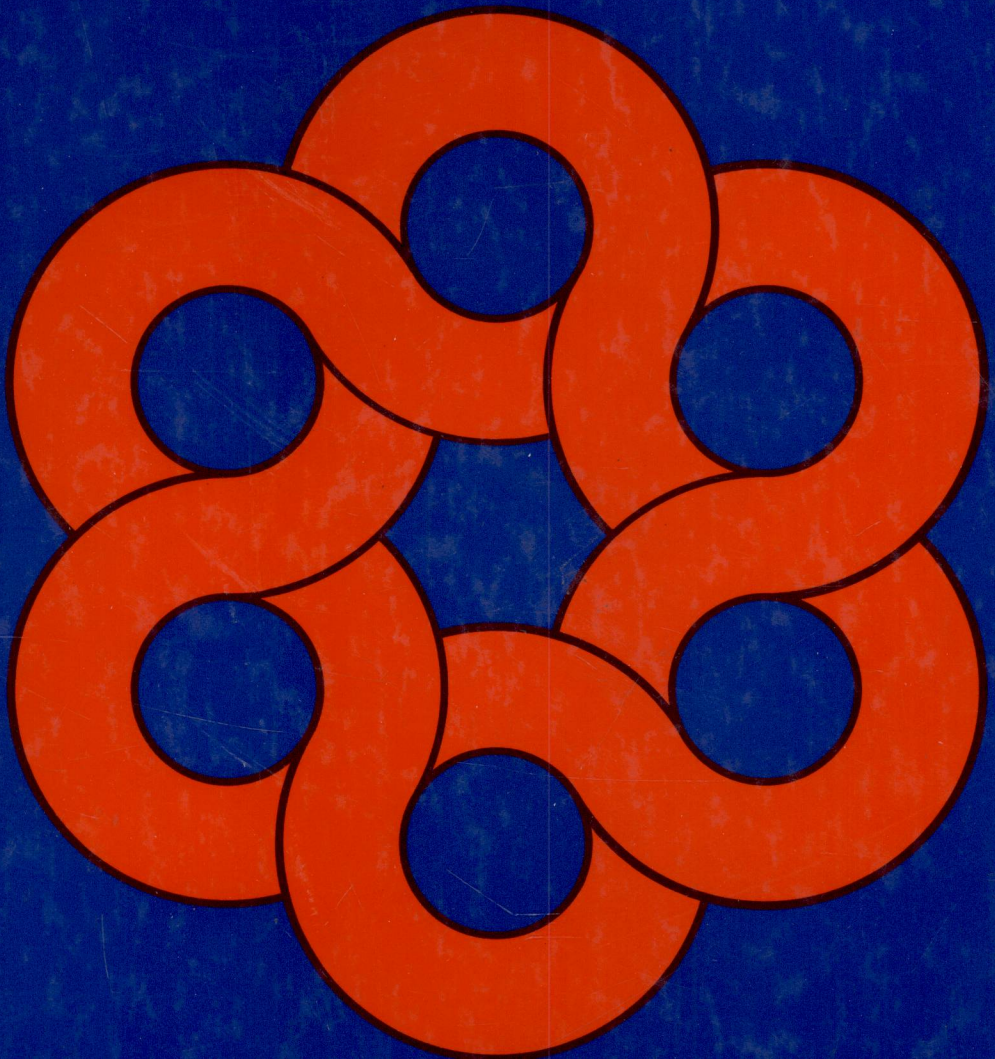
Local Area Networks

Gerd E. Keiser



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ABOUT THE AUTHOR

Gerd E. Keiser received his B.A. and M.S. degrees in mathematics and physics from the University of Wisconsin in Milwaukee, and a Ph.D. degree in solid-state physics from Northeastern University in Boston in 1973. From 1973 to 1974 he carried out research and development of state-of-the-art infrared photodetectors at the Honeywell Electro-Optics center in Lexington, Massachusetts.

In 1974 Dr. Keiser joined the GTE Government Systems Corporation in Needham Heights, Massachusetts, where he currently is the Engineering Manager of the Communication Equipment Design Department. His work here involves analyzing, designing, and developing fiber optic, microwave, and millimeter-wave information-transmission systems and networks.

