Forty-Sixth Asilomar Conference on Signals, Systems, and Computers

November 4–7, 2012

FINAL PROGRAM & ABSTRACTS

Asilomar Hotel
Conference Grounds

FORTY-SIXTH
ASILOMAR CONFERENCE ON
SIGNALS, SYSTEMS & COMPUTERS

Organized in cooperation with

ATK SPACE SYSTEMS
Monterey, California

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Welcome from the General Chairman

Prof. Miloš Doroslovački, The George Washington University

Welcome to this unique conference. Many of us come here from year to year to be exposed to new ideas and to do brainstorming about them in an informal and relaxed way, surrounded by magnificent nature. To cite John Steinbeck, Nobel Prize laureate in literature and local to this part of California: “Ideas are like rabbits. You get a couple and learn how to handle them, and pretty soon you have a dozen.” I am sure that the conference will be stimulating for your future professional endeavors.

The biggest credit for the intellectual value of the conference goes to the Technical Program Chair Erik G. Larsson and his team, made of Technical Area Chairs and Session Chairs, as well as to all of you who contributed with papers. Erik and his team prepared an excellent program of 435 papers, including 171 invited, and a tutorial session. For their outstanding work in shaping the technical program, I would like to thank Erik and the Technical Area Chairs: Henk Wymeersch, Gerald Matz, Vincent Poor, Erchin Serpedin, Marius Pesavento, Arye Nehorai, Joseph Cavallaro, Ghassan AlRegib and Phil Schniter.

The student paper contest this year attracted 87 submissions out of which nine were chosen for the final competition. The Student Paper Contest Chair Geert Leus and a panel of judges will select the best three papers after the finalists present their posters on Sunday afternoon. I invite you to attend these presentations and in that way to give support to our young colleagues who will one day build the future of science and technology.

I am looking forward to listening to the plenary talk by Prof. Richard Baraniuk from the Rice University. Rich is an extraordinary researcher, teacher and person. He has been for a long time on the frontline of research in compressive sensing, one of the most popular and challenging topics at this conference for the past several years. I am thrilled, and I guess so are you, to hear his report on what has been happening, what is going on now and where to go further.

I wish you three exciting days full of nice talks and walks. I hope that the weather will serve us well and that we will have three beautiful sunsets over the Pacific Ocean.

Miloš Doroslovački, The George Washington University, June 2012

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2012 Asilomar Conference Session Schedule

Sunday Afternoon, November 4, 2012

3:00 - 7:00 PM Registration — Merrill Hall
4:00 - 6:30 PM Student Paper Contest — Heather
7:00 - 9:00 PM Welcoming Dessert Reception — Merrill Hall

Monday Morning, November 5, 2012

7:30 - 9:00 AM Breakfast – Crocker Dining Hall
8:00 AM - 6:00 PM Registration
8:15 - 9:45 AM MA1a — Conference Welcome and Plenary Session — Chapel
9:45 - 10:15 AM Coffee Social

10:15 AM - 12:00 PM MORNING SESSIONS
MA1b Graphical Models in Signal Processing (invited)
MA2b Threshold Limits in Array Processing: Performance Analysis and Methods (invited)
MA3b Full-Duplex MIMO Communications (special session)
MA4b Green Radio (invited)
MA5b Voice Coding (invited)
MA6b DSP Architecture for Wireless Communications (invited)
MA7b Brain Dynamics: Improving Spatial and Temporal Resolution
MA8b1 Communication Systems I (poster)
MA8b2 Array Signal Processing I (poster)

12:00 - 1:00 PM Lunch – Crocker Dining Hall

Monday Afternoon, November 5, 2012

1:30 - 5:10 PM AFTERNOON SESSIONS
MP1a Compressive Sensing (invited)
MP1b Signal Processing and Learning in Complex Systems (invited)
MP2a Source Localization in Distributed Sensor Arrays (invited)
MP2b Network Beamforming (invited)
MP3a Large-Scale MIMO Systems (special session)
MP3b Coordinated Multipoint (invited)
MP4a Cognitive Radio Networks (invited)
MP4b Machine-to-Machine Communications and Networks (invited)
MP5a Image and Video Coding (invited)
MP5b Convex Optimization in Image and Video Analysis (invited)
MP6a Computer Arithmetic (invited)
MP6b Reconfigurable Architectures, Many-Core, Multi-Core, and SoC (invited)
MP7a Medical Image Analysis
MP7b Biological Modeling and Signal Analysis (partly invited)
MP8a1 MIMO Communications and Signal Processing I (poster)
MP8a2 Signal Processing and Adaptive Systems I (poster)

Monday Evening, November 5, 2012

6:00 - 9:30 PM Conference Cocktail/Social — Merrill Hall
The Cocktail/Social takes the place of Monday's dinner. No charge for conference attendees and a guest.

2012 Asilomar Conference Session Schedule

(continued)

Tuesday Morning, November 6, 2012

7:30 - 9:00 AM Breakfast — Crocker Dining Hall
8:00 AM - 5:00 PM Registration

8:15 - 12:00 PM MORNING SESSIONS

TA1a MIMO in Optical Communications (invited)
TA1b Wireless Video Transmission Systems (invited)
TA2a Game Theory in Communications (invited)
TA2b Coding Theory for the Next-Generation Storage Systems (invited)
TA3a Multiuser and Massive MIMO (invited)
TA3b Compressive Estimation
TA4a Social Networks (invited)
TA4b Signal Processing for Cyber-Security and Privacy in Networks (invited)
TA5a 3D Video Processing (invited)
TA5b Computer Arithmetic Accelerators for Signal Processing
TA6a Low Power I (invited)
TA6b Low Power II (invited)
TA7a Biological Networks and Machine Learning (partly invited)
TA7b Sequence and Genome Analysis (partly invited)
TA8a1 Array Signal Processing II (poster)
TA8a2 Signal Processing and Adaptive Systems II (poster)
TA8b1 Communication Systems II (poster)
TA8b2 MIMO Communications and Signal Processing II (poster)
TA8b3 Architecture and Implementation of Signal Processing Systems (poster)

12:00 - 1:00 PM Lunch – Crocker Dining Hall

Tuesday Afternoon, November 6, 2012

1:30 - 5:35 PM AFTERNOON SESSIONS

TP1a Network Optimization (invited)
TP1b Distributed Signal Processing (invited)
TP2a Consensus Based Algorithms
TP2b Cooperative Adaptation and Learning (invited)
TP3a Information Theoretic Signal Processing
TP3b Underwater Communications (invited)
TP4a Decoding and Detection
TP4b Smart Grid Communications and Networks (invited)
TP5a Design Methodologies and Architectures for Communications
TP5b Interference Alignment (invited)
TP6a Wireless Full Duplex
TP6b Biological Image Analysis
TP7a MIMO Radar and Waveform Design
TP7b Speech Processing and Speech Recognition (invited)
TP8a1 Relay Networks (poster)
TP8a2 Sensor and Interference Networks (poster)
TP8a3 Design Methodology and Computer Arithmetic (poster)
TP8b1 Speech, Image, and Video Processing (poster)
TP8b2 Biomedical Signal and Image Processing (poster)

Tuesday Evening Open Evening — Enjoy the Monterey Peninsula

2012 Asilomar Conference Session Schedule
(continued)

Wednesday Morning, November 7, 2012

7:30 - 9:00 AM Breakfast — Crocker Dining Hall
8:00 AM - 12:00 PM Registration — Copyright forms must be turned in before the registration closes at 12:00 noon.

8:15 AM - 12:00 PM MORNING SESSIONS
WA1a Feedback and Cooperation (invited)
WA1b Security
WA2a Distributed Algorithms for Wireless Networks
WA2b Topics in Wireless Networking
WA3a Adaptive Signal Processing
WA3b Compressive Signal Processing
WA4a Interference and Cognition
WA4b OFDM(A)
WA5a Applications of Video Processing
WA5b Image and Video Classification
WA6a CSI Feedback
WA6b Beamforming and Relaying (invited)
WA7a Applications of Sensor Array Processing
WA7b DOA Estimation
WA8 Tutorial – Coding Methods for Emerging Storage Systems (8:15 AM – 11:30 AM)

12:00 - 1:00 PM Lunch — Meal tickets may be purchased at registration desk. This meal is not included in the registration.

Student Paper Contest

Heather - Sunday, November 4, 2012, 4:00 - 6:30 PM

"Unicasting on the S-Graph"
Satyanaranaya Vuppala and Giuseppe Abreu

"Volume of Ball and Hamming-type Bounds for Stiefel Manifold with Euclidean Distance"
Renaud-Alexandre Pitaval and Olav Tirkkonen

"Distributed Gram-Schmidt Orthogonalization Based on Dynamic Consensus"
Ondrej Slučiak, Hana Straková, Markus Rupp, and Wilfried N. Gansterer

"Identifying Multiple Infection Sources in a Network"
Wuqiong Luo and Wee Peng Tay

"The Gaussian CEO Problem for a Scalar Source with Memory: A Necessary Condition"
Jie Chen, Feng Jiang and A. Lee Swindlehurst

"Transmit Beamspace Design for Direction Finding in Colocated MIMO Radar with Arbitrary Receive Array and Even Number of Waveforms"
Arash Khabbazibasmenj, Sergiy A. Vorobyov, Aboulnasr Hassanien, and Matthew W. Morency

"Screening Fundus Images for Diabetic Retinopathy"
Sohini Roychowdhury, Dara Koozekanani, and Keshab K. Parhi

"A Low-Power Dual-Path Floating-Point Fused Add-Subtract Unit"
Jae Hong Min, Jongwook Sohn, and Earl E. Swartzlander, Jr.

"Joint Tracking of Clean Speech and Noise Using HMMs and Particle Filters for Robust Speech Recognition"
Aleem Mushtaq and Chin-Hui Lee

Coffee breaks will be at 9:55 AM and 3:10 PM. (except Monday morning when refreshments will be served outside Chapel from 9:45–10:15 AM)

Monday, November 4, 2012

CONFERENCE OPENING AND PLENARY SESSION 8:15 – 9:45 AM, LOCATED IN CHAPEL

1. Welcome from the General Chairperson:

Prof. Miloš Doroslovački
The George Washington University

2. Session MA1a Distinguished Lecture for the 2012 Asilomar Conference

Compressive Sensing: 8 Years After

Prof. Richard G. Baraniuk
Victor E. Cameron Professor
Rice University

Abstract
Sensing and imaging systems are under increasing pressure to accommodate ever larger and higher-dimensional data sets; ever faster capture, sampling, and processing rates; ever lower power consumption; communication over ever more difficult channels; and radically new sensing modalities. Since its discovery in 2004, compressive sensing (CS) has stimulated a re-thinking of sensor and signal processing system design. In CS, analog signals are digitized and processed not via uniform sampling but via measurements using more general, even random, test functions. In contrast with conventional wisdom, the new theory asserts that one can combine "sub-Nyquist-rate sampling" with large-scale optimization for efficient and accurate signal acquisition when the signal has a sparse structure. In this talk, we will review the progress in field over the last eight years, with a special emphasis on the pros and cons of the technique.

Biography
Richard G. Baraniuk is the Victor E. Cameron Professor of Electrical and Computer Engineering at Rice University. His research interests lie in new theory, algorithms, and hardware for sensing, signal processing, and machine learning. He is a Fellow of the IEEE and AAAS and has received national young investigator awards from the US NSF and ONR, the Rosenbaum Fellowship from the Isaac Newton Institute of Cambridge University, the ECE Young Alumni Achievement Award from the University of Illinois, and the Wavelet Pioneer and Compressive Sampling Pioneer Awards from SPIE. His work on the Rice single-pixel compressive camera has been widely reported in the popular press and was selected by MIT Technology Review as a TR10 Top 10 Emerging Technology for 2007. For his teaching and education projects, including Connexions (cnx.org), he has received the C. Holmes MacDonald National Outstanding Teaching Award from Eta Kappa Nu, Tech Museum of Innovation Laureate Award, the Internet Pioneer Award from the Berkman Center for Internet Society at Harvard Law School, the World Technology Award for Education, the IEEE-SPS Education Award, and the WISE Education Award.

Program of 2012
Asilomar Conference
on
Signals, Systems, and Computers

Technical Program Chairman
Prof. Erik G. Larsson
Linköping University, Sweden

Session: MAb1 – Graphical Models in Signal Processing

Chair: ***Lorenzo Vangelista,*** *University of Padova*

MA1b-1 10:15 AM

Approximate Message Passing for Spectral Estimation: A Solution to the Gridding Problem?

Philip Schniter, Ohio State University; Christian Austin, MIT Lincoln Laboratory; Jason Parker, Air Force Research Laboratory

Spectral estimation is a classical problem wherein the goal is to estimate the frequencies and amplitudes of an unknown number of complex sinusoids from a finite-length noisy observation of their sum. In the conventional approach to this problem, one applies an algorithm like MUSIC or ESPRIT in conjunction with a model-order selection criterion like Akaike's. Recently, it has been suggested to approximate the observation as a noisy linear combination of a few elements from an overcomplete dictionary of sinusoids, and then solve for the approximation coefficients using a sparse-reconstruction algorithm like Lasso or OMP. In constructing the dictionary, however, one faces the so-called gridding problem: as the frequency grid used to construct the dictionary becomes more dense, the model fidelity improves, but sparse-reconstruction performance suffers due to the dictionary's increased correlation and size. In response, we propose a novel approach to spectral estimation based on the approximate message passing (AMP) framework. Whereas the AMP framework has been previously used to design sparse-reconstruction algorithms for linear, generalized linear, and bilinear observation models, we design an AMP algorithm to tackle the nonlinear spectral estimation problem, where both the frequencies and amplitudes are treated as continuous parameters to estimate. Numerical simulations show the efficacy of our proposed Spectral Estimation AMP.

MA1b-2 10:40 AM

Local Consensus Estimators for Distributed Learning of Graphical Models

Qiang Liu, Alexander Ihler, University of California, Irvine

Graphical models are useful tools for performing distributed signal processing and detection in sensor networks, but the task of learning the model from data is usually more difficult to distribute. We describe a general approach for distributed learning that combines multiple local estimators such as pseudo-likelihood components by taking a weighted linear combination. We illustrate our approach on several examples, and show that our simple weighted-averaging or max-voting estimates, when combined with estimated second-order information, perform as well as a more costly, iterative joint optimization.

MA1b-3 11:05 AM

Sparse Covariance Selection with Edge Restrictions

Anastasios Kyrillidis, Volkan Cevher, École Polytechnique Fédérale de Lausanne

We consider the sparse covariance selection problem as motivated by learning of Gauss-Markov random fields. In this setting, the learning problem corresponds to the recovery of the inverse covariance matrix of the underlying Gaussian distribution. The estimated sparsity pattern or the support of the solution then indicates the graph edges, revealing the Markov structure. We formulate the learning problem as a regression problem and present an algorithm that can incorporate problem-dependent structural constraints. In particular, we consider support restrictions that can be written as integral linear matrix inequalities as well as the restriction that the inverse covariance matrix should be positive semi-definite by definition. We then illustrate the performance of our algorithm via real and synthetic experiments.

MA1b-4 11:30 AM

Learning Graphical Models for Dynamical Processes

Andrea Montanari, Jose Bento, Morteza Ibrahimi, Stanford University

Consider the problem of learning the drift coefficient of a p-dimensional stochastic differential equation from a sample path of length T. Assuming that the drift is parametrized by a high-dimensional vector, we will study the support recovery problem in the limit in which both p and T tend to infinity. The support describes the network structure. We will discuss examples from finance and biology.

Track E. Array Signal Processing

Session: MAb2 – Threshold Limits in Array Processing: Performance Analysis and Methods

Chair: ***Mohammed Nabil El Korso,*** *Technische Universität Darmstadt*

MA2b-1 10:15 AM

Threshold Performance for Conditional and Unconditional Direction-of-Arrival Estimation

Yuri I. Abramovich, Defence Science and Technology Organisation; Ben A. Johnson, Lockheed Martin Australia and ITR

In this study, we provide comparative analysis of threshold conditions for conditional (deterministic) and unconditional (stochastic) MUSIC and maximum likelihood DOA estimation in the threshold region, and compare observed performance with the previously produced analytical studies. Random Matrix Theory results are used to explore threshold behavior of deterministic (conditional) ML DOA estimation.

MA2b-2 10:40 AM

Aspects of Threshold Region Mean-Squared Error Prediction: Method of Interval Errors, Bounds, Taylor's, and Extensions

Christ D. Richmond, Larry L. Horowitz, MIT Lincoln Laboratory

The method of interval errors (MIE) predicts mean-squared error (MSE) performance at low signal-tonoise ratios (SNR) where global errors dominate. It is algorithm specific and enabled by an estimate of asymptotic MSE performance and sidelobe error probabilities. Parameter bounds are adequate representations of the asymptotic MSE in absence of signal model mismatch, but Taylor theorem can account for this mismatch. Herein limitations of bounds versus Taylor's theorem to represent the asymptotic MSE of nonlinear schemes like maximum-likelihood are discussed. Use of first-order Taylor expansions for the purpose of improved approximation of sidelobe error probability is likewise explored.

MA2b-3 11:05 AM

Lower Bounds on the MSE for Mixed Far-Field and Near-Field Sources Direction-of-Arrivals

Alexandre Renaux, Rèmy Boyer, Paris XI Univ.; Sylvie Marcos, CNRS

Fundamental limits in terms of mean square error for source localization by an array of sensors are investigated. The context is the case of a far-field source and a near-field source for which few results are available. Particularly, in order to characterize the SNR threshold exhibited by estimators in such scenario, lower bounds other than the Cramér-Rao bound are studied.

MA2b-4 11:30 AM

On the Resolvability of Closely Spaced Targets Using a MIMO Radar

Mohammed Nabil El Korso, Technische Universität Darmstadt; Frédéric Pascal, Supélec / SONDRA; Marius Pesavento, Technische Universität Darmstadt

The resolvability of two closely spaced targets is an important performance measure in a MIMO radar problem. In this paper, we investigate the minimum signal to-noise ratio required to resolve two closely spaced targets using a MIMO radar under a colored and/or correlated noise. Toward this goal, we conduct a generalized likelihood ratio test w.r.t. the separation of direction of arrival and the separation of direction of departure. Our analytical expression reveals some insightful properties that are discussed in detail and, finally, numerical examples are provided to corroborate the proposed theoretical analysis.

Session: MAb3 – Full-Duplex MIMO Communications

Chair: ***Dan Bliss,*** *MIT Lincoln Laboratory*

MA3b-1 **10:15 AM**

Phase Noise: Understanding the Bottleneck in Full-duplex Designs

Achaleshwar Sahai, Gaurav Patel, Ashutosh Sabharwal, Rice University

In practical implementations of full-duplex, the amount of cancelation of self-interference via analog and digital processing have been reported to be less than 40 dB. In this paper, we show that the bottleneck in cancelation of self-interference is dominated by the phase noise of the transmit radio. We propose a phase noise model which shows that, unlike half-duplex, the noise floor in full-duplex rises with an increase in transmit power. We extend the phase noise model to a MIMO full-duplex and use it predict regimes of signal to noise (thermal) ratio where a bidirectional full-duplex system out-performs a half-duplex system. Finally, we provide cues for design of a better full-duplex system.

MA3b-2 **10:40 AM**

Hardware and Environmental Phenomenological Limits on Full-Duplex MIMO Relay Performance

Daniel Bliss, Timothy Hancock, Massachusetts Institute of Technology; Phil Schniter, Ohio State University

In this paper, the of performance full-duplex multiple-input multiple-output (MIMO) nodes is considered in the context of the characteristics of the hardware and the environment. Here, full duplex indicates that a node transmits and receives simultaneously in the same frequency band. It is assumed that transmit and receive phase centers are physically distinct, enabling adaptive spatial processing to mitigate self interference. In practice, the limiting issue is self interference, that is the receive antennas observe the transmitted signal. While theoretically, a system with infinite dynamic range can mitigate the self interference perfectly, in practice, receiver dynamic range, transmitter nonlinearities and noise, and channel dynamics limit the practical performance. In this paper, characteristics of the limiting factors are explored.

MA3b-3 **11:05 AM**

Open Problems in Full Duplex Wireless

Phil Levis, Stanford University

Full duplex breaks a basic assumption in the design of most wireless systems. With full duplex, a device can receive and transmit simultaneously on the same frequency. Initial work over the past two years has begun to explore how full duplex can improve wireless networks by reducing collisions, improving security, and improving throughput. In this talk I'll discuss some of our work to commercialize full duplex and the challenges we've encountered. I'll focus on the play between RF theory and RF engineering as well as some open questions that might deserve further research.

MA3b-4 **11:30 AM**

Analog and Digital Self-Interference Cancellation in Full-Duplex MIMO-OFDM Transceivers with Limited Resolution in A/D Conversion

Taneli Riihonen, Aalto University

We analyze the performance of full-duplex MIMO-OFDM transceivers with subtractive self-interference cancellation in analog and/or digital domain, i.e., before and/or after analog-to-digital converters (ADCs). In particular, the limited dynamic range of ADCs is modeled by assuming uniform b-bit quantization. We evaluate the signal to interference and noise ratio including the effects of residual self-interference due to imperfect cancellation and the quantization noise due to the limited resolution of ADCs. Consequently, this facilitates a study on the fundamental trade-off between ADC resolution, maximum transmit power, minimum physical isolation and sufficient signal to self-interference ratio needed to avoid the saturation of ADCs.

Track C. Networks

Session: MAb4 – Green Radio

Co-Chairs: ***Cristina Comaniciu,*** *Stevens Institute of Technology* ***and Aylin Yener,*** *Penn State University*

MA4b-1 **10:15 AM**

On Energy Harvesting Multi-User Networks with Energy Storage Imperfections

Kaya Tutuncuoglu, Aylin Yener, Penn State

Recent work on energy harvesting wireless networks has addressed the performance of various network structures assuming all harvested energy can be stored without loss. In practice, energy storage is far from perfect. In this paper, multi-user channels with energy harvesting nodes utilizing realistic energy storage devices are considered, and the optimal transmission policies are shown to differ fundamentally from previous policies derived ideal storage assumptions. In particular, the focus is on Gaussian broadcast and multiple access channels where energy harvesting users suffer from storage losses. It is shown that the maximum average weighted sum rate is achieved with a double threshold policy in an offline setting.

MA4b-2 **10:40 AM**

Information-Theoretically Achievable Rates in an Energy Harvesting Broadcast Channel

Omur Ozel, Sennur Ulukus, University of Maryland

We consider a broadcast channel, where the transmitter harvests energy from nature. We develop achievable rate regions for this broadcast channel setting, when the battery at the transmitter, where harvested energy is stored, has either zero or infinite capacity.

MA4b-3 **11:05 AM**

Throughput and Energy Efficiency under Queueing and Secrecy Constraints

Mustafa Cenk Gursoy, Mustafa Ozmen, Syracuse University

A broadcast model in which the transmitter sends confidential and common messages to two receivers is considered. It is assumed that the common and confidential data is stored in buffers prior to transmission and the transmitter operates under constraints on buffer violation probability. Under such constraints, effective capacity formulation is employed to determine the throughput. Moreover, energy per bit is used as the energy efficiency metric and energy efficiency is studied in the low-SNR regime. In particular, minimum energy per bit required for the reliable communication of common and confidential messages is determined and wideband slope regions are identified. The impact of buffer constraints and secrecy requirements on the energy efficiency is investigated.

MA4b-4 **11:30 AM**

Non-Invasive Green Small Cell Network

Baher Mawlawi, Ejder Bastug, Chahé Nerguizian, Sylvain Azarian, Mérouane Debbah, Supelec

For future low cost wireless networks providing high data rates with low power consumption, the promising solution is to deploy massively dense distributed small cells. Unfortunately, the aggregated signal resulting from the transmission of these multiples small cells is considered as an electromagnetic (EM) pollution for passive users who do not carry wireless devices. These users are victim of secondary electromagnetic ‘smokers’ and request from the operators to be spared from these radio electromagnetic waves. The aim of this contribution is to provide an electromagnetic friendly environment with minimum EM pollution while satisfying the Quality of Service requests of the users. The new approach consists in sending the complete EM energy towards active users equipped with wireless devices while the passive users are spared from the ubiquitous EM waves. The algorithm based on dynamic beam differentiation performs a real time mobile channel based localization of active and passive users.

Session: MAb5 – Voice Coding

Chair: ***Jerry D. Gibson,*** *University of California, Santa Barbara*

MA5b-1 10:15 AM

Scalable Wideband Speech Coding for IP Networks

Koji Seto, Tokunbo Ogunfunmi, Santa Clara University

A clear trend toward high quality voice communication has been recognized in recent years. Increasing computing power and network bandwidth have allowed wideband speech coding to be used for softphone over Internet and recent smartphones started to adopt wideband speech codec. Furthermore, Advances and wide acceptance of Voice over Internet Protocol (VoIP) drive the evolution of telephony technologies and voice communication over IP networks may become the dominant service for telephony including the wireless telephony. One of the main disadvantages of VoIP is inherently less reliable communication because of the possibility of packet loss. Most of the recent scalable wideband speech codec such as ITU-T G.729.1 or G.718 depend on Code Excited Linear Prediction (CELP) coding technique for core layer and low bit rate operations which causes error propagation in the case of packet loss and need to transmit redundant information in order to mitigate the problem. The internet Low Bit-rate Codec (iLBC) possesses inherently high robustness to packet loss which is one of essential properties for VoIP applications and therefore is considered to be more suited as a core-layer coding scheme of scalable wideband codec. We propose the scalable wideband speech codec which employs the multi-rate iLBC for core layer. The proposed codec is expected to be more robust to packet loss than recent wideband codecs and still achieves similar voice quality as those under clean channel condition.

MA5b-2 10:40 AM

Multimode Tree Coding of Speech with Backward Pitch Prediction and Perceptual Pre- and Post-weighting

Ying-Yi Li, Jerry Gibson, University of California, Santa Barbara

A low delay and low complexity Multimode Tree Coder with backward pitch prediction is proposed. For the Multimode Tree Coder, the speech is classified into five different modes, and each mode is coded at a suitable bit-rate using a tree coder with perceptual pre- and post-weighting filters. In order to improve the speech quality without delay, a backward pitch predictor is added for the Voiced mode only. Performance results show that the pitch predictor does improve the PESQ considerably. In addition, the PESQ of the Multimode Tree Coder is equivalent to the PESQ of AMR-NB at 12.2 kbps and G.727 at 32 kbps, while the delay and the computational complexity are lower than AMR-NB and the average bit-rate is about 40%-76% of G.727 at 32 kbps.

MA5b-3 11:05 AM

Source Models and Rate Distortion Bounds for Speech

Jerry Gibson, University of California, Santa Barbara

In recent years, we have developed new rate distortion bounds for voice codecs based on the linear prediction source model and both mean squared error (MSE) and perceptually weighted distortion measures. To extend this work, we discuss the critical role played by the source model in calculating rate distortion functions and describe how to select good source models for speech that allow the calculation of meaningful rate distortion bounds. In particular, we discuss how to modify the classical linear prediction model to include a mixed voiced and unvoiced excitation that includes a zero-mean unit variance sequence of independent random variables and a periodic pulse train. We show how to incorporate mixed voicing into known rate distortion theory results to obtain useful bounds. We also develop the use of frequency domain models and compare the results and approaches.

MA5b-4 11:30 AM

Compressed Sensing Based Scalable Speech Coders

Bhaskar Rao, Michelle Daniels, University of California, San Diego

Code-excited linear prediction (CELP) is one of the most commonly used approach for speech compression. The CELP coder, in particular the ACELP coder, relies on extracting an appropriate excitation sequence that is passed through a long-term and short-term linear prediction filter to synthesize the speech. One limitation of the analysis-by-synthesis search methods employed in the ACELP coder is that the positions of the non-zero entries in the excitation sequence and their gains are limited. Increasing the richness of the excitation to improve the speech quality is not only accompanied by the usual increase in the bit rate but also by a significant increase in search complexity. We propose dealing with this scalability issue by using tools from the compressed sensing (CS) domain. An analysis by synthesis coder using a CS based excitation sequence framework is developed and the encoder is shown to scale gracefully and also compares favorably in the quality to bit rate trade off comparison.

Track G. Architecture and Implementation

Session: MAb6 – DSP Architecture for Wireless Communications

Chair: ***Ahmed Eltawil,*** *University of California, Irvine*

MA6b-1 10:15 AM

Verifying Equivalence of Digital Signal Processing Circuits

Keshab Parhi, University of Minnesota

This paper will present techniques for verification of equivalence of folded pipelined digital signal processing (DSP) circuits. While two circuits can be verified to be equivalent by known techniques such as pipelining, retiming and folding, this paper instead will focus on verifying equivalence of pipelined DSP circuits by interleaved folding and hierarchical folding techniques. The interleaved folding and hierarchical folding techniques will be described with examples. Then these transformations will be used to verify that DSP circuits that do not look to be equivalent at first glance can indeed be shown to be equivalent.

MA6b-2 10:40 AM

Implementation of a Real-Time Wireless Interference Alignment Network

Jackson Massey, Jonathan Starr, Andreas Gerslauer, Robert W. Heath, Jr., University of Texas at Austin

This paper describes a testbed that implements real-time interference alignment (IA) for a network with three MIMO (multiple-input multiple-output) user pairs using software defined radio techniques. The IA implementation relies on a wired backbone to share the global channel state information and a shared clock for frequency and timing synchronization. The tesbed is used to demonstrate the viability of IA, and to show its robustness to several alternative transmission strategies including TDMA with spatial multiplexing and beamforming in terms of sum rates. The paper highlights key challenges in developing the testbed, and outlines several directions for future work to make it more realistic, such as removing the wired backbone.

MA6b-3 11:05 AM

ΣΔ Modulators for Low-power Digitally Intensive Radio Transmitters.

Rashmi Nanda, Dejan Markovic, University of California, Los Angeles

Digitally enhanced wireless transmitters are gaining prominence due to their promise of greater integration, flexibility to adapt to varying SNR conditions, and performance and area benefit that comes with CMOS feature size reduction. One of the drawbacks of digitally assisted linear RF modulators has been the high power consumption in the digital core. This arises from a need to increase the sample rate at the ΣΔ modulation stage of the transmitter. In this work we discuss a new approach that increases the order of ΣΔ modulation and reduces the sample rate without compromising the overall system integration or stability. This approach leads to significant power savings of 1.5x-2x depending upon the mode of operation.

MA6b-4 11:30 AM

A Sphere Decoding Approach for The Vector Viterbi Algorithm

Peter Kairouz, Aolin Xu, Naresh Shanbhag, Andrew Singer, University of Illinois, Urbana-Champaign

High speed mutli-input multi-ouput (MIMO) communication systems suffer from inter-channel and inter-symbol-interference. The vector Viterbi (VV) algorithm is the optimal sequence detection algorithm for this dispersive channel. In this work, we show that a sphere decoding like algorithm can be used to reduce the complexity of the VV algorithm while preserving its optimality. The trick is to transform the path metric update of each state into a problem similar to maximum likelihood detection for flat fading MIMO channels. Once this mapping is done, a sphere decoding like algorithm is formulated to update the path metrics at each stage in the trellis. This approach leads to a significant reduction in the algorithm's computational cost. We also discuss efficient architectures and implementations for this new technique. Finally, we show that the same algorithm can be modified to further reduce the complexity while still achieving a close to optimal performance.

Session: MAb7 – Brain Dynamics: Improving Spatial and Temporal Resolution

Chair: ***Hubert Preissl,*** *University of Tübingen*

MA7b-1 **10:15 AM**

Signal Artefacts in Functional MRI Studies of the Unsedated Human Fetal Brain In-Utero

Colin Studholm, University of Washington

Techniques to image the emergence of early brain function in the human fetus in-utero using MRI techniques are beginning to appear. However, the use of conventional techniques such as bold contrast fMRI rely on repeated fast imaging of brain anatomy to detect subtle changes in MRI signal. In order to provide meaningful measurements of bold contrast, the same anatomical location must be imaged repeatedly over a period of minutes with consistent signal sensitivity. This paper will describe the main sources of signal artifact introduced into fetal fMRI data by larger scale fetal head motions, and the influences they have on conventional analysis approaches used in resting state studies that make use of data driven (ICA) and hypothesis (ROI) driven analyses.

MA7b-2 **10:40 AM**

New Perspectives in MEG Functional Connectivity

Paolo Belardinelli, University of Tübingen

An insight into interactions between different brain regions is essential to understand brain functioning. Magnetoencephalography (MEG) is a well-suited tool to detect these interactions, because it provides whole head measurements of brain activity in the millisecond range. However, some spatial filter for source time-course reconstruction from the recorded signals is needed. Once reliable time-courses are available, their interactions can be studied. My talk will cover new time-course reconstruction approaches with special emphasis on effect of field spread, source correlation bias and noise disturbances. Moreover, different approaches to phase synchronization between time-courses will be treated.

MA7b-3 **11:05 AM**

Inferring Biological Network Connectivity Using a Novel Phase Synchronization Technique

Rathinaswamy Govindan, Children's National Medical Center; Jan Raethjen, University of Kiel; Adre du Plessis, Children's National Medical Center

We propose a novel phase synchronization approach by computing coherence between the phases of signals. Using second order autoregressive (AR2) process, we show that this approach is highly specific to the frequency of coupling in detecting connectivity, compared to coherence computed directly from the raw signals. We demonstrate the application of this approach to the EEG and EMG of essential tremor subjects and infer the cortical networks generating the tremor rhythms. We also discuss the application of this approach to cerebral NIRS and arterial blood pressure to quantify failure of cerebral pressure autoregulation in preterm infants. In both applications, as noted with AR2 process, phase coherence is confined to significantly fewer frequency bins than ordinary coherence, and determines the frequency of interaction more accurately.

MA7b-4 **11:30 AM**

Spatio-temporal Dynamics in Movement Control: New Vistas for Closed-loop Decoding Using MEG

Matthias Witte, University of Graz

During all stages of movement control neuronal representations have been shown to correlate with different parameters of movement. This mapping between brain signals and motor behavior can be used to infer movements in brain-computer interfaces. However, only few studies described the temporal properties of such cortical representations. Here, I will present new results demonstrating differential stability of distinct low-frequency activities in human sensorimotor cortex. Beyond principle neurophysiologic implications, these findings are discussed with regard to the feasibility of non-invasively recorded brain patterns as robust signals for future biomimetic neuroprosthetics.

Session: MAb8 – Communication Systems I 10:15 AM – 12:00 PM

Chair: ***David Browne,*** *MIT Lincoln Laboratory*

MA8b1-1
Optimum Training for CSI Acquisition in Cognitive Radio Channels

Alberto Rico-Alvariño, Carlos Mosquera, Universidade de Vigo

One of the main issues in the Overlay Cognitive Radio Paradigm (a framework where the secondary transmitter partially cooperates with the primary user) is the acquisition of channel state information at the secondary transmitter. In [1] a simple interaction framework that could allow the estimation of the channel values at the secondary transmitter was presented, although its performance was not characterized. In this paper, we extend the framework in [1] to the MIMO and SISO Time-Varying channels, present closed form expressions for the mean square error of these channel estimates, and derive optimum training sequences to minimize the estimation variance.

MA8b1-2
Spectrum Opportunity Detection with Weak and Correlated Signals

Yao Xie, Duke University; David Siegmund, Stanford University

We present a novel score detector for temporal spectrum opportunity detection in cognitive radio by exploiting the differences in both energy and correlation of the empty band and the occupied band. Motivated by the challenge of detecting a weak primary user's signal without precise knowledge of the signal, where the conventional energy detector faces the limit of "SNR wall", we assume a simple model which captures a key difference between noise and primary user's signal -- their correlation structures. Besides the merit of incorporating signal correlation, our score detector also avoids the computational complexity of covariance matrix inversion incurred by the corresponding maximum likelihood statistic assuming signal correlation. We provide a theoretical approximation to the false-alarm-rate of the score detector, which can be used to determine the threshold efficiently. We demonstrate that our approximation is quite accurate, and that our score detector has an advantage when the primary user's signal is weak and correlated.

MA8b1-3
A Blind Linear Smoothing Method for OFDM Systems without Cyclic Prefix

Xiaodong Yue, Songlin Tian, Xuefu Zhou, University of Central Missouri

A linear smoothing based blind channel estimation method for orthogonal frequency-division multiplexing (OFDM) systems over time-dispersive channel is proposed. The proposed method does not require a cyclic prefix and thus leading to higher spectral efficiency. By exploiting the block Toeplitz structure of the channel matrix, the proposed blind estimation method performs satisfactorily with very few received OFDM blocks. Therefore, it is attractive for channel estimation under fast changing channel environment. Computer simulations demonstrate the superior performance of the proposed algorithm over methods reported earlier in the literature.

MA8b1-4
Soft-Output Sphere Detection for Coded Unique Word OFDM

Alexander Onic, Alpen-Adria-Universität Klagenfurt; Andreas Schenk, Friedrich-Alexander-Universität Erlangen-Nürnberg; Mario Huemer, Alpen-Adria-Universität Klagenfurt; Johannes B. Huber, Friedrich-Alexander-Universität Erlangen-Nürnberg

Unique Word (UW) OFDM is an attractive alternative to conventional cyclic-prefix OFDM as it offers the potential to apply more sophisticated detection schemes, resulting in improved performance both in uncoded as well as coded transmission. In this paper, we study soft-output detection schemes suited for coded UW-OFDM transmission. In particular, we present an efficient implementation of near-optimum soft-output detection based on the soft-output sphere decoder (SOSD) algorithm. The performance and complexity of this approach is compared to a low-complexity linear detector (linear minimum mean squared error, LMMSE), which uses exact statistics of the residual noise for computation of the soft output. The conducted numerical simulations emphasize that the SOSD constitutes the decoding reference for uncoded as well as coded UW-OFDM transmission. Nevertheless, the LMMSE offers a good performance trade-off at a constant complexity, while the SD's complexity is variable.

MA8b1-5
A Cross-Layer HARQ Scheme Robust to Imperfect Feedback
Sébastien Marcille, Thales Communications and Security; Philippe Ciblat, Télécom ParisTech; Christophe Le Martret, Thales Communications and Security

Some recent cross-layer HARQ schemes have been designed in order to enhance the system performance at network level. However, these schemes suffer from high performance loss as soon as the feedback is imperfect. Therefore the purpose of this paper is to develop a new cross-layer HARQ scheme that is more robust to imperfect feedback, and that still has a cross-layer gain.

MA8b1-6
A Representation for the Symbol Error Rate of Arbitrary Constellations under AWGN
Adithya Rajan, Cihan Tepedelenlioglu, Arizona State University

The symbol error rate of the maximum likelihood detector for an arbitrary multi-dimensional constellation impaired by additive white Gaussian noise is characterized as the product of a completely monotone function with a non-negative power of the signal to noise ratio. Using this general result, it is proved that the symbol error rate is completely monotone if and only if the rank of its constellation matrix is either one or two. Applications to stochastic ordering of wireless system performance is also discussed.

MA8b1-7
Systematic Pruning of Blind Decoding Results
Dongwoon Bai, Jungwon Lee, Sungsoo Kim, Hanju Kim, Inyup Kang, Samsung US R&D Center

In LTE downlink control channel, a large number of blind decoding attempts are made while the number of valid codewords is limited. The blind decoding results are then verified using a 16-bit cyclic redundancy check (CRC). However, even with the 16-bit CRC, the false alarm (FA) rate of such blind decoding is inevitably high. This paper investigates the problem of pruning of blind decoding results to reduce the FA rate. To the best of our knowledge, the approach using a soft correlation metric (SCM) shows the best FA reduction performance among existing schemes. However, following the Bayes principle, we propose novel likelihood-based pruning that provides systematic balancing between the FA rate and the miss (MS) rate. Moreover, the SNR gain of our likelihood-based pruning is shown to be around 1 dB with respect to SCM-based pruning in AWGN channel. In addition to that, the simulation results show that the SNR gain of our proposed scheme is unbounded with respect to the SCM-based scheme in i.i.d. Rayleigh fading channel. The proposed likelihood-based approach can be applied to any error-correction/detection systems whose decoders make many blind decoding attempts.

MA8b1-8
Underlay Cognitive Radios with Finite Transmission Modes and Capacity Guarantees for Primary Users
Antonio G. Marques, Javier Ramos, Carlos Figuera, Eduardo Morgado, King Juan Carlos University

We design adaptive resource allocation for cognitive radios so that the sum-rate of secondary users is optimized while the damage (interference) to the primary users is keep under control. Secondary users transmit orthogonally and can implement only a finite number of power levels (finite-rate-feedback). Both limits on: a) the long-term interfering power at each primary receiver and b) the long-term capacity loss inflicted to each primary receiver, are considered. Although b) renders the resultant optimization problem non-convex, it holds that it has zero-duality gap and that, due to the favorable structure in the dual domain, it can be solved in polynomial time. Specifically, it holds that the required complexity is proportional to the number of secondary users, primary users (channels), and power levels. Extensions to handle channel imperfections and adaptive beamforming (MIMO channels) are briefly discussed.

MA8b1-9
Stochastic Soft-Input Soft-Output Detection for Intersymbol Interference Channels
Werner Haselmayr, Bernhard Etzlinger, Andreas Springer, Johannes Kepler University

We propose a fully-parallel low-complexity hardware architecture for a soft-input soft-output detector based on message passing in a factor graph. Conventionally, the message computation in the graph nodes consists of complex arithmetic operations on probabilities. Here, we represent probabilities by bit-serial streams and transform the arithmetic operations into simple bit-wise operations. This principle is known as stochastic computation and to the best of our knowledge this is its first application to a detection algorithm. We implemented the stochastic detector in VHDL and verified its BER performance through a Matlab/ModelSim cosimulation. The results show acceptable performance compared to its floating-point Matlab implementation.

MA8b1-10
Generic Low Complex Filter Bank Based Spectrum Sensing Approach for LTE Cognitive Radio

Thomas Schlechter, Mario Huemer, Alpen-Adria Universität Klagenfurt

The concept of cognitive radio (CR), allows the user equipment (UE) to scan its relevant environment with respect to the instantaneous spectrum allocation. In the original context of CR this information is used for efficient spectrum usage by different UEs using various radio access technologies. However, this concept can be further extended. Considering a UE providing long term evolution (LTE) functionality, knowledge about the environmental spectral composition is extremely valuable for the operation of the receive path. The main idea is as follows: if the UE detects many interferences, then both the analogue (AFE) and digital frontends (DFE) of the receive path have to provide full performance, e.g. highly linear amplifiers, filters of high order, etc. In the remainder of this paper these interferences will be called blockers. Full performance of the AFE and DFE results in high power consumption of the UE. If, on the other hand, there are only few blockers present, which additionally contain little energy, the receive path does not have to run in full performance mode, resulting in power saving. In this paper we present a low complex generic spectrum sensing approach, gaining knowledge about the UE's spectral environment for an appropriate reconfiguration of both the AFE and DFE. The method we use is a tree-structured subband processing technique. Subband transforms have first been introduced in the 1970s by Croiser, Esteban and Galand and have been further developed in the 1980s by Smith and Barnwell, Grenez, Mintzer, Vetterli and Vaidyanathan. The basic idea of the system we recommend has already been published in the recent past for a less general approach. In this paper we generalize this concept. At the cost of slightly higher complexity we gain flexibility of the specific application. We will give complexity estimates including comparisons to different FFT based implementations. Also simulation results will be provided to illustrate the detection performance of the given filter bank based approach.

MA8b1-11
A Study of Data Rate Equivalent UW-OFDM and CP-OFDM Concepts

Christian Hofbauer, Mario Huemer, Klagenfurt University

Unique word -- orthogonal frequency division multiplexing (UW-OFDM) is a novel transmit signal structure for OFDM where the usual cyclic prefixes (CPs) are replaced by deterministic sequences, the so-called UWs. Recent research results have demonstrated the superior BER behavior of UW-OFDM over conventional CP-OFDM used for real-world communication systems, e.g. for the IEEE802.11a WLAN standard. In this paper we extend these investigations by considering different and data rate equivalent UW-OFDM and CP-OFDM configuration setups. We show simulation results for various frequency selective environments and additionally compare UW-OFDM with UW based single carrier/frequency domain equalization (UW-SC/FDE) systems.

MA8b1-12
Constrained Least-Squares Estimation and Compensation of Phase Noise in OFDM Radio Link

Pramod Mathecken, Taneli Riihonen, Stefan Werner, Risto Wichman, Aalto University School of Electrical Engineering

In this paper, we propose a decision-feedback constrained least-squares phase noise compensation algorithm for the in-band distortion of an orthogonal frequency division multiplexing (OFDM) signal. We impose constraints on the least-squares estimates of the spectral components of the phase noise process which are then used for phase noise compensation. The rationale for imposing these constraints stems from the fact that the norm of the vector composed of these spectral components is always one, i.e., the vector is always drawn from a multi-dimensional sphere of radius one. The performance, in terms of bit-error rate, of the least-squares estimators with the different constraints are then compared with the unconstrained least-squares case.

MA8b1-13
Stopping Criteria for Iterative Decoding Based on Mutual Information

Jinhong Wu, Samsung Information Systems America; Branimir Vojcic, Jia Sheng, George Washington University

In this paper we investigate stopping criteria for iterative decoding from a mutual information perspective. We introduce new iteration stopping rules based on an approximation of the mutual information between encoded bits and decoder soft output. The first type stopping rule sets a threshold value directly on the approximated mutual information for terminating decoding. The threshold can be adjusted according to the expected bit error rate. The second one adopts a strategy similar to that of the well known cross-entropy stopping rule by applying a fixed threshold on the ratio of a simple metric obtained after each iteration over that of the first iteration. Compared with several well known stopping rules, the new methods achieve higher efficiency.

MA8b1-14
Frequency-Selective I/Q Imbalance Compensation for OFDM Receivers Using Decision-Feedback Adaptive Filtering
R. Keith McPherson, Jim Schroeder, Harris Corporation

I/Q imbalance in practical direct-conversion receivers is a major impairment in OFDM systems. The increasing demand for wider bandwidth and higher data throughput illuminates the need for robust and high performance frequency-selective I/Q imbalance compensation in OFDM direct-conversion receivers. Inspired by the 2005 work of Capozio, Pratima, and Vizzi, this paper presents an approach for mitigating frequency-selective I/Q imbalance using decision-feedback adaptive filtering. The presented approach may be viewed as a generalization of the cited 2005 work to frequency-selective operation. By making use of decision-feedback, a very high level of image rejection can be achieved, thereby enabling the use of higher order modulation on OFDM subcarriers. The method is online, fully adaptive, and is suitable for use in systems with digitally compensated carrier frequency offset (CFO). For the specific frequency-selective I/Q imbalance case considered, simulations show a significant improvement in the image rejection ratio (IRR) and the post compensation effective Eb/No, with the proposed method outperforming similar compensation methods.

