

Michael Walter

**Scattering in Non-Stationary Mobile-to-Mobile
Communications Channels**

Herausgegeben von

**Prof. Dr.-Ing. Jörg Eberspächer
Lehrstuhl für Kommunikationsnetze
Technische Universität München**

in der Reihe

Kommunikationstechnik



Herbert Utz Verlag · München

Kommunikationstechnik

Band 24

Zugl.: Diss., Ulm, Univ., 2015

Bibliografische Information der Deutschen Nationalbibliothek:
Die Deutsche Nationalbibliothek verzeichnet diese
Publikation in der Deutschen Nationalbibliografie;
detaillierte bibliografische Daten sind im Internet über
<http://dnb.ddb.de> abrufbar.

Dieses Werk ist urheberrechtlich geschützt.
Die dadurch begründeten Rechte, insbesondere die
der Übersetzung, des Nachdrucks, der Entnahme von
Abbildungen, der Wiedergabe auf fotomechanischem
oder ähnlichem Wege und der Speicherung in Daten-
verarbeitungsanlagen bleiben – auch bei nur auszugs-
weiser Verwendung – vorbehalten.

Copyright © Herbert Utz Verlag GmbH · 2017

ISBN 978-3-8316-4551-0

Printed in Germany

Herbert Utz Verlag GmbH, München
089-277791-00 · www.utz.de

Abstract

The demand for mobile communication services has been permanently growing since the emergence of digital cellular systems in the early nineteen nineties. This trend is expected to continue well into the future. However, frequency resources are limited and must therefore be used more efficiently, such that capacity can be increased without adding spectrum. A promising technique for more efficient spectrum use is the application of smart antennas at the *Base Station* (BS). Adaptive antennas enable the BS to steer adaptive antenna beams to each individual user for directive transmission and reception. With this concept inter-cell as well as intra-cell interference can be reduced significantly. In this thesis we are concerned with the capacity gain, that can be obtained by transforming the reduced interference achievable with smart antennas into expanded capacity by applying advanced *Radio Resource Management* (RRM) methods. Thereby, we focus on F/TDMA based systems like, e.g., GSM.

We start by presenting a detailed review of RRM concepts and techniques in cellular communication systems, to serve as foundation for the development of new “smart antenna aware” RRM concepts. Then an overview of smart antenna beamforming is provided, followed by the discussion of three concepts to transform the reduced interference of directive antennas into capacity gain, namely, sectorization, *Spatial Filtering for Interference Reduction* (SFIR), and *Space Division Multiple Access* (SDMA). Among the three, SDMA has the highest potential to improve capacity, if appropriate RRM approaches are applied. We also provide a discussion of the feasibility of SDMA operation in GSM systems.

In order to assess the capacity of smart antenna systems, detailed simulations are required. For this purpose we present a simulation concept, which incorporates models for the mobile radio channel, smart antenna beam forming, as well as mobility, spatial distribution, and teletraffic of mobile users. Multicellular single-tier and multi-tier environments are considered with hexagonal and irregular cell cite scenarios. Novel channel allocation strategies for fresh calls and handovers are proposed and analyzed by means of extensive system simulations in homogeneous and inhomogeneous traffic and cell site scenarios. All strategies have in common that they utilize smart antennas in order to reuse channels within each cell by means of SDMA. We start with SDMA within each cell and fixed channel-to-cell assignment, which yields considerable capacity gains. We then move on, combining SDMA with *Dynamic Channel Allocation* (DCA), where SDMA and DCA are separated through the consideration of minimal reuse distances, obtaining improved capacity results. The next step is the introduction of complete dynamic channel allocation strategies, which allow for channel reuse even in neighboring cells. Different approaches for the determination of candidate channels and several channel selection strategies are investigated. The higher degree of free-dom, which these strategies bring about, further

increases the capacity. The complete dynamic strategies are then enhanced by introducing preferred channels for each cell, in order to attempt assigning channels according to a reuse pattern, before non-preferred channels are used. This approach yields the highest capacity in comparison to all afore mentioned strategies.

We extend the introduced channel allocation and handover strategies to the case of hierarchical cellular networks with a micro-cell layer and an overlay macro-cell layer. Fast moving users are assigned to the macro-cell layer to diminish the number of handovers while users with relatively low velocities are served by the micro-cell layer to make efficient use of the given resources. Adaptive control algorithms are developed and investigated for the threshold velocity, which determines which cell-layer a mobile user is assigned to, as well as for the channel splitting between both layers.

While the focus of this thesis is on F/TDMA based systems, we derive call blocking probabilities for multi-service smart antenna CDMA systems and present numerical results for the case of two service classes. We show that in case of a limited number of channelization codes, as for instance in the UMTS downlink, the application of smart antennas can shift the capacity from being interference limited to being channel limited. Thus, in order to fully exploit the potential capacity of such systems, code reuse should be applied, which can be done in a similar fashion as in F/TDMA systems. This implicates that the RRM methods investigated for F/TDMA systems have relevance to CDMA systems as well.

