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A NEW APPROACH FOR LOCAL NETWORKS

Conventional thinking on tele-communications has led companies to use separate, dedicated networks for their different applications, such as voice, data, facsimile, process control, energy management, security, public address systems, and many others. But office automation is looming ahead, with its demands for more network capacity, so we think it is time to step back and take a broader look at communications. Are these dedicated networks really desirable—or could one (or a few) common, multi-use networks do a better job? Here is an analysis of some benefits and problems of multi-use nets.

The Dow Chemical Company is a worldwide supplier of chemicals for industrial, scientific, and commercial uses. It has headquarters in Midland, Michigan and had sales of $9 billion in 1980.

The company has a corporate tele-communications department which studies the communications marketplace and co-ordinates the work of the tele-communication departments in the various divisions. One of these is the Texas Division of Dow Chemical U.S.A., located in Freeport, Texas, on the Gulf of Mexico coast.

The Texas Division employs some 7000 people. Most of these employees work within a seven square mile area that contains the Dow Freeport complex of office buildings, processing plants, storage centers, and seaport docks. Connecting these facilities are some ninety miles of coaxial cable which provide broadband local network facilities.

Plans for the network began in 1973 when the company realized that stringing point-to-point wires to inter-connect process control computers, digital computers, plant control rooms, office buildings, and surveillance equipment would be impractical in the long run. So in 1975 the first seven-mile stretch of three-quarter inch coaxial cable (coax) was laid under the ground to connect two plant complexes. Also, one-half inch coax cable was used between buildings, and one-fourth inch coax was used within the buildings, resulting in a total of 32 miles of coaxial cable in the initial system.

Actually, two cables were laid underground. One is used and the other is for backup and for possible future expansion.

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The coaxial cable provides 300 megahertz (MHz) of bandwidth; this bandwidth is divided in half to provide 150 MHz bi-directional capabilities. The company currently uses frequency division multiplexing (that is, allocating different frequency bands for different communication channels) and analog transmission technologies on the network.

Use of the network. To date, Dow uses this broadband network for three main applications: video transmission, process control and monitoring, and data communications. The point to note is that all three are using the network simultaneously.

A primary use of the network is *video transmission.* Dow has six 6 MHz video channels which it operates much like an in-house cable television system. The six channels are used to broadcast employee education programs, emergency announcements, local and company-wide news, weather reports (which are extremely important during the hurricane season), and safety programs. Dow has some 400 television sets placed in cafeterias, office buildings, conference rooms, and throughout the processing plants to receive these broadcasts.

Of particular importance are the safety programs, which are aimed at plant and equipment operators. These video-taped programs continually remind the employees of potential safety hazards and the precautions they should take against these hazards. When a new or recurring safety problem arises, the plant's general manager can make a special video presentation describing the problem and the company's concerns. These broadcasts have a much greater impact than would written memos—and they spread the message quickly.

A number of plant control rooms also have television sets which are used to visually monitor critical equipment. In addition, the company has a video channel used for security purposes, to provide surveillance of various areas in the complex—primarily unmanned gates and entrances.

A second major use of the local network is *process control and monitoring.* Dow has numerous process control computers which use the network to monitor remote equipment, on a polled basis. In some cases, to ensure fail-safe operation if the network should become inoperative, they have micro-computers at these monitored equipment sites. But in normal operation, the data is gathered at the remote site and transmitted to the process control computers for analysis.

In addition, there are many CRT terminals used by plant supervisors to communicate with these process control computers, to access process monitoring information. And they have recently put an energy management system onto the network for one power plant.

A third, and growing, use of the network is for *data communications.* From the outset, the cable system has handled remote job entry to an IBM computer (now a 3032) at the main computer center. But they also provide both point-to-point and polled services for in-house time-sharing. And recently they introduced an electronic mail service at the center. Some 60 CRT terminals have been installed for these purposes. These terminals communicate via 4800 or 9600 bps modems (for use with broadband systems) from Amdax Corporation, of Bohemia, New York.

There are also a growing number of smaller computer centers, some using DEC equipment and DECnet protocols, that are tied to the network. Users can access these systems via the network for business data processing purposes.

In short, Dow's broadband network is serving a variety of applications: plant information dissemination (via video), process control, energy management, data communications (including remote job entry and terminals access multiple computers), and an electronic mail service.

Further, since Dow now has broadband facilities in place at almost all major world-wide locations, they are continually studying ways to take more advantage of emerging new products and services. For example, they are installing satellite communication services (specifically, Satellite Business Systems' services) that will allow broadband communications among the company's locations. They are investigating the teleconferencing possibilities this communication link can open up. They are also considering time-division multiplexing, which would significantly increase the capacity of their cable. In addition, they are closely watching the growing number of office work-station and departmental business computer systems appearing on the marketplace. They see these being major users of broadband facilities in the future.