MA8b1-15
Non-data Aided Symbol and Carrier Synchronization via Band-Edge Filters
Xiaofei Chen, Elettra Venosa, fredric harris, San Diego State University; Chris Dick, Xilinx Corp.

The carrier frequency offset and the symbol timing offset greatly degrade the performance of radio receivers. In this paper, we present a band-edge filter assisted, non-data aided, synchronization architecture that keeps the signal path operating at 2 samples/symbol in contrast with the previous solutions that operate at 4 samples/symbol. We also examine the minimum variance estimation property of the band-edge filter in estimating the timing and carrier offset parameters.

MA8b1-16
Coded QPSK Using Balanced Incomplete Block Design
Mohammad Noshad, Maite Brandt-Pearce, University of Virginia

In this paper, a new modulation scheme using quadrature phase shift keying (QPSK) for application in bipolar communication systems is presented. Balanced incomplete block designs (BIBD) are used for constructing the symbol alphabets. Each symbol is obtained by combining two bipolar BIBD codewords, one in-phase and the other quadrature-phase. Simple transmitter and receiver structures using shift registers are proposed. Due to the fixed cross-correlation property of BIBD codes, symbols have equal energies, and therefore, no threshold is needed to make a decision on the received signal. Because of the large distance between the symbols, this scheme is more power-efficient compared to PPM.

Track E. Array Signal Processing
Session: MAb8 – Array Signal Processing I 10:15 AM – 12:00 PM
Chair: ***Marius Pesavento,*** *Technische Universität Darmstadt*

MA8b2-1
Passive Radar Signal Processing in Single Frequency Networks
Konstanty Bialkowski, I. Vaughan Clarkson, University of Queensland

In this paper, we consider the problem of target detection in passive multistatic radar with multiple transmitters. Passive radar makes use of illuminators of opportunity, such as television and radio broadcast towers. As the illuminators do not cooperate with the receivers, the illuminating signal itself is unknown. The system considered is the DVB-T standard, which is often operated as part of single frequency network (SFN). In the original application of generalized canonical correlation (GCCA) to passive radar, only a single transmitter and multiple receivers were assumed. Similar to antenna arrays in communication systems, performance of the algorithm improves as separation of the receivers increases [2]. However, large separation of receivers introduces complexities in the synchronization and communication of sensor data for centralized processing. Instead by using the SFN transmitters, this complexity can be avoided by the passive radar system. To make use of SFN, the GCCA algorithm was extended to be aware of the multiple transmitters. Through this, the detection of targets is greatly improved, due to the geographic diversity of the transmitters.

MA8b2-3
How to Design a Delay-and-Sum Beamformer for Rigid Rotationally Symmetric Arrays?
Karim Helwani, Sascha Spors, Telekom Innovation Laboratories, Technische Universität Berlin; Herbert Buchner, Technische Universität Berlin

In this paper we present two novel techniques with low computational complexity and high robustness for beamforming using rigid arrays. For the first we show which approximations have to be taken in terms of applying techniques that are equivalent to delay-and-sum beamforming on rigid microphone arrays. In the second approach we exploit the technique of focused sinks for creating virtual linear microphone arrays with flexible dimensions and spacing. Such that simple techniques of beamforming using linear arrays can be applied. We derive our approaches analytically, state their theoretical limits and give simulation results and discuss the results.

MA8b2-4
Optimal Diagonal Loading for Spatial Spectrum Estimation in the Snapshot Deficient Regime
Milutin Pajovic, Massachusetts Institute of Technology/Woods Hole Oceanographic Institution; James Preisig, Woods Hole Oceanographic Institution; Arthur Baggeroer, Massachusetts Institute of Technology

A sample correlation matrix, estimated from snapshots of the received signal, plays a central role in the MPDR-based estimation of the spatial spectrum. When the number of available snapshots and the number of array sensors are of similar order, the true and estimated correlation matrices might differ significantly. Diagonal loading of the sample correlation matrix is a standard approach in dealing with the low sample support scenarios. Analysis of the optimal diagonal loading is presented here. Two optimization criteria are considered: maximization of the output signal-to-noise ratio and minimization of the mean square error between the estimated and true spectra.

MA8b2-5
2D DOA Estimation of Multiple Coherent Sources Using a New Antenna Array Configuration
Nizar Tayem, Prince Mohammad Bin Fahd University

This paper presents an efficient scheme for a two-dimensional (2-D) direction of arrival angle estimation (DOA) for multiple incident sources in the presence of coherent signals. A new antenna array configuration and innovative signal processing technique are presented. Compared with the well-known classical subspace schemes such as MUSIC and ESPRIT, the proposed method has several advantages. First, the proposed method can accurately estimate 2D DOA using a single snapshot data, whereas existing schemes need multiple snapshots. Second, it does not require forward/backward spatial smoothing of the covariance matrix or 2D iterative searching; however, existing schemes do. These advantages guarantee that the proposed scheme has a lower computational complexity and is more appropriate for high-speed wireless communication applications. The simulation results verify that the proposed method provides a better performance than the well-known ESPRIT method and L-shaped array with less computational complexity.

MA8b2-6
Performance Analysis on Synthetic Aperture Radar-based Vibration Estimation in Clutter
Qi Wang, Balu Santhanam, Matthew Pepin, Majeed Hayat, University of New Mexico

Recently, a time-frequency method based on the discrete fractional Fourier transform (DFrFT) was proposed for estimating target vibrations using synthetic aperture radar (SAR). Later on, a pseudo-subspace approach was incorporated into the DFrFT-based method. It is shown that the pseudo-subspace method provides better performance than the direct DFrFT-based method in noise. However, the performance of these two methods has not been studied in clutter that cause strong interference with signals from vibrating targets in real-world applications. In this paper, the performance of the two vibration estimation methods in clutter is characterized and compared by means of simulation. Simulation results demonstrate that the pseudo-subspace method has much better performance in low signal-to-clutter ratio than the direct DFrFT-based method.

MA8b2-7
Search Methods for Determining Direction of Arrival Acoustically
David Grasing, Sean Schumer, Anthony Rotolo, US Army

In this work several common methods for achieving direc-tional gain in a preferential direction are presented. These methods can be leverage to infer direction of arrival by searching over a set of candidate directions. The focus of this paper is on which directions of arrival one should search over. Suggestions for evaluation directions of arri-val are made. Additionally, an adaptive searching method based on the Nelder-Mead algorithm is presented. The proposed search method substantially reduces the number of candidate directions required for consideration. The search algorithm is then applied to track a small acoustic target.

MA8b2-8
Implementation and Demonstration of Receiver-Coordinated Distributed Transmit Beamforming across an Ad-Hoc Radio Network.
Pat Bidigare, Miguel Oyarzun, David Raeman, Dave Cousins, Dan Chang, Rich O'Donnell, Raytheon BBN Technologies; Rick Brown, Worcester Polytechnic Institute

Distributed transmit beamforming using an ad-hoc network of 10 RF transmitters was demonstrated using radio nodes developed from off-the-shelf components and modules. A time-slotted protocol allowed carrier phases from each transmitter to be measured at a receiver and fed back to the transmitters where Kalman filters were used to predict the offset phases and frequencies. Offsets were digitally compensated for during beamforming intervals. Beamforming gain within 0.1dB of ideal was demonstrated across 1 km at 910MHz. This is the first report (to our knowledge) of a successful outdoor RF distributed transmit beamforming experiment using independent clocks at this scale.

MA8b2-9
Algebraic Confidence for Sensor Localization
Jani Saloranta, University of Oulu; Stefano Severi, Jacobs University Bremen; Davide Macagnano, University of Oulu; Giuseppe Abreu, Jacobs University Bremen

In this paper we introduce the concept of algebraic confidence, defined as the measure of belief provided by an algebraic algorithm without a priori information of ranging statistics. We illustrate the concept by applying it to the design of a Circle-Based Interval SMACOF (CIS) algorithm which outputs an algebraic confidence level on a targets' estimates, without relying on the propagation of location distributions. The confidence levels obtained via the CIS algorithm are shown to have a linear relationship both the Fisher error ellipses derived from the Cramér-Rao lower bound (CRLB), corroborating the concept.

MA8b2-10
Breaking the Isotropic Scattering Assumption in Wide-beam Stripmap SAR Imaging
Jacob Gunther, Utah State University; Chad Knight, Space Dynamics Laboratory; Todd Moon, Utah State University

This paper considers stripmap SAR imaging using a wide-beam antenna. In this case, anisotropic scattering is observed from objects that are illuminated from a wide range of aspect angles. Traditional imaging algorithms assume isotropic scattering. This paper investigates the use of constrained optimization for jointly estimating a sequence of images that correctly account for aspect dependent scattering.

MA8b2-11
A Distributed Adaptive GSC Beamformer over Coordinated Antenna Arrays Network for Interference Mitigation
Songtao Lu, Iowa State University; Desheng Liu, Jinping Sun, Beihang University

A general framework of adaptive coordinated beamforming is proposed to enhance the performance of distributed antenna arrays network based on generalized sidelobe canceller (GSC). The proposed method exploits GSC structure to realize the convex combination of distributed neighboring nodes' weights sophistically such that the steady-state and robustness of antenna arrays network are greatly improved in strong interference environment. The optimal design as well as adaptive implementation by least-mean squares (LMS) algorithm is developed with detailed theoretical analysis on the stability and the steady-state output signal to interference plus noise ratio. Moreover, the effectiveness of the proposed method is demonstrated by simulation studies.

MA8b2-12
Spatial Coherence Modeling for Passive Ranging Using Distributed Arrays
Hongya Ge, New Jersey Institute of Technology; Ivars Kirsteins, Naval Undersea Warfare Center

This work presents our data analysis results on modeling spatial coherence in a distributed passive ranging system consists of three volumetric module arrays. Our results validate the assumption that data collected on individual modular arrays can be treated as far-field data (enabling the bearing estimation on each modular array level). Hence, the critical aspects of a passive ranging system using spatially separated arrays are the geometry of distributed modular arrays (enabling a non-coherent triangulation solution) as well as the existence of spatial coherence (to further facilitate a coherent processing).

MA8b2-13
Waveform Diversity and Optimal Change Detection
Carl Rossler, Emre Ertin, Randolph Moses, Ohio State University

We study the problem of change detection for synthetic aperture radar (SAR) when the reference and mission images are the result of interrogation with different waveforms (waveform diversity). If the same waveform were used when forming the mission and reference images, then all non-moving target, and their sidelobes, can be filtered out with background subtraction. However, if the waveforms of the mission and reference images are different, then so too are the sidelobes. Background subtraction is then in sufficient for filtering such changes. We derive an optimal change detector for diverse-waveform interrogation and apply the change detector to synthetic data.

MA8b2-14
Subband Gradient Flow Acoustic Source Separation for Moderate Reverberation Environment
Shuo Li, Milutin Stanacevic, Stony Brook University

We present a subband source separation algorithm for miniature microphone arrays with dimensions smaller than the wavelength. By relating temporal and spatial gradients of the observed microphone signals in an anechoic environment, gradient flow converts the mixture of delayed sources to linear instantaneous mixture of the time-differentiated source signals, that can be then localized and separated using static linear independent component analysis algorithms. For source separation in multi-path environment, we propose sub-band decomposition of the spatial gradients estimated over an array of 4 microphones. The static ICA algorithms are applied in each frequency band and the localization results obtained from the ICA applied on the unfiltered spatial gradients resolve the scaling and permutation indeterminacy. The simulations with the room acoustic model and experimental results with conference room recordings demonstrate over 12dB separation in moderate reverberation environment.

MA8b2-15
Gradient Flow Source Localization in Noisy and Reverberant Environment
Shuo Li, Milutin Stanacevic, Stony Brook University

Gradient flow is a technique for localization of an acoustic source using miniature microphone arrays by relating temporal and spatial gradients of the impinging source signal. The performance of the gradient flow in noisy and reverberant environment is examined and quantified through simulations that incorporate additive measurement noise, directional interference signal and room acoustic model. The algorithm demonstrates robust performance for additive signal-to-noise ratio down to 5 dB and at the signal-to-interference ratio of 10 dB. In the echoic room, localization performance starts to deteriorate under moderate reverberation conditions. The experimental results from a miniature microphone array recordings in a conference-room environment verify the presented simulations.

MA8b2-16
Analysis of Data Fusion Techniques for Small Arms Fire Localization
David Grasing, George Cakiades, Sachi Desai, U.S. Army RDECOM-ARDEC

In this paper several methods and models for improving small arms localization are investigated. Each acoustic sensor is placed at a disparate location and it is assumed that each system may or may not return an estimated range and/or azimuth shooter. Various simple geometric based data fusion methods are proposed and their performance evaluated. Models of localization errors are also proposed and these models are used herein to develop a maximum likelihood approach to data fusion. The parameters of these statistical distributions are estimated from real world data. Comparing / contrasting the results of both methods side by side, it can be shown that while the maximum likelihood based approach performs the best, decent results can be achieved with the simpler geometric based approach.

Session: MPa1 – Compressive Sensing

Chair: ***Christoph Studer,*** *Rice University*

MP1a-1 1:30 PM

Effect of Spatial Coupling and Bayesian Priors on Compressive Sensing Performance

Arian Maleki, Christoph Studer, Jianing Shi, Richard Baraniuk, Rice University

Compressive sensing (CS) enables the recovery of sparse signals from an undersampled set of linear measurements. Until recently, it has been tacitly assumed that i.i.d. random measurement kernels exhibit near best possible properties for CS. Recent discoveries, however, suggest that spatially coupled sensing matrices (having a band-diagonal structure) substantially improve the CS recovery performance in the Bayesian setting, where the empirical distribution of the non-zero entries of the sparse signal is known prior to recovery. However, the individual benefits of the Bayesian setting and spatially coupled sensing matrices remain unclear. Furthermore, the effect of spatially coupled sensing matrices on the CS recovery performance in the non-Bayesian setting, i.e., in situations where no statistical knowledge on the signal's non-zero coefficients is available, has not been studied systematically. In this paper, we investigate both questions using the approximate message passing framework.

MP1a-2 1:55 PM

Structured Signal Recovery from Single-Bit Measurements

Yaniv Plan, University of Michigan

1-bit compressed sensing was introduced by Boufounos and Baraniuk to model extreme quantization in compressed sensing; in this model each measurement consists of a single bit. Signal recovery from 1-bit measurements poses an elegant mathematical problem, and it has practical applications in analog-to-digital conversion and bit-constrained compressed sensing amid high noise. We review recent results which show that a simple convex program may be used to estimate the signal. In particular, an s-sparse signal in R^n may be accurately recovered from O(s log(n/s)) single-bit measurements. This remains true when nearly half of the measurements are randomly flipped. We describe the connection to related statistical models including sparse logistic regression. Other signal structures aside from sparsity can be also easily incorporated.

MP1a-3 2:20 PM

CoSaMP with Redundant Dictionaries

Mark Davenport, Stanford University; Deanna Needell, Claremont McKenna College; Michael Wakin, Colorado School of Mines

In this paper we study the recovery of signals from compressively sampled data in the setting where the signal is not sparse in an orthonormal basis but in a redundant dictionary. We consider a simple generalization of the CoSaMP algorithm and show that under the assumption that the measurement matrix satisfies a natural generalization of the restricted isometry property, the algorithm is guaranteed to succeed. We then conduct an in-depth study of the performance of this algorithm for a specific choice of dictionary -- the so-called "oversampled Fourier basis".

MP1a-4 2:45 PM

Compressed Sensing with Radar Applications

Max Hugel, Holger Rauhut, University of Bonn; Thomas Strohmer, University of California, Davis

In this paper, we will analyze a specific compressed sensing mechanism coming from radar. Rigorous bounds will be derived for the number of randomly selected antenna elements needed to remotely sense a given number of targets in a certain range cell. The recovery algorithm used is noise-constrained basis pursuit. What makes the analysis challenging is that even though we select the antenna positions independently at random over the aperture, the arising sensing matrix has coupled rows and columns. This requires special techniques for obtaining optimal bounds for the number of antennas needed to recover a fixed scene. We will furthermore show that the recovery is robust if the measurements are corrupted by noise and we will present numerical results validating the theoretically obtained bounds.

Session: MPb1 – Signal Processing and Learning in Complex Systems

Chair: ***Michael Rabbat,*** *McGill University*

MP1b-1 3:30 PM

Dynamics of Social Connections

Lin Li, Anna Scaglione, University of California, Davis

This paper explores the dynamics of social network formation simi- lar in spirit to the model analyzed by Jackson and Wolinsky, Journal of Economic Theory 71 (1996), 44 – 74. Agents in the network themselves decide which social links need to be formed or cut off based on the individuals' utility functions. However, there is a cost to maintain a link. In this context, the notions of stability and efficiency of a network are introduced. In general, a stable network does not necessarily correspond to an efficient network. Our goal is to understand the dynamics of such a network and how its productivity evolves over time. In the case when the society operates inefficiently, we also investigate ways to incentivize the society for total productivity.

MP1b-2 3:55 PM

Dynamic Games with Side Information in Economic Networks

Ceyhun Eksin, Pooya Molavi, Alejandro Ribeiro, University of Pennsylvania

We consider a dynamic game with information externalities. Agents' utility depends on an unknown true state of the world and actions of other agents in the network. Each agent has an initial private information about the underlying state and repeatedly observes actions of its neighbors. We analyze the asymptotic behavior of agents' expected utilities in a connected network when it is common knowledge that the agents are myopic and rational. When each stage of the game has a strict Bayesian Nash equilibrium, it is shown that any given pair of agents believe that their expected pay-off are the same in the limit. We exemplify our analysis in a setting where agents benefit from estimating the true state of the world and at the same time has the motive to coordinate with everyone else.

MP1b-3 4:20 PM

Adaptive Decision-Making over Complex Networks

Sheng-Yuan Tu, Ali Sayed, University of California, Los Angeles

It is common for biological networks to encounter situations where agents in the network need to decide between multiple options, such as deciding between following one food source or another or between moving towards a new hive or another. In previous works, we developed several powerful diffusion strategies that allow agents to estimate a model of interest in an adaptive and distributed manner through a process of in-network collaboration and learning. In this work, we consider the situation when the data observed by the agents may arise from two different distributions (or parameter vectors). We examine how agents end up opting for one distribution over the other. We also show how to implement a distributed decision-making process over the network through the design of the combination weights.

MP1b-4 4:45 PM

A Factor Graph Approach to Diffusion Adaptive Filtering Methods

Andrew Bean, Thomas Riedl, Andrew Singer, University of Illinois, Urbana-Champaign

A considerable amount of research has focused on such distributed estimation techniques as gossip and diffusion LMS/RLS, where agents make one or more observations, share their information with neighbors and derive a local estimate of a parameter of interest. We show how these cooperative algorithms can be expressed as message passing algorithms on factor graphs, thus opening the door to the use of a number of other practical and theoretical tools for the development and analysis of such algorithms. We also explore the effects of network topology on convergence behavior of the resulting algorithms.

Session: MPa2 – Source Localization in Distributed Sensor Arrays

Chair: ***Christoph Mecklenbräuker,*** *Technische Universität Wien*

MP2a-1 **1:30 PM**

Convergence Analysis of Distributed PAST Based on Consensus Propagation

Carolina del Socorro Reyes Membreno, Markus Rupp, Vienna University of Technology

Abstract: In previous work, we have analyzed the convergence properties of he Projection Approximation Subspace Tracking algorithm by means of Singular Value Decomposition methods. Based on this, we extend our analysis and study the global convergence properties of a distribued version of the PAST algorithm based on Average Consensus. We provide an insight regarding convergence in the mean and mean square, and establish step-sizes that guarantee the stability of the algorithm. Finally, we investigate the algorithm's behavior at several step-sizes by means of simulation experiments.

MP2a-2 **1:55 PM**

Localization of Acoustic Sources Utilizing a Decentralized Particle Filter

Florian Xaver, Gerald Matz, Vienna University of Technology; Peter Gerstoft, University of California, San Diego; Norbert Görtz, Vienna University of Technology

This paper presents recent results of a decentralized localization scheme in sensor networks which are embedded in a physical field. In particular, acoustic waves are emitted by sources and observed by sensors. These waves are described by partial differential equations which are transformed into a state-transition model by a numerical method. This spatial distributed set of equations is augmented by a distributed state vector corresponding to source positions and occurrence times. For decentralized estimation, a decomposed model is utilized. Supplemented by a consensus algorithm, a decentralized particle filter algorithm infers jointly the states.

MP2a-3 **2:20 PM**

Bayesian Sparse Sensing of the Japanese 2011 Earthquake

Peter Gerstoft, University of California, San Diego; Christoph Mecklenbräuker, Vienna University of Technology

Sparse sensing is a technique for finding sparse signal representations to underdetermined linear measurement equations. We use sparse sensing to locate seismic sources during the rupture of the 2011 Mw9.0 earthquake in Japan from teleseismic P waves recorded by an array of stations in the United States. The seismic sources are located by minimizing the L2 norm of the difference between the observed and modeled waveforms penalized by the L1-norm of the seismic source vector. The resulting minimization problem is convex and can be solved efficiently. Our results show clear-frequency dependent rupture modes with high-frequency energy radiation dominant in the down-dip region and low- frequency radiation in the updip region

MP2a-4 **2:45 PM**

Distributed Source Localization in Subarray Sensor Networks.

Christian Steffens, Michael Rübsamen, Marius Pesavento, Technische Universität Darmstadt

We propose a distributed direction-of-arrival (DOA)estimation technique for partly calibrated sensor arrays. The calibrated subarrays iteratively share information about the source DOAs with neighboring subarrays and update their local DOA estimates based on the locally received snapshots and the information received from adjacent subarrays. The local DOA estimates are computed by means of a novel l1-norm based covariance matrix fitting technique, which can be implemented efficiently using modern convex optimization software tools. We analyze the convergence behavior of the proposed technique, the number of resolvable sources, and the robustness to the malfunctioning of one or several subarrays.

Session: MPb2 – Network Beamforming

Chair: ***Shahram Shahbazpanahi,*** *University of Ontario Institute of Technology*

MP2b-1 **3:30 PM**

Distributed Beamforming in Coarsely Synchronized Relay Networks

Adrian Schad, Technische Universität Darmstadt; Babak Khalaj, Sharif University of Technology; Marius Pesavento, Technische Universität Darmstadt

We consider a wireless network with one source, multiple relays and multiple destinations. The source and the relays are assumed to utilize multiple antennas. To reduce the effects of frequency selectivity in source-to-relay and relay-to-destination channels and to compensate for multi-user interference and noise, the source, the relays and the destinations are designed to apply jointly optimized linear block processing of the signals. To solve the problem of maximizing the quality-of-service at the destinations, centralized and distributed algorithms are proposed. The proposed scheme generalizes the filter-and-forward relaying scheme of the literature.

MP2b-2 **3:55 PM**

Distributed Beamforming for Two-Way Relaying Networks with Individual Power Constraints

Jianshu Zhang, Florian Römer, Martin Haardt, Technische Universität Ilmenau

In this paper we study the sum rate maximization problem in a two-way relaying network with multiple single antenna amplify and forward relays, where each relay has its own transmit power constraint. This optimization problem is non-convex. Nevertheless, we first propose a global optimization based algorithm for benchmarking and analysis. Afterwards, we develop sub-optimal solutions that have a lower complexity but achieve a comparable performance.

MP2b-3 **4:20 PM**

Beamforming Design for Two-Way Relay Networks Under Per-Node Power Constraint

Shahram ShahbazPanahi, University of Ontario; Yindi Jing, University of Alberta

For two-way multi-relay networks, where each node is assumed to have its own power constraint, the relay distributed beamforming and user power control are considered under the formulation of maximizing the lower signal-to-noise ratio (SNR) of the two end users in the network. While the complexity of finding the optimal solution is too high for large networks, two sub-optimal algorithms with low complexity are proposed, which are shown to perform close to the optimal by simulation. It is also shown via simulation that proper user power control and relay distributed beamforming can significantly improve the network performance, especially when the power constraints of the two end-users in the networks are unbalanced.

MP2b-4 **4:45 PM**

Improving Achievable Rate for the Two-User SISO Interference Channel with Improper Gaussian Signaling

Yong Zeng, Mustafa Cenk Yetis, Erry Gunawan, Yong Liang Guan, Nanyang Technological University; Rui Zhang, National University of Singapore

This paper studies the achievable rate region of the two-user single-input single-output (SISO) Gaussian interference channel, when the improper Gaussian signaling is applied. Under the assumption that the interference is treated as additive Gaussian noise, we show that the user's achievable rate can be expressed as a summation of the rate achievable by the conventional proper Gaussian signaling, which depends on the users' input covariances only, and an additional term, which is a function of both the users' covariances and pseudo-covariances. The additional degree of freedom given by the pseudo-covariance, which is conventionally set to be zero for the case of proper Gaussian signaling, provides an opportunity to improve the achievable rate by employing the improper Gaussian signaling. Since finding the optimal solution for the joint covariance matrix and pseudocovariance matrix optimization is difficult, we propose a suboptimal but efficient algorithm by separately optimizing these two sets of parameters. Numerical results show that the proposed algorithm provides a close-to-optimal performance as compared to the exhaustive search method, and significantly outperforms the optimal proper Gaussian signaling scheme.

Track B. MIMO Communications and Signal Processing

Session: MPa3 – Large-Scale MIMO Systems

Co-Chairs: ***Tom Marzetta,*** *Alcatel-Lucent/Bell-Labs* ***and Saif K. Mohammed,*** *Linköping University*

MP3a-1 **1:30 PM**

Spectral Efficiency in Large-Scale MIMO-OFDM Systems with Per-Antenna Power Cost

Derrick Wing Kwan Ng, University Erlangen-Nürnberg; Robert Schober, University of British Columbia

this paper, resource allocation for multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) downlink networks with large numbers of base station antennas is studied. Assuming perfect channel state information at the transmitter, the resource allocation algorithm design is modeled as a non-convex optimization problem which takes into account the joint power consumption of the power amplifiers, antenna unit, and signal processing circuit unit. Subsequently, by exploiting the law of large numbers and dual decomposition, an efficient suboptimal iterative resource allocation algorithm is proposed for maximization of the system capacity (bit/s). In particular, closed-form power allocation and antenna allocation policies are derived in each iteration. Simulation results illustrate that the proposed iterative resource allocation algorithm achieves a close-to-optimal performance in a small number of iterations and unveil a trade-off between system capacity and the number of activated antennas: Activating all antennas may not be a good solution for system capacity maximization when a system with a per antenna power cost is considered.

MP3a-2 **1:55 PM**

On the Complementary Benefits of Massive MIMO, Small Cells, and TDD

Seyedkianoush Hosseini, University of Toronto; Jakob Hoydis, Supelec; Stephan ten Brink, Bell Laboratories, Alcatel-Lucent; Mérouane Debbah, Supelec

This paper considers a multicell network with massive multiple-input multiple-output (MIMO) base stations (BSs) augmented with randomly deployed small cells (SCs). The two tiers operate via a time-division duplex (TDD) protocol. In this regard, the advantages of TDD and the resulting uplink-downlink channel reciprocity are twofold. First, each BS can accommodate a large number of antennas without inducing prohibitive training overhead. Second, the interference covariance matrix at each BS spans the same subspace as the interference that a BS imposes on the SC tier. Hence, individual BSs design their precoders to be orthogonal to the dominant interference directions, while transmitting independent data streams to their associated users. Thus, the sum interference imposed on the SC tier is minimized. Moreover, the interference covariance can be acquired without any explicit coordination across the tiers. Building upon the work in [1], we extend the proposed covariance based precoding scheme based on a generalization of the uplink-downlink duality theorem to interference channels. This leads to symmetric uplink and downlink rates for each user. Our simulation results suggest that the proposed architecture can provide significant performance improvements as compared to several baseline schemes and the approach in [1].

MP3a-3 **2:20 PM**

Measured Propagation Characteristics for Very Large MIMO at 2.6 GHz

Xiang Gao, Fredrik Tufvesson, Ove Edfors, Fredrik Rusek, Lund University

Very large MIMO is a technique that potentially can offer large network capacities in multi-user scenarios where the users are equipped only with single antennas. In this paper we are investigating channel behavior for a realistic outdoor base station scenario using large arrays. Specifically we compare the case using a physically large 128 element linear array with the case of a compact cylindrical array using the same number of antenna ports. In the physically large array case the angular resolution is very large and users can be separated based on spherical wave fronts reaching the array. The situation is, however, different for the compact array and in the paper we analyze how this affects system performance.

Session: MPb3 – Coordinated Multipoint

Chair: ***Wing-Kin Ma,*** *Chinese University of Hong Kong*

MP3b-1 **3:30 PM**

A Decentralized Method for Joint Admission Control and Beamforming in Coordinated Multicell Downlink

Hoi-To Wai, Wing-Kin Ma, Chinese University of Hong Kong

In cellular networks, admission control and beamforming optimization are intertwined problems. While beamforming optimization aims at satisfying users' quality-of-service (QoS) requirements or improving the QoS levels, admission control looks at how a subset of users should be selected so that the beamforming optimization problem can yield a reasonable solution in terms of the QoS levels provided. However, in order to simplify the design, the two problems are usually seen as separate problems. This paper considers joint admission control and beamforming (JACoB) under a coordinated multicell MISO downlink scenario. We formulate JACoB as a user number maximization problem, where selected users are guaranteed to receive the QoS levels they requested. The formulated problem is combinatorial and hard, and we derive a convex approximation to the problem. A merit of our convex approximation formulation is that it can be easily decomposed for per-base-station decentralized optimization, namely, via block coordinate decent. The efficacy of the proposed distributed method is demonstrated by simulation results.

MP3b-2 **3:55 PM**

Analyzing the IA Feasibility Problem via New Tools from Algebraic Geometry

Liangzhong (Steven) Ruan, Vincent Lau, Hong Kong University of Science and Technology

Attributed by its breakthrough performance in interference networks, interference alignment (IA) has attracted great attention in the last few years. However, despite the tremendous works dedicated to IA, the feasibility conditions of IA processing remains unclear for most network typologies. The IA feasibility analysis is challenging as the IA constraints are sets of high-degree polynomials, for which no systematic tool to analyze the solvability conditions exists. In this work, by developing a new mathematical framework that maps the solvability of sets of polynomial equations to the linear independence of their first-order terms, we propose a sufficient condition that applies to interference networks with general typologies. We have further proved that the sufficient condition aligns with the necessary conditions under some special configurations.

MP3b-3 **4:20 PM**

Design of Coordinated Multi-Point (CoMP) Transmission and Reception Schemes for the 4G Cellular Downlink

Narayan Prasad, NEC Laboratories America, Inc.; Ali Tajer, Princeton University; Xiaodong Wang, Columbia University

Coordinated Multi-Point (CoMP) transmission and reception schemes are supported by the fourth generation (4G) cellular systems such as the 3GPP LTE-Advanced. These schemes involve a cluster of transmission points simultaneously serving several active users in a coordinated fashion. The transmission points are heterogeneous since they can comprise of Macro base stations as well as low power radio remote heads and each user can receive its data from a dynamically changing set of transmission points. In this paper, we will discuss the support for CoMP schemes in the 4G standards and then propose and analyze schemes that are largely standards compliant. The design of such schemes leverages transmit precoder design techniques as well as methods to solve certain combinatorial optimization problems.

MP3b-4 **4:45 PM**

Joint Transceiver Design and Base Station Clustering for Heterogeneous Networks

Mingyi Hong, Meisam Razaviyayn, Ruoyu Sun, Zhi-Quan Luo, University of Minnesota

We consider the resource allocation problem in heterogeneous networks (HetNet) in which base stations (BSs) are grouped into clusters to serve distributed users. The goal is to design linear transceivers and/or the cluster structure to maximize the sum of the users' utilities. When the cluster structure is fixed, we show that by a novel convex approximation of the original problem, a KKT point of the sum-utility maximization problem can be obtained by solving a series of convex subproblems. To reduce computational complexity, we further propose an efficient algorithm that solves each of the convex subproblems inexactly and establish its convergence to a KKT point. Finally, we show that this algorithm and its convergence can be extended to jointly optimize the transceivers and the cluster structure.

Track C. Networks

Session: MPa4 – Cognitive Radio Networks

Chair: ***Visa Koivunen,*** *Aalto University*

MP4a-1 1:30 PM

Cooperative Compressive Wideband Power Spectrum Sensing

Dyonisius Dony Ariananda, Geert Leus, Delft University of Technology

Compressive sampling is a popular approach to relax the requirement on the analog-to-digital converters for wideband spectrum estimation. While perfect reconstruction of sparse signals sampled below the Nyquist-rate is possible, only power spectrum recovery is required in cognitive radio applications. We propose a cooperative power spectrum sensing approach where multiple sensors cooperatively sense and reconstruct the power spectrum of the wide-sense stationary signals from sub-Nyquist rate samples without any sparsity constraints on the power spectrum. The cross-correlations between measurements from different sensors are exploited and expressed as a linear function of the original power spectrum, which is solvable using least-squares.

MP4a-2 1:55 PM

On Hybrid Cooperation in Underlay Cognitive Radio Networks

Nurul Huda Mahmood, Norwegian University of Science and Technology; Ferkan Yilmaz, King Abdullah University of Science and Technology; Geir Egil Øien, Norwegian University of Science and Technology; Mohamed-Slim Alouini, King Abdullah University of Science and Technology

In wireless systems where transmitters are subject to a strict received power constraint, such as in underlay cognitive radio networks, cooperative communication is a promising strategy to enhance network performance, as it helps to improve the coverage area and outage performance of a network. However, this comes at the expense of increased resource utilization. To balance the performance gain against the possible over-utilization of resources, we propose a hybrid-cooperation technique for underlay cognitive radio networks, where secondary users cooperate only when required. Various performance measures of the proposed hybrid-cooperation technique are analyzed in this paper, and are also further validated numerically.

MP4a-3 2:20 PM

Sequential Good Channel Search for Multi-channel Cognitive Radio

Raied Caromi, Seshadri Mohan, University of Arkansas, Little Rock; Lifeng Lai, Worcester Polytechnic Institute

We study how to quickly search for a secondary channel that has a good channel quality between the secondary transmitter and receiver. We consider a sequential search setup, in which the secondary transmitter sends training sequence over each available channel one by one. On receiving the noisy training symbols, the receiver makes two decisions. The first one is whether the pair should stop the search and use the current channel for transmission. If the pair decides to continue the search, the receiver needs to decide whether they should stay on the same channel to refine its channel estimation or switch to another channel. Optimal terminal and switching rules are provided to strike a balance between the time spent on channel search and the quality of the channel accepted for transmission. (invited paper in the “Cognitive Radio Networks” session)

MP4a-4 2:45 PM

A Sensing Policy Based on Confidence Bounds and a Restless Multi-armed Bandit Model

Jan Oksanen, Visa Koivunen, Aalto University; H. Vincent Poor, Princeton University

In this paper a simple and intuitive algorithm is proposed for stationary restless multi-armed bandit problem with an unknown reward model. The work is presented in the context of cognitive radio where secondary users try to decide which primary frequency bands they should sense (and possibly access if the band is idle), given their past observations from the bands. In our previous works [1, 2] we have considered this problem when the reward processes are assumed to be possibly non-stationary and illustrated the robustness of simple epsilon-greedy exploration. However, when the reward processes are stationary the epsilon-greedy suffers from slow convergence. The proposed algorithm in this paper for stationary rewards is an index policy, where the index of a frequency band is defined as the observed rewards sample mean and a term reflecting the sample means confidence interval. The sample mean term promotes exploitation whereas the confidence bound term encourages exploration. At each time instant the band with the highest index is sensed. The novelty of the proposed algorithm is the upper confidence bound term that increases in the proportion to the time instance since the band was last sensed. The relative increase in the confidence bound term is gradually decreased as more samples are gathered. Intuitively this makes the CR not only to be aware of what it is doing (sensing the seemingly best band) but also aware of what it is not doing (not sensing the other bands). Other confidence bound based methods in the literature, such as in [3] and [4], increase the confidence bound of the bands that are not sensed in the proportion to the total number of times the band has been sensed. According to our simulations the proposed algorithm

achieves logarithmic regret growth with many reward distributions and faster convergence than other methods in the literature. In this short summary we present the algorithm and illustrate its performance through computer simulations. The analysis of the algorithm will be presented in the extended version of the paper.

Track C. Networks

Session: MPb4 – Machine-to-Machine Communications and Networks

Chair: ***KC Chen,*** *National Taiwan University*

MP4b-1 3:30 PM

Not Every Bit Counts: Shifting the Focus from Machine to Data for Machine-to-Machine Communications

Chih-Hua Chang, Hung-Yun Hsieh, Hsuan-Jung Su, National Taiwan University

As the concept of Internet of Things (IoT) gradually being materialized, the demand for supporting machine-to-machine (M2M) communications involving a large number of machines is mounting. While several standards bodies have embarked on a series of endeavors for adapting the current communication systems towards this objective, the proposed solutions still fall short of the desirable performance for many M2M applications due to the amount of data involved. To address the "big data" problem introduced by M2M applications, we argue in this paper that instead of focusing on serving individual machines, one should focus on solutions that can better serve the data itself. To substantiate, we consider the problem of data gathering in a wide area by machines that connect wirelessly to a central aggregator. The aggregator has limited radio resources to allocate to machines for uplink transmission of collected data, and hence the problem arises as to how the resources can be effectively utilized for supporting such an M2M application. In contrast to conventional approaches on maximizing the number or sum rates of machines that can access the radio resource, we investigate an approach that takes into consideration "useful" information content that individual machines can provide for prioritization of resource allocation. Numerical results based on the proposed algorithms for solving the target problem show that although some machines cannot be served due to resource limitation, the data hence collected at the aggregator exhibits significant quality gain for the target M2M scenario compared to existing approaches. We thus motivate further investigation along this direction for M2M communications.

MP4b-2 3:55 PM

Exploring Utility-based Optimization and Management for Wireless Sensor Networks and Machine-to-Machine Communications

Petri Mähönen, Janne Riihijarvi, RWTH Aachen University

In this paper we discuss utility-based network optimization for Wireless Sensor Networks (WSNs) and Machine-to-Machine communications. In the Internet setting the utility function to be maximized is usually assumed to be a sum of individual utilities of end-to-end flows. For WSNs the situation is highly different. Usually a sensor network is deployed to monitor the evolution of a particular phenomenon over time in some region of interest. The key performance metric of the network becomes then how accurately the network measures this evolution compared to the requirements of the application. This makes utility-based reasoning on network performance much more complex for WSNs compared to the traditional Internet model, since the utility will depend in a complex manner on phenomena under study, the topology of the network, as well as on the algorithms used for state estimation from the individual measurements. We focus here on spatial and temporal monitoring problems, give an overview of the various estimation approaches that are applicable for data processing in the corresponding WSN deployments, and give examples on how utility-based optimization and be used to enhance the lifetime and performance of WSNs. We also discuss the related architectural issues, in particular how utility functions for WSNs could be expressed in a form suitable for automated processing.

MP4b-3 4:20 PM

Controlling Access Overload and Signaling Congestion in M2M Networks

Umesh Phuyal, Ali T. Koc, Mo-Han Fong, Rath Vannithamby, Intel Corporation

Access overload and signaling congestion are serious issues in M2M networks. These issues can be caused by (i) external events triggering a large number of M2M devices to connect or disconnect all at once, (ii) recurring application events that are synchronized to the exact time (e.g., hour), and (iii) malfunctioning of M2M application or server. It is vital to control access overload and signaling congestion in order to prevent the network from a complete collapse. This paper investigates several mechanisms to prevent this issue.

MP4b-4 **4:45 PM**

Dynamic Spectrum Allocation under Cognitive Cellular Network for M2M Applications

Qing Wang, IBM Research China; Bongjun Ko, IBM T. J. Watson Research Laboratory; Kwang-Cheng Chen, National Taiwan University; Junsong Wang, IBM Research China; Ting He, IBM T. J. Watson Research Laboratory; Yonghua Lin, IBM Research China; Kang-won Lee, IBM T. J. Watson Research Laboratory

In machine-to-machine (M2M) communication, smart spectrum management is vital for the system performance since there are a large number of wireless devices sharing the same limited spectrum and the spectrum resource is scarce. For the spectrum sharing, it's not only encountered in ISM band, but also in the networks with dedicated spectrums when the network is under evolution or upgrading, such as the system updating from narrow-band to broadband in SmartGrid communications. In this paper, we summarize the typical methods in wireless cellular network to improve the spectrum utilization and compare their advantages and limitations as applied to M2M communications. Based on the analysis, we propose a novel mechanism for dynamic spectrum allocation in a cognitive radio environment for SmartGrid applications using OFDMA technology and give some evaluations based on field test data. The spectrum allocation we proposed can be divided into two stages: network entry stage based on initial sensing and dynamic interference avoidance stage based on periodical sensing. At the network entry stage, we focus the discussion on the design of optimal spectrum auto planning algorithm and provide a new scheme based on backup list generation and internal/external interference differentiation. After the OFDMA based system enters into normal communication stage, interference avoidance within the allocated spectrum band is the main task of the M2M system. The in-band spectrum will be segmented into several sub-bands and be scheduled by the system based on periodical spectrum sensing results to avoid interferences coming from external devices(SCADA or unknown system) which share the same spectrum with the current system. The spectrum allocation mechanism we proposed has been used in IBM Wireless Internet-of-Thing (IoT) platform and achieved good performance during the field test.

Track H. Speech, Image and Video Processing

Session: MPa5 – Image and Video Coding

Chair: ***Marios Pattichis,*** *University of New Mexico*

MP5a-1 **1:30 PM**

Dynamically Reconfigurable AVC Deblocking Filter with Power and Performance Constraints

Yuebing Jiang, Marios Pattichis, University of New Mexico

MP5a-2 **1:55 PM**

On the Use of Image Quality Estimators for Improved JPEG2000 Coding

Thien Phan, Phong Vu, Damon Chandler, Oklahoma State University

A commonly mentioned application of image quality assessment (IQA) algorithms is their use in image coding. However, just because an IQA algorithm performs well in predicting quality on an image-quality database, this does not guarantee that the IQA algorithm will succeed in a coding context. To test the efficacy of IQA algorithms for JPEG2000 encoding, we collected subjective rankings of JPEG2000-compressed images in which a fixed amount of distortion was allocated to the subbands in various ways. We then tested the ability of various IQA algorithms in predicting these rankings. Our analysis revealed that all algorithms failed to predict the rankings on many of the images. Based on these findings, we present a new IQA algorithm which uses local DWT coefficient statistics to predict the perceived distortion. We demonstrate how this algorithm can generate higher quality images vs. other approaches.

MP5a-3 **2:20 PM**

Blind Quality Assessment of Videos Using a Model of Natural Scene Statistics and Motion Coherency

Michele Saad, Al Bovik, University of Texas at Austin

We propose a blind video quality evaluation approach that is non-distortion specific. The approach relies on a spatio-temporal model of video scenes in the discrete cosine transform (DCT) domain, and on a model that characterizes the type of motion occurring in the scenes, to predict video quality. The video quality assessment (VQA) algorithm does not require the presence of a pristine video to compare against in order to predict a quality score. The contributions of this work are three-fold. 1) We propose a spatio-temporal natural scene statistics (NSS) model for videos. 2) We propose a motion model that quantifies motion coherency in video scenes. 3) We show that the proposed NSS and motion coherency models are appropriate for quality assessment of videos, and we utilize them to design a blind VQA algorithm that correlates highly with human judgments of quality. The proposed algorithm, called Video BLIINDS, is tested on the LIVE VQA Database. We demonstrate that its performance approaches the performance of the top performing reduced and full reference algorithms.

MP5a-4 **2:45 PM**

The Emerging High Efficiency Video Coding Standard for Developing Wireless Ultrasound Video Telemedicine Systems

Andreas Panayides, Zinon Antoniou, University of Cyprus; Marios Pattichis, University of New Mexico; Constantinos Pattichis, University of Cyprus

The emerging high efficiency video compression methods and wider availability of wireless network infrastructure can significantly contribute to the development of effective mobile health systems. For medical video communications, the emerging video compression and network standards support low-delay and high-resolution video transmission, at the clinically acquired resolution and frame rates. Such advances can be used to support remote diagnosis and emergency incidents in daily clinical practice. For these mobile health application, clinical video quality needs to be evaluated for strict clinical criteria. This paper details the advances of the emerging high efficiency video coding (HEVC) standard over the H.264/AVC standard and describes clinical benefits for the wireless transmission of stroke ultrasound videos. We test different HEVC modes that include high-efficiency and low-complexity configurations, and also provide for low-delay and random access. The results are compared against similar H.264/AVC configurations and are carefully evaluated using clinical video criteria. The experimental evaluation demonstrates significant reductions in bitrate requirements for equivalent clinical quality. Wireless transmission over mobile WiMAX networks provides for low-delay medical video communication without compromising diagnostic quality.

Track H. Speech, Image and Video Processing

Session: MPb5 – Convex Optimization in Image and Video Analysis

Chair: ***Vishal Monga,*** *Penn State University*

MP5b-1 **3:30 PM**

Compressive Sensing and Sparse Array Processing

P. P. Vaidyanathan, California Institute of Technology

Assume a signal ${\bf y}$ has a sparse representation in terms of a dictionary ${\bf A}$, that is, ${\bf y}={\bf Ax}$ where ${\bf x}$ has very few, say $s,$ nonzero entries. Then ${\bf y}$ can be written as ${\bf y}={\bf A}_S{\bf x}_S$ where ${\bf x}_S$ is a $s\times 1$ vector, and ${\bf A}_S$ is a matrix with s columns, which are the atoms involved in the sparse representation. The identification of the sparse representation (i.e., the correct s columns), is in general an NP-hard problem. It is well known that this problem can be replaced with a convex problem (an l_1 optimization) under certain conditions on the matrix ${\bf A}$. Greedy pursuit algorithms can also be successfully used for solving this sparse problem, under some conditions on ${\bf A}$. In the context of array processing, the connection between the DOA estimation problem and the sparse reconstruction problem has been well known, and this has in the past been exploited successfully. Now, sparse arrays such as coprime arrays are especially suited in applications which depend only on the autocorrelation of the input signal, such as spectral estimation and DOA estimation. In such applications, the difference coarray of the array geometry plays a major role in determining the number of freedoms available in the process. For example, it is well known that specific geometries such as the coprime and nested arrays, and minimum redundancy arrays can generate $O(N^2)$ freedoms from N sensor elements. However, in the context of such sparse arrays, the special properties of the convexification of the sparse-recovery problem (arising from the nature of ${\bf A}$) have not been studied in the past, and this is the purpose of this paper. Some of these properties are related to those of Fourier frames as the paper will elaborate. Applications in sparse image reconstruction will also be outlined.

