



**FORTY-SEVENTH
ASILOMAR CONFERENCE ON
SIGNALS, SYSTEMS, AND COMPUTERS**

NOVEMBER 3–6, 2013

FINAL PROGRAM & ABSTRACTS

*Asilomar Hotel
Conference Grounds*

FORTY-SEVENTH ASILOMAR CONFERENCE ON SIGNALS, SYSTEMS & COMPUTERS

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Welcome from the General Chairman

Prof. Robert W. Heath, University of Texas at Austin

Welcome to the 47th Asilomar Conference on Signals, Systems, and Computers! I am thrilled that you are joining me at this incredible conference. I have a long history with Asilomar. I published my first paper at Asilomar in 1996, incidentally the second paper I had ever published. I have attended Asilomar most of the past 15 years, with the notable exception of when my son was born in November 2007 (a reasonable exception I think). Every year I look forward the same experiences: carrying around that thick blue abstract book in the cool morning mist, getting lost while looking for that elusive conference room (after so many years!), and wondering what surprise will be found in the dining hall for lunch. Of course, what keeps me coming back are the hot-off-the-presses technical results. Returning to Asilomar is like a high school reunion. I enjoy reconnecting with old friends and making new friends as well. I hope you find something that makes Asilomar special for you.

The technical program was expertly crafted by the Technical Program Chair Phil Schniter and his team of Technical Area Chairs: Matt McKay, Dan Bliss, Milica Stojanovic, Marco Duarte, Biao Chen, Rebecca Willett, Andreas Gerstlauer, James Fowler, and Gerald Matz. I would like to thank Phil and his team for assembling a high quality program with 445 accepted papers and 182 invited papers.

The student paper contest this year was chaired by D. Richard Brown III and received a total of 144 submissions out of which eight were chosen for final presentation. The student finalists will present poster presentations to the judges Sunday afternoon and anyone else who would like to attend. The awards for the top three papers will be made at the plenary session.

This year's plenary talk will be given by Dr. Thomas L. Marzetta, Bell Laboratories, Alcatel-Lucent. I am pleased to have someone from industry sharing his insights on signal processing for wireless communication. Tom will talk about his ground breaking work on large-scale antenna systems. He presented the first paper on this topic at Asilomar in 2006. Since that time, the area of large-scale antenna wireless (also known as massive MIMO) has exploded, including invited sessions at past Asilomar conferences, special issues in journals, and hundreds of published papers. I am looking forward to seeing what can be accomplished with many antennas.

I am thrilled to have served as this year's General Chair. I hope that you enjoy this year's Asilomar conference and that you discover everything that Asilomar has to offer.

Robert W. Heath Jr., The University of Texas at Austin, June 2013

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2013 Asilomar Conference Session Schedule

Sunday Afternoon, November 3, 2013

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 4, 2013

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

10:15–11:55 AM MORNING SESSIONS

MA1b	Full-Duplex MIMO Communications I
MA2b	Stochastic Optimization in Control and Wireless Communications
MA3b	Applications of Signal Processing in Financial Engineering
MA4b	Networking with Physical Layer Security
MA5b	Wireless Healthcare
MA6b	Underwater Acoustic Communication and Localization
MA7b	Approximate Computing
MA8b1	Biological Image Analysis (Poster)
MA8b2	Network Optimization (Poster)
MA8b3	Adaptive and Robust Methods (Poster)
MA8b4	Compressive Sensing (Poster)

12:00–1:00 PM	Lunch – Crocker Dining Hall
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Monday Afternoon, November 4, 2013

1:30–5:10 PM AFTERNOON SESSIONS

MP1a	Massive MIMO
MP1b	Distributed Coherent MIMO
MP2a	Wireless Security
MP2b	Energy Harvesting and Transfer
MP3a	Blind Source Separation and Deconvolution
MP3b	Distributed Signal Processing and Learning
MP4a	Network Optimization and Control
MP4b	Network Coding and Compression
MP5a	Extracting Information from Electrophysiology Data
MP5b	Optimization in (Bio)Medical Imaging
MP6a	Smart Grid Signal Processing
MP6b	Statistical Signal Processing
MP7a	Recent Progress in Computer Arithmetic
MP7b	3D Content Processing
MP8a1	Distributed Signal Processing (Poster)
MP8a2	Wireless Sensor Networks (Poster)
MP8a3	Array Signal Processing (Poster)
MP8a4	Speech, Audio, Image, and Video Processing (Poster)
MP8a5	Hardware Implementation (Poster)

Monday Evening, November 4, 2013

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

2013 Asilomar Conference Session Schedule

(continued)

Tuesday Morning, November 5, 2013

7:30–9:00 AM Breakfast — Crocker Dining Hall

8:00 AM–5:00 PM Registration

8:15–11:55 AM MORNING SESSIONS

- TA1a MIMO Communications
- TA1b Implementation Aspects for Full-Duplex and Large-Scale MIMO Wireless Systems
- TA2a Stochastic Geometry and Random Networks
- TA2b Random Matrices and Applications
- TA3a Active Sensing and Learning
- TA3b Optimization in Signal Processing
- TA4a Cooperation Techniques for Wireless Networks
- TA4b Body Area Nanonetworks
- TA5a Signal Processing in MEG and EEG
- TA5b Quantitative Image Analysis
- TA6a Geospatial Image Processing
- TA6b Control and Signal Processing for Information Fusion
- TA7a Heterogeneous and Reconfigurable Computing
- TA7b High Efficiency Video Coding
- TA8a1 Radar and Sonar Signal Processing (Poster)
- TA8a2 Communication Systems I (Poster)
- TA8a3 Machine Learning and Statistical Signal Processing I (Poster)
- TA8a4 Machine Learning for Biological Signals (Poster)
- TA8b1 Communications Systems II (Poster)
- TA8b2 Computer Arithmetic (Poster)
- TA8b3 MIMO Systems (Poster)
- TA8b4 Adaptive Learning and Information Theory (Poster)

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

Tuesday Afternoon, November 5, 2013

1:30–5:35 PM AFTERNOON SESSIONS

- TP1a Advanced MIMO Networking
- TP1b Full-Duplex MIMO Communications II
- TP2a Multimedia Quality Assessment
- TP2b PHY Performance Abstraction Techniques
- TP3a New Geometric Models for Processing in Big-Data World
- TP3b Low-Dimensional Signal Models
- TP4a Power Networks
- TP4b Location-Aware Networking
- TP5a Analysis of Complex Biological Systems and Omics Data I
- TP5b Analysis of Complex Biological Systems and Omics Data II
- TP6a MIMO Radar
- TP6b Target Tracking I
- TP7a Algorithm/Architecture Co-design
- TP7b Machine Learning and Statistical Signal Processing II
- TP8a1 Spectrum Sensing and Sharing (Poster)
- TP8a2 Relays in Communications (Poster)
- TP8a3 Cellular and Heterogeneous Networks (Poster)
- TP8a4 Adaptive Filtering (Poster)
- TP8b1 Electrophysiology and Brain Imaging (Poster)
- TP8b2 Multiuser MIMO Systems (Poster)
- TP8b3 Design Automation (Poster)

Tuesday Evening Open Evening — Enjoy the Monterey Peninsula

2013 Asilomar Conference Session Schedule

(continued)

Wednesday Morning, November 6, 2013

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.

