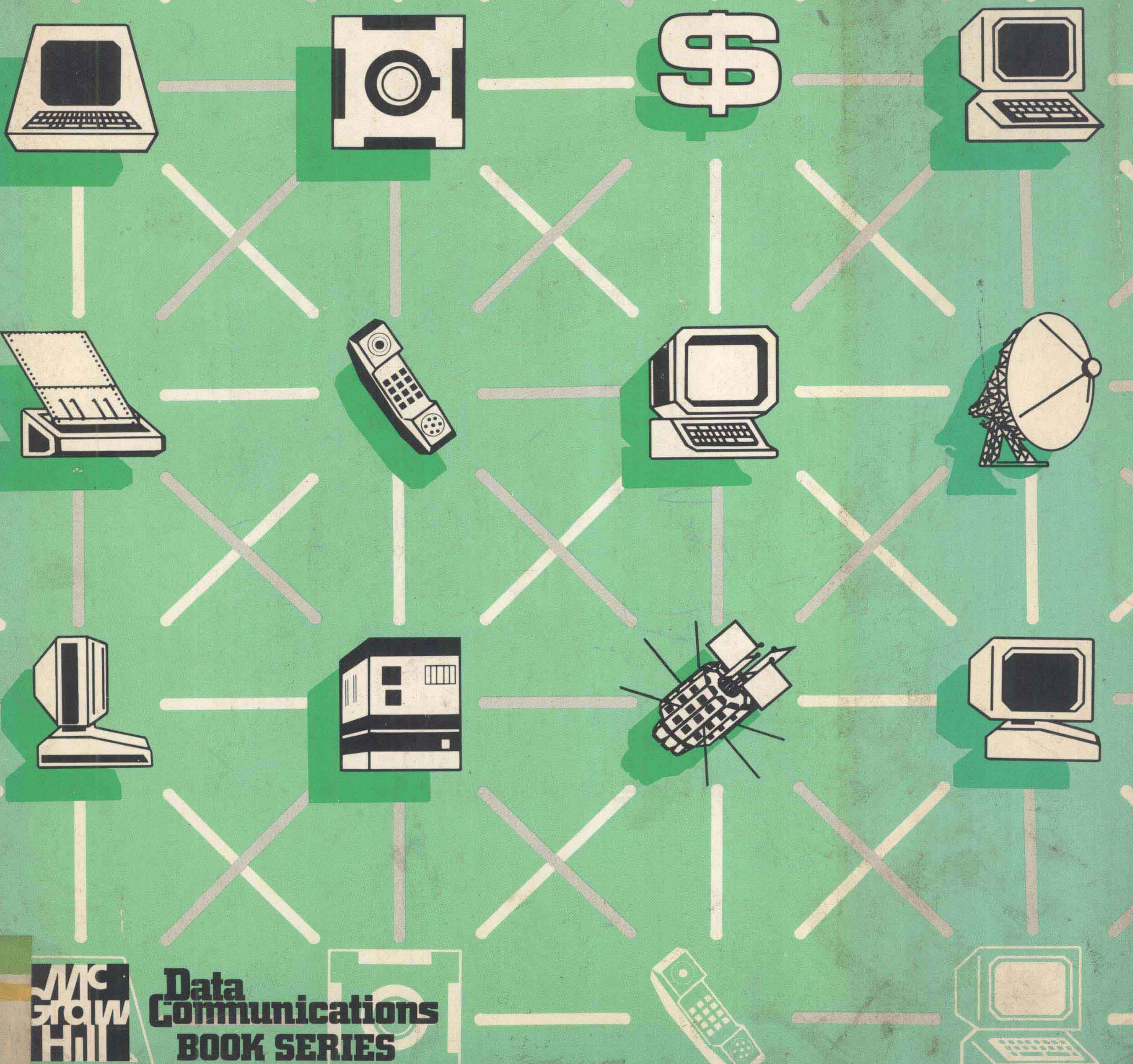
LINKING MICROCOMPUTERS

EDITED BY COLIN B. UNGARO



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LINKING MICROCOMPUTERS

Edited by Colin B. Ungaro
Editor-in-Chief,
Data Communications

McGraw-Hill Data Communications Book Series

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1221 Avenue of the Americas
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Library of Congress Cataloging-in-Publication Data
Main entry under title:

Linking microcomputers.

(Data communications book series)
Collection of articles from Data Communications magazine.
Includes index.
1. Computer networks. 2. Microcomputers.
I. Ungaro, Colin, 1952- . II. Series: McGraw-Hill Data Communications book series.
TK5105.5.L56 1985 004.6′6 85-18223
ISBN 0-07-606935-4

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Preface

From a toy to a key network component, the microcomputer has burst onto the information processing scene with bravado. Hardly a data communications user is not using or considering the purchase of microcomputers. And while it seems that the market has at least one microcomputer casualty a day, it also boasts as many startups.

Even giant IBM has scaled down to embrace the microcomputer, an event that virtually assured its place in today's and tomorrow's networks. The impact of the microcomputer has been so profound—because of the number of users it has attracted—that many believe it has given a potent shot in the arm to other data communications segments such as local networks and even modems. Indeed, the networking of microcomputers has already become one of the most important ways to utilize the machines in order to share resources and communicate information within an organization.

Meanwhile, the microcomputer's capabilities and applications have steadily increased, so that today the user has a number of options from which to choose. This book, a collection of articles from DATA COMMUNICATIONS magazine, puts the microcomputer revolution in perspective, especially from the information networking user's vantage point. It is divided into five sections: Technology, Networking, Planning and Management, Software, and Applications.

The Technology section deals with the basic theory behind the networking of microcomputers. Such topics as micro-to-mainframe links, standards, and protocols help to lay the groundwork for the articles that follow in the Networking section of the book. With the dizzying array of microcomputer products that have hit the market it is important for the user to be able to make wise microcomputer investments. The Planning and Management section will help formulate prudent strategic decisions regarding the available microcomputer networking choices. It is important to note that cost and vendor data is subject to change, so the pricing information in these articles should be treated as sample guidelines. For more up-to-date vendor and product listings, consult such sources as the DATA COMMUNICATIONS Buyers' Guide. The Software section contains a few articles that when first published did not necessarily pertain to microcomputers, but which do in varying degrees today because of the microcomputer's evolution. This is also the case with some of the articles in the Applications section.

