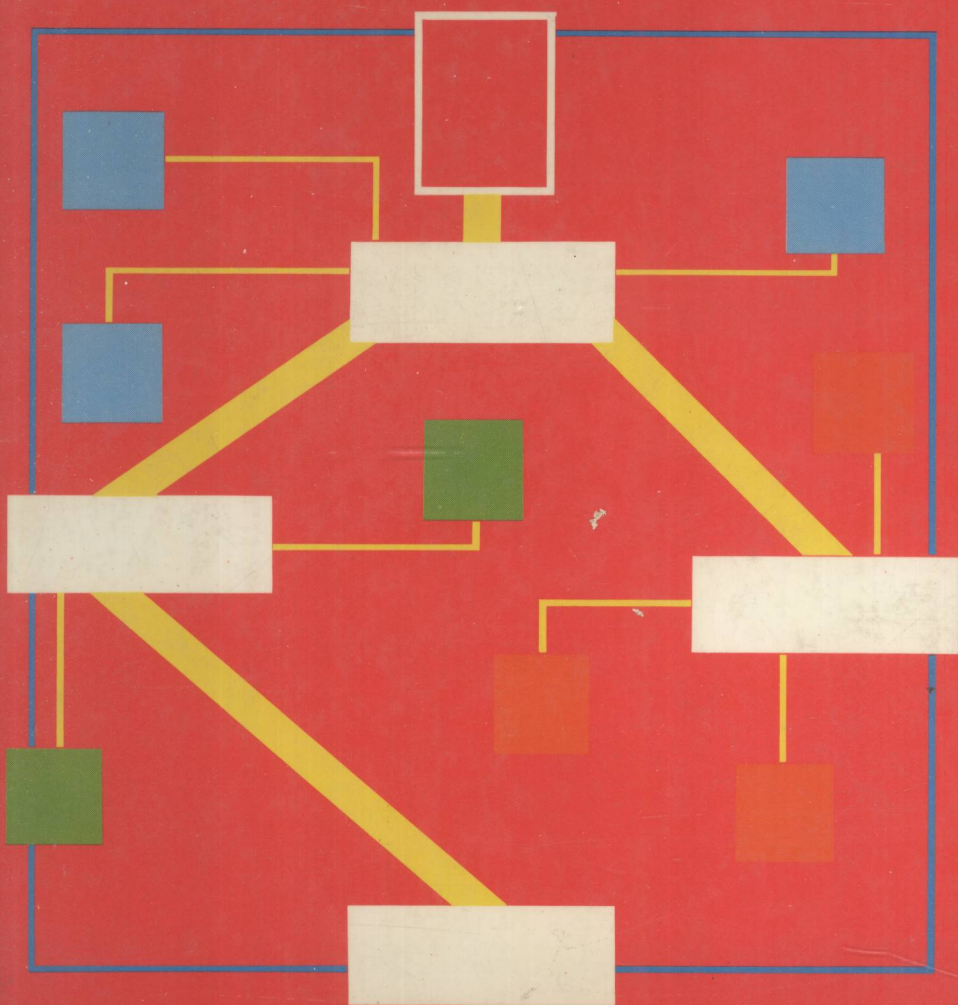


# ***LOCAL AREA NETWORKS***

## ***and their applications***



***BRENDAN TANGNEY DONAL O'MAHONY***

---

# **LOCAL AREA NETWORKS**

---

and their applications

**Brendan Tangney    Donal O'Mahony**

Trinity College, Dublin



**PRENTICE HALL**

New York

London

Toronto

Sydney

Tokyo

First published 1988 by  
Prentice Hall International (UK) Ltd,  
66 Wood Lane End, Hemel Hempstead,  
Hertfordshire, HP2 4RG  
A division of  
Simon & Schuster International Group



© 1988 Prentice Hall International (UK) Ltd

All rights reserved. No part of this publication may  
be reproduced, stored in a retrieval system, or  
transmitted, in any form or by any means, electronic,  
mechanical, photocopying, recording or otherwise,  
without the prior permission, in writing, from the publisher.  
For permission within the United States of America  
contact Prentice Hall Inc., Englewood Cliffs, NJ 07632.

