a central controller which then becomes a place of extreme vulnerability since failure of the central controller will disable the entire network. In order to overcome this deficiency the LAN protocols of today have been developed.

A given LAN terminal when it is receiving must simply listen for messages addressed to it and copy them. When the terminal has traffic to send, however, there are several general LAN protocols which may be employed. The first general area includes the contention protocols such as the very popular CSMA/CD (Carrier Sense Multiple Access/Collision Detection). In CSMA/CD a terminal wishing to transmit listens on the common data stream. When it hears no traffic it transmits its data. In order to confirm the integrity of the message it checks the same data after it has traversed the entire system and returned to the receive side of the transmitting terminal. The transmitting terminal then checks the received message and if it is unflawed it assumes that the transmission has successfully reached its destination. (It is well to note that the external protocol of the particular data circuit being served may request acknowledgement in order to fully confirm receipt of the message). If the transmitting terminal fails to receive the identical message back it assumes that the entire message was lost and tries again. Such message loss is often due to collisions with other transmissions as various units contend for the network. In order that collisions do not repeat and propagate, a unit sensing a collision with its transmission backs off for a random period before it tries again. The CSMA/CD protocol has been very successful except that when the network usage is high, more and more collisions develop and limit the throughput and in certain cases can paralyze the network.

In order to improve this situation more sophisticated protocols such as, token passing have evolved. Token passing, as the name implies, generates a unique signal and only that station having that signal in its possession can transmit. This is what is known as a deterministic protocol and can be counted upon for higher throughputs and avoids network paralysis.

It is not the object of this paper to thoroughly discuss LAN protocols; however, it is important to understand that a great deal of work has been done in protocol development and standardization. Perhaps the most concentrated and universally accepted protocol definitions have been developed by the International Standards Organization (ISO Model for Open Systems Interconnection) and IEEE 802 committees. The IEEE committees and their associated LAN standards are as follows:

802.1	Network Management
802.2	Logical Link Control Specifications
802.3	Carrier-Sense Multiple Access with Collision Detection (CSMA/CD)
802.4	Token-Passing Bus Access Method and Physical Layer Specifications
802.5	Token Ring Access Method and Physical Layer Specifications

802.6 Metro Area Networks

802.7 Cable Management Task Force

When all is said and done, local area networks have been developed to meet present day needs and represent a major area of communications. Many of these networks are implemented on broadband. Unfortunately for the cable industry, the LAN market has done an "end run" around us utilizing our technology in areas of highest importance and value in industrial, commercial and institutional environments. We have been left behind.

BROADBAND LAN's and CATV SIMILARITIES

As mentioned before, broadband LANs have been developed solidly upon CATV technology. Cable television hardware and system design is considered to be mature and reliable. There are multiple vendors producing competitive, high-quality hardware allowing the LAN designer firm assurance that he is not dealing with a technology which is "here today and gone tomorrow". LANs are generally designed to video specifications, since video transmission is the basis upon which the transmission hardware has been developed. There are very few components used in present day broadband local area networks which are not taken directly from CATV equipment lists.

By necessity virtually all LANs are two-way. The reason for this is obvious in that most of the communication needs are "request and response" or "command and status" in nature. It therefore follows that there is generally a balance of upstream and downstream traffic. For this reason single cable LANs are usually of the mid-split variety. Mid-split is used in the sense of "equal split", therefore, systems with broader bandwidths generally end up in the "high-split" or "super-split" categories, by CATV terms.

A single cable LAN is simply a mid-split architecture where the cable is routed to all parts of the facility where communications are or will be needed. The system is designed and installed with taps to accommodate the "passings" which in this case might be all offices or every possible work station in a large area, or perhaps every two-hundred square feet, or every column in open manufacturing space, etc. One very important advantage of broadband is that a properly designed system does not have to be disturbed to make moves, additions, or deletions of terminal equipment. The cost of operating downtime to make network extensions usually more than offsets the cost of a comprehensive design and complete installation, often in a very short period of time.