It is clear that the unifying thread running throughout this book is communications, and that the microcomputer will find its biggest success as a component of the information network.

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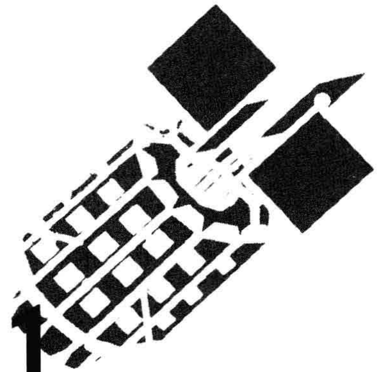
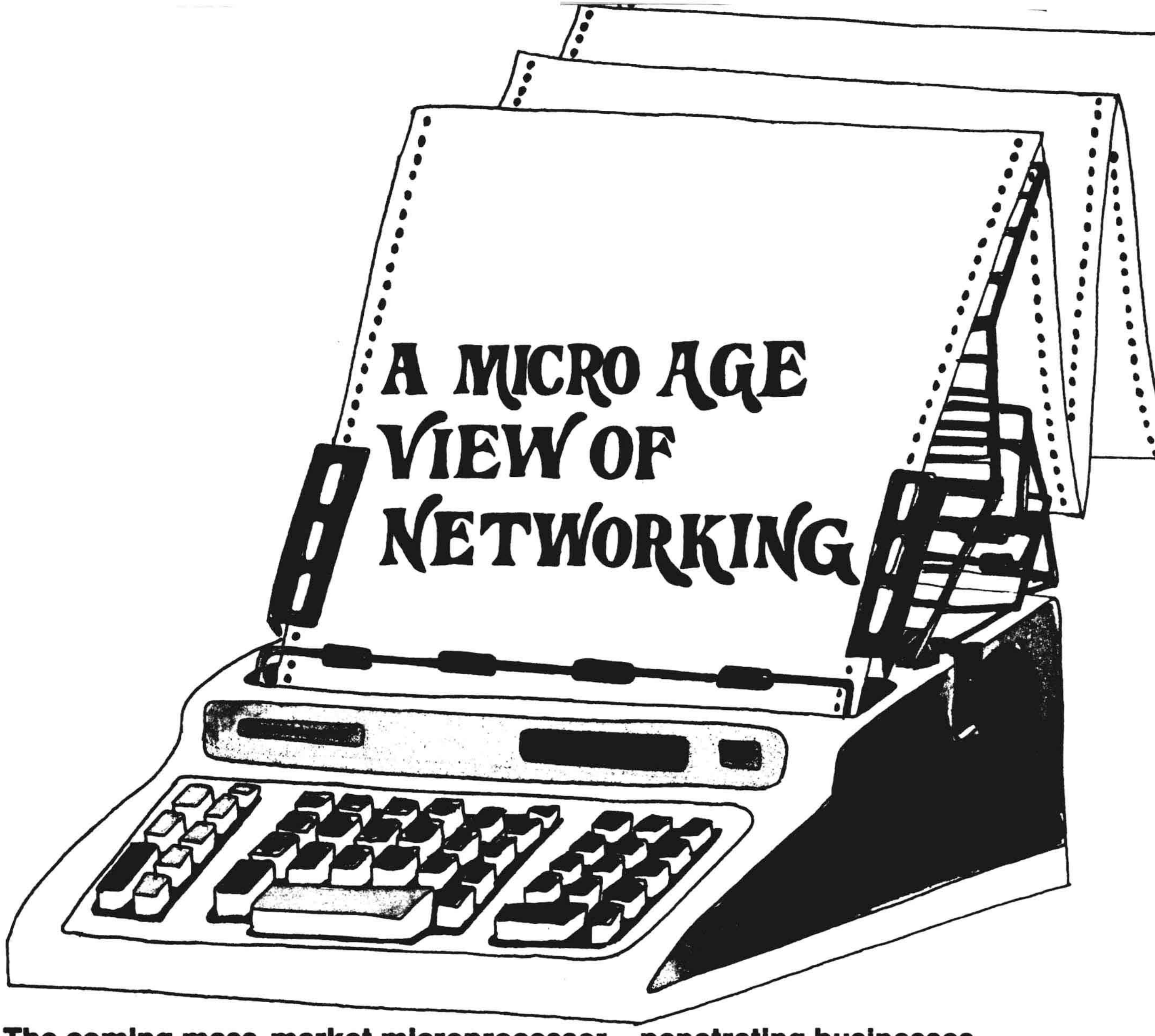
Technology





The coming mass-market microprocessor—penetrating businesses and homes—could drastically change the rules of data communications.

Today's microcomputers and microprocessors have become increasingly voracious users of data communications. But the next generation promises to be far more communications-intensive. The impact of the new Micro Age products and the changes they will precipitate will spill over into all data communications activities and create an entirely new view of the Laws of Data Communications.

The Micro Age describes an era that will be characterized by mass-marketed microprocessors and microcomputers, whose utility-performance ratios will force their appearance into virtually every home and business. While some current products, such as Radio Shack's Color Computer and Commodore's VIC-20, already cost below $400, they are not yet cheap enough to, by themselves, bring on the Micro Age. However, an extrapolation of the current marketplace predicts that the dawn of the Micro Age is anywhere from 18 months to 3 years away.

But low prices alone will not bring on the Micro Age. It is possible that these advanced products will sell for prices higher than $400; however, they will provide very large increases in utility—more "bang for the buck," if you will.

