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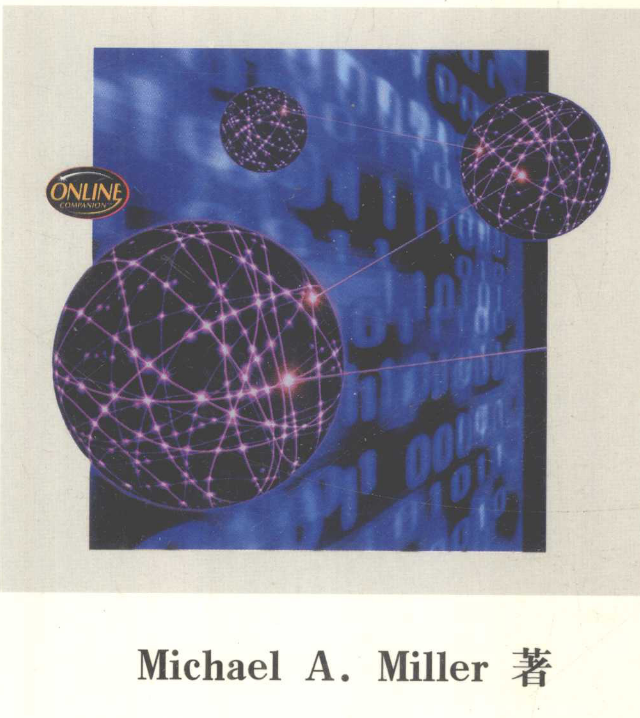
国外高校电子信息类优秀教材

数据与网络通信

Data and Network Communications

（英文影印版）



Michael A. Miller 著

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内 容 简 介

本书为国外高校电子信息类优秀教材(英文影印版)之一。

本书介绍了数据通信技术和电话系统、错误检测和修正的通用方法、两种开放系统网络层模型——OSI 和 SNA,重点是 OSI 模型的物理层和数据链接层、网络和传输层,并介绍了集成服务数字网络和路径协议、光纤网络及各种无线通信系统。

本书可作为通信专业的本科生教材,也可供相关专业技术人员参考。

Data and Network Communications

By Michael A. Miller

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Dedication

This book is dedicated to my wife, Ann, who had the patience to provide me the freedom and time to write it.

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Preface

This text on the data and network communications field is intended to be a junior or senior level text in an Electronics Technology or Technician curriculum offering one or more courses on the topic. A community college or proprietary school with a Communications specialty could teach this text's material to sophomores after a course in basic communications. In order to do justice to the numerous facets of the data and network communications fields, no one area is treated with the kind of depth necessary to produce telecommunications engineering technologists. It is intended, rather, to provide the electronics technician and technologists with sufficient background in data and network communications technology for a solid, thorough understanding of what is in the field.

It is expected that the student has had, or is familiar with, the topics in courses that cover the following material:

a) AM and FM Radio
b) Basic Communications
c) Basic Electronic Circuits and Devices
d) Basic Digital Circuits and Devices
e) Microprocessors and Basic Computer Architectures.

Chapter 1 starts by giving the student a general overview of the data communications area using a point-to-point data-link model. It lays the basis for future chapters by establishing some necessary fundamentals.

Chapter 2 deals with the telephone system from the standpoint of data transfer usage. Electrical specifications and impairments that require consideration when using the telephone system facilities for networking are also covered.

Chapter 3 provides details on some common error detection and correction methods used in data, digital, and network communications systems.

Chapter 4 presents the two most common open system network layer models for data communications networks, the open systems interconnection (OSI) and systems network architecture (SNA) models.

Chapter 5 presents protocols and specifications at the physical layer of the OSI model. It deals with a look at the hardware for low- and medium-speed data communications as interfaced through the telephone system. This includes discussions on UARTs, modems, RS232C, and other physical interfaces. Modulation techniques involving frequency, phase, and amplitude changes are also explored in relationship to communications interfacing. The chapter finishes with a brief discussion on V.32 and V.90 modems used to send and receive data at 28.8 Kbps and 56 Kbps.

Chapter 6 introduces the student to multiplexing communications channels into a single entity and to higher capacity data channel techniques. Included are time division, frequency division multiplexing, and a discussion on the concepts of T1 digital lines and the equipment used to monitor and test them.

