

Contents

Abstract	VII
List of Figures	XV
List of Tables	XXI
List of Abbreviations	XXIII
1 Introduction	1
1.1 Motivation	1
1.2 Scope of UMTS Network Dimensioning	2
1.3 Important Challenges for UMTS Network Dimensioning	4
1.4 Contributions of this Thesis	7
1.5 Thesis Overview	11
2 UMTS Evolution	15
2.1 Background of UMTS	15
2.2 UMTS Network Architecture	16
2.3 Evolution of UMTS	18
2.3.1 UMTS Release 99	19
2.3.2 High Speed Downlink Packet Access (HSDPA)	20
2.3.3 High Speed Uplink Packet Access (HSUPA)	21
2.3.4 Introduction of “All-IP” UMTS Networks	22
2.3.4.1 IP-Based UTRAN	23
2.3.4.2 Pseudo-Wire Emulation (PWE) Technology	25
2.3.5 LTE and SAE	26
3 UMTS Terrestrial Radio Access Network (UTRAN)	29
3.1 UTRAN Architecture and Interfaces	29
3.2 Generic Protocol Model for UTRAN Interfaces	31
3.3 UMTS Release 99	32
3.3.1 UTRAN Protocol Stack	33
3.3.2 Channels in the UTRAN	36
3.3.3 Iub Interface	38
3.3.3.1 Protocol Stack for the Iub User Plane	38
3.3.3.2 ATM	40
3.3.3.3 AAL2 Protocol	41
3.3.3.4 Transport Requirements on the Iub Interface	43
3.3.4 Resource Management	44
3.3.4.1 Radio Access Bearer (RAB)	44

3.3.4.2	Radio Resource Management (RRM)	46
3.3.4.3	Transport Resource Management (TRM)	49
3.4	IP-Based UTRAN	51
3.4.1	IP-Based UTRAN User Plane Protocol Architecture	51
3.4.2	QoS Support in the IP-Based UTRAN	52
3.4.2.1	Introduction of the DiffServ QoS Scheme	52
3.4.2.2	Mapping of UMTS QoS to DiffServ PHBs	56
3.4.2.3	DiffServ-Based QoS Architecture in IP-Based UTRAN	56
4	Framework of UMTS Network Dimensioning	59
4.1	Objectives of UMTS Network Dimensioning	59
4.1.1	Network Costs	59
4.1.2	Quality of Service	59
4.1.2.1	User-Relevant QoS	60
4.1.2.2	Network-Relevant QoS (Network Performance)	61
4.2	Important Issues for UMTS Network Dimensioning	61
4.2.1	Traffic Analysis	63
4.2.2	Network Topology	65
4.2.3	Traffic Control	66
4.2.4	Resource Control	67
4.2.5	Routing and Traffic Engineering	67
4.2.6	Summary	68
4.3	Framework for UMTS Network Dimensioning	68
4.4	Dimensioning Approaches	72
4.5	Conclusion	75
5	Introduction of Simulation Models	77
5.1	Requirements of Simulation Models	77
5.2	Simulation Model Framework	78
5.3	Simulation Environment	80
5.4	Simulation Model of UMTS Rel99	80
5.5	Simulation Model of IP-Based UTRAN	88
5.5.1	Exact IP-Based UTRAN Simulation Model	88
5.5.2	Simplified IP-Based UTRAN Simulation Model	89
5.5.3	Summary	90
5.6	Simulation Model of HSPA	90
5.7	Simulation Model of Combined UMTS Rel99 and HSPA	91
5.8	Traffic Models	92
5.8.1	Voice Traffic Model	92
5.8.2	Web Browsing Traffic Model	94
5.8.3	File Transfer Traffic Model	96
6	Dimensioning for Single ATM-Based Iub	99
6.1	Overview and Objectives	99
6.2	Dimensioning for Circuit-Switched Traffic	100
6.2.1	Erlang-B Formula	100
6.2.2	Multi-Dimensional Erlang-B Formula	105