MP5b-2 **3:55 PM**

Single-Image Super-Resolution Using Multihypothesis Prediction

Chen Chen, James Fowler, Mississippi State University

Image super-resolution aims to overcome resolution limitations arising from low-cost digital imaging systems and imperfect imaging environments. While many super-resolution algorithms can be broadly classified as multi-image techniques since they obtain a high-resolution image from a set of low-resolution images of the same scene at subpixel misalignments, some applications require strictly single-image operation. Typically, single-image super-resolution is example-based such that the correspondences between high-resolution and low-resolution image patches are learned from known image pairs in a database. Although these example-based algorithms operate on a single image, a training process involving many images must create the database a priori. In contrast, a single-image super-resolution method is proposed that exploits self-similarities of image patches within a single image using a multihypothesis prediction. In the proposed framework, each patch of the low-resolution image is represented as a linear combination of spatially surrounding patches which are considered to be multiple hypotheses for the current patch; coefficients of the resulting linear combination are then calculated using a Tikhonov-regularized l2-based optimization and used to generate the high-resolution image. Experimental results reveal that the proposed algorithm offers significantly higher-quality super-resolution than bilinear interpolation without the cost of a training on an extensive training set of imagery as is typical of single-image example-based techniques.

MP5b-3 **4:20 PM**

L-infinity Regularized Models for Segmentation, Cartoon-Texture Decomposition, and Image Restoration

Hayden Schaeffer, Luminita Vese, University of California, Los Angeles

We propose a cartoon-texture separation model using the pre-dual to the space of Lipschitz functions. Specifically, we decompose an image into the sum of a cartoon part, of bounded variation, and a texture part in the pre-dual of the space of bounded functions whose gradients are also bounded. This decomposition is used to analyze the various features in the image, remove noise from cartoon images, and also to help better reconstruct the texture when degraded by (known and semi-blind) blur. The algorithm is tested on both synthetic and real images, with various implementations based on duality and on projections.

MP5b-4 **4:45 PM**

Implicit Gibbs Prior Models for Tomographic Reconstruction

Pengchong Jin, Eri Haneda, Charles Bouman, Purdue University

Recent research in image denoising indicates that dictionary based learning techniques can be used to substantially improve results as compared to classical MAP inverse methods. However, while these methods are uniquely suited to image denoising, they are awkward to be adapted to the classical Bayesian inverse framework that is so widely used in problems such as tomographic reconstruction. In this paper, we demonstrate how novel prior modeling methods based on implicit Gibbs distributions can be used in MAP tomographic reconstruction to substantially improve reconstructed image quality. The concept of the implicit Gibbs distribution is to model the image using the conditional distribution of each pixel given its neighbors. It is then possible to compute a local approximation of the true Gibbs distribution from the conditional probabilities. Since the conditional probabilities of the MRF can be learned from specific training data, it is possible to learn more precise and expressive models of images which capture unique characteristics. In practice, this results in spatially adaptive MRF models, but it also provides a framework that assures convergence. We present results comparing our new method with both state-of-the-art MRF prior models and kSVD dictionary based methods for tomographic reconstruction of images. The results indicate that both subjective and objective measures of image quality are improved using our proposed model.

Track G. Architecture and Implementation

Session: MPa6 – Computer Arithmetic

Chair: ***Michael Schulte,*** *AMD Research / University of Wisconsin*

MP6a-1 **1:30 PM**

Shared Implementation of Radix-10 and Radix-16 Square Root Algorithm with Limited Precision Primitives

Milos D. Ercegovac, University of California, Los Angeles; Robert McIlhenny, Californi State University Northridge

We present a shared implementation of radix-10 and radix-16 fixed-point digit-recurrence algorithm for square root operation using limited-precision multipliers, adders, and table-lookups. We discuss the proposed algorithm, its design, and its ASIC implementation using a standard cell library. We present the cost and delay characteristics for precisions of 7 (single-precision), 8, 14 (double-precision) decimal digits, and single and double precision for radix-16. The proposed scheme uses short (2-3 digit-wide) operators which leads to compact modules, reduced interconnections and has an advantage at the layout level as well as in power optimization.

MP6a-2 **1:55 PM**

Decimal On-line Multioperand Addition

Carlos Garcia-Vega, Sonia Gonzalez-Navarro, Julio Villalba, Emilio L. Zapata, University of Malaga

In this paper we present different architectures for decimal on-line addition. The operands are represented using RBCD and the multioperand trees are built using as a component the on-line decimal full adder (olDFA) which was previously defined. We present different pipelined trees where the higher the amount of pipeline stages, the lower the cycle time. In addition, we study different multioperand architectures where the olDFA component is internally pipelined (olDFAp). We show that when dealing with decimal on-line multioperand addition, it is more efficient to work with pipelined trees having as components olDFAp modules.

MP6a-3 **2:20 PM**

Variable-Accuracy Multiplication Using Approximate Binary Logarithms and Parallel Error Correction

Michael Sullivan, Earl Swartzlander, University of Texas at Austin

Binary logarithms can be used to perform computer multiplication through simple addition. Exact logarithmic (and anti-logarithmic) conversion is prohibitively expensive for use in general multipliers; however, inexpensive estimate conversions can be used to perform low-power approximate multiplication. Such approximate multipliers have been used in domain-specific applications, but remain inflexible and inappropriate for most applications. This study examines the overheads of approximate multiplication and proposes a flexible, parallel design that can dynamically tailor the accuracy of multiplication to meet user needs. Any level of accuracy is achievable with this design, at the cost of power. Accordingly, a user with domain-specific knowledge may save energy relative to traditional multipliers while preserving program functionality.

MP6a-4 **2:45 PM**

Experiments with Multiplier Reduction Trees

Neil Burgess, David Lutz, ARM

Finding the best topology for multiplier reduction trees optimised for timing and area was until recently thought to have been solved by Oklobdzija's "n-greedy" algorithm, which constructs trees from full adders (3:2 counters) only. Recently, however, Ienne has made an argument for building multiplier trees from large counter circuits (e.g. 10:4 counter). This paper reports on synthesis experiments for multiplier trees using these two techniques.

Track G. Architecture and Implementation

Session: MPb6 – Reconfigurable Architectures, Many-Core, Multi-Core, and SoC

Chair: ***Neil Burgess,*** *ARM*

MP6b-1 **3:30 PM**

FPGA-based Processor Solution for Front-End Image Detection Applications

Colm Kelly, Thales Air Defence Limited; Roger Woods, Queen's University Belfast

In the last decade, image acquisition and processing of video data has increased greatly the need for highly-sophisticated image analysis technology. Computing solutions in the form of DSP processors, graphical processing platforms and "domain specific" solutions exist, but their fixed architecture gives a poor performance return, particularly when compared to FPGAs. Results are presented for the development of a novel FPGA-based processor for image processing. The architecture has been developed in close synergy with the software representation and programming environment to realise a solution that can be programmed. We present a programmable architecture that can enable real-time data operation for image processing; by exploiting deep processing pipelines, we show that the cost and performance of these architectures is on a par with traditional dedicated circuit based solutions.

MP6b-2 **3:55 PM**

Is There a Smarter Way to Use 100 Billion Transistors?

Muhammad Usman Khan, Francis Li, Ying Tiong, Michael Liebelt, Brian Ng, Braden Phillips, University of Adelaide

Within the next decade it will be possible to build chip multiprocessors with thousands of cores. We can expect such devices to be exceptionally good at the kinds of problems massively parallel computers are already good at. That leaves a large class of interesting problems, especially some arising from artificial intelligence, for which multi-core processors are less well suited. Are there alternative architectures, scalable to 100 billion transistors and beyond, tolerant to device faults and process variations, and more appropriate for artificial intelligence problems than thousands of cores connected by a network on chip?

MP6b-3 **4:20 PM**

Performance and Power Optimizations for Accelerated Processing Units

Michael Schulte, AMD

Accelerated Processing Units (APUs) combine general-purpose processing cores, graphics processing vector engines, other computing engines, high-speed communication paths, and shared memory to provide excellent performance and power efficiency. The Heterogeneous System Architecture (HSA) is a framework that enables programmers to access these

heterogeneous computing resources in a consistent and efficient manner. This paper provides an overview of AMD APUs and HSA. It also presents dynamic techniques to optimize the performance and power efficiency of APUs based on application characteristics.

MP6b-4 **4:45 PM**

Reliable Low Power Distributed Arithmetic Filters via N-modular Redundancy

Muhammad S. Khairy, AmirHossein Gholamipour, Fadi J. Kurdahi, Ahmed M. Eltawil, University of California, Irvine

Due to supply voltage reduction and process variations effects, the error free margin for dynamic voltage scaling has been drastically reduced. Thus, supply-Voltage Over Scaling (VOS) has emerged as an efficient means to achieve ultra-low energy efficient systems, that tradeoff energy efficiency and reliability. Recently, N-Modular Redundancy (NRM) has been used as an effective fault-tolerant design method in which N copies of an unreliable block are employed and a voting strategy such as majority, median or mean is deployed to select an output. This paper presents a novel NMR voting algorithm based on the maximum a posteriori (MAP) and the statistics of output bit-failure rate. The design of Distributed Arithmetic (DA) filters is employed to demonstrate the effectiveness of the proposed technique and show the trade-offs between the robustness of the system and the power savings. Simulation results show significant enhancement in terms of output signal to noise (error) ratio and reliability as compared to other NMR fault tolerant techniques. A case study of a low-pass DA filter employed in a simple communication system shows that up to 12% power savings could be achieved when compared to the conventional NMR while satisfying the system bit-error performance.

Track F. Biomedical Signal and Image Processing

Session: MPa7 – Medical Image Analysis

Chair: ***Alejandro F. Frangi,*** *Alejandro F Frangi, University of Sheffield, Sheffield, UK; Universitat Pompeu Fabra, Barcelona, Spain*

MP7a-1 **1:30 PM**

4D Signal Processing for Spatio-Temporal Analysis of Longitudinal 3D Imagery

Guido Gerig, University of Utah

Medical imaging studies increasingly include longitudinal or serial imaging, where subjects are imaged multiple times over time intervals given by the expected temporal evolution of disease progress or effect of therapy. Clinical assessment routinely uses terms such as development, growth trajectory, aging, degeneration, disease progress, recovery or prediction, a terminology which inherently carries the aspect of dynamic processes. We are developing new image analysis and statistical methodologies for characterization and quantification of spatiotemporal change trajectories of anatomy and function. Many of the newly developed techniques include the concept of “regression”, but applied to complex, high-dimensional data such as images or image-derived shape data. This talk will discuss recent methodological developments with applications from clinical research projects.

MP7a-2 **1:55 PM**

Computational Diffusion MRI: On Some Recent Advances and Beyond

Rachid Deriche, INRIA Sophia Antipolis

Diffusion MRI (dMRI) is the unique Magnetic Resonance Imaging modality able to quantify in vivo and non invasively the average random thermal movement (diffusion) of water molecules in biological tissues such as brain white matter. Using the water diffusion as a probe, dMRI makes it possible to reconstruct white matter fiber pathways and segment major fiber bundles that reflect the structures in the brain which are not visible to other non-invasive imaging modalities. This modern imaging modality, of great interest to neuroscientists and clinicians, has opened a number of challenging problems. In this talk, the important problems of efficiently acquiring and processing complex dMRI data will be introduced and recently developed solutions and advances will be presented. Applications to computational brain imaging will also be presented and discussed with a particular emphasize on the importance of the Riemannian geometry in the estimation, regularization and segmentation of diffusion images as well as the tracking, the reconstruction and the clustering of the bundles of white matter fibers. High Angular Resolution Diffusion Imaging (HARDI) models will also be presented to go beyond the classical Diffusion Tensor Model, well known to be inadequate in crossing fiber regions. These new algorithms open the possibility of inferring and recovering a more detailed geometric description of the anatomical connectivity between brain areas. The presentation of some open problems currently being investigated by the dMRI community will conclude the talk.

MP7a-3 **2:20 PM**

Analytics for Time-Varying Catheterization Imaging Data: A Probabilistic Approach

Ioannis Kakadiaris, University of Houston

In this talk, I will present selected methods, challenges and opportunities from our research in developing innovative computational tools to mine quantitative parameters from time-varying imaging data. Intravascular ultrasound (IVUS) is a catheter-based medical imaging technique that produces cross-sectional images of blood vessels and is particularly useful for studying atherosclerosis. First, I will present a probabilistic approach for the identification of the luminal border in IVUS images. Specifically, we parameterize the lumen contour using Fourier series. This contour is deformed by minimizing a cost function that is formulated using a probabilistic approach in which the a priori term is obtained using probability estimates provided by a Support Vector Machine classifier and texture features. Our method is capable of segmenting IVUS images from different systems and transducer frequencies without the need of any parameter tuning, and it is robust with respect to changes of the visualization parameters in different sequences. Recently, our team has developed a unique IVUS acquisition protocol and novel signal/image analysis methods for the detection (for the first time in-vivo) of 'vasa vasorum' (VV). The VV are micro-vessels that are commonly present to feed the walls of larger vessels. Recent clinical evidence has uncovered their tendency to proliferate around areas of inflammation, including the inflammation associated with vulnerable plaques. The expected impact of our work stems from the fact that sudden heart attack remains the number one cause of death in the US, and unpredicted heart attacks account for the majority of the $280 billion burden of cardiovascular disease.

MP7a-4 **2:45 PM**

Estimating 3D Tongue Motion with MR Images

Fangxu Xing, Junghoon Lee, Johns Hopkins University; Emi Z. Murano, University of Maryland; Jonghye Woo, Johns Hopkins University; Maureen Stone, University of Maryland Dental School; Jerry Prince, Johns Hopkins University

It is challenging to measure the internal muscular motion and deformation of the tongue during natural tasks such as speech and swallowing. In this paper, algorithms for processing three-dimensional dynamic cine and tagged magnetic resonance image sequences of the tongue during speech are described. The result is a time-varying map of the tissue deformation and strain inside the tongue during short speech phrases. The harmonic phase algorithm was applied to compute the 2D movements of all pixels in 26 time-frames and three orthogonal image stacks. A geometric deformable model was used to segment the tongue volume, and an incompressible deformation estimation algorithm was used to interpolate a dense 3D motion field within the tongue at every time frame. A fixed point algorithm was used to invert displacement fields so that motion between specific points in multiple sequences can be analyzed. The method was evaluated on both normal subjects and those with prior glossectomy surgery permitting comparison of normal speech strategies with strategies that are used to obtain normal-sounding speech after surgery.

Track F. Biomedical Signal and Image Processing

Session: MPb7 – Biological Modeling and Signal Analysis

Chair: ***Scott T. Acton,*** *University of Virginia*

MP7b-1 **3:30 PM**

Cell Mechanics Analysis by Physically-Constrained Optical Flow

Jean-Christophe Olivo-Marin, Timothee Lecomte, Alexandre Dufour, Nancy Guillen, Roman Thibeaux, Institut Pasteur

Cell motility is a key factor for the pathogenicity of most parasites. We aim at combining imaging and the modeling of cell mechanics in order to improve the understanding of parasites' capacity to protrude pseudopods and generate whole-cell movement. We analyzed fluorescence microscopy sequences of moving amiba where the actin-rich cytoskeletal structures have been labeled. We studied these cells by modeling them as viscous fluids, so that their movement is characterized by flow-mechanics quantities, such as local displacements, internal forces and pressure. We used an image analysis method augmented by a flow mechanics model, namely the optical flow method constrained by the Stokes equations that define the dynamics of a fluid that is incompressible, homogeneous and viscous. The system can then be set as a variational constrained-minimization problem. By using techniques from optimal control theory, it is discretized with mixed finite elements and computational fluid dynamics techniques. The resulting linear system is solved to estimate dense maps of the physical quantities. We will present results of applying the method to real biological data of amoebas observed by fluorescence microscopy and discuss the mechanisms used by the amoeba during locomotion.

MP7b-2 **3:55 PM**

Exploitation of Radar Doppler Signatures for Gait Analysis

Jennifer Palmer, Kristin Bing, Amy Sharma, Georgia Tech Research Institute

Previous studies have demonstrated that measuring changes in gait could provide an easier method of diagnosing and monitoring concussions or mild traumatic brain injury. This research study aims to determine if differences can be identified in the human walking gait under multiple conditions by evaluating radar signal returns. The research team employed a 24GHz, continuous wave COTS radar, Pocket RadarTM, to collect data. Data collections were analyzed using information-theoretic (IT) techniques to compare information entropy levels in the radar spectrograms. These algorithms were chosen because of their potential to identify similarities and differences without requiring baseline data for a specific individual. Using statistical processing, initial results show that gait abnormalities could be quantitatively distinguished.

MP7b-3 **4:20 PM**

A Third-Order Approximate Solution of the EEG Forward Problem in Four-Shell Ellipsoidal Geometry

D. Gutiérrez, M. Alcocer-Sosa, Center of Research and Advanced Studies

We present a solution of the electroencephalographic (EEG) forward problem for the case when the head's geometry is modeled using a four-shell ellipsoidal geometry and the source is a current dipole. The EEG potentials generated by this forward model have been previously approximated with elliptic integrals and harmonics up to second-order. We evaluate the contribution of the third-order terms by comparing the EEG against those generated using the second-order approximation and a realistic model solved by the boundary element method (BEM). A comparison is also performed in terms of the bias in estimating the location of brain sources when using the second and third-order forward solutions.

MP7b-4 **4:45 PM**

Phase Congruency Singular Value Decomposition for Multi-Scale Neuron Enhancement

Emmanuel Denloye-Ito, Scott Acton, University of Virginia

In this paper, we present an algorithm for enhancing neuronal structure from 3D Confocal Microscopy Images. Our algorithm first computes a multi-scale phase congruency value at every pixel from a 3D image, which assigns values that indicate the presence of image features such as edges and lines. The phase congruency of a 3D image is calculated by carefully combining the convolutions of the image with a quadrature wavelet filter bank, so we leverage this information to supplement phase features. We achieve this by calculating the products of inertia of phase congruency with respect to each of the orientations of the wavelet filter bank and then compose a phase congruency covariance matrix based on these products. We claim that the singular values of this matrix can be combined to enhance tubular structure in the image that indicate neuronal structure while filtering other structure. We compare our method to Hessian based enhancement of tubular structure to demonstrate the advantages/efficacy of our algorithm.

Track B. MIMO Communications and Signal Processing

Session: MPa8 – MIMO Communications and Signal Processing I 1:30 PM – 3:10 PM

Chair: ***Andreas Burg,*** *Ecole Polytechnique Federale de Lausanne (EPFL)*

MP8a1-1

Low-Complexity Vector Precoding for Multi-user Systems

Maitane Barrenechea, University of Mondragon; Andreas Burg, École Polytechnique Fédérale de Lausanne; Mikel Mendicute, University of Mondragon

Vector precoding enables the non-cooperative signal acquisition in the multi-user broadcast channel. The performance advantage with respect to the more straightforward linear precoding algorithms comes as a consequence of an added perturbation vector, which enhances the properties of the precoded signal. Nevertheless, the computation of the perturbation signal entails a search for the closest point in an infinite lattice, which is known to belong in the class of non-deterministic polynomial-time hard (NP-hard) problems. This contribution presents a novel tree search scheme that achieves an error-rate performance that is close to the optimum given by the sphere encoder, but with a significantly simpler tree-search structure that only considers the most promising nodes for expansion.

MP8a1-2
Non-Binary Coded Modulation and Iterative Detection for High Spectral Efficiency in MIMO

Nicholas Chang, David Romero, MIT Lincoln Laboratory

Non-binary low density parity check codes (LDPC) have been shown to outperform their binary counterparts and attain the best-known performance among error-correction codes. At the same time, it has also been established that wireless communication using multiple-input multiple-output (MIMO) schemes dramatically increases system capacity and reliability when information symbols are appropriately coded and modulated across transmit antennas. Recent works have studied techniques for applying non-binary LDPC codes to MIMO systems and demonstrated near-capacity performance. However, the constellation sizes in the proposed approaches are limited by the Galois field (GF) size of the non-binary LDPC code, thus limiting the maximum spectral efficiency of the proposed joint modulation-coding approaches. In practice, the GF size may be limited by computational complexity reasons but high spectral efficiencies are desired. Thus, we study techniques for applying non-binary LDPC codes to higher order modulations, based upon the iterative coded modulation approaches. These methods have been well-studied for binary codes but not for non-binary codes. Performance of the technique is dependent on the mapping of GF symbols to constellations, but the appropriate mapping is demonstrated to attain near-capacity performance for a rate adaptive system despite using GF sizes which are smaller than the constellation sizes. The final version will contain general results on the space-time mapping and examine low complexity options.

MP8a1-3
Low-Complexity Lattice Reduction-Aided Channel Inversion Methods for Large Multi-User MIMO Systems

Keke Zu, Rodrigo C. de Lamare, University of York; Martin Haardt, Ilmenau University of Technology

In this work, a low-complexity precoding algorithm is proposed to reduce the computational complexity and improve the performance of block diagonalization (BD)-type algorithms for large multi-user multi-input multi-output (MU-MIMO) systems. The first precoder is obtained by a channel inversion method to approximately decouple the MU-MIMO channel into equivalent single-user multi-input multi-output (SU-MIMO) channels. Then, a lattice reduction-aided linear precoder is applied to parallelize each user's streams. Simulation results show that the proposed algorithm can achieve almost the same sum-rate as RBD, substantial bit error rate (BER) performance gains and a simplified receiver structure, while requiring a lower complexity.

MP8a1-4
Multiuser Detection Performance in Multibeam Satellite Links under Imperfect CSI

Jesús Arnau, Carlos Mosquera, University of Vigo

In multibeam satellite systems, there is a growing need for signal processing techniques able to mitigate the nterference among beams, since they could enable a much more aggressive spectrum reuse. In this paper, we investigate the effect of the absence of perfect Channel State Information (CSI) at the receiver end of the multibeam satellite return link. Under the assumption of a large number of beams, random matrix theory tools are used to obtain closed-form expressions of the performance for a given channel matrix and a wide range of channel estimation techniques.

MP8a1-5
On Convergence Constraint Precoder Design for Iterative Frequency Domain Multiuser SISO Detector

Valtteri Tervo, Antti Tölli, University of Oulu; Juha Karjalainen, Renesas Mobile Europe Oy; Tad Matsumoto, Japan Advanced Institute of Science and Technology

Convergence constraint power allocation (CCPA) in single carrier multiuser (MU) single-input single-output (SISO) systems with iterative frequency-domain (FD) soft cancelation (SC) minimum mean-squared error (MMSE) equalization is considered. In order to have full benefit of iterative receiver, convergence properties need to be considered. This is motivated by the area property, which states that the area of the tunnel between the extrinsic information transfer (EXIT) curves of the soft in / soft out blocks of a concatenated system is proportional to the gap between the bit rate achieved by the system and the capacity of the channel. CCPA always guarantees the desired mutual information (MI) after the detection. In this paper, several algorithms are proposed for non-convex power minimization problem. Furthermore, EXIT analysis is performed and it is shown that the CCPA design can be done for the system considered in this paper. In the final paper, we will present a performance comparison of the proposed algorithms. We will see what is the average power consumption for each algorithm. Moreover, bit error rate (BER) performance will be presented.

MP8a1-6
Grassmannian Packings from Orbits of Projective Group Representations
Renaud-Alexandre Pitaval, Olav Tirkkonen, Aalto University

We discuss group orbits to construct codes in the complex Grassmann manifold. Finite subgroups of the unitary group act naturally on the Grassmann manifold. Given an irreducible representation of the group of the appropriate degree, its center has no effect in orbit construction. Thus, to generate Grassmann orbit codes, finite groups having a representation in the projective unitary group are of specific interest. Following this principle, we derive basic properties and describe explicit constructions of group orbits leading to some optimum packings in 2 and 4 dimensions.

MP8a1-7
Volume of Ball and Hamming-type Bounds for Stiefel Manifold with Euclidean Distance
Renaud-Alexandre Pitaval, Olav Tirkkonen, Aalto University

A commonly used distance on the the Stiefel manifold arises by treating the manifold as a surface embedded in a Euclidean hypersphere and taking the corresponding Euclidean/chordal distance. In this paper, the volume of the Stiefel manifold induced by this embedding is computed. Exploiting a power series expansion of the volume element, the volume of a small metric ball under the chordal distance is evaluated. Evaluating the volume of a metric ball is critical to derive Hamming-type bounds. Using a spherical embedding argument, we provide results generalizing previously known bounds on codes in the Grassmann manifold and the unitary group.

MP8a1-8
Distributed Resource Allocation for MISO Downlink Systems via the Alternating Direction Method of Multipliers
Satya Joshi, Marian Codreanu, Matti Latva-aho, Centre for Wireless Communications

We provide a distributed algorithm for the radio resource allocation problem in multicell downlink multi-input single-output systems, subject to satisfying quality of service requirements of each user. Specifically, the problem of minimizing total transmit power subject to signal-to-interference-plus-noise ratio constraints of each user is considered.We propose a method, based on alternating direction method of multipliers. Numerical results show that the proposed distributed algorithm has superior convergence compared with the distributed method based on dual decomposition.

MP8a1-9
Max-Rate MIMO Broadcast DFE Transceiver Design under Power and SER Constraints
Chih-Hao Liu, P. P. Vaidyanathan, California Institute of Technology

This paper studies the joint design problem of a decision feedback equalizer (DFE) transceiver and bit allocation for multi-input multi-output (MIMO) broadcast channels. The design problem is formulated as a transmission rate maximization problem for given power and symbol error rate (SER) specifications. The optimal bit allocation is derived. Under some conditions, to be described later, there exists a particular class of joint triangularization (JT) which can be applied to obtain the optimal broadcast DFE transceiver for the max-rate problem with quality of service (QoS) constraints. The optimal joint design is called the maximum rate JT broadcast DFE transceiver (MRJT). A suboptimal design, the rate maximized QR broadcast DFE transceiver (RMQR), which is always possible, is also proposed. In the simulations, several numerical results are given to demonstrate the bit rate performance of the proposed MRJT and RMQR broadcast DFE transceivers under different QoS specifications.

MP8a1-10
Performance of Asymmetric Antenna Configurations in Polarized Channels
Robert Severinghaus, Murali Tummala, John McEachen, Naval Postgraduate School

Small receivers can use dual polarization antennas to maximize received energy from single polarization transmitters. This paper analyzes the performance of these asymmetric MIMO antenna configurations in polarized, Rayleigh fading channels. Because the receiver can have knowledge of the channel's cross polar ratio, a polarization reciprocity scheme is developed. This is shown to maximize signal energy at the uplink receiver for all polarized channels. Simulations then show the symbol error probability and relationships to the channel cross-polar ratio and the number of transmitting antennas. Also, the use of Alamouti coding in a dual polarization uplink and in combination with the polarization reciprocity scheme is analyzed.

MP8a1-11
On Robust Training Sequence Design for Correlated MIMO Channel Estimation
Nafiseh Shariati, KTH Royal Institute of Technology; Jiaheng Wang, Southeast University; Mats Bengtsson, KTH Royal Institute of Technology

The problem of robust training sequence design for the purpose of multiple-input multiple-output (MIMO) channel estimation is considered. In particular, we aim to minimize the worst-case mean squared error of channel estimates which is formulated as a minimax optimization problem. Such problem is addressed efficiently using extended barrier method under a general assumption of any compact convex uncertainty set. Moreover, assuming a Kronecker MIMO channel and a unitarily invariant uncertainty set, the robust design problem is diagonalized which significantly lowers the dimensionality of the optimization problem.

MP8a1-12
The Proportional Fair Sharing Algorithm under i.i.d. Models
Matthew Pugh, University of California, San Diego

The proportional fair sharing (PFS) algorithm has been used in multi-user systems as an attempt to balance fairness and performance of the system throughput. Motivated by the cellular downlink scheduling problem, it is shown that when the rates of each user are i.i.d., the performance of the PFS scheduling algorithms is asymptotically equivalent to a purely greedy scheduling algorithm. The mean asymptotic throughput of the PFS algorithm is characterized and the rate of convergence to this limit is derived under i.i.d. models. Additionally the asymptotic covariance matrix about the convergence point is stated.

Track D. Signal Processing and Adaptive Systems
Session: MPa8 – Signal Processing and Adaptive Systems I 1:30 PM – 3:10 PM
Chair: ***Lu Chun-Shien,*** *Institute of Information Science, Academia Sinica*

MP8a2-1
Fast Compressed Image Sensing Based on Sampling Matrix Design
Chun-Shien Lu, Hung-Wei Chen, Sung-Hsien Hsieh, Academia Sinica

We study a new image sensing paradigm, called turbo fast compression image sensing, with computational complexity O(m^2), where m denotes the length of a measurement vector y=\phi x that is sampled from the signal x of length n via the sampling matrix \phi with dimensionality m\times n. In order to balance between reconstruction quality and speed, a new sampling matrix \phi is designed. The characteristics of our method are: (i) recovery speed is extremely fast due to a closed-form solution being derived; (ii) certain reconstruction accuracy is preserved because significant components of x can be reconstructed with higher priority via an elaborately designed \phi. Comparisons with state-of-the-art compressive sensing methodologies are provided to demonstrate the feasibility of our method in terms of reconstruction quality and computational complexity.

MP8a2-2
Particle Filtering for Multivariate State-Space Models
Petar M Djuric, Monica F. Bugallo, Stony Brook University

We propose and investigate a particle filtering method for multivariate state-space models. In the literature, the most studied state-space model is the linear model, which includes known matrices and known noise covariance matrices. In our work, we drop the assumption of knowing these matrices, and that converts the model to a nonlinear one. In tracking the dynamic states, we propose to integrate out all the static unknowns and therefore, we sample particles only from the space of the dynamic states. The required prior distributions for sampling are, in general, matrix-variate t distributions. The weights are obtained from computing matrix-variate t distributions too. The performance of the proposed method is examined by computer simulations.

MP8a2-3
Extracting Atmospheric Profiles from Hyperspectral Data with Particle Filters
Dustin Rawlings, Jacob Gunther, Todd Moon, Utah State University

Removing the effects of the atmosphere from remote sensing data requires accurate knowledge of the physical properties of the atmosphere during the time of measurement. There is a nonlinear relationship which maps atmospheric composition to emitted spectra, but it cannot be easily inverted. The time evolution of atmospheric composition is approximately Markovian, and can be estimated using hyperspectral measurements of the atmosphere with particle filters. The difficulties associated with particle filtering high-dimension data can be mitigated by incorporating future measurement data with the proposal density.

MP8a2-4
Using Dictionary Learning for Improving Hyperspectral Pixel Classification
Andrew Pound, Jacob Gunther, Todd K. Moon, Utah State University; Gustavious P. Williams, Brigham Young University

This paper explores the utility of using dictionary learning in conjunction with classification. This has been touched on by Charles et al, but questions arise as to the best way to perform the dictionary learning. This paper reports on experiments testing the classification capabilities of dictionaries of different sizes and explores optimal sparsity constraints. In addition to exploring the efficacy of using dictionary learning with classification, we will show results on experiments investigating the application to these methods to a time-series hyperspectral dataset, specifically focusing on the capabilities of these techniques to identify temporal features.

MP8a2-5
Fault Localization in Smart Grid Using Wavelet Analysis and Unsupervised Learning
Huaiguang Jiang, Jun Zhang, Wenzhong Gao, University of Denver

We investigate a fault localization method based on wavelet analysis and unsupervised clustering of time-frequency voltage variation features in Smart Grid (SG) systems. Specifically, the feature wavelet transform coefficients (WTCs) are computed and extracted from the voltage variation signals when power system faults take place. The feature WTCs are then processed by a hybrid unsupervised clustering algorithm to generate a fault contour map for locating the faults in the SG system. The numerical results demonstrate the feasibility, effectiveness and accuracy of our proposed method for the localization of various types of faults in SG systems.

MP8a2-6
Sensitivity of Polynomial Composition and Decomposition for Signal Processing Applications
Sefa Demirtas, Guolong Su, Alan V. Oppenheim, Massachusetts Institute of Technology

Polynomial composition is well studied in mathematics but has only been exploited indirectly and informally in signal processing. Potential future application of polynomial composition for filter implementation and data representation is dependent on its robustness both in forming higher degree polynomials from ones of lower degree and in exactly or approximately decomposing a polynomial into a composed form. This paper addresses robustness in this context, developing sensitivity bounds for both polynomial composition and decomposition and illustrates the sensitivity through simulations. It also demonstrates that sensitivity can be reduced by exploiting composition with first order polynomials and commutative polynomials.

MP8a2-7
A Variable Regularization Control Method for NLMS Algorithm
Junghsi Lee, Hsu-Chang Huang, Yuan-Ze University

Several time-varying regularized normalized least mean square (NLMS) algorithms have been derived to solve the dilemma of fast convergence rate or low excess mean-square error in the past decade. This paper proposes a variable regularization control method for the NLMS algorithm that employs the input signal power, the mean squared error and the estimated system noise power to control the variable regularization parameter. Simulation experiments show that the proposed algorithm performs very well. Furthermore, the theoretical steady-state behavior is in very good agreement with the experimental results.

MP8a2-8
Electromagnetic Field Recognition for Proactive Robot Communication Connectivity Maintenance
Mustafa Ayad, Jun Jason Zhang, Richard Voyles, Mohammad Mahoor, University of Denver

This paper presents a method for proactive robot communication connectivity maintenance based on electromagnetic field (EMF) recognition. The proposed EMF recognition method utilizes hidden Markov model (HMM) for learning EMF environments based on radio frequency (RF) signal strength measurements. A proactive motion control algorithm then uses the EMF recognition results to drive the robots towards favorable positions. The numerical simulation demonstrates promising EMF recognition results and their ability in proactive robot motion control for connectivity maintenance.

MP8a2-9
A Data Reusage Algorithm Based on Incremental Combination of LMS Filters
Luiz Chamon, Humberto Ferro, Cássio Lopes, University of São Paulo

This work proposes to use a combination of LMS filters to outperform the Affine Projection Algorithm (APA), a well-known data reusage adaptive filter. In order to do so, the data reusage LMS (DR-LMS) is shown to be an over regularized APA and an incremental counterpart of its recursion is motivated by adaptive networks. Simulations show that this combination of AFs is able to either match or outperform the APA in the mean-square sense with lower computational complexity.

MP8a2-10
Superresolution by Compressive Sensing Algorithms
Albert Fannjiang, Wenjing Liao, University of California, Davis

In this work, superresolution by 4 compressive sensing methods (OMP, BPDN, BLOOMP, BPDN-BLOT) with highly coherent Fourier measurements is comparatively studied. For closely spaced spikes up to the Rayleigh index 3, only BPDN-BLOT can localize stably the spikes below the Rayleigh length with a huge superresolution factor. For widely separated spikes, only BLOOMP and BPDN-BLOT can localize the spikes within the accuracy of one Rayleigh length, independent of the superresolution factor. In terms of the filtered L^1-error metric, BLOOMP and BPDN-BLOT outperform OMP and BPDN across various levels of noise and filtering with a much higher superresolution factor.

MP8a2-11
Compressive Ladar Detector Noise Performance
Darryl Sale, Christopher J. Rozell, Justin Romberg, Aaron D. Lanterman, Georgia Institute of Technology

In linear-mode scanning LADAR systems, a laser illuminates a small region in the scene and the field of view for the optical receiver is nearly the same size. As presented in earlier work, a Compressive LADAR (CL) system illuminates a much larger region of interest, all of which is also contained in the field of view of the receiver. If the CL is operated during daylight, this wider field of view can admit substantial background radiation, which degrades SNR. Due to the resulting increase in interference energy and noise levels, several CL operational parameters must be concurrently evaluated to yield a feasible system. In this paper, we introduce several noise sources into a CL and establish practical performance bounds.

MP8a2-12
Rank Property of the MIMO Gaussian Wiretap Channel with an Average Power Constraint
Ali Fakoorian, A. Lee Swindlehurst, University of California, Irvine

This paper considers a multiple-input multiple-output (MIMO) Gaussian wiretap channel model, where there exists a transmitter, a legitimate receiver and an eavesdropper, each equipped with multiple antennas. Perfect secrecy is achieved when the transmitter and the legitimate receiver can communicate at some positive rate, while ensuring that the eavesdropper gets zero bits of information. In this paper, we revisit the rank property of the optimal input covariance matrix that achieves the secrecy capacity of the multiple antenna MIMO Gaussian wiretap channel under an average power constraint. More precisely, we characterize the conditions under which a solution with a low-rank covariance exists by obtaining an upper bound for the rank of the optimal input covariance matrix.

MP8a2-13
Nonlinear System Identification Using Compressed Sensing
Manjish Naik, Douglas Cochran, Arizona State University

This paper describes an approach to system identification based on compressive sensing and demonstrates its efficacy on a challenging classical benchmark single-input, multiple output (SIMO) mechanical system consisting of an inverted pendulum on a cart. The differential equations describing the system dynamics are to be determined from measurements of the system's input-output behavior. These equations are assumed to consist of the superposition, with unknown weights, of a small number of terms drawn from a large library of nonlinear terms. Under this assumption, compressed sensing allows the constituent library elements and their corresponding weights to be identified by decomposing a time-series signal of the system's outputs into a sparse superposition of corresponding time-series signals produced by the library components.

MP8a2-14
The Resolution of Derived Secondary Information from Filter Banks May Not Follow Directly from the Signal Models

Victor DeBrunner, Guifeng Liu, Florida State University

Abstract--- The traditional Heisenberg-Weyl measure quantifies the joint localization, uncertainty, or concentration of a signal in the phase plane based on a product of energies expressed as signal variances in time and in frequency. Unlike the Heisenberg-Weyl measure, the Hirschman notion of joint uncertainty is based on the entropy rather than the energy. Furthermore, its definition extends naturally from the case of infinitely supported continuous-time signals to the cases of both finitely and infinitely supported discrete-time signals, the Hirschman optimal transform (HOT) is superior to the discrete Fourier transform (DFT) and discrete cosine transform (DCT) in terms of its ability to separate or resolve two limiting cases of localization in frequency, viz pure tones and additive white noise. In this paper, we implement a stationary line spectral estimation method using filter banks, which are constructed using the HOT and the DFT. We combine these filter banks with the classic interpolating procedure developed by Barry Quinn to develop our line estimation algorithm. We call the resulting algorithm the smoothed HOT-DFT line periodogram. We compare its performance (in terms of frequency resolution) to Quinn's smoothed periodogram. In particular, we compare the performance of the HOT-DFT with that of the DFT in resolving two close frequency components in additive white Gaussian noise (AWGN). We find the HOT-DFT to be superior to the DFT in frequency estimation, and ascribe the difference to the HOT's relationship to entropy. It is not well-known that the frequency estimation (i.e. the secondary inference that is desired from the signal model) is not highly connected to the modeling performance. In fact, we will show that while the energy in the residual is lower for the DFT filter bank, the frequency estimation error is lower for the spectral estimated derived using HOT-DFT filter bank.

MP8a2-15
MIMO Radar Spatial Compressive Sensing with Unknown Parameters

Marco Rossi, Alexander M. Haimovich, New Jersey Institute of Technology; Yonina C. Eldar, Technion, Israel Institute of Technology

Spatial compressive sensing advances the notion of high performance localization with undersampled arrays. In this work, we address the direction-of-arrival problem of an unknown number of targets in multiple-input multiple-output (MIMO) radar. The unknown number of targets implies a combined detection-estimation problem. Our previously proposed tree-based Multi-Branch Matching Pursuit (MBMP) algorithm is modified to handle an unknown number of targets. In the full paper, the probabilities of detection and false alarm are elucidated in terms of signal-to-noise ratio, and other system and algorithm parameters. Analysis and numerical result demonstrate that spatial compressive sensing and MIMO radar may support high performance localization at considerable hardware savings.

MP8a2-16
Classification of Multivariate Data Using Dirichlet Process Mixture Models

Petar M Djuric, Stony Brook University; Andre Ferrari, Universite de Nice-Sophia Antipolis

We address the problem of multivariate data classification by the nonparametric Bayesian methodology, where the priors are modeled as Dirichlet processes. Sets of series of data vectors are observed, where each vector in the series is modeled by a Gaussian linear regression. The classes are defined by the unknown matrices of linear coefficients of the model and the covariance matrices of the errors of the model. The number of different classes is unknown. For the unknown coefficients and covariance matrices we adopt a Dirichlet process prior with a conjugate base distribution, the matrix-normal -- inverse Wishart distribution. We implement the classification by Markov chain Monte Carlo sampling. The proposed approach is demonstrated by extensive computer simulations.

MP8a2-17
Compressed Sensing Radar Amid Noise and Clutter

Peter Tuuk, S. Lawrence Marple, Georgia Tech Research Institute

Adaptive radar processing has been wildly successful in downward looking radars that must detect moving targets in the midst of strong clutter returns. The performance of compressed sensing techniques in the presence of clutter is explored herein and compared to existing adaptive radar processing methods, including Space-Time Adaptive Processing (STAP), via Monte Carlo exploration of detection performance. Finally, we propose extensions to standard ℓ_1 optimization techniques to account for known interference covariance matrix statistics.

Session: TAa1 – MIMO in Optical Communications

Chair: ***Peter Winzer,*** *Alcatel-Lucent*

TA1a-1 8:15 AM

Experimental Characterization of the Fiber-Optic MIMO Channel

Sebastian Randel, Roland Ryf, Peter Winzer, Bell Laboratories, Alcatel-Lucent

Space-division multiplexing (SDM) is considered as a path to overcome the imminent "capacity crunch" in long-haul fiber-optic transmission systems. Recently, we applied MIMO processing to enable SDM over the coupled modes of an up to 4,200-km long transmission link. In this work, we review the characteristics of the fiber-optic MIMO channel based on laboratory measurements. We show that low outage probabilities can be obtained if all propagation modes are selectively addressed and coherently received and that the channel matrix is unitary to a large extend. We further distinguish the weakly-coupled and the strongly-coupled propagation regime and discuss strategies to minimize the channel memory by a proper optical link design.

TA1a-2 8:40 AM

Modeling of Linear and Nonlinear Coupling in Multiple-Mode Fiber Optic Transmission with MIMO Signal Processing

Cristian Antonelli, Antonio Mecozzi, University of L'Aquila; Mark Shtaif, Tel Aviv University

We discuss the modeling of linear and nonlinear signal propagation in the multi-mode fiber channel, including aspects of the fiber-optic channel's information capacity and the existence of a power optimum. Specifically, we introduce a generalized Stokes-space representation to describe signal evolution in such fibers and discuss the effect of modal dispersion representing the delay spread. We show that this phenomenon is described by a single real-valued vector whose modulus is Nakagami distributed. Furthermore, we describe nonlinear propagation in multi-mode fibers, and show that in realistic scenarios it can be modeled by means of coupled generalized Manakov equations.

TA1a-3 9:05 AM

Mode Coupling in Coherent Mode-Division-Multiplexed Systems: Impact on Capacity and Signal Processing Complexity

Joseph Kahn, Stanford University; Keang-Po Ho, Silicon Image

Mode coupling is a key to overcoming major challenges in coherent mode-division-multiplexed systems. Strong mode coupling reduces the modal group delay spread, minimizing the complexity of multi-input multi-output signal processing. Likewise, strong mode coupling mitigates the mode-dependent gain of optical amplifiers, maximizing average channel capacity. When combined with modal dispersion, strong mode coupling creates frequency diversity, dramatically reducing outage probability. Remarkably, the statistical distributions of strongly coupled modal group delays or gains depend only on the number of modes and the variances of accumulated delay or gain, and can be derived from the eigenvalue distributions of certain random matrices.

TA1a-4 9:30 AM

Physical Layer Security in Space-Division Multiplexed Fiber Optic Communications

Kyle Guan, Eva (Chen) Song, Emina Soljanin, Peter Winzer, Bell Laboratories, Alcatel-Lucent

Today's fiber-optic networks are inherently vulnerable to various types of physical-layer attacks, especially to fiber tapping. Quantum key distribution (QKD), though providing both secure key exchanges and intrusion detection, has stringent limitations on data rate and transmission reach. In this paper, we propose a new concept of secure physical-layer transmission using space-division multiplexing (SDM). We formulate and analyze the corresponding fiber tapping problem and show that SDM can provide an information-theoretically provably secure medium of transmission with the potential of supporting orders of magnitude higher information rates than what can be achieved through QKD.

Session: TAb1 – Wireless Video Transmission Systems

Chair: ***Andreas Molish,*** *University of Southern California*

TA1b-1 10:15 AM

Enhanced Adaptive Streaming over LTE-Advanced Wireless Networks

Jeff Foerster, Intel

Video content is quickly dominating the traffic over wireless networks and is creating significant challenges for managing this traffic efficiently while still delivering an acceptable quality of experience to the end user. HTTP-based adaptive streaming techniques are growing in popularity to deliver video content from over-the-top providers to mobile devices, but have not yet been specifically optimized for wireless networks. This paper will present the latest activities on optimizing adaptive streaming protocols for LTE-Advanced wireless networks, including new Quality-of-Experience feedback mechanisms, multi-user scheduling optimizations, and content-aware adaptation techniques to help minimize the transmitted bits over-the-air for a fixed user quality.

TA1b-2 10:40 AM

Subcarrier Mapping Based on Slice Visibility for Video Transmission over OFDM Channels

Laura Toni, Pamela C. Cosman, Laurence B. Milstein, University of California, San Diego

For transmission of video sequences over orthogonal frequency division multiplexing systems in slowly varying Rayleigh faded environments, we develop a cross-layer technique, based on a slice loss visibility (SLV) model used to evaluate the visual importance of each slice. Taking into account the visibility scores available from the bitstream and the instantaneous channel state information (CSI), we optimize the mapping of video slices within a 2-D time-frequency resource block, offering better protection to more visually important slices. Results demonstrate that the proposed algorithm outperforms baseline ones which do not take into account either the SLV or the CSI in the optimization.

TA1b-3 11:05 AM

Prioritized Multimode Precoding for Joint Minimization of Source-Channel Video Distortions

Amin Abdel Khalek, University of Texas at Austin; Constantine Caramanis, Robert W. Heath, Jr., The University of Texas at Austin

This paper proposes a cross-layer design that provides packet prioritization at the physical layer combined with source and link rate adaptation to jointly minimize the distortions caused by lossy compression as well as the wireless channel. With a MIMO PHY layer, packet prioritization is achieved by mapping video packets to ordered spatial streams to maximize the throughput weighted by the per-packet loss visibility. The MIMO mode controls the number of priority levels and is dynamically optimized to provide the best tradeoff between high source rate and low channel distortion. Jointly, source rate adaptation is driven by the client by estimating the end-to-end throughput based on the transmission rate.

TA1b-4 11:30 AM

Device-to-Device Communications for Wireless Video Delivery

Negin Golrezaei, Alexandros Dimakis, Andreas F. Molisch, University of Southern California

We present a novel device to device (D2D) collaboration architecture to handle the ongoing explosive increase in the demand for video content in wireless mobile devices. We show device-to-device (D2D) communications can greatly improve throughput without needing any expensive infrastructures. Users cache popular video files and - after receiving requests from other users - serve these requests via device-to-device localized transmissions. The short range of the D2D transmission enables frequency reuse within the cell. We identify a fundamental conflict between collaboration distance and interference and show how to optimize the transmission power to maximize throughput. Our main result is a closed form expression of the optimal collaboration distance as a function of the content reuse request statistics that we model by a Zipf distribution. We further present the optimal “centralized” caching policy. We show that under some conditions and by applying our proposed centralized caching policy, it is possible to have a number of D2D interference-free collaboration pairs that scales linearly in the number of nodes.