Dr. Keiser is also serving as an Adjunct Professor of Electrical Engineering at Northeastern University. In addition, he was the guest editor for the IEEE Communications Magazine in May 1985; he organized an IEEE Lecture Series on Optical Fiber Communications in 1986; and he has presented numerous invited lectures at conferences, local industries, and local professional meetings.

Dr. Keiser has published over 20 technical journal and conference papers and is the author of the book *Optical Fiber Communications*, McGraw-Hill, 1983.

TO
Ching-yun and Nishla

PREFACE

This book has been written specifically as a textbook with the purpose of providing the basic material for an introductory senior or first-year graduate course in the analysis and modeling of local area networks. It will also serve well as a working reference for practicing engineers dealing with local area network design and applications. To aid students in learning and applying it to practical designs, a collection of 150 homework problems is included. These problem sets are an important and integral part of this book. They are intended not only to help readers test their comprehension of the material covered, but also to extend and elucidate the text. A solutions manual to the problems is available to the instructor from the publisher.

The background required to study the book is only that of typical senior-level engineering students. Specifically, it is assumed that the student has been introduced to electromagnetic theory, calculus and elementary differential equations, the basic concepts of physics, and the basic concepts of electronics. Courses in communication theory and statistics are not essential, but would be helpful for gaining a full understanding of the material in this book. As an aid to students, I have included brief overviews of relevant units, probability theory, and useful mathematical formulations as appendices at the end of the book.

The book is organized to give a clear and logical sequence of topics. It progresses systematically from descriptions of local area network (LAN) architectures to signaling types and techniques, and ends with discussions on the applications of a variety of popular local area networking schemes. The introductory chapter gives a brief historical background on the evolution of communication systems and how this naturally led to the concept of a LAN. It also sets the stage for the rest of the book by describing what the key elements of a LAN are, and how LANs fit into the overall communications picture that includes computer buses, metropolitan area networks (MANs), and long-haul or wide area networks (WANs). In addition, Chapter 1 addresses some of the functions and general applications of the rapidly growing LAN field.

For two systems to communicate, they must share a common set of rules for generating and interpreting the messages they send or receive. To achieve this, a seven-layer model for network architecture has been established. This widely recognized model, which is known as the Open System Interconnection (OSI) model, is the initial topic of Chapter 2. Next Chapter 2 discusses the relationships of protocols in this model, and the chapter ends with a presentation on the meaning and implementation of each of the seven individual layers.

Chapter 3 provides an introduction and overview of communication theory, particularly as it applies to layers 1 and 2 of the OSI Model. It begins by examining signal types and the modulation techniques used to match the signal properties with the transmission characteristics of the channel. Also included are discussions of frequency response limitations, signal distortion, noise limitations, signal formatting, and multiplexing techniques as they apply to baseband and broadband local area networks. Since errors are unavoidable in any real communication system, methods for detecting and compensating for errors in a digital data stream are discussed next. The final topic in Chapter 3 concerns how communications take place between a number of different devices located at various nodes on a network.

Two important parameters of a local area network are its topology and the transmission medium that is used. These are the topics of Chapter 4, where signal power budget calculations are presented for coaxial-cable and optical-fiber media in several network topologies.

Chapter 5 presents the mathematical foundation of queueing theory which is needed to compare the different access schemes utilized in local area networks. The topics discussed will allow the analysis of message throughput, the queue lengths of messages waiting for service, and the mean response time of LAN access schemes.

Access to a LAN can be gained either in a deterministic (controlled) fashion or by a contention (random-access) scheme. These are described and compared in Chapter 6. In these discussions a key LAN performance characteristic is the throughtput or channel utilization, which is a measure of the total rate of traffic being transmitted between two nodes. A second performance parameter used to compare LAN access methods is the system delay which measures the mean transfer time from message source to destination.

A local area network as an isolated entity by itself has limited potential and usefulness. Thus Chapter 7 describes how LANs can interconnect to each other and to other wide area networks, thereby allowing the sharing of resources among different networks. The issues here include the general interconnection problem of different types of networks, procedures for routing packets across internetwork boundaries, and flow-control methodologies.

An important issue in a LAN is network reliability and availability. Thus Chapter 8 addresses methods for determining and improving network reliability through redundancy of either transmission lines or nodal equipment.

