Copyright © 2006

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England

Telephone (+44) 1243 779777

Email (for orders and customer service enquiries): cs-books@wiley.co.uk Visit our Home Page on www.wiley.com

All Rights Reserved. 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 under the terms of the Copyright, Designs and Patents Act 1988 or under the terms of a licence issued by the Copyright Licensing Agency Ltd, 90 Tottenham Court Road, London W1T 4LP, UK, without the permission in writing of the Publisher. Requests to the Publisher should be addressed to the Permissions Department, John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England, or emailed to permreq@wiley.co.uk, or faxed to (+44) 1243 770620.

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

Other Wiley Editorial Offices

John Wiley & Sons Inc., 111 River Street, Hoboken, NJ 07030, USA

Jossey-Bass, 989 Market Street, San Francisco, CA 94103-1741, USA

Wiley-VCH Verlag GmbH, Boschstr. 12, D-69469 Weinheim, Germany

John Wiley & Sons Australia Ltd, 42 McDougall Street, Milton, Queensland 4064, Australia

John Wiley & Sons (Asia) Pte Ltd, 2 Clementi Loop #02-01, Jin Xing Distripark, Singapore 129809

John Wiley & Sons Canada Ltd, 22 Worcester Road, Etobicoke, Ontario, Canada M9W 1L1

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Library of Congress Cataloging-in-Publication Data:

Armitage, Grenville,

Networking and online games: understanding and engineering multiplayer Internet games / Grenville Armitage, Mark Claypool, Philip Branch.

p. cm.

Includes bibliographical references and index.

ISBN-13: 978-0-470-01857-6 (cloth: alk. paper)

ISBN-10: 0-470-01857-7 (cloth: alk. paper)

1. Computer games - Programming. 2. TCP/IP (Computer network protocol)

3. Internet games. I. Title: Understanding and engineering multiplayer

Internet games. II. Claypool, Mark. III. Branch, Philip. IV. Title.

QA76.76.C672A76 2006

794.8'1526 - dc22

2006001044

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN-13: 978-0-470-01857-6

ISBN-10: 0-470-01857-7

Typeset in 10/12pt Times by Laserwords Private Limited, Chennai, India Printed and bound in Great Britain by CPI Antony Rowe, Chippenham and Eastbourne This book is printed on acid-free paper responsibly manufactured from sustainable forestry in which at least two trees are planted for each one used for paper production.

Contents

Author Biographies Acknowledgements	
1 Introduction	1
2 Early Online and Multiplayer Games	5
2.1 Defining Networked and Multiplayer Games	5
2.2 Early Multiplayer Games	6
2.2.1 PLATO	8
2.2.2 MultiUser Dungeons	8
2.2.3 Arcade Games	9
2.2.4 Hosted Online Games	11
2.3 Multiplayer Network Games	12
2.3.1 DOOM - Networked First-Person Shooters Arrive	12
References	14
3 Recent Online and Multiplayer Games	15
3.1 Communication Architectures	15
3.2 The Evolution of Online Games	17
3.2.1 FPS Games	18
3.2.2 Massively Multiplayer Games	21
3.2.3 RTS Games	22
3.2.4 Sports Games	24
3.3 Summary of Growth of Online Games	27
3.4 The Evolution of Online Game Platforms	29
3.4.1 PCs	29
3.4.2 Game Consoles	29
3.4.3 Handheld Game Consoles	30
3.4.4 Summary	32
3.5 Context of Computer Games	32
3.5.1 Physical Reality	32
3.5.2 Telepresence	33
3.5.3 Augmented Reality	34
3.5.4 Distributed Virtual Environments	39
References	39
4 Basic Internet Architecture	4:
4.1 IP Networks as seen from the Edge	4:
4.1.1 Endpoints and Addressing	4:

		4.1.2 Layered Transport Services	44
		4.1.3 Unicast, Broadcast and Multicast	46
	4.2	Connectivity and Routing	47
		4.2.1 Hierarchy and Aggregation	49
		4.2.2 Routing Protocols	51
		4.2.3 Per-hop Packet Transport	55
	4.3	Address Management	60
		4.3.1 Address Delegation and Assignment	60
		4.3.2 Network Address Translation	61
		4.3.3 Dynamic Host Configuration Protocol	64
		4.3.4 Domain Name System	66
		References	67
5	Netw	ork Latency, Jitter and Loss	69
		The Relevance of Latency, Jitter and Loss	69
		Sources of Latency, Jitter and Loss in the Network	70
		5.2.1 Propagation Delay and the Laws of Physics	70
		5.2.2 Serialisation	71
		5.2.3 Queuing Delays	72
		5.2.4 Sources of Jitter in the Network	73
		5.2.5 Sources of Packet Loss in the Network	74
	5.3	Network Control of Lag, Jitter and Loss	75
		5.3.1 Preferential IP Layer Queuing and Scheduling	75 76
		5.3.2 Link Layer Support for Packet Prioritisation	70 77
		5.3.3 Where to Place and Trust Traffic Classification	
	5.4	Measuring Network Conditions	78 79
	• • •	References	79 81
_	<u>.</u>		
6		ncy Compensation Techniques	83
		The Need for Latency Compensation	83
	6.2	Prediction	86
		6.2.1 Player Prediction	87
		6.2.2 Opponent Prediction	89
		6.2.3 Prediction Summary	92
	6.3	Time Manipulation	93
		6.3.1 Time Delay	93
		6.3.2 Time Warp	94
		6.3.3 Data compression	96
		Visual Tricks	97
	6.5	Latency Compensation and Cheating	98
		References	98
7	Playa	bility versus Network Conditions and Cheats	101
	7.1	Measuring Player Tolerance for Network Disruptions	101
		7.1.1 Empirical Research	102
		7.1.2 Sources of Error and Uncertainty	105
		7.1.3 Considerations for Creating Artificial Network Conditions	107
		Jan and an appropriate the content of the content o	107