Printed and bound in Great Britain by  
A. Wheaton & Co. Ltd, Exeter

---

*Library of Congress Cataloging-in-Publication Data*

---

Tangney, Brendan, 1960—  
Local area networks and their applications/  
Brendan Tangney, Donal O'Mahony.  
p. cm.  
Bibliography: p.  
Includes index.  
ISBN 0-13-539578-X  
I. Local area networks.  
I. O'Mahony, Donal, 1961—  
II. Title.  
TK5105.7.T36 1987  
004.4'8—dc19

---

---

*British Library Cataloguing in Publication Data*

---

Tangney, Brendan  
Local Area Networks and Their Applications.  
I. Local area networks (Computer networks)  
I. Title II. O'Mahony, Donal  
004.6'8 TK5105.7  
ISBN 0-13-539578-X  
ISBN 0-13-539560-7 (PBK)

---

---

# PREFACE

---

In the early 1970s, a trend began in computing away from large centralized mainframes towards smaller departmental minicomputers. The first micro-processor system was introduced around 1971 and since then cheaper and more powerful machines have appeared on the market. This trend gathered momentum and has developed into a definite movement towards single-user workstations.

One of the disadvantages of this is that facilities that were available on larger, centralized systems were lacking in the new workstation approach. These included the ability to share information, send messages from one user to another, and, most importantly, to share access to peripheral devices, e.g. printers, disks and so on.

While computing devices were getting smaller, cheaper and more powerful, advances were also being made in communications technology. In particular a new generation of networks emerged which operated in a limited geographical area, but much more reliably and at higher data transmission rates than previous networks.

The introduction of these high speed **local area networks** (LANs) opened up the possibility of attaining the advantages of workstations without losing those of centralized mainframe systems. Information could flow between individual workstations at speeds which, to a large extent, hid the fact that they were not working on the same system.

This book examines these two aspects of local networks. Part One discusses the components that go to make up a local network. Part Two looks at the higher level software that is necessary to exploit the capabilities of a 'distributed' computing system, that is one composed of a number of individual machines connected by such a LAN.

The book is suitable for use as a higher level undergraduate and post-graduate textbook. The treatment of LANs is fairly detailed and the second section serves as an introduction to distributed computing. It will also provide valuable, up-to-date knowledge for computer professionals involved in planning and implementing LANs within their organization. No prior knowledge of networks is assumed, but a basic understanding of the field of data communications and computer operating systems will be helpful. The remainder of this preface explains the layout of the book in a little more detail.

Part One of the book begins by defining what exactly we mean by the term 'network', and how a 'local area' network is distinguished from other types. Chapters 2, 3 and 4 will cover the choices available in terms of communications media, the ways in which the machines are connected (topology), and how orderly transmission is carried out (the access method). As an illustration of the techniques covered, Chapter 5 will discuss how some of the better known LANs (e.g. Ethernet, IBM's Token Ring and the Cambridge Ring) are implemented using the previously described techniques. In Chapter 6 the concept of layered protocols is introduced and we examine some of the standards that have been developed in this area.

Part Two of the book concentrates on the details of LAN-based computer systems. It begins in Chapter 7 by analyzing what the essential differences are between running a centralized system and one made up of many interlinked machines. The concept of sharing resources between nodes on a network is introduced. Chapter 8 introduces the notion of the 'client/server' model, a widely used technique for organizing access to resources. Chapter 9 focuses on one very important type of server, namely 'file servers'. This is followed in Chapter 10 by an introduction to the concept of a 'distributed system', it explores some of the issues involved in building one, and looks at some example systems including CMDS, the Newcastle Connection and Locus. We complete the section by discussing how LANs can be used in the office and factory environments.