Owing to the rapidly growing use of local area networks and their interactions with all types of other networks (often on a worldwide basis), the problem

of protecting the confidentiality and integrity of the information transmitted on these networks is of concern. Thus Chapter 9 examines network security. The discussions include vulnerablity analysis and mechanisms for achieving security. Particular emphasis is given to encryption since this is a fundamental tool for ensuring information security.

As a final topic, Chapter 10 examines application aspects of some popular LANs which are being widely used in a variety of commercial networks. These include three variations of the IEEE-802.3 standard for baseband CSMA/CD bus LANs (Ethernet, Cheapernet, and StarLAN), optical fiber versions of Ethernet, schemes used for communicating in the factory and office (the IEEE-802.4-based MAP and the IEEE-802.3-based TOP, respectively), token ring LANs as described by IEEE-802.5, and the 100-Mb/s FDDI optical-fiber token ring.

In preparing this book, I am greatly indebted to the many people with whom I had numerous discussions and who supplied me with various materials. Particular thanks go to Margaret Chan, Dr. Tri Ha, Dr. Ching-yun Keiser, and Dr. Stevan Leiden. Special thanks go to several reviewers whose comments enhanced and clarified the content and organization of the book: Pierce Cantrel, Texas A & M University; R. Lee Hamilton, Jr., The Ohio State University; Doug Jacobson, Iowa State University; Vernon Rego, Purdue University; Manos Roumeliotis, West Virginia University; Charles H. Sauer; and John A. Stankovic, University of Massachusetts—Amherst. Since the development of local area networks is the result of the work of many people from a wide variety of disciplines, this book would not have been possible without the many contributions that have appeared in the open literature. My sincerest thanks also go to Suzanne Allison, Ann Miller, Gail Pickett, and Jean-Sampson, all of whom assisted in typing the manuscript and its various drafts in an exceptionally expert fashion. As a final personal note, I am grateful to my wife Ching-yun and my daughter Nishla for their patience and encouragement during the time I devoted to writing this book.

Gerd E. Keiser

LOCAL AREA NETWORKS

CONTENTS

CHAPTER 1

OVERVIEW OF LOCAL AREA NETWORKS

Ever since ancient times, people have devised various techniques for communicating their thoughts, needs, and desires to others. In early civilized times, people tended to congregate in geographically localized clusters in which communications were adequately achieved through speech and written messages. As civilizations spread over larger geographical areas, a variety of long-distance communication methods were tried such as smoke signals, optical signals, and carrier pigeons. One of the earliest known optical transmission links,[1] for example, was the use of a fire signal by the Greeks in the eighth century B.C. for sending alarms, calls for help, or announcements of certain events. However, because of environmental and technology limitations it generally turned out to be faster and more efficient to send letter messages by a courier over the road network.

The discovery of the telegraph by Samuel F. B. Morse in 1838 ushered in a new epoch in communications—the era of electrical communications.[2] Messages

in the early nineteenth-century telegraphy systems were first encoded into strings of binary symbols, and were then manually transmitted and received. In the ensuing years developments and implementations of communication systems employing electrical signals became increasingly sophisticated leading, in turn, to the birth of telephone, radio, television, radar, and microwave links. Today these communication systems have become an integral part of everyday life with circuits spanning the entire world carrying voice, text, pictures, and many other types of information.

Along with the development of faster and higher-capacity transmission systems, the past several decades have witnessed a phenomenal growth in the computer industry. As recent advances in integrated circuit technology have allowed computers to become smaller, less expensive, and widely available, people have become increasingly interested in connecting them together to form networks. The term *network* is defined as a set of communication links for interconnecting a collection of terminals, computers, telephones, printers, or other types of data-communicating and data-handling devices. We will refer to these devices generically as *stations*. This interconnection allows these elements to exchange information. One such network is the worldwide telephone system which is an example of the so-called *long-haul network* or *wide-area network* (WAN) that interconnects widely dispersed telecommunication elements.

The successful integration and cross-fertilization of communications and geographically dispersed computing facilities has recently resulted in a tremendous demand for and growth in networks which serve a limited geographical area. In the late 1970s and early 1980s these types of networks, which are called *local area networks* (LANs), made a dramatic entrance into the communications scene. The ensuing years showed a tremendous proliferation of LAN equipment vendors who offered a wide variety of products.