8:15–11:55 AM

MORNING SESSIONS

- WA1a MIMO Interference Management
- WA1b MIMO Processing
- WA2a OFDM
- WA2b Advances in Coding and Decoding
- WA3a Adaptive Filtering
- WA3b Detection
- WA4a Relaying and Cooperation
- WA5a Image Analysis and Processing
- WA5b Target Tracking II
- WA6a Multi-Sensor Signal Processing
- WA6b Direction of Arrival Estimation
- WA7a Communication System Design
- WA7b Energy- and Reliability-Aware Design

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 3, 2013, 4:00 - 6:30 PM

Track A

“Delay-Optimal Streaming Codes under Source-Channel Rate Mismatch”

Pratik Patil, Ahmed Badr, Ashish Khisti, Wai-Tian Tan

Track C

“Throughput Improvements for Cellular Systems with Device-to-Device Communications”

PhuongBang Nguyen, Bhaskar Rao

Track D

“Recovering Graph-Structured Activations using Adaptive Compressive Measurements”

Akshay Krishnamuthy, James Sharpnack, Aarti Singh

Track E

“Adaptive Non-myopic Quantizer Design for Target Tracking in Wireless Sensor Networks”

Sijia Liu, Engin Masazade, Xiaojing Shen, Pramod K. Varshney

Track F

“Parallel and Distributed Sparse Optimization”

Zhimin Peng, Ming Yan, Wotao Yin

Track G

“FPGA Implementation of a Message-Passing OFDM Receiver for Impulsive Noise Channels”

Karl Nieman, Marcel Nassar, Jing Lin, Brian Evans

Track H

“On the Effectiveness of Natural Videos in Masking Dynamic DCT Noise”

Jeremy Evert, Damon Chandler

2013 Asilomar Conference Session Schedule

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, 2013

CONFERENCE OPENING AND PLENARY

SESSION 8:15 – 9:45 AM, LOCATED IN CHAPEL

1. Welcome from the General Chairperson:

Prof. Robert Heath

University of Texas at Austin

2. Session MA1a Distinguished Lecture for the 2013 Asilomar Conference

Large-Scale Antenna Systems: The Future of Wireless

Prof. Thomas L. Marzetta

Bell Labs, Alcatel-Lucent

Abstract

Large-Scale Antenna Systems (LSAS) - also called “Massive MIMO”, “Large-Scale MIMO”, or “Hyper-MIMO” - feature multi-user MIMO transmission of data, unprecedented numbers of service-antennas with a high ratio of service-antennas to terminals, and channel-state information derived from up-link pilots and time-division duplex (TDD) reciprocity. The scale of LSAS confers immense advantages over existing wireless schemes: huge spectral-efficiency, cheap single-antenna terminals, the replacement of expensive ultra-linear power amplifiers with many low-power low-precision units, simple but near-optimal multiplexing pre-coding and decoding, freedom from the “rich scattering environment” assumption, and effective power control based on slow-fading only. There is no obvious evolutionary path from LTE to LSAS and wireless standards committees are often resistant to radical innovations. For this reason the best initial opportunities for the commercial introduction of LSAS may be dedicated systems for communication tasks that have heretofore been considered impossible or impractical for wireless. A dedicated LSAS would use specially-designed hardware with no back-compatibility requirements, and it could operate in unlicensed spectrum which would minimize issues of standards. LSAS is likely to be very “green” compared with existing wireless technology in terms of the number of bits delivered per Joule expended.

Biography

Thomas L. Marzetta was born in Washington, D.C. He received the PhD in electrical engineering from the Massachusetts Institute of Technology in 1978. His dissertation extended, to two dimensions, the three-way equivalence of autocorrelation sequences, minimum-phase prediction error filters, and reflection coefficient sequences. He worked for Schlumberger-Doll Research (1978 - 1987) to modernize geophysical signal processing for petroleum exploration. He headed a group at Nichols Research Corporation (1987 - 1995) which improved automatic target recognition, radar signal processing, and video motion detection. He joined Bell Laboratories in 1995 (formerly part of AT&T, then Lucent Technologies, now Alcatel-Lucent). Within the former Mathematical Sciences Research Center he was director of the Communications and Statistical Sciences Department. He specializes in multiple-antenna wireless, with a particular emphasis on the acquisition and exploitation of channel-state information. He is the originator of Large-Scale Antenna Systems which can provide huge improvements in wireless spectral-efficiency and energy-efficiency over 4G technologies. Dr. Marzetta was a member of the IEEE Signal Processing Society Technical Committee on Multidimensional Signal Processing, a member of the Sensor Array and Multichannel Technical Committee, an associate editor for the IEEE Transactions on Signal Processing, an associate editor for the IEEE Transactions on Image Processing, and a guest associate editor for the IEEE Transactions on Information Theory Special Issue on Signal Processing Techniques for Space-Time Coded Transmissions (Oct. 2002), for the IEEE Transactions on Information Theory Special Issue on Space-Time Transmission, Reception, Coding, and Signal Design (Oct. 2003), and for the IEEE JSAC Special Issue on Large-Scale Multiple Antenna Wireless Systems (Feb. 2013). He is currently the lead guest editor for the JCN Special Issue on Massive MIMO (Aug. 2013). Dr. Marzetta was the recipient of the 1981 ASSP Paper Award from the IEEE Signal Processing Society. He was elected a Fellow of the IEEE in Jan. 2003.

**Program of 2013
Asilomar Conference
on
Signals, Systems, and Computers**

**Technical Program Chairman
Prof. Phil Schniter
The Ohio State University**

MA1b-1

10:15 AM

Advanced Self-Interference Cancellation and Multiantenna Techniques for Full-Duplex Radios

Dani Korpi, Tampere University of Technology, Finland; Sathya Venkatasubramanian, Taneli Riihonen, Aalto University, Finland; Lauri Anttila, Tampere University of Technology, Finland; Sergei Tretyakov, Aalto University, Finland; Mikko Valkama, Tampere University of Technology, Finland; Risto Wichman, Aalto University, Finland

In full-duplex wireless communication system, radios transmit and receive simultaneously in the same frequency band, which has high hopes increasing spectral efficiency. However, to deliver the promises it is necessary to mitigate the self-interference due to simultaneous transmission and reception, which seriously limits the maximum transmit power of the full-duplex device. Especially, large differences in power levels in the receiver front-end sets stringent requirements for the linearity of the transceiver electronics. We present an advanced architecture for a compact full-duplex multiantenna transceiver combining antenna design with analog and digital cancellation, including both linear and nonlinear signal processing

MA1b-2

10:40 AM

Effects of Channel Estimation Errors on Cochannel Full-Duplex MIMO Relays Using Adaptive Transmit Spatial Mitigation

Daniel Bliss, Yu Rong, Arizona State University, United States

Cochannel full-duplex multiple-input multiple-output (MIMO) relays employ independent transmit and receive antenna arrays to enable simultaneous transmission and reception. One of the most significant challenges is the mitigation of the relay's self-interference. While there are numerous issues, such as dynamic range, that limit the ability of the relay to mitigate the interference, in this paper issues associated with self-interference channel estimation are considered. In this paper, adaptive transmit processing is used that attempts to protect the relay's receive antenna array from self-interference. We develop estimation bounds to provide guidance on the amount of training required to effectively remove channel estimation as a limiting concern. Simulations results are presented to demonstrate the validity of the bounds.

MA1b-3

11:05 AM

New Results in Multiuser Full-Duplex

Ashutosh Sabharwal, Rice University, United States

Recent results in wireless full-duplex promise rate gains over the half-duplex counterpart when two nodes exchange messages with one another. However, when multiple full-duplex nodes operate simultaneously, significantly more internode interference is created which can limit the rate gain possible in the network. In this paper, we present new interference management strategies that allow the network to handle internode interference while obtaining rate gains by operating in full-duplex.

MA1b-4

11:30 AM

Transmit Antenna-Switched Receive Diversity for Bi-directional Beamforming in Two-Way Communications

Dongkyu Kim, Yonsei University, Republic of Korea; Hyungsik Ju, National University of Singapore, Singapore; Seokjung Kim, Haesoon Lee, Daesik Hong, Yonsei University, Republic of Korea

This paper investigates an attempt to improve reliability in two-way communication through the bi-directional use of spatial resources when time selectivity exists and instantaneous channel information is not available at the transmitter. The system, which uses spatial resources bi-directionally and employs beamforming, is called a 'bi-directional beamforming (BBF)' system. The use of full bandwidth and the reciprocity between time and frequency allow the BBF system to reduce the symbol duration. Focusing on this reduction in symbol duration, we propose a transmit antenna-switched receive diversity for BBF (TAS-BBF) scheme designed to improve reliability in time selective environments. The resulting TAS-BBF scheme with N antennas can achieve diversity order of $2(N-1)$ in fast fading environments without channel state information at the transmitter, whereas conventional schemes are only able to achieve a diversity order of N in this environment.