Growing use of tele-communications

Dow Chemical's expanding use of tele-communications is quite respresentative of what is happening in organizations around the world, both large and small. New services are becoming available by tele-communications that these organizations wish to use. Then, too, the time and cost of some business travel are being replaced by tele-communication services, such as computer message systems and tele-conferencing. The only thing particularly unusual about Dow's experience is the broadband nature of their local network.

If a question is raised about the future tele-communications needs of an organization, several uses immediately come to mind, such as voice (the telephone), data, and facsimile. But it does not take much additional thinking about the question to lengthen this list considerably.

'Conventional' uses. These include, as just mentioned, voice (telephone), data, and facsimile. But other widespread applications of tele-communications include: telex and TWX, inter-comm systems, public address systems, accessing information services (such as the bibliographic search services and stock market services), process control, monitoring of equipment, security surveillance, control of security card-key systems, electronic funds transfer, intra-plant broadcast messages, computer work-load sharing, and terminal-to-computer query systems.

But the list does not stop there. There are some applications of tele-communications that are just beginning to be installed on a fairly wide basis.

Rather new uses. These include the new automated office systems, communicating word processors, computer message systems, computer conferencing systems (where participants log on whenever and wherever convenient for them), audio and slow-scan video tele-conferencing, life safety systems (the need for which was demonstrated by recent fires at large hotels), energy management systems (as discussed in our February issue), distribution of computer software by tele-communications, and the distribution of education and training 'software.'

But still the list has not ended. There are some other types of applications that are just on the horizon.

Arriving 'soon.' These uses of tele-communications have been encountering some problems. In a few instances, the problems have been technical in nature; in other cases, the problems have been economic or political. But all have finally reached the point where they are being offered in the marketplace, so their acceptance can begin to grow.

These uses include: store-and-forward voice, simultaneous transmission of both voice and data over the same circuits, full motion video tele-conferencing, electronic mail (which we think of as sending a message electronically to a remote location, printing it out there, and delivering it by conventional mail), videotex, 'office in the home,' interactive graphics capabilities over a wide geographic area, and the local distribution system for information transmitted over satellite links.

It seems apparent that most computer-using organizations, both large and small, will be demanding more and more tele-communication services. So it behooves the management of an enterprise to seek out the best way to provide these services throughout the organization.

The subject of this report is the potential benefits of common, broadband local networks for supporting these services. This is an approach that is already in use in a number of larger companies, such as Dow Chemical. It is an approach that is ready for consideration by most medium and larger organizations. And first steps toward broadband networks are even being taken by some small organizations, via their local networks of several micro-computers.

Common local networks

Most organizations have provided for their increasing local tele-communication needs by way of separate, dedicated 'networks.' For instance, one generally finds a voice telephone network within the premises, a data communications network, perhaps a process control network, a security surveillance network, and so on.

We recently heard about one aerospace company that has investigated their in-plant networks. They had expected to find about seven networks in operation. Actually, they uncovered *nineteen* of them!

In most cases, each network has its own transmission medium (such as twisted pairs of wires) because the needs have materialized at different times. Each network has been designed for its specific purposes. There is little or no sharing of network capacity among the applications, one reason being that each network was designed to be application-specific. When a new need arises, it is given its own network.

With this proliferation of in-house networks, companies are finding that their buildings do not have much room left for more wires. The ducts and conduits are filled, and above-ceiling spaces are already taken. So where will the wires go for automated office systems, life safety systems, energy management systems, and so on? Further, even after those many wires are installed, a company is still faced with the difficult task of servicing them—and re-wiring them, as work sites are moved.

Also, this picture is reminiscent of the early days of data communications, when each new application had its own network. As the demands for data communications grew, it became apparent that these application-specific networks had to be replaced by the new application-independent ones. Much the same thing is now occurring with local networks. Based on the list given earlier, it seems very likely that the overall demand for tele-communications services will accelerate and that the problem of in-house networks will get worse—fast.

The strategic question that we think most companies should be asking at this point in time is: Would not a common, broadband network, which serves all (or most) of the applications listed above, be a wiser approach than continuing to add more dedicated networks?

A broadband local network

What is a common, broadband network? Maglaris and Lissack (Reference 1) give a good description, in terms of a local network structure that their company, Network Analysis Corporation, of Great Neck, N.Y., has proposed. This local network structure is practical with today's computer and communications technology, they say.

The authors point out that there are two general types of communications traffic—(1) bursty, delay-critical communications, such as interactive communications between a terminal and a computer, and (2) lengthy communications such as voice, file transfers, tele-conferencing, and such. An *integrated* broadband local network must be able to accomodate both types of traffic.

