DESIGNING AND IMPLEMENTING LOCAL AREA NETWORKS

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McGraw-Hill Book Company

New York St. Louis San Francisco Auckland
Bogotá Hamburg Johannesburg London
Madrid Mexico Montreal New Delhi Panama
Paris São Paulo Singapore Sydney Tokyo Toronto

Library of Congress Cataloging in Publication Data

Chorafas, Dimitris N
Designing and implementing local area networks

Includes index
1 Computer networks 2 Electronic data processing
—Distributed processing I Title
TK5105 5 C486 1984 001 64'404 83-11965
ISBN 0-07-010819-6

1234567890 DOC/DOC 89876543

ISBN 0-07-010819-6

The editors for this book were Stephen G Guty and Rita Margolies, the designer was Riverside Graphic Studio, Inc , and the production supervisor was Teresa F Leaden It was set in Caledonia by Santype-Byrd

Printed and bound by R R Donnelley & Sons, Inc

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PREFACE

This book was written for the information scientist who wants to know how to put to work to his advantage the best that current technology can offer. Since the concepts which the book conveys have only recently gained widespread acceptance, it starts with fundamentals. What is a local area network (LAN)? Why should we want to interconnect independent microcomputer systems that act as producers and consumers of information? How can we best use personal computers and LAN technology to serve organizational objectives?

A local area network is a communications facility that covers a limited topology and interconnects in an effective manner different types of servers and workstations (WS), more particularly personal and professional computers. In width it varies from 100 m to nearly 10 km depending on the architecture.

The two pillars on which a LAN rests—the physical and logical transport media and the personal computer–based WS—are the reason why today's technical press is filled with announcements of LAN products. In the steady search for productivity at the workbench, new solutions from small firms rival those from billion dollar corporations in a field that is only a few years old but is dynamic and fast-growing.

With computers and a LAN—that is, with a *myriaprocessor*—supported features, prices, and technology are distributed across a broad spectrum. This book describes the environment in which a local area network can best be put to work, its distinguishing characteristics, architectural issues, and the system design associated with them. It also discusses the real-life possibilities of myriaprocessors and the fundamental requirements for a successful application.

When we talk of local area networks, we must always remember that there is nothing about them that is totally new as to software or hardware:

- Personal computers now sell over two million a year.
- The operating system techniques are standard.
- The communications technology is well established.
- There are no applications that specifically arise from local networks per se. Even electronic mail was first implemented with standard mainframe computers.

The innovations lie in the physical-logical connection technology and its engineering to fit the characteristics of the myriaprocessors: speed, ease of use, effective range, and price. The options are many and sometimes confusing, but what particularly handicaps the persons looking toward the selection and implementation of a LAN environment is a clear view of rationality and possible advantages. Chapter 1 aims to supply that view: *The* essence of the PC and LAN revolution is individual access at an affordable price.

How does a local area network fit an office environment? Chapter 2 addresses that question, and by doing so it underscores the range of logical and physical challenges to be faced in an effective solution. Physical connection technology will continue to develop for some time, but the requirements of mass production and the installation perspectives underline the need to face the carrier problem. That is the subject of Chap. 3.

Chapter 4 treats the very important question of broadband versus baseband. First the technical characteristics and then the advantages and disadvantages that each solution will involve are considered. That is followed by Chap. 5 on protocols, synchronous and asynchronous, based on a layered approach and answering different topology requirements through alternative types of LAN architecture.

Three chapters, 6, 7, and 8, are devoted to standardization. In the first we consider the national, regional, and international normalization effort starting with the physical layer. Attention is focused on the standards organizations and their respective authorities and responsibilities. In the second we stress the work accomplished in the United States by the IEEE Project 802. The aim of this committee effort is to establish LAN standards at the two lower layers of the network connection: the physical and the data link. Three media access methods are developed: contention (CSMA/CD), token, and tree structure. They are presented and documented in the book. The third

1 MAKING USE OF HIGH TECHNOLOGY

Advanced computer and communications technology has become the key to survival of a great many financial institutions and industrial concerns. No words can better explain its role than General Electric's dictum: "Automate, emigrate, or evaporate."

Having called the able application of high technology "the most important undertaking of this century," GE has engaged in a far-sighted program of retooling its own and other factories into the automated plants of the future. The new, exciting tools and techniques are used in three broad areas of interest:

1. The *technology base*. Here the aim is to accelerate advances in productivity and product quality.
2. The thrust for *generic solutions*: developing standards and recommendations for applications, demonstrating solutions, and providing experimental facilities.
3. *Application support*: developing specialized skills through education by seminars, workshops, and dissemination media.