We conclude that smart antennas can boost the capacity of cellular systems in combination with advanced RRM approaches, which utilize SDMA and DCA techniques.

Contents

1	Introduction	1
1.1	Motivation	1
1.2	Overview and Contributions	4
2	Radio Resource Management in Cellular Systems	7
2.1	Cellular System Architecture	7
2.2	Multiple Access and Duplexing	8
2.2.1	Multiple Access Techniques	9
2.2.2	Duplexing Techniques	10
2.3	Physical and Logical Channels	10
2.3.1	Physical Channels	11
2.3.2	Logical Channels	12
2.4	The Cellular Principle	13
2.5	Channel Allocation Approaches for Cellular Systems	15
2.5.1	Fixed Channel Allocation	17
2.5.2	Dynamic Channel Allocation	20
2.5.3	Hybrid Channel Allocation (HCA) and Channel Borrowing (CB)	22
2.5.4	Conclusions	23
2.6	Power Control and Handover	24
2.6.1	Power Control	24
2.6.2	Handover	25
2.7	Capacity and Performance Measures for Cellular Systems	27
2.7.1	Link Performance	27
2.7.2	System Performance	27
2.7.3	System Capacity	28
2.7.4	Comparison of RRM Approaches	29
3	Smart Antennas - Sectorization, SFIR and SDMA	31
3.1	Smart Antennas in Cellular Systems	31
3.2	Smart Antenna Beamforming	32
3.3	Sectorization of Cells	36
3.4	Spatial Filtering for Interference Reduction (SFIR)	39
3.5	Space Division Multiple Access (SDMA)	49
3.6	Feasibility of SDMA in GSM networks	51
3.7	Conclusions	55

4	System Model and Simulation Concept	57
4.1	Cell Site Scenario Modeling	58
4.1.1	Channel Reuse Pattern	60
4.2	Antenna and Beamforming Models	61
4.3	Radio Propagation and Channel Modeling	62
4.3.1	Path Loss and Shadow Fading	64
4.3.2	Spatially Correlated Shadow Fading	65
4.3.3	Received Power and Interference	67
4.4	Modeling User Distribution, Traffic and Mobility	69
4.4.1	Teletraffic Models	69
4.4.2	Spatial Distributions	71
4.4.3	Mobility Models	72
4.5	Simulation of RRM in Cellular SDMA Systems	78
5	Radio Resource Management in Planar Smart Antenna Systems	81
5.1	Intra-Cell SDMA Channel Allocation – FCA/SDMA	82
5.1.1	Expected SNIR based Costs	83
5.1.2	Geometric Constraints based Costs	84
5.1.3	Determination of Candidate Channels	86
5.1.4	Channel Selection Strategies	87
5.1.5	Performance of FCA/SDMA	88
5.2	Hierarchical SDMA DCA	92
5.2.1	HSDCA Inter-Cell Channel Allocation	94
5.2.2	HSDCA Intra-Cell Channel Allocation	97
5.2.3	Properties of the HSDCA Algorithm	101
5.2.4	Variations of HSDCA	101
5.2.5	Performance of HSDCA	102
5.3	Complete Dynamic Channel Allocation	107
5.3.1	CDCA - Principles	107
5.3.2	CDCA - Requisites	108
5.3.3	CDCA - Decision Criteria	109
5.3.4	CDCA - Strategies	110
5.3.5	Reuse Pattern Based CDCA - CDCA/RP	111
5.3.6	Performance of CDCA and CDCA/RP	111
5.4	Performance of the RRM Approaches in an Inhomogeneous Teletraffic Scenario	116
5.5	SDMA in HSCSD and GPRS Systems	118
5.5.1	HSCSD	118
5.5.2	GPRS	121
5.6	Conclusions	121
6	Radio Resource Management in Hierarchical Smart Antenna Systems	125
6.1	Performance Measures for Hierarchical Systems	126
6.2	Inter-Layer Traffic Distribution	127