In a mere half-decade, microcomputer market sales have soared from zero to $3 billion, according to Vantage Research Corporation, in Mountainview, Calif. The market players are an odd assortment by conventional standards. They include:

- Start-up companies that have risen dramatically from spare-room, garage, or basement beginnings, among them Apple Computers, North Star, and Vector Graphic
- Consumer electronics companies such as Zenith and Radio Shack
- Toy and arcade game companies (Mattel, Atari, Exidy)
- Calculator manufacturers (Texas Instruments, Hewlett-Packard)
- International companies of several stripes (Nixdorf,

NEC Information Systems, Matsushita)

- And increasingly, traditional mainframe and minicomputer vendors (IBM, Data General, Digital Equipment Corporation, Burroughs)

Many anticipated participants—some with considerable marketing clout, such as General Electric Company and Sears Roebuck and Company—have yet to declare themselves, although their entry is inevitable. When such a variety of companies work on particular segments of this market, the traditional computer marketing rules do not apply.

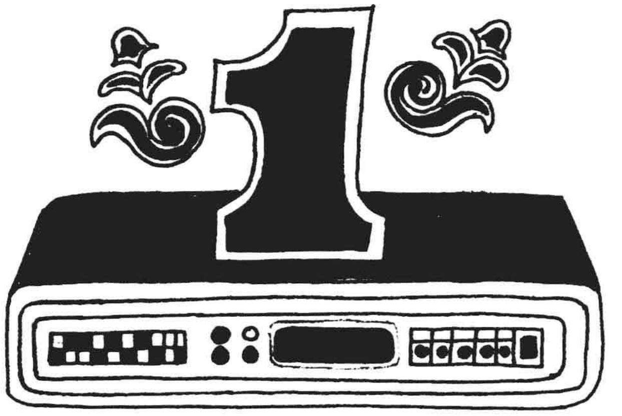
Product prices in the microcomputer market range from a minimum $199 for Sinclair's ZX-80 computer (with 1K local memory, a minimal Basic language interpreter, an alphanumeric keyboard, and a display output to a television set) to $10,000 plus for heavy-duty systems including 8-inch hard-disk storage. Some are handheld (Nixdorf's palm-size LK-3000 is one that offers a data communications option), some are desksize, but the bulk are about the size of a standard tabletop. A typical configuration selling in the $2,500 range would include 32K memory, a mini-floppy disk drive, a video monitor, and—more and more often—an acoustic or direct-connect modem.

Ever-growing uses

Today's microcomputers use communications for a number of activities. For instance, news and stock prices can be accessed from Dow-Jones. Western Union Mailgrams can be sent directly from Radio Shack TRS-80s. Information utilities such as CompuServe's MicroNet and The Source offer electronic mail, bulletin boards, database access, and multiplayer games. The information utilities are beginning to experiment with "narrowcasting"; for example, auto race fans nationwide can now dial into CompuServe's network for live, lap-by-lap reports of major races. And countless local message exchanges are operated by both clubs and individuals—often serving exceedingly specialized interests, such as the dial-up message-exchange facility in San Francisco for gay "bondage-and-discipline" enthusiasts.

Microcomputer and microprocessor data communications activity will grow along a curve, matching the pattern of increasing telephone usage during that invention's period of initial adoption; however, the curve will be compressed into far fewer years. As we progress along this curve, several new truths will take hold in the general practice of data communications. These truths can be viewed as the Micro Age Laws of Data Communications.

As you read these laws, bear in mind that the coming mass-market micro is neither a home product nor a business product. Rather, it is a personal product that will be employed in approximately the same form in both arenas—either as a microprocessor or as a microcomputer. Many of its applications will be as a communications bridge between the domains of business and home. In both these respects, it parallels the telephone, whose implementation in business differs in scale, but very little in concept, from its implementation in the home.



PROCESSING IS CHEAPER THAN BANDWIDTH

In the Computer Age, the drive has been toward ever-increasing bandwidth for data communications channels. In the Micro Age, the emphasis will shift to making more productive use of existing channel bandwidth by intensive processing of the data stream at each end of the communications channel.

We could call this the Minute Maid Law, because the underlying economics are analogous to those for orange juice processing. Minute Maid can sell its juice concentrate for less than the price of unprocessed orange juice because it avoids the cost of packaging, freezing, shipping, and warehousing water—knowing full well that its customers have water "free" and readily available at home to add before drinking.

In communications, the economics of the past favored investment in broadband channels and dumb terminals. As mass-market micros emerge, the economics are changing to favor high processing power at the sending and receiving ends. This enables the use of channels already in place—principally the existing telephone network—rather than requiring construction of extensive new channel capacity at today's inflationary costs. The Micro Age data communications strategy will encourage compression of each data stream to its irreducible minimum, for reconstitution by the receiving micro.

One implication of this is the end of character codes, such as ASCII, that are extravagantly wasteful of channel capacity. For the same reason, asynchronous protocols with their overhead of start and stop bits, designed for an age of teletypewriters, seem ill-suited to a Micro Age. The momentum will shift not only to sophisticated compression schemes such as Huffman coding but also to very intricate multiple-table versions of such approaches.

Manifesting the kindred Micro Age axiom that processing is cheaper than memory—even in a time of declining memory costs—is the design by Paul Heckel, of Interactive Systems Consultants, for the data-storage structure of the Craig handheld language translator. Heckel's assignment was to store the maximum number of vocabulary entries in a read-only-memory (ROM) capsule of given capacity. He achieved this by using Huffman codes (a variable-length scheme in which letters that appear most frequently are coded in the fewest bits) with seven different look-up tables. The table used depended on the previous letter decoded, thus taking advantage of varying frequencies for letter combinations as well as individual letters.

Heckel's approach economized only at the character level. Microprocessors might economize channel capacity further by encoding common words at the word level, by shifting to a numeric-only mode when transmitting long strings of numbers, and by employing other compression strategies.

In developing compression algorithms, the most important Micro Age rule will be to avoid standardized algorithms that become "cast in silicon." Data compression in a Micro Age should be intelligent. The transmitter can look ahead at the data stream and analyze in real time what the most efficient compression strategy would be, then include details on the changing compression algorithm as part of the data stream. As the price of memory and processing power continues to drop, the distance to which the compression processor looks ahead and the number of options it employs will grow accordingly—pushing back the point of diminishing returns.

