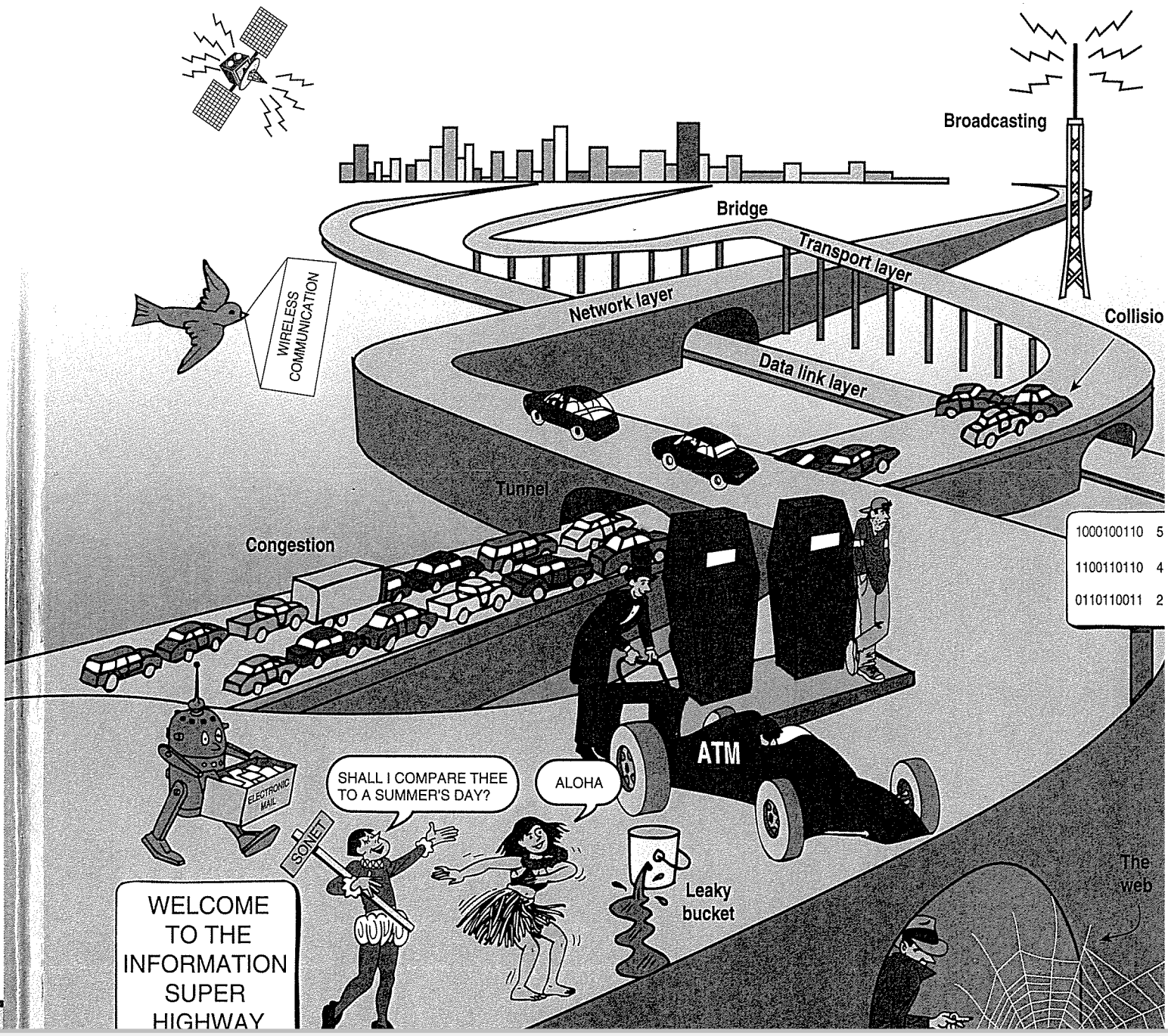
THIRD EDITION

# COMPUTER NETWORKS

ANDREW S. TANENBAUM



Library of Congress Cataloging in Publication Data

Tanenbaum, Andrew S. 1944-.
Computer networks / Andrew S. Tanenbaum. -- 3rd ed.
p. cm.
Includes bibliographical references and index.
ISBN 0-13-349945-6
1.Computer networks. I. Title.
TK5105.5.T36 1996 96-4121
004.6--dc20 CIP

Editorial/production manager: *Camille Trentacoste*
Interior design and composition: *Andrew S. Tanenbaum*
Cover design director: *Jerry Votta*
Cover designer: *Don Martinetti, DM Graphics, Inc.*
Cover concept: *Andrew S. Tanenbaum, from an idea by Marilyn Tremaine*
Interior graphics: *Hadel Studio*
Manufacturing manager: *Alexis R. Heydt*
Acquisitions editor: *Mary Franz*
Editorial Assistant: *Noreen Regina*


