



## **AROMA IST-4-027567**

**D09**

### **First report on AROMA algorithms and simulation results**

**Contractual Date of Delivery to the CEC: 30/10/2006**

**Actual Date of Delivery to the CEC: 10/11/2006**

**Author(s): See list**

**Participant(s): UPC, KCL, PTIN, TEL, TI, TID, IST-TUL**

**Workpackage: WP3**

**Est. person months: 54**

**Security: PU**

**Nature: Report**

**Version: 001**

**Total number of pages: 354**

#### **Abstract:**

This deliverable provides a description and performance evaluation of a first version of the resource management algorithms and procedures developed within WP3. The evaluation will mainly be carried out by means of simulations using the simulators at their first development stage.

**Keyword list: Quality of Service (QoS), End-to-end QoS; Radio Resource Management (RRM), Common RRM (CRRM), QoS architecture, All-IP, Heterogeneity.**

## **DISCLAIMER**

The work associated with this report has been carried out in accordance with the highest technical standards and the AROMA partners have endeavoured to achieve the degree of accuracy and reliability appropriate to the work in question. However since the partners have no control over the use to which the information contained within the report is to be put by any other party, any other such party shall be deemed to satisfied itself as to the suitability and reliability of the information in relation to any particular use, purpose or application.

Under no circumstances will any of the partners, their servants, employees or agents accept any liability whatsoever arising out of any error or inaccuracy contained in this report (or any further consolidation, summary, publication or dissemination of the information contained within this report) and/or the connected work and disclaim all liability for any loss, damage, expenses, claims or infringement of third party rights.

**DOCUMENT HISTORY**

Date	Version	Status	Comments
12.06.06	v1	Int	ToC for comments
29.09.06	v2	Int	Updated ToC (after Madrid meeting) for comments
27.10.06	v3	Int	Integrated Version
03.11.06	v4	Int	Version for PCC Review
10.11.06	001	Apr.	Approved version delivered to the Commission

## Table of Contents

<b>EXECUTIVE SUMMARY</b> .....	<b>1</b>
<b>1 INTRODUCTION</b> .....	<b>2</b>
<b>2 AROMA'S REFERENCE STUDIES SUPPORTING RRM/CRRM TECHNICAL APPROACHES</b> .	<b>4</b>
2.1 SYSTEM LEVEL PERFORMANCE GAINS WHEN CONSIDERING MIMO .....	4
2.1.1 Simulations .....	5
2.1.2 Results.....	8
2.1.3 Conclusion .....	13
2.2 VERTICAL HANDOVER DELAY ANALYSIS.....	13
2.2.1 Introduction.....	13
2.2.2 Procedure for Intra-MSD Handovers.....	13
2.2.3 Procedure for Inter-MSD Handovers.....	17
2.2.4 Traces.....	22
2.2.5 Results.....	23
2.2.6 Conclusions .....	25
<b>3 INTRINSIC RRM</b> .....	<b>25</b>
3.1 RRM ON MBMS.....	25
3.1.1 Introduction.....	25
3.1.2 Unicast via DCH .....	26
3.1.3 Broadcast via FACH .....	26
3.1.4 Trade-off DCH/FACH .....	26
3.1.5 Simulation scenarios .....	27
3.1.6 Urban residential area .....	29
3.1.7 Hot spot within urban area.....	34
3.1.8 Hot spot along main road .....	36
3.1.9 Conclusions .....	38
3.2 ENGINEERING VoIP IN UMTS R99.....	38
3.2.1 VoIP codecs according to 3GPP (AMR-NB & AMR-WB).....	38
3.2.2 VoIP – QoS characterization .....	40
3.2.3 RAB characterization for VoIP.....	42
3.2.4 Unequal Error Protection (UEP) for AMR codec .....	45
3.2.5 Simulation hypothesis.....	47
3.2.6 Simulations results.....	49
3.2.7 Conclusions .....	56
3.3 HSDPA .....	56
3.3.1 HSDPA model.....	57
3.3.2 Assumptions .....	59
3.3.3 Admission, congestion and coverage control for reference method .....	60
3.3.4 QoS measures.....	61
3.3.5 Algorithms.....	61
3.3.6 Simulation results .....	63
3.3.7 Conclusions .....	69
3.4 CROSS-LAYER RRM - TCP AWARE LINK ADAPTATION.....	70
3.4.1 Cross-layer RRM.....	70
3.4.2 TCP-aware link adaptation .....	71
3.4.3 TCP window-based flow control .....	71
3.4.4 TCP flows over wireless channels.....	72
3.4.5 Problem definition.....	73
3.4.6 Power and Rate Allocation as a Bi-objective Optimization Problem .....	79
3.4.7 Numerical Investigations .....	82
3.4.8 Conclusions .....	85
3.5 PERFORMANCE EVALUATION OF VOWLAN (IEEE 802.11B/A).....	85
3.5.1 Introduction.....	85
3.5.2 VoIP overview.....	86
3.5.3 Practical implementation .....	90
3.5.4 Simulation results .....	94

