

COMPUTER NETWORKS

A diagram showing a lightning rod (a vertical metal rod) mounted on a roof. The rod is connected to a ground wire. The word "fasting" is partially visible on the left side of the diagram.

Transport layer

Network layer

Data link layer

Congestion

1000100110	5 MIL
1100110110	4 MIL
0110110011	2 MIL

WELCOME
TO THE
INFORMATION
SUPER
HIGHWAY

SHALL I COMPARE THEE
TO A SUMMER'S DAY?

ALOHA

Leaky bucket

The web

Eavesdropper

Computer Networks

Third Edition

Other bestselling titles by Andrew S. Tanenbaum:

Operating Systems: Design and Implementation, 2nd edition

This now-classic text on operating systems is the only book covering both the principles of operating systems and their application to a real system. All the traditional operating systems topics are covered in detail. In addition, the principles are carefully illustrated by MINIX, a free UNIX-like operating system for personal computers. The second edition, which is expected in late 1996, will deal with the new POSIX-based MINIX 2.0 system. As with the first edition, the book will include a listing of the MINIX source code. New to the second edition is a free CD-ROM in each book containing the complete MINIX system (binary and source code).

Modern Operating Systems

This bestselling text presents the basics of both single processor and distributed computer systems. Tanenbaum covers traditional topics including processes, memory management, and files systems as well as key issues in distributed systems including the client-server model, remote procedure call, threads and distributed files servers. This practical guide uses UNIX, MS-DOS, Mach and Amoeba to illustrate operating system concepts.

Distributed Operating Systems

This text covers the fundamental concepts of distributed operating systems. Key topics include communication and synchronization, processes and processors, distributed shared memory, distributed file systems, and distributed real-time systems. The principles of distributed computing are illustrated in four detailed case studies using Mach, Amoeba, Chorus and DCE operating environments.

Structured Computer Organization, 3rd edition

This leading text looks at computer architecture as a series of levels. At the bottom is the hardware: transistors, gates, registers, adders, and other circuits. Then comes the microprogramming level. After that is the conventional machine level, with its ADD, MOVE, JUMP, and other instructions. On top of that is the operating system, which adds new facilities such as file management and virtual memory. The final chapter deals with two advanced topics: parallel computers and the design of RISC machines.

Computer Networks

Third Edition

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by exchanging messages over longer cables. These can be divided into local, metropolitan, and wide area networks. Finally, the connection of two or more networks is called an internetwork. The worldwide Internet is a well-known example of an internetwork. Distance is important as a classification metric because different techniques are used at different scales. In this book we will be concerned with only the true networks and their interconnection. Below we give a brief introduction to the subject of network hardware.

1.2.1. Local Area Networks

Local area networks, generally called **LANs**, are privately-owned networks within a single building or campus of up to a few kilometers in size. They are widely used to connect personal computers and workstations in company offices and factories to share resources (e.g., printers) and exchange information. LANs are distinguished from other kinds of networks by three characteristics: (1) their size, (2) their transmission technology, and (3) their topology.

LANs are restricted in size, which means that the worst-case transmission time is bounded and known in advance. Knowing this bound makes it possible to use certain kinds of designs that would not otherwise be possible. It also simplifies network management.

LANs often use a transmission technology consisting of a single cable to which all the machines are attached, like the telephone company party lines once used in rural areas. Traditional LANs run at speeds of 10 to 100 Mbps, have low delay (tens of microseconds), and make very few errors. Newer LANs may operate at higher speeds, up to hundreds of megabits/sec. In this book, we will adhere to tradition and measure line speeds in megabits/sec (Mbps), not megabytes/sec (MB/sec). A megabit is 1,000,000 bits, not 1,048,576 (2^{20}) bits.