Prentice-Hall, Inc.
A Simon & Schuster Company
Upper Saddle River, New Jersey 07458

The publisher offers discounts on this book when ordered in bulk quantities. For more information, contact:
Corporate Sales Department, Prentice Hall PTR, One Lake Street, Upper Saddle River, NJ 07458.
Phone: (800) 382-3419; Fax: (201) 236-7141. E-mail: corpsales@prenhall.com



Printed in the United States of America
10 9 8 7 6 5 4

ISBN 0-13-349945-6

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*

town, and the other one's wife was the town telephone operator. He quickly saw that either he was going to have to invent automatic telephone switching equipment or he was going to go out of business. He chose the first option. For nearly 100 years, the circuit switching equipment used worldwide was known as Strowger gear. (History does not record whether the now-unemployed switchboard operator got a job as an information operator, answering questions such as: What is the phone number of an undertaker?

The model shown in Fig. 2-34(a) is highly simplified of course, because parts of the "copper" path between the two telephones may, in fact, be microwave links onto which thousands of calls are multiplexed. Nevertheless, the basic idea is valid: once a call has been set up, a dedicated path between both ends exists and will continue to exist until the call is finished.

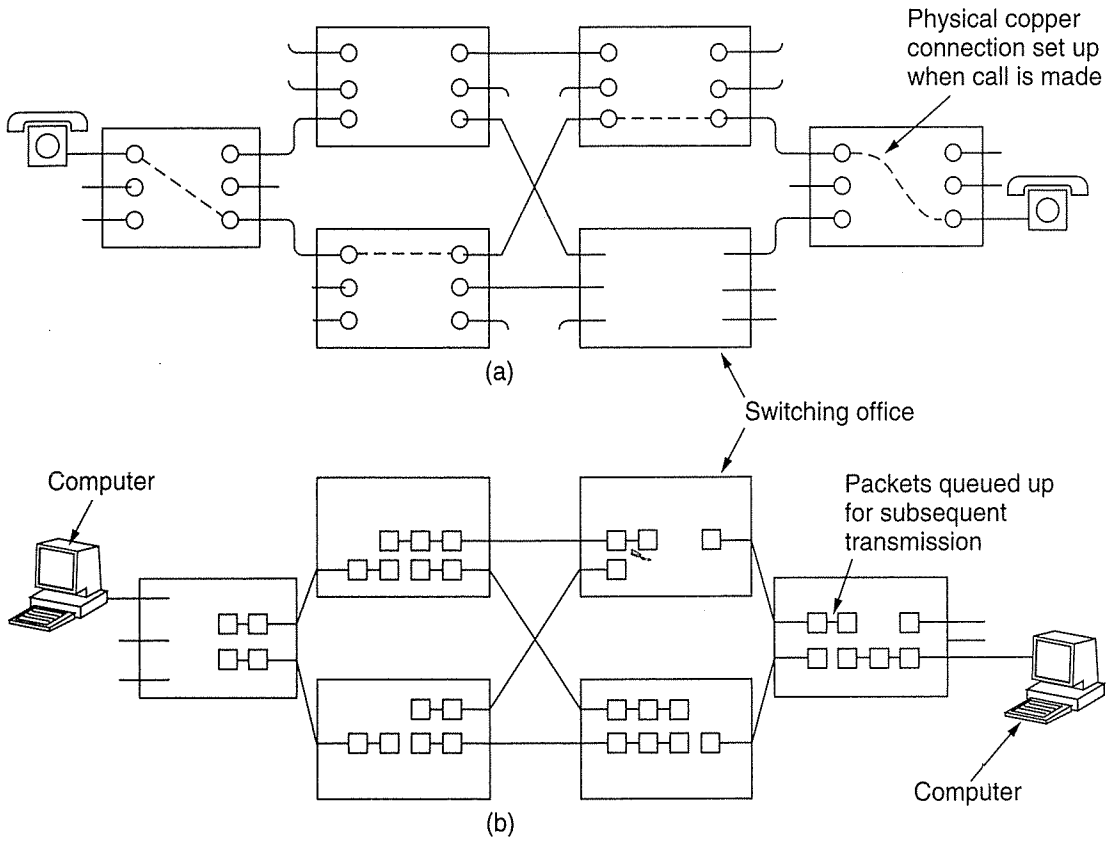



**Fig. 2-34.** (a) Circuit switching. (b) Packet switching.

An important property of circuit switching is the need to set up an end-to-end path *before* any data can be sent. The elapsed time between the end of dialing and the start of ringing can easily be 10 sec, more on long-distance or international calls. During this time interval, the telephone system is hunting for a copper path, as shown in Fig. 2-35(a). Note that before data transmission can even begin, the call request signal must propagate all the way to the destination, and be

town, and the other one's wife was the town telephone operator. He quickly saw that either he was going to have to invent automatic telephone switching equipment or he was going to go out of business. He chose the first option. For nearly 100 years, the circuit switching equipment used worldwide was known as Strowger gear. (History does not record whether the now-unemployed switchboard operator got a job as an information operator, answering questions such as: What is the phone number of an undertaker?