Session: TAa2 – Game Theory in Communications

Co-Chairs: ***Marco Luise,*** *University of Pisa* ***and Giacomo Bacci,*** *University of Pisa*

TA2a-1 8:15 AM

Distributed Spectrum Sharing Policies for Selfish Users with Imperfect Monitoring Ability

Yuanzhang Xiao, Mihaela van der Schaar, University of California, Los Angeles

We develop a novel design framework for dynamic spectrum sharing among secondary users (SU) who adjust their power levels under interference temperature (IT) constraints imposed by primary users. Since SUs are selfish and interacting with each other repeatedly, and can only observe whether IT constraints are violated imperfectly, we model their interaction as a repeated game with imperfect monitoring. We characterize the set of Pareto optimal operating points achievable by deviation-proof spectrum sharing policies, which are policies that selfish users find it in their interest to comply with. For any operating point in this set, we show how to construct a deviation-proof policy to achieve it. The constructed policy is amenable to distributed implementation, and outperforms existing policies that dictate users to transmit at constant power levels when multi-user interference is strong.

TA2a-2 8:40 AM

Energy Efficiency Games for Backhaul Traffic in Wireless Networks

Tao Lin, Tansu Alpcan, Kerry Hinton, University of Melbourne

Next-generation wireless networks will be more dynamic and heterogeneous as indicated by developments of small cell networks, cognitive radio, and lightRadio. The increasing demand for data traffic necessitates improved efficiency in wireless networks both in terms of spectrum usage and the management of mobile traffic. Cloud computing methods have been proposed to achieve these goals while reducing deployment and operational costs. Specifically, energy consumption is becoming an important bottleneck in wireless network infrastructure. This paper presents a game-theoretic framework for improving energy efficiency of wireless networks by focusing on energy-aware resource allocation in backhaul cloud computing. The problem is formulated as a multi-objective optimisation with two confliction sub-objectives: system power consumption and load balance. Then a noncooperative game is defined and proved as a potential game. Performance results for the proposed algorithm are demonstrated with numerical simulations.

TA2a-3 9:05 AM

Mean Field Energy Games in Wireless Networks

François Mériaux, Laboratoire des Signaux et Systèmes (L2S); Vineeth S. Varma, Orange Labs; Samson Lasaulce, Laboratoire des Signaux et Systèmes (L2S)

This work tackles the problem of energy-efficient distributed power control in wireless networks with a large number of transmitters. The problem is modeled by a dynamic game. Each transmitter-receiver communication is characterized by a state given by the available energy and/or the individual channel state and whose evolution is governed by a certain dynamics. As equilibrium analysis in such a (stochastic) game is generally difficult and even impossible, the problem is approximated by exploiting the large system assumption. Under an appropriate exchangeability assumption, the corresponding mean field game is well defined and studied in detail for special cases. The main contribution of this work is to show how mean field games can be applied to the problem under investigation and provide illustrative numerical results.

TA2a-4 9:30 AM

Learning Efficient Satisfaction Equilibrium via Trial and Error in Decentralized Wireless Networks

Samir Perlaza, Princeton University; Zhu Han, University of Houston; H. Vincent Poor, Princeton University

In this paper, learning dynamics to achieve efficient satisfaction equilibria (ESE) based on the paradigm of trial and error are presented. In particular, these learning dynamics are adapted to the context of decentralized self-configuring networks. The underlying assumption of this work is that radio devices are completely unaware about the global configuration of the network. The only information gathered by each radio device is the knowledge of whether it is satisfying or not its own individual performance requirements. The main result presented in this paper is a behavioral rule that achieves an epsilon ESE under the condition that every radio device interacts trough mutual interference with all the other devices. In game theoretical terms, this condition requires the game to be inter-dependent. This condition is typically met in dense adhoc networks. Aside from the formal proof of convergence to epsilon ESE, simulations results in typical scenarios of channel selection and power control are presented to verify our theoretical results.

Session: TAb2 – Coding Theory for the Next-Generation Storage Systems

Chair: ***Lara Dolecek,*** *University of California, Los Angeles*

TA2b-1 10:15 AM

Content-assisted File Decoding for Nonvolatile Memories

Anxiao Jiang, Yue Li, Yue Wang, Texas A&M University; Jehoshua Bruck, California Institute of Technology

With the explosive growth of data storage, it is increasingly critical to decode files with an extremely small failure probability. Traditionally, error-correcting codes have been a powerful approach for protecting data. To further reduce decoding failures, we explore an additional tool that uses a data-pattern store to help decode files. The store records categorized data patterns, such as words, phrases, etc., in existing files. Compared to existing source coding techniques, it can capture the sparsity of valid data patterns with lower complexity. As an efficient implementation, -- especially motivated by the increasingly popular non-volatile memories (e.g., flash memories), which provide high-speed random access and large capacity at low cost, -- the store can be stored in a large memory when files are decoded, and the validity of data patterns can be verified using the store very efficiently in a content-addressable fashion, fully utilizing the random access capability of the memory. We study the content-assisted file decoding scheme, and analyze its performance.

TA2b-2 10:40 AM

LDPC Codes on Euclidean Geometries: Trapping Set Structure

Qiuju Diao, Ying Tai, Shu Lin, Khaled Abdel-Ghaffar, University of California, Davis

This paper analyzes the trapping structure of Euclidean Geometry (EG) LDPC codes. A trapping set is modeled as a sub-geometry of the geometry based on which an EG-LDPC code is constructed. Using this geometrical model, the configuration of a trapping set of a given size can be determined. It is shown that an EG-LCPC code does not have harmful trapping sets with sizes smaller than its minimum distance. Consequently, the error-floor of an EG-LDPC is dominated by its minimum distance. Since EG-LDPC codes have large minimum distances, it is expected that they have very low error-floor.

TA2b-3 11:05 AM

Covering Codes for Multilevel Flash Memories

Kathryn Haymaker, Christine Kelley, University of Nebraska-Lincoln

Write-once-memory (WOM) and flash codes are used to increase the number of writes in flash memories in order to improve the lifetime of flash based storage systems. An early construction method of binary WOM codes used cosets of a binary linear code in the writing process, and the covering radius of the code was used to determine the number of writes possible. In this paper, we look at how this can be generalized for codes on multilevel flash cells, and examine possible applications of the covering radius in rank modulation codes.

TA2b-4 11:30 AM

Comparison of ECC Performance on MLC and TLC Flash Memories

Paul H. Siegel, Brian K. Butler, Scott Kayser, Eitan Yaakobi, Xiaojie (Eric) Zhang, University of California, San Diego

Using an extensive database of measured errors on MLC and TLC flash memories, we compare the performance of several high-rate algebraic and graph-based error-correcting codes (ECCs). The codes compared include BCH and Reed-Solomon codes, as well as new cell-level coding schemes that address the dominant error types observed in the measured errors. The graph-based codes that we consider include “random,” quasi-cyclic, and protograph-based LDPC codes. The iterative message-passing decoding algorithms that we compare include variants of min-sum and sum-product decoding, combined with a novel non-uniform quantization scheme that mitigates the deleterious effect of numerical message saturation on error-rate performance and substantially lowers the observed error floors with little impact on decoding complexity.

Session: TAa3 – Multiuser and Massive MIMO

Chair: ***Haralabos Papadopoulos,*** *DoCoMo Labs USA*

TA3a-1 8:15 AM

Downlink Outage Probability in MIMO HetNets

Harpreet S. Dhillon, University of Texas at Austin; Marios Kountouris, École supérieure d'électricité; Jeff Andrews, University of Texas at Austin

A baseline framework to study the effect of multiple antenna techniques on coverage probability is developed for cellular networks with multiple classes of base stations, known as heterogeneous cellular networks, or "HetNets". The effect of various multiple antenna techniques -- such as beamforming and spatial multiplexing -- is characterized in terms of their effective channel gains, which are then used to derive the downlink Signal-to-Interference-Ratio (SIR) distribution and consequently the outage probability using tools from stochastic geometry.

TA3a-2 8:40 AM

Coverage and Capacity in mmWave MIMO Systems

Salam Akoum, Omar El Ayach, Robert W. Heath, Jr., University of Texas at Austin

Millimeter wave systems are being considered for cellular broadband communication to alleviate the bandwidth crisis at lower frequencies. Beamforming is crucial in mmWave systems to overcome the large path-loss and achieve good link quality performance. In this paper, we propose an analytical framework to analyze mmWave broadband, characterized by large antenna arrays and small cell sizes. We use tools from stochastic geometry to model the small cell network associated with mmWave base stations deployment. We derive tractable expressions for coverage and capacity in mmWave broadband networks and we use them to establish a baseline comparison with microwave communication using advanced multiple antenna processing.

TA3a-3 9:05 AM

A Millimeter-Wave Massive MIMO System for Next Generation Mobile Broadband

Zhouyue Pi, Jianzhong Zhang, Farooq Khan, Samsung Corp.

The spectacular growth of mobile data traffic calls for drastic improvement in mobile network capacity beyond current 3G/4G networks. In this paper, we describe a millimeter-wave massive MIMO system that taps the vast spectrum in 3 – 300 GHz. We discuss the unique advantages of millimeter waves such as spectrum availability and large beamforming gain in small form factor. We also provide an overview of the essential transceiver and antenna technologies that enable mobile communication in such high frequencies. We describe a practical millimeter-wave massive MIMO system that can provide Giga bps data rate at distance up to 500 meters and support mobility up to 350 kmph. We show in system simulation that such a system with basic configuration achieves more than 30 times cell capacity and cell-edge throughput than a 20-MHz LTE systems.

TA3a-4 9:30 AM

Towards Improving LTE SU/MU-MIMO Performance: Issues in Channel Estimation, Interpolation and Feedback

Ozgun Y. Bursalioglu, Sean A. Ramprashad, Haralabos C. Papadopoulos, NTT DoCoMo Labs

We consider the challenging problem of improving the throughput of Single-User MIMO (SU-MIMO) and Multi-User MIMO (MU-MIMO) in the present 3GPP Long Term Evolution (LTE) design. The current design, based on limited (low-rate) implicit Channel State Information (CSI) feedback has largely been optimized for relatively-high mobility macro-cellular scenarios. It is known, however, that such limited feedback inherently limits the CSI accuracy at the transmitter (CSIT), and results in severely inter-stream interference limited operation, in particular for MU-MIMO. Consequently, much of the recent effort towards improving MU-MIMO (and SU-MIMO) performance has focused on increasing this feedback rate. However, improvements obtained solely by increased feedback tend to fall short of what should be expected in both SU-MIMO and MU-MIMO. As we will show, in addition to CSI feedback, other elements of the LTE design are also very important. These elements include downlink channel estimation, the granularity of CSI feedback in frequency, channel quality indicators, dedicated training during channel estimation, and pilot placement and interpolation in the OFDM plane. The existing LTE design of such elements works sufficiently well in the context of a limited feedback design, and for macro-focused scenarios which are characterized by high-frequency selectivity. In both cases, CSIT is a very coarse representation of the channel state, and thus errors introduced by such elements may dominate limits in performance. However, with increased CSI feedback, finer CSI feedback granularity in frequency, and/or lower-frequency selective scenarios (which can characterize small cells), such elements begin to dominate. The paper will discuss the interplay of these factors, and will provide detailed link-level evaluations of various feedback, pilot and interpolation designs demonstrating the above effects. By doing so, we hope to bring some clarity to the underlying practical and theoretical issues that are limiting MIMO performance improvements in LTE.

Session: TAb3 – Compressive Estimation

Chair: ***Wee Peng Tay,*** *Nanyang Technological University*

TA3b-1 **10:15 AM**

Compressive Estimation in AWGN: General Observations and a Case Study

Dinesh Ramasamy, Sriram Venkateswaran, Upamanyu Madhow, University of California, Santa Barbara

Compressive random projections followed by ℓ_1 reconstruction is by now a well-known approach to capturing sparsely distributed information, but applying this approach via discretization to estimation of continuous-valued parameters can perform poorly due to basis mismatch. However, we show in this paper it is still possible to capture the information required for effective estimation using a small number of random projections. We characterize the isometries required for preserving the geometric structure of estimation in additive white Gaussian noise (AWGN) under such compressive measurements. Under these conditions, estimation-theoretic quantities such as the Cramer-Rao Lower Bound (CRLB) are preserved, except for attenuation of the Signal-to-Noise Ratio (SNR) by the dimensionality reduction factor. For the canonical problem of frequency estimation of a single sinusoid based on N uniformly spaced samples, we show that the required isometries hold for $M = O(\log N)$ random projections, and that the CRLB scales as predicted. While we prove isometry results for a single sinusoid, we present an algorithm to estimate {\it multiple} sinusoids from compressive measurements. Our algorithm combines coarse estimation on a grid with iterative Newton updates and avoids the error floors incurred by prior algorithms which apply standard compressed sensing with an oversampled grid. Numerical results are provided for spatial frequency (equivalently, angle of arrival) estimation for large (32×32) two-dimensional arrays.

TA3b-2 **10:40 AM**

On Application of LASSO for Sparse Support Recovery with Imperfect Correlation Awareness

Piya Pal, P. P. Vaidyanathan, California Institute of Technology

In this paper, the problem of identifying the common sparsity support of multiple measurement vectors (MMV) is considered. Denoting y[n]=Ax_{s}[n],1<=n<=L, as the L measurement vectors of size M, A as the measurement matrix and x_{s}[n] as the unknown vectors of size N with same sparsity support denoted by the set S_{x} with |S_{x}|=D, it has been shown in a recent paper by the authors that when the elements of x_{s}[n] are uncorrelated from each other, one can recover sparsity levels as high as O(M^{2}) for suitably designed measurement matrix. This result was shown for the ideal correlation knowledge, which is true in the limit as L tends to infinity. In this paper, we formulate the problem of support recovery in the non ideal setting, i.e., when the correlation matrix is estimated with finite L. The resulting support recovery problem which explicitly utilizes the correlation knowledge, is shown to be formulated as a LASSO. The performance of such ``correlation aware" LASSO is analyzed by providing lower bounds on the probability of successful recovery as a function of the number L of measurement vectors. Numerical results are also provided to demonstrate the superior performance of the proposed correlation aware framework over conventional MMV techniques under identical conditions.

TA3b-3 **11:05 AM**

Compressive Multiplexers for Correlated Signals

Ali Ahmed, Justin Romberg, Georgia Institute of Technology

Compressive sensing ideas have been employed previously in devising efficient sampling strategies with implementable components for sparse signals. One of the proposed hardware in this regard is compressive multiplexer for sub Nyquist rate acquisition of an ensemble of sparse signals using a single Analog to Digital Converter (ADC). This paper introduces several compressive multiplexing architectures that are useful for the compressive acquisition of "correlated" signals. We present three different compressive multiplexers that enable sub Nyquist rate acquisition of correlated ensemble under different set of constraints on the input signals. All of the theoretical results presented for these sampling schemes can also be viewed as a low rank recovery results from \textit{structured} random measurements. We close the discussion with some applications.

TA3b-4 **11:30 AM**

Optimal Acquisition Policy for Compressed Measurements with Limited Observations

Sourabh Bhattacharya, Ashutosh Nayyar, Tamer Basar, University of Illinois, Urbana-Champaign

In this paper, we explore the problem of optimizing the measurement policy in finite horizon sequential compressive sensing when the number of samples are strictly restricted to be less than the overall horizon of the problem. We assume that at each instant the sensor can decide whether or not to take an observation, based on the quality of the sensing parameters. The objective of the sensor is to minimize the coherence of the final sensing matrix. This problem lies at the intersection of {\it{usage limited

sensing}} and sequential compressive sensing. First, we formulate the dynamic program corresponding to the decision problem. Next, we propose a policy that satisfies a dynamic program similar to the original one. We show that the proposed policy is myopic. Moreover, we show that this policy is optimal for low-dimensional problems.

Track C. Networks

Session: TAa4 – Social Networks

Chair: ***Pierre-Andre Maugis,*** *Sorbonne University*

TA4a-1 8:15 AM

Hub Discovery in Partial Correlation Graphical Models

Al Hero, University of Michigan

This work will present late-breaking results related to the recent work of Hero and Rajaratnam on hub discovery in partial correlation graphical models (arXiv:1109.6846). The referenced paper treats the problem of screening a p-variate sample for strongly and multiply connected vertices in the partial correlation graph associated with the the partial correlation matrix of the sample. This problem, called hub screening, is important in many applications ranging from network security to computational biology to finance to social networks. In the area of social networks a hub of observed interactions between criminal suspects could be an influential ringleader. The techniques and theory presented in this paper permit scalable and reliable screening for such hubs. It extends previous work on correlation screening by the authors to the more challenging problem of partial correlation screening for variables with a high degree of connectivity. In particular we consider 1) extension to the more difficult problem of screening for partial correlations exceeding a specified magnitude; 2) extension to screening variables whose vertex degree in the associated partial correlation graph, often called the concentration graph, exceeds a specified degree.

TA4a-2 8:40 AM

Geometric Network Analysis Tools

Michael Mahoney, Stanford University

Large social and information networks are typically modeled as graphs, i.e., as data structures that have combinatorial but not-obviously geometric properties. Thus, many of the most popular tools in statistics and machine learning, e.g., SVD, PCA, RKHSs, manifolds, and their variants and generalizations, are far from immediately-applicable for such network data. Many of these popular tools have a geometric underpinning, which provides relatively nice algorithmic properties, robustness to noise, and a basis for inference and learning. On the other hand, it is known that the key to understanding the worse-case behavior of many graph algorithms lies in understanding the metric and geometric embedding properties of different classes of graphs. Here, we describe the use of geometric properties underlying scalable worst-case graph approximation algorithms for analyzing the empirical properties of large and adversarially-structured informatics graphs. A key issue will be understanding the statistical properties implicit in worst-case approximation algorithms. These geometric network analysis tools can be used as very fine "experimental probes" of the structure of networks with millions or more of nodes, thus permitting one to test commonly-made data analysis hypotheses (such as that the data live in a nice low-dimensional place or have intuitive clustering structure). In addition, these tools can be used to characterize very finely the coupling between local (often roughly Euclidean) properties and global (typically expander-like or hyperbolic) properties in large networks arising in many areas of data analysis.

TA4a-3 9:05 AM

Learning over Social Networks via Diffusion Adaptation

Xiaochuan Zhao, Ali Sayed, University of California, Los Angeles

This work applies diffusion adaptation strategies to the study of the learning dynamics over social networks. The strategy consists of two steps: one step deals with the update of the belief of each node and a second step performs aggregation of information from neighbors. Both steps rely solely on local data. We examine the stability and convergence properties of the resulting network dynamics. We also examine the value of information and how the distribution of informed agents affect the learning process and the flow of information.

TA4a-4 9:30 AM

Large Networks of Dynamic Agents: Consensus under Adversarial Disturbances

Dario Bauso, Tamer Basar, University of Illinois, Urbana-Champaign

Reaching consensus is a fundamental problem in multi-agent systems. In this talk, we discuss consensus problems in an adversarial environment. The set up of the problem in its generic form can be used to describe the opinion dynamics in social networks. In particular, we consider a large network with two types of dynamic agents. One type is a group of consensus-seeking agents who aim to reach agreement with other agents in their neighborhood. The other type is a group of malicious or stubborn agents who seek to force the value of consensus to their own desired values. Each agent reacts to the accessible information at

each time by finding an optimal control policy that minimizes independently its long-term cost functional. Our goal is to study the problem in a large-population regime, where an appropriate game solution concept, the mean-field Nash equilibrium, can be characterized by Riccati equations. These equations result from the HJB optimality criterion coupled with two nonlinear PDEs that describe the state evolutions of the population of the legitimate agents and malicious agents, respectively.

Track C. Networks

Session: TAb4 – Signal Processing for Cyber-Security and Privacy in Networks

Chair: ***Lalitha Sankar,*** *Arizona State University*

TA4b-1 10:15 AM

Secure Estimation in Cyber-Physical Systems

Yilin Mo, Bruno Sinopoli, Carnegie Mellon University

We consider the problem of estimating a Gaussian random variable based on m noisy measurements that can be manipulated by an adversary. The adversary is assumed to have full information about the true value of the random variable to be estimated as well as the values of all the measurements. However, it can only manipulate up to n of the m measurements. The estimation problem is formulated as a minimax optimization problem, where one seeks to construct an optimal estimator that minimizes the ``worst-case'' mean square error against all possible manipulations by the adversary. We prove one necessary condition for the estimator to be optimal. Moreover, we provide a suboptimal estimator which is asymptotically optimal when n/m goes to 0.

TA4b-2 10:40 AM

Analyzing Privacy and Utility Using Axioms

Daniel Kifer, Bing-Rong Lin, Penn State University

Statistical analysis of sensitive data involves two key concepts: privacy and utility. Privacy is a limit on inference about certain information and involves perturbing the data or the analysis. Utility is a measure of the amount of statistical information that is retained after perturbation. In this paper we describe an axiomatic approach to analyzing privacy and utility. The axioms turn privacy definitions and utility measures into mathematical objects that can be subjected to a rigorous analysis. We also show how axioms can be used to identify rational and irrational choices in the design of privacy definitions and utility measures.

TA4b-3 11:05 AM

Quantifying the Delay-Privacy Trade-off in the Design of a Scheduling Policy

Sachin Kadloor, Negar Kiyavash, University of Illinois, Urbana-Champaign; Parv Venkitasubramaniam, Lehigh University

When a processor is shared by multiple users, the delays experienced by jobs from one user are a function of the arrival pattern of jobs from other users, and the scheduling policy of the server. Consequently, a scheduling system creates a timing side channel in which information about arrival pattern from one user is inadvertently leaked to another. In this work, this information leakage is studied for a two user scheduling system. We first introduce a measure of privacy and then demonstrate that no scheduler can provide maximum privacy without idling/taking vacations, and consequently no policy can simultaneously be delay and privacy optimal.

TA4b-4 11:30 AM

A Formal Framework for Joint Privacy and Security Modeling and Analysis in Data and Communication Networks

John Baras, University of Maryland

We develop a formal framework to model and analyze combined security and privacy requirements in data and communication networks. The network is modeled by two interacting multigraphs: one representing the logical (social, organizational) relationships between nodes (users, servers), and a second one representing the physical interconnections between nodes. Nodes and links in both multigraphs are annotated by weights (numerical, logical, rules) that represent security and privacy requirements. Our recent theory of multiple semiring optimization and tradeoff analysis in networks forms the foundation. Automatic theorem proving and satisfiability methodologies are also employed. Extensions to dynamic networks, privacy and security, are described.

Session: TAa5 – 3D Video Processing

Chair: ***Patrick Le Callet,*** *Polytech'Nantes Université de Nantes*

TA5a-1 **8:15 AM**

Full-Reference Quality Assessment of Stereoscopic Images by Modeling Binocular Rivalry

Ming-Jun Chen, Che-Chun Su, University of Texas at Austin; Do-Kyoung Kwon, Texas Instruments; Lawrence K. Cormack, Alan Bovik, University of Texas at Austin

We develop a framework for stereoscopic image quality assessment (QA) that accounts for binocular rivalry. An intermediate image is generated which when viewed stereoscopically is designed to have a perceived quality close to that of the cyclopean image. We hypothesize that performing stereoscopic QA on the intermediate image yields higher correlations with human subjective judgments. The experimental results confirm the hypothesis and show that the proposed framework significantly outperforms conventional 2D QA metrics when predicting the quality of stereoscopically viewed images.

TA5a-2 **8:40 AM**

Visual Quality in Stereoscopic 3DTV

Ramanathan Palaniappan, Nikil Jayant, Georgia Institute of Technology; Pravin Mane, VQLink

As part of an ongoing research program in 3DTV, we have evaluated video quality in compressed 3DTV sequences using human viewers as well as HVS-tuned objective measurements, over a broad range of bit rates. Our results describe the correlation between the subjective and objective approaches. They also validate an artifact- suppression theory according to which the perceived quality in 3DTV follows that of the higher-quality view in the left-right pair, under realistic circumstances of bit rate allocation.

TA5a-3 **9:05 AM**

Depth Map Estimation in DIBR Stereoscopic 3D Videos Using a Combination of Monocular Cues

Mohammed Aabed, Dogancan Temel, Mashhour Solh, Ghassan AlRegib, Georgia Institute of Technology

We propose a method to reconstruct the depth map from multiple estimated depth maps relying on monocular cues. Based on extracted depth cues from luminance, chrominance, motion and texture, we obtain an optimal depth estimation by analytically deriving the best combinations. We first analyze a ground truth depth map to extract a set of depth cues. Then, using these depth cues, we process the colored reference video to reconstruct the depth map. We tested this approach on different video sequences with different monocular properties. The results show that the extracted depth maps generate a 3D video with quality close to the video rendered using the ground truth depth map. We report subjective and objective results using 3VQM.

TA5a-4 **9:30 AM**

Perceptual Depth Indicator for S-3D Content Based on Binocular and Monocular cues

Pierre Lebreton, Alexander Raake, Telekom Innovation Laboratories; Marcus Barkowsky, Patrick Le Callet, LUNAM Université, Université de Nantes

3D video quality of experience (QoE) is a multidimensional problem; many factors contribute to the global rating like image quality, depth perception and visual discomfort. Due to this multidimensionality, in addition to assessment of the quality degradation due to coding or transmission, the appropriateness of the non-distorted signal should be addressed. One important factor here is the depth information as it perceived by observers provided by the source sequences. From an application-perspective, the perceptual depth-characteristics of source content are of relevance for pre-validating whether the content is suitable for 3D video services. In addition, assessing the interplay between binocular and monocular depth features and depth perception are relevant topics for S-3D video perception research. To achieve the evaluation of the suitability of 3D content, this paper describes both a subjective experiment and a new objective indicator based on monocular and binocular perceptual cues to evaluate depth as one of the added values of S-3D video.

Session: TAb5 – Computer Arithmetic Accelerators for Signal Processing

Chair: ***Roger Woods,*** *Queen's University Belfast*

TA5b-1 **10:15 AM**

Imprecise Arithmetic for Low Power Image Processing

Pietro Albicocco, Gian Carlo Cardarilli, University of Rome Tor Vergata; Alberto Nannarelli, Technical University of Denmark; Massimo Petricca, Marco Re, University of Rome Tor Vergata

Sometimes reducing the precision of a numerical processor, by introducing errors, can lead to significant performance (delay, area and power dissipation) improvements without compromising the overall quality of the processing. In this work, we show how to perform the two basic operations, addition and multiplication, in an imprecise manner by simplifying the hardware implementation. With the proposed "sloppy" operations, we obtain a reduction in delay, area and power dissipation, and the error introduced is still acceptable for applications such as image processing.

TA5b-2 **10:40 AM**

Linearization Using Efficient Complex Polynomial Evaluations

Pouya Dormiani, Milos Ercegovac, University of California, Los Angeles

Digit-serial techniques for evaluating linearization transformations needed to compensate for nonlinear effects in power amplifiers are presented. Our contributions include detailed designs suitable for implementation, algorithmic techniques for increasing throughput and experimental results in FPGAs.

TA5b-3 **11:05 AM**

FPGA-Accelerated Simulation of Truncated-Matrix Multipliers

George Walters, Penn State Erie, The Behrend College

Truncated-matrix multipliers offer significant reductions in area, power and delay, at the expense of increased computational error. Extensive bit-accurate simulation is often necessary to evaluate the trade-offs and choose the best parameters for a particular application. This paper presents a method for simulating truncated-matrix multipliers using a field-programmable gate array (FPGA). The method is applicable to most error correction methods published to date, and is simple to implement. It enables real-time simulation in actual applications, exhaustive simulation of large design spaces, and Monte Carlo simulation with more trials than other simulation options. When implemented in a Virtex-5 FPGA, the simulation runs at the same speed as a standard round-to-nearest multiplier, performing more than 2^29 simulations per second per embedded multiplier.

TA5b-4 **11:30 AM**

A Low-Power Dual-Path Floating-Point Fused Add-Subtract Unit

Jae Hong Min, Jongwook Sohn, Earl E. Swartzlander, Jr., University of Texas at Austin

This paper examines a low-power consumption dual-path fused floating-point add-subtract unit and compares it with previous fused add-subtract units such as the single path fused add-subtract unit with/without enhanced aligning and compound adder-round unit and the high-speed dual-path fused add-subtract unit. The high-speed dual-path fused add-subtract unit has less latency than the single-path fused add-subtract units, but with higher power consumption. To reduce the power consumption, a dual-path fused add-subtract unit with a simplified far/close path scheme is proposed; the significand addition, subtraction and round are not included in the far/close paths while each path of the high-speed version has these units. The significand adder and subtractor are shared by far/close path. The power consumption of the proposed design is 18% lower than the high-speed single path fused add-subtract unit at a 10% cost in latency; however, the proposed dual-path fused add-subtract unit is 24-26% faster than the two single-path fused add-subtract units.

Track G. Architecture and Implementation

Session: TAa6 – Low Power I

Chair: ***James Stine,*** *Oklahoma State University*

TA6a-1 **8:15 AM**

Breaking the 3-D IC Power Delivery Wall

Mircea Stan, Kaushik Mazumdar, University of Virginia

Several power "walls" that must be overcome in future technologies are the 3-D IC power delivery wall and the on-chip power regulation efficiency wall. In 3-D ICs, power is consumed in the volume of the 3-D chip, but can be delivered only to a 2-D surface - as the number of layers in a 3-D IC becomes larger, the greater the mismatch between 3-D consumption and 2-D delivery. The efficiency of on-chip regulators, which bounds the overall power efficiency of an IC, is not unique to 3-D, but becomes essential due to the volumetric nature of the system. This paper studies voltage stacking of multi-layer heterogeneous 3-D systems with distributed DC-to-DC on-chip regulators. The physical layering of 3-D IC naturally maps to a voltage stacked solution that overcomes some of the difficulties with voltage stacking in 2-D, such as isolating the stacked domains from the substrate.

TA6a-2 **8:40 AM**

A Review of QCA Adders and Metrics

Weiqiang Liu, Maire O'Neill, Queen's University of Belfast; Earl Swartzlander, University of Texas at Austin

Quantum-dot Cellular Automata is a potential game changer for integrated circuit design and development. The still evolving technology promises very small, very fast and very low power computation. It differs from current integrated circuit technology in that on chip communication is relatively slow while logic operations are fast. This paper reviews several designs for QCA adders and develops a number of criteria for them.

TA6a-3 **9:05 AM**

Circuits for Ultra-low Power Millimeter-Scale Sensor Nodes: Progress, Opportunities, and Challenges

Yoonmyung Lee, Dennis Sylvester, David Blaauw, University of Michigan

Bell's Law predicts continual scaling of the size of computing systems, and the next of these systems is about to emerge: millimeter-scale sensor nodes. These miniature wireless sensors will enable multiple new applications in a wide range of fields, including medical diagnosis, infrastructure monitoring and military surveillance. However, this form factor remains beyond the capabilities of modern integrated circuit design techniques due to extremely small battery size. This presentation describes new circuit design techniques for ultra-low power operations that can be applied to digital processors, memory, power management, and a special focus on standby mode operation, which will bring millimeter scale sensor nodes into reality.

TA6a-4 **9:30 AM**

Distributed Power Delivery for Energy Efficient and Low Power Systems

Selcuk Kose, University of South Florida; Eby Friedman, University of Rochester

The performance of an integrated circuit depends strongly upon the power delivery system. With the introduction of ultra-small on-chip voltage regulators, novel design methodologies are needed to simultaneously determine the location of the on-chip power supplies and decoupling capacitors. In this work, the effect of physical distance from the power supplies and decoupling capacitors to the load circuitry on the overall system performance is evaluated. A unified design methodology is proposed to determine the optimal location of the power supplies and decoupling capacitors in high energy efficient, low power integrated circuits.

Track G. Architecture and Implementation

Session: TAb6 – Low Power II

Chair: ***James Stine,*** *Oklahoma State University*

TA6b-1 **10:15 AM**

The Energy-Efficiency of Asynchronous Architectures

Rajit Manohar, Cornell University

Asynchronous circuits have the potential to improve the energy-efficiency of large-scale digital systems. The benefits of asynchronous circuits include switching activity only when there is useful computation being performed, and the ability to optimize for average-case delays rather than the worst-case timing path in the system. This benefit is partially offset by the overheads introduced to implement synchronization and delay-insensitive communication. We present an analysis of these trade-offs, showing where asynchronous circuits have energy-efficiency benefits over their synchronous counterparts, and vice versa.

TA6b-2 **10:40 AM**

Optimized Low-Power Elementary Function Approximation for Chebyshev Series Approximations

Masoud Sadeghian, Oklahoma State University; James Stine, Oklahoma State Universtiy

This paper presents a method for computing elementary function using optimized number of most significant bits of coefficients along with truncated multipliers for designing interpolators. The method proposed optimizes the initial coefficient values, which leads to minimize the maximum absolute error of the interpolator output by using a Chebyshev series approximation. The resulting designs can be utilized for any approximation for functions up with smaller requirements for table lookup sizes. Designs for several interpolators that implement are presented and analyzed. This paper demonstrates that optimal coefficient values with high precision and smaller lookup table sizes can be optimally compared to standard coefficients for interpolators.

TA6b-3 **11:05 AM**

Yield-Driven Minimum Energy CMOS Circuit Design

Max Korbel, Dylan Stow, Chris Ferguson, David Harris, Harvey Mudd College

CMOS circuits operating near or below threshold offer the lowest energy per computation. Previous work reduces the total energy by using minimum sizing and lowering the voltage without concern for yield. To achieve better yield, the voltage or size must increase. The minimum energy point for minimum-sized NAND2 gates is 0.475 V consuming 0.0275 fJ/cycle with a gate failure rate of 2×10-4. However, to achieve a failure rate of 10-6, minimum energy is achieved by widening pMOS transistors by 50%, increasing total energy by 11.9%, which is 7.2% better than minimum width devices and higher voltage.

TA6b-4 **11:30 AM**

Power Efficient Design of Parallel/Serial FIR Filters in RNS

Massimo Petricca, Pietro Albicocco, Gian Carlo Cardarilli, University of Rome Tor Vergata; Alberto Nannarelli, Technical University of Denmark; Marco Re, University of Rome Tor Vergata

It is well known that the Residue Number System (RNS) provides an efficient implementation of parallel FIR filters especially when the filter order and the dynamic range are high. The two main drawbacks of RNS, need of converters and coding overhead, make a serialized implementation of the FIR filter potentially disadvantageous with respect to filters implemented in the conventional number systems. In this work, we show a number of solutions which demonstrate that the power efficiency of RNS FIR filters implemented serially is maintained in ASIC technology, while in modern FPGA technology RNS implementations are less efficient.

Session: TAa7 – Biological Networks and Machine Learning

Chair: ***Olgica Milenkovic,*** *University of Illinois, Urbana-Champaign*

TA7a-1 8:15 AM

Wavelet Packets Based Clustering for the Study of Functional Connectivity in the Rat Brain

Alessio Medda, Georgia Institute of Technology; Shella Keilholz, Emory University School of Medicine

In this paper we propose a data driven clustering method for the study of functional connected region in the brain. In particular, wavelet packets are used because of their ability to best analyze nonlinear and nonstationary type signals, and their theoretically optimally whitening properties for 1/f-like processes. We combine feature extraction by wavelet packets with agglomerative clustering using standardize Euclidian distance as dissimilarity measure. Early results indicate that this approach produces clusters that are well matched to classical anatomical regions in the sensorimotor cortex of the brain.

TA7a-2 8:40 AM

Reconstructing a Sparse Matrix Using Row and Column Pooling

Or Zuk, Broad Institute of MIT and Harvard

We present the problem of reconstructing a sparse matrix by performing a combination of two types of pools 'row-pooling' and 'column-pooling'. Each pool gives a (noisy) measurement vector representing a linear combination of either several rows or several columns in the matrix. The problem is motivated by a particular application in molecular biology, of measuring an RNA-protein interaction network. We describe a pooling design and an efficient algorithm for matrix reconstruction from combinations of row and column pools. We show that under certain sparsity conditions, the combined approach is more efficient than a more standard approach performing either row pooling or column pooling solely.

TA7a-3 9:05 AM

Alignment of Multiple Biological Networks Based on Semi-Markov Random Walk Scores

Sayed Mohammad Ebrahim Sahraeian, Byung-Jun Yoon, Texas A&M University

In this paper, we present a novel computational method for aligning multiple biological networks. The proposed method starts by computing probabilistic node correspondence scores for all network pairs based on a semi-Markov random walk model. The computed scores are used to gradually build up the network alignment in a greedy manner, according to the maximum expected accuracy principle. We show that the proposed multiple network alignment method outperforms many existing algorithms, in terms of both computational efficiency as well as alignment accuracy.

TA7a-4 9:30 AM

Reducing the Number of Features for Seizure Prediction of Spectral Power in Intracranial EEG

Yun Park, Brown University; Theoden Netoff, Keshab Parhi, University of Minnesota

For the pursuit of a low-powered implantable device for seizure prediction, we investigate small numbers of key features of spectral power in intracranial electroencephalogram (iEEG) by two-step recursive feature elimination using support vector machines (RFE SVMs). In the previous work, we proposed a prediction algorithm using 27-54 spectral power features and nonlinear SVM classification and achieved high prediction rate; however, when it comes to an implantable device, it may suffer from their high complexity. In this paper, we demonstrate that using only 6 or 9 key spectral power features and linear SVM classification can still produce high prediction rate while lowering its complexity significantly.

Session: TAb7 – Sequence and Genome Analysis

Chair: ***Sharon Aviran,*** *University of California, Berkeley*

TA7b-1 10:15 AM

Sparse Inference of Regulatory Networks Using Information-Theoretic Methods

Mo Deng, Amin Emad, Olgica Milenkovic, University of Illinois, Urbana-Champaign

We consider the problem of estimating the (directional) topology of regulatory networks assuming sparse network connectivity, and linear or polynomial functional dependencies between the expression profiles of interacting entities. For estimation purposes, we propose combining compressive sensing methods with Granger causality and information bottleneck models. The former model allows for inferring Granger-type causal relationships between interacting entities, while the second method allows for incorporating prior information into the model via inclusion in an information-theoretic optimization constraint. Our method is tested on E.coli and S. cerevisiae datasets.

TA7b-2 10:40 AM

Structural Stabilization of RNA-Protein Binding Sites through High Linkage SNPs

Matthew Halvorsen, Joshua S. Martin, Wes Sanders, Justin Ritz, Alain Laederach, University of North Carolina, Chapel Hill

A majority of SNPs (single nucleotide polymorphisms) map to non-coding and intergenic regions of the genome. Non-coding SNPs are often identified in Genome Wide Association Studies (GWAS) as strongly associated with human disease. High-accuracy single nucleotide resolution SHAPE chemical mapping reveals that multiple, disease-associated SNPs result in substantial changes in the structural ensemble of mRNAs in agreement with computational predictions. Furthermore it is always possible to restore the mRNA to its wild-type ensemble with several different “correcting” mutations. Our data confirm that diseases including Chronic Obstructive Pulmonary Disease (COPD), -thalassemia, hyperferitinemia cataract syndrome, Retinoblastoma, and cartilage hair hypoplasia can be caused by a “RiboSNitch;” i.e. an RNA that changes structure if a particular disease-associated SNP is present. The structural change observed is analogous to that of a bacterial Riboswitch in that it likely regulates translation. These data further suggest that specific pairs of SNPs in high linkage disequilibrium (LD) will form RNA structure-stabilizing haplotypes (SSHs). We identified 484 SNP pairs that form SSHs in UTRs of the human genome, and in eight of the to 10 SSH-containing transcripts, SNP pairs stabilize IGF2BP, AGO, PUM2 and/or TNRC6 RNA protein binding sites. The ubiquitous nature of SSHs in the transcriptome ans their overlap with PAR-Clip determined RNA/protein interaction sites suggests that certain haplotypes are conserved to avoid RiboSNitch formation. Furthermore, analysis of human population genetics in the structural context of the transcriptome may help identify RNA “hotspots” for disease.

TA7b-3 11:05 AM

Detection of Antipodal Persistence in Large Scale Differential Gene Expression Experiments

Alfred Hero, Robert Brown, Hamed Firouzi, University of Michigan, Ann Arbor

This paper proposes a correlation-based statistical analysis method for detecting differential gene expression in a large scale gene assays, such as mRNA chips, where there are many fewer samples than gene probes. The correlation analysis method screens the sample correlation graph for variables that have high correlations that change sign under two different treatments. Tight false positive control is obtained using results from large deviations of gram matrices for the small sample regime. We will illustrate the method for a large scale human flu virus challenge study.

TA7b-4 11:30 AM

Efficient Genotyping of Individuals Using Overlapping Pool Sequencing and Imputation

Farhad Hormozdiari, Zhanyong Wang, Wen-Yun Yang, Eleazar Eskin, University of California, Los Angeles

Next generation sequencing technologies are rapidly decreasing the cost of obtaining genetic information. The cost for utilizing one of these technologies consists of a sample preparation step and a sequencing step of the prepared sample. The dramatic increase in the efficiency of the sequencing technology makes the costs of the sequencing step negligible for small target regions. Thus the main remaining cost is the sample preparation step. Using overlapping sequencing pools where samples are mixed together into pools which are prepared and sequenced together has been shown to reduce the cost significantly for collecting information on genetic variants which only occur in a few of the samples. These methods utilize ideas from compressed sensing. In this paper, we extend this approach to utilize additional information from reference genetic variation datasets which provide the correlation structure between genetic variants. Utilizing this information, we can significantly increase the efficiency of overlapping pool sequencing.

Session: TAa8 – Array Signal Processing II 8:15 AM – 9:55 AM

Chair: ***Peter Gerstoft,*** *University of California, San Diego*

TA8a1-1

An Analytical Framework for Transmit Beamforming with Peak Power Constraint

Zhenhua Yu, Xiaoli Ma, G. Tong Zhou, Georgia Institute of Technology

Multi-antenna transmit beamforming is a well-adopted technique at base stations to reduce interference and improve communication quality. The radiation pattern in beamforming is determined by both the weights and the configurations of antenna array. In base stations, orthogonal frequency-division multiplexing (OFDM) signals and multi-carrier wideband code division multiple access (WCDMA) signals exhibit high peak-to-average-power ratio (PAPR), which could be severely distorted by the non-linearity of power amplifiers (PAs). The beam patterns may be impaired as well. Due to the beamforming weights, the transmitted signals on multiple chains may have different average and peak power. In addition, the PAs on different chains exhibit their own non-linear characteristics. Therefore, the problem for multi-antenna transmit beamforming non-linearity is more complicated than that for single chain transmission. In this paper, we study transmit beamforming system with peak power constraint, i.e., the PA model is the soft limiter model. We provide a framework for analyzing the clipping effects in a transmit beamforming system. Three metrics are adopted to characterize the impairments: (i) the power gain pattern; (ii) the beamforming error pattern; and (iii) the signal-to-distortion power ratio (SDR) pattern. Both numerical derivations and simulations are provided to measure the proposed metrics.

TA8a1-2

On the Applicability of Source Localization Techniques to Passive Multistatic Radar

Daniel Hack, Lee Patton, Matrix Research, Inc.; Braham Himed, Michael Saville, Air Force Research Laboratory

The source localization problem concerns the geolocation of an emitter whose transmission is observed by geographically separated receivers. The passive multistatic radar (PMR) problem concerns the geolocation of a target that scatters an illumination signal to geographically separated receivers. By modeling the scattering target as an emitter, the techniques of source localization can be brought to bear on the PMR problem. In this work, we relate the source localization and PMR problems in a common framework. The resulting performance equations are then used to comment on the applicability of source localization techniques in PMR. Specifically, we show that the two problems are not identical due to differences in the signal environment and signal-to-noise regimes, which may limit the utility of source localization techniques in PMR.

TA8a1-3

Sparse Frequency Diverse MIMO Radar Imaging

Changchang Liu, Weidong Chen, University of Science and Technology of China

By synthesizing multiple frequency signals into a wideband signal, the frequency diverse multiple-input-multipleoutput (FD-MIMO) radar has the potential to achieve higher resolution than ordinary MIMO radar. However, conventional imaging methods based on Matched Filter (MF) can not enjoy good inversion performance. From the perspective of the range angle frequency (RAF) domain, this paper analyzes the reason for the poor imaging result and derives the limit of resolution for FD-MIMO radar. Therefore, for better imaging performance, we consider to exploit the sparsity of the scatterers in the scene of interest. Unlike most existing sparse imaging methods which extract the range and angle information simultaneously, here we propose a novel approach to recover the range and angle space separately, an approach that not only has lower computer complexity but also takes the various noises of different propagation channels into consideration. For angle compression, the weighted simultaneous orthogonal matching pursuit (WSOMP) method is proposed to utilize both inter-and intra-sparsity of the echoes while taking into account the noise differences among propagation channels. For range compression, the inverse fast Fourier transform (IFFT) operation is implemented to each nonzero angle profile. Simulation results verify the effectiveness of the proposed method.

TA8a1-4

EEG Source Localization Using Beamforming in Energy-Constrained Regions

D. Gutiérrez, C. C. Zaragoza-Martínez, Center of Research and Advanced Studies

We present a source localization method for electroencephalographic (EEG) data based on the linearly constrained minimum variance and eigencanceller beamformers. A region-of-interest (ROI) is selected through a short-term estimate of the signal's energy as constraint. Such constrain is only valid on the scalp, then an affine transformation is applied to map it to the brain cortex. Then, beamforming is applied only over the ROI which allows for a reduction in the computational cost for the source localization process. The applicability of the proposed method is shown through a series of numerical examples using real EEG data.

TA8a1-5
Hybrid Cramer-Rao Lower Bound for Sniper Localization via a Helicopter-Based Acoustic Array

Lou Fertig, Georgia Tech Research Institute

In this work, we derive the Hybrid Cramer-Rao Lower Bound (HCRLB) for sniper localization performance via a helicopter-based acoustic array. Our work differs from previous publications in two important respects. First, previously published results assume that bullet characteristics are perfectly known to the acoustic array (which is highly questionable) while our approach exploits a stochastic model to assess the substantial impact of imperfect knowledge of the bullet. Second, previously published results assume ground or aerostat based arrays, while we address issues associated with a helicopter-based array.

TA8a1-6
A ML Localizer of Multiple Radar Targets

Francesco Bandiera, Michele Mancino, Giuseppe Ricci, University of Salento; Danilo Orlando, ELETTRONICA S.p.A.

