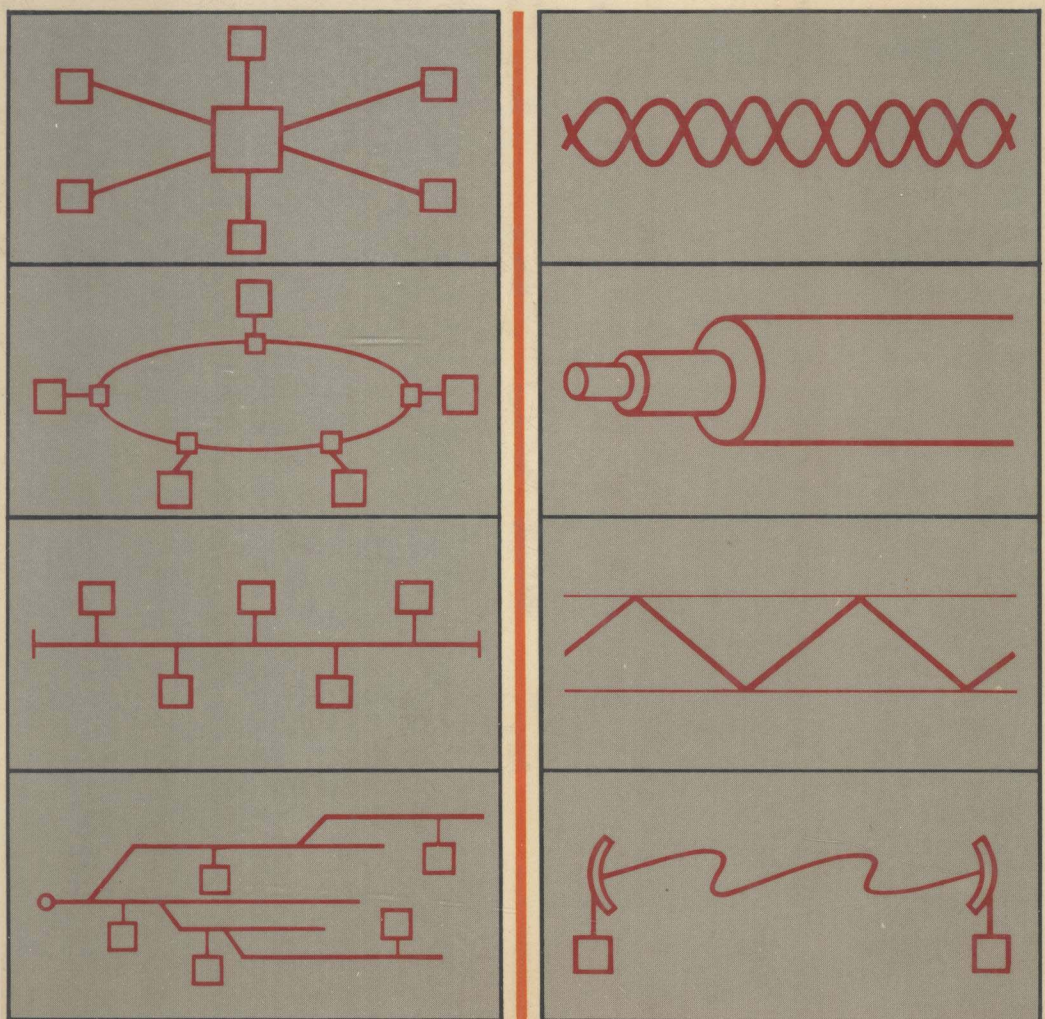
LOCAL NETWORKS

An Introduction

WILLIAM STALLINGS



WILLIAM STALLINGS, Ph.D.

LOCAL NETWORKS

An Introduction

Macmillan Publishing Company
New York

Collier Macmillan Publishers
London

Macmillan Publishing Company
866 Third Avenue, New York, New York, 10022

Collier Macmillan Canada, Inc.

Library of Congress Cataloging in Publication Data
Stallings, William.
Local networks.