One of the major differences between typical CATV and broadband LANs regards size. A typical LAN for a modest industrial or commercial installation may utilize less than a mile of plant. A 20-mile LAN is a large one and may support 10,000 drops. The layout of an LAN to cover offices or a grid in a manufacturing area often results in relatively close spacing of taps and drops. Eight-way taps are commonly employed. This means that there is less cable loss in a typical run (and a higher percentage of flat loss) and often a lower range in tap values. This gives the feeling that LAN design may be somewhat simpler than CATV design. There are, however, some mitigating circumstances. First, it is common and often necessary to hold tighter tolerance on tap levels than in traditional CATV. In some cases LAN designers use taps with adjustable pads built in to allow trimming to the precise tap level desired. Beyond that it must be remembered than an LAN is a two-way cable network; therefore, the upstream design must match the downstream design. In this regard it is desirable that all modems be preset to the same transmitter output level so that there is one common alignment for all modems allowing new or replacement equipment to be installed without field adjustment. A few "back of the envelope" calculations will show the difficulties encountered in matching slopes and levels, upstream and downstream, to achieve $\pm$ 1.5 dB tap level tolerances simultaneously with a $\pm$1.0 dB spread of transmitter levels arriving at the headend.

Some LAN users have chosen dual trunk systems. A dual trunk configuration might typically employ cable carriage from 40 to 400 MHz on both inbound and outbound cables. A dual cable LAN takes the signals from the inbound cable to the headend and simply combines them with the other inbound trunks and reverses the flow to the outbound cable without frequency translation ("regeneration" or "remodulation" of some signals may be performed at the headend). Notice the difference between this and CATV dual cable where 50 - 450 MHz may go downstream simultaneously on two parallel cables and there may be one or two sub-split upstream paths requiring frequency translation of any upstream (inbound) signals desired on the downstream (outbound) path. Dual cable LAN systems eliminate the spectrum losses caused by diplex filters but normally do not use the range from perhaps 5 - 40 MHz, which in part offsets the first saving.

In single cable usage modems are generally configured to transmit at low frequencies and receive at high frequencies (although this is not universally held). Modem frequency assignments in a dual cable system usually employ transmitter and receiver frequencies within the same general frequency range of a few TV channels. This is a convenience because it allows blocks of contiguous spectrum to be allocated to a certain network or service and does not require frequency translation. It also somewhat simplifies modem design due to the similar transmit and receive frequencies. On the other hand, with connections from each cable going to each modem in the system, there is the potential of excessive local coupling between cables interfering with the desired signals which have been returned from the headend. The requirement here is that modems must have sufficient isolation to limit the maximum possible coupled signal to an insignificant level in terms of data channel interference.

RELIABILITY

Obviously, reliability and availability are key in LAN operation. In considering the cable system itself, redundancy is often employed in a number of ways. In the layout of the physical plant it is well to establish diverse trunk cable routings, thereby limiting physical damage at any one location to a single trunk. In other words, multiple trunks should be dispersed and ideally only come together at the headend. Where redundant cable exists it should be routed separately from the main system. In one design two interleaving systems were used so that any location served was near to both systems. In case of a failure on one system an easy switch-over could be accomplished, restoring circuits quickly.

Power systems should also be designed so that failure of one power supply does not affect both the main and backup systems. Distributed standby power is often used, however, location of all power supplies in the headend is desirable if possible. If standby power is provided for the headend equipment it can also be provided for the entire power system from the same source. Headend-mounted power supplies are protected from physical damage and are also provided a more favorable operating environment.