In the present paper, we focus on the design and the analysis of a scheme aimed at estimating the position of multiple point-like targets that fall among three adjacent samples of the matched filter output by exploiting spillover of targets' energy. The analysis, also in comparison to a possible competitor, proves the superiority of the multitarget scheme.

TA8a1-7
Recursive Updating Algorithm for Robust Capon Beamforming with Steering Vector Mismatches

Evgeny Mavrychev, Nizhniy Novgorod State Technical University

A new algorithm for robust adaptive beamforming is designed in this paper. It is assumed that steering vector is mismatches due to propagation effects, array calibration errors, etc. The proposed algorithm is based on recursive updating of sample covariance matrix and adaptive diagonal loading. New implementation of robust Capon beamformer (RCB) is more robustness to non-stationary interference environment. Simulation results confirm efficiency of recursive robust adaptive beamformer.

TA8a1-8
A Generalized Sinusoidal Frequency Modulated Waveform for Active Sonar

David Hague, John Buck, University of Massachusetts Dartmouth

Active sonar systems employ Frequency Modulated (FM) waveforms to detect and resolve targets in reverberation limited environments and accomplish both tasks more successfully than Continuous Wave (CW) waveforms. The Sinusoidal FM (SFM) is one such waveform which modulates the signal's frequency by a sinusoidal function. The SFM attains better reverberation suppression performance than the CW but due to its periodic modulation has poorer range resolution than many other FM waveforms. This raises the question of whether FM waveforms with time-varying sinusoidal modulation functions can circumvent this limitation. This research investigates a waveform with a generalized sinusoidal modulation function of which the SFM is a special case. The waveform's range and velocity resolution and reverberation suppression performance is then compared to the SFM and other well established FM waveforms.

TA8a1-9
Consistent Linear Tracker with Position and Range Rate Measurements

Steven Bordonaro, Naval Undersea Warfare Center; Peter Willett, Yaakov Bar-Shalom, University of Connecticut

In active sonar and radar applications measurements include range, bearing and often range rate. When tracking using range and bearing measurements only, a Converted Measurement Kalman Filter (CMFK) is often employed. Previously proposed extensions of the CMKF to include range rate are either limited to cases with small bearing errors or require the use of an non-linear extension to Kalman Filter, such as the Extended Kalman Filter (EKF) or the Unscented Kalman Filter (UKF). The goal of this paper is to introduce a measurement conversion from range, bearing and range rate to Cartesian position and velocity that enables the use of a linear CMKF whose performance exceeds that of the EFK and UKF.

TA8a1-10
Joint Adaptive Beamforming and Echo Cancellation Using a Non Reference Anchor Array Framework
Karan Nathwani, Rajesh Hegde, Indian Institute of Technology Kanpur

In this paper, a method to combine adaptive beamforming microphone arrays with acoutic echo cancellation is proposed. A non reference array framework is used herein where an auxiliary microphone array is used to capture the interfering speech sources, in addition to the primary microphone array that captures the source of interest. An adaptive LC-MV beamformer developed in the context of multi speech source environments is combined with an acoustic echo cancellor by appropriately anchoring the the auxiliary microphone array. Experimental results on clean speech acquisition on cell phone like devices indicate reasonable improvement over various beamforming methods.

TA8a1-11
Tensor Decompositions with Vandermonde Factor and Applications in Signal Processing
Mikael Sorensen, Lieven De Lathauwer, KU Leuven

Tensor decompositions involving a Vandermonde factor are common in signal processing. For instance, they show up in sensor array processing and in wireless communication. We explain that by simultaneously taking the tensor nature and the Vandermonde structure of the problem into account new uniqueness results and numerical methods for computing a tensor decomposition with Vandermonde structure can be obtained.

TA8a1-12
A Correction and Generalization to the Sparse Learning via Iterative Minimization Method for Target off the Grid in MIMO Radar Imaging
Changchang Liu, Li Ding, Weidong Chen, University of Science and Technology of China

The sparse learning via iterative minimization (SLIM) method has been shown to be effective in high resolution imaging for MIMO radar model in [1]. However, the echo model there is derived directly from the discrete form according to the prior gridding of the imaging space and the assumption that all scatterers are located exactly on the grid. Therefore, here we generalize the echo model to its continuous form for arbitrarily-located scatterers. By comparing the two models, we firstly point out one derivation mistake in the previous model. Then, we analyze the extent to which the previous model and the SLIM method would be influenced by the range and angle deviation of scatterers off the grid. Based on our analysis, since the sampling interval and the size of the discretized range bin in the previous model is designed according to the time duration of the transmitted subpulse, the range deviation has no significant influence on the imaging performance. However, the angle deviation is likely to lead to a mismatched basis matrix and thus severely affect the reconstruction result by SLIM. Therefore, the self-update basis SLIM (SUB-SLIM) method is proposed to deal with the off-angle-grid scatterers by alternatively sparse imaging and adaptively refining the angle bins. Numerical results illustrate the effectiveness of our method and the related analysis.

TA8a1-14
Velocity Spectrum Analysis in Seismic Prospecting Combining Detection Principles, Beamspace Techniques and Coherent Signal-Subspace Processing
Rafael Krummenauer, Martin Tygel, Amauri Lopes, University of Campinas

We revisit the conventional velocity analysis in seismic data processing with the purpose of enhancing the temporal resolution and the sensitivity of the coherency measure in the velocity spectrum. To that end, we exploit the fact that seismic signals are coherent, wideband and tend to be sparse in the time domain. To compose an appropriate methodology, given these data features, we employ some well-established techniques of array signal processing: coherent signal-subspace approach, beamspace processing and detection theory. The methodology was tested for a real 2D offshore data and has shown success for the outlined purposes.

TA8a1-15
Cooperative Localization in Wireless Networks under Bandwidth Constraints
Panos Alevizos, Nikos Fasarakis-Hilliard, Aggelos Bletsas, Technical University of Crete

This work studies algorithms that require minimum number of exchanged messages between cooperating (for localization purposes) nodes. This work is motivated by long-baseline (LBL) acoustic positioning in underwater systems, where acoustic modems are narrow-band and thus, exchanging large amounts of data among network nodes is prohibitive. Bandwidth-limited versions of cooperative localization algorithms are proposed, achieving two orders of magnitude reduction of total exchanged

numbers (for the studied scenario), without compromising localization accuracy, compared to classic wide-band cooperative localization. Furthermore, new versions further improve localization accuracy, compared to state-of-the-art. The algorithms have been tested with Gaussian, as well as non-Gaussian ranging errors.

TA8a1-16
Cramer-Rao Lower Bounds for Estimation of Phase in LBI Based Localization Systems
Mohammad Pourhomayoun, Mark Fowler, Binghamton University

This paper derives the Cramer-Rao lower bound (CRLB) on estimates of phase in long baseline interferometry (LBI) based localization systems. LBI localization is a classical method for finding the location of a non-cooperative emitter by estimating the phase difference between received signals by two sensors spatially separated on a single platform. In this paper, we derive the CRLB for phase difference in LBI-based systems by modelling the received signal as deterministic unknown that is considered as nuisance parameters to be estimated. Consequently, the CRLB computations become much more complicated in this case. Finally, we provide the discussion for our results.

Track D. Signal Processing and Adaptive Systems
Session: TAa8 – Signal Processing and Adaptive Systems II 8:15 AM – 9:55 AM
Chair: ***Vitor Nascimento,*** *University of Sao Paulo*

TA8a2-1
Comparison of Least Mean Fourth and Least Mean Square Tracking
Eweda Eweda, National Knowledge Center, Abu Dhabi

The paper provides new results concerning the tracking performance of the least mean fourth algorithm in comparison with that of the least mean square algorithm. The analysis is done in the context of tracking a Markov plant with a white Gaussian input. The comparison is done in terms of the minimum mean square deviation attained by each algorithm over the stability range of its step-size. Gaussian, uniform, and binary distributions of the plant noise are considered. Conditions that make one algorithm outperform the other are determined. Analytical results are supported by simulations.

TA8a2-2
Extending MC-SURE to Denoise Sensor Data Streams
Mandoye Ndoye, Chandrika Kamath, Lawrence Livermore National Laboratory

A signal processing method is proposed to adaptively denoise sensor streaming data corrupted by noise that can be approximated as additive white Gaussian. This on-line filtering method takes advantage of the Monte-Carlo Stein's Unbiased Risk Estimate (MC-SURE) algorithm, which enables a blind optimization of the denoising parameters for a wide class of filters. We formulate a straightforward and practical framework for adequately denoising real sensor streaming data by identifying and solving the challenges that arise as the MC-SURE algorithm is applied in on-line data processing settings. The proposed technique has been tested using real datasets.

TA8a2-3
Improved Robustness and Accelerated Power Amplifier Identification with Adaptive Wiener Models in the Complex Domain
Robert Dallinger, Markus Rupp, Vienna University of Technology

Identification of microwave power amplifiers including their memory effects, can be done computationally inexpensive with adaptive Wiener models that consist of a transversal filter followed by a static nonlinearity parametrised using a polynomial basis. For identification of both blocks with simultaneously running gradient type algorithms, the resulting combined adaptive scheme suffers from low learning speed and vulnerability to instability. If the identification is done consecutively, the stability region is well defined but the estimates do not reach the minimum mean square error (MSE). As a remedy, we propose a repetition of such consecutive identifications. By this, stability is preserved but the MSE achieves values near to the minimum. Extending recent results found for the real-valued case, we motivate the use of certain time-variant step-sizes enabling robust and fast simultaneous adaption in the complex domain.

TA8a2-4
Efficient FFT Based Comb Filtering without Doing the FFT
Jim Rasmussen, The MITRE Corporation

This paper outlines a new comb filter implemention. Comb filters are used in several applications. For example, the CIC filter is often used in multi-rate signal processing. IIR comb filters are used to notch out harmonic interference. The FFT can also be used as a comb filter, but because of the computational complexity and other limitations, it is not usually used for this application. A new formulation of the FFT comb filtering has been discovered that eliminates all limitations of the FFT method and provides advantages over the IIR comb filter. In this paper, it is mathematically proven that the FFT comb filter can be transformed to a computationally efficient equivalent structure and can also be implemented as a simple FIR filter.

TA8a2-5
A Connection-Constraint Algorithm for a Sparse Adaptive Photonic Filter
Suk-seung Hwang, Chosun University; John J. Shynk, University of California, Santa Barbara

A sparse reconfigurable adaptive filter (SRAF) for a photonic switch consists of a large number of input and output delays, sparse reconfigurable connections, and adaptive weights. Recently, it was shown that a modified system-based (MSB) algorithm for the SRAF is more efficient than conventional algorithms such as the previous cross-correlation-based (CCB) and system-based (SB) approaches. In this paper, we propose a connection-constraint for the MSB algorithm that chooses the most effective elements among the entire connection matrix. The proposed method allows any input to be connected to any output with an arbitrary weight, and is more efficient than conventional approaches due to a reduced computational complexity. We provide a computer simulation example to demonstrate the performance of the connection-constraint algorithm for a system identification application.

TA8a2-6
Discriminative Dictionary Learning via Mutual Exclusion
Raghu Raj, U.S. Naval Research Laboratory

We apply our recently developed concept of mutual exclusivity [1] in the context of discriminative coding, to the problem of learning dictionary for representing signals drawn from N classes in a way that optimizes their discriminability. We first briefly review our mutual-exclusivity concept and then deploy it a simple discriminative dictionary learning algorithm that directly generalizes the well-known KSVD algorithm which is addressed for the traditional problem of signal coding. We carefully delineate the role that we envision our algorithm to play in an Automatic Target Recognition system as well as the avenues for future research stemming from this work.

TA8a2-7
Convergence Analysis of Clipped Input Adaptive Filters Applied to System Identification
Mehdi Bekrani, Andy W. H. Khong, Nanyang Technological University

One of the efficient solutions for identification of long FIR systems is the three-level clipped input LMS/RLS (CLMS/CRLS) adaptive filter. The contribution of this paper is two-fold. We first derive the initial convergence of the CLMS and CRLS algorithm for both time-invariant and time-varying system identification. In addition, to enhance the performance of these algorithms, we derive the optimal step-size and forgetting factor for CLMS and CRLS to achieve a low steady-state misalignment.

TA8a2-8
Sparse RLS Adaptive Filter with Diagonal Loading
Yuriy Zakharov, University of York; Vitor Nascimento, University of São Paulo

In this paper, we propose an adaptive algorithm for sparse identification. The algorithm is based on diagonal loading which attracts sparsity and dichotomous coordinate descent iterations which reduce complexity. Simulation results show that the algorithm has performance close to the performance of the oracle RLS algorithm with perfect knowledge of the support and yet has as low complexity as O(N) operations per sample, where N is the filter length.

TA8a2-9
Distributed Consensus Based Joint Resource and Routing Optimization in Wireless Sensor Networks
Markus Leinonen, Marian Codreanu, Markku Juntti, University of Oulu

We consider distributed total transmit power minimization in single-sink data gathering wireless sensor network via joint optimization of routing and resource allocation with given source rates. There exists numerous decentralized cross-layer optimization algorithms over the physical and network layer which are based on standard dual decomposition. We propose a distributed optimization algorithm based on consensus optimization combined with alternating direction method of multipliers for solving the problem with a small amount of message passing. Numerical examples are provided to illustrate significantly faster convergence of the proposed optimization algorithm compared to the state of the art methods based on dual decomposition.

TA8a2-10
Tracking Analysis of the ε-NSRLMMN Algorithm
Mohammed Faiz, Azzedine Zerguine, King Fahd University of Petroleum and Minerals

In this work, expressions for the tracking excess-mean-square error (EMSE) and optimum step-size of the $\epsilon-$normalized sign regressor least mean mixed-norm (NSRLMMN) adaptive algorithm are derived. Finally, extensive simulation results performed are found to corroborate very closely with the theoretical results for correlated Gaussian data.

TA8a2-11
Homotopy algorithm Using Dichotomous Coordinate Descent Iterations for Sparse Recovery
Yuriy Zakharov, University of York; Vitor Nascimento, University of São Paulo

We propose a computationally efficient technique for recovery of sparse signals, which is based on dichotomous coordinate descent iterations, homotopy, and reweighting. We derive optimal rules for adding and removing elements to/from the support, guaranteeing that the cost function is minimized. Numerical examples show that the proposed technique achieves a mean-squared error smaller than that of the YALL1 algorithm and complexity comparable to that of the matched pursuit algorithm.

TA8a2-12
Hirschman Uncertainty Using Rényi, Instead of Shannon, Entropy is Invariant to the Rényi Entropy Order
Kirandeep Ghuman, Victor DeBrunner, Florida State University

The Hirschman Uncertainty [1] is defined by the average of the Shannon entropies of a discrete-time signal and its Fourier transform. The optimal basis for the Hirschman Uncertainty has been shown to be the picket fence function,as given in a previous paper of ours [2]. In this paper, we develop a new uncertainty measure that incorporates the Rényi entropy instead of the Shannon entropy, and we show that this new uncertainty, which may be viewed as a generalized form of the Hirschman Uncertainty, is in fact invariant to the Rényi entropy order, typically denoted by the term . This powerful characteristic strongly suggests that Hirschman Uncertainty is a fundamental characteristic of digital signals. Note, too, that the picket fence functions found in [2] minimize the generalized Hirschman Uncertainty for all , not just for the Shannon entropy of alpha = 1.

TA8a2-13
Joint Distributed Parameter and Channel Estimation in Wireless Sensor Networks via Variational Inference
Aitzaz Ahmad, Erchin Serpedin, Hazem Nounou, Mohamed Nounou, Texas A&M University

The problem of joint distributed estimation of a source parameter and channel coefficients in a wireless sensor network (WSN) scenario is considered. In order to ease the complexity involved in computing an exact expression for the joint posterior density, a sub-optimal approach based on variational inference is employed, whereby an auxiliary distribution is obtained yielding minimum KL divergence with the true posterior. Assuming an orthogonal access channel between the sensors and the fusion center (FC), explicit expressions are derived for parameter as well as channel matrix distributions, and extensions to vector parameter estimation are also discussed.

TA8a2-14
Performance Analysis for 2-D Convolution Implemented with the 2-D Modified Discrete Fourier Transform
Chandrashekar Radhakrishnan, University of Illinois; William Jenkins, Pennsylvania State University

Recently the Quadratic Modified Fermat Number Transform (QMFNT) was extended to an analogous Modified Discrete Fourier Transform (MDFT) that enables overlap-add FFT block processing to be implemented without zero padding, resulting in reduced computational complexity and lower power requirements for nanoscale VLSI implementations. The MDFT was then extended to two dimensions and an experimental example was presented to illustrate how the 2-D extension manages two-dimensional wrap around effects. This paper presents an analysis of the how the modulation parameters should be chosen under various circumstances and how the computational complexity of the 2D-MDFT compares with more traditional 2D-FFT block processing.

Track A. Communications Systems
Session: TAb8 – Communication Systems II 10:15 AM – 12:00 PM
Chair: ***Yao Xie,*** *Duke University*

TA8b1-1
Experimental Analysis of Cyclostationary Detectors under Cyclic Frequency Offsets
Eric Rebeiz, Paulo Urriza, Danijela Cabric, University of California, Los Angeles

Cyclostationary detection involves detecting cyclic features of modulated signals which are function of the signal's symbol rate and carrier frequency. Typical radio imperfections such as phase noise at the local oscillators and clock jitter at the A/D result in imperfect knowledge of the transmit parameters at the sensing radio. These imperfections result in cyclic frequency offsets which degrade the performance of cyclostationary detectors. In this paper, we propose a cyclic feature detector robust to cyclic frequency offsets, and experimentally show the gains achieved with the proposed method as compared to the conventional cyclostationary detectors.

TA8b1-2
Buffer Aware Power Control for Cognitive Radio Networks
Eman Naguib, Tamer Elbatt, Mohammed Nafie, Nile University

In this paper we study the problem of buffer-aware power control in underlay cognitive radio networks, mainly investigating the role of buffer state information (BSI), manifested through the secondary users' queue lengths, along with their channel state information. Towards this objective, we formulate a constrained optimization problem and cast it into a sequential Geometric Programming formulation to find the set of secondary user transmit powers that maximize the buffer length weighted sum rate subject to signal-to-interference-and-noise-ratio and maximum power constraints. The gathered numerical results confirm the key role BSI plays in balancing the fundamental throughput-delay trade-off in cognitive radio networks.

TA8b1-3
Suboptimal Method for Pilot and Data Power Allocation in Combined Positioning and Communications OFDM Systems
Rafael Montalban, Gonzalo Seco-Granados, Universitat Autònoma de Barcelona; A. Lee Swindlehurst, University of California, Irvine

The use of multicarrier signals for combined positioning and high data rate communications systems requires accurate estimation of timing offset and channel impulse response in order to achieve desirable performance. Previous works have investigated the optimal pilot structures for joint timing offset and channel impulse response estimation, and the capacity maximizing pilot and data power allocation when taking only channel estimation into account. We study the problem of capacity maximization in an OFDM system when a certain time-delay estimation accuracy is required, thus taking into account the capabilities of the designed signal for positioning. We propose a suboptimal method to design pilot and data power allocation using as a criterion a lower bound on capacity and a constraint on the Cramér-Rao bound of the time-delay estimation.

TA8b1-4
Stochastic Online Learning under Unknown Time-Varying Models
Pouya Tehrani, Qing Zhao, University of California, Davis

An online learning problem under stochastic time-varying models is considered. The problem is treated as a generalization of the classic multi-armed bandit problem when the arm distributions are time-varying. The objective is to study the impact of time-varying arm distributions on the performance of the player's strategy. Sufficient conditions on the rate of model variations under which learning can or cannot improve the regret order are established.

TA8b1-5
Spectrum Sensing Scheduling in a Cost-based Framework
Aditya Kelkar, Qi Cheng, Oklahoma State University

In cognitive radio (CR) networks, the efficiency of spectrum sensing is affected by many factors. High sensing accuracy can help reduce interference and improve the spectrum utility. However, it requires a large amount of sensing resources including multiple collaborative CRs/long sensing time. In this paper, a cost-based framework is proposed for spectrum sensing scheduling, in which all these factors are modeled by certain cost or gain of the system. A sequential energy detector is adopted for sensing. Depending on the decision made, the CRs decide whether to wait as the channel is occupied or to start data transmission as there is a spectral hole. The optimal number of CRs, sensing accuracy levels and wait/transmission time are obtained such that the average gain including both sensing and wait/transmission stages are maximized. The effects of various parameters are analyzed.

TA8b1-6
The Optimal Fusion Rule for Cooperative Spectrum Sensing from a Diversity Perspective
Dongliang Duan, Liuqing Yang, Louis L. Scharf, Colorado State University

Cooperation among secondary users can greatly improve the spectrum sensing performance in cognitive radio. In our previous work [1], we proposed the diversity as a measure of the cooperative gain and developed several cooperative spectrum sensing schemes based on some pre-defined local threshold selections. In this paper, we start the cooperative spectrum sensing development from the fusion rule selection. The detailed analysis of two relatively simple and mathematically tractable rules, namely the AND and the OR rules, is provided in this paper. Interestingly, it is found that the AND rule results in the same performance as the non-cooperative sensing strategy and thus cannot achieve diversity gain at all. On the other hand, it is shown that when SNR is large, the OR rule is optimum according to the large deviation analysis [2] and proved to achieve the maximum diversity gain with better performance than our previous sensing scheme developed in [1]. Based on the fixed decision rule, we find the optimal local sensing threshold accordingly. Simulation results are provided to show the performance of our developed cooperative spectrum sensing scheme.

TA8b1-7
Diffuse Mid-UV Communication in the Presence of Obscurants
Derek Young, Jerry Brewer, Jeannette Chang, Tina Chou, Jacques Kvam, Matthew Pugh, Sandia National Labs

Communication using mid-ultraviolet radiation between 200 nm and 280 nm has received renewed attention due to advancements in UV LED emitters and unique propagation characteristics at these wavelengths. Atmospheric gases absorb light at mid-UV so that receivers or sensors operating on the earth's surface receive no interference from solar radiation. This so-called "solar-blind" region of the spectrum allows the use of single-photon detection techniques. Further, UV light is strongly scattered by molecules in the air, enabling non-line-of-sight (NLOS) communication. We extend previous work in this area by incorporating angle-dependent Mie scattering into one of the standard propagation models, in an effort to include the effects of aerosols. Experimental results from outdoor measurements using a fog generator are also presented.

TA8b1-9
Weighted Cyclic Prefix OFDM: PAPR Analysis and Performances Comparison with DFT-Precoding
Damien Roque, GIPSA-lab and DGA; Cyrille Siclet, Jean-Marc Brossier, GIPSA-lab; Pierre Siohan, Orange-Labs

In this paper, we present a weighted cyclic prefix orthogonal frequency-division multiplexing (WCP-OFDM) transceiver as a generalization of traditional cyclic prefix (CP)-OFDM. In time-variant channels, this multicarrier transmission scheme may mitigate inter-channel interference (ICI) thanks to the use of non-rectangular pulse shapes. A precoding step may be required in order to reduce the peak-to-average power ratio (PAPR) at the transmitter output. For instance, a discrete Fourier transform (DFT) precoder leads to a singlecarrier transmission scheme with frequency domain equalization. We analyze the consequences of such a precoding, in terms of performances, in the context of a time-frequency selective channel.

TA8b1-10
Predicting Communications Activity in the Radio Spectrum
David Browne, MIT Lincoln Laboratory

This work is concerned with predicting when incumbent users of the radio spectrum will temporarily vacate a band so that an opportunistic user can communicate. We show that spectrum traffic is modeled as a hidden Markov process and the conditions under which this model holds. We further show how to extend the model to a case of a multiantenna receiver that exploits spatio-temporal covariance for improved prediction. Performance comparisons will be made between existing and proposed approaches using simulated traffic and over-the-air recordings of communications traffic.

TA8b1-11
Cross-Layer Transmission Rate/Power Policy for Cognitive Multi-Access Networks with Imperfect Sensing
Ghada Saleh, Amr El-Keyi, Mohammed Nafie, Nile University

We consider an underlay cognitive radio network with a primary user and a secondary user transmitting to a common receiver. The secondary user senses the primary user's channel to determine whether the primary user is active or idle. The secondary user's transmission policy is determined via a probabilistic cross-layer algorithm in which the secondary user's average packet delay is minimized subject to constraints on its average transmission power and the maximum probability of collision at the primary user. The cross-layer algorithm determines the number of packets the secondary user transmits and the power policy used to transmit these packets.

TA8b1-12
A Cross Layer Routing Protocol for Cognitive Radio Networks Using Channel Activity Tracking
Sandeep Gogineni, Syracuse University; Onur Ozdemir, ANDRO Computational Solutions; Engin Masazade, Chilukuri Mohan, Pramod Varshney, Syracuse University

We propose a cross-layer routing protocol in cognitive radio networks (CRNs), where spectrum sensing, medium access control (MAC) and routing are carried out simultaneously at each node. First, we propose a sensing scheme using a sequential Bayesian estimation procedure, where each sensor computes the posterior probability of channel availability for each frequency band. Then, for the MAC layer, we design a reward metric based on the posterior probability of channel availability and achievable channel capacity. Finally, in the network layer, we adopt a Best-first-search routing algorithm to select the node in the direction of the destination to forward the packet. The performance of the proposed scheme is evaluated by computing the number of successful packet transmissions between a given source - destination pair and the number of collisions with the primary users.

Track B. MIMO Communications and Signal Processing
Session: TAb8 – MIMO Communications and Signal Processing II 10:15 AM – 12:00 PM
Chair: ***Ali Tajer,*** *Wayne State University*

TA8b2-1
Relaying and Base Station Cooperation: a Comparative Survey for Future Cellular Networks
Raphael Rolny, Marc Kuhn, Armin Wittneben, Swiss Federal Institute of Technology Zurich; Thomas Zasowski, Swisscom ICC

We develop a unified framework to investigate the performance of future cellular networks with relays and/or coordinated multipoint (CoMP) transmission. Based on this framework, we study the benefits of CoMP and relaying in a realistic setup. We consider CSI inaccuracies, different power levels, and simple (thus practically relevant) cooperation schemes with different complexity: non-cooperative reference, DF relaying with relay selection, base station cooperation with block zero forcing, and a combination of relaying and CoMP. Based on computer simulations, we compare the different schemes with respect to performance, robustness, complexity, and required transmit power.

TA8b2-2
A Feasibility Study on Opportunistic Interference Alignment: Limited Feedback and Sum-Rate Enhancement

Hyun Jong Yang, Stanford University; Won-Yong Shin, Dankook University; Bang Chul Jung, Gyeongsang National University; Arogyaswami Paulraj, Stanford University

In this paper, we address two feasibility issues of the opportunistic interference alignment (OIA) for multi-input multi-output (MIMO) interfering multiple-access channels. In the conventional OIA framework, it is assumed that a base station (BS) has full information on the weight vector used at each mobile station (MS). Furthermore, a user is selected only for decreasing the other cell interference (for the optimal degrees-of-freedom, DoFs) regardless of its signal channel gain. In practical cellular networks, however, the exact weight vector may not be known at BS due to signaling overhead limitation and the sum-rate is more important performance metric than DoFs. We first propose a codebook-based MIMO OIA scheme in which the weight vector at each MS is chosen from a pre-defined codebook. Simulation results show that the proposed code-based OIA scheme can achieve nearly the optimal performance of the conventional OIA with significantly reduced feedback overhead. We also propose a two-step OIA technique which considers not only interference but also signal channel gain from each MS to its home cell BS. Simulation results show that the proposed two-step OIA technique outperforms the conventional OIA scheme in terms of sum-rate.

TA8b2-3
Joint Interference and Phase Alignment in Multiuser MIMO Interference Channels

Seyed Morteza Razavi, Tharmalingam Ratnarajah, Mathini Sellathurai, Queen’s University Belfast

It has been shown that interference alignment (IA) is able to achieve the capacity of wireless interference networks. However each node requires at least local channel state information (CSI) to align the interference. After that, zero-forcing is needed to recover the d degrees of freedom related to each transmitter-receiver pair. In this paper we present a novel technique consisting of both interference and phase alignment in K-user interference systems employing M-ary phase-shift keying (M-PSK) modulation. We first utilize standard interference alignment (IA) to eliminate the interference caused by each transmitter to the other K-1 receivers. Then instead of performing the zero-forcing (ZF) projections to extract the signal subspace, we utilize the availability of local CSI at each transmitter to align the phases of transmitted symbols such that they add up coherently at the intended receivers and therefore achieve maximum ratio combining diversity of order d for each degree of freedom. This phase alignment precoding gives more instantaneous output SNR without the need to increase the transmitted power. Simulation results show that the proposed joint interference and phase alignment (JIPA) technique achieves higher sum rate and better symbol error performance than ZFIA.

TA8b2-4
User-Aided Sub-Clustering for CoMP Transmission: Feedback Overhead vs. Data Rate Trade-off

Lars Thiele, Fraunhofer Heinrich Hertz Institute

The need for cell densification leads to inter-cell interference mitigation techniques known as coordinated multi- point (CoMP) transmission and reception. This work focuses on the Long Term Evolution - Advanced (LTE-A) frequency division duplex (FDD) downlink. In order to group active users for clustered zero-forcing (ZF) beamforming, we will introduce a greedy user scheduling method using a projection-based rate approximation metric. The clusters are defined in a network- centric fashion, where users are allowed to provide channel feedback for the whole cluster or a sub-set only.

TA8b2-5
Chance Constrained and Ergodic Robust QoS Power Minimization in the Satellite Downlink

Andreas Gründinger, Arailym Butabayeva, Michael Joham, Wolfgang Utschick, Technische Universität München

We focus on the linear beamformer design based on quality-of-service (QoS) power minimization in the satellite downlink with perfect and statistical channel state information (CSI) users. Contrary to the usual rate requirements for the perfect CSI users, we consider either ergodic or outage constrained rate requirements for the statistical CSI users. Modeling the fading channels as zero-mean Gaussian vectors with rank-one covariance matrices, tractable ergodic mutual information and outage probability expressions are obtained. While the resulting outage constrained rate requirements can directly be reformulated to equivalent signal-to-interference-and-noise-ratios (SINRs) this is not possible for the ergodic rate constraints. However, representing the necessary useful signal power of each user as a function of the experienced interference and linearizing this interference function, the usual SINR representation is obtained. Based on this observation, a sequential approximation strategy is proposed that solves a QoS power minimization with standard SINR constraints in each iteration. In the numerical results section, the convergence properties and the achieved performance of this sequential QoS optimization are discussed.

TA8b2-6
Joint Channel and Data Estimation for MIMO Communications with Sparse Pilots
Yejian Chen, Stephan ten Brink, Bell Laboratories, Alcatel-Lucent

We present a joint channel and data estimation algorithm for communication across multiple antenna channels, and illustrate its performance by example of a 2x1 Space-Time Block Coding (STC) scheme as well as a 2x2 Spatial Multiplexing (SMX) scheme. The dedicated trellis tracking algorithm allows to estimate multiple channel coefficients in parallel while simultaneously performing a posteriori Probability (APP) detection of the transmitted bits. Link layer simulations show that the ergodic capacity can be gradually approached with incremental a priori knowledge, as stemming from an outer channel decoder, even in situations with very sparsely distributed pilot symbols, where conventional channel estimators would fail.

TA8b2-7
Simulated Annealing User Scheduling for Coordinated Heterogeneous MIMO Networks
Hakimeh Purmehdi, Robert Elliott, Witold Krzymien, University of Alberta, and TRLabs

In this paper, a reduced complexity simulated annealing user scheduling algorithm to maximize the sum rate for the downlink of a coordinated multi-cell multiple-input multiple-output (MIMO) system is proposed. The users' data signals are transmitted cooperatively via the base stations of a cluster within the sectorized multicell heterogeneous cellular network. Assuming perfect channel state information, the performance of this system with the proposed algorithm is investigated. The simulations demonstrate the effectiveness of the proposed method in terms of sum rate, which is very close to the performance of the optimal but highly complex exhaustive search with much lower complexity.

TA8b2-8
Carrier-Cooperative Zero-Forcing for Power Minimization in Parallel MIMO Broadcast Channels
Stephan Herrmann, Christoph Hellings, Wolfgang Utschick, Technische Universität München

We consider the power minimization problem with per-user minimum rate constraints for parallel multiple-input multiple-output (MIMO) broadcast channels employing zero-forcing beamforming. Recent results have shown that spreading data streams across several carriers—so called carrier-cooperative (CC) transmission—can lead to a reduction of the sum transmit power in such a scenario. However, using state-of-the-art power minimization algorithms based on zero-forcing, only carrier-noncooperative (CN) solutions can be obtained. In this paper, we derive a novel algorithm that is capable of finding CC transmit strategies and can achieve a significant decrease in sum transmit power compared to a conventional zero-forcing power minimization method. The key point of the algorithm is that it combines greedy allocation of data streams, which is a popular technique to optimize zero-forcing strategies, with a gradient-based update of the filter vectors, which is a way to ensure that CC solutions can be obtained. Numerical simulations show that the advantage of the new algorithm is most pronounced in an environment where users have spectrally similar channels.

TA8b2-9
Performance of MMSE Multi-antenna Receiver under Hierarchial Poisson Random Fields of Interferences
Wei Shi, James Ritcey, University of Washington

The cumulative distribution function (CDF) of the signal-to-interference-plus-noise-ratio (SINR) for multi-antenna receiver using optimal combining is studied in this paper. In the presence of hierarchical multi-layer Poisson fields of interferences and independent Rayleigh fading between antennas, the CDF exhibits linear superposition property for multiple layers. This superposition property is used to generalize known results for single layer of homogenous Poisson interferences to multiple-layer, non-homogenous Poisson interferences and clustered Poisson interferences.

TA8b2-10
Concurrent Training and Data Transmission in Multiple-Access Channels
Adriano Pastore, Javier Rodríguez Fonollosa, Universitat Politècnica de Catalunya

We propose a training-based communication scheme for multiple-access channels, in which pilot symbols sent over one link may overlap in time with data symbols sent on another link. Thereby we define a training scheme that is non-orthogonal, given that training periods are not globally time-multiplexed with data transmission phases. The proposed scheme bears similarity with embedded pilot schemes, in that the impact of pilot overhead is reduced, although both approaches are fundamentally different because here, the training and data symbols are not additively combined at the transmit side. An achievable multiple-access ergodic rate region is computed based on well-known worst-case noise mutual information bounds.

TA8b2-11
Best and Worst-Case Statistics for Linear Beamforming in the MISO Correlated Broadcast Channel
Vasanthan Raghavan, University of Southern California; Stephen Hanly, Macquarie University

A spatially correlated broadcast setting with M = 2 antennas at the base-station (BS) and M = 2 users (each with a single antenna) is considered. The users are assumed to have perfect channel state information (CSI) about their links and the BS has only statistical information about each user's link. A linear beamforming strategy is employed at the BS with one spatial eigenmode allocated to each user. Two CSI-based schemes are considered in this work: an optimistic perfect CSI-based minimum mean-squared error (MMSE) beamforming scheme and a pessimistic statistical linear beamforming scheme. It is of interest to understand the gap in ergodic sum-rate achievable with these two schemes across a large class of channel covariance matrices. In particular, the set of covariance matrices that maximize (or minimize) this gap correspond to settings where the utility of channel state feedback is maximized (or minimized). Initial results are provided to address this problem in the low- and the high-SNR extremes with an outline provided for completing this program and addressing other interesting settings.

TA8b2-12
From Single- to Multi-User Scheduling in LTE-A Uplink Exploiting Virtual MIMO
Martin Kurras, Lars Thiele, Fraunhofer Heinrich Hertz Institute

In Long Term Evolution - Advanced (LTE-A) uplink user equipments (UEs) can be equipped with more than one transmit antenna. This is taken into account in this paper by investigations on beam-forming in terms of quantization by codebooks and feedback granularity in frequency domain. After this parameter study a scheduling algorithm from literature is taken and extended towards fairness in terms of scheduled resources. The main contribution of this paper is that we extend this single-user (SU) scheduling algorithm to a multi-user (MU) scheduling algorithm exploiting virtual multiple-input multipleoutput (MIMO). Note that our proposed algorithm can be applied on any SU scheduler. The continuous bandwidth constraint for assigned resources in uplink is considered through this paper. The evaluation is done by extensive system level simulations in a 3GPP conform multi-cell scenario. Initial results show that our MU scheduling extension exploiting virtual MIMO, can improve the system throughput by approximately 33 % compared to standard SU scheduling in uplink.

Track G. Architecture and Implementation
Session: TAb8 – Architecture and Implementation of Signal Processing Systems **10:15 AM – 12:00 PM**
Chair: ***Jörn W. Janneck,*** *Lund University*

TA8b3-1
Receiver Implementations for Co-Channel Interference Suppression in MIMO-OFDM
Johanna Ketonen, Markku Juntti, University of Oulu

Suppression of co-channel interference in the receiver of a MIMO-OFDM system is considered. The interference and noise spatial covariance matrix measured on the pilot subcarriers is used in data detection. The impact of the accuracy of the matrix decomposition on the structure of the covariance matrix is studied. An algorithm to adapt the accuracy of the matrix decomposition and the use of interference suppression is proposed. The complexity and performance of eigenspace tracking is also considered. The different interference mitigation methods are implemented. Eigenspace tracking performs well in some scenarios but the complexity and memory requirements are high. A good performance is achieved with the adaptive algorithm in all interference scenarios and the power consumption of the receiver can be reduced by adapting the interference mitigation.

TA8b3-2
Implementation of LS, MMSE and SAGE Channel Estimators for Mobile MIMO-OFDM
Johanna Ketonen, Markku Juntti, University of Oulu; Jari Ylioinas, Nokia Siemens Networks; Joseph R. Cavallaro, Rice University

The use of decision directed (DD) channel estimation in a MIMO-OFDM downlink receiver is studied in this paper. The 3GPP LTE based pilot structure is used as a benchmark. The space-alternating generalized expectation-maximization (SAGE) algorithm is used to improve the performance from that of the pilot symbol based least-squares (LS) channel estimator. The DD channel estimation improves the performance with high user velocities, where the pilot symbol density is not sufficient. It can also be used to reduce the pilot overhead without any performance degradation. Minimum mean square error (MMSE) filtering can also be used in estimating the channel in between pilot symbols. The pilot based LS, MMSE and the SAGE channel estimators are implemented and the performance-complexity trade-offs are studied.

TA8b3-3
Low Complexity Opportunistic Decoder for Network Coding
Bei Yin, Michael Wu, Guohui Wang, Joseph R. Cavallaro, Rice University

In this paper, we propose a novel opportunistic decoding scheme for network coding which reduces the decoder complexity and increases throughput. Network coding can significantly improve throughput and reliability, especially for multicast transmissions. The complexity of the network decoding algorithm is high, especially when the size of the network coding coefficient matrix is large. Although different software and hardware approaches were proposed to accelerate the decoding algorithm, the decoder remains to be the bottleneck. In this paper, we propose a novel decoding scheme by exploiting the structure of the network coding matrix. In addition, we implement the scheme on FPGA and show that compared with the widely used Gaussian elimination, our scheme reduces the decoding complexity and improves the throughput.

TA8b3-4
Sparse Polynomial Equalization of an RF Receiver via Algorithm, Analog, and Digital Codesign
Andrew Bolstad, Benjamin A. Miller, Karen Gettings, Mike Ericson, Helen Kim, Merlin Green, Dan Santiago, MIT Lincoln Laboratory

Nonlinear circuit behavior degrades system performance of RF receivers operating near the compression point, causing both in-band and out-of-band distortions. Linearity can be improved through analog design changes at the cost of greater power consumption. Alternatively, digital compensation algorithms can alleviate nonlinear distortions, but standard combinatorial models of nonlinear system behavior can require high-power digital circuits. We present preliminary results of a co-optimized receiver and digital equalizer achieving 80 dB spur free dynamic range over 49 MHz while dissipating 132 mW. We describe the codesign process used to optimize power consumption across analog and digital circuits while meeting high linearity requirements.

TA8b3-5
Implementation of a QPSK Transceiver for Software Defined Radio on a Graphic Processing Unit (GPU)
Rehan Muzammil, M. Salim Beg, The Aligarh Muslim University; Mohsin M. Jamali, University of Toledo

High transmission bit rate in wireless channels gives rise to severe Inter-Symbol Interference (ISI) and this makes the detection task very challenging. In such cases, Near-Maximum-Likelihood (NML) detection provides good performance. This work presents parallel implementation of a QPSK transceiver using NML detection on an NVIDIA Graphics Processing Unit (GPU) for Software Defined Radio (SDR) systems. The data is transmitted over a frequency selective channel and experimental results are obtained. Results for varying Signal to Noise Ratios (SNR) for different channel configurations are compared and are shown in this summary.

TA8b3-6
Karatsuba Implementation of FIR Filters
Pietro Albicocco, Gian Carlo Cardarilli, Salvatore Pontarelli, Marco Re, University of Rome Tor Vergata

In this paper, the authors propose the implementation of a programmable Finite Impulse Response (FIR) filter based on the use of the Karatsuba formula. The Karatsuba formula is used to speed-up the multiplication of large numbers by splitting the operands in two parts of equal length. In the paper, experiments based on a STM 90 nm technology implementing FIR filters in transposed form show a reduction in the hardware complexity, low power consumption and increased speed.

TA8b3-7
Real-Time Hardware Design for Improving Laser Detection and Ranging Accuracy
Jarrod Brown, Graduate Student; Clay Hughes, Linda DeBrunner, Florida State University

Digital signal processing algorithms for estimating target range and backscatter intensity from laser detection and ranging systems are limited by the sampling rate of data collected and computation time requirements. An interpolating matched filter algorithm, deployed on a field programmable gate array, improves range accuracy while maintaining a low sampling rate. Research and simulation results comparing the effectiveness of different reference waveform models and interpolation factors are presented. A matched filter with zero padding interpolation using a Gaussian shape reference waveform and an interpolation factor of 32 showed an 87% improvement in range accuracy over the peak detector design currently used in real-time LADAR systems.

TA8b3-8

Dataflow Programming in CAL—Balancing Expressiveness, Analyzability, and Implementability

Johan Eker, Ericsson Research; Jörn Janneck, Lund University

Dataflow programming and the CAL language is presented as a means to address current challenges in program- ming parallel hardware such as multicore systems and FPGAs. The careful design of the CAL language, where expressiveness is balanced with analyzability and implementability makes it a promising tool for implementation of parallel applications. The language itself as well as the design considerations are presented and illustrated with a number of different use cases from a wide range of application domains.

Track A. Communications Systems

Session: TPa1 – Network Optimization

Chair: ***Atilla Eryilmaz,*** *Ohio State University*

TP1a-1 **1:30 PM**

Joint Transmission Scheduling and Congestion Control for Adaptive Streaming in Wireless Device to Device Networks

Dilip Bethanabhotla, Giuseppe Caire, Michael Neely, University of Southern California

This paper considers the jointly optimal design of transmission scheduling and admission control for adaptive streaming over wireless device to device networks. We formulate the problem as a dynamic network utility maximiza- tion and observe that the resource allocation decomposes into the subproblems of admission control and transmission scheduling. The algorithms designed are simple and can be implemented in a distributed fashion without centralized control. The admission control decision involves each user adaptively deciding the quality of the video chunk that it should download based on the network congestion it observes in its immediate neighborhood. This form of admission control is compatible with the current trend of video streaming with DASH protocol over HTTP. This paper also provides deterministic bounds on the delay with which data is received from various queues in the network. This deterministic delay bound enables users to stream video smoothly without interruptions by pre-fetching and initially filling up their buffers with the appropriate number of chunks.

TP1a-2 **1:55 PM**

Gossip-Based Random Projection Algorithm for SVMs

Lee Soo Min, Angelia Nedich, University of Illinois, Urbana-Champaign

We present distributed random projected-gradient algorithm for Support Vector Machines (SVMs) that can be used by multiple agents communicating over a network. The agents need to cooperatively find a separating hyperplane for the data that is distributed among them in the network. In the primal SVM formulation, the objective function is given as a sum of convex functions and the constraint set is an intersection of a collection of constraint sets. Each agent minimizes a local objective subject to its local constraint sets, and it maintains its own estimates that are communicated to its local neighbors. The agents communicate over a connected network according to a gossip model. The novel part of the proposed algorithm is a random selection of a constraint set for estimate update. We investigate convergence behavior of the algorithm and present some simulation results.

TP1a-3 **2:20 PM**

Random Hamiltonian Cycles with Random Link Deletions

Joohwan Kim, R. Srikant, University of Illinois, Urbana-Champaign

We are motivated by the problem of designing peer-to-peer network topologies with optimal delay properties. In earlier work, we showed that topologies constructed from random Hamilton cycles have small neighborhood sizes while also delivering near-optimal throughput and streaming delay. In this paper, we will explore the robustness properties of this algorithm.

TP1a-4 **2:45 PM**

Temporal Statistical Characterization of Interference for Joint Encoding and Random Access

C. Emre Koksal, Atilla Eryilmaz, Nithin Sugavanam, Oklahoma State University

We consider a random extended network with nodes remaining active for a generally distributed random duration. We characterize the temporal statistical properties of the multiuser interference experienced by a typical node. Based on the insights drawn, we develop a joint encoding and random access scheme. We analyze the performance of our scheme and discuss the impact of the use of adaptive power control on the individual and global performance.

Track D. Signal Processing and Adaptive Systems

Session: TPb1 – Distributed Signal Processing

Co-Chairs: ***Hongbin Li,*** *Stevens Institute of Technology* ***and Jun Fang,*** *Stevens Institute of Technology*

TP1b-1 **3:30 PM**

Gossip-based Distributed Stochastic Approximation: The Price of Non-double Stochasticity

Gemma Morral, Pascal Bianchi, Gersende Fort, Institut Telecom / Telecom ParisTech / CNRS-LTCI; Jérémie Jakubowicz, Institut Telecom / Telecom Sud Paris

This paper investigates the problem of distributed stochastic approximation in multi-agent systems. The algorithm under study consists of two steps: a local stochastic approximation step at each agent and a gossip step that drives the network to a consensus. The gossip step uses row-stochastic matrices to weight network exchanges. Gossip-matrices are often also assumed column-stochastic in the literature. Unfortunately, column-stochasticity implies significant restrictions on the communication protocol and prevents from using simple broadcast protocols. Under the assumption of decreasing step sizes, it is proved that the network is driven to a consensus at overwhelming speed and that the average estimate converges to the desired points. When the gossip matrices are doubly stochastic, a central limit theorem is established and it is proved that the performance of the algorithm is identical to that of a centralized algorithm. When the gossip matrices are non doubly stochastic, the normalized estimation error converges in distribution to a Gaussian mixture. In that case, a performance gap w.r.t. the centralized algorithm exists and is characterized.