These are the approaches to the *implementation of the microprocessors that are revolutionizing communications, business systems, manufacturing, technology, and military equipment.* We are becoming a technology-driven society to which the present generation, with its image problems, is adjusting with difficulty. The next generation, however, will take computers, communications, and intelligent workstations for granted. Today, fifth-grade kids learn about computers and sixth-graders start programming and get hands-on experience.

At present the hardware is mindless and acquires an intellectual cast only through software, but by year 2000 the following developments may take us to intelligent machines:

1. Very large scale integration
2. Universal, inexpensive broadband communications
3. Voice recognition and voice answerback
4. Human language man-machine communications
5. Self-sustaining associative databases
6. Cryogenic circuitry approximating biological densities
7. Holographic memories
8. Hardware and software adaptive to environmental stimuli
9. Teachable computers
10. Brain-type metalanguage
11. Automated intuition
12. Brain augmentation through high-level intelligence

While that transition is taking place over 20 or so years, we must remember that, aside from it, the pace of technological development has accelerated and our human capital finds it hard to adjust to the new realities. The two necessities for growth and survival are *to accept change*, which in at least some areas is part of the ongoing evolution, and *to manage information as a vital resource comparable to food and energy*.

Japanese manufacturers are in the forefront in these respects: They believe the time has come to change strategy and not just follow what others are doing in information technology, but do better. They also see clearly the connection between international bargaining power and technology. But where do American and European companies stand?

AN "INDUSTRIAL STRENGTH" MACHINE

Most of the terminals that connect office desks to company mainframes are dumb. In contrast, the personal computer (PC) is developing into an intelligent user-programmable terminal. It is a monotask (*one machine, one man, one terminal*) but multiprocessor; it is a low-cost, high-capacity device. Putting computing power in the hands of end users is therefore the way more companies are going; there is a significant trend toward multifunction workstations as opposed to single-function terminals.

Furthermore, the difference in price between a personal computer and a simple terminal is quite significant—in favor of the PC.

Broadly, the PC line divides into the home and the professional microcomputers. As Fig. 1-1 demonstrates, the latter are more expensive than consumer-oriented machines. The "industrial strength" micros are not always found in walk-in retail stores.

Although off-the-shelf software is widely available, a professional

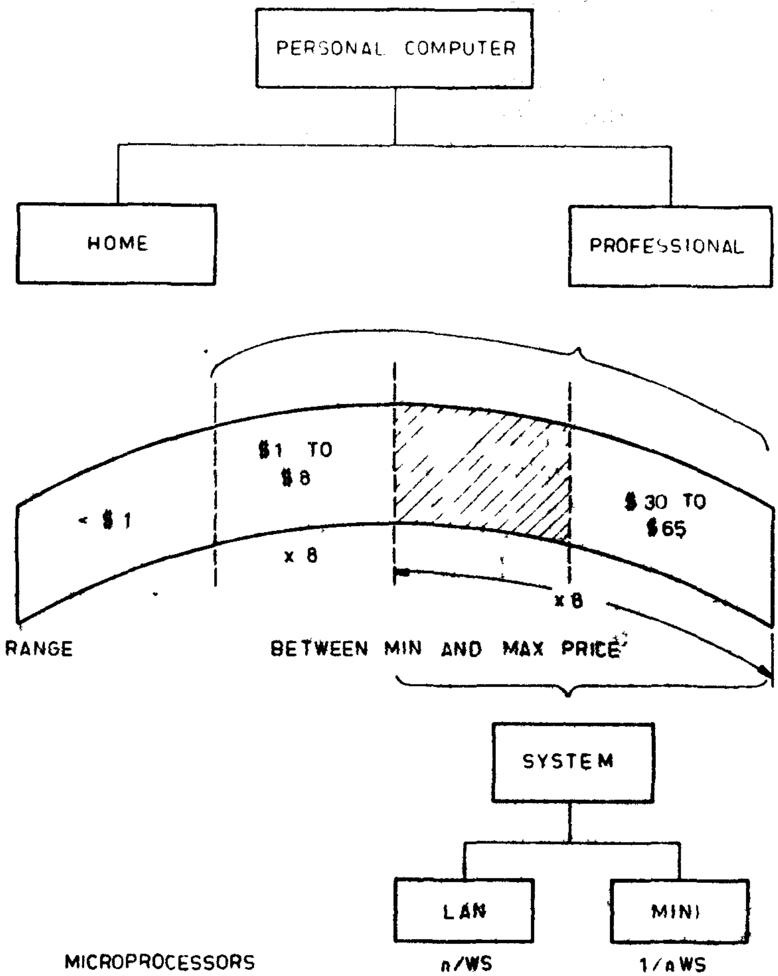

Figure 1-1. Division of the home and professional PC market, price ranges, and comparison of LAN and shared mini solutions in terms of microprocessor power per workstation. The difference in microprocessor power is n^2 per ws.

microcomputer most often runs programs that have been written for or tailored to a particular business. In this respect, an industrial strength micro challenges a dumb terminal because the latter must draw on the power of a bigger, centralized computer. Frequently, the results are delays, downtime, and user unhappiness.