The following are trademarks: UNIX (A T & T Bell Laboratories); DEC and DECnet (Digital Equipment Corporation); Ethernet (IBM); WangNet (Wang Corporation).

## ACKNOWLEDGEMENTS

David Brownbridge, David Hutchison and Les Smith for comments on early versions of the manuscript. Maggie McDougall and Abigail Cooke for editing and production. Stephen and Neville for inspiration, our parents for opportunity. But above all, Tricia and Mary for patience, support, encouragement, etc.

---

# CONTENTS

---

Preface	ix
Acknowledgements	x

## Part One LOCAL AREA NETWORKS

<b>Chapter 1</b>	<b>What is a LAN?</b>	<b>3</b>
1.1	What is a network?	3
1.2	Working definition of a LAN	4
1.3	Classification of LANs	4
1.4	References	5
<b>Chapter 2</b>	<b>Transmission Media and Techniques</b>	<b>6</b>
2.1	Data transmission techniques	6
2.1.1	Baseband transmission	7
2.1.2	Modulated transmission	8
2.1.3	Broadband transmission	8
2.2	Choice of medium	9
2.2.1	Copper versus optical media	9
2.2.2	Suitability for data traffic	9
2.2.3	Noise problems	10
2.3	Twisted pair cable	11
2.4	Coaxial cable	12
2.5	Optical fibers	12
2.6	Other media	13
2.7	Summary	14
2.8	References	14
<b>Chapter 3</b>	<b>Network Topologies and Wiring Considerations</b>	<b>15</b>
3.1	The star or radial topology	16
3.1.1	Advantages of the star	16
3.1.2	Disadvantages of the star	18

---

3.2	The bus topology	18
3.2.1	Advantages of the bus topology	18
3.2.2	Disadvantages of the bus	19
3.3	The ring topology	20
3.3.1	Advantages of the ring	20
3.3.2	Disadvantages of the ring	21
3.4	Hybrid topologies	21
3.4.1	The tree topology	21
3.4.2	The star-ring topology	23
3.5	Conclusions	24
3.6	References	25
<b>Chapter 4</b>	<b>Network Access Control</b>	<b>26</b>
4.1	Packet format	27
4.1.1	Preamble or start-of-packet indicator	27
4.1.2	Addressing information	28
4.1.3	Control information	28
4.1.4	Data field	29
4.1.5	Error check	29
4.2	Sharing the medium	29
4.3	Contention-based access methods	30
4.3.1	Multiple access	30
4.3.2	Carrier sense multiple access (CSMA)	30
4.3.3	Carrier sense multiple access with collision detect (CSMA/CD)	31
4.3.4	Register insertion	31
4.4	Non-contention based access methods	34
4.4.1	Slotted rings	34
4.4.2	Token passing	35
4.5	Comparison between CSMA/CD and token passing	39
4.6	Conclusions	40
4.7	References	41
<b>Chapter 5</b>	<b>LAN Implementations</b>	<b>42</b>
5.1	Introduction	42
5.2	Ethernet	42
5.2.1	Physical layer	43
5.2.2	Datalink layer	46
5.2.3	System parameters	48
5.2.4	Broadband Ethernet and other developments	49
5.3	The Cambridge Ring	49
5.3.1	The physical layer	50
5.3.2	The data link layer	51
5.3.3	The packet protocol	56
5.4	IBM's local networks	56
5.4.1	The PC Network	57
5.4.2	The token ring network	59