Bibliography: p.
Includes index.
1. Computer networks. 2. Electronic data processing
—Distributed processing. I. Title.
TK5105.5.S78 1984 001.64'404 83-5423
ISBN 0-02-415460-1

Printing: 4 5 6 7 8 Year: 4 5 6 7 8 9 0 1 2

ISBN 0-02-415460-1

PREFACE

Perhaps no other major innovation in data processing or data communications has been so widely discussed or so eagerly anticipated before its maturity as local networks. Local networks are attractive for such features as high availability and the ability to support multiple vendor equipment. And, although the technology is rapidly evolving, the principal architectural forms and design approaches have emerged.

Objectives

This book focuses on the broad and constantly changing field of local networks. The aim of the text is to provide a reasoned balance among breadth, depth, and timeliness. The book emphasizes topics of fundamental importance concerning the technology and architecture of local networks. Certain key areas, such as the network interface and performance, are treated in some detail. Others, such as security and reliability, can only be treated in an introductory fashion.

The book explores the key topics in the field in the following general categories:

- *Technology and architecture:* There is a small collection of ingredients that serves to characterize and differentiate local networks, including transmission medium, network topology, communication protocols, switching technique, and hardware/software interface.
- *Network type:* It is convenient to classify local networks into three types, based partly on technology and partly on application. These are local area network (LAN), high-speed local network (HSLN), and digital switch/computerized branch exchange (CBX).
- *Design approaches:* While not attempting to be exhaustive, the book exposes and discusses important issues related to local network design.

Conspicuously missing from this list is a category with a title such as "typical systems." This book focuses on the common principles underlying the design and implementation of all local networks. It should, therefore, give the reader sufficient background to judge and compare local network products. A description of even a small sample of such systems is beyond the scope of this book. Discussions of specific systems are included herein only when they are the best vehicle for communicating the concepts and principles under discussion.

In terms of style, the book is primarily:

- *Descriptive:* Terms are defined and the key concepts and technologies are discussed in some detail.
- *Comparative:* Wherever possible, alternative or competing approaches are compared and their relative merits, based on suitable criteria, are discussed.

On the other hand, analytic and research-oriented styles are present to a much lesser degree. Virtually all of the mathematical content is confined to the chapters on performance, and even there, the emphasis is on results rather than derivations.

Intended Audience

This book is intended for a broad range of readers interested in local networks:

- *Students and professionals in computer science and data communications:* The book is intended as both a textbook for study and a basic reference volume for this exciting area within the broader fields of computer science and data communications.
- *Local network designers and implementors:* The book discusses the critical design issues and illustrates alternative approaches to meeting user requirements.
- *Local network customers and system managers:* The book alerts the reader to some of the key issues and tradeoffs, and what to look for in the way of network services and performance.

The book is intended to be self-contained. For the reader with little or no background in data communications, a brief primer is included.

Plan of the Text

The book is organized to clarify both the unifying and differentiating concepts underlying the field of local networks. The organization of the chapters is as follows:

1. *Introduction:* This chapter defines the term local network and looks at some of the applications and advantages and disadvantages.
2. *Topics in data communications and computer networking:* This necessarily brief survey explains the relevant concepts used throughout the book.
3. *Local network technology:* Focuses on the key characteristics of transmission medium and topology. The classification of local networks used in this book is presented and discussed.

4, 5. *Local area networks:* The term local area network (LAN) is often mistakenly identified with the entire field of local networks. LANs are general-purpose in nature and most of the better-known local networks fall into this class. The major types of LANs—baseband bus, broadband bus/tree, and ring—are described and compared. The important issue of medium access control protocols is explored. The standards currently being developed for LANs are also described.

6. *High-speed local networks:* This chapter focuses on a special purpose high-speed type of local network, examining current technology and standards and possible future directions.
7. *Circuit-switched local networks:* Networks in this category constitute the major alternative to LANs for meeting general local interconnection needs. The category includes the data-only digital switch and the voice/data computerized branch exchange (CBX). This chapter explores the technology and architecture of these devices and examines their pros and cons relative to LANs.
8. *The network interface:* The nature of the interface between an attached device and LAN or HSLN is an important design issue. This chapter explores some alternatives.

9, 10. *Network performance:* The purpose of these chapters is to give some insight into the performance problems and the differences in performance of various local networks.