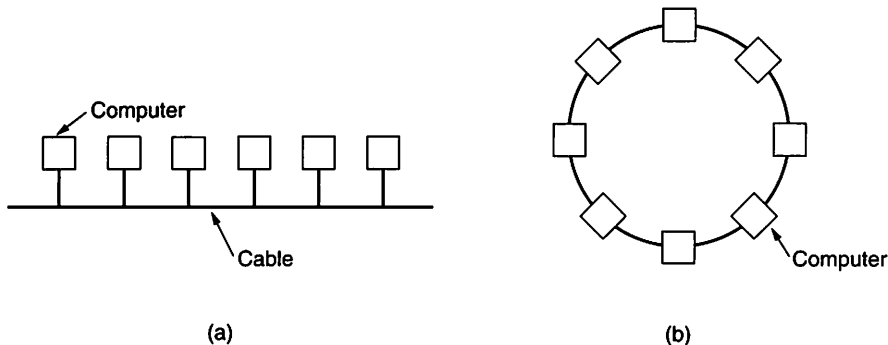


Fig. 1-3. Two broadcast networks. (a) Bus. (b) Ring.

Various topologies are possible for broadcast LANs. Figure 1-3 shows two of them. In a bus (i.e., a linear cable) network, at any instant one machine is the

members in the humanities who do not wish to get into the computer maintenance business, and the latter for physicists who want to crunch numbers. As a consequence of these various networks and facilities, the following scenarios are easy to imagine:

1. LAN-LAN: A computer scientist downloading a file to engineering.
2. LAN-WAN: A computer scientist sending mail to a distant physicist.
3. WAN-WAN: Two poets exchanging sonnets.
4. LAN-WAN-LAN: Engineers at different universities communicating.

Figure 5-33 illustrates these four types of connections as dotted lines. In each case, it is necessary to insert a “black box” at the junction between two networks, to handle the necessary conversions as packets move from one network to the other.

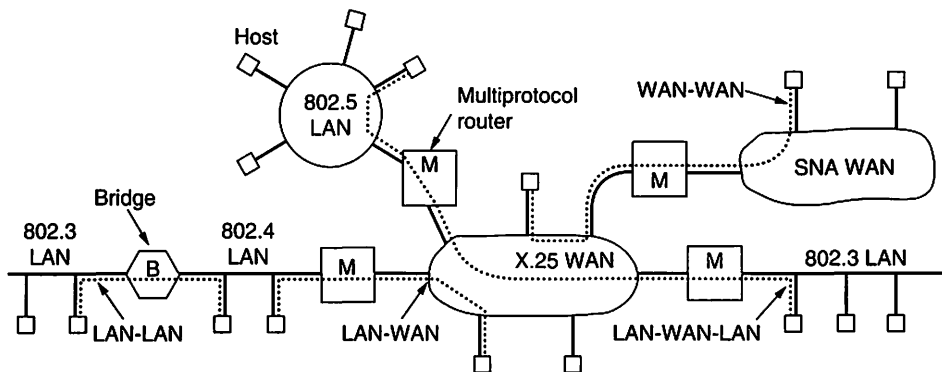


Fig. 5-33. Network interconnection.

The name used for the black box connecting two networks depends on the layer that does the work. Some common names are given below (although there is not much agreement on terminology in this area).

- Layer 1: Repeaters copy individual bits between cable segments.
- Layer 2: Bridges store and forward data link frames between LANs.
- Layer 3: Multiprotocol routers forward packets between dissimilar networks.
- Layer 4: Transport gateways connect byte streams in the transport layer.
- Above 4: Application gateways allow interworking above layer 4.

For convenience, we will sometimes use the term “gateway” to mean any device that connects two or more dissimilar networks.

At the far end, the car is let loose on the English roads and once again continues to move under its own power. Tunneling of packets through a foreign network works the same way.