The model shown in Fig. 2-34(a) is highly simplified of course, because parts of the "copper" path between the two telephones may, in fact, be microwave links onto which thousands of calls are multiplexed. Nevertheless, the basic idea is valid: once a call has been set up, a dedicated path between both ends exists and will continue to exist until the call is finished.

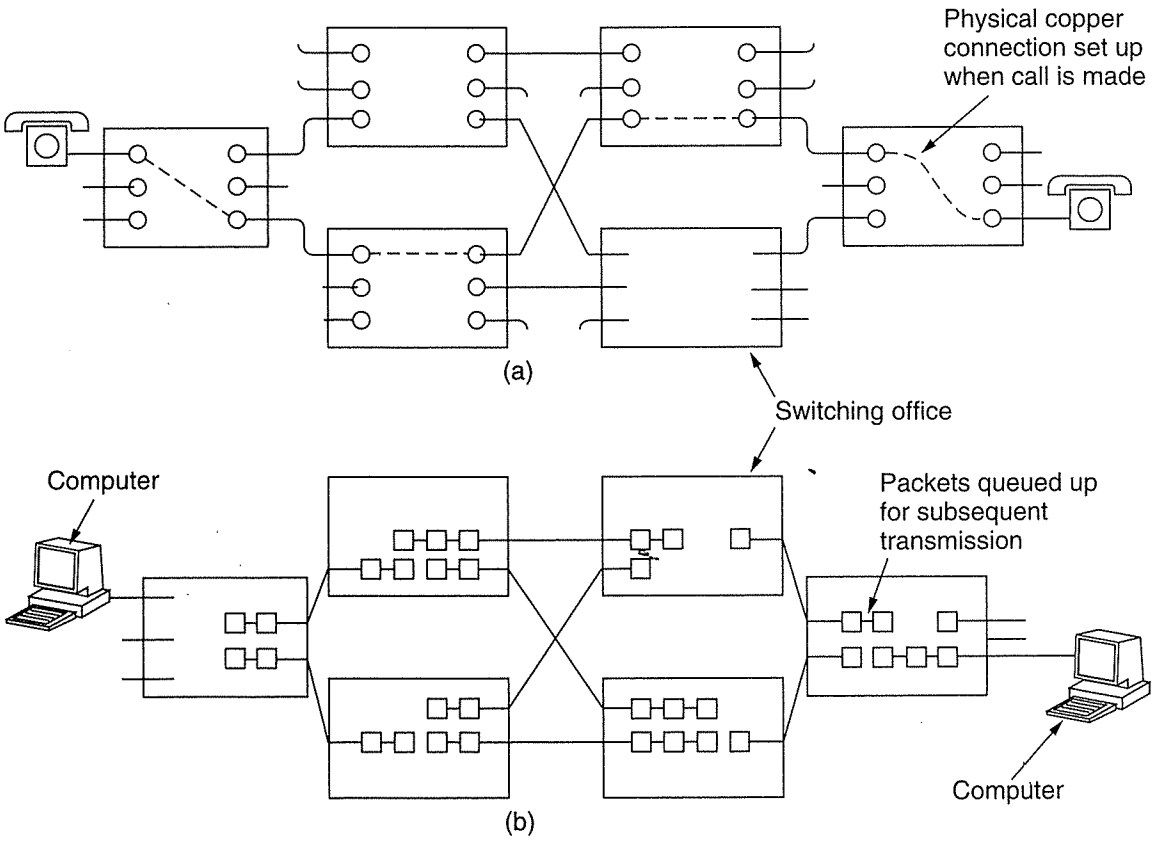



**Fig. 2-34.** (a) Circuit switching. (b) Packet switching.

An important property of circuit switching is the need to set up an end-to-end path *before* any data can be sent. The elapsed time between the end of dialing and the start of ringing can easily be 10 sec, more on long-distance or international calls. During this time interval, the telephone system is hunting for a copper path, as shown in Fig. 2-35(a). Note that before data transmission can even begin, the call request signal must propagate all the way to the destination, and be

acknowledged. For many computer applications (e.g., point-of-sale credit verification), long setup times are undesirable.