Chapter 7 takes the student to the next layer of the OSI model, the data-link layer. Basic types of data-link protocols, the asynchronous data-link protocol and BISYNC are introduced followed by an indepth look at the bit-oriented SDLC/HDLC protocol.

Chapter 8 covers a wide variety of communications networks including local area networks (LAN) and the IEEE 802 standard for networking, which are discussed in detail in this chapter.

Chapter 9 deals with integrated services digital networking and routing protocols. These include ISDN, digital subscriber line (DSL), ATM, and Frame Relay protocols. These services are provided for combined services such as voice, video, and data to be transmitted simultaneously across the public services telephone network.

Chapter 10 provides discussion of an application of both the network and transport layers of the OSI model. These are amply represented in the most widely used network today, the Internet. This chapter will supply an overview of the Internet including security issues, and then launch into the details of the TCP/IP protocol that makes its existence possible.

Chapter 11 discusses fiber optics and fiber-optic networks. In a text of this nature, a single chapter on fiber optics cannot cover this vast subject in its entirety, which usually requires a separate tome. However, it is the author's intent to provide enough material on the topic so that the student obtains a good background on the subject.

Chapter 12 brings us to the concepts and applications of various wireless communications systems. It starts with an overview of microwave communications, moves into cellular telephones, wireless networks, and ends with a thorough discussion on satellite networks.

Five appendixes are provided:

Appendix A is a list of all the abbreviations and acronyms used in this text and in the data and network communications field.

Appendix B shows the complete extended ASCII character set.

Appendix C provides a network timeline from a historical perspective.

Appendix D gives a brief overview of facsimile (fax) transmissions that are considered "optional" in a data communications course. They are presented here for those instructors who feel they are still of some value.

Appendix E is a list of solutions to the odd numbered questions at the end of each chapter.

The author wishes to show his appreciation to the editors and assistants at Delmar: Greg Clayton, Michelle Cannistraci, Amy Tucker, et al. for their guidance and help during the writing and reviewing of this text. Additional thanks are extended to the professional instructors who took time to thoroughly review the manuscript and make the many suggestions that were incorporated into the book to make it more complete and accurate. Specifically, those reviewers are:

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Contents

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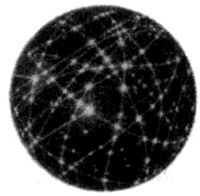
CHAPTER 1

Introduction to Data and Network Communications



OBJECTIVES

After completing this chapter, the student should be able to:

- discuss the history of data communications and networking.
- define basic data communications terminology.
- have an overview of a data communications system and its basic underlying characteristics.
- define the parts of a two-point communication model.
- realize the benefits of an open systems concept of communications modeling.
- define the character types represented in a binary character code.
- identify different data types, rates, and binary data formats.

OUTLINE

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1.2 Data Communications System
1.3 Communication Links
1.4 Character Codes
1.5 Digital Data Rates
1.6 Serial Data Formats
1.7 Encoded Data Formats

1.1 INTRODUCTION

Now that we are fully absorbed by the Information Age and spending more time communicating and gathering information through the Internet, it has become necessary to have a working knowledge of the technology behind the scenes. We are faced with terms like baud rate, modems, cellular phones, TCP/IP, ATM, ISDN, etc., and trying to make decisions about our communications needs involving the systems that these terms apply to. In order to develop a useful working understanding of this technology requires you to have a good understanding of the background technology and basics of data communications.

Historical Perspective

alphanumeric
printable characters in a character code, comprised of alphabet, numerical, and punctuation characters.

character code
binary code representing alphanumeric, formatting and data link characters.

continuous wave keying (CWK)
form of data transmission that uses the presence of a sine wave to represent a logic 1 and the absence, a logic zero. A form is used in Morse code where the duration of the signal represents a dot or a dash and the absence of the signal indicates no information is being sent.