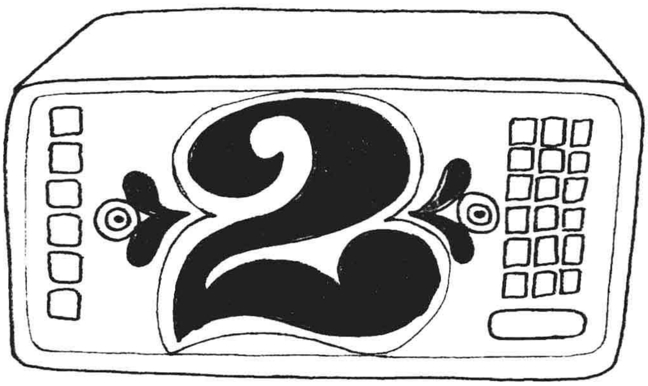
A second benefit of such an "intelligent-compression" approach is increased universality of communications opportunities. Where necessary, the transmitter can send its compression algorithm and any required look-up tables down the line in advance of the data stream. No equipment need be obsoleted as data compression technology advances. Each can talk to every other at the maximum common level of capability.

Compression need not be limited to alphanumeric data. Graphics are subject to many compression approaches. Entire standardized business forms, such as an industry-standard purchase order, might be specified by a single forms code. The receiving micro would reference a local file to draw the form. In place of facsimile, information about type fonts and sizes might be encoded in the data stream to be reproduced by advanced displays and multifont printers such as the Sanders Technology Media 12/7. Image compression will also support the mass-market microprocessor's evolution into the videophone.

Early AT&T experiments with Picturephone employed data compression and motion prediction, but the economics were not favorable then. With every passing year, Picturephone accommodates more and more picture types. We may be a long way from compressing a Busby Berkeley spectacular into 9.6 kbit/s, but we are getting close to providing pictures of a person talking and moving about.

In addition to applying standard compression approaches for squeezing redundant data out of video, micros might cope by using techniques such as building facial features from an electronic version of the identification kits police use to make composite pictures of suspects. Standard topological models of eyes, lips, and noses would be on-line to both transmitter and receiver, letting the transmitter find the closest library match for each feature and send its code and customizing data that would build an exact match at the other end.

We might not always be able to squeeze full-motion color video into a standard phone channel, but the system could be designed to degrade softly, dropping out color or shifting to spaced sequences of still pictures whenever the data requirements rise past the channel capacity. This is not ideal, but it is a videophone approach that could be implemented with no new network investment. The approach can also be designed to upgrade softly, so that when a broaderband channel is available between two micros, they can take advantage of the extra capacity to handle ever-busier images without degrading.



TRANSMISSION EFFICIENCY IS CHEAPER THAN BANDWIDTH

Transmission Efficiency is Cheaper than Bandwidth could be regarded as a special case of the previous law, because it refers to transmission efficiency gained by intensive signal processing. Computer Age economics has favored installation of high-bandwidth digital channels for transmitting large volumes of data. Only a few special circumstances could justify the expense of pushing standard analog phone circuits to the limits of their transmission potential. Also, high-speed modems require lots of very delicate, sensitive, and expensive analog circuitry.

Today, however, the job of that analog circuitry is being done digitally, in real time, by audio signal-processing chips that are much less costly. The prices for high-speed digital modems are still not down to levels suitable for the mass market, but the potential for major cost reduction is now there. If manufacturers were to place orders for enough 9.6-kbit/s direct-connect modem chips to include in every TRS-80, Apple, Commodore, NEC, and similar microcomputers to be built in 1982, prices would take a big tumble.

Digital networks are the darling of the Computer Age because they operate at a level of efficiency that permits relatively simple circuits for encoding and decoding. Since data transmission in the beginning involved relatively few locations, it seemed more practical to provide separate channels. Today, circuitry to transform data from digital to analog and back—virtually at will—is cheap, but building new channel capacity to serve the data communications needs of mass-market microprocessors will come only at crushing costs.

The question is dominated by a $111 billion imperative. That is the value *Fortune* magazine placed last year on the Bell System's installed plant. No doubt the figure is higher now and should also be increased by the value of the non-Bell plant. Most of this plant was built in times of deflated dollars, low interest rates, lighter taxes, and less-intrusive government regulation. It no longer makes sense to invest in new channel capacity until transmission efficiency is increased to where it squeezes every last bit of capacity from the channels already in place.

Being in place is another part of the equation. The number of locations requiring data communications is about to jump by several orders of magnitude. The mass-market microprocessor is ready to happen, but it requires fast communications to achieve its critical mass of marketplace value, and it cannot stand the delay of waiting while coaxial cable or optical fiber is strung to every home and desk in America or until satellite dishes are put on every roof. Even ignoring the construction-time constraint, the fragile economics of the mass-market microprocessor will not stand an extra $111 billion or so in its cost structure. Yet data rates in the 300-bit/s range would too greatly impair the microprocessor's utility and put too much of a strain in added connect time on existing network facilities. These economic facts dictate that the existing analog network is the channel of choice for mass-market microprocessors and that the new products will have to maximize their efficient use of it.

Transmission at 300 bit/s uses 4 percent or less of a good telephone circuit's potential. Mass-market microprocessors will smash this barrier. This situation, mated with intelligent data compression, could fatally attack the economic underpinnings of high-bandwidth digital networks such as XTEN, ACS, and SBS, and even local networks such as Ethernet. Far from being advanced concepts, these are well on their way to being dated concepts of Computer Age thinking, prematurely obsoleted by a Micro Age.

Of course, it will not be possible to get 9.6 kbit/s out of every circuit every time. But, like the data compression processor, the circuitry to maximize transmission efficiency can afford to be intelligent in a Micro Age. At the beginning of each connection, the sender and receiver can jointly evaluate the characteristics of the channel and adjust traffic through the circuit to the maximum consistent with a preset standard of reliability. The process can be dynamic over the course of the transmission, allowing adjustment for changing circuit conditions. Even the overhead for error-detecting and correcting codes can be adjusted in real time; on favorable circuits, the sender and receiver could agree to shift to error-trap schemes with lower overhead whenever sampling indicates the circuit is sufficiently reliable.

As higher-bandwidth circuits are added to the network, intelligent transmission processors in microprocessors will be capable of using them to full advantage. But there will be no need to rush construction of these. They can be incorporated in the network under normal expansion and maintenance schedules.

