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Volume 62

Multiantenna Channels: Capacity, Coding and Signal Processing

DIMACS Workshop
Signal Processing for Wireless Transmission
October 7–9, 2002
DIMACS Center

Gerard J. Foschini
Sergio Verdú
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American Mathematical Society

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Center for Discrete Mathematics
and Theoretical Computer Science
A consortium of Rutgers University, Princeton University,
AT&T Labs–Research, Bell Labs (Lucent Technologies),
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This DIMACS volume presents the proceedings from the workshop Signal Processing for Wireless Transmission held at the DIMACS Center, Rutgers University, October 7–9, 2002.

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Foreword

A workshop on Signal Processing for Wireless Transmission was held at Rutgers University on October 7–9, 2002. We would like to express our appreciation to Gerard Foschini and Sergio Verdú for their efforts to organize and plan this successful conference.

The workshop was part of the Special Focus on Computational Information Theory and Coding. We extend our thanks to Robert Calderbank, Chris Rose, Amin Shokrollahi, Emina Soljanin, and Sergio Verdú for their work as special focus organizers.

The workshop brought together theoreticians and practitioners working on wireless communications, information, and coding theory from a variety of perspectives. The main themes of the workshop included capacity of multiantenna channels and of vector broadcast channels, "dirty-paper" coding, signal processing, and ad hoc networking in wideband channels. These are all major themes in current research in physical-layer design for wireless communication.

DIMACS gratefully acknowledges the generous support that makes these programs possible. The National Science Foundation; the New Jersey Commission on Science and Technology; DIMACS' partners at Rutgers, Princeton, AT&T Labs-Research, Bell Labs, NEC Laboratories America, and Telcordia Technologies; and its affiliated partners at Avaya Labs, IBM Research, and Microsoft Research have generously supported the special focus.

Fred S. Roberts
Director

Robert Tarjan
Co-Director for Princeton

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Preface

The DIMACS Workshop on Signal Processing for Wireless Transmission was held at Rutgers University on October 7–9, 2002, under the auspices of the DIMACS Special Focus on Computational Information Theory and Coding. Twenty-six invited presentations were delivered (http://dimacs.rutgers.edu/Workshops/Wireless/) by leading researchers in the fields of wireless communications, information and coding theory. Workshop attendees included researchers from institutions in North America, Europe, the Middle East and Asia. Through the agency of DIMACS, we were able to support the participation of a substantial number of students. In the true spirit of a workshop, there was considerable interaction among participants, accentuated by a sense of excitement over the presentation of fast-breaking results.

Several forces are coalescing to make this an exciting time in the field of physical-layer design for wireless communication: the relentless advance in VLSI technology, the recent breakthroughs in signal processing for multiantenna and multiuser systems, and the increased pressure for efficient utilization of scarce spectral resources. These forces make information-theoretic limits and the means of approaching them increasingly relevant for emerging wireless communication systems. This volume gives a snapshot of the range of challenges that are currently garnering a great deal of attention from the research community.

The first group of contributions on "Capacity of Multiantenna Channels" follows in the line of information-theoretic research pioneered at Bell Labs in the mid 1990s. The contribution by Xu, Chizhik, Huang and Valenzuela adds realism to the modeling of multiantenna channels by incorporating a number of key effects not captured in the canonical model. Even though much of the early emphasis on the information-theoretic analysis of multiantenna channels was on high signal-to-noise ratio (SNR) contexts, many practical embodiments, particularly in cellular systems, operate at low received energy per bit. The paper by Tulino, Lozano and Verdú considers the bandwidth-power tradeoff in the low SNR regime. The surprising relevance of large random matrix methods to systems with small numbers of antennas is illustrated in the paper by Moustakas, Simon and Sengupta, even with correlated channel coefficients. In another departure from the canonical setting, Simon and Moustakas analyze the impact of channel information at the transmitter array and determine under what conditions beamforming is optimal.

The second group of papers is devoted to the capacity of vector broadcast channels and its relationship with the problem of "dirty-paper coding". In dirty-paper coding, introduced by Costa in 1983 building upon earlier work, in addition to the background noise, an interference component is present which is known at the transmitter but not at the receiver. Dirty-paper coding is especially relevant to downlink communication, where the base station knows the channels and therefore knows the multiuser interference affecting each transmission. Although the sum-capacity has been solved recently, determination of the entire capacity region of the vector broadcast channel remains an open problem. Important advances towards its solution were announced at the workshop and reported in the paper by Jindal, Vishwanath, Jafar and Goldsmith; the paper by Tse and Viswanath; as well as the one by Vishwanath, Kramer, Shamai, Jafar and Goldsmith. The remaining issue to be settled in order to claim that the region put forth in those papers is the actual capacity region is the question of optimality of Gaussian codebooks.

The constructive counterpart to the capacity of dirty-paper coding is attracting considerable research. Caire and Shamai consider the application of low-density parity check codes and pulse-amplitude modulation in the design of systems that approach the fundamental limits when the interference is known at the transmitter only causally. After a tutorial presentation of dirty-paper coding, Foschini and Diaz explore what can be achieved with both one-dimensional lattices and in the asymptote of high-dimensional lattices.

The third part of the volume is devoted to signal processing. The analysis of the average computational complexity by Hassibi and Vikalo of the near-optimal sphere-decoding algorithm shows the considerable promise of this technique, which has applications beyond combating multiuser/multiantenna interference. A method to lower the signal processing complexity in channels with rapid fluctuations is presented in the contribution by Chizhik. This makes the gains promised by information-theoretic results approachable even in situations previously thought to be problematic. Foschini and Sellathurai show how to arrange a signal in space-time so as to achieve capacity with one-dimensional codecs when there is only one receive antenna. The technique is also shown to be effective in approaching capacity when the number of transmit antennas is much larger than the number of receive antennas. The use of iterative reception in conjunction with space-time codes is explored in the paper by Biglieri, Nordio and Taricco. Space-time block codes for channels that incorporate multiuser, intersymbol and multiantenna interference are considered by Diggavi, Al-Dhahir and Calderbank, who derive a simple formula for the diversity order. Most of the papers in this field assume perfect channel knowledge at the receiver. Samardzija and Mandayam explore the effect of imperfect channel estimation on achievable data rates.

The last group of papers in the volume explores issues related to ad hoc networking in wideband channels. Souilmi and Knopp examine the rates achievable by flash signaling in ultrawideband channels when only channel statistics are known at the receiver. Maric and Yates put forth the "accumulative broadcast" strategy in multihop environments where the objective is to minimize total transmitted energy.

It is a pleasure to acknowledge the expert guidance of Professor Fred S. Roberts, director of DIMACS. He generously provided his help and advice during the organization of the workshop and the preparation of this volume. We are also grateful to Ms. Shirley Hill of the American Mathematical Society for her diligent processing of the contents of this book. Finally, it is a pleasure to thank all the authors for their outstanding efforts that made this volume a reality.

Gerard J. Foschini and Sergio Verdú

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The book is suitable for graduate students and researchers interested in mathematical problems of communication theory.

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