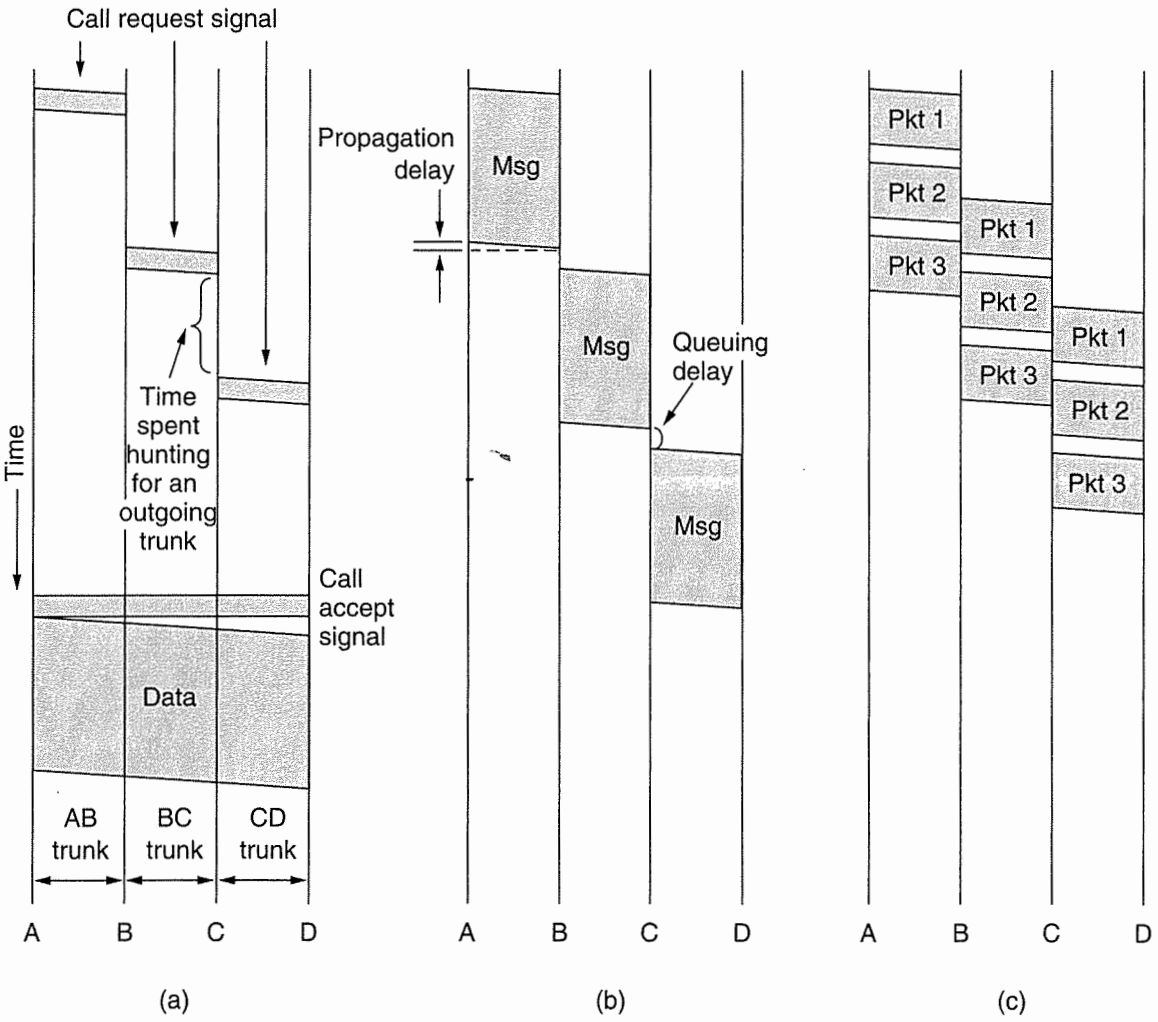



**Fig. 2-35.** Timing of events in (a) circuit switching, (b) message switching, (c) packet switching.

As a consequence of the copper path between the calling parties, once the setup has been completed, the only delay for data is the propagation time for the electromagnetic signal, about 5 msec per 1000 km. Also as a consequence of the established path, there is no danger of congestion—that is, once the call has been put through, you never get busy signals, although you might get one before the connection has been established due to lack of switching or trunk capacity.

An alternative switching strategy is **message switching**, shown in Fig. 2-35(b). When this form of switching is used, no physical copper path is established in advance between sender and receiver. Instead, when the sender has a block of data to be sent, it is stored in the first switching office (i.e., router) and then forwarded later, one hop at a time. Each block is received in its entirety, inspected

DOCKET ALARM

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

**LAW FIRMS**
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

**FINANCIAL INSTITUTIONS**
Litigation and bankruptcy checks for companies and debtors.

**E-DISCOVERY AND LEGAL VENDORS**
Sync your system to PACER to automate legal marketing.