PROCESSING IS CHEAPER THAN CONNECT TIME

If one key to the Micro Age is using the existing analog network to its maximum capacity, another key is avoiding its use whenever local resources can substitute. The objective is to avoid creating a need for new network plants, which comes much more dearly than local storage and processing power at Micro Age prices. Therefore, microprocessors and microcomputers should communicate only when absolutely necessary and then for the shortest possible time.

While technology is helping the cost of long-haul circuits fall, the local connection floor, toward which they are falling, shows the converse tendency to rise. If microprocessors cause a significant rise in peak network usage or average connect time, required new construction will cause the floor to rise even faster. Thus, microprocessors must be able to talk fast and finish quickly.

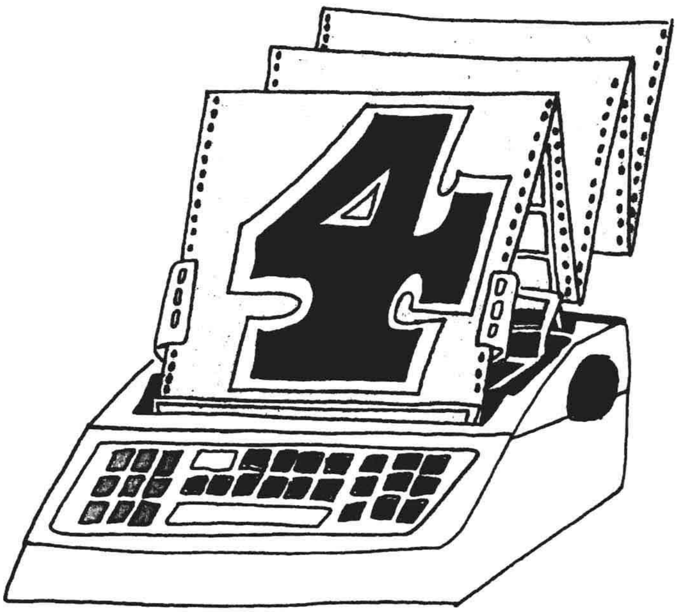
This means all interactive applications using communications should employ the local power at both ends to the fullest. For example, if a database is being accessed through a tree structure, the main headings of the tree should be transmitted once at the beginning of the session and displayed by the local processor thereafter. If softkeys, prompts, or control messages are used, their handling should be done by the local intelligence.

In a Micro Age, local processing is not only cheaper than teleprocessing, it is functionally better. This is seen by a comparison of two modern computer games: the multiplayer, real-time "Space War" game available to CompuServe Information Service subscribers, and the similar, single-player game for the Atari 400 microcomputer.

The CompuServe game offers the appeal of competition among up to eight players simultaneously, all of whom may be located far from each other. In this game, crude diagrams are slowly drawn with ASCII characters, and players control moves by nonintuitive keyboard sequences. By contrast, the Atari game is visualized in color animation just one step short of Star Wars and enhanced by audio effects; player control is by joysticks and softkeys. A Micro Age approach would be to combine the network game's multiplayer appeal with the standalone micro's speed of play, simplicity, and visual elegance. The local processor would handle display and control functions, while sending and receiving minimum kernels of data via the network to describe each move. This division-of-labor principle holds true for nearly all practical applications as well as for games.

Another application of the microprocessor's intelligence, perhaps using circuit-load data provided by the network, will be deciding when it is more beneficial to strobe the connection instead of maintaining it continuously. The microprocessor can monitor intervals between bursts of transmission and decide in real time when the average intervals and applicable tarriffs favor setting up a new connection for each data exchange. This can even be adjustable to respond to the user's priorities regarding economy versus speed. The technique might serve as an alternative to packet switching for some purposes.

In evaluating how practical it is to rely on local storage, we should not base our judgment on the capacities of today's audio cassette and mini-floppy storage devices. Mass-market micros are likely to have gigabyte (10^{12}) quantities of mass storage on-line, probably provided by optical-magnetic combination-medium disks and by tape cassettes employing longitudinal video recording (LVR) technology. (This writer has a patent application pending for such a device.) These multibillion-character devices with quasi-random access will allow convenient, rapidly accessible storage of such items as standard business forms, order forms, and invoices.



4 DATA COMMUNICATIONS SEEKS ITS OWN LEVEL

Mass-market sales volume for the coming micros will depend on its offering a threshold minimum of utility to purchasers. To help achieve that utility, such products will need to be polymorphous communicators, capable of receiving data in many forms. The mass-market microprocessor will likely include as standard equipment:

- A 9.6-kbit/s direct-connect modem with processing power and software for the three kinds of efficiency optimization just described
- A broadcast receiver that can capture data encoded in transmissions ranging across a spectrum from FM subcarrier channels to full-band TV channels
- A local communications system for control applications, operating via power line carrier or infrared transmissions
- Peripherals capable of reading information published on optical disks and LVR cassettes

Each instance of communications with a future microprocessor will employ the channel or combination of channels that best satisfies the needs of both sender and receiver. Transactions of varying natures will gravitate to the appropriate level of channel according to several variables. The possible values of the variables define a matrix, and a data exchange's position within this matrix will suggest the optimum choice of channel. The process is not unlike that of choosing, in an earlier era, whether a message would best be communicated via telephone call, telegram, night letter, regular letter, or printed newsletter.

The variables include (1) the amount of data that needs to move in each direction, (2) the urgency of need for the information, (3) the number of parties desiring the same information, (4) the value of the information to each party, (5) the frequency with which the parties will refer to the data once transmitted, and (6) the rate at which elements of the information are likely to change.

