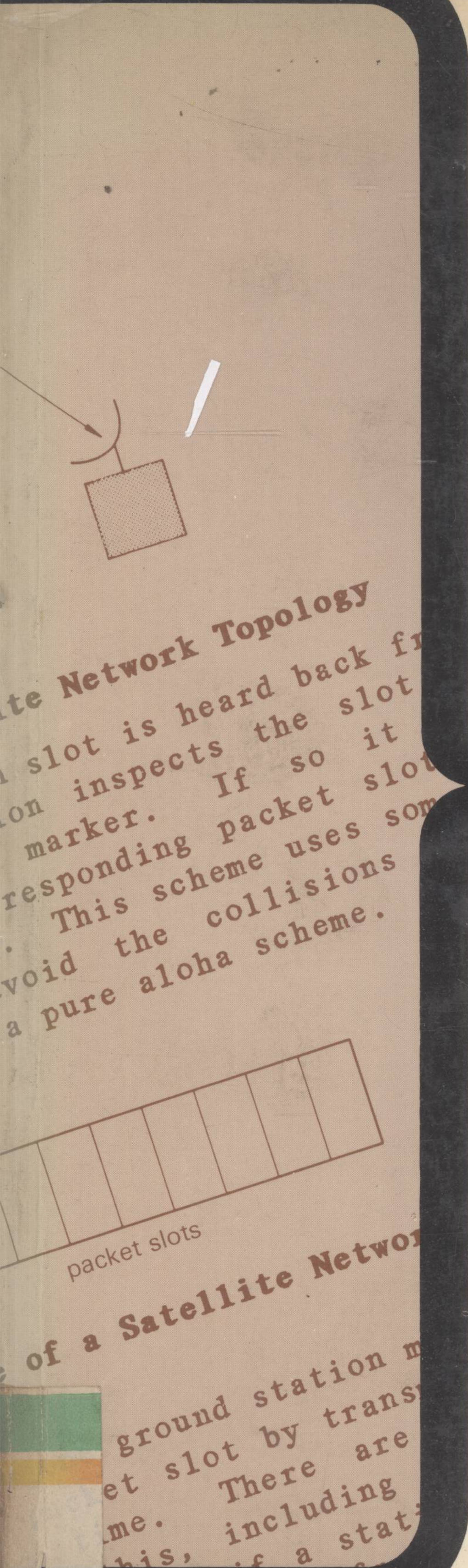

Computer Communications

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Preface

The subject of computer communications is changing very rapidly. Improvements in terminal access, aligned with the development of timesharing, has brought hands-on experience to a large number of non specialist users. Computer networks have made available vast computing resources and data banks to these users. This book is for anyone familiar with using computers who wishes to understand the techniques used in computer communications. It is also an introduction to the architecture of present day computer communication systems.

I would like to thank Roland Ibbett, Steve Treadwell, Peter Kirstein and Del Thomas for their invaluable advice and encouragement. My thanks also to Malcolm Stewart and the staff at Macmillan. The late Gareth Pugh encouraged my interest in computer communications and provided the opportunity to develop the material for this book. The text was formatted on a UNIX computer system: I am grateful to Professor Kirstein for permission to use this system. I am indebted to NEC Telecommunications Europe for the use of a spinwriter printer on which the master copy was produced.

Finally, no amount of words can express my debt to Jo and Rosemary for patiently bearing with this project over the last three years.

Contents

1 Introduction

This text is concerned with the way computer-based information is transferred over long distances, and with the organisation of the communication system to meet various needs. A computer system usually consists of a CPU, memory, peripherals (on site) and communication devices. These are normally connected together by one or more short, high speed, data highways (figure 1.1). Computer organisation around the data highway is one of the topics of computer architecture. This book assumes the reader has some knowledge of computer system organisation and is familiar with using a computer. The subject of computer communications involves the problems and solutions of transporting data over distances longer than the internal computer data highway. For practical purposes we will treat a communications device as a piece of equipment that is used to transfer computer data to other equipment outside the computer room. There are exceptions of course: for example the computer console terminal may use communications techniques covered in this book, and some devices such as tape drives and large discs may be 'outside' the computer room. Figure 1.2 shows the various types of communication arrangements that will be covered. Each type of organisation and the techniques used for the device and the computer to exchange information will be dealt with.

