THE COMPETITIVE INTERNET SERVICE PROVIDER

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NETWORK ARCHITECTURE, INTERCONNECTION, TRAFFIC ENGINEERING AND NETWORK DESIGN

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Foreword

The Internet is a fact of everyday life for vast numbers of people who use it explicitly, or even implicitly, as they go about their business or leisure – doing web searches, downloading files for their next meeting, making Voice-over-IP telephone calls, accessing e-mail, booking holidays, ordering goods, and so on. Users and usage alike are increasing dramatically, all over the globe, and the Internet is firmly established as a critical infrastructure. The user-view of the network comes through the medium of the web browser, and although many factors are jointly responsible for the end-to-end performance experienced by the user, there is no doubt that the Quality of Service (QoS) of the underlying network is one of the most important elements. The role of Internet Service Providers (ISPs), via which most people access the network, is therefore crucial.

In this book, Oliver Heckmann focuses on the world of the ISP and in particular on the efficiency of their network operation and on the QoS that they (aim to) provide. He structures the book into four parts, namely the ISP market, network architecture, interconnection issues, and traffic and network engineering. In that way he situates descriptions of the technology issues and emerging solutions in their proper context. New strategies and insights are presented that can help ISPs realise their QoS targets.

It is an undeniable fact that QoS-engineering has been difficult to 'sell' ever since the early work on QoS architectures began to appear in the early to mid 1990s. Partly this was because the proposed solutions seemed too complicated, and partly because it was felt that the Internet could cope without them – especially where over-engineered and where excess bandwidth is available (nearly always the case in the network core). However, perhaps the main reason was the lack of a compelling commercial reason for network operators to deploy QoS solutions. Now, or soon, the time may be right to do so, because of new and increasing competition amongst Internet Service Providers and the commercial pressures that surely dictate the urgent need to assure customers of an excellent level of service at all times.

This book gives a comprehensive coverage of the technical components needed by Internet Service Providers in the world in which they are all competing to succeed. I welcome its addition to the series, and highly recommend it to anyone with an interest in Quality of Service and the efficient operation of networks.

David Hutchison
Lancaster University
January 2006

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General Abbreviations

1GE	1-Gigabit Ethernet
10GE	10-Gigabit Ethernet
ABE	Alternative Best-effort
AC	Admission Control
ACK	Acknowledgement (Packet)
ADSL	Asymmetric Digital Subscriber Lines
AdSpec	Advertisement Specification
AF	Assured Forwarding
AH	Authentication Header
AIMD	Additive Increase - Multiplicative Decrease
AISP	Access Internet Service Provider
ANSI	American National Standards Institute
AOL	America Online
API	Application Programming Interface
APS	Automatic Protection Switching
AQM	Active Queue Management
AS	Autonomous System
ASP	Application Service Provider
ATM	Asynchronous Transfer Mode
B&B	Branch & Bound
B2B	Business to Business
B2C	Business to Consumer
BA	Behaviour Aggregate
BB	Bandwidth Broker
BE	Best-effort
BGP	Border Gateway Protocol
BRITE	Boston University Representative Internet Topology Generator
BSD	Berkeley Software Distribution
BSP	Backbone Service Provider
CAIDA	Cooperative Association for Internet Data Analysis
CBQ	Class Based Queueing
CBR	Constant Bit-rate