Track A – Communications Systems

Session: MAb2 – Stochastic Optimization in Control and Wireless Communications

Chair: *Vincent Lau, Hong Kong University of Science and Technology (HKUST)*

MA2b-1

10:15 AM

Enhancing the Delay Performance of Dynamic Backpressure Algorithms

Ying Cui, Edmund Yeh, Northeastern University, United States

The backpressure algorithm for dynamic network resource allocation achieves throughput optimality by making use of one-hop queue length differences. This elegant algorithm, on the other hand, does not yield good delay performance in general. We introduce a new class of enhanced dynamic backpressurebased algorithms which make use of a general queue-dependent bias function. These enhanced algorithms exploit queue state information beyond one hop. We prove the throughput optimality and characterize the utility-delay tradeoff of the enhanced algorithms. We further elaborate on two specific algorithms within this class, which have demonstrably improved delay performance while maintaining acceptable implementation complexity.

MA2b-2

10:40 AM

A Study of Estimation and Communication Tradeoff Using an Event-Based Approach

Ling Shi, Hong Kong University of Science and Technology, China

The last decade has witnessed an increasing interest in the area of wireless sensor networks and networked control systems, which have a broad range of applications. Remote state estimation is a key component in such systems, where sensors collect and send their data to a remote state estimator/controller via a wireless communication network. The finite communication bandwidth and limited sensor communication energy are natural constraints for remote state estimation problems. Less sensor-to-estimator communication saves bandwidth and energy, which, however, deteriorates the remote estimation performance. On the other hand, more sensor-to-estimator communication guarantees the remote estimation quality, which, however, may not even be possible due to the resource constraint. Therefore it is critical to study the tradeoff between the estimation quality and communication resource. In this paper, we present an event-based sensor scheduling approach which is proven to outperform the widely used periodic sensor schedules, and achieves a desired tradeoff between the estimation and the communication.

MA2b-3

11:05 AM

Event-Triggered Anytime Control with Random Processor Availability and Dropouts

Wann-Jiun Ma, University of Notre Dame, United States; Daniel Quevedo, University of Newcastle, Australia; Vijay Gupta, University of Notre Dame, United States; Serdar Yuksel, Queen's University, Canada

Control of a non-linear process with computation and communication constraints is studied. The sensor transmits information to a remote controller across an analog erasure channel which introduces i.i.d. packet dropouts. The sensor adopts an event-triggered transmission scheme to minimize communication. Processing resource availability for calculating the control input is assumed to be stochastic in time and intermittently insufficient. To safeguard for time-steps when the processor is unavailable for control, an anytime control algorithm is implemented. Sufficient conditions for stochastic stability of the resulting closed loop are presented. Performance gains are illustrated through simulation studies.

MA2b-4

11:30 AM

Convergence of Mixed Timescales Cross-Layer Stochastic Optimization

Junting Chen, Vincent Lau, Hong Kong University of Science and Technology, Hong Kong SAR of China

This paper considers a cross-layer optimization problem driven by two timescale stochastic state processes. We focus on the convergence behavior of a two-timescale stochastic gradient algorithm, which is challenging due to the mutual coupling of the multi-timescale variables. Specifically, we model the stochastic dynamics of the two-timescale algorithms using the stochastic differential equation (SDE) and the study of algorithm convergence is equivalent to the study of stochastic stability in a virtual system. We derive a sufficient condition for the mean square stability and a tracking error upper bound for the two-timescale algorithm are derived. Based on these results, an adaptive compensation algorithm and a dynamic step size selection algorithm are proposed to enhance the tracking performance. Finally, we illustrate the framework by an application example in wireless heterogeneous network.

Track D – Signal Processing and Adaptive Systems

Session: MAb3 – Applications of Signal Processing in Financial Engineering

Chair: *Daniel Palomar, Hong Kong University of Science and Technology (HKUST)*

MA3b-1

10:15 AM

ARCH Modeling in the Presence of Missing Data

Pascal Bondon, CNRS, France

The problem of estimating an autoregressive conditionally heteroscedastic (ARCH) model in the presence of missing data is investigated. A two-stage least squares estimator which is easy to calculate is proposed and its strong consistency and asymptotic normality are established. The behaviour of the estimator for finite samples is analyzed via Monte Carlo simulations, and is compared to a Yule-Walker estimator and to some estimators based on a complete data set obtained after filling the missing observations by imputation procedures. An application to real data is also reported.

MA3b-2

10:40 AM

Modeling Transaction-Level Asset Prices by Point Processes

Alexander Aue, University of California, Davis, United States; Lajos Horvath, University of Utah, United States; Clifford Hurvich, Philippe Soulier, New York University, United States

TBD

MA3b-3

11:05 AM

Structured Regularization for Large Vector Autoregression

William B. Nicholson, David S. Matteson, Jacob Bien, Cornell University, United States

TBD

MA3b-4

11:30 AM

Robust Order Execution Under Box Uncertainty Sets

Yiyong Feng, Daniel Palomar, Hong Kong University of Science and Technology, Hong Kong SAR of China; Francisco Rubio, Genetic Finance Limited, Hong Kong SAR of China

Order execution for algorithmic trading has been studied in the literature as a means of determining the optimal strategy by minimizing a trade-off between expected execution cost and risk. However, the variance has been recognized not to be practical since it is a symmetric measure of risk and, hence, penalizes the low-cost events. In this paper, we propose the use of the conditional value-at-risk (CVaR) of the execution cost as risk measure for the multiple assets case order execution problem. In addition, for the particular box type parameter estimation errors, we extend both the existing mean-variance approach and our proposed CVaR approach to their robust designs.

Track C – Networks

Session: MAb4 – Networking with Physical Layer Security

Chair: *Emre Koksal, The Ohio State University*

MA4b-1

10:15 AM

Creating Erasure Channels for Wireless Network Secrecy

Panagiotis Kostopoulos, Marios Gkatzianas, Christina Fragouli, Katerina Argyraki, Suhas Diggavi, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

We present a secrecy mechanism suitable for wireless channels. We create erasure broadcast channels by judiciously introducing random interference and beamforming along with secrecy coding. We then use this created erasure channel for interactive secrecy.

MA4b-2

10:40 AM

Guessing a Password over a Wireless Channel: On the Effect of Noise Non-uniformity

Flavio Calmon, Muriel Médard, Massachusetts Institute of Technology, United States; Mark Christiansen, Ken Duffy, National University of Ireland, Maynooth, Ireland

In this paper, we investigate the effect of noise non-uniformity on different physical layer security metrics. We show how the number of guesses required by an adversary to discover a password sent over a wiretap channel can be affected by incorrect uniformity assumptions. In particular, when the noise is not perfectly uniform over the typical set, we use recent results in guesswork to characterize the impact on information-theoretic security properties. These results provide new insights for designing and measuring the performance of physical layer security schemes.

MA4b-3

11:05 AM

Key Generation under Active Attacks

Heng Zhou, Worcester Polytechnic Institute, United States; Lauren Hui, Air Force Research Laboratory, United States; Lifeng Lai, Worcester Polytechnic Institute, United States

In this paper, we consider the key generation problem from two-way wireless channels with the presence of an active attacker. In the model considered, the active attacker will send attack signal of his choice to interrupt the key generation process. We show that the optimal attack strategy for the attacker is to send Gaussian jamming signal. Furthermore, we characterize the attacker's optimal power allocation strategy that minimizes the key rate.

MA4b-4

11:30 AM

Basic Limits of RF-Fingerprint Based Authentication

Onur Gungor, C. Emre Koksall, Hesham El Gamal, The Ohio State University, United States

RF fingerprinting exploits the variations in the RF chain of radios to uniquely identify transmitters, and distinguish adversarial transmissions from legitimate nodes. We develop a systematic approach rooted from information theory to understand basic performance limits of RF fingerprinting. We develop a novel channel model to cover RF fingerprinting systems and associated basic metrics to evaluate their security. We show that concepts analogous to symmetrizability and simulatability are required to guarantee security of RF fingerprinting systems.

