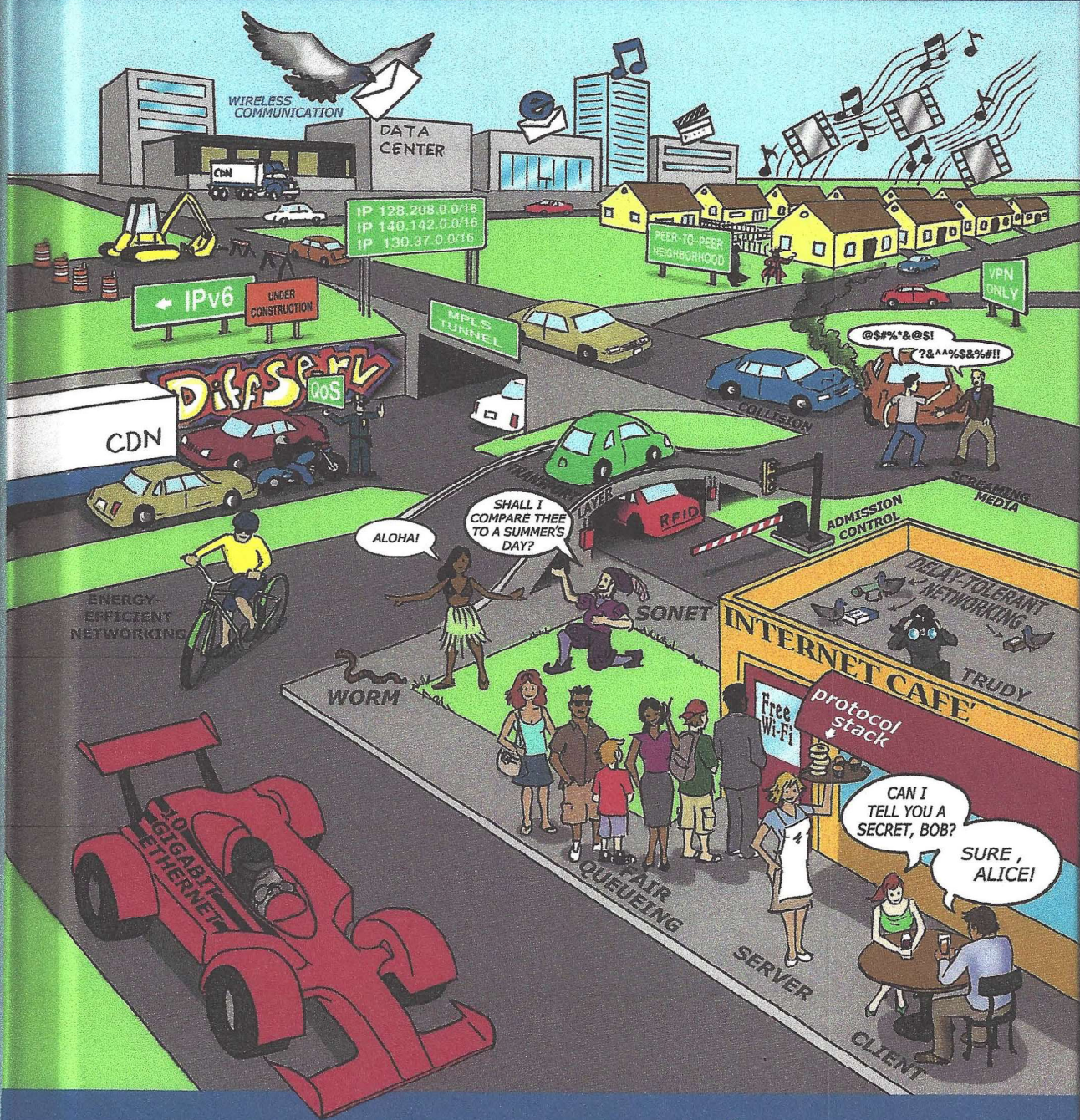


FIFTH EDITION

COMPUTER NETWORKS



TANENBAUM | WETHERALL

COMPUTER NETWORKS

FIFTH EDITION

ANDREW S. TANENBAUM

*Vrije Universiteit
Amsterdam, The Netherlands*

DAVID J. WETHERALL

*University of Washington
Seattle, WA*

PRENTICE HALL

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Paris Montreal Toronto
Delhi Mexico City Sao Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Editorial Director: Marcia Horton
Editor-in-Chief: Michael Hirsch
Executive Editor: Tracy Dunkelberger
Assistant Editor: Melinda Haggerty
Editorial Assistant: Allison Michael
Vice President, Marketing: Patrice Jones
Marketing Manager: Yezan Alayan
Marketing Coordinator: Kathryn Ferranti
Vice President, Production: Vince O'Brien
Managing Editor: Jeff Holcomb
Senior Operations Supervisor: Alan Fischer
Manufacturing Buyer: Lisa McDowell
Cover Direction: Andrew S. Tanenbaum,
David J. Wetherall, Tracy Dunkelberger

Art Director: Linda Knowles
Cover Designer: Susan Paradise
Cover Illustration: Jason Consalvo
Interior Design: Andrew S. Tanenbaum
AV Production Project Manager:
Gregory L. Dulles
Interior Illustrations: Laserwords, Inc.
Media Editor: Daniel Sandin
Composition: Andrew S. Tanenbaum
Copyeditor: Rachel Head
Proofreader: Joe Ruddick
Printer/Binder: Courier Companies, Inc.
Cover Printer: Courier Companies, Inc.

