

# Contents

<b>Preface</b>	<b>xi</b>
<b>List of Abbreviations</b>	<b>xiii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 What are Location-based Services? . . . . .	1
1.2 Application Scenarios . . . . .	3
1.2.1 Business Initiatives . . . . .	3
1.2.2 Public Initiatives . . . . .	7
1.3 LBS Actors . . . . .	10
1.4 Standardization . . . . .	11
1.5 Structure of this Book . . . . .	13
<b>Part I Fundamentals</b>	<b>15</b>
<b>2 What is Location?</b>	<b>17</b>
2.1 Location Categories . . . . .	17
2.2 Spatial Location . . . . .	19
2.2.1 Coordinate Systems . . . . .	19
2.2.2 Datums . . . . .	23
2.2.3 Map Projections . . . . .	27
2.3 Conclusion . . . . .	33
<b>3 Spatial Databases and GIS</b>	<b>35</b>
3.1 What are Spatial Databases and GIS? . . . . .	36
3.2 Geographic versus Spatial Data Models . . . . .	36
3.3 Representing Spatial Objects . . . . .	38
3.3.1 Raster Mode . . . . .	38
3.3.2 Vector Mode . . . . .	39
3.3.3 Representing Topological Relationships . . . . .	41
3.3.4 Database Approaches for Spatial Objects . . . . .	43
3.4 Features and Themes . . . . .	45
3.4.1 Conceptual Schemes . . . . .	47
3.4.2 Operations . . . . .	48

3.4.3	Topological Predicates . . . . .	49
3.4.4	Queries . . . . .	50
3.5	Algorithms of Computational Geometry . . . . .	53
3.6	Geography Markup Language . . . . .	55
3.7	Conclusion . . . . .	59
<b>4</b>	<b>Basics of Wireless Communications</b>	<b>61</b>
4.1	Signals . . . . .	61
4.1.1	Modulation . . . . .	63
4.1.2	Representing Signals in the Frequency Domain . . . . .	64
4.1.3	Signal Spectrum and Bandwidth . . . . .	66
4.2	Propagation of Radio Signals . . . . .	68
4.2.1	The Electromagnetic Spectrum . . . . .	68
4.2.2	Antennas . . . . .	70
4.2.3	Speed of Electromagnetic Waves . . . . .	72
4.2.4	Attenuation . . . . .	75
4.2.5	Multipath Propagation . . . . .	76
4.2.6	Doppler Effect . . . . .	78
4.3	Multiplexing and Multiple Access . . . . .	79
4.3.1	SDM and SDMA . . . . .	80
4.3.2	FDM and FDMA . . . . .	80
4.3.3	TDM and TDMA . . . . .	81
4.3.4	CDM and CDMA . . . . .	82
4.4	Conclusion . . . . .	86
<b>5</b>	<b>Cellular Networks and Location Management</b>	<b>89</b>
5.1	Overview of Cellular Systems . . . . .	90
5.2	Principles of Cellular Networks . . . . .	91
5.2.1	GSM Architecture . . . . .	93
5.2.2	GPRS Architecture . . . . .	95
5.2.3	UMTS Architecture . . . . .	96
5.3	Mobility Management . . . . .	97
5.4	Common Concepts of Location Management . . . . .	99
5.4.1	Location Update and Paging . . . . .	99
5.4.2	Database Concepts . . . . .	102
5.5	Location Management in CS Networks . . . . .	103
5.5.1	Identifiers and Addresses . . . . .	104
5.5.2	Localization and Routing . . . . .	106
5.5.3	Location Updates . . . . .	107
5.6	Location Management in PS Networks . . . . .	109
5.6.1	Localization and Routing . . . . .	109
5.6.2	Characteristics of CS and PS Traffic . . . . .	112
5.6.3	Location Updates . . . . .	115
5.7	Conclusion . . . . .	119

<b>Part II Positioning</b>	<b>121</b>
<b>6 Fundamentals of Positioning</b>	<b>123</b>
6.1 Classification of Positioning Infrastructures . . . . .	126
6.1.1 Integrated and Stand-alone Infrastructures . . . . .	127
6.1.2 Network and Terminal-based Positioning . . . . .	128
6.1.3 Satellites, Cellular, and Indoor Infrastructures . . . . .	128
6.2 Basic Positioning Methods . . . . .	130
6.2.1 Proximity Sensing . . . . .	130
6.2.2 Lateration . . . . .	131
6.2.3 Angulation . . . . .	138
6.2.4 Dead Reckoning . . . . .	140
6.2.5 Pattern Matching . . . . .	142
6.2.6 Hybrid Approaches . . . . .	142
6.3 Range Measurements . . . . .	143
6.3.1 Time Measurements . . . . .	144
6.3.2 Received Signal Strength . . . . .	148
6.4 Accuracy and Precision . . . . .	148
6.5 Error Sources . . . . .	151
6.6 Conclusion . . . . .	154
<b>7 Satellite Positioning</b>	<b>155</b>
7.1 Historical Background . . . . .	155
7.2 Orbital Motion of Satellite Systems . . . . .	157
7.2.1 Satellite Orbits . . . . .	157
7.2.2 Keplerian Elements . . . . .	160
7.3 Global Positioning System . . . . .	162
7.3.1 GPS Segments . . . . .	162
7.3.2 Satellite Constellation . . . . .	164
7.3.3 Pilot Signals and Spreading Codes . . . . .	165
7.3.4 Navigation Message . . . . .	168
7.3.5 GPS Services . . . . .	170
7.3.6 GPS Positioning . . . . .	171
7.3.7 GPS Error Budget . . . . .	174
7.4 Differential GPS . . . . .	177
7.5 Galileo . . . . .	179
7.6 Conclusion . . . . .	183
<b>8 Cellular Positioning</b>	<b>185</b>
8.1 Positioning in GSM Networks . . . . .	185
8.1.1 GSM Air Interface . . . . .	186
8.1.2 GSM Positioning Components . . . . .	190
8.1.3 Cell-Id Combined with Timing Advance . . . . .	192
8.1.4 E-OTD . . . . .	194
8.1.5 U-TDoA . . . . .	208