---

5.5	WangNet	73
5.5.1	WangNet cabling	73
5.5.2	Bandwidth allocation	74
5.5.3	WangNet summary	76
5.6	Micronets	76
5.6.1	AppleBus	77
5.7	PBX systems	78
5.7.1	Techniques used	79
5.7.2	PBX summary	79
5.8	References	79
<b>Chapter 6</b>	<b>Communication Protocols</b>	<b>81</b>
6.1	Layered protocols	84
6.1.1	Functionality of layers	84
6.1.2	Flexibility	86
6.1.3	Virtual circuits and datagrams	87
6.2	Proprietary network architectures	88
6.2.1	Systems network architecture	88
6.2.2	Digital's network architecture	91
6.3	Non proprietary standards	93
6.3.1	Open systems interconnection (OSI)	93
6.3.2	IEEE Project 802	96
6.3.3	Cambridge Ring-related standards	98
6.4	Layered architecture implementations	99
6.4.1	IMB LAN software	100
6.4.2	DECnet	104
6.4.3	TCP/IP	106
6.5	Lightweight protocols	107
6.6	Communication protocols summary	108
6.7	References	109

## **Part Two DISTRIBUTED SYSTEMS**

<b>Chapter 7</b>	<b>Utilizing a LAN</b>	<b>113</b>
7.1	Motivation	113
7.2	Advantages of LANs	114
7.3	Properties of centralized systems	116
7.4	Problems with LANs	116
7.5	Sharing	117
7.6	Examples	117
7.6.1	File transfer	118
7.6.2	Office automation	118
7.6.3	Industrial control	118
7.6.4	Distributed systems	118
7.7	Summary	119
7.8	References	119



---

<b>Chapter 8</b>	<b>Network Servers</b>	<b>120</b>
8.1	Introduction	120
8.2	Resource sharing	120
8.3	The client server model	121
8.4	Communication aspects	122
8.4.1	Print server	123
8.4.2	Terminal server	124
8.4.3	Disk server	125
8.5	Disk server implementations	125
8.5.1	Client machine implementation – local disk	126
8.5.2	Client machine implementation – remote disk	126
8.5.3	Disk server implementation	127
8.5.4	Shared areas	128
8.6	Transparency	130
8.7	Summary	130
8.8	References	131
<b>Chapter 9</b>	<b>File Servers</b>	<b>132</b>
9.1	Introduction	132
9.2	File server interface	132
9.3	Issues	135
9.3.1	Independent failure modes	135
9.3.2	Protection	135
9.3.3	Robustness	137
9.3.4	Replication	137
9.3.5	Transactions	141
9.3.6	Protocol and performance issues	156
9.4	Example systems	159
9.4.1	Felix	159
9.4.2	Netware	160
9.4.3	ISO file transfer and access management (FTAM) protocols	160
9.5	Summary	162
9.6	References	162
<b>Chapter 10</b>	<b>Distributed Systems</b>	<b>163</b>
10.1	Approaches to building a distributed system	164
10.2	The server versus the integrated model	165
10.3	The importance of the file system	166
10.4	Issues	167
10.4.1	Naming	167
10.4.2	Transparency	170
10.4.3	Control	172
10.4.4	Communication aspects	172
10.4.5	Languages	181
10.4.6	Application domain	182

---

10.5	Examples	182
10.5.1	CMDS	183
10.5.2	The Newcastle Connection	189
10.5.3	Locus	195
10.6	Summary	200
10.7	References	200
<b>Chapter 11</b>	<b>Office and Factory Automation</b>	<b>202</b>
11.1	Office automation	202
11.2	Office communications	203
11.2.1	The telephone	203
11.2.2	Video conferencing	204
11.2.3	Printed documents	204
11.2.4	Document storage	205
11.3	Office automation summary	206
11.4	The IBM approach	206
11.4.1	Document interchange architecture (DIA)	207
11.5	X.400 message handling system (MHS)	211
11.5.1	The X.400 model	211
11.5.2	Message content	212
11.5.3	Relationship to the OSI model	212
11.5.4	Application in LANs	213
11.5.5	Summary	213
11.6	Factory automation	213
11.7	Manufacturing automation protocol	215
11.8	The ISO subset	215
11.8.1	The physical layer	215
11.8.2	The datalink layer	216
11.8.3	The network layer	217
11.8.4	The transport layer	218
11.8.5	The session layer	218
11.8.6	The presentation layer	218
11.8.7	The application layer	218
11.9	Elements of MAP networks	220
11.9.1	The MAP backbone architecture	221
11.9.2	The MAP cell architecture	222
11.10	Summary of MAP	224
11.11	The technical and office protocol (TOP)	225
11.12	Summary	226
11.13	References	227
Appendix A	Differential Manchester encoding	228
Appendix B	Error checking	230
Appendix C	TCP/IP	231
Index		241