Track F – Biomedical Signal and Image Processing

Session: MA5 – Wireless Healthcare

Chair: *Yuejie Chi, The Ohio State University*

MA5b-1

10:15 AM

A Unified Framework for Energy Efficient Physical Activity Tracking

Daphney-Stavroula Zois, Urbashi Mitra, University of Southern California, United States

A unified framework of joint state tracking and control design is proposed for energy-efficient physical activity tracking in heterogeneous Wireless Body Area Networks (WBANs). The objective is to devise sensor selection strategies for the WBAN's fusion center to optimize the trade-off between tracking performance and energy consumption. Our recently proposed Kalman-like estimator is employed for state tracking. The associated mean-square error and an appropriate energy consumption metric are used in a partially observable Markov decision process formulation to derive the optimal selection strategy. Low-complexity suboptimal strategies are also proposed. Numerical results are provided using real WBAN experimental data.

MA5b-2

10:40 AM

Practical Energy Expenditure Estimation for Human Daily Activity Using Mobile Phones

Mi Zhang, Harshvardhan Vathsangam, Alexander Sawchuk, Gaurav S. Sukhatme, University of Southern California, United States

Regular physical activity plays a significant role in maintaining one's health and energy expenditure measurement is an important dimension in this domain. The challenge in obtaining a practical solution for predicting energy expenditure is to use a few sensors as possible in a 24-by-7 setting. In this paper, we address these issues with a novel machine learning technique to predict energy expenditure for everyday living. We combine activity recognition and activity-dependent Bayesian regression using data from accelerometer and gyroscope embedded inside a smart phone. We show how one can develop accurate, phone-based energy expenditure models that work with minimal prior information about a person. Through our work we demonstrate a use-case of continuous human activity monitoring and energy expenditure tracking.

MA5b-3**11:05 AM****Compressed Sensing for Energy-Efficient Wireless Telemonitoring: Challenges and Opportunities**

Zhilin Zhang, Samsung R&D Institute America-Dallas, United States; Bhaskar D. Rao, Tzzy-Ping Jung, University of California, San Diego, United States

As a lossy compression framework, compressed sensing has drawn much attention in wireless telemonitoring due to its ability to reduce energy consumption and make possible the design of low-power devices. In this paper we discuss several challenges for compressed sensing, which are mainly due to non-sparsity of recorded signals. We then propose a spatio-temporal sparse Bayesian learning algorithm, which shows the desired ability to recover such non-sparse signals, due to its exploitation of spatio-temporal correlation structures in multichannel signals. Finally, we give an application of wireless telemonitoring of drivers' EEG signals for drowsiness detection.

MA5b-4**11:30 AM****Contactless Sensing of Physiological Signals Using Wideband RF Probes**

Ju Gao, Emre Ertin, The Ohio State University, United States; Santosh Kumar, University of Memphis, United States; Mustafa al'Absi, University of Minnesota, United States

Long-term monitoring of physiology at large-scale can help determine potential causes and early biomarkers of fatal diseases of slow accumulation such as cancer and heart diseases that are major causes of mortality. Physiological monitoring today, however, requires wearing of sensors such as electrodes for ECG and belt around lungs for respiration, not suitable for long term monitoring. In this paper, we discuss the design of a non-contact mobile physiological sensing platform that relies on RF probing of the body using wideband waveforms. The body acts as a time-varying channel for each transmit and receive pair of antennas. We present channel estimation algorithms tailored for the nearfield wideband MIMO sensing setting. Experimental data demonstrates that temporal and spatial variations in the channel estimate can be associated with respiration and heartbeats.

*Track E – Array Signal Processing***Session: MAb6 – Underwater Acoustic Communication and Localization**

Co-Chairs: *Shengli Zhou, University of Connecticut and Geert Leus, TU Delft*

MA6b-1**10:15 AM****Effective Inter-carrier Interference Reduction Techniques for OFDM Underwater Acoustic Communications**

Miaowen Wen, Xiang Cheng, Peking University, China; Xilin Cheng, Liuqing Yang, Colorado State University, United States; Bingli Jiao, Peking University, China

Rapid time-varying, phase variation, and Doppler shift constitute the nature of the underwater acoustic (UWA) communications environment. As a consequence, the effect of inter-carrier interference (ICI) becomes significantly critical for an orthogonal frequency division multiplexing (OFDM) based UWA system. To tackle this problem, several ICI countermeasures, including optimal correlative coding, two-path transmission, and mirror-mapping based self-cancellation techniques, are proposed. Experimental tests corroborate the efficiency of the proposed methods, showing that a large enhancement of carrier-to-interference power ratio and a significant improvement of bit error rate performance can be achieved.

MA6b-2**10:40 AM****DMC-MAC: Dynamic Multi-Channel MAC in Underwater Acoustic Networks.**

Hamid Ramezani, Geert Leus, Technical University of Delft, Netherlands

In this article, we focus on the broadcasting task in an underwater acoustic sensor network when a few sensor nodes want to transmit their packets to the nodes within their communication range. Here, we utilized the relative position information of the transmitting nodes to adaptively determine the best channel allocation (multichannel transmission) and packet transmission scheduling that minimizes the collision-free broadcasting duration. Analytical results and examples show that adaptive multichannel packet transmission scheduling greatly reduces the broadcasting duration, and hence improves network efficiency.

MA6b-3

11:05 AM

Target Localization and Tracking in a Random Access Sensor Network

Kivanc Kerse, Fatemeh Fazel, Milica Stojanovic, Northeastern University, United States

We develop a framework for detection, localization and tracking of multiple objects in a wireless sensor network. Taking into account the knowledge of the target signature and drawing on the low-dimensional nature of a typical sensing field, the proposed algorithm integrates the detection and localization tasks into a joint sensing-communication architecture.

MA6b-4

11:30 AM

Field Test Results of an On-Demand Collaborative Underwater Localization Protocol

Kaleel Mahmood, Patrick Lazar, Tausif Shaikh, Johanna Thomas, Shengli Zhou, University of Connecticut, United States

In this paper we consider the issue of localization in the context of underwater sensor networks which contain anchor nodes with unknown positions and asynchronous clocks. A local map is established during an initialization phase through message exchanges among the anchor nodes. Afterwards, through a sequential broadcasting protocol the entire network can be localized simultaneously with minimal overhead. This paper will report field test results of a complete localization procedure in a swimming pool and in a local lake.

Track G – Architecture and Implementation

Session: MA7 – Approximate Computing

Chair: *Alberto Nannarelli, Technical University of Denmark*

MA7b-1

10:15 AM

Exploiting Inherent Application Resilience Through Approximate Computing

Vinay Chippa, Swagath Venkataramani, Purdue University, United States; Srimat Chakradhar, NEC Laboratories America, Inc., United States; Kauhik Roy, Ananad Raghunathan, Purdue University, United States

Many applications from existing and emerging application domains such as graphics, multimedia, recognition, mining etc., produce acceptable outputs despite in-exactness in their underlying computations. Approximate computing is a rapidly evolving area of research that exploits this inherent application resilience to realize highly efficient (energy or performance) hardware implementations. Contrary to conventional design practice, strict equivalence (Boolean/Numerical) across layers of design abstraction (algorithm to circuits) is relaxed and approximations are introduced while ensuring acceptable “quality” at the application output. As a first step to enable such design approaches, we present scalable effort hardware, a design paradigm that allows modulation of effort expended by the hardware in executing an application. Hardware systems are designed to provide a trade-off between computation accuracy and energy by identifying scaling mechanisms at algorithm, architecture, and circuit levels. The exposed “effort knobs” can be set at design time for a given application or dynamically controlled at run time. Embodying the aforementioned design principle, several research efforts have investigated design techniques for approximate computing, spanning software, architecture, and circuits. The primary focus of this paper is to present a comprehensive summary of such circuit design methodologies and provide insights into architectural schemes for building systems with approximate functional units.

MA7b-2

10:40 AM

Computing with Parsimonious Resource Budgets: An Evaluation of Inexact Design Approaches

Avinash Lingamneni, Rice University, United States; Christian Enz, Centre Suisse d’ Electronique et de Microtechnique, Switzerland; Krishna Palem, Rice University, United States; Christian Piguet, Centre Suisse d’ Electronique et de Microtechnique, Switzerland

Inexact computing has been receiving increasing attention lately owing to its ability to trade perceptually- or statistically-acceptable quality degradation for substantial savings in the hardware resource costs (quantified through energy, delay and/or area). A multitude of design approaches targeting different layers of abstraction have been proposed to maximize the cost-accuracy tradeoff gains in error-resilient systems (e.g. DSP and multimedia). However, detailed analysis and comparison of these inexact design approaches under varying resource budgets was found lacking. In this paper, we strive to provide a thorough evaluation of existing inexact approaches under a variety of resource constraints that would assist in recognizing and applying the appropriate technique(s) for maximizing the resulting accuracy tradeoff gains.