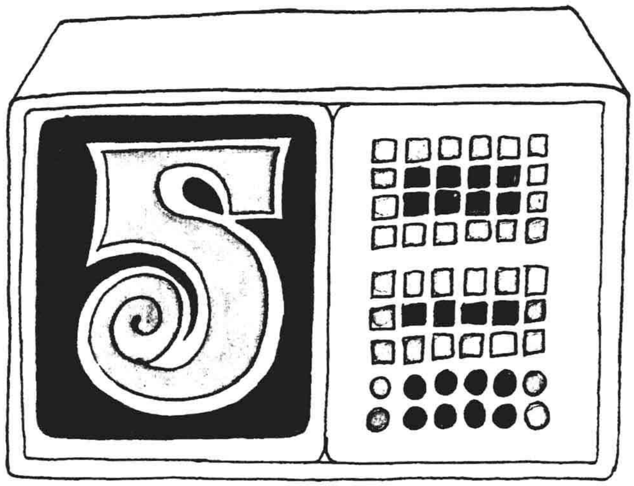
In general, smaller volumes of data are best suited to the telephone network, middle-size volumes to broadcast transmission, and large volumes to physical distribution. The other variables act to lessen applicability of this general rule. Hybrid and combination channels will often result.

Air travel data is a good illustration. If the casual traveler wants flight availability and cost information, the most suitable channel is to phone an inquiry to someone with access to the data. In the Micro Age, the channel of choice would remain the telephone, except it would be used for a microprocessor-to-microprocessor call.

The travel agent refers to the same data constantly. Today, he finds it worthwhile to subscribe to the printed *Official Airline Guide* (OAG). His optimum Micro Age channel would remain physical distribution—an enhanced OAG in optical disk form. However, he still needs two additional levels of information: updates about schedule and fare changes and details of seat availability. The amount of the schedule-and-fare change data, the number of people likely to desire it, and the frequency with which it changes all point to broadcast as the optimal channel. Updates to the optical-disk OAG might be sent at 6 A.M. every morning via an FM subcarrier, for automatic reception and recording on the magnetic "pocket part" of each travel agent's optical/magnetic combo-disk. The same variables, applied to information about seat availability, require telephone connection. (Today, many travel agents with terminals access all three levels of information via telephone line communications. The evolving cost structures of the Micro Age will cause this to become an uneconomical choice. Each level of data will move to the channel that fits it best.)

Mass penetration of microprocessors could well create a climate for reevaluation of some spectrum allocations for broadcast services. With a sufficiently broad user base, a case might be made to the Federal Communications Commission for using some TV channels, either part- or full-time, for data transmission to microprocessors. Some of this might remain "broadcast" transmission, like sending the OAG updates to subscribers, but could also include private message traffic transmitted in bursts for capture and local storage on LVR cassettes. For example, a microprocessor owner might order data from an on-line database via a telephone connection and receive confirmation in the form of a transmission time, frequency, and cipher key. The encoded data would then automatically be pulled off the air, deciphered, and stored by the micro.

Closer to "broadcast" would be transmission of magazines via a TV channel. Subscribers' microprocessors would tune in the right station at the designated time (perhaps off-hours when the station is not providing programming) to receive the latest copy. Such applications could range from Micro Age versions of mass magazines such as *Time* to specialized publications such as law reporters.



MICROPROCESSORS APPLY CENTRIFUGAL FORCE

A general law of microprocessors is that they encourage dispersion of resources and activities away from centers, but the effect is particularly seen in communications. Mass-market microprocessors will encourage a quantum jump in the existing trend toward distributed processing and distributed databases. The favorable economics of equipping travel agencies with high-capability, standalone microprocessors instead of terminals and then distributing huge quantities of relatively stable data, such as the OAG, on optical disks rather than via a network, indicates the general direction. The same effect will be seen wherever and whenever similar conditions apply.

It is becoming a better value to duplicate stable data at every point where it is used than to build and maintain channels connecting to a central file. And it makes less and less sense to "add value" to data in the network, either by translation among communications protocols or by storing and forwarding, when these capabilities will be an integral part of every microprocessor and microcomputer.

There is only one standard communications protocol needed for the Micro Age—one defining a header for all initial transmissions that contains all information needed for the microprocesser to interpret the following communications accurately. Development of elaborate and complex computer-oriented communications protocols is contrary to the spirit and dynamics of the Micro Age.

Fitting into data communications

The existing telephone network seems best suited as the channel for two-way communications by mass-market microprocessors. But certain enhancements must be provided to encourage this. Standards and circuitry need to be developed for the interpolation of voice and audio-encoded data on the same analog channel, for videophone and similar purposes. It will likely prove necessary to compress voice on the channel in order to make more room for data.

The network must also add data to its ringing signal for indicating whether the telephone call is intended for microprocessor or humans. This will allow the receiving microprocessor to pass on the rings of calls intended for their owners, but to intercept and suppress the rings of microprocessor-to-microprocessor calls, then pick up the line in auto-answer mode and do the necessary business.

To speed display of a first picture on videophone calls, a standard should be created that permits transmission of the initial picture data as part of the ringing sequence. In this way, the receiving micro could usually process this lengthiest part of the video transmission even before the called party picks up the line. If the party does not answer, the receiving micro simply flushes the data from its buffer, and the network treats it as an uncompleted call.

Also, the hard-wired telephone network offers the best existing facility for capturing and processing financial transactions resulting from information exchange. The network can positively identify a transaction as originating from a particular telephone number and can pass associated information along to the microprocessor at the called number in order to establish reliable billing details. Billing, collection, and remittance services by the network itself would be available as an optional extra.

This will be an additional source of hybrid transactions. In the earlier example describing the transmission of a magazine's contents, the subscriber's micro might first automatically dial a "900" mass calling number at a preset time to receive a cipher key. The hard-wired connection configured to receive the key would also initiate billing to the calling number for a "copy" of the magazine. Then the magazine itself could be sent enciphered via a broadcast channel that better fits that part of the transmission.

Since the future microprocessor will incorporate an enhanced telephone, it is logical to assume that makers of telephone terminal equipment will enter the market, alongside the great variety of other companies. Phone equipment will become central in configuring local networks for the Micro Age office. The new economics of the Micro Age favor evolution of computerized branch exchange (CBX)-type of local phone systems into the principal office communications channel, rather than new installations of high-bandwidth networks.