The transfer of data in digital form began around 1832 with the advent of Morse code, a systematic code that represents the printable characters of a language using a form of binary data. These characters are letters, numbers, or punctuation marks and are called **alphanumeric** as a class. Combinations of dashes (long signals) and dots (short signals) were used to code each character. A collection of these combinations is known as a **character code.** For Morse code to work, a signal or electrical current is placed onto an interconnecting line between a sender and a receiver when a switch of the key is closed by the sender. Short key closures created dots while longer closures produced dashes. The form of data modulation using a sine wave voltage as the signal is called **continuous wave keying (CWK)** because the signal itself is a continuous audio oscillation that is placed on or off the line by use of the key. The switching on and off of a direct current (DC) in place of the audio signal is also referred to as keying. In the latter case, an electromagnetic relay is energized in the presence of the current and released when the key or switch opens and removes current from the line. The length of time the relay is energized determines if a dash or dot has been sent.

Morse code served as a primary means of communicating information across vast distances for a considerable amount of time. With the invention of the telephone in 1876 and the creation of the telephone company system a year later, quicker means of transferring data evolved. By 1881, long distance trunk lines connected major cities in the eastern United States, eventually resulting in the birth of Atlantic Telephone and Telegraph (AT&T) in 1885. The early use of the telephone system and its principal use today is for voice communication. However, it was soon discovered that binary data could be converted to voice signals and sent over the telephone lines. Different methods had to be developed to generate the data and voice signals from the sender and interpret them at the receiving end. One of those developments was an early type of printer/keyboard, created by the Teletype Corporation, which employed electromechanical relays to replace the action of the key. Instead of continuing with dots and dashes, these teletype machines used the presence or absence of a 20 ma current to represent binary data. The presence of the 20 ma current signifies a logic high or "one" state often called a **mark** and the absence of current, a logic low or "zero" state called a **space.** The current either energized or released a relay as described above. These teletype machines combined with equipment that allowed them to be interfaced to the telephone system, provided the machinery for the development of Teletype and Telex systems in the 1930s.

mark
logic 1.

space
logic 0.

baud rate
digital information transfer rate.

bits per second
rate at which raw serial binary data is sent and received.

bps
bits per second.

Teletype machines were slow, noisy, and consumed large amounts of power. The Teletype system used in the United States sent and received data at a **baud rate** of 110 bits per second (bps). Baud rate is a measure of the rate at which binary data are transmitted and received. Part of the basis for a baud rate is the number of binary digits or bits are sent within one second. This measure is called the bit rate and the measurement is known as **bits per second** or **bps.** Differences between baud rate and bit rate occur because they

raw binary data
digital data bits without any interpretation of meaning or use.

throughput
rate at which information is transferred from one point to another.

symbol
an electrical parameter used to represent one or more data bits.

define different but related information. The bit rate is a measure of **raw binary data,** which is the flow of binary bits with little concern to the actual content that they represent. Baud rate, on the other hand, is more of an information flow-through rate that factors in consideration about actual information data and noninformation overhead data.

Baud rate is a closer measure of information **throughput,** or the effective information data transfer rate from sender to receiver. Bit and baud rates are mathematically related with the result, for instance, that 110 bps baud rate actually translates to a binary bit rate of about 100 bps. It is easy to confuse baud and bit rate at lower data rates since they are both measured in bits per second.

As we get into higher data rates later on, we translate information rate into symbols per second or sps. A **symbol** is any element of an electrical signal that can be used to represent one or more binary data bits. The rate at which symbols are transmitted is the symbol rate in SPS. This rate may be represented as a systems baud rate in much the same manner that bits per second can be interpreted as a baud rate.

The tendency in studying data communications and, to a lesser extent, its application in the field, is to dismiss the differences between baud rate and bit or symbol rate. Many authors and working professionals use the terms interchangeably. For many low-speed applications the differences between them are insignificant. Thus 300 and 1200 bps modems originally used with personal computers were frequently referred to as 300 or 1200 baud modems. There is no problem here, since at these rates, one symbol is produced for each data bit, resulting in very similar numbers for bit, symbol, and baud rates. One note, some 1200 baud modems use a type of modulation scheme that produces two bits per symbol. In that case, there is certainly a difference between bit and symbol rates. Until the distinction becomes significant in a particular area under discussion, this text will consider bit and baud rate as being similar. This is not to minimize the differences, but a good many concepts are unaffected by them. Analysis of data transfer efficiency, rates, and bandwidth limitations is specified using baud rate. In those contexts the difference is critical.

