
Delivering Voice over IP Networks

Second Edition

DANIEL MINOLI
EMMA MINOLI



Wiley Publishing, Inc.

Publisher: Robert Ipsen
Editor: Margaret Eldridge
Assistant Editor: Adaobi Obi
Managing Editor: Angela Smith
New Media Editor: Brian Snapp
Text Design & Composition: North Market Street Graphics

Designations used by companies to distinguish their products are often claimed as trademarks. In all instances where John Wiley & Sons, Inc., is aware of a claim, the product names appear in initial capital or ALL CAPITAL LETTERS. Readers, however, should contact the appropriate companies for more complete information regarding trademarks and registration.

This text is printed on acid-free paper. ∞

Copyright © 2002 by Dan Minoli, Emmanuelle Minoli. All rights reserved.

Published by Wiley Publishing, Inc., Indianapolis, Indiana

Published simultaneously in Canada.

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, scanning or otherwise, except as permitted under Sections 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4744. Requests to the Publisher for permission should be addressed to the Legal Department, Wiley Publishing, Inc., 10475 Crosspointe Blvd., Indianapolis, IN 46256, (317) 572-3447, fax (317) 572-4447, E-mail: permcoordinator@wiley.com.

This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold with the understanding that the publisher is not engaged in professional services. If professional advice or other expert assistance is required, the services of a competent professional person should be sought.

Library of Congress Cataloging-in-Publication Data:

Minoli, Daniel
Delivering voice over IP networks / Dan Minoli, Emma Minoli.— 2nd ed.
p. cm.
ISBN 0-471-38606-5
1. Internet telephony. 2. TCP/IP (Computer network protocol). 3. Digital telephone systems. 4. Computer networks. 5. Data transmission systems. I. Minoli, Emma. II. Title.

TK5105.8865 .M57 2002
621.385—dc21

2002071368

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic versions. For more information about Wiley products, visit our web site at www.wiley.com.

Printed in the United States of America.

10 9 8 7 6 5 4 3 2 1

Contents

<i>PREFACE</i>	xiii
<i>ACKNOWLEDGMENT</i>	xv
<i>ABOUT THE AUTHORS</i>	xvii

Chapter 1: Introduction and Motivation 1

1.1	INTRODUCTION	1
1.2	DRIVERS FOR VOICE OVER IP	6
	THE NEGATIVE DRIVERS	12
1.3	APPROACHES FOR IP-BASED VOICE SYSTEMS	14
	VOICE SERVERS APPROACH	15
	IP VOICE AND VIDEO PHONES	18
1.4	THE FUTURE	18
	REFERENCES	18

Chapter 2: An Overview of IP, IPOATM, MPLS, and RTP 21

2.1	INTRODUCTION	21
2.2	INTERNET PROTOCOL	24
	THE ROLE OF THE IP	24
	IP ROUTING	26
	IP DATAGRAMS	29
	SUPPORT OF VOICE AND VIDEO IN ROUTERS	32
	IP VERSION 6 (IPv6)	33
2.3	IP OVER ATM (IPOATM)	36
2.4	BASIC SYNOPSIS OF MPLS	39
	MPLS FORWARDING/LABEL-SWITCHING MECHANISM	41
	MPLS LABEL-DISTRIBUTION MECHANISM	43
2.5	REAL-TIME TRANSPORT PROTOCOL (RTP)	45
2.6	RTP CONTROL PROTOCOL (RTCP)	50
2.7	STREAM CONTROL TRANSMISSION PROTOCOL (SCTP)	52

2.8	ATM QoS MECHANISMS	54
	QUALITY OF SERVICE PARAMETERS	56
	QoS CLASSES	57
	REFERENCES	59
	NOTES	61

Chapter 3: Issues in Packet Voice Communication 63

3.1	INTRODUCTION	63
	SCOPE	64
	SUMMARY OF RESULTS	65
3.2	TRAFFIC MODELS	66
	INTRODUCTION	66
	SPEECH EVENTS	66
	SPEAKER MODELS	67
	CALL ORIGINATION MODEL	72
3.3	PERFORMANCE CRITERIA	74
	RESULTS OF SUBJECTIVE STUDIES	74
	SMOOTHNESS CRITERIA	76
3.4	LINK MODEL	78
	INTRODUCTION	79
	MODEL DESCRIPTION	79
3.5	RESULTS	84
	PROPERTIES OF THE DELAY DISTRIBUTION	84
	FINITE-BUFFER CASE	86
	EFFECT OF SPEECH MODELS	88
	OPTIMAL PACKET LENGTH	90
	TRANSIENT BEHAVIOR	92
3.6	CONCLUSION	95
	REFERENCES	96

Chapter 4: Voice Technologies for Packet-Based Voice Applications 101

4.1	INTRODUCTION	101
	GENERAL OVERVIEW OF SPEECH TECHNOLOGY	101
	WAVEFORM CODING	102
	VOCODING (ANALYSIS/SYNTHESIS) IN THE FREQUENCY DOMAIN	107
4.2	G.727: ADPCM FOR PACKET NETWORK APPLICATIONS	111
	INTRODUCTION	111
	ADPCM ENCODER PRINCIPLES	114
	ADPCM DECODER PRINCIPLES	121

4.3	EXAMPLE OF APPLICATION	123
	REFERENCES	123
	NOTES	123

Chapter 5: Technology and Standards for Low-Bit-Rate Vocoding Methods 125

5.1	INTRODUCTION	125
	OVERVIEW	127
	VOCODER ATTRIBUTES	128
	LINEAR PREDICTION ANALYSIS-BY-SYNTHESIS (LPAS) CODING	130
5.2	INTRODUCTION TO G.729 AND G.723.1	133
	DIFFERENTIATIONS	133
	STANDARDIZATION PROCESS	134
	STANDARDIZATION INTERVAL	135
5.3	G.723.1	136
	INTRODUCTION	136
	ENCODER/DECODER	136
5.4	G.728	138
	LD-CELP ENCODER	139
	LD-CELP DECODER	140
5.5	G.729	140
	ENCODER	141
	DECODER	143
5.6	EXAMPLE OF APPLICATIONS	145
	H.263 VIDEO CODING FOR LOW-BIT-RATE COMMUNICATION	145
	H.324 MULTIMEDIA COMMUNICATION	146
	H.323 MULTIMEDIA COMMUNICATIONS STANDARD FOR LANs AND ENTERPRISE NETWORKS	148
	REFERENCES	150
	NOTES	151

Chapter 6: Voice over IP and the Internet 153

6.1	INTRODUCTION	153
6.2	IP/INTERNET BACKGROUND	157
	INTERNET PROTOCOL SUITE	157
	THE INTERNET	157
6.3	VOICE TRANSMISSION AND APPROACHES IN ATM, FRAME RELAY, AND IP	162
	ATM	162
	FRAME RELAY	164
	IP	164

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.