Although it might have appeared that local area networking was a new technology, LANs actually evolved from existing methods of networking and communications. The factors that brought about the rapid rise in the popularity of LANs were the dramatic advances in integrated circuit technology that allowed a small computer chip in the 1980s to have the same processing capabilities of a room-sized computer of the 1950s. This allowed computers to become smaller and less expensive, while they simultaneously became more powerful and versatile.

1.1 THE EVOLUTION OF LOCAL AREA NETWORKS

To see how LANs evolved, let us look at the history of communication networks. Data communication networks resulted from the convergence of two different technologies: computers and telecommunications. This convergence is depicted in Figs. 1.1 through 1.4. In the 1950s computers were large complex machines that could only be operated by specially trained personnel. Jobs in the form of punched cards, paper tape, or magnetic tape were manually brought to

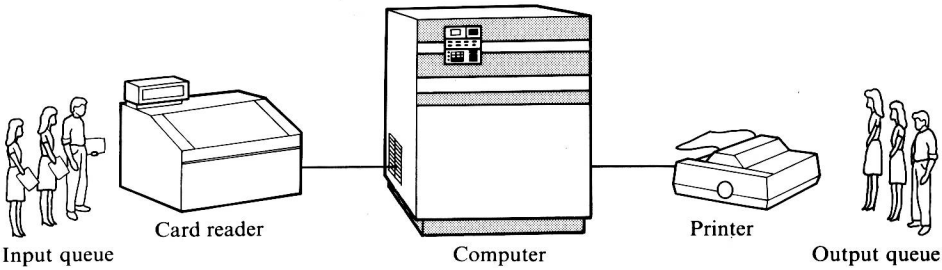

FIGURE 1.1
Jobs were processed in batches in the 1950s with no direct user-to-computer interaction.

the machine to be run in single-process batches. Thus, no direct communications were involved between the computer and the user. This batch process was very unwieldy because of the remoteness of the system from the user, and the long time that was often spent between job submission and receipt of the output.

In the 1960s advances in teletypewriter and data transmission technologies led to the development of the interactive terminal. This device allowed users to remotely access a computer directly via a low-speed data line that connected the terminal to the computer. Thus a very simple type of computer network that we see in Fig. 1.2 was established. Users could now interact directly with the

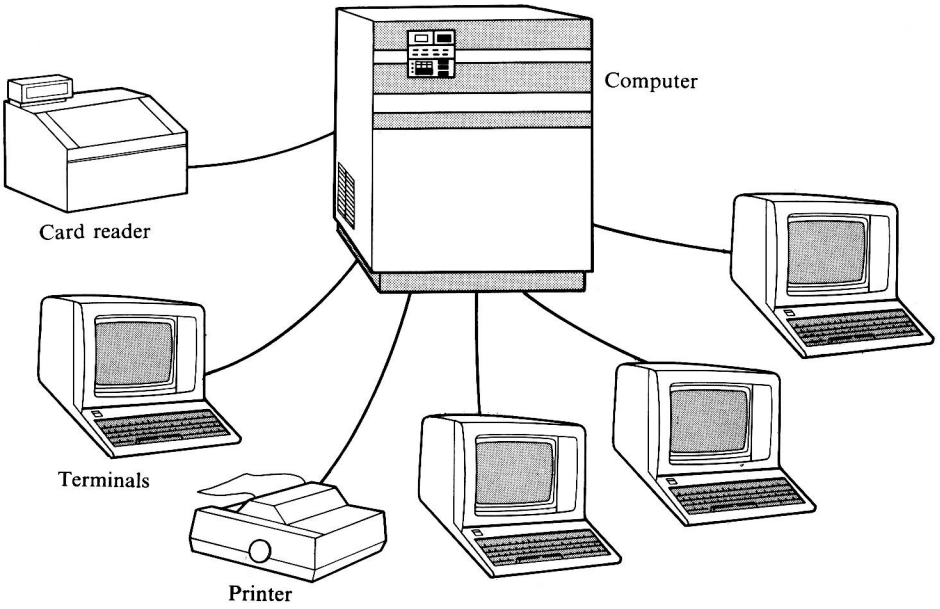

FIGURE 1.2
The interactive terminal allowed direct user-to-computer access.