11. *Internetworking:* In the majority of cases, local networks will be connected in some fashion to other networks. Some alternatives are explored.
12. *Local network design issues:* The purpose of this chapter is to give the reader some feel for the breadth of design issues that must be addressed in implementing and operating local networks.

In addition, the book includes an extensive glossary, a list of frequently-used acronyms, and a bibliography. Each chapter includes problems and suggestions for further reading.

The book is suitable for self-study and can be conveniently covered in a one-semester course.

A final note: a considerable fraction of the material is organized with reference to the Open Systems Interconnection (OSI) model and the local network standards being developed. This structure is suggestive of the certain future direction of local network architecture, and, equally important, it provides a terminology and frame of reference that is becoming universal in networking discourses.

Related Volumes

Two of my other books may be of interest to students and professionals. *Local Network Technology* (IEEE Computer Society Press, 1983) is a companion to this text, and follows the same topical organization. It contains reprints of many of the key references used herein; these are indicated by an asterisk when mentioned in the recommended reading section of each chapter. The address of the IEEE Computer Society Press is P.O. Box 80452, Worldway Postal Center, Los Angeles, CA 90080; telephone (714) 821-8380.

Another related text is *Data and Computer Communications,* forthcoming from Macmillan. This book covers fundamental concepts in the areas of data transmission, communication networks, and computer-communications protocols.

Acknowledgments

Many people have helped me during the preparation of this book. I would like particularly to acknowledge and thank the following people. K.C. Houston first introduced me to this fascinating field and provided me with the opportunity to pursue my interest. George Arnovick, Lynn DeNoia, Donald DeVorkin, Harvey Freeman, Kathy Hanson, Mary Loomis, Ira Pohl, Bart Stuck, and Gene Swystun reviewed all or a portion of the manuscript. Dave Carlson, George Jelatis, and Bob Donnan of the IEEE 802 Committee and Dolan Toth of the ANS X3T9.5 Committee reviewed the descriptions of the respective standards; of course, any errors remaining in the text are my responsibility. My editor, Sally Elliott, shepherded the book through all the stages from proposal to printing in as rapid and professional a manner as one could wish for. Alice Wilding-White did an amazingly fast job of typing the manuscript. And, finally, my wife Tricia provided the two ingredients essential to the writing of this book: her patience and encouragement.

W.S.

CONTENTS

CHAPTER 1

Introduction

1.1

A DEFINITION OF LOCAL NETWORKS

To formulate a definition of the term *local network*, and to characterize the purposes of such networks, it is important to understand the trends that have brought about local networks.

Of most importance is the dramatic and continuing decrease in computer hardware costs, accompanied by an increase in computer hardware capability. Today's microprocessors have speeds, instruction sets, and memory capacities comparable to medium scale minicomputers. This trend has spawned a number of changes in the way information is collected, processed, and used in organizations. There is increasing use of single-function systems and intelligent workstations, to make systems friendlier and more accessible to the users. The decrease in hardware cost correspondingly decreases hardware life cycles, which exacerbates software conversion problems. These conversion costs may be reduced by decomposing large computer systems into smaller, separate components.

All of these factors lead to an increased number of systems at a single site: office building, factory, operations center, and so on. At the same time there

is likely to be a desire to interconnect these systems for a variety of reasons, including:

- To exchange data between systems
- To provide backup in realtime applications.
- To share expensive resources

To appreciate this last reason, consider that although the cost of data processing hardware has dropped, the cost of essential electromechanical equipment, such as bulk storage and line printers, remains high. In the past, with a centralized data processing facility, these devices could be attached directly to the central host computer. With the dispersal of computer power, these devices must somehow be shared.

We will elaborate on these and other reasons later in this chapter. For now, the discussion above should be enough to motivate the following definition of a *local network*:

A local network is a communications network that provides interconnection of a variety of data communicating devices within a small area.

There are three elements of significance in this definition. First, a local network is a communications network, not a computer network. In this book we deal primarily with issues relating to the communications network. The network software and protocols that are required for attached computers to function as a network are beyond the scope of this book. As a corollary to this definition, note that a collection of devices interconnected by individual point-to-point links is not included in the definition nor in this book.

