EURASIP Journal on Applied Signal Processing 2004:5, 587–590

Editorial

Sergio Barbarossa

Department of Information and Communication, University of Rome "La Sapienza," 00184 Rome, Italy
Email: sergio@infocom.ing.uniroma1.it

Constantinos Papadias

Bell Labs, Lucent Technologies, 791 Holmdel-Keyport Road, Holmdel, NJ 07733, USA
Email: papadias@bell-labs.com

H. Vincent Poor

Department of Electrical Engineering, Princeton University, Princeton, NJ 08544, USA
Email: poor@princeton.edu

Xiaowen Wang

Agere Systems, Allentown, PA 18109, USA
Email: xiaowenw@agere.com

The topic of multiple-input multiple-output (MIMO) systems is one that has attracted a significant amount of attention in the research community over the past decade or so. MIMO systems refer to wireless systems that are equipped with multiple antenna elements on either side of a communication link. Propelled by the startling discovery in the mid 1990's that the capacity of MIMO systems grows roughly proportionally with the minimum number of antenna elements on each side of the wireless link, the field has undergone an explosive growth in both the academic and the industrial communities that has led to many further important advances. These advances have brought about not only the definition of new subareas of focused research, but also, equally importantly, a reconsideration of older techniques and a cross-fertilization of ideas from several other overlapping fields.

One of the research areas that has both affected strongly MIMO systems and has been equally affected by them is that of signal processing, as many of the developed/demonstrated MIMO transceiver architectures are based on advanced signal processing techniques. On the transmitter side, one can view most space-time coding/spatial multiplexing techniques as solving a problem of space-time signal design. On the receiver side, various flavors of multiuser detectors, space-time decoders, and related techniques for MIMO channel estimation and tracking (e.g., including blind/semiblind processing) are also typically derived in a signal processing framework.

More recent research on MIMO systems has started to focus on new areas of interest. At the link level, such areas are the handling of cochannel (e.g., in-cell and out-of-cell) interference; the development of precoding techniques at the transmitter to preempt adverse channel effects; and the design and use of efficient receiver-to-transmitter feedback mechanisms to improve the link throughput. In parallel, many studies have focused on the application of such MIMO techniques to specific transmission formats (dictated by different air interfaces) such as CDMA, OFDM, and so forth. Moving up the protocol stack, the interaction of MIMO techniques with MAC layer procedures such as adaptive retransmission and scheduling is an area that has started producing important know-how, especially regarding the suitability of MIMO techniques in high-speed data systems. Moving beyond wireless links, architecting an entire wireless network that uses MIMO connections poses a number of important questions, both at a fundamental level (e.g., MIMO network capacity) and at a practical level (e.g., MIMO network design).

With all of the above in mind, this special issue aims at giving a well-rounded snapshot of recent advances that cover most of these topics, with a special emphasis on signal processing methodologies as a design tool. As progress in the field is both rapidly emerging and voluminous, it has clearly not been our intent to provide an exhaustive coverage of all MIMO topics but rather a good selection of recent studies that are indicative of the progress in the field.

The papers included in this special issue address a broad range of issues arising in the development and application of MIMO techniques. These contributions range from general space-time coding and processing techniques and analytical methodologies to specific implementation issues arising in particular wireless standards and environments and to fundamentals of wireless MIMO networks. Among other topics, they touch upon the areas of transmitter and receiver design, blind and training-based techniques, link-level and system-level studies, open- and closed-loop systems, physical layer and higher layer issues, and wireless LAN and cellular applications.

The specific contributions of the papers in this issue are summarized in the following paragraphs.

Invited paper

In their invited paper, Jafar, Foschini, and Goldsmith present an in-depth analysis of the so-called "PhantomNet" wireless network concept. In such a network, the best possible service is provided to new users joining the network without affecting existing users. The problem is addressed in its full generality, that is, assuming multiple cells, users, and antennas, and results are obtained for both uplink and downlink communication. Optimality is sought in terms of the multiuser capacity region. This leads to a high degree of generality of the presented results and solutions. Furthermore, despite the inherent differences between the two directions of communication (and the resulting differences between the corresponding solutions), the authors demonstrate a remarkable symmetry between the uplink and downlink problems.

Channel estimation and multiuser detection in MIMO systems

In the first paper of this section, J. Du and Y. Li study the problem of channel estimation for D-BLAST OFDM systems. The authors propose a layerwise channel estimation algorithm that takes advantage of the D-BLAST structure. Further performance improvements are realized by introducing a subspace tracking scheme.

In the next paper, Buzzi, Grossi, and Lops study the problem of blind multiuser detection in asynchronous DS-CDMA systems equipped with multiple antennas. Several novel blind schemes are proposed and their performance is evaluated, showing their multiple access interference suppression capability, despite the absence of channel state information.