The increase in the organisational complexity of computer communications reflects the trend in computing overall. Increased computing power, the cost of which is falling, is enabling the more efficient usage of resources, such as communications devices, the cost of which is rising. Even where communications costs are falling the cost of computing power is falling faster. This theme can be seen as a growing trend throughout the book. As all communications uses limited bandwidth channels, more and more complexity is added to the

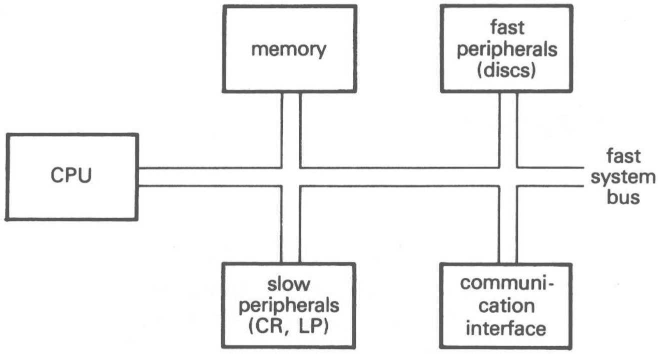

Figure 1.1 **Computer System Components**

communications system to obtain the maximum efficiency from the communications channel. Increasing the system complexity requires more computing power, but the cost of extra processing is outweighed by the improved efficiency of the system.

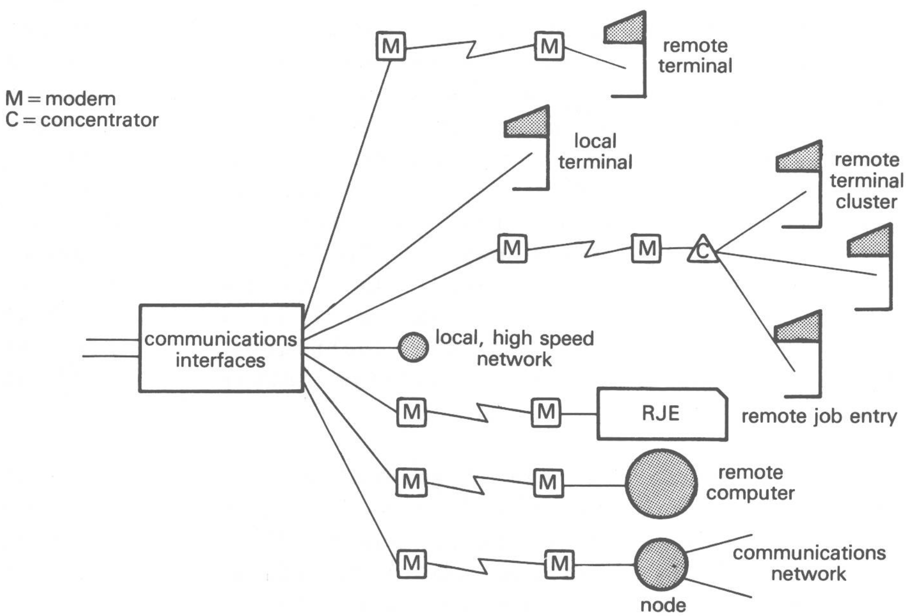

Figure 1.2 **Communications Systems**

This text uses a 'bottom up' approach, by explaining the basic principles of data communication and applying them to a physical application first, then covering more complex organisations and eventually reaching computer networks.

Throughout the book various different techniques are explained, and their advantages and disadvantages pointed out. The reader is asked to compare techniques and realise that there are situations where one technique is more useful than another but that full consideration should be given to all factors before deciding. The factors affecting the usage of various techniques are an important consideration of the book.