TP1b-2 **3:55 PM**

Distributed Maximum a Posteriori Probability Estimation for Tracking of Dynamic Systems

Felicia Jakubiec, Alejandro Ribeiro, University of Pennsylvania

We present a framework for the estimation of time-varying random signals with wireless sensor networks. Given a continuous time model, sensors collect noisy observations according to the discrete-time equivalent system defined by the sampling period of observations. Estimation is performed locally using a maximum a posteriori probability estimator (MAP) within a time window. To incorporate information from neighboring sensors we introduce Lagrange multipliers to penalize the disagreement between estimates. We show that the distributed (D-) MAP algorithm is able to track dynamical signals with an error characterized in terms of problem constants. This error vanishes with the sampling period if the log-likelihood function satisfies a smoothness condition.

TP1b-3 **4:20 PM**

Identifying Multiple Infection Sources in a Network

Wuqiong Luo, Wee Peng Tay, Nanyang Technological University

Estimating which nodes are the infection sources that introduce a virus or rumor into a network, or the locations of pollutant sources, plays a critical role in limiting the potential damage to the network through timely quarantine of the sources. In this paper, we derive estimators for the infection sources and their infection regions based on the infection network geometry. We show that in a geometric tree with at most two sources, our estimator identifies these sources with probability going to one as the number of infected nodes increases. We extend and generalize our methods to general graphs, where the number of infection sources are unknown and there may be multiple sources. Numerical results are presented to verify the performance of our proposed algorithms under different types of graph structures.

TP1b-4 **4:45 PM**

Distributed Learning in Large Scale Multi-Agent Games: A Modified Fictitious Play Approach

Brian Swenson, Soummya Kar, Carnegie Mellon University

The paper concerns the development of distributed equilibria learning strategies in large-scale multi-agent games with repeated plays. With inter-agent information exchange being restricted to a pre-assigned communication graph, the paper presents a modified version of the fictitious play algorithm that relies only on local neighborhood information exchange for agent policy update. Under the assumption of uniform agent utility functions that are permutation-invariant, the proposed distributed algorithm leads to convergence of the agent empirical play histories to a subset of the Nash equilibria, designated as the consensus-equilibria. Applications of the proposed distributed framework to strategy design problems encountered in large-scale traffic networks are discussed.

TP1b-5 **5:10 PM**

An Iterative Precoding Approach for Joint Transmission of Distributed Correlated Sources

Jun Fang, University of Electronic Science and Technology of China; Hongbin Li, Stevens Institute of Technology

We consider the problem of transmitting multiple spatially distributed correlated sources to a common destination (e.g. a fusion center or an access point) in wireless sensor networks (WSNs). The correlated data from multiple sensors are jointly transmitted to the destination via orthogonal channels. We assume that the channel between each sensor and the receiver is multiple-input multiple-output (MIMO), with each sensor and the receiver equipped with multiple transmit/receive antennas. In this framework, we study the problem of joint design of linear precoders for all sensors by assuming the knowledge of the instantaneous channel state information (CSI), with the objective of maximizing the mutual information between the sources and the destination. We propose a Gauss-Seidel iterative approach which successively optimizes the precoding matrix associated with each sensor, while fixing the other precoding matrices. Numerical results show that the algorithm provides an effective solution with a fast convergence rate.

Track C. Networks

Session: TPa2 – Consensus Based Algorithms

Chair: ***Lara Dolecek,*** *University of California, Los Angeles*

TP2a-1 **1:30 PM**

Toward Resource-Optimal Averaging Consensus over the Wireless Medium

Matthew Nokleby, Rice University; Waheed U. Bajwa, Rutgers; Robert Calderbank, Duke University; Behnaam Aazhang, Rice University

We carry out a comprehensive study of the resource costs of distributed averaging consensus in wireless sensor networks. In particular, we consider two metrics appropriate to the wireless medium: total transmit energy and time-bandwidth product. Most previous approaches, such as gossip algorithms, focus only on the total number of transmissions, which only approximates the required resources. Under a path-loss dominated protocol interference model, we study the performance of several popular gossip algorithms, showing that they are nearly order-optimal with respect to transmit energy but strictly sub-optimal with respect to time-bandwidth product. We also propose a hierarchical scheme, tailored for the wireless medium, and show that in general this approach is nearly order-optimal with respect to time-bandwidth product but strictly sub-optimal with respect to transmit energy. For the special case of free-space propagation, however, the proposed hierarchical scheme is approximately order-optimal with respect to both metrics.

TP2a-2 **1:55 PM**

Distributed Average Consensus Using Bounded Transmissions

Sivaraman Dasarathan, Mahesh Banavar, Cihan Tepedelenlioglu, Andreas Spanias, Arizona State University

The problem of estimating the average of samples measured at the nodes of a network is considered. A distributed consensus algorithm in which every sensor maps its state value through a bounded function before transmission is proposed. It is shown that when the step size of the algorithm is chosen appropriately, the state values of all the nodes converge exponentially to the sample average of the initial observations provided that the transmission function has a bounded first derivative. The convergence factor is shown to depend on the derivative of the transmission function and its optimization with respect to a design parameter is discussed. The performance of various bounded transmission functions are studied through simulations. It is illustrated that functions whose derivative is uniformly large converge faster.

TP2a-3 **2:20 PM**

Distributed Gram-Schmidt Orthogonalization Based on Dynamic Consensus

Ondrej Sluciak, Vienna University of Technology; Hana Strakova, University of Vienna; Markus Rupp, Vienna University of Technology; Wilfried Gansterer, University of Vienna

We propose a novel distributed QR factorization algorithm for orthogonalizing a set of vectors in a wireless sensor network. The algorithm originates from the classical Gram-Schmidt orthogonalization which we formulate in a distributed way using the dynamic consensus algorithm. In contrast to existing distributed QR factorization algorithms, all elements of matrices Q and R are computed simultaneously and updated iteratively after each transmission. Assuming synchronous message broadcasting and communication only with neighboring nodes without any central computing unit (fusion center), we prove convergence of the algorithm. We investigate the algorithm in terms of numerical accuracy and we discuss the influence of the initial data distribution on the algorithm performance. Moreover, we provide a comparison with existing distributed QR algorithms in terms of communication cost and memory requirements, and we illustrate the comparison by simulations.

TP2a-4 **2:45 PM**

Simultaneous Distributed Sensor Self-Localization and Target Tracking Using Belief Propagation and Likelihood Consensus

Florian Meyer, Erwin Riegler, Ondrej Hlinka, Franz Hlawatsch, Vienna University of Technology

We propose a distributed simultaneous localization and tracking (SLAT) algorithm that jointly performs cooperative sensor self-localization (CSL) and distributed target tracking (DTT) in a wireless sensor network without a fusion center. The SLAT algorithm is a combination of an iterative message passing scheme on a factor graph with a likelihood consensus scheme. The latter is applied to parametric messages in order to convey relevant information to all sensors. Simulation results demonstrate the improved performance of the SLAT algorithm compared to state-of-the-art separate CSL and DTT algorithms.

Track D. Signal Processing and Adaptive Systems

Session: TPb2 – Cooperative Adaptation and Learning

Co-Chairs: ***Danilo Mandic,*** *Imperial College* ***and Ali Sayed,*** *University of California, Los Angeles*

TP2b-1 **3:30 PM**

Mean-Square Analysis of Continuous-Time Distributed Estimation Strategies

Vitor Nascimento, University of São Paulo; Ali Sayed, University of California, Los Angeles

We have recently proposed continuous-time distributed learning strategies that allow a network of nodes to share the information they gather from their surroundings, and collectively solve a common problem. Using deterministic arguments, we were able to prove that, under certain conditions, these strategies are able to solve problems that the individual nodes alone would not be able to tackle. In this work we study these continuous-time strategies from a stochastic point of view, showing the underlining cost function that is solved by the network and evaluating the influence of noise in the quality of the solution computed by the network.

TP2b-2 **3:55 PM**

Extrinsic Gossip and Reducing Self-reinforcement in Distributed Consensus

Andrew Bean, Angelia Nedich, Andrew Singer, University of Illinois, Urbana-Champaign

The traditional framework for gossip exchanges local information with neighbors enabling local interactions to be reinforced in a manner reminiscent of short cycle behavior of iterative decoding of LDPC codes under belief propagation. In this paper we study the convergence behavior of iterative consensus algorithms in which local, self-reinforcement is impeded through a modification of the standard "gossip" update, which we call "extrinsic gossip." We also investigate the impact of the network connectivity structure on the convergence.

TP2b-3 **4:20 PM**

Non-linear Least Squares Estimation via Network Diffusion

Simon Li, Anna Scaglione, University of California, Davis

Network diffusion algorithms are proving to be powerful methods to solve non-linear optimization problems. Among them, classical non-linear least square problems are frequently well matched to sensor observations. Unfortunately, convergence proofs rest on the convexity of the functions considered and the question is if it is possible to regularize and relax the problem to address a more general class of scenarios. In particular, we consider a case where special state-sensors in the network have

a partial observation of the unknown state, and others observe a non-linear function of the state embedded in noise. This is the case of the power grid, where special costly sensors nowadays are able to read directly state variables, while the predominant sensors readings are non-linearly related with the state vector. We show that convergence can critically depend on the placement of the state-sensors and that the network can learn its global state via near-neighbours communications efficiently, which is a first important step to introduce intelligent decentralized wide area control.

TP2b-4 4:45 PM

Fast Cooperative Distributed Learning

Dusan Jakovetic, Jose M F. Moura, Joao Xavier, Carnegie Mellon University

We present fast gradient like algorithms for cooperative learning and classification that converge O(1/k) where k is the number of iterations. This compares very favorably with other recently proposed distributed gradient optimization algorithms that converge O(1/\sqrt{k}). We present the cooperative algorithm, show its convergence rate, and apply it to a learning problem and to spectral sensing in cognitive radio.

TP2b-5 5:10 PM

Exploiting the Noncircularity of Complex Cooperative Learning Systems

Dahir Dini, Danilo Mandic, Imperial College London

We consider complex valued adaptive diffusion (cooperative learning) systems, in conjunction with the recently introduced ‘augmented complex statistics’ and widely linear modelling, which allow for a unified framework for dealing with both second order circular (isotropic) and noncircular (anisotropic) complex signals. The analysis shows that the widely linear strategies offer more degrees of freedom and higher accuracy compared to the standard ‘strictly linear’ approaches. Simulations on synthetic benchmark and real-world renewable energy noncircular data support the analysis.

Track D. Signal Processing and Adaptive Systems

Session: TPa3 – Information Theoretic Signal Processing

Co-Chairs: ***P. P. Vaidyanathan,*** *California Institute of Technology* ***and Piya Pal,*** *California Institute of Technology*

TP3a-1 1:30 PM

The Gaussian CEO Problem for a Scalar Source with Memory: A Necessary Condition

Jie Chen, Feng Jiang, Arnold Swindlehurst, University of California, Irvine

In wireless sensor networks, many monitoring problems can be cast in the form of distributed data collection and centralized data fusion. If the data links from the sensors to the fusion center have limited capacity, there is a tradeoff between estimation precision and transmission rate. This is equivalent to the so-called indirect multiterminal source coding problem, and the Berger-Tung inner bound is the best known achievable rate region boundary. In this paper, we attempt to evaluate the Berger-Tung achievable sum rate for a Gaussian scalar source with arbitrary memory, and we find an analytic necessary condition which the solution to the sum rate problem must satisfy. Based on our analytic form of the condition, we discuss how to compute the rate-distortion curve. We also note that the solution is compatible with previous findings in rate distortion theory.

TP3a-2 1:55 PM

Empirical Rate-Distortion Study of Compressive Sensing-based Joint Source-Channel Coding

Muriel L. Rambeloarison, Soheil Feizi, Georgios Angelopoulos, Muriel Medard, Massachusetts Institute of Technology

In this paper, we present an empirical rate-distortion study of a communication scheme that uses compressive sensing (CS) as joint source-channel coding. We investigate the rate- distortion behavior of both point-to-point and distributed cases. First, we propose an efficient algorithm to find the L1- regularization parameter that is required by the Least Absolute Shrinkage and Selection Operator which we use as a CS decoder. We then show that, for a point-to-point channel, the rate- distortion follows two distinct regimes: the first one corresponds to an almost constant distortion, and the second one to a rapid distortion degradation, as a function of rate. This constant distortion increases with both increasing channel noise level and sparsity level, but at a different gradient depending on the distortion measure. In the distributed case, we investigate the rate-distortion behavior when sources have temporal and spatial dependencies. We show that, taking advantage of both spatial and temporal correlations over merely considering the temporal correlation between the signals allows us to achieve an average of a factor of approximately 2.5x improvement in the rate-distortion behavior of the joint source-channel coding scheme.

TP3a-3 **2:20 PM**

Greedy Adaptive Measurements with Signal and Measurement Noise

Entao Liu, Edwin Chong, Louis Scharf, Colorado State University

The purpose of this article is to examine greedy adaptive measurement policies in the context of a linear Gaussian measurement model with an optimization criterion based on information gain. In the special case of sequential scalar measurements, we provide sufficient conditions under which the greedy policy actually is optimal in the sense of maximizing the net information gain. In the general setting, we also discuss cases where the greedy policy is not optimal.

TP3a-4 **2:45 PM**

Role of Bandwidth in the Quality of Inversion of Linear Multirate Systems with Noise

P. P. Vaidyanathan, Piya Pal, California Institute of Technology

A multirate system called the fractional sampling rate alteration system makes frequent appearance in many signal processing applications including fractionally spaced equalizers (FSE) and in multirate feedback control. In some applications it is necessary to invert this system, as in the example of a zero-forcing FSE. There is usually noise at the input of the inverse, and the noise amplification properties depend crucially on the bandwidth of the original system, as shown in this paper. Even though this effect is qualitatively known in FSE applications, the purpose of this paper is to provide the quantitative theoretical foundations for this effect. It will be shown that if the system has excess bandwidth, then the noise gain can be readily controlled, whereas unbounded noise amplification can result if there is no excess bandwidth.

Track A. Communications Systems

Session: TPb3 – Underwater Communications

Chair: ***Geert Leus,*** *Delft University of Technology*

TP3b-1 **3:30 PM**

Differentially Coherent OFDM with Fractional FFT Demodulation

Yashar M Aval, Millica Stojanovic, Northeastern University

OFDM supports differentially coherent detection in each narrow subband, thus offering an appealing alternative to single-carrier modulation when channel variation aggravates coherent tracking. We advocate the use of differential encoding in frequency domain, as it capitalizes on bandwidth-efficient designs with narrow carrier spacing, and propose a detection method that deals with attendant inter-carrier interference. The receiver uses several FFT demodulators, each offset by a fraction of carrier spacing, and combines their outputs in a manner that minimizes the error in data detection. Extensive real data results demonstrate the capability to outperform coherent detection, at low overhead and without front-end resampling.

TP3b-2 **3:55 PM**

Channel Estimation for Multi-layer Block Transmissions over Underwater Acoustic Channels

Srinivas Yerramalli, University of Southern California; Zijian Tang, Netherlands Organization for Applied Scientific Research; Urbashi Mitra, University of Southern California

Underwater acoustic channels can be represented by a multi-scale, multi-lag (MSML) channel model in which the transmitted signal reaches the receiver via diverse propagation paths with the distortion on each path governed by a distinct time scale. Recently, a discretized version of the MSML channel for passband signaling was proposed which enables multi-layer signaling over underwater channels. The received signal is characterized by inter-scale interference in addition to delay spread. In this paper, a new channel estimation scheme to estimate multi-layer channel coefficients is proposed. Different from traditional channel estimation algorithms, the proposed algorithms takes into account inter-scale interference and enables the equalization of multi-layer transmissions over UWA channels.

TP3b-3 **4:20 PM**

Outage Performance of a Multiuser Distributed Antenna System in Underwater Acoustic Channels

Zhaohui Wang, Shengli Zhou, University of Connecticut; Zhengdao Wang, Iowa State University; Josko Catipovic, Naval Undersea Warfare Center; Peter Willett, University of Connecticut

Recently considerable attention has been paid to the underwater acoustic networks. Although various networking protocols have been proposed, information-theoretical analysis on the network capacity is quite limited. In this work, we focus on the outage performance of the underwater distributed antenna system (DAS) with multiple users, which consists of randomly distributed

users within an operation area, and geographically distributed base stations which are cable-connected. With the acoustic signal attenuation in underwater taking into account, both the uplink and downlink outage performance of the DAS system are investigated by varying system parameters, such as the number of users, the antenna location, and the size of the operation area. Extensive numerical results are used to validate our analytical results.

TP3b-4 **4:45 PM**

Underwater Channel Aware Routing

Paolo Casari, Matteo Lazzarin, Michele Zorzi, University of Padova

In this paper, we address the problem of routing in underwater networks in the presence of fading. We define the utility related to the choice of a given relay in terms of the probability that the this relay experience a channel power gain that exceeds a given threshold. We express this utility as a function of range and depth of each relay using heuristic function that approximate the spatial variation of the relay utility, and compare our policies against channel-oblivious policies and as well as optimum policies based on the full knowledge of the channel propagation.

TP3b-5 **5:10 PM**

Soft-Adaptive Turbo Equalization- Using Soft Information in Adaptation

Atulya Yellepeddi, Massachusetts Institute of Technology/Woods Hole Oceanographic Institute; James Preisig, Woods Hole Oceanographic Institute

Turbo equalizers have been exploited in communication systems due to their excellent performance in practice. In many scenarios, including wireless underwater acoustic communication, the equalizer needs to be adaptive. This paper proposes a method to make use of the soft information available in the turbo loop in the adaptation process. We demonstrate by testing the system with data from the KAM11 experiment that using soft information in adaptation improves the performance of the system over just using this information in the feedback filter, which is an approach that has been taken in the past. We explore how to combine these various approaches and the effect that this has on performance in various scenarios.

Track A. Communications Systems

Session: TPa4 – Decoding and Detection

Chair: ***Rodrigo de Lamare,*** *University of York*

TP4a-1 **1:30 PM**

Low-Complexity and Approximative Sphere Decoding of Sparse Signals

Benjamin Knoop, Till Wiegand, Steffen Paul, University of Bremen

Multiuser detection can be implemented at the sink of a sensor network to receive the various signals of its sensor nodes. Assuming low transmission activities, the sparse nature of the sensor signals can be utilized. In this paper, we propose a sphere decoding algorithm based on an extended distance metric that takes the a priori probability into account. By intentionally violating the ideal check of the sphere constraint, many improbable transmit hypotheses can be dismissed early, thus reducing decoding complexity but without notable loss of quality.

TP4a-2 **1:55 PM**

Dynamic Threshold Schemes for Multi-Level Nonvolatile Memories

Frederic Sala, Ryan Gabrys, Lara Dolecek, University of California, Los Angeles

In nonvolatile memories, reading stored data is typically done through the use of predetermined fixed thresholds. However, due to problems commonly affecting such memories, including voltage drift, overwriting, and inter-cell coupling, fixed threshold usage often results in significant asymmetric errors. To combat these problems, the notion of dynamic thresholds was introduced and applied to the reading of binary sequences. In this paper, we explore the use of dynamic thresholds for multi-level cell (MLC) memories. We provide a general scheme to compute and apply dynamic thresholds and derive performance bounds. We show that the proposed scheme compares favorably with the optimal thresholding scheme. Finally, we develop asym- metric limited magnitude error-correcting codes tailored to take advantage of dynamic thresholds.

TP4a-3 **2:20 PM**

Iterative Detection and Decoding for MIMO Systems with Knowledge-Aided Belief Propagation Algorithms

Jingjing Liu, Peng Li, Rodrigo de Lamare, University of York

We consider the problem of iterative detection and decoding (IDD) for multi-antenna systems with LDPC codes. Two novel belief propagation algorithms are proposed, which exploit the knowledge about short cycles in the graph structure and hypergraph's expansion. Simulation results show that both proposed algorithms consistently outperform existing algorithms when performing IDD in multi-antenna systems with a small number of decoding iterations.

TP4a-4 **2:45 PM**

Quantization, Absorbing Regions and Practical Message Passing Decoders

Behzad Amiri, University of California, Los Angeles; Shayan Garani Srinivasa, Western Digital Corporation; Lara Dolecek, University of California, Los Angeles

Low-density parity-check (LDPC) codes and accompanying message passing decoding algorithms are a popular choice for data encoding and decoding in modern communications and storage systems. To reduce implementation complexity, the messages in a practical message passing decoder are necessarily quantized. While it is well-known that the performance of practical message passing decoders in the high-reliability regime is governed by non-codeword decoding errors, a precise characterization of the relationship between such errors, the quantization choice and the overall performance is still missing. Absorbing regions act as ``decoding regions'' around certain non-codeword fixed points known as absorbing sets. In this work, we take a closer look at the interplay between quantization and absorbing regions. We provide the first comprehensive study of a range of quantization choices, the impact of quantization on the candidate absorbing regions, and derive guidelines for practical decoders. We show that, due to the non-linear dynamics of message passing decoders, coarser quantization may in fact perform better than finer quantization. Results of the type presented in this work can be particularly useful in designing high-performance decoders for very high-reliability storage systems, such as emerging data storage hard disk and solid state drives.

Track C. Networks

Session: TPb4 – Smart Grid Communications and Networks

Co-Chairs: ***Anna Scaglione,*** *University of California, Davis* ***and Zhifang Wang,*** *University of California, Davis*

TP4b-1 **3:30 PM**

Demand Response in Radial Distribution Networks

Na Li, Lingwen Gan, Steven Low, California Institute of Technology; Lijun Chen, University of Colorado at Boulder

This paper studies real-time demand response in a radial distribution network to compensate electricity supply deficit, by formulating it as a social welfare maximization subject to power flow constraints and operation constraints. The resulting problem is nonconvex and thus difficult to solve. We propose a convex relaxation and provide several sufficient conditions under which the relaxation is exact. Based on the convex relaxation, we propose a distributed demand response algorithm to coordinate the user consumptions to maximize the social welfare.

TP4b-2 **3:55 PM**

Competitive Privacy in the Smart Grid

Lalitha Sankar, Princeton University; Soummya Kar, Carnegie Mellon University; H. Vincent Poor, Princeton University

The requirement of wide-area monitoring in the deregulated electric grid is driving the need for distributed state estimation. This leads to a novel problem of competitive privacy amongst energy providers (operators) that captures the conflict between the need for collaboration to estimate the global system state with high fidelity (utility) and the need to withhold data (privacy) for competitive reasons. The precise tradeoff between utility and privacy is made explicit using rate distortion theory with privacy constraints. Practical implementation using message passing is introduced and discussed.

TP4b-3 **4:20 PM**

Secure Network and Information Architectures for Smart Grid Data Analysis and Control

Marina Thottan, Young Jin Kim, Gary Atkinson, Bell Laboratories, Alcatel-Lucent

The Smart Grid is being referred to as the "Energy Internet of the Future". However there are fundamental differences between the Internet and the energy grid. The energy grid is used to actuate physical systems and therefore requires very stringent communication and security requirements. This is especially the case with the advent of Smart Grid applications such as electric vehicles and renewable energy sources that can significantly impact the stability and operation of the grid. This talk will highlight the research challenges that need to be addressed to design a secure and reliable network and information architecture. The architecture is expected to support data sharing, analytics and control functions that are necessary for reliable and secure grid operation. Innovative communications and information technology solutions that are essential to meet the design challenges for a modern electric grid will also be presented.

TP4b-4 **4:45 PM**

The Impact of Volatile Generation/Load Profile in Smart Grid on the Grid Vulnerability to Cascading Overload Failures

Zhifang Wang, Virginia Commonwealth University

The cascading failures are severe threats to modern power grid operations. Smart grid will face even more volatile generation/load therefore transmission profiles, due to the introduction of intermittent renewable generations, the higher penetration of Electrical Vehicles, and various demand response programs from smart loads. In this paper we make efforts to propose appropriate dynamic models for smart grid generation/load/transmission line flows in order to capture the unpredictable volatility and analyze its impact on the grid vulnerability to cascading overload failures. We will also discuss the possible ways to manage the risks of such cascading failures.

TP4b-5 **5:10 PM**

Power Resource Allocation in a Network of Fast Charging Stations

George Michailidis, Michael Devetsikiotis, Safak Bayram, University of Michigan

Track G. Architecture and Implementation

Session: TPa5 – Design Methodologies and Architectures for Communications

Chair: ***Joseph R. Cavallaro,*** *Rice University*

TP5a-1 **1:30 PM**

High-Level Architecture Modeling and Exploration for Streaming Applications

Usman Mazhar Mirza, Flavius Gruian, Lund University

Multi/many core platforms are increasingly employed to cope with the demands of modern multimedia, networking and other streaming applications. Selecting the best architecture for a set of such applications is complex, and without coding for each specific system, the choice is made based on experience. In this paper we use CAL, a dataflow language for specifying streaming applications, to model both the software and generic hardware platforms. The hardware model is combined with the mapped application in a high-level unified model, which is simulated to obtain performance estimates, intended to give feedback during design space exploration.

TP5a-2 **1:55 PM**

Sequential Decoding of Non-Binary LDPC Codes on Graphics Processing Units

David Romero, Nicholas Chang, MIT Lincoln Laboratory

Non-binary low density parity check codes (LDPC) have been shown to attain near-capacity error correcting performance in noisy wireless communication channels. It is well known that these codes require a very large number of operations per-bit to decode. This high computational complexity makes graphics processing units (GPUs) an attractive platform for acceleration of the decoding algorithm. The seemingly random memory access patterns associated with decoding are generally beneficial to error-correcting performance, but present a challenge to designers who want to leverage the computational capabilities of the GPU. In this paper we describe the design of an efficient decoder implementation based on GPUs, and a corresponding set of powerful non-binary LDPC codes. Using the belief propagation algorithm with a sequential message updating scheme, it is shown that we are able to exploit parallelism inherent in the decoding algorithm while decreasing the number of decoding iterations required for convergence.

TP5a-3 **2:20 PM**

A GPU Implementation of Belief Propagation Decoder for Polar Codes

Bharath Kumar Reddy, Nitin Chandrachoodan, Indian Institute of Technology, Madras

A parallel implementation of the belief propagation decoder for Polar codes is presented. The decoder exploits parallelism both at the bit level and between independent code words. The behaviour of the decoder is studied for different tradeoffs in memory and register usage. It is shown that the parallel implementation makes efficient use of GPU resources, and can scale with future changes in GPU architectures.

TP5a-4 **2:45 PM**

High Performance Efficient Parallel Nonbinary LDPC Decoding on GPU

Guohui Wang, Hao Shen, Bei Yin, Yang Sun, Joseph R. Cavallaro, Rice University

Nonbinary Low-density parity-check (LDPC) codes are a class of error correcting codes constructed over the Galois field GF(q) for q>2. As extensions of binary LDPC codes, nonbinary LDPC codes can provide better error-correcting performance when the code length is short or moderate, however, at a cost of higher decoding complexity. In this paper, a graphics processing unit (GPU)-based massively parallel implementation of nonbinary LDPC decoding accelerator is proposed to achieve both good flexibility and scalability. To the best of the authors' knowledge, this paper is the first to propose the high performance decoding implementation of the nonbinary LDPC on GPU. According to GPU's specific SIMT architecture, a novel selective Min-Max decoding algorithm is proposed to reduce the computational complexity. The methodology to map the decoding algorithm to the heterogeneous platform consisting CPU and GPU is discussed. Moreover, the memory access pattern of nonbinary LDPC decoding is analyzed to allow us to take full advantage of the GPU's memory hierarchical architecture. The preliminary experiment results show that our GPU-based implementation can achieve very high throughput comparable to VLSI implementations reported in the related work, while providing greater flexibility and scalability.

Track B. MIMO Communications and Signal Processing

Session: TPb5 – Interference Alignment

Chair: ***Tharm Ratnarajah,*** *Queen's University Belfast*

TP5b-1 **3:30 PM**

System-level Performance of Distributed Cooperation

Ratheesh Mungara, Geordie George, Angel Lozano, Universitat Pompeu Fabra

Distributed cooperation schemes such as Interference Alignment or Maximum SINR (Signal-to-Interference-and-Noise Ratio) hold the promise of an increased number of spatial degrees of freedom and, with that, of substantially higher spectral efficiencies. Most results available to date, however, have been obtained in simplified settings featuring a small number of transmitters and receivers in isolation. While such controlled settings are excellent platforms to develop ideas and build intuition, they also conceal important aspects that are inherent to actual wireless systems. Chief among these is the fact that any small set of cooperating transmitters and receivers is bound to be embedded within a large system featuring many other transmitters and receivers. This paper studies the system-level performance of distributed cooperation schemes with the goal of gauging the gains that can be realistically expected.

TP5b-2 **3:55 PM**

On the DoF of the Multiple-Antenna Time Correlated Interference Channel with Delayed CSIT

Xinping Yi, David Gesbert, Eurecom Institute; Sheng Yang, Mari Kobayashi, École supérieure d'électricité

We consider the time-correlated multiple-antenna interference channel where the transmitters have (i) delayed channel state information (CSI) obtained from a feedback channel as well as (ii) imperfect current CSIT, obtained e.g. from prediction on the basis of these past channel samples. We derive the degrees of freedom region for the two-user MISO interference channel under such conditions. In doing so we propose an optimal scheme relying on a form of space-time alignment combined with interference quantization. Extensions to some MIMO cases are also considered.

TP5b-3 **4:20 PM**

Linear Transceiver Design for the Noisy Gaussian MIMO Interference Channel with Partial CSI

Francesco Negro, Eurecom Institute; Irfan Ghauri, Infineon Technologies France; Dirk Slock, Eurecom Institute

TP5b-4 **4:45 PM**

On the Nuclear Norm Approach for Interference Alignment

Huiqin Du, Tharm Ratnarajah, Queen's University Belfast

This paper considers a K-user multiple-input multiple-output (MIMO) interference channel in which uncoordinated interference appears. Due to the uncoordinated interference, perfect interference alignment may be not attained. In order to maximize the achievable spatial degree of freedom per user, the interference alignment is formulated as rank constrained rank minimization problem which maximizes the rank of the interference matrix while keeping full-rank constraint on the direct signal space. Because of the non-convexity of the optimization problem, we propose a new approach to provide tight convex approximation for the rank operator, instead of using the standard nuclear norm approximation. The optimum precoders and receiving subspaces are obtained iteratively via alternating minimizing approach, with convergence guaranteed. Simulation results are presented to validate the effectiveness of the proposed algorithms.

TP5b-5 **5:10 PM**

Interference Alignment in Coordinated Multi-Point Systems

Seyed Morteza Razavi, Tharm Ratnarajah, Queen's University Belfast

Interference alignment is a promising means to provide spectrally efficient communications within interference channels. It is however far more theoretical rather than practical. One possible practical implementation of interference alignment is in the downlink of multi-point communications. Since communication quality in interference-limited cellular networks depends heavily on the coordination among base stations for mitigating the interference, joint interference alignment and coordinated multi-point design would lead to significant increase in the total throughput of wireless networks.

Track B. MIMO Communications and Signal Processing

Session: TPa6 – Wireless Full Duplex

Chair: ***Ashutosh Sabharwal,*** *Rice University*

TP6a-1 **1:30 PM**

Decode-and-Cancel for Interference Cancellation in Full-duplex Networks

Jingwen Bai, Ashutosh Sabharwal, Rice University

Since the state of art in full-duplex wireless communication requires extra antennas and RF resources, the initial application of full-duplex will likely be at infrastructure nodes. In a full-duplex network where the infrastructure node communicates with uplink and downlink half-duplex mobile nodes simultaneously in the same band, one impeding factor is inter-node interference between the mobile nodes. To alleviate inter-node interference, we propose a scheme called decode-and-cancel for leveraging a side channel based on the multi-radio interfaces on current mobile devices. Under per-device power constraint, the achievable sum-rate of decode-and-cancel is derived and compared for both Gaussian and fading channels. The results show that as SNR becomes large, decode-and-cancel asymptotically will achieve a multiplexing gain of 2 with optimal power allocation. Furthermore, the proposed decode-and-cancel scheme has the highest impact when the signal and inter-node interference have commensurate power in which case previous schemes without utilizing the side channel fail to leverage FD gains.

TP6a-2 **1:55 PM**

Full-Duplex MIMO Relaying: Achievable Rates under Limited Dynamic Range

Brian Day, Ohio State University; Daniel Bliss, Adam Margetts, MIT Lincoln Laboratory; Philip Schniter, Ohio State University

In this paper we consider the problem of full-duplex multiple-input multiple-output (MIMO) relaying between multi- antenna source and destination nodes. The principal difficulty in implementing such a system is that, due to the limited attenuation between the relay's transmit and receive antenna arrays, the relay's outgoing signal may overwhelm its limited-dynamic-range input circuitry, making it difficult—if not impossible—to recover the desired incoming signal. While explicitly modeling transmit- ter/receiver dynamic-range limitations and channel estimation error, we derive tight upper and lower bounds on the end-to-end achievable rate of decode-and-forward-based full-duplex MIMO relay systems, and propose a transmission scheme based

on maximization of the lower bound. The maximization requires us to (numerically) solve a nonconvex optimization problem, for which we detail a novel approach based on bisection search and gradient projection. To gain insights into system design tradeoffs, we also derive an analytic approximation to the achievable rate and numerically demonstrate its accuracy.

TP6a-3 2:20 PM

Full Duplex Wireless Communications with Partial Interference Cancellation

Jianshu Zhang, Seyed Omid Taghizadeh Motlagh, Ilmenau University of Technology; Jian Luo, Fraunhofer Heinrich-Hertz-Institute; Martin Haardt, Ilmenau University of Technology

In this paper we study the achievable sum rate in a full-duplex point-to-point communication system with partial self-interference cancellation capability. Thereby, the self interference can be completely subtracted at the receiver side only if its power is below a certain threshold. We have developed the optimal power allocation scheme for the SISO setup, the optimal beamforming algorithms for the MISO setup, and the optimal precoder for the MIMO setup. The numerical results show that under this assumption a significant gain over half duplex mode is obtained only in the high SNR regime and the magnitude of the gain depends on the self-interference cancellation ability.

TP6a-4 2:45 PM

Wideband Digital Cancellation for Full-Duplex Communications

Mohammad Ali Khojastepour, Sampath Rangarajan, NEC Laboratories America, Inc.

In this paper, we consider the problem of canceling self-interference received by a wireless node from the transmitted signal from the same node. We consider separate antennas for transmission and reception. The self-interference signal is partly known to the node since the transmitted signal is known at the receive antenna with the exception of the channel gain and multipath effect. We investigate the limitation of digital cancellation in solving the problem of self-interference cancellation and seek efficient algorithms that can be used in wideband and frequency selective channels as well as the narrowband and frequency flat channels. We show that limitations of analog to digital converters (ADC) such as the dynamic range and quantization resolution are the main obstacle in restricting the isolation levels of the selfinterference signal that can be achieved by employing digital cancelation. We provide design guidelines and a specific digital cancelation system with an enhanced effective resolution and larger dynamic range by an intelligent feedback loop. We also address the problem of wideband digital cancellation by using the theory of sparse signal recovery.

Track F. Biomedical Signal and Image Processing

Session: TPb6 – Biological Image Analysis

Chair: ***Scott T. Acton,*** *University of Virginia*

TP6b-1 3:30 PM

Assessment of Wallerian Degeneration by Automated Image Analysis

Andrea Vaccari, Kanchana Gamage, Sapir Nachum, Barry Condron, Christopher Deppmann, Scott Acton, University of Virginia

Axonal degeneration is a hallmark of both developmental and pathological events. Degenerating axons appear as either interruptions in the cytoskeletal network or aggregates along the axon. Since manual quantification of this degeneration event is cumbersome and time consuming, automating this process promises to expedite drug discovery as treatment for axonal injury or neurodegenerative disorders such as Alzheimer's disease. In this paper we present a multiscale approach to segment the degenerative features from the intact axonal structure. The segmentation involves delineation of the axons and detection of breaks and blebbing in the axonal cytoskeleton. The solution involves tools from morphology, active contours and graph theory. The delineated set of degenerative features is then associated with the originating axons to allow the measurement of several quantities such as size distribution/density and density variation per unit length.

TP6b-2 3:55 PM

Robust Biological Image Sequence Analysis Using Graph Based Approaches

B.S. Manjunath, Diana Delibaltov, Karthikeyen Shanmuga Vadivel, Vignesh Jagadeesh, University of California, Santa Barbara

In this paper we develop graph-based methods for the analysis of image-sequences from various biological datasets. We address applications such as tracing over 3-D stacks, tracking over time, segmentation, and matching. Topics discussed include LP-relaxations, network flows and Spectral Graph Cuts. We present results on a variety of datasets such as 3-D confocal membrane volumes of the ascidian Ciona, electron micrograph stacks from the rabbit retina, several time sequence data.

TP6b-3 **4:20 PM**

A Linear, Transportation-based, Embedding Method for Analyzing Biomedical Images

G.K. Rohde, W. Wang, S. Basu, D. Slepcev, Carnegie Mellon University

A fundamental difficulty facing those who wish to extract quantitative information from biomedical images is finding a manner with which to compare two morphological examplars (cells or sub cellular structures). We present a new approach for finding a linear embedding for a set of images that is isometric to a transportation-based metric. The approach is capable of quantifying both shapes as well as textures, is generative, and facilitates the use of geometric data processing techniques such as LDA and PCA.

TP6b-4 **4:45 PM**

An Information Theoretic Framework for MRI Preprocessing, Multiclass Feature Selection and Segmentation of PF Tumors

Shaheen Ahmed, Emory U.; K.M. Iftekharuddin, Old Dominion University; E.O. George, University of Memphis

In our earlier works, we demonstrated that multiresolution texture features such as fractal dimension (FD) and multifractional Brownian motion (mBm) offer robust tumor and non-tumor tissue segmentation in brain MRI. We also showed the efficacy of these and other features such as intensity and shape factor to delineate cyst from tumor tissue segments. To achieve this goal, we obtained novel multiclass Kullback Leibler Divergence (KLD) feature selection techniques to effectively select features for tumor (T), cyst (C) and non-tumor (NT) tissues types in multimodal MRI. In this work, we propose an information theoretic framework for improved pediatric posterior fossa tumor segmentation. Our proposed method combines all necessary steps such as MRI inhomogeneity correction, feature extraction, multiclass feature selection and T, C and NT tissue segmentation respectively in an integrated framework. Our integrated framework allows one to observe effect of each step in the end tumor segmentation results. Finally, we evaluate our method using eight pediatric patients in T1, T2 and FLARI modalities.

TP6b-5 **5:10 PM**

The Effect of Image Registration on the Localization of Single Molecules in Microscopy Experiments

Raimund Ober, Edward Cohen, University of Texas at Dallas

Image registration is an important processing step in fluorescent microscopy, for example in tracking or super-resolution methods. Precision localization of single fluorescent molecules from a quantum limited photon detection process, subject to Gaussian readout noise, is key to providing insight into biological processes at a cellular level. It is therefore important to know the effect that registration has on the localization of a single molecule. Here we present a rigorous mathematical approach to image registration that accounts for point-wise errors in localizing the control points. From this we derive expressions for the localization errors caused by the registration process, showing dependence on the number of control points and their associated photon counts.

Track E. Array Signal Processing

Session: TPa7 – MIMO Radar and Waveform Design

Chair: ***Marius Pesavento,*** *Technische Universität Darmstadt*

TP7a-1 **1:30 PM**

Transmit Beamspace Design for Direction Finding in Colocated MIMO Radar with Arbitrary Receive Array and Even Number of Waveforms

Arash Khabbazibasmenj, Sergiy Vorobyov, Aboulnasr Hassanien, Matthew Morency, University of Alberta

Colocated multiple-input multiple-output (MIMO) radar is used for direction-of-arrival (DOA) estimation. The case of even but otherwise arbitrary number of transmit waveforms is considered. In order to obtain a virtual array with a large number of virtual antenna elements and at the same time obtain a significant signal-to-noise ratio (SNR) gain, a proper beamspace is designed. Moreover, to allow for simple DOA estimation algorithms at the receive array, the rotational invariance property (RIP) for the virtual array is guaranteed at the transmit array by a proper beamspace design. The main idea of such beamspace design is to obtain the RIP by imposing a specific structure on the beamspace matrix and then designing the beamspace matrix to obtain a desired beampattern and a uniform power distribution across antenna elements. Simulation results demonstrate the advantages of the proposed DOA estimation method based on colocated MIMO radar with beamspace design.

TP7a-2 **1:55 PM**

Jammer Detection and Estimation with MIMO Radar

Xiufeng Song, Peter Willett, Shengli Zhou, University of Connecticut

Deceptive jamming is a common technique for an intelligent target to spoof a monostatic radar system. Specifically, the target firstly intercepts the transmitted signal of a radar system, and then sends it back with a controlled delay. As the deceptive pulse generally has stronger power than the direct reflection, a false `detection' would be claimed by the radar system. In this paper, we will show the multiple-input multiple-output (MIMO) radar systems are capable of countering the deceptive jamming.

TP7a-3 **2:20 PM**

Non-linear Processing for Multicarrier MIMO Radar for Improved Target Resolution

Mir H. Mahmood, Mark R. Bell, Purdue University

The matched filter receiver is derived with signal-to-noise ratio (SNR) or detection performance as the optimality criterion, and does not consider target resolution. In this paper, we investigate non-linear processing schemes which can provide resolution better than the matched filter receiver. A Multicarrier MIMO Radar is considered, where each transmit antenna uses a different subcarrier. First, we derive ambiguity function for such a system. Then we study the improvement in delay-Doppler images of proposed non-linear processing schemes when compared with optimal linear matched filter processing. Closed form expressions for probability of detection and false alarm for proposed schemes are then derived. We observe that our non-linear schemes provide significant improvement in target resolution with very small degradation in detection performance.

TP7a-4 **2:45 PM**

Generating Correlated QPSK Waveforms by Exploiting Real Gaussian Random Variables

Jardak Seifallah Jardak, Tunisia Polytechnic School (TPS)-University of Carthage; Sajid Ahmed, Slim Alouini, King Abdullah University of Science and Technology

The design of waveforms with specified auto- and cross-correlation properties has a number of applications in multiple-input multiple-output (MIMO) radar, one of them is the desired transmit beampattern design. In this work, an algorithm is proposed to generate quadrature phase shift-keying (QPSK) waveforms with required cross-correlation properties using real Gaussian random-variables (RV's). This work can be considered as the extension of what was presented in \cite{SA.FI} to generate BPSK waveforms. This work will be extended for the generation of correlated higher-order PSK and QAM modulation schemes that can better approximate the desired beampattern.

Track H. Speech, Image and Video Processing

Session: TPb7 – Speech Processing and Speech Recognition

Chair: ***Tokunbo Ogunfunmi,*** *Santa Clara University*

TP7b-1 **3:30 PM**

Reproducing Kernel-based Methods for Extracting and Identifying Noise-Robust Speech Features

Shantanu Chakrabartty, Michigan State University

A key challenge in designing noise-robust speech and speaker recognition systems is to alleviate performance degradation due to inherent mismatch between training and deployment conditions. Several remedial techniques proposed over the last two decades have offered modest performance improvement, but a universally effective and robust solution to the vexing mismatch problem has remained elusive. One of the possible causes which is well known in the speech recognition community is the severe inadequacy of the piecewise stationary, linear filtering model of speech production as a proper representation of the physical process. Under clean recording conditions (laboratory setting), most learning algorithms like hidden Markov models (HMMs) and support vector machines (SVMs) exploit only dominant (typically linear) features that hence are easily corrupted by ambient noise. A more promising approach towards extracting noise-robust speech features is to use kernel-based algorithms that operate under the premise that robustness in speech signal is encoded in high-dimensional temporal and spectral manifolds which remain intact even in the presence of ambient noise. In this paper, we describe two kernel-based algorithms for identifying these noise-invariant manifolds. The first algorithm uses a kernel-based nonlinear predictive coding procedure that yields speech features which are robust to non-stationary noise contaminating the speech signal. Features maximally insensitive to additive noise are obtained by growth transformation of regression functions that span a Reproducing Kernel Hilbert Space (RKHS). The features are normalized by construction, and extract information pertaining to higher-order statistical correlations in the speech signal. The second and more computationally efficient features known as "Sparse Auditory Reproducing Kernel" (SPARK) coefficients are extracted under the hypothesis that the noiserobust information in speech signal is embedded in a reproducing kernel Hilbert space (RKHS) spanned by physiologically motivated overcomplete, nonlinear, and time-shifted gammatone basis functions. The feature extraction algorithm first involves computing kernel based similarity between the speech signal and the

time-shifted gammatone functions, followed by feature pruning using a simple pooling technique ("MAX" operation). We report and demonstrate performance improvements achieved by speech recognizers trained on speech features extracted by both of these RHKS based algorithms.

TP7b-2 3:55 PM

Joint Tracking of Clean Speech and Noise Using HMMS and Particle Filters for Robust Speech Recognition

Aleem Mushtaq, Chin-Hui Lee, Georgia Institute of Technology

We propose a dynamic joint tracking framework to monitor the clean speech signal and noise simultaneously in order to obtain good noise statistics in particle filter compensation (PFC) for robust speech recognition. The information available from clean speech tracking is used for noise estimation. We show that with a more accurate estimation of actual noise statistics, the overall recognition performance of the PFC algorithm improves further over tracking only clean speech. Moreover, availability of dynamic noise information enhances the robustness of the algorithm in case of large fluctuations in noise parameters. We report on experimental results obtained with the Aurora-2 connected digit recognition task, and show that the performance for the additive noise cases improves over the multi-training conditions if the noise mean is updated dynamically.

TP7b-3 4:20 PM

Sparsity-Constrained Stranded Gaussian Mixture Hidden Markov Models for Automatic Speech Recognition

Yong Zhao, Biing-Hwang (Fred) Juang, Georgia Institute of Technology

In this paper, we propose an extension of the stranded Gaussian mixture (SGMM)-HMMs to achieve more accurate representation of heterogeneous speech data for speech recognition. As opposed to the regular GMM-HMM, the SGMM-HMM aims to explicitly model the relationships among the mixture components. The transition network among mixture components encodes a set of possible trajectories of acoustic feature sequences for the given model. Accurately representing the underlying transition structure is crucial for the SGMM model to produce an optimal recognition performance against variations in speakers and environmental conditions. We propose to learn the SGMM structure by imposing sparsity constraints. In particular, entropic priors are incorporated in the maximum a posteriori (MAP) estimation of the mixture transition matrices. Experimental results on the Aurora 2 database show that the sparsity-constrained SGMM model consistently outperforms the original SGMM model.

TP7b-4 4:45 PM

Visual Speech Recognition Using Stereo-Vision Image

Chao Sui, Mohammed Bennamoun, Roberto Togneri, Serajul Haque, Damien Pontifex, University of Western Australia

Visual speech recognition using images of lip regions (lip-reading) has been an area of intense research in the past decades and the algorithm is being continually developed for improving the accuracy. Particularly, deformable models, such as Active Shape Models (ASMs) and Active Appearance Models (AAMs) have gained great popularity and are still active research directions in this area. However, due to the lack of a well-designed and robust 3D audio-visual speech recognition (AVSR) data corpus, there is no research conducted on evaluating different 3D visual speech features for AVSR. In this paper, we extract 2D/3D ASM features and 2D/3D AAM features from an audio-visual corpus of Australian English called AusTalk, and compare the performances of these features for speech recognition. Experimental results show that 3D based features perform better than 2D based features.