Another blind detection scheme that is specifically tailored to space-time differentially encoded systems is presented in the paper by Zhang and Ilow. Their proposed receiver algorithm is based on constant modulus characteristics of signaling and it is suitable for a rich multipath environment. The scheme requires no channel estimation and can work with small numbers of signal samples.

In their paper, Y. Du and Chan examine a technique for speeding up the search for an optimal multiuser detection solution using a genetic algorithm. The authors first study the objective function of the genetic algorithms. Then they propose two detectors to generate the seed chromosome of the initial population. Their results show that the proposed scheme not only reduces the computational complexity of finding the detector, but also improves performance.

MIMO systems, space-time coding, and beamforming

In the first paper of this section, C. Li and Xiaodong Wang compare the performance of three well-known MIMO techniques: BLAST, space-time block coding (STBC), and linear precoding/coding (i.e., beamforming) in the context of WCDMA. The authors study the signal-to-noise properties analytically, and the bit error rate performance via simulations. They also consider a subspace method for implementing the linear precoding method (which requires channel knowledge at the transmitter). The authors evaluate the trade-offs between BLAST and STBC in terms of data-rate and diversity in this situation (see also the following paper in this section) and demonstrate that subspace-based beamforming can be effectively realized in WCDMA systems.

In the next paper, Mecklenbräuker and Rupp consider a new STBC scheme that extends the well-known Alamouti codes to the situation in which the number of transmit antennas is an arbitrary power of two. Further solutions for arbitrary even numbers of transmit antennas are also presented, which offer improved orthogonalization properties while preserving high diversity. The authors also consider schemes that trade off the properties of Alamouti and BLAST-type systems (see also Li's and Wang's paper above) to achieve a continuous trade-off between quality of service and data rate. The appropriate trade-off can be selected using only the number of transmit antennas. Implications of these techniques for UMTS are also discussed.

MIMO systems and interference

In his paper, Blum studies the problem of maximum system mutual information in MIMO systems that employ antenna selection in the presence of interference. This leads to optimal signaling covariance matrices for the interesting case of limited channel feedback required for antenna selection.

The paper by Song and Blostein studies the effect of colored space-time interference on MIMO systems, emphasizing the problems of channel estimation, data detection, and interference correlation estimation. The focus is on the case of one dominant interferer and the quantification of its impact on the performance of a generalized BLAST ordered data detection algorithm. The authors show that exploiting the interference's spatio-temporal nature can result in important gains.

MIMO techniques in current/emerging air interfaces

In the first paper of this section, J. Liu and J. Li study some practical issues arising in the application of MIMO OFDM to high-rate wireless LAN systems. The authors propose signaling and corresponding synchronization, channel estimation, and detection schemes that are backward compatible with the existing 802.11a standard. They also propose the use of a BLAST-type data transmission scheme and a simple LS-based soft detector to reduce the complexity of the receiver.

In the next paper, Hansen, Affes, and Mermelstein revisit the problem of multiuser detection in CDMA networks. The authors apply an interference subspace rejection technique to the downlink of networks in which the spreading factors or modulation used by the interferer may not be known. The schemes proposed in the paper require no prior knowledge of these factors. A new code allocation scheme is also proposed to reduce the complexity of the proposed interference cancellation schemes.

The paper by González-López, Míguez, and Castedo presents a maximum likelihood channel estimation scheme that is suitable for turbo equalization in a space-time coded system. The authors apply their scheme to GSM-based transmission in a subway tunnel. Their experiment shows a significant reduction in the required training sequence length.

In the final paper of this section, Leus, Petré, and Moonen propose novel transmit diversity and corresponding space-time chip equalization techniques for DS-CDMA systems. Their proposed scheme is shown to achieve both maximal antenna diversity and maximal multipath diversity.

Resource allocation and feedback in multiple antenna systems

In the first paper of this section, Han, Farrokhi, and K. J. Ray Liu revisit the problem of jointly optimizing power control and beamforming to minimize the cochannel interference. The authors optimize the bit error rate directly in calculating the power and beamforming vector. Both the power control and beamforming algorithms are updated iteratively and are shown to converge.

In their paper, Chung, Lozano, Huang, Sutivong, and Cioffi study closed-loop MIMO systems. In order to achieve the closed-loop capacity, the authors propose to use a low rate feedback channel to provide rate and power information to the transmitter. Two joint rate and power allocation schemes are proposed and studied by the authors. Their results show that the performance loss due to the quantization of power is marginal, and that the MIMO system demonstrates an average rate close to capacity with the low-rate feedback channel and strong coding scheme.

Higher layer issues in MIMO systems

In the final paper of the special issue, Zheng, Lozano, and Haleem propose an ARQ scheme based on the BLAST system. The authors suggest the use of separate ARQ for each layer of the BLAST transmission. This multiple ARQ structure not only improves the throughput, but also facilitates the interference cancellation.