What has been said of centralized mainframes is to a lesser extent true of minicomputers. Whereas microprocessor-based workstations in a local area network (LAN) feature n processors, where $n \geqslant 1$, a number of dumb terminals attached to a mini share a single processor. The difference in computer power is n^2 in favor of the LAN. Furthermore, the LAN provides these user advantages:

1. Greater reliability
2. Better-supported facilities
3. Faster response time
4. Internetworking capabilities
5. Polyvalent messaging systems
6. Flexibility in applications programming (AP)
7. Significant advantages in workstation selection

Today in talk about communications, personal computers are pretty much regarded as terminal emulators. But as the PC takes on networking functions through interconnection in LANs, end users will take advantage of the local processor power of small deskdrawer computers and electronic message systems will flourish and proliferate. A microprocessor-based workstation (WS) with memory capability assures that many of the user's needs can be met at the user's site. This leaves the larger computer free to work on bigger problems, safekeep the user's text and data, and store rarely accessed information and thus act as a warehouse of valuable resources.

The next WS generation will be designed for the separation of data from the programs, will have dictionary addressing, will be equipped with instructions needed to create, modify, destroy, and materialize information elements, and will include a high degree of integrity and security features. Database capabilities will be an outstanding feature of the system. In the 1983 to 1986 time frame, the professional PC will take on the characteristics of one or more of the following three classes of devices:

1. A WS installed under every desk linked to a local text and database and to a long-haul engine (mini, mainframe, text and data warehouse) through a LAN.

2. A small business system of the kind developed since the late 1970s.

3. A communications terminal equipped with a lot of data communication protocols and switchable to different networks.

During the same time period, a significant increase in message exchange will call for other services to be supported through local intelligence. For instance, in electronic message exchange, *smart forms* will become very important. A good deal of mail system capability is not used primarily for messaging; instead it is used for such forms-related tasks as order entry.

This is where the smart forms are valuable. They include user-oriented prompts, flexible (user-defined) programs, and choice of language (QuickComm supports eight languages). A user-defined forms capability in a message system is a way to extend the use of the system and to handle structured information effectively.

Local intelligence will be supported through an impressive range of microprocessor lines. Among the leading current products are Intel's 8086 and 8088. Both are 16-BPW (bits per word) machines, but the 8086 has a 16-bit and the 8088 an 8-bit bus. (The cost difference between the 8- and 16-BPW microprocessors is today quite negligible.) Intel's iAPX 432 has 32 BPW and a 32-bit bus.

Newer developments go well beyond that level. The 80186 is a 16-BPW "board on a chip" compatible with the 8086 but incorporating 55,000 transistors. The 80286 incorporates 130,000 transistors; it is a virtual memory machine and has memory management built into it. In both microprocessors the clock is at the 10-MHz (megahertz) level, but design makes the 80186 twice the 8086 speed and the 80286 four times the 8086 speed. (With the 8086 memory, access takes four cycles; whereas 80186 works at two cycles and 80286 at one cycle. Hence, the 8086 is waiting on memory access).

Furthermore, the 80186 addresses 1 MB (megabyte), and the 80286 addresses 2 MB. These are not in the future; they are currently available machines. The 80186 and 80286 are now being tested on user premises. (The IBM PC employs the 8088, and the persistent rumor is that IBM did the specs for the 80286. IBM is Intel's biggest customer, and since late 1982 a major shareholder.)

To appreciate the generation of microprocessors now in advanced stages of development, note that the IBM 4300 line, the HIS DPS 8, the Univac, and the Burroughs machines work at 8 MHz. In comparison with them the 1 MHz of Apple II and the 2 MHz of Apple III are dwarfish. That is not true of the new machines. The microprocessors currently integrated in PCs compare very favorably with the machines cited above, as Table 1-1 shows. New developments go well beyond the prevailing mainframe level.