While a wide variety of transmission media—twisted pairs of wires, coaxial cable, microwave, infra-red links, fiber optics, etc.—could be used, they propose the use of high quality coaxial cable, developed for community antenna television (CATV) systems, because of its availability and economy. This type of coax is semi-rigid, using a solid aluminum sheath as the outer conductor. (Standard coax has a wire mesh sheathing and is not very satisfactory for broadband use.) Further, CATV coax has a wide bandwidth, of almost 300 megahertz (MHz), which is capable of carrying 30 color TV programs for many miles with little signal distortion. They propose using this bandwidth in a 'radio frequency' manner. That is, they suggest that the bandwidth from 54 MHz to 300 MHz be divided into 41 channels of 6 MHz each. Each of these channels could carry conventional analog signals or digital signals (at somewhere between 5 mbps and 10 mbps, depending upon the modulation method used and the width of the guard bands between the channels). They propose using the bandwidth by frequency division multiplexing because of the availability of components. However, time division multiplexing could be used where it is appropriate. Also, this coax has a very low bit error rate (about one error in each 100,000,000 bits transmitted), and other desirable characteristics.

Maglaris and Lissack discuss two structures for the network. One approach is to use just one cable, with the different application units (terminals, computers, etc.) connected to the cable via radio frequency (RF) interface units. Essentially, these interface units are radio transmitting and receiving stations. Most interface units would be set for one transmitting and one receiving frequency; however, tunable interface units are available, if needed.

The total bandwidth of this single cable would be divided into two halves—one half would be used for the transmitting channels and the other half for the receiving channels. At one end of the coax is a 'head-end' which receives all transmissions, shifts their carrier frequencies to the appropriate receiving channel frequencies, and retransmits them on those receiving channels. Note that signals would be going in both directions simultaneously within the cable; for this to work, bi-directional amplifiers are needed. Also, a terminator is needed at the end opposite the head-end, to absorb the old signals.

The other approach is to use *two* coaxial cables, one for transmitting and one for receiving. Since the cost of the coaxial cable is small compared with the other equipment attached to the network, and since this approach doubles the available bandwidth, this is the one they prefer. Again, a head-end is needed for receiving the transmitted signals, shifting their carrier frequencies, and putting them out on the receiving cable.

With either of these approaches, any node on the network can transmit to any other node within the same application—that is, which uses the same transmitting and receiving channels. The different applications are kept separate by being assigned different channels. In fact, some of the applications can use digital signals and some can use analog. All of the hardware used by this proposed network would be standard wideband devices, mostly from CATV technology.

But this is only part of the picture. As was mentioned earlier, Maglaris and Lissack say that the local network must be able to handle both bursty, delay-critical traffic and lengthy traffic such as file transfers and voice. So they propose two types of channels on this network: *contention* channels and *reserved* channels.

A contention channel would operate like a packet switched network. The transmission speed they propose is 1.544 mbps, which is the speed of the telephone T1 digital carrier. Access to a contention channel would be by the 'carrier sense multiple access, with collision detection' (CSMA/CD) method, such as is used by Ethernet and some other leading local networks. So, in effect, each contention channel would operate much like an Ethernet network (which has just one channel that operates at 10 mbps). Each 6 MHz channel could provide enough bandwidth for several contention channels.

A reserved channel, on the other hand, would operate like a circuit in a circuit switched network. It would be used for the long transmissions, such as file transfers, voice traffic, tele-conferencing, and so on. If necessary, a full 6 MHz band could be used for one reserved channel, or it could be divided into sub-channels of lesser bandwidth. The reserved channels would be under the control of a 'network control center' (NCC), a computerized function, which would be responsible for accepting requests and allocating the use of the reserved channels.

When an application wished to use a reserved channel, it would send its request to the NCC by way of a contention channel. If the appropriate channel is available, that uses the proper transmitting and receiving frequencies, the NCC would allocate it to the requesting node. Relevant protocols would set up the session with the desired receiving node. This call setup would be done via the contention channel. Information would flow in the reserved channel as independent datagram packets, without the need for flow control and sequencing that are found in the virtual circuit discipline.

Some other points about a broadband network (from several sources) should be mentioned briefly. The topology of the network can be tree-like, with major limbs, branches, sub-branches, and so on. It is easy to extend the network; just 'tap in' to the nearest point of the cable. Also, to add (say) a terminal, just tap the nearest branch of the network, install the interface unit, and run a local drop cable to the terminal. Also, because RF technology is used, distance limitations are not nearly as severe as they are with, say, the Ethernet (which uses the baseband technology, to be discussed shortly).

This, then, is a picture of what an integrated, broadband local network might be like. The technology is available for supporting it. The total bit-carrying capacity would be somewhere in the range of 200 to 400 mbps *per two-cable network*, which is a huge capacity. And if that capacity is not enough, the network could have one or more 'gateways,' for connecting to other networks, including other local networks as well as common carrier networks.

Are they practical?