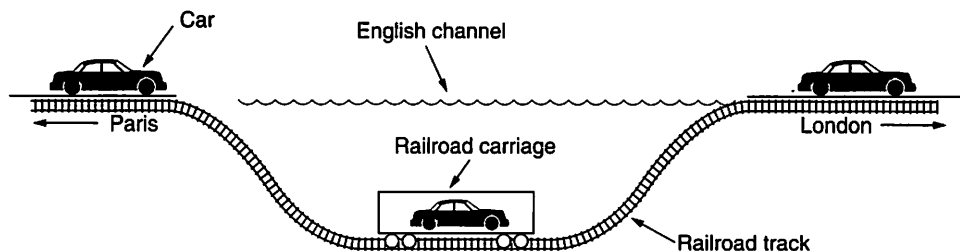


Fig. 5-39. Tunneling a car from France to England.

5.4.5. Internetwork Routing

Routing through an internetwork is similar to routing within a single subnet, but with some added complications. Consider, for example, the internetwork of Fig. 5-40(a) in which five networks are connected by six multiprotocol routers. Making a graph model of this situation is complicated by the fact that every multiprotocol router can directly access (i.e., send packets to) every other router connected to any network to which it is connected. For example, *B* in Fig. 5-40(a) can directly access *A* and *C* via network 2 and also *D* via network 3. This leads to the graph of Fig. 5-40(b).

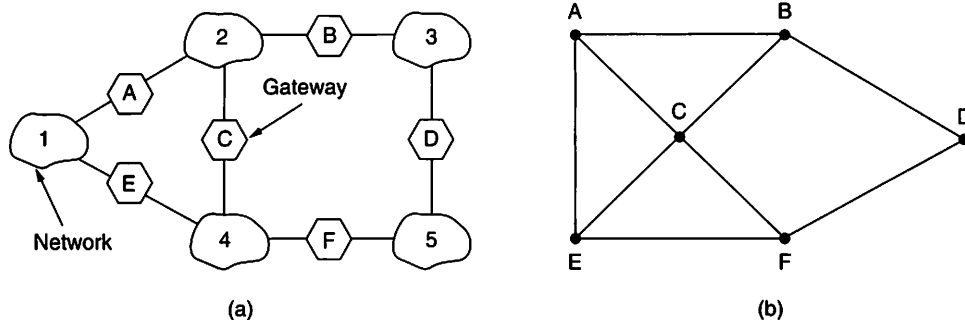
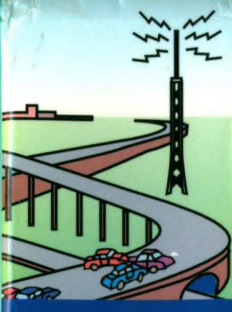


Fig. 5-40. (a) An internetwork. (b) A graph of the internetwork.

Once the graph has been constructed, known routing algorithms, such as the distance vector and link state algorithms, can be applied to the set of multiprotocol routers. This gives a two-level routing algorithm: within each network an **interior gateway protocol** is used, but between the networks, an **exterior gateway protocol** is used (“gateway” is an older term for “router”). In fact, since



TANENBAUM

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COMPUTER NETWORKS

ANDREW S. TANENBAUM

Computer Networks is the ideal introduction to today's and tomorrow's networks. This classic best-seller has been totally rewritten to reflect the networks of the late 1990s and beyond.

Author, educator, and researcher Andrew S. Tanenbaum, winner of the ACM*Karl V. Karlstrom Outstanding Educator Award, carefully explains how networks work inside, from the hardware technology up through the most popular network applications. The book takes a structured approach to networking, starting at the bottom (the physical layer) and gradually working up to the top (the application layer). The topics covered include:

- Physical layer (e.g., copper, fiber, radio, and satellite communication)
- Data link layer (e.g., protocol principles, HDLC, SLIP, and PPP)
- MAC Sublayer (e.g., IEEE 802 LANs, bridges, new high-speed LANs)
- Network layer (e.g., routing, congestion control, internetworking, IPv6)
- Transport layer (e.g., transport protocol principles, TCP, network performance)
- Application layer (e.g., cryptography, email, news, the Web, Java, multimedia)

In each chapter, the necessary principles are described in detail, followed by extensive examples taken from the Internet, ATM networks, and wireless networks.

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Modern Operating Systems

Distributed Operating Systems

Structured Computer Organization, 3rd edition

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