

Contents

<i>Preface</i>	<i>page</i>	ix
<i>Abbreviations</i>		xi
1	Introduction	1
1.1	Terms and definitions	3
1.2	Who is who	5
1.2.1	Rulemaking, regulation, and standardization	5
1.2.2	Research	6
1.3	How to use this book	7
1.3.1	Target audience	7
1.3.2	Overview for non-experts	8
1.3.3	In-depth studies for the experienced reader	9
2	Intra-vehicle communication	12
2.1	In-vehicle networks	13
2.2	Automotive bus systems	15
2.2.1	CAN	15
2.2.2	LIN	21
2.2.3	MOST	24
2.2.4	FlexRay	27
2.3	In-vehicle Ethernet	32
2.3.1	Background	32
2.3.2	Adaptations for vehicular networks	34
2.3.3	Introduction into cars	36
2.4	Wireless in-vehicle networks	37
3	Inter-vehicle communication	38
3.1	Applications	39
3.1.1	Traffic information systems	39
3.1.2	Intersection collision warning systems	46
3.1.3	Platooning	48
3.1.4	Traffic-light information and control	50

Contents

3.1.5	Entertainment applications	53
3.2	Requirements and components	56
3.2.1	Application demands	56
3.2.2	Metrics to assess IVC solutions	62
3.2.3	Communicating entities	65
3.2.4	Communication principles	68
3.3	Concepts for inter-vehicle communication	71
3.3.1	FM radio and DAB	72
3.3.2	Cellular networks	76
3.3.3	Ad-hoc routing	80
3.3.4	Broadcasting	85
3.3.5	Geographic routing	96
3.4	Fundamental limits	100
3.4.1	Towards heterogeneous networks	100
3.4.2	The broadcast storm problem	102
3.4.3	Scalability of VANETs	104
4	Access technologies	106
4.1	Cellular networks	107
4.1.1	GSM	110
4.1.2	UMTS	112
4.1.3	LTE	113
4.1.4	Future developments	115
4.1.5	Use of cellular networks for IVC	116
4.2	Short-range radio technologies	118
4.2.1	Wireless LAN	119
4.2.2	IEEE 802.11p	122
4.2.3	Higher-layer protocols	125
4.3	White spaces and cog radio	129
4.3.1	Cognitive radio	130
4.3.2	TV white space	131
4.3.3	Use of white space for IVC	132
5	Information dissemination	136
5.1	Ad-hoc routing	138
5.1.1	Proactive routing protocols	139
5.1.2	Reactive routing protocols	140
5.1.3	Application in VANETs	145
5.2	Geographic routing	152
5.2.1	Geographic routing	153
5.2.2	Virtual-coordinate-based routing	157
5.3	Beaconing	167
5.3.1	Self-organized traffic information system	167

5.3.2	Cooperative awareness messages	172
5.4	Adaptive beaconing	174
5.4.1	Adaptive traffic beacon	175
5.4.2	Decentralized congestion control	185
5.4.3	Dynamic beaconing	191
5.5	Geocasting	196
5.5.1	ETSI GeoNetworking	197
5.5.2	Decentralized environmental notification messages	200
5.5.3	Topology-assisted geo-opportunistic routing	201
5.6	Infrastructure support	205
5.6.1	Roadside units	206
5.6.2	Parked vehicles	211
5.7	DTN and peer-to-peer networks	217
5.7.1	Distributed vehicular broadcast	219
5.7.2	MobTorrent	222
5.7.3	PeerTIS	225
6	Performance evaluation	229
6.1	Performance measurements	229
6.1.1	Concepts and strategies	230
6.1.2	Field operational tests	231
6.1.3	Simulation techniques	243
6.2	Simulation tools	255
6.2.1	Network simulation	256
6.2.2	Road traffic simulation	259
6.2.3	IVC simulation frameworks	262
6.3	Scenarios, models, and metrics	264
6.3.1	Scenarios	265
6.3.2	Channel models	274
6.3.3	Driver behavior	285
6.3.4	Metrics	290
7	Security and privacy	302
7.1	Security primitives	303
7.1.1	Security objectives and technical requirements	303
7.1.2	Security relationships	307
7.1.3	Certificates	308
7.1.4	Security vs. privacy	311
7.2	Securing vehicular networks	311
7.2.1	Using certificates for IVC	311
7.2.2	Performance issues	313
7.2.3	Certificate revocation	315
7.2.4	Position verification	316

Contents

7.3 Privacy	317
7.3.1 Location privacy	318
7.3.2 Tracking options	319
7.3.3 Temporary pseudonyms	321
7.3.4 Exchanging pseudonyms	323
<i>References</i>	325
<i>Index</i>	348