Just how practical are these common, broadband networks? Stuart Wecker and Marvin Sirbu discussed some of the requirements for local networks at a session of the 1981 Office Automation Conference (Reference 2). Their ideas may help one to judge just where the state of the art stands today.

They point out how wide a range of needs a multi-use local net must cover. Information block sizes can range from eight bits (for digitized voice) to hundreds of bits or more (for text). Some time delay characteristics are critical; for instance, if voice blocks are delayed in transit, the speaker may "sound like Donald Duck." Also, the bandwidth needs vary enormously. Overnight store-and-forward message systems may need only 300 to 1200 bps in order to operate. The retrieval and display of documents, however, may need speeds of between 9 and 30 kbps. Voice needs the equivalent of 56 kbps. Compressed facsimile images need 250 kbps for good transmission time, and non-compressed images need 1.5 to 3 mbps. Video conferencing, with full motion, needs 6 mbps. Further, said Sirbu, the demand for bandwidth will increase because users prefer images, and images take more bandwidth than text or numbers.

Also, asked Wecker, should the channel bandwidths be allocated statically or dynamically?

Networks must be flexible, said Sirbu. It must be possible to inter-connect them to other networks with different capacities—including in-plant, private long haul, and common carrier networks.

It seems to us that the ideas presented by Maglaris and Lissack cover these requirements quite well. The use of contention and reserved channels solve some of the needs. Further, the reserved channels can have 6 MHz bandwidth, or sub-multiples of this bandwidth, as the different applications require.

Allan I. Edwin (in Reference 3) discusses today's broadband network technology in a brief, readable overview. His views are based upon the broadband networks that his company (Interactive Systems/3M, of Ann Arbor, Michigan, a part of the 3M Company) has installed for customers since 1972. The network structure that he describes differs from that of Maglaris and Lissack, but there are points of similarity.

Edwin's structure uses a single coaxial cable, with two-way communication provided by means of the 'mid-split' of frequencies discussed earlier. Multiple channels are created by frequency division multiplexing. Each interface unit or modem that is attached to the cable is tuned to one frequency for transmitting and to another frequency for receiving.

For point-to-point use, the interface unit accepts all received signals, since everything received on that frequency is for it. For multi-drop use, where one channel is shared by up to 8, 16, or 32 relatively slow speed devices, the interface units must be intelligent enough to determine which messages are for them. A message may be a poll, telling the device that it can now transmit any data it has ready to send.

Also, time division multiplexed channels are available, for use where many user devices (such as terminals or data acquisition units) share the same channel. A control unit is needed to provide the enabling signals to the modems, telling them when they can transmit.

Video and audio applications also can use their assigned channels and sub-channels on the same network. Since one such network can provide many channels, all of these uses can be occurring simultaneously.

So Edwin agrees that common, broadband networks are practical with today's technology.

Four months ago, Wang Laboratories, Inc. announced its new Wangnet, a broadband local network based on the use of standard CATV components. The bandwidth (from 10 MHz to 350 MHz) is currently divided into three 'bands'—an inter-connect band, a Wang band, and a utility band—but these use only about one-third of the total bandwidth. Hence, other types of bands can be added in the future.

The inter-connect band allows non-Wang terminals with RS-232 or RS-449 interfaces to connect to the network and communicate with units on the same band or on the other bands. Two types of channels are available in this band, dedicated and switched, and two transmission rates are available on it, 9.6 kbps and 64 kbps.

The Wang band allows Wang 2200 and VS mini-computer systems, as well as Wang's 'office information systems,' to inter-communicate, with transmission speeds of up to 12 mbps. The Wang band also supports Wang's 'Mailway' computer message system.

The utility band consists of several channels for use with freeze-frame and full-motion video. Its components were available at the time of announcement. Components for the other bands will be released starting in the first quarter of 1982.

Two other leading suppliers (of broadband modems) are active in this type of local network market. They are: Amdax Corporation of Bohemia, New York, and Network Resources division of Sytek Inc., of Sunnyvale, California.

Are common, broadband local networks practical? It appears that Network Analysis Corp., Interactive Systems/3M, Wang Laboratories, Amdax, and Sytek believe that they are.

But what about Ethernet and other local networks of its type? How do they fit in?

Baseband networks

The Ethernet—originally developed by Xerox (discussed in our June 1980 issue) and now jointly supported by Xerox, DEC, and Intel—is perhaps the best known baseband local network. It is being offered for use in automated office systems and for communicating between terminals, minis, and micro-computers. HYPERchannel, developed by Network Systems Corporation of Brooklyn Park, Minnesota (and also discussed in the same issue), was the first commercial baseband local network, designed for use with large mainframes. Because of the publicity and advertising space given to Ethernet, we will use it in the following discussion as representative of this type of network.

A real battle in the marketplace may be shaping up between baseband technology and broadband technology—although Maglaris and Lissack propose a way to reconcile the two.