The Telex system, used in Europe, was slower yet, ambling along at a mere 50 bps rate. These speeds were dictated by the need to operate the relays allowing them sufficient time to switch on and off. Additionally, since these machines were electromechanical in nature, they were highly prone to mechanical failures and constant adjustments and maintenance.

At about the same time, Marconi had invented radio transmissions and work was under way to establish wireless communications. The first amplitude modulated (AM) radio broadcasts as a commercial endeavor was radio station KDKA in Pittsburgh in 1921. By 1934 the United States government stepped in to regulate the growing additions to the nation's airwaves and the Federal Communications Commission (FCC) was born.

The Computer and Data Communications

Parallel work moving communications toward today's information highway involved the computer, for without it we would still be keying in a lot of data by hand. The idea of doing math calculations using binary numbers had been toyed with by the telephone company's research arm, Bell Labs, for a number of years before a teletype machine was interfaced to one of these electronic calculators in 1940. What emerged from this marriage was the electronic computer. Data could be entered in from the teletype machine keyboard, processed by the calculator, and the results printed out on the teletype printer. Like the teletype machines, the calculator portion was derived from more relays because the binary system could easily be represented by a closure (logic 1) or open (logic 0) state of the relay. The first computers, the ENIAC Mark I and II were huge systems occupying many rooms and consuming large amounts of power to operate them.

The next big break came in 1947 with the invention of the transistor. Many functions of the relays had been replaced by vacuum tubes. These devices were improvements over relays since they no longer had movable parts, but they still consumed a lot of power. In addition, the vacuum tube, which required a filament element to produce heat to "agitate" electrons into movement, required air conditioned rooms to dissipate the heat they generated. The transistor provided all kinds of relief—no moving parts, much less heat created, small in size, and less expensive to make. It was what the computer world was waiting for.

Several different events in the 1950s impacted the future of data communications. One was the production of the first computer by International Business Machines (IBM)—big blue was launched. IBM became the leading producer of mainframe computers in the world, setting standards for many others to follow for years. The next big impact was heralded throughout the world as Russia launched the first satellite, Sputnik 1, in 1957. Today the greatest percentage of our daily communications is carried by communications satellites covering the globe. A less heralded event than Sputnik I, but one with as much influence on how we communicate, occurred in 1958 with the first coast-to-coast microwave radio link in Canada. Also that year, America entered the space race by launching Explorer 1, beginning many years of space insanity and rapid technological advancements.

Integrated circuits arrived in 1959 along with the first mini-computer, the PDP-1, based on the UNIX operating system. An operating system (OS) is a computer program that is used to configure the computer so that it can be used. Operating systems also provide utility programs that allow users to perform basic tasks by typing commands directly on the computer's command line. Communication satellites were launched into operation beginning in the 1960s. During this period small solid-state lasers are developed along with fiber optic cables that are used to carry the light generated by these small lasers leading to communications by light waves.

The Telephone System

Up to the year 1968, if a vendor wanted to connect communications equipment to the telephone company's system, they had to rent the interface equipment from the telephone company. Many of these companies felt that this was unfair and led to a monopolizing of the phone system by AT&T. In response to the pressure from these companies, the government, through the Federal Communications Commission (FCC), produced Rule 67. This was a voluminous document, which clearly specified what a company had to do to be allowed to directly connect equipment to the phone company network. Despite the numerous rules and specifications detailed in that ruling, a number of manufacturers did proceed to develop and market modems for the purpose of allowing two computers to send and receive data over the telephone lines. A **modem** is a device that converts between the serial

modem
unit that converts between digital data and analog data.

digital data form produced by a computer to a form of analog signal that can be sent through the telephone voice circuits. On the receive side of the communications line, a modem reverses the process, returning the analog data back to serial digital data.

Microprocessors and PCs

There is no doubt that the information age would never have emerged without the appearance of the microprocessor in the early 1970s. INTEL is credited with producing the first line of commercial microprocessors, starting with the 4004 and 8008. Over the years the industry has dutifully tracked INTEL's progress as each new microprocessor generation brought new and more powerful computers for our use. However, INTEL's processors were not the ones used to launch the personal computer into existence. Instead, an offshoot company, called ZILOG founded by three ex-INTEL engineers, developed the Z80 microprocessor used by an electronic hobby outfit called Radio Shack that resulted in the TRS-80 personal computer. The TRS-80 used a language called Basic, which was written by a pair of professors at Dartmouth College as a teaching language. Programs were entered by hand from the keyboard and later through an audio cassette interface.