The text begins in chapter 2 by looking briefly at some transmission theory, mainly to establish that there is a limit on the rate at which information may be transferred in a medium, indicating that the medium is a resource which needs to be used efficiently. The use of wire as a medium is investigated as far as transferring characters is concerned. Chapter 3 looks at the particular problems of using the Public Switched Telephone Network (PSTN), and why the PSTN is so important in communications. Chapters 2 and 3 cover the use of the two most common media for actually transferring data. Chapter 4 goes on to look at the organisation of terminal networks and multiplexing techniques that can be used to optimise the use of a communications medium.

The use of messages rather than single characters as a unit of data transfer is taken up in chapter 5, which also introduces the idea of a protocol. Distributed computing as a part of communications is discussed briefly in chapter 5. The impact of errors and their unavoidability is pointed out in chapter 6, with the techniques used to try to discover and recover from errors. As most message-based protocols use a combined error recovery and flow control technique, the use of flow control is shown at the end of chapter 6.

The various technologies used in packet switched computer networks are introduced in chapter 7. Chapter 8 is concerned with with the X25 network access protocol. In chapter 9 the host-to-host protocols are introduced and some discussion of the host-network interface is given. Chapter 10 introduces some problems in computer network organisation by treating a network as a system and looks at techniques for optimising the system performance.

The text is designed as an introduction to the various techniques of computer communications, and the interested reader is encouraged to pursue the further details of the techniques. A bibliography of books and collections of introductory papers is given as a starting point for deeper study.

2 *Transmission in Wires*

The point at which computer communications and electronic data transmission overlap is in the transmission of data in wires. Virtually all computer communications involves the use of wire. The few exceptions are very high speed transfers using waveguides, optical fibres and radio frequencies.

To transfer information three components are needed: a sender, a receiver and a suitable medium. In this chapter we will concentrate on the principles of how to use a suitable medium for computer data communications.

2.1 Information Channel Theory

Waves are used to carry information through most media, especially those being used in real time. A book does not communicate in real time as the reader cannot respond by asking questions and the author cannot respond to the reader by attempting to answer them. A conversation is a real time communication. The simplest wave possible is the sine or cosine wave. Each wave has three characteristics: amplitude, frequency and phase.

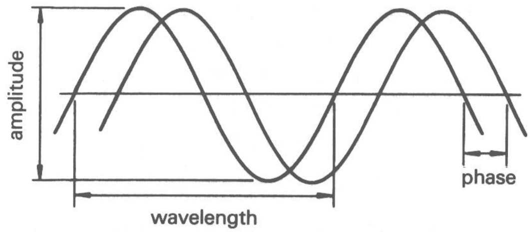

Figure 2.1 **Simple Signal Wave Components**

Figure 2.1 shows the simple wave and its components. Amplitude is an absolute measure of the height of the wave, the units depend on how the height is measured and in what medium it occurs. For instance a voltage wave

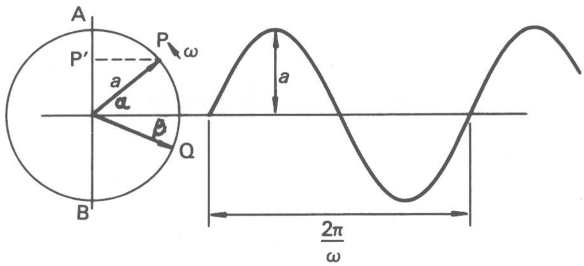

Figure 2.2 **Generation of a Simple Wave**

in a piece of wire would have its amplitude measured in volts, a sound wave travelling through the air would have an amplitude measured in millibars. The frequency is an absolute measure - for our purposes it is the number of times a wave shape repeats in a second. The phase is a relative measure: it is the difference in time between two waves. The phase difference of two waves is normally given as an angle, as will be explained later on. Amplitude, frequency and phase are important in data communications because they are used to code information using modulation, which is described in the next chapter. To understand phase and frequency in a simple wave look at figure 2.2, which shows how a simple (sine) wave can be made by projecting a rotating arm on to a plane.