The term 'baseband' refers to the fact that the frequency spectrum for this type of network begins with direct current and extends up to (say) tens of megahertz. (With broadband, the lower end of the frequency spectrum—say, the first 10 or 50 MHz—is not used.)

An Ethernet-like baseband network is a passive network. The interface units are not a part of the network itself; they just tap into it. So there are no active network elements to malfunction and make the whole network inoperative, as can happen with broadband networks. Also, connecting to a baseband network requires relatively inexpensive equipment, while tapping in to a broadband network requires the use of RF interface units. The upper limit in transmission speed, for a baseband network, is measured in tens of millions of bits per second—for instance, 10 mbps for Ethernet and 50 mbps for HYPERchannel. Access to a baseband network generally is by the CSMA/CD contention method.

These features would seem to make baseband networks formidable contenders. What features do broadband networks have to offer in competition?

For one thing, a baseband network is, almost by definition, a dedicated network designed for one type of use. This basic use is for short, bursty communications between computers, terminals, and peripherals, where speed of access does not have to be guaranteed. Also, no other signals, such as analog voice signals, can share the same network. Lengthy operations, such as file transfers, would have a degrading effect on access to the network by other users; simultaneous transmissions are not possible.

For another thing, a baseband network has an upper length limit of something like 1000 to 4000 feet. In order to extend the network in length—say, to connect to other buildings in an industrial campus—it is necessary to use one or more other baseband networks with 'gateways' (involving amplifiers) to connect them. In such a case, the baseband network no longer is fully passive. Broadband networks, on the other hand, can operate up to tens of miles of distance, if so required.

Baseband networks probably will be widely used for such applications as inter-connecting automated office work-stations, or connecting terminals to minis and micros, or connecting mainframes together for load-sharing. As such, they will require the addition of more cables (often coax cables) to the already-crowded spaces in walls and ceilings. Since they cannot perform all of the functions that broadband networks can, they cannot replace existing cabling to as great an extent as the latter.

As mentioned earlier, Maglaris and Lissack propose a way to reconcile the two technologies. A contention channel on their proposed integrated network would operate—from the viewpoint of the user—much like a baseband network. So, to convert an existing baseband network to a broadband net, the "addition of a simple RF modem will provide compatibility to existing baseband interfaces," they say. However, note that broadband works best with CATV coax, while baseband networks may be installed with regular coax or even twisted pairs of wires.

The picture may become a bit more complex in the future, however. A standards committee of the Institute of Electrical and Electronic Engineers (IEEE) has proposed *two* access standards for local networks—CSMA/CD and token-passing. CSMA/CD is a statistical access method; it provides an average access time to the network, not a guaranteed one. For uses that demand guaranteed access, such as some process control applications or digitized voice traffic, the token-passing access method is required. We will not discuss token-passing other than to say that it is a more complex method than CSMA/CD and apparently not all of the technical details have yet been worked out.

Although they did not address this point, Maglaris and Lissack might say that token-passing local nets could be converted to the reserved channels on the type of network they propose.

One last point about these two technologies. Both seem to be making efforts to use the inter-connection standards proposed by the International Standards Organization, the 'open system inter-connection' standards for protocols. These OSI proposals involve the use of seven levels of protocols. It will be some years before the full effect of these proposed standards will be felt, of course. But when they do begin to reach the marketplace, it will make life easier for users when they want to install new networks.

Some pros and cons

The idea of a common, broadband network for providing communication services for most of the applications listed earlier is sure to raise a controversy. In anticipation of that controversy, we will list and discuss some of the arguments that we have come across which will be brought up against the idea, as well as some arguments in favor of the common network.

The arguments against

Not all of the components are yet available. While a common, broadband network would make extensive use of CATV technology, some of the necessary components are missing. For one thing, all of the different levels of protocols are not yet available. Users may have to develop their own protocols, at this point in time, for some types of applications. Also, specialized interface units will be needed for each general type of use. These are not yet on the market, in any real sense.

We cannot wait for these components. Most computer-using organizations are faced with a continuing problem of adding new communications capabilities. At any point in time, there can be an urgent need for something new—for facsimile, say, or office automation, or process control. Or a new in-plant telephone system may be urgently needed.

Where urgent needs exist, the executives responsible for providing communication services will want to rely on familiar, tested technology in order to provide those services in the shortest possible time. In fact, it may well cost them their jobs if they recommend installing unfamiliar, untested technology—and then run into serious problems of making it work.

The RF interface units are costly. As mentioned, these units are the equivalent of radio transmitting and receiving stations. Terminal interface units cost about $500 each; television interface units cost more. For a network serving many devices, these units can add up to a significant amount of money.

How would we convert? One not-unusual argument will be, "We have so many wires in place now that we do not know what to do. There is no way that we can tear out all those wires in order to install a common network to replace them and still continue to run our business."