Networking

At about the same time as the TRS-80 was introducing the world to personal computers, the first data local area network (LAN), called ETHERNET was deployed to interconnect mainframes with terminals throughout a building. It was not long afterwards that Compuserve, one of the first of many bulletin board services, arrived to bring information into home owner's personal computers via telephone lines and modems.

In 1975 Bill Gates started Microsoft and in 1976 Steve Jobs and Stephen Wozniak began Apple. The computer industry was off and running. IBM entered the PC battles in 1981 and began to dominate the market as it had with mainframes. Apple remains its chief competitor, and in 1983, brought out the first graphic user interface (GUI) with the LISA computer. Microsoft responds with Windows 1.0 in 1985, which was a poor system in comparison. To round off the beginnings, add the inclusion of NETWARE 286 by NOVELL for interconnecting personal computers into a local area network (LAN).

Data rates for transmission have been on the rise. Early modems connected to personal computers ran at 300 bps. By 1987, 9600 bps modems were available. Networks, too, improved rapidly. Novell revised Netware for the 386 microprocessor-based IBM PC with NETWARE 386 in 1989. A fiber optic network, *fiber distributed data interface (FDDI),* came into being to handle faster data transfers. Networking across the telephone system gets a boost in 1990 from the Integrated Services Digital Network, or ISDN, which carries voice, binary data, and video information on the telephone lines.

Today, we have advanced versions of Windows that are adapted to network use and are vastly improved over the earlier versions. A number of companies are vying for the pieces of the network pie, making all kinds of super programs available to the endusers as a result. Not to be dismissed is the impact of the Internet on everyone's life. If nothing more, the amount of advertisement that ends with an Internet address is staggering. Every magazine has a "web site."

The Internet

The Internet, which we have ignored to now, has been an ongoing system during this entire time period. Developed in the late 1950s as a network to share research information between military and university researchers. By 1984, it serviced approximately 1,000 users. As network technology improved, the number of users increased tenfold by 1988. When the system was opened wide for any users, its use escalated well beyond the projections anyone had to over one million users in 1992, up to 3 million in 1994 and 6 million a year later. What lies behind the popularity of the Internet is the access to all kinds of information at a reasonable cost to the user. You can shop on the Internet, make airline reservations, get educated, just plain chat, look up all kinds of information, entertain yourself with all kinds of amusements, and exchange ideas with people of like interests. The Internet is Highway 1 of the information super highway—welcome to the information age.

A more concise timeline list of events that impacted on the data communication and network industry is offered in Appendix F at the back of the book. A lot of additional items are included that were not discussed in the brief coverage in this section.

Section 1.1 Review Questions

1. What is an early data communications system that uses continuous wave modulation?
2. What do mark and space tcnes represent?
3. What is used as a measure of serial data rate?
4. What function does a Modem provide?
5. What is the first data local area network (LAN)?

1.2 DATA COMMUNICATION SYSTEM

Data Communications Link

node
entry point into a network.

primary station
controlling station in a network.

remote or **secondary station**
non-controlling station in a data link.

line control unit
controls the interface of peripheral devices to the data terminal.

The components of a basic communications link between two endpoints, or **nodes,** is illustrated in Figure 1-1. A node is any connection point to a communications link. For this two-point network, the node points are the **primary station** and the **remote** or **secondary station** at the other end of the communications link. Station refers to any section of hardware whose purpose is to communicate with another piece of communications hardware at a different location. Data link refers to the process of connecting or linking two stations together.

A primary station is responsible for establishing and maintaining the data link between it and a secondary station. Data sent from one station to another usually originates in parallel binary form from one or more peripheral devices connected to that station through a **line control unit.** This unit supplies the interface to the communications station and control of peripheral devices including, but not limited to, computer terminals, printers, keyboards, facsimile (FAX) machines, and data display terminals.

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