CD	Compact Disc
CDN	Content Delivery Network
CIDR	Classless Inter-domain Routing
CL	Controlled Load Service
COPS	Common Open Policy Service
CoS	Class of Service
CP	Content Provider
CPU	Central Processing Unit
CR-LDP	Constraint-based Routing Support for LDP
CSFQ	Core-stateless Fair Queueing
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
CS	Class Selector
DCCP	Datagram Congestion Control Protocol
DE-CIX	Deutscher (German) Commercial Internet Exchange
DFN	Deutsches Forschungsnetz (German Research Network)
Diffserv	Differentiated Services
DNS	Domain Name System
DP	Dynamic Programming
DPS	Dynamic Packet State
DPT	Dynamic Packet Transport
DRR	Deficit Round Robin
DS	Diffserv, Differentiated Services
DSCP	Differentiated Services Codepoint
DSD	Duplicate Scheduling with Deadlines
DSL	Digital Subscriber Lines
DVD	Digital Versatile Disc
ECN	Explicit Congestion Notification
EDF	Earliest-deadline-first
EF	Expedited Forwarding
EIGRP	Enhanced Interior Gateway Routing Protocol
ENO	End-user Network Operator
ESP	Encapsulating Security Payload
FCFS	First Come First Serve
FEC	Forwarding Equivalence Class
FF	Fixed Filter
FFQ	Frame-based Fair Queueing
FIFO	First In First Out
FilterSpec	Filter Specification
FlowSpec	Flow Specification
FPS	First Person Shooter
FTP	File Transfer Protocol
GCRA	Generic Cell Rate Algorithm
GE	Gigabit Ethernet
GMPLS	Generalised MPLS
GS	Guaranteed Service
GT-ITM	Georgia Tech Internetwork Topology Models

HDLC	High-level Data Link Control
HFSC	Hierarchical Fair Service Curve
HPFQ	Hierarchical Packet Fair Queueing
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IGRP	Interior Gateway Routing Protocol
IKE	Internet Key Exchange Protocol
ILEC	Incumbent Local Exchange Carrier
IMAP	Internet Message Access Protocol
InfoSP	Information Service Provider
INSP	Internet Network Service Provider
Intserv	Integrated Services
IOS	(Cisco) Internet Operating System
IOTP	Internet Open Trading Protocol
IP	Internet Protocol
IPng	Internet Protocol, Next Generation (=IPv6)
IPsec	IP Security Protocol
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
IS	Intserv, Integrated Services
ISDN	Integrated Services Digital Network
IS-IS	Intermediate System to Intermediate System Routing Protocol
ISP	Internet Service Provider
IT	Information Technology
ITU-T	International Telecommunications Union – Telecommunications Standardization Sector
IXP	Internet Exchange Point
JUNOS	Juniper Network Operating System
LAN	Local Area Network
LDP	Label Distribution Protocol
LFVC	Leap Forward Virtual Clock
LINX	London Internet Exchange
LP	Linear Programming
LSP	Label Switched Path
LSR	Label Switching Router
MAC	Media Access Control
MAN	Metropolitan Area Network
MBone	Multicast Backbone
MIP	Mixed Integer Programming
MLD	Multicast Listener Discovery
MMORPG	Massive Multiplayer Online Roleplaying Game
MPEG	Motion Pictures Experts Group

MPLS	Multi-protocol Label Switching
MPλS	Multi-protocol Lambda Switching
MPRASE	Multi-period Resource Allocation at System Edges
MSS	Maximum Segment Size
MTU	Maximum Transmission Unit
NAP	Network Access Point
NAT	Network Address Translation
NNTP	Network News Transfer Protocol
NS2	Network Simulator 2
NSF	National Science Foundation
NSFNet	National Science Foundation Network
OC	Optical Carrier
OLO	Other Local Operator
OSI	Open Systems Interconnection
OSPF	Open Shortest Path First
OXC	Optical Cross-connect
P2P	Peer-to-peer
PCBE	Price-controlled Best-effort
PDB	Per Domain Behaviour
PDH	Plesiochronous Digital Hierarchy
PDU	Protocol Data Unit
PGPS	Packetised General Processor Sharing
PPP	Point-to-point Protocol
PHB	Per Hop Behaviour
PI	Proportional Integrator
PLC	Packet Loss Concealment
PLR	Packet Loss Recovery
PMP	Paris Metro Pricing
POP	Point of Presence
POTS	Plain Old Telephone Service
PPP	Point to Point Protocol
QBSS	QBone Scavenger Service
QoS	Quality of Service
RAM	Random Access Memory
RED	Random Early Detection
REM	Random Exponential Marking
RFC	Request for Comments
RIP	Routing Information Protocol
RP	Retail Provider
RSpec	Reservation Specification
RSVP	Resource Reservation Protocol
RSVP-TE	RSVP Traffic Engineering Extensions
RTP	Real-time Transport Protocol
RTS	Real-time Strategy (Game)
RTT	Round-trip Time
SACK	Selective Acknowledgement