In broadband LANs great emphasis is placed on system performance. Frequent level checks, rebalancing as required, leakage monitoring and repair (which guards against data channel interference from ingress) and other measures are employed to continually optimize system performance. One of the important tools for system maintenance is broadband status monitoring. There are a number of status monitoring products available to the CATV industry, most of them associated with the trunk amplifiers. Usually, measurements of pilot levels are made and checked against nominal and reports of the system flatness are generated for each amplifier. Other data is collected on individual amplifier parameters such as voltages and internal temperatures. Some status monitoring systems employ upstream switches for location and control of ingress. Status monitoring system reports are usually displayed on a stand-alone computer or terminal.

Local area networks employ very sophisticated data communications products. These network products include many devices and methods for gathering statistics and analyzing data transmission performance under the control of a network manager computer. These "network managers" are very comprehensive from the data transmission point of view, however, they do not include monitoring of the medium, in this case, the broadband cable. A more desirable status monitoring configuration for the broadband medium generates information on the medium performance and provides this to the network management computer thereby rounding out the monitoring and control functions by addition of this critical information.

The Network Technologies Division of AM Cable TV Industries, Inc., has recently announced the TMC-8000 product which includes end-of-line status monitoring so that level measurement units can be placed either in-line or at any drop in the entire system. These units are permanently located and are also capable of generating measurement pilots. With a modest headend controller, pilot generation and measurement may be initiated throughout the system at user-selectable frequencies at 50 kHz increments across the spectrum, both upstream and downstream. Measurements of system signals may also be made with the pilots disabled. In addition, three position switches (0 dB, -6 dB, and OFF) may be located throughout the system for ingress location and control. A unique system of calibration allows very precise level measurements providing the control necessary on these critical networks.

All remote units of the TMC system are organized on a narrow-band, polled, two-way data channel to handle both command and status information. This data channel protocol includes data transmission performance analysis of the command and control messages. Diagnostic information gained from the TMC data stream is useful in identifying the parts of the network which exhibit degredation by analysis of data transmission errors. Certain versions of the TMC operating software contain facilities for input of the topology of the cable network (a system map). This information, when compared against the location of failed units, generates pointers to indicate the most probable locations of cable system component failures.

Output of the TMC system is available in three forms. Stand-alone operation is possible with an IBM PC-XT with proprietary user-friendly software. In a simpler version a stand-alone monitor is provided to access the controller. For use with a network management computer, serial data streams in and out convey all necessary information. The TMC comprises a stand-alone status monitoring system with many features optimized for the broadband LAN arena, and is directly applicable to cable systems as well.

CHALLENGES FOR CABLE OPERATORS

Other industries have capitalized upon the high quality performance of broadband networks and the maturity of the cable products available to generate great utility outside of the traditional CATV market. These are areas in which cable operators could have been involved and reaped benefits for participation. In the main, these opportunities are passing us by, due largely to lack of interest on the cable side. The growth of broadband local area networks is increasing even at this late date. Cable operators often have opportunities within their franchises to serve schools, colleges, universitites, municipal governments, commercial complexes and industrial plants. The cable operator who gets the job of designing, installing and maintaining a network can benefit with substantial revenues.

The lowest level of involvement by the cable operator is probably where he simply supplies service to tie together LAN locations. This is usually a straight-forward job utilizing point-to-point circuits. Hardware is available (modems, etc.,) and careful design and maintenance will yield high-quality, dependable performance. Design, installation and operation of entire networks requires deeper involvement, and usually produces more revenues. The action necessary is to seek out local present or potential LAN users and propose participation in their projects.

There is an area which is just now taking shape, in which we may have many opportunities to participate. "Smart buildings" and the "office-of-the-future" are areas where a heavy dependance will be laid upon communications. Broadband has many advantages which qualify it as the most preferable choice in many cases. You know how to use broadband effectively. You may have to learn a little about data but your first job is to design, install and maintain our own technology. You have tuned CATV technology over the years to provide high-quality TV service. That should qualify you to provide high-quality broadband networks for other services. Now is the time to get "up to speed" in these developing areas and aggressively pursue these opportunities.