PART ONE

---

# **LOCAL AREA NETWORKS**

---



## CHAPTER ONE

---

# WHAT IS A LAN?

---

A concise definition of what constitutes a local area network is difficult to produce. An easier approach is to first define what a computer network is, and then to distinguish LANs as a subset of these. When the term computer network was first used, it described any interconnections between computers. Since that time, three subclasses have emerged that are distinguished primarily by their geographical scope.

The first of these is the *wide area network* (WAN). This network spans a large area—possibly several continents. The second major type is the *local area network* (LAN) and, as the name suggests, it is confined to relatively small areas such as a building or a group of buildings, for example a university campus. A third type, which is just emerging at the time of writing, is the *metropolitan area network* (MAN). The scope of this class of network lies between LANs and WANs, i.e. spanning a small city or a town.

In naming these types of network, the main distinguishing factor would appear to be the size of the area covered. This factor has major effects on the technology used to implement the network, its administration and the type of applications that can be implemented on it. The ramifications of these factors will emerge in the course of this book.

### 1.1 WHAT IS A NETWORK?

Tanenbaum [1] defines a network as ‘an interconnected collection of autonomous computers’. Two computers are said to be interconnected if they are capable of exchanging information. Central to this definition is the fact that the computers are *autonomous*. This means that no computer on the network can start, stop, or control another. This excludes from our definition any system where terminals or other peripheral devices are connected to a central host: for example, an IBM 370 configured with multiple 3270 terminals connected to it.

Another type of system that we exclude from our discussions is where two or more processors are connected together via either a common bus or an area of shared memory. While this may conform to the definition above, the problems involved differ significantly from other types of networks.

## 1.2 WORKING DEFINITION OF A LAN

Having defined what is meant by a network, the next task is to distinguish between LANs and WANs. LANs are different in the following important respects.

- The distance between the nodes is limited. There is an upper limit of approx 10 km, and a lower limit of 1 m.
- While WANs usually operate at speeds of less than 1 mega-bit per second, LANs normally operate at between 1 and 10 mbps. Using optical fiber technology, it is possible to achieve speeds of the order of hundreds of megabits per second.
- Because of the short distances involved, the error rates in LANs are much lower than in WANs. This extra reliability has an impact on both the protocols used in their operation and the range of applications that they can support.
- The distance limitations involved in LANs normally mean that the entire network is under the ownership and control of a single organization. This is in sharp contrast to WANs, where the network typically spans national boundaries. In this case, the network is normally operated by the country post and telecommunications authorities rather than by its users.

This fact has no bearing on the performance of the LAN, although it does have a major impact on the way in which it is administered. The localized control of the facility greatly increases flexibility.

It can be seen from the above, that LANs differ from other types of network in that the area that they cover is limited. This means they can operate at high speeds and with very low error rates. These two properties are the main distinguishing features of LANs.

The first local networks were introduced into the academic world in the mid-1970s and, as the technology developed, they were adopted by the major computer manufacturers. By the early 1980s, most major hardware companies were offering LAN-based products. At the time of writing, the lower level aspects of LANs are starting to stabilize. Of the many approaches advocated by the researchers, a select few are becoming international standards, and are being adopted by computer users.

## 1.3 CLASSIFICATION OF LANS

There are many different network implementations that conform to the above criteria, each adopting a different approach. To distinguish between different

---

types of LAN, one usually examines three things: the media used to connect the nodes, the pattern of connection or *topology*, and the algorithms used to control access to the medium. The next three chapters will examine each of these in some detail before going on to see how companies and researchers have implemented them in Chapter 5.