The introduction of professional computers to the workplace is challenging in three ways:

1. The first challenge is to plan for one *umbrella technology*, that will furnish a broad array of capabilities directly to users. All of the office and industrial implementation fields we know today will be subsumed in that technology.
2. The second challenge is to *eliminate barriers* even if the traditional separation of technologies is reflected in everything that touches on computer work. Here it is important to understand that the technological basis for separation is crumbling. That should foster a desire to broaden interests and embrace a total view of information technology.
3. The third challenge is to expand *information management* by enriching the information component with color and graphics

TABLE 1-1 A COMPARISON OF MICROPROCESSORS

	Intel 8086	Motorola 68000	Zilog Z8000	National Semiconductor 16000
Year of introduction	1978	1980	1979	1981
Basic clock	5 (4–8)	5–8	4 (2.5–4)	10
BPW	16	32	16	16
Basic instructions	95	61+	110	100
Use of microcode	No	Yes	No	No
General-purpose registers	14	16	16	8
Floating point	No	No	No	No
Pins	40	64	48/40	48/40
Direct access, in megabytes	1	16/64	48	16
Address size in bits	20	24	16	
Interrupt provisions	Yes	Yes	Yes	Yes
Stacks	Yes	Yes	Yes	Yes
Arrays	No	No	No	Yes
Virtual system structure	No	No	No	16032 only
Debug mode	No	Yes	No	No

> and by providing advanced security and protection capabilities. This will lead to a proliferation of nontechnical users and a burgeoning demand for additional functions.

Until now, information management has been the sole interest of computer specialists, but data handling systems are expanding to meet the requirements of management at large. Any approach to the management of information must meet all three challenges. If it does, it will broaden marketing and implementation perspectives.

INCREASING INTELLIGENCE AND EASE OF USE

With ultimately increased intelligence and ease of use, computers and communications will be better able to assist man. Among the prerequisites are the ability to process information by using everyday language, put stored knowledge to practical use, and promote the functions of learning, associating, and inferring. Now, however, the essence of the personal computer revolution is individual access to computing power at an affordable price. Besides cost-effectiveness, a personal computer in the executive and clerical environments has the benefits of:

- Distributed processing
- Local databases
- Gateway to mainframes or minis
- Interconnection through LAN
- Fast response in interaction with a powerful local computer

Good solutions must combine the latest in hardware with innovative software. A major competitive advantage is a variety of compatibles and add-on features developed around the workstation. The current trend is toward a proliferation of workstations with increasingly intelligent features. If a company doesn't supply such supports, it will most likely lose the best of its people and not attract good replacements.

Voice recognition and voice synthesis will be among the most attractive add-on features in coming years. Voice-actuated equipment is bound to get cheaper and have an increased vocabulary. Today the 100-word units are becoming a base offering.

Voice recognition first found a solid application in quality control, where it improves operator accuracy and reduces the chance of errors. Nippon Electric has introduced a voice input processor with a 120-word vocabulary for use with its personal computers. It sells for $500.

By 1985 it is expected that continuous-speech systems with vocabularies of up to 500 words will be available and that the vocabulary will be increased to 1500 words by 1987.

Evaluating voice recognition capabilities is a tricky business because of the signal-to-noise ratio, the random characteristics of the environment, and a change of voice due to emotion or fatigue. Also, the industry is still searching for an accurate continuous-speech recognition algorithm. At present the process requires very large 32- and 64-bit high-speed machines. The issue is that, whereas current commercial systems can recognize a limited number of isolated words, the office environment calls for the recognition of continuous speech and large vocabularies with high accuracy independently of the speaker.

Nevertheless, manufacturers anticipate that speech recognition capability will be the primary feature of the next WS generation. Developers are working to reduce the number of components in a speech recognition preprocessor circuit to one very large scale integrated circuit with both analog and digital components. Until they are successful at an affordable price, however, user-friendly solutions to the man-machine communication problem will be supported by graphic tablets. A graphic tablet, or graphic pad, is a printed circuit board (PCB) whose elements have numeric codes that are defined by PCB records in the database design file. First appearing in computer-aided design (CAD), such pads provided user-friendly capabilities for scaling, rotation, volume accumulation, error message diagnostics, and generally programmable formats. They now find a range of applications in management, including banking, in connection with PCs and LANs.

The tablets are well suited to help in an applications environment which changes very rapidly, because they can be effectively reprogrammed to meet different functional requirements and to help in transition. They are particularly well suited to a structured input, and such solutions can fit the user level if we care to define with precision what we have to do. Understandably, the definition has to be dynamic: environmental changes want it that way.

Alternatively, when PCs and LANs are at a premium, we can use touch-sensing video screens. Rather than pushing buttons, switches, or keyboards, the user points to (touches) a computer-generated display on a terminal screen equipped with a touch-sensing device.

In terms of implementation, voice output is more advanced than voice input. Increasingly, computers vocalize. At a Grand Union supermarket in Stratford, Connecticut, the terminal at the checkout counter records the price of each item and also announces it to the