

Contents

1	Introduction	1
1.1	Contributions of the Thesis	4
1.2	Organization of the Thesis	5
2	Preliminaries	7
2.1	Distributed Systems	7
2.2	Algorithms, Protocols, and State Model	7
2.3	Execution Model and Schedulers	9
2.4	Notions of Time	12
2.5	Other Communication Models	14
2.6	Anonymity and Node Identifiers	15
2.7	Single vs. Multiple Protocols	17
2.8	Virtual Topologies	19
3	Fault-Tolerance	21
3.1	Classification of Faults	21
3.2	Types of Fault-Tolerance	22
3.3	Self-Stabilization	24
3.4	Self-Stabilization via Transformation	26
3.5	Criticism of Self-Stabilization	27
4	Proving Self-Stabilization	29
4.1	Potential Functions	30
4.2	Convergence Stairs	32
4.3	Graph Reduction	33
4.4	State Analysis	34
4.5	Composition	35
4.6	Serialization	38
4.6.1	Definition	39
4.6.2	Construction	40
4.6.3	Partial Serialization	43
4.6.4	Practicability and Impossibility	45
4.6.5	Dependency graphs	47

4.6.6	Non-deterministic protocols	47
4.7	Discussion	48
5	Fault-Containing Self-Stabilization	51
5.1	Contamination	52
5.2	Definition of Containment	56
5.3	Related Concepts	60
5.3.1	Safe Convergence	60
5.3.2	Adaptive Self-Stabilization	61
5.3.3	Containment of Time-Bounded Byzantine Faults	62
5.4	Containment via Global Synchronization	62
5.4.1	Serialization	66
5.5	Problem-Specific Solutions	68
5.6	Probabilistic Containment	70
5.6.1	Error-Detecting Codes	70
5.6.2	Weak Stabilization	71
5.7	Priority Scheduling	74
5.8	Containment via Local Synchronization	75
5.8.1	Cells	76
5.8.2	Cell Dialog	77
5.8.3	Cell Transitions	81
5.8.4	Fault-Repair	85
5.8.5	Analysis	89
5.8.6	Optimizations and Modifications	104
5.9	Discussion	106
6	Local k-Placement with Local Minimum Variance	109
6.1	The Local k -Placement Problem	110
6.2	Related Problems	111
6.2.1	Balancing Load	111
6.2.2	Optimized Placement	112
6.3	Reductions to Flow Problems	113
6.4	Placement Algorithm	114
6.5	Potential Function	118
6.5.1	Central Scheduler	119
6.5.2	Distributed Scheduler	123
6.6	Analysis	128
6.7	Integration	131
6.8	Concluding Remarks	135

7	Fault-Containment in Dynamic Networks	137
7.1	Super-Stabilization	138
7.2	Fault-Containing Super-Stabilization	141
7.3	The Transformation	143
7.3.1	Backup Placement Requirements	146
7.3.2	Spawning and Deleting Instances	147
7.3.3	Refined Cells	148
7.3.4	Lower Layer	153
7.3.5	Upper Layer	156
7.3.6	Middle Layer	160
7.3.7	Fault Repair	162
7.4	Analysis	169
7.4.1	Proof of Self-Stabilization	171
7.4.2	Proof of Fault-Containing Super-Stabilization	178
7.4.3	Proof of Fault-Containing Self-Stabilization	186
7.4.4	Serialization	187
7.5	Optimizations	191
7.6	Discussion	191
8	Concluding Remarks	195
	Bibliography	199
	List of Symbols	209
	List of Figures	211
	List of Tables	213
	Author's Publications	
	Curriculum Vitae	