

Contents

Abstract	iv
Preface	vi
1 Introduction	1
2 Single Provider - General Network Topology	7
2.1 Introduction	7
2.2 The Model	11
2.2.1 Network Performance Model	11
2.2.2 Demand Model	13
2.2.3 Example	17
2.3 Fixed Capacity	20
2.3.1 Welfare-Maximization	20
2.3.2 Monopoly	22
2.4 Price and Capacity Decisions	24
2.4.1 Welfare-Maximization	24
2.4.2 Monopoly	27
2.4.3 Ramsey Pricing	31
2.4.4 Comparisons	39
2.5 Conclusion	42
3 Market Structure for Tandem Data Networks	43
3.1 Introduction	43
3.2 The Model	47

3.3	Cross-Traffic	48
3.3.1	Fixed Capacity	49
3.3.2	Price-Capacity Game	59
3.4	Local- and Cross-Traffic	70
3.4.1	Fixed Capacity	72
3.4.2	Price-Capacity Game	78
3.5	Conclusion	86
4	Efficient Monopoly: Sensitivity Analysis	87
4.1	Introduction	87
4.2	Multiple Priority Service Classes	88
4.2.1	Model	89
4.2.2	Welfare-Maximization	90
4.2.3	Monopoly	94
4.3	Other Demand Curves	95
4.4	Additive Delay Cost Structure	101
4.4.1	Delay Cost Structure and Demand Equations	101
4.4.2	Fixed Capacity	103
4.4.3	Price and Capacity Decisions	103
4.5	Conclusion	106
A	Proofs for Chapter 2	108
A.1	Proof of Theorem 2	108
A.2	Proof of Theorem 3	108
A.3	Proof of Theorem 4	109
B	Proofs for Chapter 3	110
B.1	Proof of Theorem 5	110
B.2	Proof of Theorem 6	111
B.3	Proof of Theorem 7	112
B.4	Proof of Theorem 8	113
B.5	Proof of Theorem 9	116
B.6	Proof of Theorem 10	117

C Proofs for Chapter 4	118
C.1 Proof of Lemma 1	118
C.2 Proof of Lemma 2	119
C.3 Proof of Theorem 11	120
C.4 Proof of Theorem 13	121
C.5 Proof of Theorem 14	122
C.6 Proof of Theorem 15	125

List of Figures

2.1	Example Network	18
2.2	Quality of Service for Linear Delay Discount Function	20
2.3	Monopoly: Utilization and Rate-Of-Return as a Function of the Delay Sensitivity	30
2.4	Ramsey Pricing with Zero Rate-Of-Return: Lagrange Multiplier and Capacity Cost Multiplier as a Function of the Delay Sensitivity	35
2.5	Ramsey Pricing with Zero Rate-Of-Return: Link Utilizations and Inverse Capacity Cost Multiplier as a Function of the Delay Sensitivity	37
2.6	Ramsey Pricing with Zero Rate-Of-Return: Link Profits as a Function of the Delay Sensitivity	38
2.7	Welfare-Maximization, Monopoly, and Ramsey Pricing with Zero Rate-Of-Return: Net Values as a Function of the Delay Sensitivity	41
3.1	Two Providers - Two Links: Price Reaction Curves for High Elasticity . . .	51
3.2	Two Providers - Two Links: Price Reaction Curves for Low Elasticity . . .	52
3.3	Demand Rate Ratio as a Function of the Number of Providers	56
3.4	Price Ratio as a Function of the Number of Providers	57
3.5	Net Value Ratio as a Function of the Number of Providers	58
3.6	Equilibrium Price as a Function of the Marginal Link Capacity Cost	65
3.7	Equilibrium Capacity as a Function of the Marginal Link Capacity Cost . .	66
3.8	Equilibrium Consumer Surplus as a Function of the Marginal Link Capacity Cost	67
3.9	Equilibrium Profit as a Function of the Marginal Link Capacity Cost	68
3.10	Equilibrium Net Value as a Function of the Marginal Link Capacity Cost .	69
3.11	Two-Link Tandem Network with Cross-Traffic and Local-Traffic	71

3.12 Monopoly and Two Providers: Equilibrium Cross-Traffic Price Ratio as a Function of the Delay Sensitivity Ratio	81
3.13 Monopoly and Two Providers: Demand Rates as a Function of the Local-to-Cross-Traffic Delay Sensitivity Ratio.	82
3.14 Monopoly: Profit, Consumer Surplus, and Aggregate Net Value, as a Function of the Delay Sensitivity Ratio	83
3.15 Two Providers: Profit, Consumer Surplus, and Aggregate Net Value, as a Function of the Delay Sensitivity Ratio	84
3.16 Monopoly and Two Providers: Ratios of Profits, Consumer Surpluses, and Aggregate Net Values, as a Function of the Delay Sensitivity Ratio	85
4.1 Ratio of Monopoly to Efficient Demand Rate for a Linear Combination of the Isoelastic and Affine Marginal Value Curves, as a Function of the Delay Sensitivity	99
4.2 % Welfare Loss for a Linear Combination of the Isoelastic and Affine Marginal Value Curves, as a Function of the Delay Sensitivity	100