Consider the arithmetic: Say a Micro Age phone circuit is a virtual equivalent of a 50-kbit/s digital link. (This assumes a 9.6-kbit/s transmission and a gain from data compression of slightly better than 5:1.) A CBX capable of handling 60 simultaneous connections then has total virtual bandwidth equivalent to a 3-MHz Ethernet-type system. A theoretical advantage of Ethernet is that it can at one time devote all 3 MHz of its capacity to a single sender-receiver pair, but on average, assuming relatively equal distribution of demand, could offer only 50 kHz to each of 60 simultaneous connections. At that point, the choices are equal, except that the phone wiring is already in place and the Ethernet is not. Also, given the Micro Age likelihood of a microprocessor on every desk—an environment where 60 simultaneous conversations is not unlikely—local storage and processing power would make 50-kbit/s equivalent links sufficient for most purposes. (This is not an argument against high-bandwidth link installations. Far from it—it is a warning against expensive retrofitting. The money would be better spent buying more capabilities for micros.)

Cautions and forecasts

The mass-market microprocessor is a factor which is unaccounted for by the conventional wisdom of data communications, yet it packs enough punch to change all the rules. Today's microcomputers strongly suggest the likelihood that awesomely capable mass-market microprocessors will follow. The technology for such products is now mostly in place, and the little still missing seems in reach of short-term development efforts. The destiny of a Micro Age now seems to hang on marketing and financial considerations rather than technological ones. One principal lack is an infrastructure to support micros' usefulness. Before we could enter an Auto Age, we needed highways as well as automobiles. Now we need highway equivalents for microprocessors and microcomputers in which data communications plays a large role.

This promises a positive-feedback relationship. Well-conceived data communications arrangements can strongly influence the development of the mass-market microprocessors. And the mass-market microprocessor can affect data communications like nothing before it. Those who reach out to exploit this synergy will prosper. Any who ignore it risk obsolescence. ■

JIM EDLIN is a San Francisco-based consultant specializing in the advent of the mass-market microprocessor. He is co-author (with David Bunnell) of Micro: The Next Watershed Invention and How It Will Change Your Life, *which will be published later this year by Warner Books.*

Hal Becker, Information Management Consultant, Phoenix, Ariz.

Semiconductor trends are clues to the future of networking

Avoid obsolescence and anticipate networking changes by watching the trends and advances in the semiconductor industry.

Data communications technology is advancing so rapidly that the data communications manager is faced with the following truism: Regardless of what purchase or network decision he makes today, something better will be available next year. For the director of data communications, charged with maintaining and upgrading an information network, this truism is either a benefit or a problem, depending on whether or not he anticipates advances and changes in his field.

Much progress in data communications results from advances in semiconductor technology. These technological advances are providing users with equipment such as faster, less expensive computers and communications devices that have greater capacities and capabilities. For the data communications manager to best evaluate and anticipate these and other new products and plan ways to incorporate the latest gear into his network, he must be aware of the trends and advances in the semiconductor industry.

But these trends and advances are only part of the information management story. The impact of the semiconductor industry on future data communications products must be viewed in light of the overall information management environment.

The information management resources of an enterprise consist of four related subsets: components, information, personnel, and supporting services.

- Components are the hardware and ancillary devices that perform the functions necessary to process information, move information through a network, and store information. Combinations of these three functions are used to record the current state of the enterprise, analyze past states, and project future states through simulation and modeling techniques.
- Information consists of the data that reflects the present, past, and projected states of the enterprise and the various procedures (manual and automated) for managing that data. It also means the manual and automated control logic for integrating and coordinating all information management activities.
- Personnel involved in information management includes every employee. Some manage information using strictly manual procedures. Others are occasional users of automated procedures. Still others are entirely dependent on automated information-management procedures. The personnel group also includes those responsible for the design, selection, installation, operation, and evaluation of the automated procedure.
- Supporting services include the electrical power, water, gas, environmental control, facilities management, transportation, and related activities required for the efficient, economical operation of information management resources.

In most cases, these four resource groups are distributed among multiple, geographically separate locations within an enterprise. Successful information management requires that the resources can not only execute their individual roles but also interact to meet the information needs of the enterprise.

Integrated-circuit (IC) technology is already a pervasive force in all four of these information-management resources categories. ICs contribute to building, operating, processing, and managing the resources, controlling their interactions, and moving information.

The ICs on a semiconductor chip replace numerous transistors and other discrete components that previously performed information-management and communications functions (see "Semiconductors and integrated circuits"). The IC chips are, for example, processors of different architectures (8, 16, or 32 bits), and memories of various capacities and types, such as read and write access (RAM), read only (ROM),

Semiconductors and integrated circuits

The earliest ICs combined the functions of a small number of transistors on a single small slice or "chip" of a semiconductor material. Placed in a ceramic or plastic package with metallic connecting leads and mounted on a circuit board, the IC provided the same functionality as discrete components, but was faster, used less space and less power, and cost less than the transistors it replaced.

The most commonly used semiconductors—materials that behave both as an insulator and a conductor—are germanium and silicon. Other materials are being evaluated in the quest for faster circuits. One particularly promising compound consists of gallium and arsenic and is known as gallium arsenide (GaAs). In addition to its semiconducting properties, this compound can convert electricity directly into coherent light—an important property, for example, when designing transmitters for the fiber-optic end of a communications system. Although GaAs circuits operate several times faster than those based on silicon technology, a number of significant fabrication problems await resolution before volume production begins.

The digital IC's basic logic elements—called gates—are interconnected on the IC to produce adders, shift registers, memory units, and other functions. Early ICs that replaced a small number of transistors are called small-scale integrated (SSI) circuits. Technology improvements produced ICs with over a hundred gates per chip, a method known as medium-scale integration (MSI). Later chips, with several hundred gates were produced by large-scale integration (LSI). Now, chips with thousands of gates—very-large-scale integration (VLSI)—are made routinely.

A RAM IC is used for the temporary storage of digital information that can be written onto or from it. It usually is the main memory element in computers of all sizes. Information stored in RAM will remain there until it is rewritten with different information or until the electrical power is shut off, at which time it disappears. RAM is thus a volatile form of storage. A ROM is used for the permanent storage of information that will be read repeatedly. The information is fabricated into the chip during its manufacturing process. ROM information cannot be altered. It does not disappear when power is removed and is thus a nonvolatile form of storage.