Credits and acknowledgments borrowed from other sources and reproduced, with permission, in this textbook appear on appropriate page within text.

Many of the designations by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and the publisher was aware of a trademark claim, the designations have been printed in initial caps or all caps.

Copyright © 2011, 2003, 1996, 1989, 1981 Pearson Education, Inc., publishing as Prentice Hall. All rights reserved. Manufactured in the United States of America. This publication is protected by Copyright, and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or likewise. To obtain permission(s) to use material from this work, please submit a written request to Pearson Education, Inc., Permissions Department, 501 Boylston Street, Suite 900, Boston, Massachusetts 02116.

Library of Congress Cataloging-in-Publication Data

Tanenbaum, Andrew S., 1944-
Computer networks / Andrew S. Tanenbaum, David J. Wetherall. -- 5th ed.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-0-13-212695-3 (alk. paper)
ISBN-10: 0-13-212695-8 (alk. paper)
1. Computer networks. I. Wetherall, D. (David) II. Title.
TK5105.5.T36 2011
004.6--dc22

2010034366

7 8 9 10 V092 16 15 14

PEARSON

To Su
and th

To Ka

The
stage

ence
of the
their
thou-
com-
ed by
e job.
on of

a col-
Two
ation.
ared,
sizes,
er to
e of a

work
em, a
t sys-
Of-
re, is
buted
nts a

Users
make
hard-
user
e and

work.
s, the
e (es-

or ex-
files
user.

Although this book primarily focuses on networks, many of the topics are also important in distributed systems. For more information about distributed systems, see Tanenbaum and Van Steen (2007).

1.1 USES OF COMPUTER NETWORKS

Before we start to examine the technical issues in detail, it is worth devoting some time to pointing out why people are interested in computer networks and what they can be used for. After all, if nobody were interested in computer networks, few of them would be built. We will start with traditional uses at companies, then move on to home networking and recent developments regarding mobile users, and finish with social issues.

1.1.1 Business Applications

Most companies have a substantial number of computers. For example, a company may have a computer for each worker and use them to design products, write brochures, and do the payroll. Initially, some of these computers may have worked in isolation from the others, but at some point, management may have decided to connect them to be able to distribute information throughout the company.

Put in slightly more general form, the issue here is **resource sharing**. The goal is to make all programs, equipment, and especially data available to anyone on the network without regard to the physical location of the resource or the user. An obvious and widespread example is having a group of office workers share a common printer. None of the individuals really needs a private printer, and a high-volume networked printer is often cheaper, faster, and easier to maintain than a large collection of individual printers.

However, probably even more important than sharing physical resources such as printers, and tape backup systems, is sharing information. Companies small and large are vitally dependent on computerized information. Most companies have customer records, product information, inventories, financial statements, tax information, and much more online. If all of its computers suddenly went down, a bank could not last more than five minutes. A modern manufacturing plant, with a computer-controlled assembly line, would not last even 5 seconds. Even a small travel agency or three-person law firm is now highly dependent on computer networks for allowing employees to access relevant information and documents instantly.

For smaller companies, all the computers are likely to be in a single office or perhaps a single building, but for larger ones, the computers and employees may be scattered over dozens of offices and plants in many countries. Nevertheless, a sales person in New York might sometimes need access to a product inventory

database in Singapore. Networks called **VPNs (Virtual Private Networks)** may be used to join the individual networks at different sites into one extended network. In other words, the mere fact that a user happens to be 15,000 km away from his data should not prevent him from using the data as though they were local. This goal may be summarized by saying that it is an attempt to end the "tyranny of geography."

In the simplest of terms, one can imagine a company's information system as consisting of one or more databases with company information and some number of employees who need to access them remotely. In this model, the data are stored on powerful computers called **servers**. Often these are centrally housed and maintained by a system administrator. In contrast, the employees have simpler machines, called **clients**, on their desks, with which they access remote data, for example, to include in spreadsheets they are constructing. (Sometimes we will refer to the human user of the client machine as the "client," but it should be clear from the context whether we mean the computer or its user.) The client and server machines are connected by a network, as illustrated in Fig. 1-1. Note that we have shown the network as a simple oval, without any detail. We will use this form when we mean a network in the most abstract sense. When more detail is required, it will be provided.

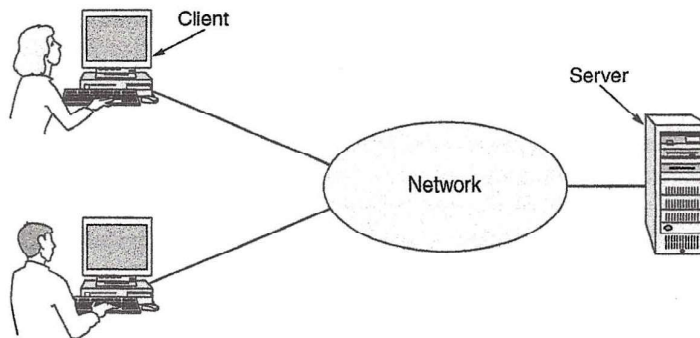


Figure 1-1. A network with two clients and one server.

This whole arrangement is called the **client-server model**. It is widely used and forms the basis of much network usage. The most popular realization is that of a **Web application**, in which the server generates Web pages based on its database in response to client requests that may update the database. The client-server model is applicable when the client and server are both in the same building (and belong to the same company), but also when they are far apart. For example, when a person at home accesses a page on the World Wide Web, the same model is employed, with the remote Web server being the server and the user's personal

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.