3.5.5	Conclusions .....	107
<b>4</b>	<b>AUTOMATED TUNING MECHANISMS .....</b>	<b>108</b>
4.1	MOTIVATION .....	108
4.2	FUNCTIONAL ARCHITECTURE.....	109
4.2.1	Off-line automated tuning framework .....	109
4.2.2	On-line automated tuning framework .....	110
4.3	SELECTED OPTIMISATION PARAMETERS AND QUALITY INDICATORS .....	114
4.3.1	Data KPIs.....	114
4.3.2	Automatic planning and optimization.....	115
4.3.3	Example - admission control algorithm (UMTS).....	117
4.4	AUTOMATED TUNING STRATEGIES.....	118
4.4.1	Rule-based tuning strategies – CPICH tuning.....	118
4.4.2	Rule-based tuning strategies – Load Factor tuning.....	130
4.4.3	Conclusions .....	134
4.5	AUXILIARY MECHANISMS.....	134
4.5.1	Problem Formulation .....	134
4.5.2	Cell interference flow .....	135
4.5.3	Actual cell interference flow.....	137
4.5.4	Simulations .....	138
4.5.5	Conclusions .....	141
<b>5</b>	<b>COMMON RRM.....</b>	<b>142</b>
5.1	INTRODUCTION .....	142
5.2	ANALYTICAL CRRM CHARACTERISATION: 4D MARKOV MODEL.....	143
5.2.1	Introduction .....	143
5.2.2	Analytical Model.....	143
5.2.3	RAT Selection Policies and State Transition Feasibilities .....	146
5.2.4	Multi-mode Terminal Availability Impact on RAT Selection Procedures .....	156
5.2.5	Performance Metrics .....	158
5.2.6	Results.....	160
5.2.7	Conclusions .....	166
5.3	ANALYTICAL CRRM OPTIMISATION: UTRAN/GERAN TRAFFIC SPLITTING .....	167
5.3.1	Introduction.....	167
5.3.2	Problem formulation .....	167
5.3.3	Traffic allocation optimisation .....	169
5.3.4	Results.....	171
5.3.5	Conclusions .....	172
5.4	A GENERIC CRRM METRIC: THE FITTINGNESS FACTOR .....	173
5.4.1	Introduction .....	173
5.4.2	Fittingness factor definition.....	173
5.4.3	Initial RAT selection algorithm.....	175
5.4.4	Vertical handover algorithm.....	176
5.4.5	Examples of computation of the suitability factor Q for different RATs and services..	176
5.4.6	Results.....	178
5.4.7	Conclusions .....	182
5.5	A CRRM APPROACH BASED ON COST FUNCTIONS.....	182
5.5.1	Introduction .....	182
5.5.2	Previous work .....	182
5.5.3	Cost Function Model.....	183
5.5.4	Results.....	186
5.5.5	Results Analysis .....	190
5.5.6	Conclusion .....	192
5.6	CRMM BASED ON RADIO QUALITY .....	192
5.6.1	Introduction.....	192
5.6.2	Overview of 3GPP UTRAN/GERAN inter-working mechanisms.....	192
5.6.3	Simulation results .....	202
5.6.4	Conclusions .....	211
5.7	A CRRM APPROACH INCLUDING ENHANCED UPLINK AND IEEE 802 FAMILY .....	212
5.7.1	Introduction .....	212
5.7.2	Simulator and scenario description .....	214