Second, we interpret the phrase *data communicating devices* broadly, to include any device that communicates over a transmission medium. Examples:

- Computers
- Terminals
- Peripheral devices
- Sensors (temperature, humidity, security alarm sensors)
- Telephones
- Television transmitter and receivers

Of course, not all types of local networks are capable of handling all of these devices.

Third, the geographic scope of a local network is small. The most common occurrence is a network that is confined to a single building. Networks that span several buildings, such as on a college campus or military base, are also common. A borderline case is a network with a radius of a few tens of kilometers. With appropriate technology, such a system will behave like a local network.

Another element that could be added to the definition is that a local network is generally privately owned rather than a public or commercially available utility. Indeed, typically, a single organization will own both the network and the attached devices.

Some of the typical characteristics of local networks are:

- High data rates (0.1 to 100 Mbps)
- Short distances (0.1 to 25 km)
- Low error rate (10^{-8} to 10^{-11})

The first two parameters serve to differentiate local networks from two cousins: multiprocessor systems and long-haul networks. This is illustrated in Figure 1.1. The figure indicates three types of local networks: local area networks, high speed local networks, and computerized branch exchanges. These will be defined in Chapter 3.

Other distinctions can be drawn between local networks and its two cousins, and these have a significant impact on design and operation. Local networks generally experience significantly fewer data transmission errors and significantly lower communications costs than those of long haul networks. Cost-performance tradeoffs are thus significantly different. Also, because local networks are generally owned by the same organization as the attached devices, it is possible to achieve greater integration between the network and the devices; this topic is explored in Chapter 8.

A distinction between local networks and multiprocessors systems is the degree of coupling. Multiprocessor systems are tightly coupled, usually have some central control, and completely integrate the communications function. Local networks tend to exhibit the opposite characteristics.

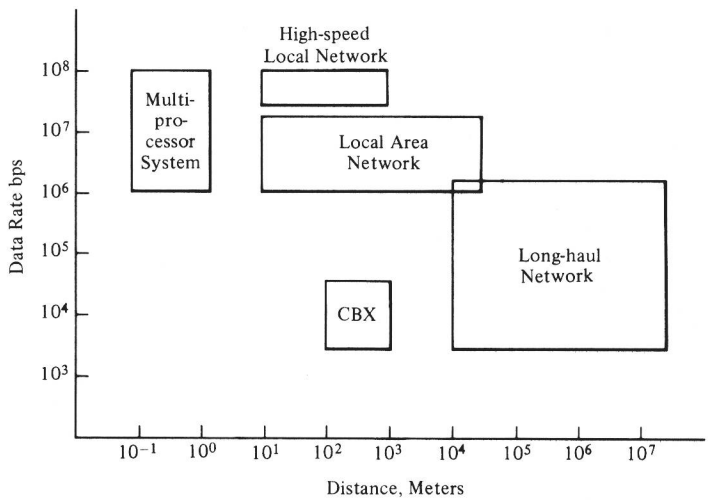


FIGURE 1–1. Comparison of Multiprocessor Systems, Local Networks, and Long-Haul Networks

BENEFITS AND PITFALLS

Table 1.1 lists some of the major benefits of a local network. Whether these are realized or not, of course, depends on the skill and wisdom of those involved in selecting the local network.

Perhaps the most important benefit of a local network relates to system evolution. In a non-networked installation, such as a time-sharing center, all of the data processing power is in one or a few systems. Changes tend to be few and traumatic. By dispersing a site's computer power among a number of systems, it is possible to replace applications or computer systems gradually, avoiding the all-or-nothing approach.

A local network tends to improve the reliability, availability, and survivability of a data processing facility (see Section 12.2). With multiple interconnected systems, the loss of any one system should have minimal impact. Further, key systems can be made redundant so that other systems can quickly take up the load after a failure.

We have already mentioned resource sharing. This includes not only expensive peripheral devices, but data. Data can be housed and controlled from a specific facility but, via the network, be available to many users.