TP7b-5 5:10 PM

On the Integration of Time-Frequency Masking Source Separation and Missing Data Speech Recognition in Underdetermined Environments

Ingrid Jafari, Serajul Haque, Roberto Togneri, Sven Nordholm, University of Western Australia

The successful implementation of automatic speech recognition systems in the real world depends on its ability to handle realistic environments with unfavorable conditions such as reverberation and multiple interfering speakers. Previous research has identified the MENUET-FCM as a viable algorithm for multisource separation in the presence of reverberation; the MENUET-FCM is dependent on the estimation of time-frequency masks (TF) for separation, where each TF point is estimated for its reliability and assigned a representative membership score. The MENUET-FCM has previously been evaluated with a standard speech recognizer with encouraging results, however for further robustness, in this study we propose that the inherent information of the target speakers and interferences captured from the MENUET-FCM scheme may enable the efficient design of additional TF masks for implementation in a missing data speech recognizer, where the bounded probabilistic distribution of the interferences will be used to determine the reliability of each spectro-temporal region. The performance will be evaluated on connected digit recognition in the presence of several English speaking interferers in a reverberant enclosure.

Session: TPa8 – Relay Networks 1:30 PM – 3:10 PM

Chair: ***Maite Brandt-Pearce,*** *University of Virginia*

TP8a1-1

On OFDMA Resource Allocation for Delay Constrained HARQ Systems

Sébastien Marcille, Thales Communications and Security; Philippe Ciblat, Télécom ParisTech; Christophe Le Martret, Thales Communications and Security

The paper addresses multiuser power and bandwidth allocation in an OFDMA system using HARQ for a Rayleigh channel. New algorithms for minimizing the total transmit power under individual rate and delay constraints are proposed.

TP8a1-2

Cooperative AF MIMO Wireless Relay Networks under Relay Power Constraint

Kanghee Lee, Hyuck Kwon, Hyunggi Kim, Wichita State University; Hyuncheol Park, Yong Lee, Korea Advanced Institute of Science and Technogy

This paper presents an amplify-and-forward (AF) relay scheme for M-source-M-destination pairs and N relay nodes. Cooperative minimum mean square error (MMSE) and zero-forcing (ZF) strategies for wireless relay networks under the relay power constraint are investigated. The main contribution of this paper is the derivation of both the MMSE-based and the ZF-based amplifying relay matrices (ARMs) under the relay power constraint. By adopting the ARMs derived, the cost function and the total signal component power (SCP) of the received signals at the destination nodes are investigated. Finally, the system bit error rate (BER) performance is evaluated theoretically by using the cost function and total SCP behaviors, and numerically by using Monte-Carlo simulations.

TP8a1-3

Average Sum-BER Analysis of AF Two-way Relay Networks with Direct Links

Cihan Tepedelenlioglu, Hyunjun Kim, Arizona State University

Unified average sum-bit error rate (BER) analysis is carried out for amplify-and-forward (AF) two-way relay networks with direct links in Rayleigh fading. Average combined sum-BER bounds are provided in closed-form with a simple expression for different protocols including a novel one using four time slots. High signal-to-noise ratio (SNR) performance is also presented for its simplicity. Finally, all performance is compared using simulations, and it can be seen that the proposed protocol with normalized rate and power outperforms other protocols when average transmit powers from two sources are sufficiently different.

TP8a1-4

Performance Analysis of Amplify-and-Forward Relaying Using Fractional Calculus

Mehdi Mortazawi Molu, Norbert Goertz, Vienna University of Technology

The paper provides a simple approach to analyse the performance of Amplify-and-Forward relaying systems that operate on a block Rayleigh fading channel. The probability density function (PDF) of an equivalent Source-to-Relay-to-Destination (S-R-D) channel involves modified Bessel functions of the second kind. Using fractional calculus mathematics, a simple, yet novel approach is introduced to rewrite the modified Bessel functions in a special series form using simple elementary functions. Although other ways to rewrite the modified Bessel functions in series form have been published, we point out that our new series representation is different in that it allows to derive a novel S-R-D channel model that is convenient to work with, without any convergence problems. By obtaining a simple channel model for S-R-D link, we derive the PDF of the equivalent overall channel that is observed by the destination (including both the S-R-D and S-D channels). Using this simple expression for the equivalent overall channel, performance analysis of the relaying system turns to be feasible for every measure e.g. ergodic capacity, outage or bit error probability. Based on the new analytical channel model, we derive novel theoretical expressions for various performance measures of the relaying system. The theoretical results are confirmed by numerical results based on Monte-Carlo simulations.

TP8a1-5
Delay-Optimal Multi-flow Buffered Decode-and-Forward Relay Communications with Limited Renewable Energy Storage
Fan Zhang, Vincent Lau, Hong Kong University of Science and Technology

We consider the delay minimization for multi-flow buffered decode-and-forward relay systems with renewable energy source. The problem is modeled as an infinite horizon average cost Constrained Markov Decision Process. We shall first derive an equivalent Bellman equation based on a reduced state space. Using a fluid approximation approach, we derive the power, rate and link selection policy, which is asymptotically optimal for small slot duration. We further propose a distributed online learning algorithm to estimate the per-flow value functions as well as the Lagrange multipliers, and establish the technical proof for the almost-sure convergence of the proposed learning algorithm.

TP8a1-6
Relay Selection in Amplify-and-Forward Relay Networks with Frequency Selective Fading
Qingxiong Deng, Andrew G. Klein, Worcester Polytechnic Institute

We consider relay selection in cooperative relay networks with frequency selective fading, and focus on a system where multiple amplify-and-forward relays share a single channel orthogonal to the source. We propose a relay selection method that can achieve the optimal diversity-multiplexing tradeoff (DMT), as proven by outage analysis. This relay selection method, combined with zero-padded transmission and maximum likelihood sequential estimation (MLSE), can achieve full diversity as corroborated by numerical results. However, in practice, MLSE may not be affordable due to its high complexity. Hence another relay selection method based on the average decision-point SNR is proposed for linear zero-forcing equalization at the destination to asymptotically achieve optimal DMT.

TP8a1-7
On SINR Balancing for a Two-Hop Downlink Channel
Jan Schreck, Slawomir Stanczak, Technische Universität Berlin

The downlink of a two-hop network, where a base station uses a number of relays to communicates with multiple terminals, is considered. A half duplex constrained is assumed but in each hop the same spectral resources are used, therefore, interference within one hop occurs. To efficiently utilize the wireless medium, balancing the rates of the first and second hop on each link is essential. We consider amplify and forward and decode and forward relaying, characterize the feasible rate regions for the downlink scenario, formulate a SINR--balancing problem and propose and compare different algorithms that balance the rates on the first and second hop on each link.

TP8a1-8
A Power Saving Dual-Hop Architecture Based on Hybrid Spatial Modulation
Athanasios Stavridis, Sinan Sinanovic, University of Edinburgh; Marco Di Renzo, French National Center for Scientific Research (CNRS); Harald Haas, University of Edinburgh

In this paper, we propose a novel Dual-Hop architecture based on Zero Forcing (ZF) precoding and Spatial Modulation (SM) that employs a centralized or a distributed detection algorithm at the Relay Nodes (RNs). Using Tikhonov Regularization (TR), we form a precoding technique that significantly reduces the transmitted power at the Source Node (SN). Moreover, the use of TR helps in the case of correlated channels at the first hop. Finally, we extend our scheme in order to take into account realistic Channel State Information (CSI) at the the Source Node (SN).

TP8a1-9
On the Performance Loss of Distributed over Centralized Relay Beamforming
Qiang Xiao, University of Toronto; Min Dong, University of Ontario Institute of Technology; Ben Liang, University of Toronto

In this paper, we analyze the loss due to distributed nature of relay beamforming in an amplify-and-forward relay network. The optimal relay beamforming in both centralized multi-antenna single relay scenario and distributed single-antenna multi-relay scenario are compared under individual antenna/relay power budgets to account for the realistic practical constraints. The maximum received SNR under optimal beamforming does not have a closed-form solution for both cases in general. However, we obtain its closed-form expression under optimal beamforming when relaying is noiseless, and further obtain the analytical expression of the expected SNR ratio to quantify the distributed beamforming loss. Our results show that the loss due to distributed processing is at least 1.12dB, and increases unbounded with the increasing number of relays. For noisy relaying, we show that the maximum SNR under optimal beamforming in the centralized case can be obtained using a semi-closed-form solution along with bi-section search, and we study the effect of relay noise on the SNR loss through numerical simulations.

TP8a1-10
SNR Advantage of Group Transmissions in Multihop Networks with Amplify-and-forward Relays
Birsen Sirkeci-Mergen, San Jose State University

In this work, we study transmission of a single message over multiple levels of relays in a cooperative network. Relays, which are grouped into predetermined levels, amplify-and-forward (AF) the receptions from previous levels after combining them optimally (to achieve multihop diversity). We provide expressions for the asymptotic statistics of the accumulated signal-to-noise ratio (SNR) obtained in the limit where the number of nodes in a given group increases while the total power is fixed. Furthermore, we compare the performance of finite density networks with infinite density networks for different levels of multihop diversity. This work quantifies the advantages of dense deployment and multihop diversity in wireless networks with AF relays.

Track C. Networks

Session: TPa8 – Sensor and Interference Networks 1:30 PM – 3:10 PM

Chair: ***Lifeng Lai,*** *Worcester Polytechnic Institute*

TP8a2-1
Multiple Access Game with a Cognitive Jammer
Karim Khalil, Eylem Ekici, Ohio State University

We consider a two-user multiple access game in which one player (primary user) is interested in maximizing its data rate at the minimum possible transmission power and the other player (secondary, cognitive user) can either jam the primary traffic or coordinate with the primary user and send its own message to the common destination. The cognitive user employs noise forwarding as a leverage to maximize its own data rate by forcing the primary user to decrease its power level. First, the unique Nash equilibrium of the non-cooperative static game is derived and shown to be inefficient for certain ranges of channel gains and cost parameters. Then, a Stackelberg game formulation is considered in which the primary user is the leader. Here, interestingly, it is shown that the secondary user accepts to play as the follower where the Stackelberg equilibrium dominates the Nash equilibrium and hence lose-lose situations are eliminated.

TP8a2-2
Stochastic Ordering of Interferences in Large-scale Networks
Junghoon Lee, Cihan Tepedelenlioglu, Arizona State University

This paper introduces stochastic ordering of interference distributions in large-scale networks modeled as point process. Since closed-form results for the distributions of interference for such networks are only available in limited cases, network interferences are compared using stochastic orders, even when closed form expressions for interferences are not tractable. We show that the interference from a large-scale network depends on the fading distributions with respect to the stochastic Laplace transform order. Conditions on the path-loss model is also established to have stochastic ordering between interferences. Monte-Carlo simulations are used to supplement our analytical results.

TP8a2-3
Improving WLAN-Based Indoor Mobile Positioning Using Sparsity
Mohammad Pourhomayoun, Mark Fowler, Binghamton University

Growing demand for Indoor Localization and Navigation, and increasing importance of Location Based Services (LBS) necessitates methods that can accurately estimate the position of mobile devices in environments where the GPS does not work properly. In this paper, we propose a novel localization method that uses spatial sparsity to improve the indoor mobile positioning. The simulation results show the high performance of the proposed method and its robustness to multipath conditions compared to other existing methods. The proposed method has less complexity, less cost and higher robustness to configuration changes compared to common methods such as RSS Fingerprinting approaches.

TP8a2-4
Parameter Tracking via Optimal Distributed Beamforming in an Analog Sensor Network
Feng Jiang, Jie Chen, Lee Swindlehurst, University of California, Irvine

We consider the problem of optimal distributed beamforming in a sensor network where the sensors observe a dynamic parameter in noise and coherently amplify and forward their observations to a fusion center (FC). The FC uses a Kalman filter to track the parameter using the observations from the sensors, and we show how to find the optimal gain and phase of the sensor transmissions under both global and individual power constraints in order to minimize the mean squared error (MSE) of the

parameter estimate. For the case of a global power constraint, a closed-form solution can be obtained. A numerical optimization is required for individual power constraints, but the problem can be relaxed to a semidefinite programming problem (SDP), and we show how the optimal solution can be constructed from the solution to the SDP. Simulation results show that compared with equal power transmission, the use of optimized power control can significantly reduce the MSE.

TP8a2-5
On the Diversity Multiplexing Tradeoff in a 4-user Clustered Z-channel

Myung Gil Kang, Young-bin Kim, Wan Choi, Korea Advanced Institute of Science and Technology (KAIST)

We study a new interference channel called 4-user clustered Z-channel containing 4 clusters and each cluster consists of 2 single-antenna distributed nodes. 4 clusters construct a Z interference channel and a 2-user interference channel is formed between connected two clusters. We analyze diversity multiplexing tradeoff (DMT) in this channel model with joint decoding. We also propose an interference alignment scheme using only partial channel phase information and analyze DMT for the proposed interference alignment scheme. Eventually, we show that the interference alignment and joint decoding should be switched depending on multiplexing gain for achieving better DMT performance.

TP8a2-6
Distributed Cross-Layer Optimal Power and Rate Control in Single-Hop Wireless Interference Networks

Ying Cui, Stephen Hanly, Macquarie University

We study distributed optimal power and rate control in general single-hop wireless interference networks. We take into account the decoding errors due to channel outage by introducing ``effective utility'' associated with the average correctly received data rate, and formulate the effective network utility maximization (ENUM) w.r.t. power and rate control. The ENUM is a non-convex stochastic NUM. By introducing ``average SINR'', we transform the ENUM into a convex problem. Borrowing the load-spillage characterization of the average SINR, we obtain a distributed stochastic algorithm. Using stochastic approximation, we show that the proposed algorithm converges almost surely to the optimal solution.

TP8a2-7
Performance Analysis of Ad Hoc Networks with Interference Alignment

Yi Luo, Huiqin Du, Tharm Ratnarajah, Dave Wilcox, Queen's University Belfast

The performance of ad hoc networks is fundamentally limited by interference, especially by the interference from nearby transmitting nodes. In this work, we introduce vector space interference alignment (IA) to an ad hoc network scenario to efficiently eliminate interference. However, according to its feasibility conditions, vector space IA is impractical to implement in dense ad hoc networks directly. Therefore, we define an IA range to divide the ad hoc network into smaller local networks. The interference induced by the transmitters located in the prespecified IA range is completely aligned and eliminated via an IA approach. Considering the effect of the interference from the transmitters located outside the IA range, the upper and lower bounds of outage probability and transmission capacity are characterized. Monte Carlo simulation results have validated the performance improvement provided by the proposed IA scheme in ad hoc networks.

TP8a2-8
Convergence Properties of Incremental Subgradient Algorithms for Least-Squares Source Localization

Michael Rabbat, McGill University; Angelia Nedic, University of Illinois

We consider the problem of localizing a single source using received signal strength measurements gathered at a number of sensors. We assume that the measurements follow the standard path loss model and are corrupted by additive white Gaussian noise. Under this model, the maximum likelihood solution to the source localization problem involves solving a non-linear least squares optimization problem. We study convergence properties of incremental gradient methods for solving this problem. Remarkably, despite the fact that the problem is non-convex, a class of normalized incremental least squares problems generates a sequence of iterates which are attracted to the global optimum.

TP8a2-9
Traffic Handling of Hybrid MAC in IEEE 802.15.4 Networks

Jae-Seok Bang, Hyung-Sin Kim, Yong-Hwan Lee, Seoul National University

In this paper, we consider traffic handling techniques for the enhancement of quality of service (QoS) in data transmission of IEEE 802.15.4 networks. IEEE 802.15.4 networks employ a hybrid medium access control scheme for the data transmission, which comprises contention access period (CAP) and contention free period (CFP). We make end devices select the transmission

period (i.e., CAP or CFP) according to their traffic characteristics and QoS requirements in a distributed manner and the coordinator manage the CFP according to the data reception statistics. Finally, simulation results show that the proposed scheme can improve the QoS with reduced computing complexity.

TP8a2-10
Lifetime Maximization in Distributed Sensor Network with Event Triggered Adaptive Filtering
Amaresh Malipatil, Yih-Fang Huang, University of Notre Dame

We address the problem of maximizing the lifetime of a wireless sensor network (WSN), engaged in tracking a parameter vector, subject to a mean-squared-deviation (MSD) constraint . We employ an event-triggered approach by using set-membership normalized-least-mean-squares (SM-NLMS) adaptive filter in each node wherein the parameter estimate is updated, and hence transmitted to a fusion node (FN), only when the estimation error exceeds a predefined threshold. We pose the problem of maximizing network lifetime (NLT) as an optimization problem which turns out to be non-convex. We propose a suboptimal iterative solution for this problem and show through simulations that the NLT is enhanced significantly compared to a time-triggered approach such as NLMS.

TP8a2-11
Joint Localization and Clock Synchronization for Wireless Sensor Networks
Sundeep Prabhakar Chepuri, Geert Leus, Alle-Jan van der Veen, Delft University of Technology

Localization and clock synchronization are two key challenges in Wireless Sensor Networks (WSNs) and are often treated separately. In this paper, we propose a novel approach for joint localization and clock synchronization in a fully-asynchronous network using anchors. We make use of the Asymmetric Time-stamp Exchange (ATE) protocol to record the time-stamps. A closed form Least Squares (LS) and weighted LS estimators are proposed to jointly estimate all the unknown clock-skews, clock-offsets, and the target node position. A newly derived Cram\'er-Rao Lower Bound (CRLB) is used as a benchmark to analyze the performance of the proposed estimators.

Track G. Architecture and Implementation
Session: TPa8 – Design Methodology and Computer Arithmetic 1:30 PM – 3:10 PM
Chair: ***Milos Ercegovac,*** *University of California, Los Angeles*

TP8a3-1
Runtime Voltage/Frequency Scaling for Energy-Aware Streaming Applications
Flavius Gruian, Lund University

Power and energy consumption, today essential in all types of systems, can be minimized by scaling the voltage/frequency at runtime. Efficient management requires not only pertinent decisions, but also early access to workload information as well as domain specific solutions. This paper focuses on runtime energy management for streaming applications, based on a number of orthogonal techniques to estimate future workload. Briefly, the manager uses a combination of slack distribution, compile-time hints, buffer pressure and priorities to reduce the energy consumption.

TP8a3-2
Residue Codes for Error Correction in a Combined Decimal/Binary Redundant Floating Point Adder
Shehab Y. Elsayed, Hossam A. H. Fahmy, Cairo University; Muhammad S. Khairy, University of California, Irvine

As fault rates increase when technology advances from one node to another, fault tolerance becomes vital for the reliability of arithmetic circuits. This work represents an attempt to achieve fault tolerance for a combined IEEE decimal-64/binary-64 floating point redundant adder by using residue codes. To our knowledge, this is the first implementation of a residue error correction scheme in decimal and binary arithmetic circuits. The proposed circuit has the ability of all-digit error correction assuming that errors occur only in the main adder.

TP8a3-3
Hardware Implementation of the Hirschman Optimal Transform
Soumak Mookherjee, Linda DeBrunner, Victor DeBrunner, Florida State University

In this paper, a hardware architecture for the Hirschman Optimal Transform (HOT) is proposed. The HOT promises faster computation than the FFT with reduced area, yet can be used in similar ways. In fact, the HOT can potentially yield faster FIR convolution and superior spectral analysis methods. An N=K2 point HOT is composed of K, K-point DFTs. For our work, these K-point DFTs are computed using decimation-in-frequency. In this paper, we discuss the implementation details of the HOT. To evaluate the effectiveness of the implementation, we compare the HOT implementation with the FFT implementation for various sizes. We also consider various levels of precision within the implementation. The computational error, space requirements, and maximum throughput are used in the analysis of the implementations. Field Programmable Gate Arrays (FPGAs) are used to implement the algorithms.

TP8a3-4
Partitioning and Mapping Dynamic Dataflow Programs
Mehmet Ali Arslan, Jörn Janneck, Krzysztof Kuchcinski, Lund University

Mapping is an important factor in exploiting the parallelism of programs that are to be run on manycore systems. In this paper we focus on mapping CAL dataflow programs to a multiprocessor system in an efficient way regarding execution time and resource demands. We use traces and architecture descriptions as input for the mapping process that employs constraint programming and heuristics, such as critical path analysis, to provide solutions to this problem.

TP8a3-5
Effects on Power Saving of Butterfly and Inverse Butterfly Nets Integration in Embedded Processors
Gian Carlo Cardarilli, Princeton University; Luca Di Nunzio, Rocco Fazzolari, Marco Re, Ruby B. Lee, University of Rome Tor Vergata

Many software functions aren't always efficiently executed using standard microprocessors. This is because the granularity of these operations is often different with respect to that of the microprocessor's native word length. In this work it will be shown that integrating Hardware Accelerators in a standard microprocessor it's possible to obtain a reduction of the microprocessor energy consumption with a significant performance improvement. The system analyzed refers to author's previous work where they showed the speed-up factor obtained with the integration of a Bit Manipulation Unit with Altera NIOS-2 soft processor.

TP8a3-6
Modified Non-restoring Division Algorithm with Improved Delay Profile and Error Correction
Kihwan Jun, Earl Swartzlander, Jr., University of Texas at Austin

This paper focuses on improving performance of non-restoring division by reducing the delay and correcting its innate error. Although the digit recurrence division is lower in complexity and occupies a smaller area than division by convergence, it has a drawback: slow division speed. To mitigate this problem, three modification ideas are proposed here for the non-restoring division, the fastest division algorithm of the digit recurrence division methods. Secondly, there is an error regarding a least significant bit of a quotient for the non-restoring division since it needs to convert its +1 and -1 quotient bits to a conventional binary number using an adder and complement logic. And, it leads the non-restoring division always have one as a least significant bit of a quotient. To remove the error, the new logic to generate the LSB of the quotient correctly is explained in this paper.

TP8a3-7
Analysis of Trade-offs in V2P-Table Design for NAND Flash
Borja Peleato, Rajiv Agarwal, John Cioffi, Stanford University

Flash memory uses relocate-on-write, also called out-of-place write for performance reasons. Data files are partitioned across several flash pages, whose physical addresses might not be sequential. It therefore becomes necessary to keep a virtual-to-physical address table mapping the files to their physical addresses. This paper explores different policies for constructing such table and characterizes the trade-off that they offer in terms of write speed, endurance, complexity, and reliability of the flash memory.

TP8a3-8
Toward Efficient Execution of Dataflow Actors
Gustav Cedersjö, Jörn Janneck, Lund University

Dataflow descriptions are a natural match to appli- cation areas such as signal processing, cryptography, networking, image processing, and media coding. This paper addresses the problem of efficiently executing the basic elements of a dataflow program, its actors, written in a language such as MPEG's RVC-CAL. Using actor machines as an execution model for dataflow actors, we devise a metric for measuring the quality of a translation in terms of program size and execution efficiency, and then build, evaluate and compare a number of translators with each other and prior art, using MPEG reference code as a benchmark.

Track H. Speech, Image and Video Processing
Session: TPb8 – Speech, Image, and Video Processing 3:30 PM – 5:10 PM
Chair: ***Katia Estabridis,*** *Naval Air Weapons Center*

TP8b1-1
Improved Modeling of the Correlation Between Continuous-Valued Sources in LDPC-Based DSC
Mojtaba Vaezi, Fabrice Labeau, McGill University

Accurate modeling of the correlation between the sources plays a crucial role in the efficiency of distributed source coding (DSC) systems. This correlation is commonly modeled in the binary domain by using a single binary symmetric channel (BSC), both for binary and continuous-valued sources. We show that "one" BSC cannot accurately capture the correlation between continuous-valued sources; a more accurate model requires "multiple" BSCs, as many as the number of bits used to represent each sample. We incorporate this new model into the DSC system that uses low-density parity-check (LDPC) codes for compression. The standard Slepian-Wolf LDPC decoder [1] requires a slight modification so that the parameter of all BSCs is integrated in the log-likelihood ratios (LLRs). Further, using an interleaver the data belonging to different bit-planes are shuffled to introduce randomness in the binary domain. The new system has the same complexity and delay as the standard one. Simulation results prove the effectiveness of the proposed model and system.

TP8b1-2
Multispectral Vegetation Detection for Improved SAR CCD
Bea Yu, Rhonda Phillips, MIT Lincoln Laboratory

Synthetic Aperture Radar Coherent Change Detection's (SAR CCD) sensitivity to changes in ground surface height is coupled with sensitivity to other environmental changes such as minor movement in vegetation. The CCD Clutter Location, Estimation and Negation (CLEAN) algorithm decreases the false alarm rate in SAR CCD ground disturbance detection algorithms using intensity information in SAR images to discriminate false alarms from changes of interest. Unfortunately, CLEAN has difficulty identifying vegetation using only SAR imagery and vegetation is problematic in SAR CCD. In this paper, we propose an extension to CLEAN fusing information from multispectral imagery with SAR intensity information for more robust vegetation classification. Experimental results show that our algorithm significantly improves ground disturbance identification in SAR CCD.

TP8b1-3
HVS Based Dictionary Learning for Scalable Sparse Image Representation
Bojana Begovic, Vladimir Stankovic, Lina Stankovic, University of Strathclyde; Samuel Cheng, School of Electrical and Computer Engineering

A novel dictionary learning design, driven by the Human Visual System (HVS) perception characteristic, for scalable representation of natural images is proposed. It builds upon the K-SVD algorithm, which learns non-scalable dictionaries for natural images. We introduce regularization over the K-SVD dictionary atom update stage, enabling scalable sparse image reconstruction. Mainly, emphasis is on the dictionary's low and high spatial frequency components. Experimental results demonstrate the practicality of the proposed scheme for effective scalable sparse recovery of dynamic data changing over time (e.g., video). For the aforementioned purpose the proposed method outperforms the conventional K-SVD algorithm on average by 10.8[dB].

TP8b1-4
Regional Features with Adaptable Global Mappings for Recognition Systems
Katia Estabridis, Naval Air Weapons Center

This paper proposes an adaptive recognition system that integrates local and global features while jointly classifying and learning from unlabeled data. Dictionaries based on local descriptors serve as the basis for the recognition system and at the same time provide spatial-mappings derived from the location of the selected features during classification (via l_1 minimization techniques). The mappings provide a global object representation that is further utilized to discriminate among classes with candidate descriptors. Additionally updating or learning new local descriptors (via non-parametric Bayes) from unlabeled data within a dictionary framework, provides the flexibility needed when training data is limited.

TP8b1-5
A Robust Super Resolution Method for Video
Nafise Barzigar, Aminmohammad Roozgard, Samuel Cheng, Pramode Verma, University of Oklahoma

Super resolution reconstruction produces a higher resolution image based on a set of low resolution images, taken from the same scene. Recently, many papers have been published, proposing a variety algorithms of video super resolution. This paper presents a new approach to video super resolution, based on sparse coding and belief propagation. First, find the candidate pixels on multiple frames using sparse coding and belief propagation. Second, exploit the similarities of candidate pixels using the Non-local Means method to average out the noise among similar patches. The experimental results show the effectiveness of our method and demonstrate its robustness to other super resolution methods.

TP8b1-6
An Efficient Video Denoising Method Using Decomposition Approach for Low-Rank Matrix Completion
Nafise Barzigar, Aminmohammad Roozgard, Samuel Cheng, Pramode Verma, University of Oklahoma

Denoising as one of the most significant task in video processing was studied widely in the literature. We propose an efficient video denoising method based on decomposition approach for matrix completion. A noisy video is processed in blockwise manner and for each processed block we find similar blocks in other frames. The similar blocks then will stack together and unreliable pixels will remove using fast matrix completion method [1]. We demonstrate the effectiveness of our algorithm in removing the mixed noise through the results. Our results also proved the effectiveness of our algorithm in removing noise from regular structures. We also compare with other denoising technique using matrix completion. Our method results in comparable performance with significantly lower computation complexity.

TP8b1-7
Speech Enhancement of Color Noise Using Empirical Mode Decomposition
Min-Sung Koh, Esteban Rodriguez-Marek, Eastern Washington University

This paper introduces a new speech enhancement algorithm, which is efficient for color noises such as pink and babble noises. The algorithm applies the minimum variance estimator into each intrinsic mode function (IMF) obtained by the empirical mode decomposition (EMD). Since speech enhancement algorithms typically apply the white noise assumption, a prewhitening step is necessary to deal with various color noises. The algorithm presented in this paper is applicable into color noises such as pink and babble noises without the whitening process, because the noises' variances in each IMF signal show smaller fluctuations than without EMD. Experimental data demonstrates the effectiveness of the introduced algorithm for color noises without any whitening process.

TP8b1-8
Objective Quality Assessment of Multiply Distorted Images
Dinesh Jayaraman, Anish Mittal, Anush Moorthy, Alan Bovik, University of Texas at Austin

Subjective studies have been conducted in the past to obtain human judgments of visual quality on distorted images in or- der to benchmark objective image quality assessment (IQA) algorithms. However, existing subjective studies have obtained human ratings on images that were corrupted by only one of many possible distortions. However, the majority of images that are available for consumption may generally be corrupted by multiple distortions. Towards broadening the corpora of records of human responses to visual distortions, we recently conducted a study on two types of multiply distorted images to obtain human judgements of the visual quality of such images. Further, we compared the performance of several existing objective image quality measures on the new database.

TP8b1-9

Temporal Dispersal of Multiple Representations for Error-Resilient Video Streaming

Sourabh Khire, Georgia Institute of Technology; Arturo Rodriguez, Cisco Systems; Nikil Jayant, Georgia Institute of Technology

Video streaming over wireless and cellular networks is hampered by burst errors and signal loss intervals. In this paper, we propose a scheme for error-resilient video streaming known as Multiple Representation Coding (MRC). In the MRC scheme, multiple independently decodable representations are generated from the source video. These multiple representations are then temporally dispersed on a single video stream to ensure that spatio-temporally co-located segments of the sequence corresponding to different multiple representations are not impaired by the same burst loss. Results demonstrate that the MRC scheme can facilitate a graceful recovery from impairments due to burst or signal losses.

TP8b1-10

A New Map-based Approach to Video De-interlacing Using Forward-Backward Algorithm

Farhang Vedadi, Shahram Shirani, McMaster University

De-interlacing is revisited as the problem of assigning a sequence of interpolation methods (interpolators) to a sequence of missing pixels of an interlaced frame (field). With this assumption, our algorithm undergoes transitions from one interpolator to another as it moves from one missing pixel position to the next one. We assume that the next state depends only on the current state which implies a first-order Markov-chain on the sequence of interpolators. For estimation of the optimum sequence of interpolators our algorithm introduces a novel cost function and then makes use of Forward-Backward algorithm to find the global optimum sequence of interpolators. Simulation results prove that the proposed method is superior to the well-known de-interlacing algorithms proposed in this field.

TP8b1-11

A Novel De-interlacing Method Based on Locally-Adaptive Nonlocal-Means

Roozbeh Dehghannasiri, Shahram Shirani, McMaster University

This paper presents an efficient method for video de-interlacing based on Nonlocal-means (NL-means). In the proposed scheme, every interpolated pixel is set to a weighted average of its neighboring pixels. Weights of the pixels are calculated according to the radiometric distance between the surrounding areas of them and the pixel being interpolated. To calculate the weights, we need an estimate of the progressive frames. Therefore, we de-interlace them using a simple and reliable edge-based de-interlacing method. We use steering kernel in NL-means to adapt it locally to the features of the image. Experimental results show the effectiveness of our method.

TP8b1-12

Regularization Function for Video Super-Resolution Using Auxillary High Resolution Still Images

Seyedreza Najafi, Shahram Shirani, McMaster University

This paper addresses the problem of video super-resolution using regularized reconstruction approach. A solution is proposed to effectively exploit information from auxiliary high-resolution images which have been shot from the same scene and are available along with the low-resolution frames. A regularization function is proposed which is built based on auxiliary high-resolution images as specific samples. It is an energy function inspired by non-local means filter and reconstructs each pixel of degraded frame by minimizing its distance from a set of candidate pixels with locally similar texture in the auxiliary images. Promising results from simulations show effectiveness of proposed algorithm.

TP8b1-13

Making Image Quality Assessment Robust

Anish Mittal, Anush Moorthy, Alan Bovik, University of Texas at Austin

We develop a robust framework for natural scene statistic (NSS) model based blind image quality assessment (IQA). The robustied IQA model utilizes a robust statistics approach based on L-moments. Such robust statistics based approaches are eective when natural or distorted images deviate from assumed statistical models, and achieves better prediction performance on distorted images relative to human subjective judgments. We also show that the robust model can make IQA resilient against small variations in the distortions the model is trained on. This is demonstrated by training the robust model on distortions in the LIVE IQA database,then testing it on distortions in the TID database.

TP8b1-15
Probabilistic Three-pass SAR Coherent Change Detection
Jarred Barber, Stephen Kogon, MIT Lincoln Laboratory

Coherent Change Detection (CCD) is a powerful technique for detecting fine scene changes between two Synthetic Aperture Radar (SAR) images taken at different times. SAR CCD imagery can detect ground disturbances caused by vehicles or other activities that are invisible in optical or traditional SAR imagery. One problem with the extreme sensitivity of CCD is the presence of false alarms (clutter) introduced by phenomena such as low SNR (esp. radar shadows) and vegetation. This paper proposes a method for combining two CCD images, generated from three SAR passes of the same area, to cancel out false alarm regions and show only changes from man-made activities of interest, such as vehicle tracks.

TP8b1-16
A Generalized Likelihood Ratio Test for SAR CCD
Michael Newey, Gerald Benitz, Stephen Kogon, Massachusetts Institute of Techology Lincoln Laboratory

We present a generalized likelihood ratio test for detecting changes between synthetic aperture radar pairs. Our model improves upon previous work by including noise in the model, and by optimizing the likelihood parameters separately at each pixel. Including noise allows us filter out change due to noise (shadows). We compare results from our statistic with the standard coherence statistic in collected synthetic aperture radar data.

TP8b1-17
Camera Placement for Handheld 3D Video Communications
Stephen Mangiat, Jerry Gibson, University of California, Santa Barbara

In this paper, we investigate the effect of stereo camera baseline on 3D perception and realism for handheld 3D video communications. Using a handheld device equipped with an autostereo- scopic display, a front-facing stereo camera can capture the two views necessary for 3D viewing. However, consideration must be paid to the camera separation (baseline) in order to balance both viewer comfort and realism. Using display-camera geometry, we derive a relationship be- tween real depths, perceived depths, and retinal disparities. We then estimate the best baseline to capture disparities within a user's face that are consistent with the size of the face on a hand- held display, and contrast these results with traditional rules of thumb used by stereographers. Subjective evaluation on a handheld 3D device of images captured by a beam-splitter stereo rig support these results.

TP8b1-18
Depth-Less 3D Rendering
Mashhour Solh, Ghassan AlRegib, Georgia Institute of Technology

We propose a new view synthesis without using a depth map for stereoscopic images with small baseline. The new technique utilizes the linear relationship between local luminance changes for small horizontal shifts in an image. In this paper, we prove the linear relationship between local luminance changes and small horizontal shifts. Then, we will use this relationship to derive a 3D wrapping to render 3D images in absence of a depth map. The rendered images using the proposed technique will be evaluated subjectively and objectively and compared to rendered images using depth maps.

Track F. Biomedical Signal and Image Processing
Session: TPb8 – Biomedical Signal and Image Processing 3:30 PM – 5:10 PM
Chair: ***Keshab K. Parhi,*** *University of Minnesota*

TP8b2-1 *[Paper TP8b2-1 will be presented in MP8a.]*
Ultrasonic Bone Assessment of the Distal Forearm
Jonathan Kaufman, Gangming Luo, CyberLogic, Inc.; Robert Siffert, Mount Sinai School of Medicine

The objectives of this study were to evaluate the capability of a novel ultrasound device to clinically estimate bone mineral density (BMD) at the 1/3rd radius. The device rests on a desktop and is portable, and permits real-time evaluation of the radial BMD. The device measures two (2) net time delay (NTD) parameters, NTD-DW and NTD-CW. NTD-DW is defined as the difference between the transit time of an ultrasound pulse to travel through soft-tissue, cortex and medullary cavity, and the transit time through soft tissue only of equal overall distance. NTD-CW is defined as the difference between the transit time of an ultrasound pulse to travel through soft-tissue and cortex only, and the transit time through soft tissue only again of equal overall distance. The square root of the product of these two parameters is a measure of the radial BMD at the 1/3rd location as measured by dual-energy x-ray absorptiometry (DXA). A clinical IRB-approved study measured ultrasonically 49 adults at the 1/3rd radius. BMD was also measured at the same anatomical site and time using DXA. A linear regression using NTD produced a linear

correlation coefficient of 0.94 (P<0.001). These results are consistent with previously reported simulation and in vitro studies. In conclusion, although x-ray methods are effective in bone mass assessment, osteoporosis remains one of the largest undiagnosed and under-diagnosed diseases in the world today. The research described here should enable significant expansion of diagnosis and monitoring of osteoporosis through a desktop device that ultrasonically assesses bone mass at the 1/3rd radius.

TP8b2-2
Performance Analysis of a 2-D EEG Compression Algorithm Using an Automatic Seizure Detection System

Hoda Daou, Fabrice Labeau, McGill University

A recently developed compression algorithm that uses DWT, SPIHT and smoothness transforms to compress EEG channels in 2-D proved to give very low distortion values for high compression ratios. Although RD performance is a commonly used metric in signal compression, in medical signals, it is important to preserve important diagnostic information. In order to move towards such a diagnostics-oriented performance assessment, we propose in this paper a framework to evaluate the performance of EEG compression mechanisms in terms of post-compression seizure detection capability. In particular, we show that the above-mentioned 2-D algorithm can maintain diagnostic features down to bitrates of 2 bits per sample.

TP8b2-3
A Novel Method for Tumor Localization and Tracking in Radiation Therapy

Mohammad Pourhomayoun, Mark Fowler, Zhanpeng Jin, Binghamton University

Since the position of tumor changes during radiation therapy (because of respiration or patient movements), real-time tumor tracking is necessary in radiation therapy in order to deliver a sufficient dose of radiation to the tumor without damaging the surrounding healthy tissues. In this paper, we propose a novel tumor positioning method based on spatial sparsity. We estimate the position by processing the received signals from only one implantable RF transmitter. The method is easier to implement, non-iterative, faster and more accurate compared to common magnetic transponder based methods. We evaluate the performance of the proposed method using Monte-Carlo simulation.

TP8b2-4
Screening Fundus Images for Diabetic Retinopathy

Sohini RoyChowdhury, Dara Koozakanani, Keshab K. Parhi, University of Minnesota

We present a novel two-stage system that detects diabetic retinopathy (DR) using fundus photographs. The first stage of this system masks out the background consisting of the optic disc, using a novel Region of Intersection (RoI) algorithm that is 99.7% accurate in locating the optic disc, and the vascular arc on 4 distinct public data sets. ROC analysis depicts that the second-stage of the system classifies bright lesions with 82.87% sensitivity, 94.36% specificity and 0.9593 AUC, and it detects red lesions with 75.5% sensitivity, 93.73% specificity 0.8663 AUC using the Gaussian Mixture Models. Further, free-response receiver operation characteristic (FROC) analysis shows that our detection system achieves a sensitivity of 80% for bright lesion detection, and 64% for red lesion detection at 0.5 false positives per image on the DIARETDB1 [1] data set. Thus, the performance of our DR detection system compares favorably with existing works and hence it can be applied to enhance the effectiveness in screening patients for diabetic retinopathy.

TP8b2-5
EEG/MEG Artifact Suppression for Improved Neural Activity Estimation

Alexander Maurer, Lifeng Miao, Arizona State University; Jun Jason Zhang, University of Denver; Antonia Papandreou-Suppappola, Arizona State University

Electroencephalography (EEG) and magnetoencephalography (MEG) measurements can be used to model neural activity as current dipoles with corresponding positions and moments. Some of the EEG/MEG measurements, however, are artifacts that do not originate from the brain; these artifacts include patient movement, normal heart electrical activity, muscle and eye movement, and equipment and environmental clutter. We propose a novel approach that integrates particle filtering with the probabilistic data association filter in order to validate neural measurements and suppress artifacts before estimating neural activity. Simulations demonstrate that this approach provides more accurate estimates of the dipole source parameters than when only particle filtering is used.

TP8b2-6

Beta Process Based Adaptive Learning of Immunosignaturing Peptide-Antibody Factors

Anna Malin, Narayan Kovvali, Antonia Papandreou-Suppappola, Arizona State University; Jun Jason Zhang, Denver University; Stephen Johnston, Phillip Stafford, Arizona State University

Previously, antibody profiling for patients has been demonstrated using immunosignaturing, and the method was combined with the nonparametric Bayesian technique of Dirichlet Process (DP) mixture modeling to adaptively classify patients by disease. However, the approach relied on dramatic feature reduction of the peptide microarray data and direct association of the features to classification groups, and did not leverage relationships between the disease states and latent factors underlying the data (e.g. antibody grouping). In this paper, we propose a novel adaptive learning method for identification of the underlying latent factors in immunosignaturing peptide microarray data followed by classification based on the discovered factors. Our approach utilizes the Beta Process (BP) to learn a nonparametric Bayesian latent factor model for the microarray data. We provide a Markov chain Monte Carlo (MCMC) algorithm for efficiently estimating the BP latent factor model parameters. In addition to factor visualization, this methodology illustrates inter-relationships between different disease states, and can be used to adaptively detect new biothreat agents in a dynamic setting.

Track A. Communications Systems

Session: WAa1 – Feedback and Cooperation

Chair: ***Giuseppe Abreu,*** *Jacobs University*

WA1a-1 **8:15 AM**

Random Access on Graphs: A Survey and New Results

Enrico Paolini, University of Bologna; Gianluigi Liva, German Aerospace Center (DLR); Marco Chiani, University of Bologna

This paper overviews the recently proposed coded slotted ALOHA (CSA) random access scheme and presents some new results in this topic. In CSA, a linear block code is employed by each user to encode segments of his bursts prior to transmission. The choice of the code is performed with no coordination with the other users. On the receiver side interference cancellation combined with decoding of the local codes is performed to recover from collisions, achieving a throughput close to 1 packet/slot. This process may be represented as an iterative decoding algorithm over a sparse bipartite graph.

WA1a-2 **8:40 AM**

Node Cooperation with Local Views

David Kao, Ashutosh Sabharwal, Rice University

In wireless networks, nodes often only have a partial and mismatched local view of the whole network. In this paper, we study the impact of such mismatched network state knowledge on cooperative transmitter and receiver techniques. We derive the local view capacity region for 2-flow interference channel and demonstrate that cooperation enlarges the capacity region in many cases.

WA1a-3 **9:05 AM**

A Feedback Strategy for the Full-Duplex Butterfly Network

Aydin Sezgin, Anas Chaaban, Ruhr-University Bochum; Daniela Tuninetti, University of Illinois, Chicago

The symmetric half-duplex Gaussian butterfly network has been studied by Avestimehr et al. in 2009, where the capacity of the linear deterministic case and the approximate capacity of the Gaussian case were characterized. In this work, we consider the full-duplex case with feedback. Namely, we consider a butterfly network, with a backward channel from the relay to the transmitters, where all nodes are full duplex. The backward channel is used for feedback from the relay to the two transmitters as a means for enhancing the performance of the network. It turns out that this form of feedback can indeed increase the capacity of the network. We establish a feedback scheme for the network and study the impact of feedback on this setup in different scenarios.

WA1a-4 **9:30 AM**

Characterizing the Mutual Information Distribution of MIMO Systems: Beyond the Gaussian Approximation

Shang Li, Matthew McKay, Hong Kong University of Science and Technology; Yang Chen, University of Macau

This paper investigates the mutual information distribution of MIMO channels. We further develop our recent work [1], where an exact expression was derived for the moment generating function in terms of a Painleve V differential equation, along with a Gaussian approximation. Based on the exact representation, we systematically compute closed-form expressions for the

high-order cumulants of the mutual information distribution to leading order in the number of antennas, as well as first-order correction terms which provide improved accuracy for finite-length arrays. These results yield considerable new insight, for example, providing a technical explanation as to why the Gaussian approximation is quite robust to the system parameters for the case of unequal transmit and receive antenna arrays, whilst for equal antenna arrays it deviates strongly as the SNR increases. In addition, by employing our new expressions for the higher order cumulants, we draw upon the Edgeworth expansion technique to propose a refined Gaussian approximation. This approximation is shown to give a very accurate closed-form characterization of the mutual information distribution, both around the mean and also in the tail region of interest for the outage probability.

Track A. Communications Systems

Session: WAb1 – Security

Chair: ***A. Lee Swindlehurst,*** *University of California, Irvine*

WA1b-1 10:15 AM

Distributed Jamming for Secure Communication in a Poisson Field of Legitimate Nodes and Eavesdroppers

Wei Shi, James Ritcey, University of Washington

This paper investigates studies how cooperative jamming helps improve the secrecy throughput of large decentralized networks where the locations and channel state information (CSI) of eavesdroppers are both unknown. The spatial distribution of legitimate nodes including transmitter, receiver and helping jammers, and eavesdroppers are modeled as Poisson point process. The helping jammers, equipped with multiple antennas, broadcast artificial noise that confuses eavesdropper but zero-forcing to the legitimate receiver. A jamming protocol based on the RTS/CTS handshake of IEEE 802.11 standard is proposed for decentralized implementation. Closed-form results analyzes the benefits of jamming on secure communications according to MAC-related parameters such as the density of jammers and eavesdroppers. Our results show that multi-antenna jammers can significantly increase the secrecy of the network, compared to single-antenna jammers.

WA1b-2 10:40 AM

Deploying Multi-antenna Energy-Harvesting Cooperative Jammers in the MIMO Wiretap Channel

Amitav Mukherjee, Nokia Research Center; Jing Huang, University of California, Irvine

We consider the deployment of an energy harvesting (EH) cooperative jammer (CJ) to increase the security of a three-terminal wiretap channel with a passive eavesdropper, all users being equipped with multiple antennas. Optimal offline CJ policies with full side information and online CJ policies with causal side information are presented, and the impact on the MIMO secrecy rate is quantified. A numerical example is shown to elucidate scenarios where EH cooperative jammers can augment the security of the wiretap channel.

WA1b-3 11:05 AM

Unicasting on the S-Graph

Satyanaranaya Vuppala, Giuseppe Abreu, Jacobs University Bremen

We consider the secrecy capacity of unicast channels of ad hoc networks exposed to randomly located eavesdroppers, as modeled by S-Graphs. Expressions that quantify the impact of fading and of the density of legitimate nodes relative to that of eavesdroppers are obtained, in terms of the probability that secrecy capacities of unicast channels are non-zero. The results indicate that depending on the relative density of eavesdroppers and the fading intensity, the secrecy capacity of unicast channels subject to fading may be higher that under AWGN.