5.7.3	<i>Simulation results</i> .....	215
5.7.4	<i>Conclusions</i> .....	218
5.8	COMMON CONGESTION CONTROL ALGORITHM .....	219
5.8.1	<i>Introduction</i> .....	219
5.8.2	<i>Framework Architecture for Common Congestion Control (CCC)</i> .....	220
5.8.3	<i>Congestion Control Strategies in a GERAN/UTRAN Scenario</i> .....	221
5.8.4	<i>Study Cases and Simulation Environment</i> .....	230
5.8.5	<i>Simulation Results</i> .....	232
5.8.6	<i>Conclusions</i> .....	238
5.9	EFFECTS OF COMPRESSED MODE ON CRRM PERFORMANCE .....	238
5.9.1	<i>Introduction</i> .....	238
5.9.2	<i>System Description</i> .....	239
5.9.3	<i>Compress Mode Operation</i> .....	242
5.9.4	<i>Results and Discussion</i> .....	243
5.9.5	<i>Conclusions</i> .....	248
<b>6</b>	<b>END-TO-END QoS</b> .....	<b>249</b>
6.1	3GPP QoS MODELS .....	249
6.1.1	<i>QoS model in R5/R6</i> .....	249
6.1.2	<i>QoS Model in SAE/LTE</i> .....	254
6.1.3	<i>End-to-End QoS interworking architecture</i> .....	256
6.1.4	<i>QoS provisioning for I-WLAN</i> .....	259
6.2	SCOPE AND KEY DRIVERS .....	260
6.2.1	<i>E2E QoS in the medium-term vision</i> .....	261
6.2.2	<i>E2E QoS in the long-term vision</i> .....	262
6.3	FUNCTIONAL MODEL: AROMA'S PERSPECTIVE .....	263
6.3.1	<i>Introduction</i> .....	263
6.3.2	<i>A functional reference QoS framework</i> .....	264
6.3.3	<i>Implementation aspects</i> .....	268
6.3.4	<i>Conclusions</i> .....	268
6.4	ESTIMATION OF THE CAPACITY IN OVERPROVISIONED IP-RAN .....	268
6.4.1	<i>Study framework</i> .....	269
6.4.2	<i>Scenario definition</i> .....	271
6.4.3	<i>Simulation description</i> .....	273
6.4.4	<i>Results</i> .....	275
6.4.5	<i>Conclusions</i> .....	277
6.5	IMPACT OF RESOURCE LIMITATIONS IN THE TRANSPORT NETWORK .....	278
6.5.1	<i>Simulation scenario</i> .....	278
6.5.2	<i>Link Capacity Limitations in Downlink</i> .....	282
6.5.3	<i>Link Capacity Limitations in Uplink</i> .....	286
6.5.4	<i>Impact of the Transport Format Combination</i> .....	289
6.5.5	<i>Impact of SHO Settings</i> .....	292
6.5.6	<i>Impact of Traffic Mix Composition</i> .....	294
6.5.7	<i>Conclusions</i> .....	297
6.6	COORDINATED ADMISSION CONTROL FRAMEWORK .....	297
6.6.1	<i>TNL Admission Control support in 3GPP</i> .....	298
6.6.2	<i>Admission control algorithm for the transport network: a metrics proposal</i> .....	298
6.6.3	<i>RRM algorithm for the radio access</i> .....	299
6.6.4	<i>Hard TNL admission control strategy</i> .....	299
6.6.5	<i>Comparison of the considered TNL admission control strategies</i> .....	302
6.6.6	<i>Conclusions</i> .....	304
6.7	QoS MECHANISMS IN THE IP-TRANSPORT OF A LTE-RAN .....	305
6.7.1	<i>Introduction</i> .....	305
6.7.2	<i>Related work</i> .....	306
6.7.3	<i>MPLS enabled micromobility</i> .....	307
6.7.4	<i>Simulation results</i> .....	308
6.7.5	<i>Conclusions</i> .....	316
<b>7</b>	<b>IMPLEMENTATION ASPECTS</b> .....	<b>317</b>
7.1	METHODOLOGY .....	317
7.1.1	<i>Algorithm selection</i> .....	317

