

# Computer Systems

## A Programmer's Perspective

Randal E. Bryant

Carnegie Mellon University

David R. O'Hallaron

Carnegie Mellon University and Intel Labs

Prentice Hall

Boston Columbus Indianapolis New York San Francisco Upper Saddle River  
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montreal Toronto

Editorial Director: Marcia Horton  
Editor-in-Chief: Michael Hirsch  
Acquisitions Editor: Matt Goldstein  
Editorial Assistant: Chelsea Bell  
Director of Marketing: Margaret Waples  
Marketing Coordinator: Kathryn Ferranti  
Managing Editor: Jeff Holcomb  
Senior Manufacturing Buyer: Carol Melville  
Art Director: Linda Knowles  
Cover Designer: Elena Sidorova  
Image Interior Permission Coordinator: Richard Rodrigues  
Cover Art: © Randal E. Bryant and David R. O'Hallaron  
Media Producer: Katelyn Boller  
Project Management and Interior Design: Paul C. Anagnostopoulos, Windfall Software  
Composition: Joe Snowden, Coventry Composition  
Printer/Binder: Edwards Brothers  
Cover Printer: Lehigh-Phoenix Color/Hagerstown

Copyright © 2011, 2003 by Randal E. Bryant and David R. O'Hallaron. 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.

Many of the designations by manufacturers and seller 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.

Library of Congress Cataloging-in-Publication Data

Bryant, Randal.

Computer systems : a programmer's perspective / Randal E. Bryant, David R. O'Hallaron.—2nd ed.

p. cm.

Includes bibliographical references and index.

ISBN-13: 978-0-13-610804-7 (alk. paper)

ISBN-10: 0-13-610804-0 (alk. paper)

1. Computer systems. 2. Computers. 3. Telecommunication. 4. User interfaces (Computer systems) I. O'Hallaron, David Richard. II. Title.

QA76.5.B795 2010

004—dc22

2009053083

10 9 8 7 6 5 4 3 2 1—EB—14 13 12 11 10

PEARSON

ISBN 10: 0-13-610804-0  
ISBN 13: 978-0-13-610804-7