



Contents

1	Introduction	11
1.1	Problem Statement	11
1.2	Contributions of this Thesis	12
1.3	Structure of this Thesis	16
2	Background	17
2.1	Multimedia Content Distribution	17
2.1.1	Challenges and Classification of Multimedia Streaming	17
2.1.2	Multimedia Coding Techniques	18
2.2	P2P Systems	21
2.2.1	Classification of P2P systems	21
2.2.2	Attacks on P2P Systems	22
2.2.3	Countermeasures against Attacks on P2P Streaming	26
2.2.4	Summary	28
2.3	Simulation of Communication Networks	28
2.3.1	Discrete Event Simulation	28
2.3.2	OMNeT++	29
2.4	Summary	33
3	Requirements and State of the Art	35
3.1	Requirements of an IPTV System	35
3.1.1	Functional Requirements	35
3.1.2	Non-Functional Requirements	36
3.2	IP Multicast	38
3.3	Content Distribution Networks	40
3.4	Application Layer Multicast	41
3.4.1	General Classification of ALM Approaches	42
3.4.2	Push-based ALM	43
3.4.3	Pull-based ALM	51
3.4.4	Hybrid ALM	57
3.4.5	Peer-Assisted ALM Streaming	61
3.4.6	Summary	63
3.5	Topology-Aware P2P Overlays	67
3.5.1	Packet Reflection and Path Painting	67
3.5.2	Underlay Fused with Overlays	69
3.5.3	Topology-Aware Overlay Networks	70
3.5.4	Summary of Topology-Aware P2P Overlays	71
3.6	Discussion	72



4	P2P-based IPTV Content Distribution	75
4.1	System Overview	76
4.1.1	Server-Side Assistance	77
4.1.2	ALM Algorithm	78
4.2	System Model for P2P-based IPTV	80
4.3	Near-Optimal Stable IPTV Topologies	83
4.3.1	Construction Rules for Near-Optimal Stable Streaming Topologies	83
4.3.2	Distributed Construction of Near-Optimal Stable Topologies	87
4.3.3	Summary of Near-Optimal Stable Topologies	91
4.4	Manipulation-Resistant ALM Topology Construction	92
4.4.1	Distribution of Topology Information	93
4.4.2	Bootstrapping Joining Nodes	94
4.4.3	Node Promotion and Degradation	95
4.4.4	Reliability Estimation	95
4.4.5	Repair Mechanism	96
4.4.6	Summary	99
4.5	Node Heterogeneity and Mobility	100
4.5.1	Client Bandwidth Heterogeneity	100
4.5.2	Client Mobility	103
4.5.3	Summary of Node Heterogeneity	106
4.6	Underlay-Aware Topology Construction	106
4.6.1	Peer-assisting ALM Routers	107
4.6.2	Underlay-Aware Overlay Construction	111
4.6.3	Summary of Underlay-Awareness	126
4.7	Combination of Mechanisms to an Integrated IPTV System	127
5	Evaluation	131
5.1	Qualitative Discussion of AREA IPTV	131
5.1.1	Functional Requirements	132
5.1.2	Non-Functional Requirements	133
5.1.3	Summary	143
5.2	Additional Metrics	144
5.2.1	Internal Attacker Model	144
5.2.2	Metrics for Underlay-Awareness and Resilience against Underlay Attacks	147
5.3	Assumptions and Models	150
5.3.1	AREA IPTV Simulation Framework	150
5.3.2	Network Model	153
5.3.3	User Model	155
5.3.4	General Setup of Experiments	157
5.4	Evaluation of Overlay Construction	157
5.4.1	Distributed Construction of Near-Optimal Stable Topologies	157
5.4.2	Overlay Resilience against Internal Attackers	164
5.4.3	Node Mobility	173
5.4.4	Overlay Construction Summary	176
5.5	Evaluation of an Underlay-Aware Overlay Construction	176
5.5.1	ALM Routers	177
5.5.2	Underlay-aware ALM Topology Construction	182



5.5.3	Summary of the Underlay-Aware Topology Construction	190
5.6	Evaluation of Combined Mechanisms	191
5.6.1	Simulation Setup	191
5.6.2	Expectations	193
5.6.3	Results	193
5.6.4	Summary of the Evaluation of Combined Mechanisms	195
5.7	Summary	196
6	Conclusion and Outlook	199
6.1	Summary	199
6.2	Future Work	201
	Bibliography	203
	Acronyms	215