7.1.2	<i>Functional Description of the algorithm</i> .....	317
7.1.3	<i>Practical implementation approaches and identification of critical aspects</i> .....	318
7.1.4	<i>Performance assessment for practical implementations</i> .....	318
7.1.5	<i>Potential algorithm enhancements and/or new system capabilities requirements</i> .....	318
7.1.6	<i>Methodology application example</i> .....	319
7.1.7	<i>Conclusions</i> .....	325
<b>8</b>	<b>CONCLUSIONS</b> .....	<b>326</b>
<b>9</b>	<b>ACRONYMS</b> .....	<b>331</b>
<b>10</b>	<b>REFERENCES</b> .....	<b>333</b>
<b>11</b>	<b>APPENDIX 1. DISTRIBUTION FUNCTION OF THE PROPAGATION LOSS</b> .....	<b>344</b>
<b>12</b>	<b>APPENDIX 2. IUB INTERFACE MODELLING IN IP-RAN</b> .....	<b>345</b>
12.1	IP-RAN MODEL .....	345
12.2	IUB INTERFACE DESCRIPTION .....	347
12.3	CONSIDERATIONS ON TRAFFIC FLOW AND TRANSPORT OVER IUB .....	349
12.3.1	<i>MAC/RLC Function distribution across UTRAN and UE</i> .....	349
12.3.2	<i>Synchronisation and Delay requirements</i> .....	350
12.3.3	<i>Options to improve bandwidth efficiency for IP transport option in Iub</i> .....	351
12.4	IUB SIMULATION MODEL .....	352

## Authors list

Barbaresi, Andrea (TI)  
Casadevall, Fernando (UPC)  
Colonna, Massimo (TI)  
Correia, Luís M. (IST-TUL)  
Dahlén, Anders (TEL)  
d'Orey, Pedro M. (PTIN)  
Ferrús, Ramon (UPC)  
Fischer, Markus (PTIN)  
Galeana, Hiram (UPC)  
Gelabert, Xavier (UPC)  
Gomes, Álvaro (PTIN)  
González, Beatriz (TID)  
Goria, Paolo (TI)  
Kuipers, Martijn (IST-TUL)  
Ljung, Rickard (TEL)  
Mantovani, Andrea (TI)  
Majkowski, Jakub (UPC)  
Monteiro, João (PTIN)  
Nafisi, Nima (KCL)  
Olmos, Joan (UPC)  
Pérez-Romero, Jordi (UPC)  
Sallent, Oriol (UPC) - Editor  
Serrador, António (IST-TUL)  
Trogolo Alessandro (TI)  
Vega, Avelina (TID)  
Wang, Lin (KCL)  
Zarba, Giovanna (TI)



## **EXECUTIVE SUMMARY**

The scope of this document is to describe and present an initial evaluation of a first version of resource management algorithms and procedures developed within WP3. The evaluations have been carried out by means of simulations using the first version of the developed simulators, whose capabilities are reported in D06. Also, analytical models have been derived in order to gain insight into some of the targeted problems.

Based on the consideration that it ought to be mandatory to increase and harmonise the general knowledge on RRM strategies, and in order to facilitate the future success of 3G and beyond networks with an ever increasing sophistication in RRM strategies, intrinsic RRM studies in novel technologies such as e.g. HSDPA, HSUPA and MBMS are developed together with further knowledge on how to manage wireless technologies such as WLAN. Furthermore, taking into account that the network optimization process could imply the tuning of a large set of radio parameters in thousands of cells in the UMTS Terrestrial Radio Access Network (UTRAN), some initial automated tuning mechanisms for RRM parameters are discussed.

On the other hand, for each of legacy and emerging technologies, the development of Common RRM (CRRM) algorithms within the radio access network (RAN) is vital for a proper functioning of a heterogeneous network topology. Building on top of IST-EVEREST results on CRRM functional model and algorithms, new concepts and approaches are identified, developed and evaluated, also including additional technologies such as HSUPA or WLAN.

Based on ongoing efforts at 3GPP aiming at the specification of evolved network architecture, the key drivers for E2E QoS are discussed in this document. In this context, a functional reference QoS model is proposed, accompanied by preliminary resource management strategies considering both the radio and the IP segments co-ordinately and operating synergistically. Finally, a basic methodology for moving from conceptual algorithms proposals towards their practical implementation is covered.

The rest of this deliverable is structured as follows. Section 2 is devoted to provide some preliminary technical studies with broad applicability for the rest of the activities. Section 3 is devoted to intrinsic RRM mechanisms. Section 4 covers automated tuning of RRM parameters, while Section 5 is devoted to CRRM. Then, Section 6 presents the overall vision of the resource management problem encompassing radio and IP segments as well as some initial evaluations. Section 7 sets the pillars for the definition of an implementation methodology. Finally, Section 8 summarizes the conclusions.