Imagine that a chart recorder is moving through **AB** and the pen marks the projection **P'** of the point **P** moving round the circle at constant speed. Assume that when the time (t) is zero **P** lies on the x axis ($\alpha = 0$ radians). If **P** rotates at a constant velocity of ω radians/second then at any time t the angle α is

$$\alpha = \omega t \quad \text{radians} \qquad (2.1)$$

The projection on to **AB**, which is drawn on our chart, and shown on the right of the circle is (from equation 2.1)

$$a \sin(\alpha) = a \sin(\omega t) \qquad (2.2)$$

When **P** has completed a revolution it begins to repeat the pattern, one revolution or cycle drawing a complete pattern or wave. One revolution consists of 2π radians; the time taken for that revolution is $(2\pi)/\omega$ seconds. The frequency of a wave is the number of revolutions in a second, which is the inverse of the time for one revolution

$$\text{frequency} = \omega/(2\pi) \tag{2.3}$$

Now consider a second point **Q** which sets off at the same speed as **P**, and therefore has the same frequency, but at a point β radians away from **P**. The difference between the two waves is one of phase, **Q** is β radians out of phase with **P**. Phase can only be measured between two waves.

Any two simple waves having the same amplitude and frequency, and with a phase difference of zero are equal and indistinguishable. Information can be coded and transmitted in waves by changing the values of one or more of the components. Speech involves using frequency to get high or low sounds, amplitude to get loud or quiet sounds and combinations of amplitude, frequency and phase to make sounds, words and sentences carry information through air.

Information

At this point we should consider what is meant by information. The transfer of information between a sender and receiver is the purpose of a communication. Consider the analogy of sound: it is possible to hear sounds which have no meaning at all (they contain no information), apart from their presence. When we hear speech it usually means something, provided it is clear enough and in a suitable language. The purpose of computer communications is to transfer information between various pieces of computing machinery, though other signals not containing information may also be present. The term 'information' represents an abstract concept; for information to be transferred it has to be represented by something more substantial that can be carried. In computer communications, as in computers, the information is usually coded as patterns of bits.

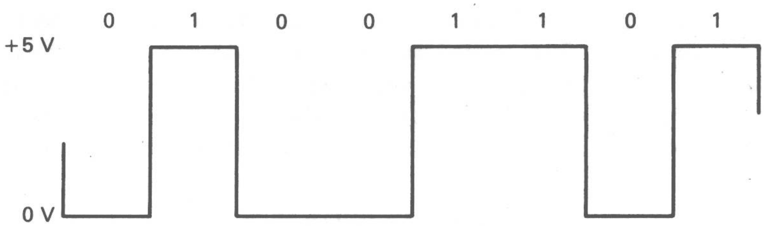

Figure 2.3 **Square Wave Coding of a Bit Pattern**

In a medium such as wire these bit patterns can be represented by voltages using only two values, say 0 volts and +5 volts. The use of two value signals leads to 'square waves', so called because when the signal changes it produces a characteristic 'square' shape when displayed on a graph or oscilloscope. Figure 2.3 shows a square wave and the information that it could represent.

A regular square wave is one that changes its signal level (or displacement) regularly with time. The frequency of a regular square wave is the inverse of the time between one signal level change and the next level change in the same direction. From figure 2.3 it can be seen that a wave carrying information does not change regularly but depends on the information. Usually the frequency of a square wave carrying data is the maximum possible number of changes, this is equivalent to data of alternate 1s and 0s (01010101...). A signal such as that in figure 2.3 is called digital because it has only a few values for the amplitude (in this case +5 V and 0 V). The term 'digital' distinguishes a square wave from a continuous wave called 'analogue'. The wave in figure 2.1 is analogue as it has a smoothly changing displacement. A square wave is a digital signal.

Square waves, and in fact waves of any shape, can be shown to be made up of simple sine and cosine waves, such as those in figure 2.1. Each constituent simple wave will differ from the others in its values of amplitude, frequency and phase. A square wave which repeats itself every second has a frequency of 1 Hz (Hz is the unit symbol for hertz; that is cycles or