	7.2	Communication Models, Cheats and Cheat-Mitigation	108
		7.2.1 Classifying and Naming Methods of Cheating	109
		7.2.2 Server-side Cheats	109
		7.2.3 Client-side Cheats	111
		7.2.4 Network-layer Cheats	115
		7.2.5 Cheat-mitigation	116
		References	118
8	Broad	lband Access Networks	121
	8.1	What Broadband Access Networks are and why they Matter	121
		8.1.1 The Role of Broadband Access Networks	121
		8.1.2 Characteristics of Broadband Access Networks	121
	8.2	Access Network Protocols and Standards	123
		8.2.1 Physical Layer	124
		8.2.2 Data Link Layer	125
	8.3	Cable Networks	125
	8.4	ADSL Networks	127
	8.5	Wireless LANs	128
		8.5.1 IEEE 802.11 Wireless LAN Standards	129
		8.5.2 Wireless LAN Architectures	129
		8.5.3 Recent Developments in WLAN Quality of Service	131
	8.6	Cellular Networks	132
		8.6.1 GPRS and EDGE	132
		8.6.2 3G Networks	133
	8.7	Bluetooth Networks	134
	8.8	Conclusion	135
		References	136
9	Whe	re Do Players Come from and When?	137
		Measuring Your Own Game Traffic	138
		9.1.1 Sniffing Packets	138
		9.1.2 Sniffing With Tcpdump	140
	9.2	Hourly and Daily Game-play Trends	142
		9.2.1 An Example Using Quake III Arena	142
		9.2.2 An Example Using Wolfenstein Enemy Territory	144
		9.2.3 Relationship to Latency Tolerance	144
	9.3	Server-discovery (Probe Traffic) Trends	145
		9.3.1 Origins of Probe Traffic	145
		9.3.2 Probe Traffic Trends	146
	9.4	Mapping Traffic to Player Locations	148
		9.4.1 Mapping IP Addresses to Geographic Location	148
		9.4.2 Mapping by Latency Tolerance	149
		References	149
10	Onli	ne Game Traffic Patterns	151
	10.1	Measuring Game Traffic with Timestamping Errors	152
		Sub-second Characteristics	153

<u>viii</u> Contents

		10.2.1 Ticks, Snapshots and Command Updates	153
		10.2.2 Controlling Snapshot and Command Rates	155
		Sub-second Packet-size Distributions	156
	10.4	Sub-Second Inter-Packet Arrival Times	162
		10.4.1 Example: Wolfenstein Enemy Territory Snapshots	164
		10.4.2 Example: Half-life 2 Snapshots and Client Commands	164
	10.5	Estimating the Consequences	167
	10.6	Simulating Game Traffic	168
		10.6.1 Examples from Halo 2 and Quake III Arena	169
		10.6.2 Extrapolating from Measurements with Few Clients	172
		References	172
11	Futur	re Directions	175
		Untethered	175
		11.1.1 Characteristics of Wireless Media	176
		11.1.2 Wireless Network Categorization	177
	11.2	Quality of Service	178
		11.2.1 QoS and IEEE 802.11	179
		11.2.2 QoS Identification	179
	11.3	New Architectures	180
	11.4	Cheaters Beware	181
	11.5	Augmented Reality	182
		Massively Multiplayer	182
		Pickup and Putdown	183
		Server Browsers	183
		References	184
12	Settir	ng Up Online FPS Game Servers	107
		Considerations for an Online Game Server	187
		Wolfenstein Enemy Territory	187
	14.4	12.2.1 Obtaining the Code	188
		12.2.2 Installing the Linux Game Server	188
		12.2.3 Starting the Server	189
		12.2.4 Starting a LAN Server	191
		12.2.5 Ports You Need Open on Firewalls	192
		12.2.6 Dealing with Network Address Translation	193 193
		12.2.7 Monitoring and Administration	193
		12.2.8 Automatic Downloading of Maps and Mods	194
		12.2.9 Network Performance Configuration	190
		12.2.10 Running a Windows Server	197
		12.2.11 Further Reading	198
	12.3	Half-Life 2	
		12.3.1 Obtaining and Installing the Linux Dedicated Server	198 199
		12.3.2 Starting the Server for Public Use	200
		12.3.3 Starting a LAN-only Server	200
		12.3.4 Ports You Need Open on Firewalls	202
		12.3.5 Dealing with Network Address Translation	202
		12.3.6 Monitoring and Administration	
		12.3.7 Network Performance Configuration	203 204
		z=1011 11011011 1 CIJOI HUNCE CONJUGUI CHION	204

	12.3.8 Running a Windows Server	204
	12.3.9 Further Reading	206
12.4 Configuring FreeBSD's Linux-compatibility Mode		206
	12.4.1 Installing the Correct Linux-compatibility Libraries	206
	12.4.2 Ensuring the Kernel 'Ticks' Fast Enough	207
	References	208
13	Conclusion	209
	13.1 Networking Fundamentals	209
	13.2 Game Technologies and Development	210
	13.3 A Note Regarding Online Sources	211

Contents

Index

ix

213