MA7b-3

11:05 AM

On Robustifying Applications by Casting Them as Markov Chain Algorithms

Biplab Deka, University of Illinois at Urbana-Champaign, United States; Alex Birklykke, University of Aalborg / University of Illinois at Urbana-Champaign, United States; Henry Duwe, University of Illinois at Urbana-Champaign, United States; Vikash Mansighka, Massachusetts Institute of Technology, United States; Rakesh Kumar, University of Illinois at Urbana-Champaign, United States

It is well-known that soft-errors compromise system dependability. As such, algorithmic structures with inherent ability to overcome computational errors are of significant interest. To increase dependability, we propose to cast deterministic calculation problems such as integer sorting and Boolean satisfiability in terms of stochastic algorithms based on Markov chains. We use transition operators from the Markov chain Monte Carlo literature to build solutions to deterministic problems. In this light, execution errors can be seen as additional randomness injected into a process that is already intentionally random, leaving room for greater robustness. We empirically evaluate our hypothesis by both an algorithmic fault injection and a Pintool-based methodology. We show that our Markov chains for sorting and satisfiability essentially cast as stochastic local searches are significantly more robust than deterministic baselines when subject to state transition errors. The Pintool results show that dedicated hardware must be considered to fully leverage the robustness.

MA7b-4

11:30 AM

On Approximate Arithmetic

Milos D. Ercegovac, University of California, Los Angeles, United States

Approximate arithmetic has been de-facto in computing systems using fixed -point (non-integer) and floating-point algorithms. The main goal has been to obtain exact or close to exact results by deploying error mitigation techniques ranging from increasingly sophisticated rounding to interval arithmetic. Errors committed have been considered bad. Lately, however, ideas have emerged how to make errors help reduce delays of operations, power dissipation and energy consumption. Errors, now often seen as helpful, became intentional feature in the design because of tangible payoffs and application-based error tolerance. We survey several approaches and results in approximate arithmetic including our work.

Track F – Biomedical Signal and Image Processing

Session: MA8 – Biological Image Analysis

10:15 AM–11:55 AM

Chair: *Sally Wood, Santa Clara University*

MA8b1-1

An Automated Algorithm for the Quantification of hCG Level in Novel Fabric-Based Home Pregnancy Test Kits

Manasa K, Manasa Priya K V S N L, Sadhana Reddy Sadu, Sumohana Channappayya, Sivaramakrishna Vanjari, Indian Institute of Technology Hyderabad, India; Dhananjaya Dendukuri, Swathy Sridharan, Tripurari Choudhary, Paridhi Bhandari, Achira Labs, India

We report a new image processing algorithm that extracts quantitative information about the concentration of human chorionic gonadotropin (hCG), an important early pregnancy marker, from commercially available qualitative home pregnancy kits. The algorithm could potentially be ported onto a simple camera based cell phone making it a low-cost, portable point-of-care device as opposed to costly and time consuming clinical labs for accurate quantitative determination of hCG. The algorithm takes the image of the test result as input, classifies and determines the hCG concentration based on the RGB intensities of the test line. The efficacy of the algorithm is demonstrated using control samples on commercially available strips as well as novel fabric based strips designed for this application

MA8b1-2

Waveform Processing for Protein Multi-Alignment by Mapping Locational, Structural and Functional Attributes

Alexander Maurer, Brian O'Donnell, Antonia Papandreou-Suppappola, Arizona State University, United States

We propose an alignment approach based on a joint similarity measure of multiple protein attributes. We map protein locational, structural and functional attributes onto a highly-localized three-dimensional (3-D) Gaussian chirp waveform. By allowing the waveform to undergo unique transformations in the time-frequency plane, we allocate distinct parameters to represent the different attributes. Each waveform uniquely maps sequence denotation location, structure position and directionality, and functionality of the protein within the body. Protein matching by expanding the mapped waveforms using an appropriately designed basis dictionary provides a similarity measure that encompasses denotation, 3-D geometry and semantic similarities. Simulations demonstrate the performance of the joint alignment approach to infer evolutionary relationships.

MA8b1-3

3D Medical Image Denoising Using 3D Block Matching and Low-Rank Matrix Completion

Aminmohammad Roozgard, Nafise Barzigar, Pramode Verma, Samuel Cheng, University of Oklahoma, United States

3D Denoising as one of the most significant tools in medical imaging was studied in the literature. However, most existing 3D medical data denoising algorithms have assumed the additive white Gaussian noise. In this work, we propose an efficient 3D medical data denoising method that can handle a noise mixture of various types. Our method is based on modified 2D Adaptive Rood Pattern Search (ARPS) [1] and low-rank matrix completion as follows. In our method, a noisy 3D data is processed in blockwise manner, for each processed 3D block we find similar 3D blocks in 3D data, where we use overlapped 3D patches to further lower the computation complexity. The 3D blocks then will stack together and unreliable voxels will be replaced using fast matrix completion method [2]. Experimental results show that the proposed method is able to robustly denoise the mixed noise from 3D medical data.

MA8b1-4

Automated Denoising and Segmentation of Optical Coherence Tomography Images

Sohini Roychowdhury, Dara D. Koozekanani, Keshab K. Parhi, University of Minnesota, United States

This paper presents a novel automated system that denoises and segments seven sub-retinal layers in optical coherence tomography (OCT) images. First, the OCT images are subjected to Wiener deconvolution by varying the noise variance from 10^{-1} to 10^{-15} . A new Fourier-domain structural error is introduced in this paper, and the deconvolved OCT image with the least structural error is selected as the denoised image. The properties of the structural error metric are studied, and it is shown that the error metric satisfies convexity property. For each image, the proposed denoising method increases the image SNR by 6.9 dB on average compared to 5 dB increase reported so far, and attains a mean peak SNR (PSNR) of 23.036 dB. Next, high-pass filters are applied to the denoised images in an iterative manner to extract the seven sub-retinal layers. The proposed system requires on average 10.65 seconds for denoising an image and 22.07 seconds for segmenting seven sub-retinal layers. This is a significant improvement over manual segmentation that requires up to 12 minutes per image.

MA8b1-5

Fourier Descriptor Based Diagnosis of Vocal-Fold Partial Asymmetry from High Speed Image Sequences

Jasmin Gonzalez, Sally Wood, Yuling Yan, Santa Clara University, United States

There is strong interest in fast and accurate automated examination and detection of pathologies in vocal fold function. Such systems could assist in detecting abnormalities during screenings, monitor treatment progress, and compare results after therapy or surgical intervention. It has been shown that analysis of the vocal fold area as a function of frame can be beneficial in the detection and diagnosis of pathologies due to frequency disturbances. However, this method is less effective in detecting asymmetry due to paralysis or obstruction in the laryngeal area. Here, we present alternative approaches to aid the diagnosis of vocal fold asymmetries.

MA8b1-6

Prostate Cancer Detection and Gleason Grading of Histological Images using Shearlet Transform

Hadi Rezaeilouyeh, Mohammad H. Mahoor, University of Denver, United States; Francisco La Rosa, University of Colorado, United States; Jun Jason Zhang, University of Denver, United States

In this paper we propose a method for representation and classification of microscopic tissue images using the shearlet transform. The objective is to automatically process biopsy tissue images and assist pathologists in analysing carcinoma cells, e.g., differentiating between benign and malignant cells in prostate tissues. Furthermore, we will automatically grade the cancer using the Gleason grading system. The main contribution of this paper is the use of a holistic based method instead of going through the tedious task of image segmentation, and the use of the shearlet method instead of traditional signal processing methods. Compared with wavelet filters such as the Gabor filter, shearlet has inherent directional sensitivity which makes it suitable for characterizing small contours of carcinoma cells. By applying a multi-scale decomposition, the shearlet transform captures visual information provided by edges detected at different orientations and multiple scales. For this purpose each image is represented using histogram of shearlet coefficients and then used for classification of benign and malignant tissues and also Gleason grading of cancer using support vector machines. Our preliminary results show that we can achieve a classification rate of 90% while we maintain low complexity comparing to other methods.