TABLE 1.1 Benefits and Pitfalls of Local Networks

Potential Benefits
System evolution: incremental changes with contained impact
Reliability/availability/survivability: multiple interconnected systems disperse functions and provide backup capability
Resource sharing: expensive peripherals, hosts, data
Multivendor support: customer not locked in to a single vendor
Improved response/performance
User needs single terminal to access multiple systems
Flexibility of equipment location
Integration of data processing and office automation
Potential Pitfalls
Interoperability is not guaranteed: software, data
A distributed data base raises problems of integrity, security/privacy
Creeping escalation: more equipment will be procured than is actually needed
Loss of control: more difficult to manage and enforce standards

A local network provides at least the potential of connecting devices from multiple vendors, thus giving the customer greater flexibility and bargaining power. However, a local network will provide only a rather low or primitive level of interconnection. For the network to function properly, higher levels of networking software must be supplied within the attached devices (see Section 2.3 and Chapter 8).

These are, in most cases, the most significant benefits of a local network. Several others are also listed in Table 1.1.

Alas, there are also some pitfalls, or at least potential pitfalls. As we mentioned, a local network does not guarantee that two devices can be used cooperatively, a concept known as *interoperability*. For example, two word processors from different vendors can be attached to a local network, and can perhaps exchange data. But they probably will use different file formats and different control characters, so that it is not possible, directly, to take a file from one and begin editing it on the other. Some sort of format-conversion software is needed.

With a local network, it is likely that data will be distributed or, at least, that access to data may come from multiple sources. This raises questions of integrity (e.g., two users trying to update the data base simultaneously) and security and privacy.

Another pitfall is what Martin refers to as "creeping escalation" [MART81b]. With the dispersal of computer equipment and the ease of incrementally adding equipment, it becomes easier for managers of suborganizations to justify equipment procurement for their department. Although each procurement may be individually justifiable, the totality of procurements throughout an organization may well exceed the total requirements.

There is also a loss of control problem. The prime virtue of networking—distributed systems—is also its prime danger. It is difficult to manage this resource, to enforce standards for software and data, and to control the information available through a network.

We close this discussion with a sobering summary in Table 1.2 based on a recent survey of local network users. While some users noted positive effects from the installation of a local network, a similar number reported negative effects. The conflicting and exaggerated claims of vendors plus the multiplicity of choices has led to confusion and disappointment. Local networks will aid an organization only if they are chosen and managed properly.

1.3 APPLICATIONS

The range of applications for local networks is wide, as indicated by the broad definition given above. Table 1.3 lists some of the potential applications. Again, we emphasize that not all local networks are capable of supporting all applications.

TABLE 1.2 Organizational Effects of Local Networks

Affected Area	Positive Effects	Negative Effects
Work quality	Wider data accessibility; fewer "lost" items. Wider participation in creating and reviewing work	Indeterminate or mediocre data quality; reduced independence and initiative
Productivity	Increased work load handled by more powerful office-systems equipment	Greater resources used to perform inconsequential work
Employee changes	Improved skill levels in current staff More challenging work Reduced status distinctions	Fewer jobs for marginal performers Less personal interaction Insufficient status distinctions
Decision-making effectiveness	Quicker availability of relevant facts Greater analytic capability More people involved in hypothesis building and testing	Factual component of decision making becomes too high "Forest and trees" problem could encourage "group think"
Organizational structure	More effective decentralization	Decentralization can get out of control
Costs	Overall cost reduction	Overall cost increase; soft benefits used as justification
Total impact	Permits the planning of new business approaches	Creates increased complexity and poorly functioning dependence relationships

Source: [EDN82].

TABLE 1.3 Local Network Applications

- Data Processing
  - Data entry
  - Transaction processing
  - File transfer
  - Inquiry/response
  - Batch/RJE
- Office automation
  - Document/word processing
  - Electronic mail
  - Intelligent copying/facsimile
- Factory automation
  - CAD/CAM
  - Inventory control/order entry/shipping
- Energy management
  - Heating
  - Ventilation
  - Air Conditioning
- Process control
- Fire and security
  - Sensors/alarms
  - Cameras and monitors
- Telephones
- Teleconferencing
- Television
  - Off-the-air
  - Video presentations