In such a situation, those responsible for telecommunications will prefer to solve each new service requirement as it arises. They will somehow find ways to cram more wires into the existing ducts or conduits, for as long a time as possible.

These new uses are fine, but they will not all arise at once. Some of the applications listed earlier will not arrive for years. By that time, local network technology will have moved far ahead of where it is now. So, says this argument, why rush into a common network now when the real need for one may be years away?

A common, broadband network is vulnerable. "If it goes down, all communications stop, and we just could not afford to take that risk." The proponents of this argument say that if one of today's in-plant networks goes down, it generally does not affect the functioning of the others. So, they say, do not put all applications on one network, particularly one that has active elements which can malfunction and thus bring down the whole network.

How do you handle voice traffic on a local network? While the broadband local network discussed by Maglaris and Lissack proposes to carry voice traffic as well as other types of traffic, if one studies the broadband networks that have been installed, it will be noted that they handle little or no voice traffic. Voice traffic does require a different type of channel than does interactive computer use, as Maglaris and Lissack point out, and they propose to handle voice on circuit-switched reserved channels.

But the channels are not the main problem, say the proponents of this question; rather, the problem is connnecting each phone to the network. It makes no sense to use a $500 RF interface unit for connecting a $35 telephone to the network. Until this problem is solved, broadband networks are not practical for voice traffic, they say.

Where do the new PABXs fit in? They represent advanced technology. The private automated branch exchanges (sometimes called 'computerized PBXs) do offer new, interesting services for voice, data, and some other types of traffic. They can handle many voice-grade lines, and some now digitize voice right at the telephone handset and can simultaneously handle a 9600 bps data stream and a voice conversation on the same voice-grade telephone circuit. PABXs offer nice features such as call forwarding, automatic re-dialing if the called line is busy, least-cost routing of long distance calls, etc. Moreover, they are not theoretical ideas; they can be seen in operation today. "It is true that they cannot handle full-motion video and other wide bandwidth applications, but we won't have those applications for years," say the advocates of this argument.

Again, numerous organizations will choose to make progress slowly and carefully—and will put in something like a PABX now and defer the idea of a common, broadband network until later.

These, then, are some of the arguments that we have come across that attack the idea of the common, broadband network. In its place, the presenters of these arguments prefer to use conventional, tested solutions. Further, they point out, these solutions are being improved all of the time, so that progress will be made toward reducing tele-communications problems.

The arguments for

The proponents of common, broadband networks bring up some counter arguments.

Digging the hole deeper. The tele-communication services at many (most?) organizations have been developed haphazardly, say the advocates of this argument. Tele-communications really is in a 'hole' with the myriad of networks that now exist. Contuinuing the policy of conventional thinking is only digging the hole deeper, making it more and more expensive to get out of the hole when it is finally essential to do so.

You don't have to convert everything at once. It may be that a broadband network is installed for just *one* new application, which will use only a small fraction of its total capacity. The cost of the broadband network may be greater than the cost of conventional wiring, as far as that one application is concerned. But as more applications are added to the network, the economics will become more and more favorable.

In short, say the proponents of this argument, if you agree that a common, broadband network is the direction of the future, begin installing one just as soon as you reasonably can.

Select an application for which all of the components *are* available today. You possibly will install several 'generations' of broadband networks over the first five years or so; don't demand the ultimate on your first try.

With your first broadband network in place, you will then be able to convert some other existing in-plant applications to it, one at a time—and then take out the existing wires once they are no longer needed. And note: the copper in those existing wires can be sold, to help pay the cost of the broadband network.

You have no flexibility with conventional networks. Most of today's installed in-plant networks have fairly narrow bandwidths, the equivalent of voice-grade telephone channels. Further, they have been designed for specific purposes. So it is generally impractical to do much sharing of capacity on these networks among several applications.

With broadband networks, you have considerable flexibility to allocate bandwidth as it is needed. There is just nothing like this flexibility to be obtained from most of today's conventional networks.

Design your local network as a distributed one. The design principles for a highly reliable network have been known for years. Paul Baran described them in a landmark series of Rand Corporation reports entitled 'On distributed communications,' published over twenty years ago.

Today's conventional in-plant networks are not all that reliable and secure; typically, not a lot of redundancy has been used. A broadband network can include engineered redundancy, with multiple paths between any pair of nodes. Such a network can offer *more* safety and reliability than most of today's networks.

Broadband networks aren't incompatible with PABX. In a sense, a broadband network would just replace a lot of the cabling that now clogs the conduits at many organizations. Circuit switching, such as done by PABXs, would still be needed for what Maglaris and Lissack call the reserved channels in a broadband network. True, today's PABXs have not been designed to handle circuit switching in this environment. But if broadband networks become popular, you can be sure that suitable PABX offerings will appear.