8.2	Positioning in UMTS Networks . . . . .	211
8.2.1	UMTS Air Interfaces . . . . .	211
8.2.2	UMTS Positioning Components . . . . .	217
8.2.3	Cell-based Methods . . . . .	218
8.2.4	OTDoA-IPDL . . . . .	220
8.2.5	RIT Measurements in UMTS . . . . .	221
8.3	Assisted GPS in GSM and UMTS . . . . .	225
8.4	Positioning in other Cellular Systems . . . . .	229
8.5	Conclusion . . . . .	230
<b>9</b>	<b>Indoor Positioning</b> . . . . .	<b>233</b>
9.1	WLAN Positioning . . . . .	233
9.1.1	Principles of WLAN Positioning . . . . .	234
9.1.2	WLAN Fingerprinting . . . . .	236
9.2	RFID Positioning . . . . .	239
9.3	Indoor Positioning with GPS . . . . .	240
9.4	Non Radiolocation Systems . . . . .	241
9.4.1	Infrared-based Systems . . . . .	241
9.4.2	Ultrasound-based Systems . . . . .	243
9.5	Conclusion . . . . .	244
	<b>Part III LBS Operation</b> . . . . .	<b>247</b>
<b>10</b>	<b>Interorganizational LBS Operation</b> . . . . .	<b>249</b>
10.1	LBS Supply Chain . . . . .	250
10.2	Scenarios of the LBS Supply Chain . . . . .	252
10.3	Supplier/Consumer Patterns for Location Dissemination . . . . .	254
10.3.1	Querying . . . . .	254
10.3.2	Reporting . . . . .	255
10.3.3	Evaluation of Querying and Reporting . . . . .	256
10.4	Privacy Protection . . . . .	257
10.4.1	Characteristics of Privacy Protection for LBSs . . . . .	258
10.4.2	Definition of Privacy . . . . .	259
10.4.3	Concepts and Mechanisms for Privacy Protection . . . . .	261
10.5	Conclusion . . . . .	269
<b>11</b>	<b>Architectures and Protocols for Location Services</b> . . . . .	<b>271</b>
11.1	GSM and UMTS Location Services . . . . .	273
11.1.1	LCS Network Architecture . . . . .	275
11.1.2	LCS Functional Entities . . . . .	276
11.1.3	Location Procedures . . . . .	279
11.1.4	Privacy Options . . . . .	283
11.1.5	Outlook to Future Releases . . . . .	286
11.2	Enhanced Emergency Services . . . . .	288
11.2.1	Wired Enhanced Emergency Services . . . . .	289
11.2.2	Wireless Enhanced Emergency Services . . . . .	290

- 11.3 Mobile Location Protocol . . . . . 294
  - 11.3.1 MLP Structure and Location Service . . . . . 294
  - 11.3.2 Example . . . . . 297
  - 11.3.3 Outlook to Future Releases . . . . . 300
- 11.4 WAP Location Framework . . . . . 301
  - 11.4.1 WAP Overview . . . . . 301
  - 11.4.2 WAP Location Services . . . . . 302
- 11.5 Parlay/OSA . . . . . 305
- 11.6 Geopriv . . . . . 307
  - 11.6.1 Geopriv Entities . . . . . 308
  - 11.6.2 Location Objects . . . . . 309
  - 11.6.3 Geopriv Outlook . . . . . 311
- 11.7 Conclusion . . . . . 312
  
- 12 LBS Middleware . . . . . 315**
  - 12.1 Conceptual View of an LBS Middleware . . . . . 316
  - 12.2 Location API for J2ME . . . . . 318
    - 12.2.1 Overview of J2ME . . . . . 318
    - 12.2.2 Location API for J2ME . . . . . 320
  - 12.3 OpenGIS Location Services . . . . . 322
    - 12.3.1 Information Model . . . . . 326
    - 12.3.2 Core Services . . . . . 328
  - 12.4 Conclusion . . . . . 335
  
- 13 LBS – The Next Generation . . . . . 337**
  
- Bibliography . . . . . 343**
  
- Index . . . . . 353**