6.2.3	Iub Dimensioning with the Erlang-B Formula.....	109
6.2.4	Validation of Erlang Model.....	111
6.2.5	Dimensioning Results	114
6.2.6	Summary	116
6.3	Dimensioning for Elastic Traffic.....	116
6.3.1	Transmission Control Protocol (TCP).....	117
6.3.2	Related Work.....	120
6.3.3	Processor Sharing Model for Elastic Traffic.....	121
6.3.4	Application of M/G/R-PS Model for Dimensioning Iub Interface	122
6.3.5	Basic M/G/R-PS Model	124
6.3.6	Extended M/G/R-PS Model	127
6.3.7	Suggested Extensions on M/G/R-PS Model for Iub Dimensioning.....	129
6.3.7.1	Extension for case with Single RAB and not Applying CAC.....	130
6.3.7.2	Extension for case with Single RAB and Applying CAC.....	132
6.3.7.3	Extension for case with Multiple RABs and not Applying CAC	133
6.3.7.4	Extension for case with BRA and not Applying CAC.....	136
6.3.7.5	Extension for case of Mixing with Circuit-Switched Traffic.....	137
6.3.8	Validation of Extensions of Processor Sharing Models.....	139
6.3.8.1	Simulation Environment	139
6.3.8.2	Single RAB without Applying CAC.....	140
6.3.8.3	Single RAB with CAC	143
6.3.8.4	Multiple RABs without Applying CAC.....	145
6.3.8.5	BRA without Applying CAC	148
6.3.8.6	Elastic Traffic Mixed with Circuit-Switched Traffic.....	149
6.3.9	Dimensioning Procedures	150
6.3.10	Dimensioning Results	153
6.3.11	Summary	157
6.4	Dimensioning for Transport Network Performance.....	157
6.4.1	System Models for the Iub Interface	158
6.4.1.1	Delay Analysis on the Iub	158
6.4.1.2	System Models	160
6.4.2	UMTS Iub Traffic Characteristics.....	162
6.4.2.1	Squared Coefficient of Variation	162
6.4.2.2	Self-Similarity of Elastic IP Traffic	163
6.4.3	Analytical Dimensioning Models with MMPP	164
6.4.3.1	Markov Modulated Poisson Process (MMPP).....	165
6.4.3.2	MMPP(2)/D/1.....	166
6.4.3.3	MMPP(2)/D/1 – Non-Preemptive Priority	169
6.4.3.4	Iub Dimensioning with MMPP	171
6.4.3.5	Validations	173
6.4.4	Analytical Dimensioning Models with BMAP	177
6.4.4.1	Batch Markovian Arrival Process (BMAP)	177
6.4.4.2	BMAP/D/1	182
6.5	Dimensioning for HSPA	183
7	Dimensioning for Single IP-Based Iub	187
7.1	Overview and Objectives	187
7.2	Dimensioning for Circuit-Switched Traffic	188

7.3	Dimensioning for Elastic Traffic.....	188
7.3.1	Analytical Models for the IP-Based Iub Dimensioning.....	189
7.3.2	Validation of Analytical Dimensioning Models	193
7.3.3	Dimensioning Procedure	196
7.3.4	Dimensioning Results	197
7.4	Comparing the ATM and IP-Based Iub	198
7.5	Summary	202
8	Dimensioning for Multi-Iub RAN Scenario	203
8.1	Overview and Objectives	203
8.1.1	Dimensioning of Individual Links	204
8.1.2	Overbooking of the Iub Backbone Link.....	204
8.2	Dimensioning for Circuit-Switched Traffic	206
8.2.1	Network Dimensioning Approach	206
8.2.2	Applicability of the Dimensioning Approaches.....	209
8.2.3	Summary	211
8.3	Dimensioning for Elastic Traffic in ATM-Based UTRAN.....	211
8.3.1	Estimation of End-to-End Application Performance	212
8.3.2	Dimensioning Approaches	217
8.3.3	Dimensioning Results	220
8.3.4	Summary	223
8.4	Dimensioning for Elastic Traffic in IP-Based UTRAN	223
8.4.1	Dimensioning Approaches	224
8.4.2	Dimensioning Results	227
8.4.3	Summary	232
8.5	Overbooking of the Iub Backbone Link.....	233
8.5.1	Overbooking of ATM-Based Iub Backbone Link.....	233
8.5.2	Overbooking of IP-Based Iub Backbone Link.....	237
8.5.3	Comparing ATM and IP-Based Multi-Iub RAN.....	242
8.5.4	Summary	244
9	Conclusion and Outlook	247
	Appendix	251
A.1	ATM Cell Format.....	251
A.2	AAL2 Packet Formats	251
A.3	ATM Service Categories and QoS Parameters	253
A.4	Ethernet	255
A.5	Random Early Detection and Weighted RED	255
A.6	AMR.....	258
A.7	Self-Similarity	260
A.8	ATM Workstation and Server	261
A.9	Introduction for HSPA (HSUPA/HSDPA)	262
A.10	Simulation Model of HSPA	267
A.11	Multiplexing Schemes for the IP-Based UTRAN.....	269
A.12	Exact IP-Based UTRAN Simulation Model	271
A.13	Impact of TCP Slow Start	273
A.14	Processor Sharing among Multiple RABs	273

- A.15 Dimensioning for HSPA Traffic 274
- A.16 Use of Traffic Separation for Transport of HSPA and Rel99 282
- A.17 Dimensioning for Mixed Traffic Cases (ATM-Based Iub)..... 295
- A.18 Validating Dimensioning Approaches for Multi-Iub IP RAN..... 296
- A.19 Investigating Overbooking in the ATM-Based UTRAN 299
- A.20 Statistical Evaluation: Confidence Interval..... 304
- A.21 Statistical Evaluation: Limited Relative Error 307
- A.22 Comparing ATM and IP-Based UTRAN..... 308

Bibliography