WA1b-4 11:30 AM

Secrecy Capacity Limits of Multiple Antenna Multiple Eavesdropper Multicast

Jafar Mohammadi, Michal Kaliszan, Slawomir Stanczak, Jan Schreck, Berlin Institute of Technology

In this paper we study the scaling of achievable secrecy rates for multicast communication scenarios with multiple antenna transmitter and multiple eavesdropper. We introduce bounds on the achievable secrecy rate. Then we use them to analyse the scaling of the system in three cases, namely increasing the number of legitimate users while the number of eavesdroppers and antennas are constants, increasing the number of eavesdroppers while the number of legitimate users and antennas are constant, and increasing the number of transmit antennas while the number of users are constant. In the last part, the theoretical analysis is justified by simulations.

Session: WAa2 – Distributed Algorithms for Wireless Networks

Chair: ***Lee Swindlehurst,*** *University of California, Irvine*

WA2a-1 8:15 AM

Distributed and Autonomous Resource Allocation for Femto-Cellular Networks

Harald Burchardt, University of Edinburgh; Zubin Bharucha, DoCoMo Euro-Labs; Harald Haas, University of Edinburgh

A distributed and autonomous technique for resource and power allocation in femto-cell networks is presented. Resource blocks (RBs) are assigned to the user(s) in each cell individually without coordination between base stations (BSs). The allocatability of each resource is determined using only local information: • the user's required rate; • the quality of the desired signal; • the level of interference incident on each RB; and • the frequency-selective fading on each RB. Using fuzzy logic, these inputs are combined to determine which RBs are most suitable for allocation in a particular cell. A comprehensive study of this system yields a staggering system performance improvement over state-of-the-art interference coordination techniques.

WA2a-2 8:40 AM

Universal Computation with Low-Complexity Wireless Relay Networks

Eric Slottke, Raphael Rolny, Armin Wittneben, Swiss Federal Institute of Technology Zurich

We propose a method for enabling complex computations in a network of low-complexity wireless devices. By utilizing multihop relaying, such devices can form the wireless equivalent of an artificial neural network (ANN). We provide a method for programming the network functionality in a decentralized fashion and demonstrate the robustness of wireless ANNs against node failures and imperfections. Applications of this scheme exist in low-complexity sensor networks, where elaborate calculations can be carried out in a distributed fashion, or for creating powerful ANNs with very high degrees of interconnectivity realized by the wireless medium.

WA2a-3 9:05 AM

A Unified Analysis of CDF-based Distributed Scheduling in a Heterogeneous Multicell

Yichao Huang, Bhaskar D. Rao, University of California, San Diego

This paper analyzes the performance of distributed scheduling policies in a generic heterogeneous multicell downlink. Our focus is on the utilization of the cumulative distribution function (CDF)-based scheduling policy to guarantee scheduling fairness and simultaneously obtain multiuser diversity gain. Under the standard Rayleigh fading assumption on both the desired signal and the intercell interference, we derive the CDF of the selected user's signal-to-interference-plus-noise ratio (SINR), and utilize the obtained CDF to develop a unified analysis of average system performance utilizing a general performance measure. The closed form results are specialized to three performance metrics: rate, probability of error, and moment of the SINR. The corresponding results for the round robin policy and the greedy policy are also provided for comparison and completeness.

WA2a-4 9:30 AM

Unsupervised Algorithms for Distributed Estimation over Adaptive Networks

Muhammad Bin Saeed, Azzedine Zerguine, Salam Zummo, King Fahd University of Petroleum and Minerals; Ali Sayed, University of California, Los Angeles

Several algorithms have been developed that utilize the distributed structure of an ad hoc wireless sensor network for estimating a certain parameter of interest. None of these algorithms, however, performs blind estimation. In this work, we formulate two newly-developed blind recursive algorithms based on singular value decomposition (SVD) and Cholesky factorization-based techniques. These adaptive algorithms are then used for blind estimation in a wireless sensor network using diffusion of data among cooperative sensors. Simulation results conducted show that the performance greatly improves over the case where no cooperation among sensors is involved.

Session: WAb2 – Topics in Wireless Networking

Chair: ***Harald Haas,*** *University of Edinburgh*

WA2b-1 10:15 AM

Joint Design of Multi-resolution Codes and Intra/Inter-layer Network Coding

Tong Wang, Muriel Medard, Lizhong Zheng, Massachusetts Institute of Technology

In this paper, we study the joint design of multi-resolution (MR) coding and network coding. In the network coding model, we present two coding schemes, intra-layer and inter-layer network coding and use two elements as design parameters: 1) redundancy at different layer; 2) whether to code within a layer or across layers. Two metrics, average distortion and total redundancy, are used to characterize quality and efficiency. We define the notion of redundancy plane and provide coding strategies based on this plane. We show that inter-layer coding is always better or at least as good as intra-layer coding in the whole redundancy plane. Our coding strategies give guidelines for choosing between the two coding schemes in different situations and how to replace inter-layer coding with intra-layer coding while achieving the same performance in terms of quality and efficiency.

WA2b-2 10:40 AM

Link Allocation, Routing, and Scheduling for Fading Hybrid FSO/RF Networks

Yi Tang, Maite Brandt-Pearce, University of Virginia

Hybrid free space optical (FSO)/RF networks have recently been proposed as an improved architecture for wireless mesh networks (WMN), providing broadband communications. In this paper we study the throughput improvement achieved by augmenting an RF WMN suffering from channel fading with an FSO network. We address the problem of optimally allocating FSO links and routing traffic through the hybrid network. The results show that the throughput of the original RF network increases dramatically using our algorithm. We also propose a distributed hierarchical routing algorithm for hybrid FSO/RF networks.

WA2b-3 11:05 AM

Approximating the Capacity of Wireless Multiple Unicast Networks by Discrete Superposition Model

Nicolas Schrammar, Mikael Skoglund, KTH Royal Institute of Technology

The discrete superposition model (DSM) is intended to approximate the capacity region of AWGN networks. Finding the capacity region in the DSM is simpler due to its discrete and deterministic properties. For unicast in relay networks and for the multi-user interference channel it has been shown that the capacity regions of the DSM and of the AWGN model are within a constant gap. We extend this result to multiple unicast in networks consisting of broadcast and multiple-access channels by using a recent result on polymatroidal networks. We show that the capacity regions of the two models are within a constant additive gap and a constant multiplicative gap.

WA2b-4 11:30 AM

Convolutional Network Codes for Reliable Point-to-Point Wireless Communication

Samantha Summerson, Rice University; Anuj Batra, Texas Instruments

This paper considers the idea of using convolutional network codes to code across blocks of packets at the transmitter in order to increase the reliability of a wireless link. The encoding and decoding operations exploit traditional convolutional codes and Viterbi decoders, respectively, and are defined in such a way to be compatible with existing technologies. We present results for the packet error rate (PER) of various convolutional network coding schemes and show that there is a steep decline in the PERs as the signal-to-noise ratio (SNR) increases. We also show that it is possible to achieve large coding gains when a soft network decoder is used.

Session: WAa3 – Adaptive Signal Processing

Chair: ***Cedric Richard,*** *Université Nice Sophia Antipolis*

WA3a-1 8:15 AM

Diffusion Least-Mean Squares over Distributed Networks in the Presence of MAC Errors

Saeed Ghazanfari-Rad, Fabrice Labeau, McGill University

This paper presents the formulation and steady-state analysis of the distributed estimation algorithms based on diffusion cooperation scheme, in which all nodes in the network communicate employing a non-ideal channel access mechanism. We formulate and study a two-node network and derive the closed-form expressions of the steady-state mean-square deviation (MSD). We also assess the mean performance and stability condition. The proposed analytical framework enables us to investigate the effects of the medium access control (MAC) layer performance on the behavior of the diffusion least-mean squares (LMS) algorithm in terms of the convergence speed and the steady-state error that is validated by performing Monte Carlo simulations. Simulation and analysis confirm that a high probability of collision at the MAC level, results in lower convergence speed and higher steady-state MSD for distributed estimation algorithm.

WA3a-2 8:40 AM

Stochastic Adaptive Filtering Using Model Combinations

Chandrasekhar Radhakrishnan, Andrew Singer, University of Illinois, Urbana-Champaign

Voltage overscaling (VOS) is an aggressive power-reduction technique that has been proposed for ultra low-power DSP systems. Aggressive voltage scaling makes VOS based computations susceptible to timing violations. One method for mitigating such timing violations is to use a reduced-precision replica (RPR) of the main computational blocks for detecting errors. The main computational block is susceptible to timing errors, while the RPR is not. On error detection, the output of the RPR replaces the full-precision output. In this work, we explore the combination-of-adaptive-filters approach to power reduction, by model combination of a high-precision adaptive filter (that is susceptible to errors) and a low precision adaptive filter (that is not). A steady state analysis of the approach is given here, and the final paper will also include a transient analysis.

WA3a-3 9:05 AM

A Closed-Form Condition for Convergence of the Gaussian Kernel-Least-Mean-Square Algorithm

Cédric Richard, Université de Nice Sophia-Antipolis; Jose Carlos M. Bermudez, Federal University of Santa Catarina, Florianòpolis

Kernel adaptive filtering has been recognized as an appealing solution to the nonlinear adaptive filtering problem, as working in reproducing kernel Hilbert spaces allows the use of linear structures to solve nonlinear estimation problems. Algorithms developed using these ideas include the kernel-LMS algorithm, the kernel-RLS, and the kernel-NLMS. In addition to the choice of the usual linear adaptive filter parameters, designing kernel adaptive filters requires the choice of the kernel and its parameters. One of our recent works has brought a new contribution to the discussion about kernel-based adaptive filtering by providing the first convergence analysis of the kernel-LMS algorithm with Gaussian kernel. The aim of this paper is to provide a closed-form necessary and sufficient condition of stability, which allows us to examine how the stability limits vary as a function of the step-size, the kernel bandwidth, and the filter length.

WA3a-4 9:30 AM

Complex Colored Water-Filling Algorithm for Gain Allocation in Proportionate Adaptive Filtering

Kevin Wagner, Naval Research Laboratory; Milos Doroslovacki, George Washington University

A complex colored water-filling algorithm is derived for gain allocation in proportionate-type NLMS filtering under the assumption that the input signal is Gaussian and the covariance and pseudo-covariance are known. The algorithm is derived by minimizing the mean square weight deviation at every time instance, where the weight deviation is defined as the difference between the unknown impulse response and the estimated impulse response at the current time. A single real-valued gain is used to simultaneously update both the real and imaginary parts of the estimated impulse response.

Session: WAb3 – Compressive Signal Processing

Chair: ***Sergiy Vorobyov,*** *University of Alberta*

WA3b-1 10:15 AM

2D Signal Compression via Parallel Compressed Sensing with Permutations

Hao Fang, Sergiy A. Vorobyov, Hai Jiang, Omid Taheri, University of Alberta

We propose a new scheme to compress 2D signals using compressed sensing in which the reconstruction can be performed in parallel. By performing certain permutation on a 2D signal, all columns are insured to have approximately the same density level and can be sampled using the same measurement matrix. We prove that with a good permutation, the size of the measurement matrix is reduced and a tighter upper bound on reconstruction mean square error can be achieved. To illustrate this scheme, we apply it to video compression and use zigzag-scan-based permutation for reference frames and compressed-sensing-test-based permutation for non-reference frames.

WA3b-2 10:40 AM

Detecting an Abrupt Change of Finite Duration

Blaise Kévin Guépié, Lionel Fillatre, Igor Nikiforov, Université de Technologie de Troyes

This paper addresses the detection of a suddenly arriving signal of finite duration. In contrast to the traditional abrupt change detection framework where the post-change period is assumed to be infinitely long, the detection of a suddenly arriving short signal should be done before it disappears. Hence, the maximum delay for detection should be upper bounded and the traditional quickest change detection criterion is compromised. The new proposed optimality criterion promotes the maximization of the signal detection probability provided that the detection delay and the false alarm rate are upper bounded. A suboptimal detection algorithm based on a window limited cumulative sum test with a variable threshold is proposed. The proposed method is analyzed theoretically and by simulation in case of Gaussian observations. A finite variable threshold is necessary to optimize the proposed algorithm which outperforms the conventional CUSUM test.

WA3b-3 11:05 AM

Adaptive Sensing: A Tight Lower Bound and the Near-Optimal Compressive Binary Search

Matthew Malloy, Robert Nowak, University of Wisconsin Madison

This paper considers the problem of sparse signal recovery using adaptive sensing. We present a lower bound on the SNR required for exact signal recovery, derived from the data processing inequality and techniques from sequential analysis. We then propose a modification to and an extension of the Compressive Binary Search, which result in a procedure within a multiplicative factor of 2 sqrt(2) of the lower bound.

WA3b-4 11:30 AM

Rapid Sensing of Underutilized, Wideband Spectrum Using the Random Demodulator

Andrew Harms, Princeton University; Waheed Bajwa, Rutgers University; Robert Calderbank, Duke University

Efficient spectrum sensing is an important problem given the large and increasing demand for wireless spectrum and the need to protect incumbent users. We can more efficiently use large swaths of underutilized spectrum by designing spectrum sensors that can quickly, and power-efficiently, find and opportunistically communicate over unused (or underutilized) pieces of spectrum, such as television bands. In this paper, we concentrate on a particular sensing architecture, the Random Demodulator (RD) and look at two aspects of the problem. First, we offer fundamental limits on how efficiently any algorithm can perform the sensing operation with the RD. Second, we analyze a very simple, low-complexity algorithm called one-step thresholding that has been shown to work near-optimally for certain measurement classes in a low SNR setting or when the non-zero input coefficients are nearly equal. We rigorously establish that the RD architecture is also well-suited for near-optimal recovery of the locations of the non-zero frequency coefficients in similar settings using the one-step thresholding.

Session: WAa4 – Interference and Cognition

Chair: ***Urs Niesen,*** *Bell Laboratories, Alcatel-Lucent*

WA4a-1 8:15 AM

Interference Alignment for Channel-Adaptive Waveform Modulation

Urs Niesen, Thomas Marzetta, Bell Laboratories, Alcatel-Lucent

For communication channels with delay spreads that are longer than the symbol interval, orthogonal frequency-division multiplexing is unusable due to its redundant cyclic prefix. In this regime other techniques are therefore required to deal with inter-symbol interference. In this paper we introduce a new modulation scheme that achieves perfect immunity from inter-symbol interference and perfect diagonalization of the channel. A crucial component of this scheme is interference alignment: portions of the potential inter-symbol interference are arranged to lie in the same output subspace, thereby increasing the number of available interference-free input waveforms.

WA4a-2 8:40 AM

On the Discrete Superposition Model of Partially Cognitive Interference Channels

Nicolas Schrammar, Chao Wang, Lars K. Rasmussen, Mikael Skoglund, KTH Royal Institute of Technology

We find an achievable rate region for the partially cognitive interference channel in the weak interference regime, where the cognitive transmitter learns the primary message over a noiseless link with finite capacity. The rate region is established in the discrete superposition model, which has the property of approximating the AWGN model within a constant gap. In the high SNR regime our region is close to known outer bounds on the AWGN capacity region, yet its formulation is sufficiently simple to give valuable insights. Interestingly, the cognitive transmitter does not need to learn the complete primary message in order to achieve the rate region of the fully cognitive interference channel. The capacity of the noiseless link between the two transmitters is sufficiently large if it equals the single-user capacity of the cross-link from primary transmitter to secondary receiver.

WA4a-3 9:05 AM

Interference Management for Cognitive Radio Systems Exploiting Primary IR-HARQ: a Constrained Markov Decision Process approach

Romain Tajan, University of Cergy - Pontoise; Charly Poulliat, University of Toulouse; Inbar Fijalkow, University of Cergy - Pontoise

In this paper we propose to address the problem of joint optimal rate and power allocation for secondary user in an Opportunistic Spectrum Sharing (OSS) context with a primary user implementing an Incremental Redundancy Hybrid ReQuest (IR-HARQ) access protocol. We start from the description of an IR-HARQ protocol using ACcumulated Mutual Information to propose a Constrained Markov Decision Process (CMDP) model. We show that in this particular context CMDP can be used to efficiently solve this problem. And we finally give the algorithm to compute joint optimal rate and power allocation for secondary users.

WA4a-4 9:30 AM

Energy-Aware Cooperative Quickest Detection for Cognitive Radio Networks

Yan Xin, Kyungtae Kim, Sampath Rangarajan, NEC Laboratories America, Inc.

We consider a centralized cognitive radio network with two secondary users (SUs) and a fusion center. Roughly speaking, sensing with a single SU is most favorable in terms of energy consumption but least favorable in terms of detection delay whereas it is vice versa for sensing with two fully cooperative SUs. To balance between detection delay and energy consumption, we propose a partially cooperative sensing approach called the two-threshold cumulative sum (CUSUM). Unlike the conventional CUSUM, this approach employs an additional threshold to determine whether and when two SUs need to cooperatively perform sensing. We further extend this method to the multiple SU problem and propose a multi-threshold CUSUM. Via Monte-Carlo simulation, we demonstrate that the proposed two-threshold CUSUM can achieve flexible tradeoffs between detection delay and energy consumption.

Session: WAb4 – OFDM(A)

Chair: ***Michael Zoltowski,*** *Purdue University*

WA4b-1 10:15 AM

Effect of Oscillator Phase Noise and Processing Delay in Full-Duplex OFDM Repeaters

Taneli Riihonen, Pramod Mathecken, Risto Wichman, Aalto University

We study the performance of a non-regenerative OFDM repeater link impaired by oscillator phase noise which is modeled as a Wiener process. In particular, we compare two different repeater designs, namely the case of employing separate oscillators for down- and upconversion and the case of reusing a single oscillator for both purposes. When the repeater is implemented with only one oscillator, the repeater's processing delay becomes a key parameter affecting the severity of spectral spreading caused by phase noise. We show that the transmit-side noise can partially revert the effect of receive-side noise when processing delay is short enough. Spectral spreading is analyzed by calculating the power-spectral density of the excess phasor process due to imperfect oscillators. We also evaluate end-to-end transmission rate of the repeater link and study the degradation caused by phase noise in terms of the processing delay.

WA4b-2 10:40 AM

Weighted CDF-based Scheduling for an OFDMA Relay Downlink with Partial Feedback

Anh Nguyen, Yichao Huang, Bhaskar Rao, University of California, San Diego

Modern wireless systems with relays are targeted to support a variety of services with a diversity of rates and priorities. To support these services and to make best use of the wireless resources, channel state information is often required at the transmitter. However, a large number of resource blocks and users in a downlink OFDMA system make full feedback expensive. In this paper, a partial feedback OFDMA system is considered where each user feeds back only the best M channel quality information (CQI) among the total number of resource blocks. To ensure fairness and to exploit multiuser diversity, we utilize the weighted cumulative distribution function (CDF) of the received CQI for scheduling. The weights are chosen to exactly control the amount of resources allocated to different users based on their rate requirement. Analytical results on CDF of system's throughput are derived and the match between the analytical and the simulation result is observed through numerical simulations. The analytical results are applicable to two useful network models, one consists of only macro users and the other consists of both macro users and users communicating through relays.

WA4b-3 11:05 AM

Transmitter-Side Timing Adjustment to Mitigate Interference between Multiple Nodes for OFDMA Mesh Network

Sungeun Lee, Qingsong Wen, Xiaoli Ma, Georgia Institute of Technology

We propose new timing adjustment techniques at the transmitting nodes of the OFDMA mesh networks in order to minimize mutual-pair interference (MPI) as much as possible. The proposed methods suggest the adjustment parameters for the received signals from multiple transmitting nodes to be aligned as much as possible for multiple receiving nodes simultaneously. First, minimum distance condition is suggested and the corresponding linear programming method is introduced. Next, the least squares (LS) technique is applied for timing adjustment, and the decentralized adjustment scheme is developed based on LS solution. The performance results confirm that the proposed timing adjustment scheme dramatically improve the overall performance of OFDMA mesh networks because it can effectively reduce the amount of MPI caused by asynchronous feature of the OFDMA mesh network.

WA4b-4 11:30 AM

Detection of Code Spread OFDM Based on 0-1 Integer Quadratic Programming

Ali Elgharini, Purdue university

In this paper we introduce Integer Quadratic Programming (MIQP) approach to optimally detect QPSK Code Spread OFDM (CS-OFDM) by formulating the problem as a combinatorial optimization problem. The Branch and Bound (BB) algorithm is utilized to solve this integer quadratic programming problem. Furthermore, we propose combined preprocessing steps that can be applied prior to BB so that the computational complexity of the optimum receiver is reduced. The first step in this combination is to detect as much as possible symbols using procedures presented in [9], which is basically based on the gradient of quadratic function. The second step detects the undetected symbols from the first step using MMSE estimator. The result of the latter step will be used to predict the initial upper bound of the BB algorithm. Simulation results show that the proposed preprocessing combination when applied prior to BB provides optimal performance with a significantly reduced computational complexity.

Session: WAa5 – Applications of Video Processing

Chair: ***Mashhour Solh,*** *Texas Instruments, Inc.*

WA5a-1 8:15 AM

Automatic Track Tracing in SAR CCD Images Using Search Cues

Miriam Cha, Rhonda Phillips, MIT Lincoln Laboratory

In this paper, we present an algorithm for automatic vehicle track tracing in synthetic aperture radar coherent change detection(SAR CCD) images using search cues. The framework consists of two main steps. The first step uses a rotating matched filter template based on cross-correlation in SAR CCD images. Given a search cue, the algorithm searches the orientations of the individual pixels that best matches the template. The second step includes track tracing from the orientation image obtained from the previous step. The tracing algorithm aims to maximize the length of the global curve, and minimize the square sum of the differences in local neighboring pixel orientations.

WA5a-2 8:40 AM

H.264/AVC Data Hiding Based on Intra Prediction Modes for Real Time Applications

Samira Bouchama, Research Center on Scientific and Technical Information; Latifa Hamami, National Polytechnic School of Algiers; Hassina Aliane, Research Center on Scientific and Technical Information

The existing data hiding methods for the newest video codec H.264/AVC exploit its several modules such as the discrete cosine transform coefficients or the prediction modes. In this paper, a new data hiding approach is presented by exploiting the intra prediction modes for the 4x4 luminance blocks. The objective is to ensure a relatively high embedding capacity and to preserve the encoding and the decoding times in order to satisfy real-time applications. The intra prediction modes are divided into four groups composed of modes of close prediction directions. The data embedding is based on modifying modes of the same group in order to maintain visual quality and limit the number of additional calculation procedures. The increase of embedding capacity relies on the group composed on four modes since it allows the embedding of two bits per mode.

WA5a-3 9:05 AM

A Computer Vision System for Monitoring Vessel Motion in Conjunction with Vessel Wake Measurements

Sam Tan, Jenelle Armstrong Piepmeier, David Kriebel, United States Naval Academy

Vessel generated wake wash can lead to erosion of loose bank sediments and the destruction of fragile aquatic habitats. Although various studies have been done to quantify the magnitudes of boat wakes and their associated energy, there is yet to be a single model which can universally predict wave heights across different vessel sizes, boating speeds and hull forms. The goal of this study is to collect the data necessary to develop an updated equation model capable of predicting boat-generated wave heights given a set of pre-defined parameters. While rigorous field testing can be conducted to increase the sample size of past studies, limitations due to cost and time usually makes it challenging to do so. In this study, a new method of conducting vessel wake studies using video observations is proposed and evaluated. Using a remote web-based camera, vessel traffic along a section of the Severn River in Annapolis, MD, was recorded and subsequently processed using known computer vision techniques such as optical flow and morphology. This tracking tool brings together computer vision techniques in MATLAB (Simulink) to track transiting vessels and obtain boat parameters usually investigated in vessel wake studies including 1) vessel length, 2) vessel speed, and 3) distance of its sailing line from the shore. The system was calibrated so that image data could be converted to real world lengths and speed. When matched with wave records obtained using an underwater wave gage (Nortek AWAC), these measurements create a new database from which relationships between vessel size, boating speeds, and their associated maximum wave heights can be examined. The results of this study were used to generate a new family of improved equations for the purpose of developing a unified description of vessel generated waves. This study also revealed the viable prospect of a quick, low cost, but effective manner of conducting vessel wake studies that can be utilized in the future to better analyze the environment impacts of boating and vessel traffic.

WA5a-4 **9:30 AM**

Acoustic Monitoring Techniques for Avian Detection and Classification

Golrokh Mirzaei, Mohammad Wadood Majid, Selin Bastas, University of Toledo; Jeremy Ross, Bowling Green State University; Mohsin Jamali, University of Toledo; Peter Gorveski, Joseph Frizado, Verner Bingman, Bowling Green State University

Many birds and bats are found dead near the vicinity of wind turbines. So it is important to assess the behavior of birds and bats in wind farm areas and develop mitigation techniques to reduce their mortality. Acoustic monitoring techniques have been developed in this work for monitoring of birds and bats. Spectrogram-based Image Frequency Statistics (SIFS) is used for feature extraction and Evolutionary Neural Network (ENN) is used for classification purposes. Data was collected near Lake Erie in Ohio for 2011 spring and fall migration. Data analysis was performed in accordance to needs of wildlife biologists.

Track H. Speech, Image and Video Processing

Session: WAb5 – Image and Video Classification

Chair: ***Dihong Tian,*** *Cisco Systems, Inc.*

WA5b-1 **10:15 AM**

A Joint Sparsity Model for Video Anomaly Detection

Xuan Mo, Vishal Monga, Pennsylvania State University; Raja Bala, Zhigang Fan, Xerox Research Center Webster

Video anomaly detection can be used in the transportation domain to identify unusual patterns such as traffic violations, accidents, unsafe driver behavior, street crime, and other suspicious activities. A common class of approaches relies upon object tracking and trajectory analysis. A key challenge is the ability to effectively handle occlusions among objects and their trajectories. Another challenge is the detection of joint anomalies between multiple moving objects. Recently sparse reconstruction techniques have been used for image classification, and shown to provide excellent robustness to occlusion. This paper proposes a new joint sparsity model for anomaly detection that effectively addresses both the robustness to occlusion and the detection of joint anomalies involving multiple objects. Experimental results on real and synthetic data demonstrate the effectiveness of our approach for both single-object and multi-object anomalies.

WA5b-2 **10:40 AM**

Learning Dictionaries with Graph Embedding Constraints for Image Classification

Karthikeyan Natesan Ramamurthy, Jayaraman J. Thiagarajan, Prasanna Sattigeri, Andreas Spanias, Arizona State University

Several supervised, semi-supervised and unsupervised machine learning schemes can be unified under the general framework of graph embedding. Incorporating graph embedding principles into sparse representation based learning schemes can provide an improved performance in computer vision tasks. In this work, we propose a general dictionary learning procedure for computing discriminative sparse codes that obey graph embedding constraints. Furthermore, we develop the local discriminant sparse coding and the semi-supervised discriminant sparse coding algorithms for supervised and semi-supervised learning. Results with the AR face database show that the learned dictionaries result in sparse codes that perform better than other baseline approaches.

WA5b-3 **11:05 AM**

Training Image Classifiers with Similarity Metrics, Linear Programming, and Minimal Supervision

Karl Ni, Ethan Phelps, MIT Lincoln Laboratory; Katherine Bouman, Massachusetts Institute of Technology; Nadya Bliss, MIT Lincoln Laboratory

Image classification is a classical computer vision problem with applications to semantic image annotation, querying, and indexing. Recent and effective generative techniques assume Gaussianity, rely on distance metrics, and estimate distributions, but are unfortunately not convex nor scalable. We propose image content classification through convex linear programming using similarity metrics rather than commonly used Mahalanobis distances. The algorithm is solved through a hybrid iterative method that takes advantage of optimization space properties. Our optimization problem exclusively uses dot products in the feature space, and therefore can be extended to non-linear kernel functions in the transductive setting.

WA5b-4 **11:30 AM**

Randomized Tensor-based Algorithm for Image Classification

Ryan Sigurdson, University of Rochester; Carmeliza Navasca, University of Alabama at Birmingham

We present a method for the image classification problem. First, the set of images is organized in a tensor format. Then, we define several classes in terms of subtensors of the same type of images. The method relies on the tensor dimensionality reduction algorithm to create the basis of the subtensors. Our algorithm was tested on the AT\&T database of faces. From our experiments, the algorithm successfully classifies unknown images from the measured residual

Track B. MIMO Communications and Signal Processing

Session: WAa6 – CSI Feedback

Chair: ***Robert Heath,*** *University of Texas at Austin*

WA6a-1 **8:15 AM**

Feedback Bit Allocation in a Gateway Channel

Sung Lock Seo, Jung Hoon Lee, Wan Choi, Korea Advanced Institute of Science and Technology (KAIST)

This paper consider a gateway channel where multiple source and destination pairs communicate with the aid of a single relay. We propose a feedback bit allocation strategy when destinations share a limited feedback channel. The proposed feedback allocation strategy is shown to increase the achievable sum rate in the gateway channel by allocating more feedback bits to the destination who has a better source-to-relay channel.

WA6a-2 **8:40 AM**

Tomlinson-Harashima Precoding for Multiuser MIMO Systems with Quantized CSI Feedback

Liang Sun, Ming Lei, NEC Labs China

This paper considers the implementation of Tomlinson-Harashima (TH) precoding for multiuser MIMO systems based on quantized channel state information (CSI) at the transmitter side. Compared with the previous results by Fisher, et al.[1], our scheme applies to more general system setting where the number of users in the system K can be not equal to the number of transmit antenna nT. We also study the achievable average sum rate of the proposed quantized CSI feedback-based TH precoding scheme. The expression of an upper bound on the mean loss in average sum rate due to CSI quantization is derived. We also present some numerical results. Both the analytical and numerical results show that nonlinear precoding suffers from imperfect CSI more greatly than linear precoding. Nonlinear TH precoding can achieve much better performance than that of linear zero-forcing precoding for both perfect CSI and quantized CSI cases. In addition, our derived upper bound for TH precoding converges to the true rate loss faster than the upper bound for zero-forcing precoding obtained by Jindal in [2] as the number of feedback bits increases.

WA6a-3 **9:05 AM**

CSI Feedback Delay and Degrees of Freedom Gain Trade-Off for the MISO Interference Channel

Namyoon Lee, Robert W. Heath, Jr., University of Texas at Austin

Channel state information at transmitter (CSIT) plays a significant role in managing interference in many wireless communications. Due to time-varying wireless channel characteristic and feedback delay, the transmitter may not employ CSI and it results in degrading system performance. Thus, it is an important problem for characterizing the behavior of how the CSI feedback delay affects to system performance. As an initial step to address this problem, in this paper, a simple CSI feedback delay-degrees of freedom (DoF) gain trade-off is characterized for the 3-user multiple-input-single-output interference channel. To characterize this trade-off, a new transmission method called space-time interference alignment is proposed, which actively exploits not only the current CSI but also the outdated CSI. From this trade-off characterization, an insight is provided about the interplay between CSI feedback delay and DoF gain perspective.

WA6a-4 **9:30 AM**

Sum Rate Analysis and Quantizer Design for a Quantized Heterogeneous Feedback MIMO OFDMA Downlink

Yichao Huang, Bhaskar D. Rao, University of California, San Diego

In this paper, we analyze the effect of quantization on a multiuser MIMO OFDMA downlink employing heterogeneous partial feedback design method, which adapts users' feedback resources to their frequency domain channel statistics. This adaptive feedback design is investigated for the best-M partial feedback scheme, and the closed form expression for the sum rate under finite-rate quantization is derived for a system employing transmit antenna selection/maximum ratio combining (TAS/MRC) spatial diversity scheme under the generalized Nakagami fading channels. The sum rate provides a basis for determining the different quantization levels of an optimal non-uniform quantizer. For complexity reasons, a low complexity near optimal quantization strategy is proposed which employs uniform quantization with optimized intervals.

Track B. MIMO Communications and Signal Processing

Session: WAb6 – Beamforming and Relaying

Chair: ***Shahram Shahbazpanahi,*** *University of Ontario Institute of Technology*

WA6b-1 **10:15 AM**

SINR Constrained Beamforming for a MIMO Multi-user Downlink System

Qingjiang Shi, Alcatel-Lucent Shanghai Bell Company; Meisam Razaviyayn, Mingyi Hong, Zhi-Quan Luo, University of Minnesota

We consider the problem of multi-user downlink beamforming where each base station transmits data to its intended mobile stations. Both the base stations and the users are equipped with multiple antennas. The objective of beamforming is to minimize the power consumption in the network while satisfying the users' SINR constraints. Based on the analysis of the KKT conditions of the problem, we propose a low complexity iterative algorithm that computes an approximate solution to the problem. The numerical experiments show that the proposed algorithm is efficient in achieving low power consumption while satisfying the QoS constraints. Moreover, our theoretical analysis indicates that the algorithm monotonically converges to a KKT point of the problem.

WA6b-2 **10:40 AM**

Pragmatic Multi-cell MIMO Beamforming with Decentralized Coordination

Harri Pennanen, Antti Tölli, Matti Latva-aho, University of Oulu

This paper considers a TDD based coordinated multi-cell multiuser MIMO system. Optimization problem is sum power minimization among BSs with minimum SINR constraint per each user. The problem is jointly non-convex with respect to transmit and receive beamformers. We propose a sub-optimal MIMO beamforming design where transmit and receive beamformers are updated consecutively using decentralized coordination. Each user updates its receive beamformer by employing MMSE receiver which is then used for uplink pilot signaling to convey an effective channel state information to each BS. With this knowledge, each BS updates its transmit beamformers locally using primal decomposition requiring limited backhaul information exchange among BSs. Alternating between receive and transmit beamforming optimization steps, algorithm converges to a locally optimal solution in a static channel scenario. Numerical results show similar performance as in the centralized case. Furthermore, significant performance gain over multi-cell MISO beamforming is demonstrated.

WA6b-3 **11:05 AM**

A Total Power Minimization Approach to Relay Selection for Two-Way Relay Networks

Saurabh Talwar, Shahram ShahbazPanahi, University of Ontario Institute of Technology

In this paper, we develop an optimal relay selection strategy for a two-way relay network consisting of two transceivers and multiple relay nodes. Our relay selection approach is based on finding the relay which results in the minimal power consumption in the entire network while ensuring the transceivers' quality of services (QoSs), measured by their received signal-to-noise ratios (SNRs), are above certain given thresholds. We show that such a relay selection scheme yields a closed-form solution for power allocation among the two transceivers and the optimally selected relay.

WA6b-4 **11:30 AM**

Joint Network-Channel-Coded Multi-Way Relaying

Andreas Winkelbauer, Gerald Matz, Vienna University of Technology

We propose a joint network-channel coding scheme for multi-way relay networks, generalizing existing methods for the two-way relay channel. With our scheme, the relay performs log-likelihood ratio (LLR) quantization and symbol-wise network encoding, resulting in very low relay complexity. We design the LLR quantizers using the information bottleneck framework and we discuss two different coding strategies at the relay. The transmission of the network-coded soft information from the relay to the terminals is carefully designed, to optimize the performance of our scheme. The individual terminals perform iterative joint decoding of (a subset of) all messages received from the other terminals. Numerical simulations demonstrate the effectiveness of the proposed relaying protocol, showing that our scheme scales well with the number of terminals and is suitable for asymmetric channel conditions and rate requirements.

Track E. Array Signal Processing

Session: WAa7 – Applications of Sensor Array Processing

Chair: ***Martin Haardt,*** *Technische Universität Ilmenau*

WA7a-1 **8:15 AM**

Maximum Likelihood Source Localization in a Pipe using Guided Acoustic Waves

Nicholas O'Donoughue, Joel Harley, Chang Liu, Jose' M.F. Moura, Irving Oppenheim, Carnegie Mellon University

We discuss image formation using Maximum Likelihood (ML) for the localization of active sources in pipes. We make use of surface guided waves (similar to Lamb waves in plates). We utilize a data-driven approach based on {\em a priori} measurements of the Green's function for a pre-defined number of grid points to overcome the complex modeling problem of dispersive, multi-modal guided wave modes in this environment. We then compute the ML estimate of source intensity at each pixel given some received signal vector. We compare this approach to both backprojection and MUSIC imaging for the same set of reference data. We show that, in the laboratory, all three approaches successfully localize multiple sources. We also conduct a similar test with {\em in situ} measurements on a hot water return pipe and show that only the ML estimation approach is capable of accurately identifying multiple sources.

WA7a-2 **8:40 AM**

Field Testing of Indirect Displacement Estimation Using Accelerometers

Viswanadh Kandula, Linda DeBrunner, Victor DeBrunner, Michelle Rambo-Roddenberry, Florida State University

Displacement measurements of structures like bridges are helpful in many ways. Understanding bridge response to increasing loads is of interest in bridge analysis and load rating. Currently used direct displacement methods such as laser systems and displacement transducers are expensive, time consuming and difficult to deploy, particularly on an in-service bridge. One indirect method would be to use accelerometers to obtain displacement by directly integrating twice. Accelerometers are inexpensive and easy to deploy; however noisy measurements render such a technique infeasible. We propose a novel solution using signal models in adaptive-sized blocks with automatic order detection to obtain a clean acceleration signal that can be directly integrated twice to obtain the displacement. Our method was evaluated by conducting a test on an in-service concrete slab-on-steel girder bridge. Our results show that accurate displacements are determined from the measured accelerations.

WA7a-4 **9:30 AM**

Clipping Effect on Radiation Pattern in Downtilt Beamforming

Qingsong Wen, Sungeun Lee, Xiaoli Ma, Georgia Institute of Technology

In this paper, we investigate the features of radiation pattern of vertical beamforming (a user specific downtilt) when clipping technique is applied for each antenna to reduce the PAPR problem. First, the signal and noise radiation patterns are defined and analyzed in one-beam and two-beam downtilt cases, then we prove that in one-beam downtilt the clipping noise has the same radiation pattern as that of the original signal, but it is changed in two-beam downtilt. Last, we split the clipping noise into two parts, desired noise and undesired noise, and prove that in two-beam downtilt the desired noise will approximately produce the same radiation pattern as that of original signal while the undesired noise will create undesired radiation pattern, which causes unexpected noise pattern. Simulation results show that the analysis matches the numerical results very well.

Session: WAb7 – DOA Estimation

Chair: ***Alexandre Renaux,*** *Université d'Orsay*

WA7b-1 10:15 AM

A Robust L-1 Penalized DOA Estimator

Ashkan Panahi, Mats Viberg, Chalmers University of Technology

This paper concerns the problem of Direction of Arrival (DOA) estimation from complex-valued data by Least Absolute Shrinkage and Selection Operator (LASSO). A tractable method has already been introduced as the SPS-LASSO, which generally solves the problem of regularization parameter selection in the complex-valued LASSO problems. Still, dependence on the grid size and the polynomial time of performing convex optimization technique in each iteration, in addition to the deficiencies in the low noise regime, confines its performance for DOA estimation. This work presents methods to apply LASSO without grid size limitation and less complexity generalizing the ideas of SPS-LASSO. As we show by simulations, the proposed methods loose a negligible performance compared to the Maximum Likelihood (ML) estimator, which needs combinatorial time by exhaustive search. The proposed techniques are also compared to the RELAX method of DOA estimation which shows its superiority in complex scenarios as well as its resolution restrictions.

WA7b-2 10:40 AM

Adaptive Direction Detection of Extended Targets in Noise Plus Unknown Subspace Interference

Francesco Bandiera, University of Salento; Olivier Besson, ISAE (Institut Supérieur de l'Aéronautique et de l'Espace); Giuseppe Ricci, University of Salento

We address adaptive detection of extended radar targets embedded in homogeneous Gaussian noise plus subspace interference. We assume that the actual steering vector lies in a fixed and unknown direction of a preassigned and known subspace, while interfering signals are supposed to belong to an unknown subspace, with directions possibly varying from one resolution cell to another. The resulting detection problem is formulated in the framework of statistical hypothesis testing and solved using an ad hoc algorithm strongly related to the GLRT. A preliminary performance analysis, carried out also in comparison to natural competitors, is also presented.

WA7b-3 11:05 AM

A Semi-algebraic Framework for Approximate CP Decompositions via Joint Matrix Diagonalization and Generalized Unfoldings

Florian Roemer, Carola Schroeter, Martin Haardt, Ilmenau University of Technology

The Canonical Polyadic (CP) decomposition of R-way arrays is a powerful tool in multilinear algebra. Algorithms to compute an approximate CP decomposition from noisy observations are often based on Alternating Least Squares (ALS) which may require a large number of iterations to converge. To avoid this drawback we investigate semi-algebraic approaches that algebraically reformulate the CP decomposition into a set of simultaneous matrix diagonalization (SMD) problems. In particular, we propose to combine the benefits of two different existing semi-algebraic approaches based on SMDs: the "Closed-Form PARAFAC" (CFP) framework which selects the model estimate from multiple candidates obtained by solving multiple SMDs and the "Semi-Algebraic Tensor Decomposition" (SALT) algorithm which considers a "generalized" unfolding of the tensor in order to enhance the identifiability. In this paper we show that the resulting novel framework offers a large number of degrees of freedom to flexibly adapt the performance complexity trade-off.

WA7b-4 11:30 AM

Direction of Arrival Estimation of Correlated Signals Using a Dynamic Non-uniform Linear Array

Dyonisius Dony Ariananda, Geert Leus, Delft University of Technology

In this paper, a new direction of arrival (DOA) estimation method for possibly correlated sources is evaluated by considering a uniform linear array (ULA) and a periodic scanning where a single scanning period contains several time slots and in different time slots, different sets of antennas in the ULA are deactivated leading to a dynamic non-ULA. We collect the spatial correlation matrices of the output of the antenna arrays for all time slots and are able to present them as a linear function of the correlation matrix of the received signal at the investigated angles. Depending on the number of time slots per scanning period and the number of active antennas per time slot, the entire problem can be presented as an over-determined system. If the rank condition of the system matrix is satisfied, it is possible to estimate the correlation matrix of the received signal at the investigated angles

using a two-step least-squares approach. The diagonal elements of this correlation matrix can be used to indicate the received power at the investigated angles and thus the DOA estimates can be obtained by locating the peak values of the diagonal elements.

WA8 (Tutorial) 8:15 AM

Coding Methods for Emerging Storage Systems

Presenters: Prof. Lara Dolecek, UCLA and Prof. Anxiao (Andrew) Jiang, Texas A&M University

Summary: Recent surge in large-scale data storage systems has created an immediate need to develop new coding methodologies attuned to the needs of emerging non-volatile memory technologies. In this tutorial, aimed at a broad audience, we will first discuss new channel models for these technologies and demonstrate why the existing coding methods are increasingly inadequate. We will then survey recently proposed error correcting codes, modulation schemes and rewriting codes, all designed to meet the physical characteristics of non-volatile memories while ensuring maximum lifetime and reliability. The tutorial will conclude with a discussion of several of the open problems in this emerging area.

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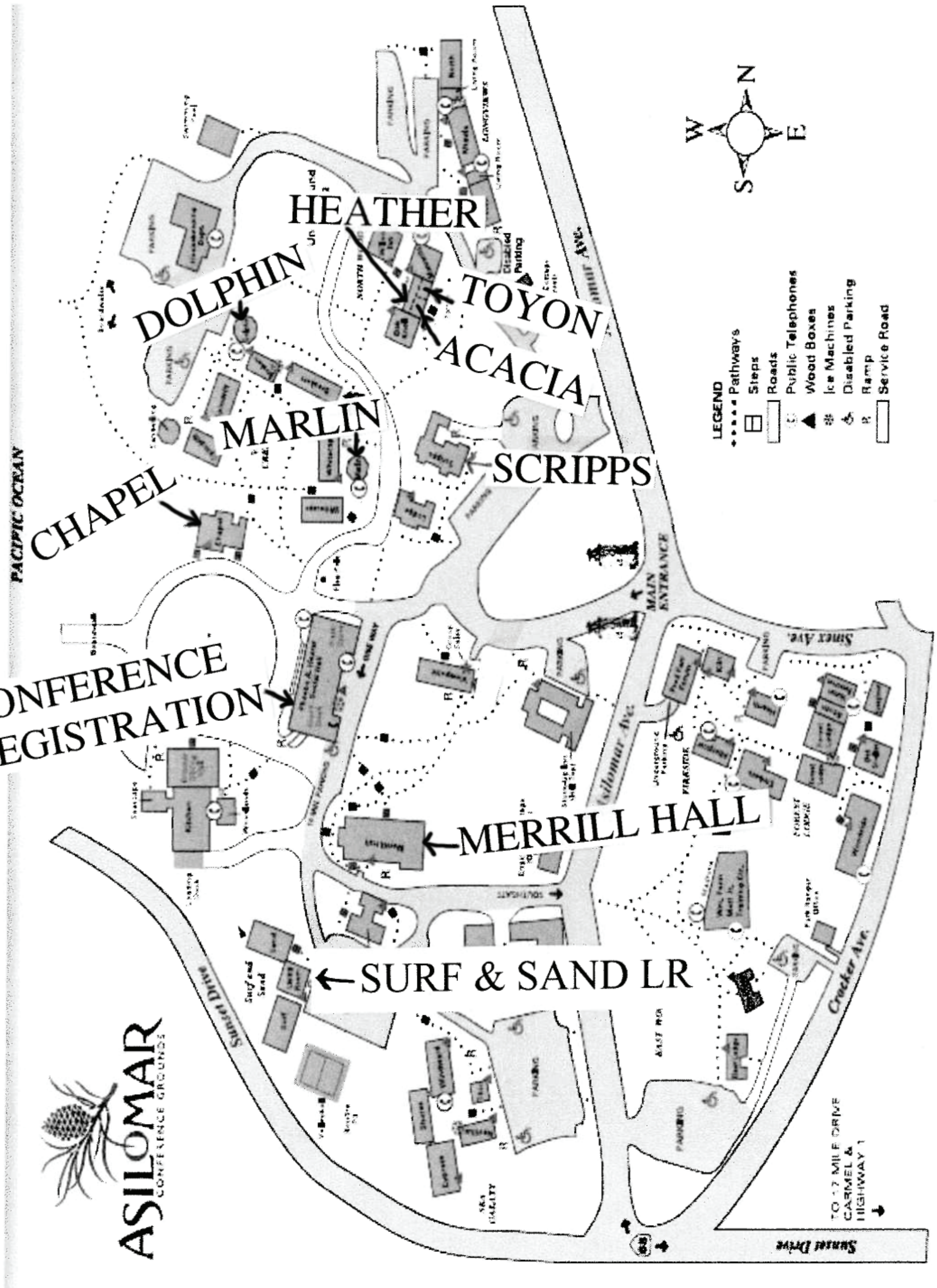

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Sunset Drive
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CARMEL &
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