Also, now that simultaneous voice and data are practical on the same circuit, one RF modem can serve both a terminal and a telephone. The economics of the modem are not so severe, in this case.

These, then, are the main arguments that we came across which favor the installation of common, broadband networks.

To see how one very large organization has approached the installation of broadband networks, consider the case of General Motors Assembly Division.

General Motors Assembly Division

Samuel M. Smith, in Reference 4, discusses the first four years of experience with broadband local networks at General Motors Assembly Division (GMAD) plants. His paper gives a good insight into the advantages and problems of introducing this type of network.

GMAD began a study in 1974 to determine how best to tie together the large number of online terminals and plant-floor mini-computers that would be installed in each of their plants within the next five years or so. The recommendation of the study team was to use broadband coaxial cable networks for in-plant data communications. The advantages that were foreseen for this type of network included lower costs (as compared with dedicated cabling in conduits for each application), immunity to electrical noise, and the ability to have a systematic, uniform approach to high speed plant communications.

At about this same time, the idea of facilities monitoring systems caught their attention. Such a system would include the monitoring of certain plant equipment, the control of large energy-consuming equipment, security monitoring, and assistance in the security watch function. So this facilities monitoring application was chosen for the initial use of a local broadband net. The first such network was installed in a GMAD plant in the fall of 1975.

What happened in the following four years was a gradual evolution of the broadband network—an evolution which can be viewed in terms of three 'generations' of networks.

The basic network architecture stayed the same over the three generations. GMAD uses a single trunk coaxial cable system with standard CATV cables, connectors, directional couplers, and amplifiers. The 300 MHz bandwidth is divided into two halves; the low end is from 11 to 120 MHz and the high end is from 160 to 300 MHz. As discussed earlier in this issue, a head-end is used which receives all transmissions, shifts their frequencies, and sends them out on the appropriate receiving channels. These low-end and high-end bandwidths are divided into 6 MHz channels.

At the outset, the facilities monitoring application involved only inbound traffic, from sensors at various places in a plant to the mini-computers that performed the monitoring. The head-end function was put in each mini.

A number of difficulties came to light with this first network. Some of the coax cable fittings were improper. Some installers used the wrong tools. Some amplifiers were mounted in inaccessible places, making maintenance on them very difficult. In one case, a wrong type of coax was ordered. It was installed—and resulted in marginal signal levels.

Since the broadband networks were to be installed at GMAD plants around the country, it was soon apparent that the network design should be improved. The second generation of network provided a better coverage of a plant complex, and allowed for both transmitting and receiving by the remote units. The head-end function was moved out of the minis, to give more options on where it could be located. But there was still only one head-end, with no back-up, and this was considered undesirable.

The third generation, for which installation began in 1979, was the first to use corporate standards for broadband coaxial networks. Also, a back-up for the head-end function was provided, along with automatic switchover to the back-up when it was needed. And signal specifications were developed for both voice and video signals. A full duplex mode of operation was provided.

Applications for the network grew rapidly, Smith reported. In addition to facilities monitoring and energy management, these applications included: employee badge reader controllers being tied to the main plant computer; terminal-to-computer communication, with a gateway to common carrier networks so terminals can access computer data in other parts of the country; a material status query system; some voice communications, through the use of audio modems; and four channels of closed circuit television. Also, the coaxial cable is used for delivering 60 cycle electrical power to some of the remote units.

In what way do they want to see these networks improve at GMAD? There is always a need for newer, more capable equipment, said Smith. But the major needs are more basic—better service, diagnosis, and reliability. They have found the basic reliability of the coax network to be high, once everything is accurately checked and the start-up problems have been ironed out. But things do go wrong, and when they do, it often is hard to diagnose the problem and recover from the failure in the industrial environment in which these networks operate. The equipment and the maintenance techniques must be simplified, to help the plant people keep the networks running.

The broadband networks, said Smith, began with a promise of high-speed, economical, reliable, and flexible communications in each assembly plant. GMAD is now well along the way toward fulfilling that promise. But progress has been made carefully, to insure that the networks are sufficiently reliable and secure for the critical nature of the systems which use them.

Common networks for you?

Our opinion is that, like the relatively new application-independent data networks (such as IBM's SNA), common broadband local networks represent the direction of the future. Multiple dedicated networks are just too costly and too inflexible to meet the mushrooming needs for tele-communications services.

If you wish to start moving in this direction, a good way to start is to select *one* new application—where a network will have to be installed anyway—and put it on a broadband network. This approach may require more time and cost that installing a dedicated network for that application. Also, there are numerous issues to be settled, such as who is to be responsible for keeping a common network in operation. But you will be laying a good groundwork for a rapid future growth in tele-communications services.