SCFQ	Self-clocked Fair Queueing
SCORE	Stateless Core
SCP	Strategic Consultant Provider
SDH	Synchronous Digital Hierarchy
SDL	Simplified Data Link
SFQ	Start Time Fair Queueing
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SLO	Service Level Objective
SLS	Service Level Specification
SMS	Short Message Service
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
SONET	Synchronous Optical Networking
SP	Service Provider
SSH	Secure Shell
SSP	Storage Service Provider
STM	Synchronous Transfer Mode
TCAM	Ternary Content Addressable Memories
TCP	Transmission Control Protocol
TCS	Traffic Conditioning Specification
ToS	Type of Service
TSpec	Traffic Specification
TTL	Time to Live
UDP	User Datagram Protocol
UMS	Unified Messaging Service
URL	Uniform Resource Locator
US	United States
VBR	Variable Bit-rate
VC	Virtual Clock
VoIP	Voice over IP
VPN	Virtual Private Network
VPOP	Virtual POP (Point Of Presence)
VQ	Virtual Queue
WAN	Wide Area Network
WDM	Wavelength-division Multiplexing
WFQ	Weighted Fair Queueing
WF2Q	Worst-case Fair Weighted Fair Queueing
WRR	Weighted Round Robin
WWW	World Wide Web
YESSIR	Yet another Sender Session Internet Reservations

Abbreviations of Models and Algorithms

Chapter 8	see also Table 8.8
IS-α_{GS}	Intserv QoS System with parameter α_{GS}
sDS-c-p	Standard Diffserv with Central Bandwidth Broker and Parameter p
sDS-d-p	Standard Diffserv with Decentral Bandwidth Broker and Parameter p
sDS-n	Standard Diffserv without Bandwidth Broker
oDS-c-p	Olympic Diffserv with Central Bandwidth Broker and Parameter p
oDS-d-p	Olympic Diffserv with Decentral Bandwidth Broker and Parameter p
oDS-n	Olympic Diffserv without Bandwidth Broker
BE-OF	Best-effort System with Overprovisioning Factor OF
Chapter 10	
OPT	Minimal Cost Interconnection Model (Model 10.1)
H TR	Transit Heuristics
H PA	Peer-with-all Heuristics
H PS	Peer-at-selected-IXPs Heuristics
H EV	Evolution Heuristics
MT	Minimum Number of Transit Providers Policy (Model 10.2)
MC	Minimum Free Capacity Policy (Model 10.3)
AF	Anticipating Failure Policy (Model 10.4)
MCAF	Combined MC and AF Policy
PB	Peering Bonus (Model 10.5)
HC	Hop Constraint (Model 10.6)
HP	Hop Count Penalty Costs Policy (Model 10.7)
PC	Penalty Costs Policy (Model 10.8)
LC	Limiting Change Policy (Model 10.9)
Chapter 12	see also Table 12.3
SP	Shortest Path Routing
CC	Path Selection Strategy Minimising (Weighted) Congestion Costs
CC$_{uw}$	Path Selection Strategy Minimising Unweighted Congestion Costs
U$_{max}$	Path Selection Strategy Minimising Max. Utilisation
U$_{max}$**L**$_{av}$	Path Selection Strategy Minimising Max. Utilisation and Av. Load
U$_{max}$**P**$_{av}$	Path Selection Strategy Minimising Max. Util. and Av. Path Length
U$_{max}$**U**$_{av}$	Path Selection Strategy Minimising Max. Utilisation and Av. Utilisation

$\mathbf{U}_{av}$	Path Selection Strategy Minimising Av. Utilisation
$\mathbf{U}_{av}\mathbf{P}_{av}$	Path Selection Strategy Minimising Av. Util. and Av. Path Length
$\mathbf{p}_{av}\mathbf{L}_{av}$	Path Selection Strategy Minimising Av. Path Length and Av. Load
$\mathbf{L}_{av}$	Path Selection Strategy Minimising Av. Load

Chapter 13

CE	Capacity Expansion
TMCE	Combined Traffic Engineering and Capacity Expansion
T	Threshold-based Capacity Expansion Strategy