## 1.4 REFERENCES

- 1 Tanenbaum, A.S., *Computer Networks*, Prentice Hall Inc., Englewood Cliffs, New Jersey, 1981.

## CHAPTER TWO

---

# TRANSMISSION MEDIA AND TECHNIQUES

---

As with any network, LANs must have a connecting medium of some sort to carry the information from node to node. Because wiring a building is a major expense to the potential LAN user, he must ensure that the system he uses fulfills certain criteria before embarking on the work. The medium chosen must be robust, that is, it must be immune to natural and environmental hazards, for example electrical noise, lightning and other forms of *electromagnetic interference* (EMI). For maximum availability of the network, the system must be serviceable. This means that mishaps such as cable breaks and node failures must be easily repairable or bypassed. The final cost of installation of the network will be affected by the cost of the medium, together with the cost of connecting each node to it.

Transmission speed is an important parameter of a network which will depend largely on the range of applications envisaged. These range from *terminal-to-host* traffic, for which speeds of below 1 kilobit per second are adequate, to applications such as graphic image and file transfer which need speeds of the order of megabits per second. The medium chosen will have to accommodate current as well as projected requirements over the system's expected lifetime of 15 years or more.

In order to appreciate the problems involved in medium selection, we must first look at the ways in which information is transmitted.

## 2.1 DATA TRANSMISSION TECHNIQUES

There are many ways of transmitting digital information through a medium. Making the choice between one technique and another is normally a question of striking a balance between performance, in terms of the speed and accuracy



of transmission, and cost. Certain parameters of the system are crucial in determining the former.

The normal way to transmit information through a medium is to vary an electrical signal at the transmitting end by some means, and detect these variations at the receiver. There are two major obstacles to successful reception: *attenuation* and *noise*. Noise can emanate from a variety of sources in the environment and serves to distort the signal. Attenuation is a measure of how much the strength of the signal is reduced in passing through the medium. It is proportional to the distance traveled and will be present to differing degrees depending on the frequency of the signal being transmitted. This dependency on frequency serves to further distort a signal as it passes through the medium.

For a particular medium, there will be a range of frequencies that can be transmitted through it without incurring significant attenuation. If the transmitter strays outside this range, reception will be difficult. In determining how much 'information' can be sent through the cable the most important aspect to consider is the width of this frequency range. This is known as the *bandwidth* of the medium.

Given that the transmission medium has a particular bandwidth, there are a variety of ways of transmitting information through it. In LANs, these are usually divided into *baseband* and *broadband* transmission. The details of these two methods will be described in the following sections.

### 2.1.1 Baseband transmission

When transmitting digital information, the simplest scheme is to have two voltage levels to represent 1s and 0s. Figure 2.1 shows how a number of bits have been encoded in this manner. More sophisticated schemes such as Manchester encoding (see Appendix A) can be used.

In baseband transmission, this voltage-encoded signal is applied directly to the medium. The signal is attenuated in its passage through the medium, causing the quality of the received signal to decrease with distance traveled.

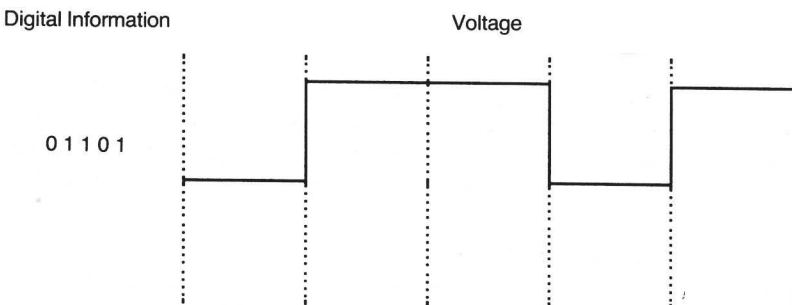


Figure 2.1 Digital information represented as a voltage