MA8b2-1

Cooperative AF Wireless Relay Strategy under Relay Power Constraint

Kanghee Lee, Hyuck M. Kwon, Edwin M. Sawan, Wichita State University, United States; Hyuncheol Park, Korea Advanced Institute of Science and Technology, Republic of Korea

This paper presents an optimal relay amplifying matrix based on various schemes, such as zero-forcing (ZF) and minimum mean square error (MMSE), for a cooperative amplify-and-forward (AF) wireless relay network consisting of a one source-one-destination pair with a single antenna and one relay with N antennas. The total relay transmission power constraint is employed. Even though different schemes and methods are applied to determine the optimal relay amplifying matrix, the identical one is derived. By adopting the derived optimal relay amplifying matrix, various analytical and numerical discussions, such as achievable rate (AR), are presented.

MA8b2-2

SNR-Based Channel Pairing Design in Multichannel TDBC-Based, Two-Way Relaying

Mingchun Chang, Min Dong, University of Ontario Institute of Technology, Canada

In this paper, we investigated into the design of channel pairing for time-division broadcast (TDBC)-based two-way relaying in a multichannel system with two terminal nodes and one relay node. With broadband systems of large number of subchannels, our focus is on efficient pairing strategy. We first show that, unlike in the one-way case, efficient SNR-based pairing strategy is not optimal for two-way pairing. We proposed a few suboptimal pairing algorithms with different complexity, ranging from $O(N \log N)$ to $O(N^3)$. Simulation results show that our proposed sorting-based algorithm is an attractive strategy providing very good performance with the lowest complexity of $O(N \log N)$.

MA8b2-3

An Exhaustive Message Splitting Scheme for Partial Decode-Forward in a Three-Relay Network

Yao Tang, McGill University, Canada; Mai Vu, Tufts University, United States

We introduce exhaustive message splitting for partial decode-forward in a single-source single-destination relay network with N relays, in which every relay subset has a private message to decode. We apply this idea to a three-relay network and propose a partial decode-forward scheme based on block Markov encoding with exhaustive message splitting and derive its achievable rate. A directed graph of the superposition codebook structure is provided to assist the understanding of the code hierarchy. We also apply the scheme to a Gaussian network and show that our scheme generalizes network decode-forward in [1] and the private message scheme in [2].

MA8b2-4

Convergence Analysis of Mixed Timescale Cross-Layer Stochastic Optimization

Junting Chen, Vincent Lau, Hong Kong University of Science and Technology, Hong Kong SAR of China

This paper considers a cross-layer optimization problem driven by multi-timescale stochastic exogenous processes in wireless communication networks. Due to the hierarchical information structure in the wireless network, a mixed timescale stochastic iterative algorithm is proposed to track the time-varying optimal solution of the cross-layer optimization problem, where the control variables are partitioned into short-term controls updated in a faster timescale, and long-term controls updated in a slower timescale. We focus on establishing a convergence analysis framework for such multi-timescale algorithms, which is difficult due to the timescale separation of the algorithm and the time-varying nature of the exogenous processes. To cope with this challenge, we model the algorithm dynamics using stochastic differential equations (SDEs) and show that the study of the algorithm convergence is equivalent to the study of the stochastic stability in a virtual stochastic dynamic system (VSDS). Leveraging the techniques of Lyapunov stability, we derive a sufficient condition for the algorithm stability and a tracking error bound in terms of the parameters of the multi-timescale exogenous processes. Numerical results match with the theoretical insights and demonstrate performance advantage for the proposed mixed timescale algorithm.

MA8b2-5

On Achievable Degrees of Freedom of 3-User MIMO Interference Channels

Lu Yang, Wei Zhang, University of New South Wales, Australia

Achievable Degrees of Freedom is studied in this paper for 3-user MIMO interference channels with M transmit antennas per transmitter and N receive antennas per receiver. Three interference alignment (IA) based signal transmission strategies are proposed and the achievable DoF is derived. It is shown that the achievable DoF of the proposed interference alignment scheme based on the best signal transmission strategy reaches the outer-bound in most cases.

MA8b2-6

Grassmannian Delay-Tolerant Limited Feedback for Interference Alignment

Zhinan Xu, Thomas Zemen, Telecommunications Research Center Vienna (FTW), Austria

In this paper, we propose a delay-tolerant limited feedback algorithm for single-input single-output (SISO) interference alignment. We exploit the temporal correlation of the channel impulse response and the finite frame length to model the channel impulse response with a low dimensional basis expansion. The algorithm tracks and feeds back the evolution of the basis expansion coefficients on the Grassmannian manifold. These coefficients allow the transmitter to predict the future channel realizations to compensate the feedback delay. By feeding back the quantized basis expansion coefficients instead of the channel impulse responses, the number of feedback bits can be substantially reduced. Our numerical results demonstrate that by exploiting the subspace structure of the time-variant channel we can reduce the amount of feedback to 1-2 bits per channel realization.

MA8b2-7

Minimum Cost Caching-Aided Multicast under Arbitrary Demand

Jaime Llorca, Antonia Tulino, Bell Labs, Alcatel-Lucent, United States

We address the content distribution problem as a network information flow problem on a caching augmented graph for which we provide a linear programming (LP) -based information theoretical lower bound. We show that while the LP solution involves high exponential complexity, the structure of the caching and transport configuration problems can be exploited to provide a set of solutions that tradeoff complexity with optimality. In particular, we show that while polynomial-time delivery schemes that employ random linear-coded transmission along with uncoded popularity-based caching are order-optimal under heavy tail Zipf popularity distributions, when the Zipf parameter decreases, the use of uncoded popularity-based vector caching can maintain constant-to-optimal performance at the expense of exponential-time network-coded transmission schemes that create multicasting opportunities even for users requesting distinct subsets of content objects.

MA8b2-8

Distributed Node-Weighted Connected Dominating Set Problems

Sattar Vakili, Qing Zhao, University of California, Davis, United States

The Minimum Connected Dominating Set (MCDS) problem is to find a subset of vertices in a given graph G such that the set is connected and any vertex of graph G is either in the set or adjacent to a node in the set. This problem is shown to be NP-Hard and the best polynomial time approximation factor is $O(\log n)$ where n is the number of vertices. The MCDS problem and its derivations are of interest in many network applications such as finding a minimum size virtual backbone for routing and broadcasting in ad-hoc networks. In this paper, we consider node-weighted CDS problem where positive real valued weights are assigned to the vertices and the objective is to find a CDS with minimum weight. We propose the first distributed algorithm for the problem and demonstrate it has optimal $O(\log n)$ approximation ratio. We then consider the case where the node weights are random variables with unknown distributions and develop a distributed learning algorithm based on the multi-armed bandit theory. We show that the distributed learning algorithm offers the optimal logarithmic regret order with respect to the time horizon length.

MA8b3-1

Low-Complexity Variable Forgetting Factor Constant Modulus RLS-based Algorithm for Blind Adaptive Beamforming

Boya Qin, Yunlong Cai, Zhejiang University, China; Benoit Champagne, McGill University, Canada; Minjian Zhao, Zhejiang University, China

In this paper, we propose a novel low-complexity variable forgetting factor (VFF) mechanism to enhance the performance of recursive least squares (RLS) algorithms for adaptive blind beamforming. The beamformer is designed according to the constrained constant modulus (CCM) criterion, and the proposed algorithm operates in the generalized sidelobe canceler (GSC) structure for implementation. The proposed variable forgetting factor mechanism employs a new component updated by the time average of the constant modulus (CM) cost function, to adjust the forgetting factor. A complexity comparison is provided to show its advantages over existing methods. The study of the steady-state analysis is carried out. Simulation results which are presented for a nonstationary scenario illustrate that the proposed variable forgetting factor mechanism achieves a superior performance compared to existing algorithms.