We believe that the included papers present an excellent sampling of state-of-the-art research in the field of MIMO communications and signal processing. We would like to thank all of the authors for their timely contributions and we anticipate that these papers will make this special issue a useful reference that will act as a catalyst for further exciting research in the field of MIMO systems.

Sergio Barbarossa
Constantinos Papadias
H. Vincent Poor
Xiaowen Wang

Sergio Barbarossa graduated in 1984 and received his Ph.D. degree in 1989 from the University of Rome "La Sapienza," Italy. From 1984 to 1986, he was a Radar System Engineer at Selenia. In 1988, he was at the Environmental Research Institute of Michigan (ERIM), Ann Arbor, USA. From 1989 to 1991, he was with the University of Perugia and in 1991, he joined the University of Rome "La Sapienza," where he is now a Full Professor. Since 1997, he is a Member of the IEEE Signal Processing for Communications Technical Committee. From 1998 to 2000, he served as an Associate Editor for the IEEE Transactions on Signal Processing. He coauthored a paper that received the 2000 IEEE Best Paper Award in the Signal Processing for Communications area. He has been the General Chairman of the SPAWC 2003 (Rome, 2003). He has held visiting positions at the University of Virginia in 1995 and 1997, University of Minnesota in 1999, and Polytechnic University of Catalunya, Spain, in 2002. He is the author of a research monograph on Multiple Antenna Systems (Artech House, 2004). He is the scientific responsible, for his University, of two IST European projects on space-time coding and multihop networks. His current research interests lie in the area of self-organizing networks, random graphs, and distributed space-time coding.

Constantinos Papadias was born in Athens, Greece, in 1969. He received his Diploma of electrical engineering from the National Technical University of Athens (NTUA) in 1991 and the Ph.D. degree in signal processing (highest honors) from the Ecole Nationale Supérieure des Télécommunications (ENST), Paris, France, in 1995. From 1992 to 1995, he was Teaching and Research Assistant at the Mobile Communications Department, Eurécom, France. From 1995 to 1997, he was a Postdoctoral Researcher at Stanford University's Smart Antennas Research Group. In November 1997, he joined the Wireless Research Laboratory of Bell Labs, Lucent Technologies, Holmdel, NJ, as member of technical staff. He is now Technical Manager in Global Wireless Systems Research Department, Bell Lab's, overseeing several research projects, with an emphasis on space-time and MIMO systems. He has authored several papers, patents, and standards contributions on these topics and he recently received the IEEE Signal Processing Society's 2003 Young Author Best Paper Award. He is a Member of the Signal Processing for Communications Technical Committee of the IEEE Signal Processing Society and Associate Editor for the IEEE Transactions on Signal Processing. Dr. Papadias is a Senior Member of IEEE and a Member of the Technical Chamber of Greece.

H. Vincent Poor received the Ph.D. degree in EECS from Princeton University in 1977. From 1977 until 1990, he was at the University of Illinois at Urbana-Champaign. Since 1990, he has been at Princeton University, where he is the George Van Ness Lothrop Professor in Engineering. Dr. Poor's research interests are in the areas of wireless networks, advanced signal processing, and related fields. He is the author of more than 500 publications in these areas, including the recent book *Wireless Communication Systems: Advanced Techniques for Signal Reception* (Prentice-Hall, Upper Saddle River, NJ, 2004). Dr. Poor is a Member of the U. S. National Academy of Engineering, and is a Fellow of the IEEE, the Institute of Mathematical Statistics, and other organizations. In 1990, he served as President of the IEEE Information Theory Society, and in 1991–1992, he was a Member of the IEEE Board of Directors. Among his recent honors are the IEEE Graduate Teaching Award in 2001, the Joint Paper Award of the IEEE Communications and Information Theory Societies in 2001, the NSF Director's Award for Distinguished Teaching Scholars in 2002, and a Guggenheim Fellowship in 2002–2003.

Xiaowen Wang received her B.S. degree from the Department of Electronics Engineering, Tsinghua University, Beijing, China in 1993, and the M.S. and Ph.D. degrees from the Department of Electrical and Computer Engineering, University of Maryland, College Park, MD, in 1999 and 2000, respectively. From 1993 to 1996, Dr. Wang was a Teaching Assistant at Tsinghua University, Beijing, China. From 1996 to 2000, she was a Research Assistant at the University of Maryland, College Park, MD. Since 2000, she has been with the Wireless Systems Research Department, Agere Systems (formerly Bell Labs, Lucent Technologies, Microelectronics). Her research interests include adaptive digital signal processing, wireless communications, and networking. Dr. Wang was ranked the first among the class of Department of Electronics Engineering for her B.S. degree from Tsinghua University in 1993, and was the recipient of the Graduate School Fellowship from University of Maryland.