

Hans-Florian Geerdes

UMTS Radio Network Planning:
Mastering Cell Coupling for Capacity Optimization

VIEWEG+TEUBNER RESEARCH

Advanced Studies Mobile Research Center Bremen

Herausgeber | Editors:

Prof. Dr. Otthein Herzog

Prof. Dr. Carmelita Görg

Prof. Dr.-Ing. Bernd Scholz-Reiter

Das Mobile Research Center Bremen (MRC) erforscht, entwickelt und erprobt in enger Zusammenarbeit mit der Wirtschaft mobile Informatik-, Informations- und Kommunikationstechnologien. Als Forschungs- und Transferinstitut des Landes Bremen vernetzt und koordiniert das MRC hochschulübergreifend eine Vielzahl von Arbeitsgruppen, die sich mit der Entwicklung und Anwendung mobiler Lösungen beschäftigen. Die Reihe „Advanced Studies“ präsentiert ausgewählte hervorragende Arbeitsergebnisse aus der Forschungstätigkeit der Mitglieder des MRC.

In close collaboration with the industry, the Mobile Research Center Bremen (MRC) investigates, develops and tests mobile computing, information and communication technologies. This research association from the state of Bremen links together and coordinates a multiplicity of research teams from different universities and institutions, which are concerned with the development and application of mobile solutions. The series “Advanced Studies” presents a selection of outstanding results of MRC’s research projects.

Hans-Florian Geerdes

UMTS Radio Network Planning: Mastering Cell Coupling for Capacity Optimization

VIEWEG+TEUBNER RESEARCH

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Dissertation Technische Universität Berlin, 2008

D 83

mrc

Mobile Research Center

Gedruckt mit freundlicher Unterstützung des
MRC Mobile Research Center der Universität Bremen

Printed with friendly support of
MRC Mobile Research Center, Universität Bremen

1st Edition 2008

All rights reserved

© Vieweg+Teubner | GWV Fachverlage GmbH, Wiesbaden 2008

Readers: Christel A. Roß

Vieweg+Teubner is part of the specialist publishing group Springer Science+Business Media.
www.viewegteubner.de



No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the copyright holder.

Registered and/or industrial names, trade names, trade descriptions etc. cited in this publication are part of the law for trade-mark protection and may not be used free in any form or by any means even if this is not specifically marked.

Cover design: KünkelLopka Medienentwicklung, Heidelberg

Printing company: STRAUSS GmbH, Mörlenbach

Printed on acid-free paper

Printed in Germany

ISBN 978-3-8348-0697-0

Abstract

This thesis deals with UMTS radio network planning, which aims at achieving maximum coverage and capacity in third-generation cellular systems at low cost. UMTS uses W-CDMA technology on the radio interface. More traffic can be served than in previous systems, but the precise capacity of a cell depends on the current user positions, traffic demands, and channel conditions. Furthermore, cells are coupled through interference and need to be considered jointly. Static system models include all these factors and support network planning decisions in practice. They contain thousands of users in typical city-wide scenarios and model each link explicitly. Until now, only time-consuming simulation methods are known for accurately evaluating expected network capacity under random variations of the input data. Known optimization schemes either rely on a simplified capacity model, or they use complex models, which are hard to analyze theoretically.

These problems are addressed with new models and methods for UMTS capacity evaluation and planning. Interference-coupling complementarity systems are first introduced as a concise static system model. They extend known models by including the new concept of perfect load control. This allows to treat individual users implicitly even if some traffic cannot be served, so the model dimension depends only on the number of cells. Subsequently, expected-coupling estimates provide a first-order approximation of expected cell load and user blocking. Their computation requires no simulation, but only a single evaluation of the complementarity system. Experiments on realistic data validate the new system model and confirm that the performance estimates are informative for planning.

The expected-coupling estimates are the basis of a new challenging optimization model that maximizes expected capacity via a deterministic objective. The model contains an accurate notion of cell coupling and is stated in closed form. It admits structural analysis, which leads to new mixed integer programming formulations, lower bounds, and heuristic solution algorithms. Four case studies on large realistic datasets demonstrate that the planning heuristics run efficiently and produce highly efficient configurations.

The results establish a top-level perspective on the relations between cells in UMTS radio networks. This paradigm allows new insights into capacity optimization and makes effective radio network planning with an accurate notion of capacity computationally feasible in practice.

Acknowledgments

My scientific development was only possible with the help and support of many people. I thank Andreas Eisenblätter for invaluable guidance, advice, and discussions. I thank my professor, Martin Grötschel, for letting me work in a challenging and stimulating environment, in which I never lacked for anything. My work has greatly profited from many discussions with colleagues in the graduate school MAGS at TU Berlin, in the research center MATHEON in Berlin, in the MOMENTUM project consortium, in the COST 273 sub working group MORANS, and with my colleagues at the Optimization Department at ZIB. I thank the team at the ZIB library for always quickly providing me with any literature I needed. I thank my students Normen Rochau, Franziska Ryll, Christian Schäfer, and Jonas Schweiger for their help in experiments and for insightful discussions. I also thank Prof. Adam Wolisz for agreeing to referee this thesis.

This thesis could not have reached its final version without the help of a number of people. I thank Mathias Bohge, Andreas Eisenblätter, Marc Pfetsch, James Groß, Tobias Harks, Bertolt Meyer, Christian Raack, Jonas Schweiger, Hans Selge, and Ulrich Türke for careful and quick proof-reading and their constructive feedback. I am indebted to Mario Olszinski for his out-of-the-box thinking and ingenious tips in questions of design and layout. I thank Andreas Eisenblätter for ceding and adapting his implementations of crucial software components.

I thank my parents for supporting me throughout the years; without it, this all would have been impossible. I thank my twin sister for being there, always and before everybody else. I thank my grandmother for accommodating me in the comfort of her home for three weeks, during which I found the peace to develop many ideas that shaped this work. I thank my friends for distracting me. I thank Martin for his enduring support.

Contents

Abstract · v

1 Introduction · 1

2 Radio network modeling and performance evaluation for UMTS · 7

- 2.1 Cellular wireless communication networks · 8
- 2.2 The UMTS radio interface · 11
- 2.3 Methodology of performance evaluation · 18
- 2.4 The classical static model · 19
- 2.5 Performance evaluation with static simulation · 27
- Things to remember · 33

3 Interference-coupling complementarity systems · 35

- Related work · 36
- 3.1 Linear interference-coupling equation systems · 37
- 3.2 Perfect load control and complementarity systems · 41
- 3.3 Generalized pole equations · 52
- 3.4 Performance indicators · 56
- Things to remember · 61

4 Expected-interference-coupling estimates for network performance · 63

- Related work · 64
- 4.1 The reference method: simplified Monte Carlo simulation · 64
- 4.2 Expected interference coupling with medians of attenuation · 67
- 4.3 Refined estimates for the expected grade of service · 73
- 4.4 Computational experiments · 77
- 4.5 Conclusions on system modeling and performance evaluation · 88
- Things to remember · 91

5 Network performance optimization · 93

- 5.1 Prerequisites: objectives, parameters, and optimization methods · 94
- 5.2 Survey of network planning literature · 104
- 5.3 Optimization models · 111
- 5.4 Computational case studies · 120
- 5.5 Analysis of case study results · 139
- 5.6 Conclusions on performance optimization · 147
- Things to remember · 149

6 Conclusion · 151**Appendices · 153**

- A Data for network planning · 155
- B Additional details on computational results · 163

Acronyms and Symbols · 169**Index · 173****Bibliography · 175**