MA8b3-2

Parameter Bounds Under Misspecified Models

Christ Richmond, Larry Horowitz, MIT Lincoln Laboratory, United States

A class of parameter bounds emerges as a consequence of the covariance inequality, i.e. Cauchy-Schwarz inequality for expectations. The expectation operator forms an inner product space. Flexibility in the choice of expectation integrand and measure for integration exists, however, to establish a class of parameter bounds under a general form of model misspecification, i.e. distribution mismatch. The Cramér-Rao bound (CRB) primarily, and secondarily the Barankin, Hammersley-Chapman-Robbins, and Bhattacharyya bounds under misspecification are considered. Huber's sandwich covariance is easily established as the misspecified CRB, and a generalization of the Slepian-Bangs formula under misspecification is provided.

MA8b3-3

High Resolution Doppler and Delay Estimation

Benjamin Friedlander, University of California, Santa Cruz, United States

Receiving a signal which is a weighted sum of Doppler and delay shifted versions of a transmitted signal arises in various engineering systems including radar, sonar, and communications. It is often desired to estimate the Doppler and delay parameters from noisy measurements of the transmitted signal. An estimation algorithm is developed herein for the Doppler frequencies and delays for a specific choice of the transmitted signal. The algorithm is based on a computationally efficient search-free frequency estimation technique for the sum of complex exponentials. The algorithm provides high resolution - it is able to estimate closely spaced delays and Dopplers which are not resolvable by conventional processing techniques. Asymptotic performance bounds are developed for the estimated parameters.

MA8b3-4

Enhanced Edge Kernel Estimation for Robust Positioning

Davide Macagnano, Giuseppe Destino, University of Oulu, Finland

We consider a localization problem of multiple sources from range and angle measurements. To exploit the heterogeneity of the information we show how to formulate the problem as an optimization over an edge-kernel matrix and how to utilizing recent advances of robust principal component analysis applied to low-rank matrix recovery to improve the estimation of the edge-kernel as well as of a residual kernel-error matrix. These information are then employed to improve the estimation of the unknown source locations by means of constrained weighted linear least square fitting that matches the estimated edge-points to the source's coordinates. Our preliminary simulation results show that the advantage of the proposed nuclear-norm optimization over classical spectrum truncation and SDP-based formulations of the problem.

MA8b3-5

QR-TLS ESPRIT for Source Localization and Frequency Estimations

Nizar Tayem, Muhammad Omer, Prince Mohammad Bin fahd University, Saudi Arabia

This paper presents a subspace decomposition based algorithm for joint frequency of arrival (FOA) and direction of arrival (DOA) estimation. The proposed QR-TLS method relies on forming a Toeplitz structured matrix from the incident source signals at an antenna array. The structure of the problem favors the application of QR factorization which yields signal subspace at the expense of less computations. Total least squares (TLS) solution is then applied to find the frequency and angle estimates from the signal space. The proposed QR-TLS method avoids the computations of determining the cross-correlation matrix and to apply computationally complex eigen value decomposition (EVD) or singular value decomposition (SVD) for signal subspace as required by the conventional algorithms. In addition, the proposed method can provide FOA and DOA estimates for coherent and non-coherent sources without using spatial smoothing techniques. The low computational complexity and cost favors real time applicability of the proposed method. The performance of the proposed method is shown in simulations and the results are compared with some variations in the same method.

MA8b3-6

Parallel TSQR-TLS and QR-TLS factorization for Joint Time Delay and Frequency Estimation

Nizar Tayem, Muhammad Omer, Syed Raza, Mohammad Lakkis, Prince Mohammad Bin fahd University, Saudi Arabia

Abstract — In this paper we present two methods for joint estimation of time of arrival (TOA) and frequency of arrival (FOA) is presented for multiple incident sources based on the subspace decomposition techniques called QR-TLS and TSQR-TLS. The proposed methods employ a pair of spatially separated sensors to receive the multiple incident source signals. A data matrix is constructed in a form of a Henkel matrix from the multiple snapshots of the received signal. The information of both TOA and FOA of the multiple incident sources is extracted from the data matrix by applying QR technique in the first method and a recent idea of tall skinny QR (TSQR) factorization in the second method. The estimates of the TOA and FOA are obtained from the signal subspace by applying total least squares (TLS) method. The simulation results are presented to assess the performance of the proposed method. The effect of parametric variations on the performance has also been analyzed. Further, the computational times of the proposed methods are also compared with each other.

MA8b3-7

Analyzing the FD-MIMO Sparse Imaging under Carrier Frequency Offsets From the Perspective of Point Spread Function

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

In this paper, we address the problem of the frequency diverse multiple-input-multiple-output (FD-MIMO) radar sparse imaging with imperfect carrier frequency synchronization. From the perspective of classical point spread function (PSF) in range-angle plane, we get to know that the different scatterers in the interested scene would no longer share the same PSF. Instead, the scatterers located in different range bins would have distinct PSFs. Furthermore, for different sources to produce carrier frequency offsets, we find that those who are relevant to the receivers would result in more severe impact on the PSF due to the caused cross-interference between the range-angle dimensions. We further present a non-rigorous threshold of the carrier frequency offsets to suggest the boundary beyond which the resulting PSF would be totally distorted. Correspondingly, we propose to iteratively compensate the effect of carrier frequency offsets after sparse reconstruction when those offsets are controllable. Simulations demonstrate the reasonable results inferred from the analytical derivation and verify the effectiveness of the proposed algorithm.

MA8b3-8

A Generalized Framework for Development of Partially-Updated Signal and Parameter Estimation Algorithms Based on Subspace Optimization Constraints

Brian Agee, B3 Advanced Communication Systems, United States

A generalized framework for development of subspace constrained partially-updated (SCPU) signal and parameter estimation algorithms is proposed and demonstrated via analysis and computer simulation. Conventional partial-update (PU) methods are first reviewed and interpreted as a sequence of cost function optimizations subject to a hard parameter constraint. The SCPU method is then introduced as an equivalent optimization subject to a soft subspace constraint. It is shown that the new method removes adaptive misadjustment inherent to conventional PU methods, and allows generalization of the partial-update methods to much broader classes of signal and parameter estimation algorithms, including blind and nonblind ML estimation methods.

MA8b4-1

Model-Based Compressive Harmonic-Aware Matching Pursuit: An Evaluation

Bashar Ahmad, University of Cambridge, United Kingdom; Wei Dai, Cong Ling, Imperial College London, United Kingdom

This paper addresses devising a reliable model-based Harmonic-Aware Matching Pursuit (HAMP) for reconstructing sparse harmonic signals from their compressed samples. The performance guarantees of HAMP are provided; they illustrate that the introduced HAMP requires notably less data measurements and has lower computational cost compared with other greedy techniques. The complexity of formulating a structured sparse approximation algorithm is highlighted and the inapplicability of the conventional thresholding operator to the harmonic model is demonstrated. The harmonic sequential deletion algorithm is then proposed and other sparse approximation methods are evaluated. The superior performance of HAMP is depicted in the presented experiments.

MA8b4-2

An Adaptive Compressive Sensing with Side Information

William Guicquero, CEA-Leti: Laboratoire d'électronique des technologies de l'information, France; Pierre Vandergheynst, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Antoine Dupret, CEA-Leti: Laboratoire d'électronique des technologies de l'information, France

Compressive sensing [1] measurements generally do not provide as much understandable information as traditional compressed domains. With the rise of compressive sensing imagers it becomes necessary to define relevant sensing schemes. Apply the same linear projection to reduced signal supports optimizes the reconstruction time and makes the sensing strategy more applicable. This work proposes to add new statistical measurements to adapt the sensing strategy. Since these new measurements become practical on a real sensor it can improve the use of image compressive sensing by providing some useful features for other applications. In addition, those measures can improve significantly the reconstruction quality.

MA8b4-3

Multi-Capture High Dynamic Range Compressive Imaging

William Guicquero, CEA-Leti: Laboratoire d'électronique des technologies de l'information, France; Pierre Vandergheynst, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Antoine Dupret, CEA-Leti: Laboratoire d'électronique des technologies de l'information, France

We propose a novel approach to reconstruct High Dynamic Range images from a little number of compressive measurements. The reconstruction algorithm directly merges the information of multi-capture Bayerized images. It simultaneously performs demosaicing and naïve predefined tone-mapping. Two different color spaces are taken into account at the reconstruction stage to add multiple constraints on the signal. The proposed method provides a new way to understand multi-capture information to compensate nonlinearities due to saturation. This technique requires some prior knowledge of the pixel behavior. Yet, it could already be applied using existing compressive measurements performed by actual Compressive Sensing image sensors.