A PROM is a read-only memory that has its information entered permanently, after the manufacturing process. An engineer enters information in this nonvolatile IC storage device by selectively applying electrical power that burns open fusible links, thus creating the desired bit pattern. Early PROMs could be programmed once, at which time they essentially became ROMs.

In contrast, an EPROM can be programmed repeatedly with different information. Early forms were built with a small, clear glass window on the surface. When exposed to an ultraviolet light, the information stored in the device was erased, readying it for a new program. Later versions (E^2PROM) simplified the process by eliminating the need for ultraviolet light to erase the information and used electrical signals instead. This enables them to be programmed remotely.

Integrated circuits are also used to build a variety of processors that, when coupled with one or more forms of memory device (such as RAM or ROM) result in a computer. A complete processor on a single chip is commonly called a microprocessor. Early microprocessors were built around a 4-bit architecture. This means that all registers, data paths, and logic elements can accommodate 4 binary digits at once. Designers overcame the limitations of 4-bit microprocessors by introducing 8-bit architectures. Many popular microcomputers are built with 8-bit devices. Sixteen-bit microprocessor architectures have recently appeared, offering still greater power and speed.

Larger computers that use many different types of ICs, for both processing and memory functions, are also evolving rapidly. Thirty-two-bit architectures with substantial memory capacities (multiple megabytes) have been announced. While still called minicomputers, they rival the performance of the very-large-scale mainframe computers of just a few years ago.

programmable (PROM), and erasable (EPROM and E^2PROM).

Supporting peripheral chips such as UARTS, controllers, and, more recently, chips containing kernels of operating systems, also help these processor and memory chips do their jobs. Various chips are combined to build large devices such as computers, terminals, modems, and multiplexers.

Today's network environment

To be maximally effective, all information-management resources of an enterprise must be capable of varying degrees of interaction. Networks will play the major role in achieving this interaction.

For some information-management requirements, a centralized network configuration offers the optimum solution. Others, because of size and organizational complexity, require the distribution of resources to meet information needs. Still others centralize some functions, distribute others, and allow the installation of small, freestanding, independent information-management systems to meet the needs of local users.

IC technology has made possible an increasingly diverse number of network devices to meet user needs. Unfortunately, it has also created a compatibility problem between these devices. Compatibility will likely become the most significant selection criterion—superseding functionality, cost, speed, and other traditional evaluation parameters. ICs will play a major role in providing the network with devices that allow its resources to attain acceptable compatibility levels.

Besides the great variety of available network devices, the trend today is toward more intelligent devices. This trend will result, for example, in new devices that can recognize and analyze more two- and three-dimensional patterns than previous equipment, in addition to verbal speech patterns. It also means that devices will accept and store analog and digital information from any program-controlled device and, in turn, control other devices.

ICs and data communications

The increasing intelligence of devices in the network processing environment is primarily due to advances in IC technology. Intelligence in computerized devices is defined for this article as the processing and memory capacity that controls a device and information passing through the device.

The choice of a processor to control a device involves many factors, including the complexity of the task to be performed, size limitations, number of links, terminals, ports, or other interface requirements, and speed of data stream(s) being handled. Additional factors are on-board (within the device) storage requirements, cost per device, reliability, expansion capabilities, and programming considerations.

Today's processors span a spectrum, including:

- Microcomputers containing the processor logic and adequate memory (ROM and/or RAM) on a single chip that is easily built into a device.
- Microprocessors on a single chip that, when combined on a circuit board with ROM and/or RAM memory chips, results in a microcomputer that plugs into a device.
- Larger microprocessors consisting of several chips on a circuit board that, when combined with additional memory and external interface boards (links, terminal) result in a microcomputer that is integrated into the subject device.
- Still larger micro- or minicomputers configured within a cabinet that includes considerable memory and capacity for external interface boards.

The architecture of these processors ranges from 4 bits to 8, 16, and in some new systems, 32 bits.

A relatively simple task like managing an access-control system—a magnetically encoded card used to enter a computer room or controlled area—can be handled with an inexpensive 4-bit microprocessor. Time-division or frequency-division multiplexers to transmit multiple bit streams over a single link may require the capabilities of an 8- or 16-bit architecture. A network processor handling a large number of various links and the traffic flow from hundreds or thousands of source/destination devices requires a 16- or 32-bit architecture with considerable memory (a megabyte or more) and access to peripheral disks for queueing and journaling functions.

The program logic that executes in the processor(s) of the smaller devices can be loaded in a variety of ways. The simplest is the use of ROM chips that have a copy of the program built in by the chip manufacturer. Since the logic in a ROM chip is fixed, it should be used only in situations where the probability of a change is extremely low. When change is required, the device must be taken out of service and the ROM chip replaced with the new version.


Bell Labs

1. Chips on a wafer. *The wafer contains 64 Bellmac-4 microcomputer chips. A portion of one chip, enlarged 400 times, appears on the video screen in the background.*

Program logic can also be entered through PROM chips. The manufacturer generates the program and enters it into the PROM using a PROM programmer. If the logic changes, the ROM chips are programmed and sent out to replace the earlier version. Considerable time and cost savings result since a new ROM chip does not have to be fabricated (see "Fabricating chips").

Write and erase it

E^2PROMs offer considerable flexibility in adapting to the changing needs of network devices. The initial control program is entered into the E^2PROM at the time the chip is inserted into a device.

Since E^2PROMs are electronically erasable and programmable, later changes can be made from remote locations. A programmer simply sends a new version of the program through the network to the devices, where it replaces the obsolete version. It is not necessary to remove the chip from the device that houses it. When required, sufficient redundancy can be built into the device so that the service disruption during the program update is minimized or eliminated entirely.

Since E^2PROMs are nonvolatile, program logic stored within them is not lost if the subject device loses electrical power. However, associated RAM contents used by microprocessors for the manipulation and control of information are lost when a power failure occurs.

Fortunately, a solution exists. The relatively low power requirements of RAMs—particularly those made with CMOS (complementary metal oxide semiconductor) technology—suggests that on-board batteries may be used to prevent such a loss. Products are available with RAM capacities of 16 kbytes and batteries that will hold the data for two years or more. They are sold as individual memory boards for use by the man-