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Next month, we will discuss the question of portable software for mini- and micro-computers. With the rapid spread of minis and micros in business, users will soon find themselves face-to-face with the familiar problem of wanting to replace some of these computers with newer, more powerful hardware—and will wonder if their programs will run on the new hardware. There are some things that can be done to make such conversions go easier.

Then, in January, we will address the question of 'practical office automation'—which means "making the best use of what you already have." Some organizations have been doing a good job of moving toward the automated office in a planned, step-by-step manner. We will describe how they have been accomplishing this..

WHAT ABOUT NEW 'VOICE GRADE' DEVELOPMENTS?

Does the future 'belong' to broadband local networks? What about the new developments in voice-grade telephone circuit technology?

One of the leading annual tele-communications conferences is presented by the Tele-Communications Association (TCA) each September in San Diego, California. At the conference month before last, some 175 tele-communications exhibitors showed their latest products and services. We attended, to see what kind of answer we might find to the above questions. And what an interesting exhibition it was!

At high technology exhibitions (such as computers and communications), it is not unusual to see one new technology emerge as *the* theme of the particular exhibition. At the TCA conference, two developments struck us: (1) freeze-frame video for tele-conferencing over regular voice-grade circuits, and (2) simultaneous voice and data transmitted over a single voice-grade circuit.

With freeze-frame video, a picture is transmitted over a telephone circuit in from 8.5 to 70 seconds, depending upon the resolution desired. A typical transmission time is about 30 seconds. Freeze-frame shows no motion, just a series of still pictures, but it does give some feeling of a face-to-face meeting. The audio portion of the conference is continuous, of course. Since only voice-grade circuits are used, transmission costs are relatively low; also, more than two sites can participate by using 'conference call' techniques.

Simultaneous voice and data over the same telephone circuit is being accomplished by converting the analog voice signals to digitized voice *right in the telephone instrument.* A terminal is connected to the telephone instrument, which in turn is connected to a private automated branch exchange (PABX). The telephone instrument creates a bit stream of from 64 kbps to 72 kbps (depending upon the brand); 56 kbps is used for the voice signal and up to 9.6 kbps for the data. The telephone and the terminal can be in use simultaneously on completely unrelated calls. No modem is needed for the terminal for in-plant calls. For accessing outside data services, the PABX selects a modem from a bank of modems and assigns it to the terminal.

There were numerous other interesting voice-grade developments shown at the TCA exhibits, including voice messaging (store-and-forward voice), audio tele-conferencing (like conference calls), and interactive graphics for tele-conferencing. Tele-conferencing received lots of attention.

Do such improvements in the use of voice-grade circuits change the picture for broadband local networks, as discussed in this issue? We see both Yes and No answers.

Yes. The new offerings will certainly encourage the continued use of existing telephone technology. Progress is being made, so why change to something new like broadband?

No. The new offerings represent additional loads for the existing telephone circuits. If network capacity is a problem now, it will be worse in the future. The new offerings are just 'digging the hole deeper.'

One person we contacted in connection with this issue is Mark Dineson, of Oak Hills, California. He has written a number of articles on broadband local networks that have appeared during the past year or two; for instance, see *Computerworld*, March 17, 1980, In-Depth report; and *Data Communications*, February 1980, p. 61 ff.

Dineson makes the point that, at numerous organizations, ceilings already sag under the weight of existing cables. Cable trays are overloaded. Underground ducts are filled. Coaxial cables to terminals create veritable 'snake farms.' Under such conditions, it is difficult to move people and their tele-communications units (terminals, phones, etc.) from one area of a building to another. As the existing network gets overloaded with traffic, replacing it or reconfiguring it can be costly.

One good answer to these problems, says Dineson, is the broadband local network that serves multiple tele-communication needs. Such a network is appropriate where there is a mix of tele-communication services, where there is a fairly large area to be served (in contrast to a single office or a small building), and where there is a frequent need to move tele-communications units from one place to another. A broadband network probably is not the best solution where these criteria do not apply, he says. In addition, a broadband network is relatively easy to reconfigure and to repair.

The cost of broadband (CATV) coaxial cable ranges from $0.70 to $3.00 per foot installed; the cable itself costs about 33 cents per foot, according to Dineson. Terminal interface units cost about $500 each, while video interface units cost from $1200 to $2000. So the cost of a broadband network will not be trivial.

(There are other problems associated with broadband local networks, of course; some were mentioned earlier in this issue. Another arises when the cabling must cross a public thoroughfare, and the legal restrictions to this. Still another arises when several suppliers are involved—interface units, network design, cable installation, etc.—and each claims someone else is responsible for a difficulty.)

The message that comes through to us from the TCA conference is that the use of tele-communications services will accelerate, as the new offerings are accepted by the marketplace. The message that comes through to us from Dineson is that today's cabling 'mess' will only get worse—and that a broadband local network provides a much better basis for serving the future tele-communications needs.

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