6.3	Investigated Hierarchical Cellular Network Model	128
6.4	Adaptive Radio Resource Management in Hierarchical Cellular Networks	129
6.4.1	Threshold Velocity Control	130
6.4.2	Channel Distribution Control	132
6.5	Performance of Hierarchical Cellular SDMA Systems	134
6.5.1	Results and Discussion	136
6.5.2	SDMA/Omnidirectional Hierarchical System	141
6.6	Conclusions	144
7	Applicability of F/TDMA-based RRM Approaches to CDMA Systems	145
7.1	System Model and Assumptions	146
7.2	Capacity Considerations	148
7.3	Spatial Traffic Model	148
7.4	Single Service Blocking Probability	150
7.5	Multi Service Blocking Probability	151
7.6	Numerical Results without Code Limitation	151
7.7	Code Limitation	155
7.8	Numerical Results with Code Limitation	159
7.9	Conclusions	160
8	Conclusions and Outlook	161
8.1	Conclusions	161
8.2	Outlook	163
A	Computation of Angle and Distance Variations for the Steady Route Mo- bility Model	165
B	Description of Used Simulation Scenarios	167
B.1	Homogeneous One Tier Scenario	167
B.2	Inhomogeneous One Tier Scenario	169
B.3	Two Tier Scenario	171

Kommunikationstechnik

- Band 24: Michael Walter: **Scattering in Non-Stationary Mobile-to-Mobile Communications Channels**
2016 · 164 Seiten · ISBN 978-3-8316-4551-0
- Band 23: Christian Hartmann: **Radio Resource Management in Cellular F/TDMA Smart Antenna Systems**
2017 · 208 Seiten · ISBN 978-3-8316-4541-1
- Band 22: Daniel Medina: **Geographic Load Share Routing in the Airborne Internet**
2011 · 136 Seiten · ISBN 978-3-8316-4118-5
- Band 21: Alexander Arkhipov: **IFDMA for Uplink Mobile Radio Communication Systems**
2010 · 156 Seiten · ISBN 978-3-8316-0962-8
- Band 20: Peter Tabery: **Mobilitätsunterstützung mit Programmierbaren Netzen**
2007 · 172 Seiten · ISBN 978-3-8316-0685-6
- Band 19: Dominic Schupke: **Cycle-Based Protection for Optical Transport Networks**
2005 · 164 Seiten · ISBN 978-3-8316-0463-0
- Band 18: Christian Bettstetter: **Mobility Modeling, Connectivity, and Adaptive Clustering in Ad Hoc Networks**
2004 · 240 Seiten · ISBN 978-3-8316-0397-8
- Band 15: Erik Haas: **Design, Evaluation and Implementation of a Multi-Carrier Transmission System for Aeronautical Communications**
2003 · 195 Seiten · ISBN 978-3-8316-0212-4
- Band 14: Wolfgang Kellerer: **Serverarchitektur zur netzunabhängigen Dienststeuerung in heterogenen Kommunikationsnetzen**
2002 · 200 Seiten · ISBN 978-3-8316-0123-3
- Band 13: Bernhard Quendt: **Agentenunterstützte Steuerung von Multimedadiensten**
2000 · 186 Seiten · ISBN 978-3-89675-790-6
- Band 12: Axel Jahn: **Ressourcenverwaltung in Kommunikationsnetzen mit niedrigfliegenden Satelliten**
2000 · 223 Seiten · ISBN 978-3-89675-703-6
- Band 11: Andreas Iselt: **Ausfallsicherheit und unterbrechungsfreies Ersatzschalten in Kommunikationsnetzen mit Redundanzdomänen**
1999 · 218 Seiten · ISBN 978-3-89675-621-3
- Band 10: Markus Fiedler: **Erforderliche Kapazität beim Multiplexen von ATM-Verbindungen**
1998 · 301 Seiten · ISBN 978-3-89675-385-4
- Band 9: Andreas Kirstädter: **Verteilte Koordinierungsverfahren für ATM-Vermittlungen mit Eingangspuffern**
1998 · 175 Seiten · ISBN 978-3-89675-295-6
- Band 8: Thomas Bauschert: **Optimale Dimensionierung von ATM-Weitverkehrsnetzen mit mehrstufiger Durchschaltung**
1997 · 182 Seiten · ISBN 978-3-89675-263-5

Band 6: Thomas Kober: **Anwendungsbezogene Reservierungsstrategien für ATM-Wählverbindungen**
1997 · 174 Seiten · ISBN 978-3-89675-232-1

Band 5: Christian Winkler: **Eine skalierbare Server- und Netzarchitektur für den verbindungslosen Dienst im B-ISDN**
1997 · 170 Seiten · ISBN 978-3-89675-228-4

Band 4: Harald Müller: **Flexible Signalisierungsarchitektur für Multimediadienste mit heterogenen Endgeräten**
1996 · 206 Seiten · ISBN 978-3-89675-152-2

Band 3: Bernhard Edmaier: **Pfad-Ersatzschaltverfahren mit verteilter Steuerung für ATM-Netze**
1996 · 180 Seiten · ISBN 978-3-89675-112-6

Erhältlich im Buchhandel oder direkt beim Verlag:
Herbert Utz Verlag GmbH, München
089-277791-00 · info@utzverlag.de

Gesamtverzeichnis mit mehr als 3000 lieferbaren Titeln: www.utzverlag.de