

Contents

1	Introduction	1
1.1	Motivation	2
1.2	Broker-based Service Level Management	3
1.3	Research Goals and Challenges	4
1.4	Contributions	6
1.5	Structure of this Thesis	8
2	Background	11
2.1	Cloud Computing	11
2.1.1	Definition	11
2.1.2	Enabling Technologies	17
2.1.3	Related Paradigms	20
2.2	Service Level Management	23
2.2.1	Definition	23
2.2.2	Service Level Agreements	25
2.2.3	Quality of Service	26
2.3	Automated Electronic Negotiations	31
2.3.1	Negotiation Mechanisms	31
2.3.2	Utility Theory and Pareto-Efficiency	33
2.4	Monitoring	35
2.4.1	Definition	35
2.4.2	Monitoring Objectives in Cloud Computing	36
2.4.3	General Monitoring Principles	37
3	Related Work	39
3.1	Pareto-Efficient Negotiations	39
3.2	Reliable Monitoring	44
3.3	Robust Monitor Placement	52
4	Basic System Design - CSLAB.KOM	63
4.1	Service Level Management Broker	63
4.2	Negotiation Design	65
4.2.1	Negotiation Requirements	65
4.2.2	Generic Model of Negotiation Performance	66
4.2.3	Basic Negotiation Model	67

4.3	Monitoring Design	70
4.3.1	Availability of Cloud Services	70
4.3.2	Reasons for Downtimes	72
4.3.3	Monitoring Requirements	73
4.3.4	Basic Monitoring Approach	76
4.3.5	Monitoring Level Agreements	80
4.4	Summary	81
5	Pareto-Efficient Negotiations - CSLAB-Neg.KOM	83
5.1	Problem Statement	83
5.2	Ex Post Pareto-Efficiency Reference Model	85
5.3	Pareto-Efficient Negotiation Mechanism	87
5.3.1	Meta-Strategy	87
5.3.2	Negotiation Protocol	90
5.3.3	Negotiation Strategies	91
5.3.4	Negotiation Algorithm	97
5.4	Summary	110
6	Reliable Monitoring - CSLAB-Mon.KOM	111
6.1	Problem Statement	111
6.2	Approach for Reliable Consumer Side Availability Monitoring	113
6.2.1	Data Collection	113
6.2.2	Data Aggregation	115
6.2.3	Influence of Frequency and Sample Size on Accuracy	118
6.2.4	Influence of Packet Loss on Accuracy	130
6.3	Summary	135
7	Robust Monitor Placement - CSLAB-Loc.KOM	137
7.1	Problem Statement	138
7.2	Formal Notations	140
7.3	Exact Optimization Approach - CSLAB-Loc-Exa.KOM	143
7.3.1	Optimization Model	143
7.3.2	Linearization and Single Objective Transformation	147
7.4	Heuristic Placement Strategies	150
7.4.1	Heuristic Optimization Approach - CSLAB-Loc-Start.KOM	151
7.4.2	Heuristic Improvement Approach - CSLAB-Loc-Imp.KOM	155
7.5	Summary	164
8	Evaluation	165
8.1	Major Objectives	165
8.1.1	Pareto-Efficient Negotiations	165
8.1.2	Reliable Monitoring	167

8.1.3	Robust Monitor Placement	168
8.2	Pareto-Efficient Negotiations - CSLAB-Neg.KOM	169
8.2.1	Simulation Framework	169
8.2.2	Experimental Setup	171
8.2.3	Results and Discussion	174
8.3	Reliable Monitoring - CSLAB-Mon.KOM	183
8.3.1	Prototypical Implementation	183
8.3.2	Experimental Setup	185
8.3.3	Results and Discussion	186
8.4	Robust Monitor Placement - CSLAB-Loc.KOM	194
8.4.1	Optimization Framework	194
8.4.2	Experimental Setup	196
8.4.3	Results and Discussion	199
8.5	Summary	205
9	Summary and Outlook	207
9.1	Summary	207
9.2	Outlook	211
	References	213
A	Appendix	235
A.1	TCP Behavior in the Presence of Packet Loss	235
A.2	Additional Results of the Evaluation of CSLAB-Neg.KOM	235