MA8b4-4

Bayesian Compressed Sensing with Unknown Measurement Noise Level

Thomas L. Hansen, Peter B. Jørgensen, Niels L. Pedersen, Carles Navarro Manchón, Bernard H. Fleury, Aalborg University, Denmark

In sparse Bayesian learning (SBL) approximate Bayesian inference is applied to find sparse estimates from observations corrupted by additive noise. Current literature only vaguely considers the case where the noise level is unknown a priori. We show that for most state-of-the-art reconstruction algorithms based on the fast inference scheme noise precision estimation results in increased computational complexity and reconstruction error. We propose a three-layer hierarchical prior model which allows for the derivation of a fast inference algorithm that estimates the noise precision with no complexity increase. Numerical results show that it matches or surpasses other algorithms in terms of reconstruction error.

MA8b4-5

Power Spectrum Blind Sampling Using Minimum Mean Square Error and Weighted Least Squares

Bamrung Tausiesakul, Nuria González Prelcic, University of Vigo, Spain

We present a new power spectrum recovery method for time domain approach in power spectrum blind sampling. A weighted least squares (WLS) criterion is adopted with the aim to minimize the mean square error (MSE) of the correlation estimate of the input data. It is shown by derivation that optimal weighting matrix is equal to the inverse of the covariance matrix of the correlation estimate of the output data. The derived weight can also be shown to be optimal in MSE sense for the power spectrum estimation. We also provide an optimization framework for the design of multicorset sampling pattern with the aim to minimize the MSE of the power spectrum. The resulting integer nonlinear programming problem is solved using exhaustive search. Numerical examples are provided and indicate that the weighted minimal MSE pattern that adopts the WLS provides significant improvement of the MSE in the power spectrum recovery over the minimal-sparse-ruler-based pattern and the minimal-MSE-based pattern that invoke usual least squares criterion.

MA8b4-6

Mixing Space-Time Derivatives for Video Compressive Sensing

Yi Yang, Hayden Schaeffer, University of California, Los Angeles, United States; Wotao Yin, Rice University, United States; Stanley Osher, Level Set Systems, United States

With the increasing use of compressive sensing techniques for better data acquisition and storage, the need for efficient, accurate, and robust reconstruction algorithms continues to be in demand. In this work we present a fast total variation based method for reconstructing video compressive sensing data. Video compressive sensing systems store video sequences by taking a linear combination of consecutive spatially compressed frames. In order to recover the original data, our method regularizes both the spatial and temporal components using a total variation semi-norm that mixes information between dimensions. This mixing provides a more consistent approximation of the connection between neighboring frames with little to no increase in complexity. The algorithm is easy to implement since each iteration contains two shrinkage steps and a few iterations of conjugate gradient. Numerical simulations on real data show large improvements in both the PSNR and visual quality of the reconstructed frame sequences using our method.

MA8b4-7

Compressive Measurement Designs for Estimating Structured Signals in Structured Clutter: A Bayesian Experimental Design Approach

Swayambhoo Jain, Akshay Soni, Jarvis Haupt, University of Minnesota, Twin Cities, United States

This work considers an estimation task in compressive sensing, where the goal is to estimate an unknown signal from compressive measurements that are corrupted by additive pre-measurement noise (interference, or “clutter”) as well as post-measurement noise, in the specific setting where some (perhaps limited) prior knowledge on the signal, interference, and noise is available. The specific aim here is to devise a strategy for incorporating this prior information into the design of an appropriate compressive measurement strategy. Here, the prior information is interpreted as statistics of a prior distribution on the relevant quantities, and an approach based on Bayesian Experimental Design is proposed. Experimental results on synthetic data demonstrate that the proposed approach outperforms traditional random compressive measurement designs, which are agnostic to the prior information, as well as several other knowledge-enhanced sensing matrix designs based on more heuristic notions.

Track B – MIMO Communications and Signal Processing

Session: MPa1 – Massive MIMO

Chair: *Erik Larsson, Linköping University*

MP1a-1

1:30 PM

Spectral Efficiency of the Multipair Two-Way Relay Channel with Massive Arrays

Hien Quoc Ngo, Erik G. Larsson, Linköping University, Sweden

We consider a multipair two-way relay channel where multiple communication pairs share the same time-frequency resource and a common relay node. We assume that all users have a single antenna, while the relay node is equipped with a very large antenna array. We consider two transmission schemes: (I) separate-training zero-forcing (ZF) and (II) a new proposed coupled-training ZF. For both schemes, the channels are estimated at the relay by using training sequences, assuming time-division duplex operation. The relay processes the received signals using ZF. With the separate-training ZF, the channels from all users are estimated separately. By contrast, with the coupled-training ZF, the relay estimates the sum of the channels from two users of a given communication pair. This reduces the amount of resources spent in the training phase. Self-interference reduction

is also proposed for these schemes. When the number of relay antennas grows large, the effects of interpair interference and self-interference can be neglected. The transmit power of each user and of the relay can be made inversely proportional to the square root of the number of relay antennas while maintaining a given quality-of-service. We derive a lower bound on the capacity which enables us to evaluate the spectral efficiency. The coupled-training ZF scheme is preferable for the high-mobility environment, while the separate-training ZF scheme is preferable for the low-mobility environment.

MP1a-2

1:55 PM

How Bad is FDD for Large-Scale Antenna Systems?

Thomas L. Marzetta, Bell Labs, Alcatel-Lucent, United States

It is self-evident that frequency-division duplex (FDD) is vastly inferior to time-division duplex (TDD) for training-based Large-Scale Antenna Systems (also known as Massive MIMO, Large-Scale MIMO, Hyper-MIMO, etc.). Just how much worse is FDD? This question is answered quantitatively for a simplified scenario comprising a single cell having M service-antennas, K terminals, and i.i.d. Rayleigh fading. TDD operation entails transmitting up-link orthogonal pilot sequences from which the service-antennas estimate the up-link channel - equal to the down-link channel via reciprocity - and then using the down-link channel estimates to transmit down-link data through conjugate beam-forming. A simple capacity lower-bound for this scheme already exists. FDD operation consists of four separate operations: transmission of down-link orthogonal pilot sequences, transmission of the received pilot signals on the up-link with optional orthogonal spreading sequences (e.g. analog multi-access MIMO), transmission of up-link pilot sequences, and finally down-link transmission of data via conjugate beam-forming that utilizes the down-link channel estimates derived from the two up-link transmissions. The new result obtained is a capacity lower-bound for this FDD scheme. The TDD and FDD bounds, plotted as functions of the slot-duration and other parameters, illustrate the huge superiority of TDD over FDD.

MP1a-3

2:20 PM

Massive MIMO Channels - Measurements and Models

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

Spatial multiplexing using massive MIMO has been shown to have very promising properties, including large increases in spectral efficiency and several orders of magnitude lower transmit powers, as compared to today's access schemes. These properties have been studied mostly for theoretical channels with i.i.d. complex Gaussian coefficients. To efficiently evaluate massive MIMO access schemes in more realistic scenarios, we need new channel models that include characteristics important for massive MIMO performance. We pursue this by analyzing measurement data from several measurement campaigns in the 2.6 GHz frequency range, using different antenna array structures with 128 antenna elements. Key propagation characteristics are identified from measurements and developed into channel models. Massive MIMO performance is evaluated for the proposed channel models and compared with that obtained with measured and i.i.d. channels.

MP1a-4

2:45 PM

A Low-Complexity Linear Precoding and Power Allocation Scheme for Downlink Massive MIMO

Shahram Zarei, Wolfgang Gerstacker, Robert Schober, University of Erlangen-Nuernberg, Germany

We present a low-complexity linear precoding and power allocation scheme for downlink transmission in massive multiple-input multiple-output (MIMO) systems. Massive MIMO systems offer a very high spectral efficiency while keeping the total energy consumption low. Furthermore, if the channel state information (CSI) is perfectly known at the base station, the transmit power of the users for uplink transmission can be reduced by a factor proportional to the number of base station antennas. These considerations and some other properties render massive MIMO systems a promising technology for application in future communication systems. In this work, we consider a single-cell downlink massive MIMO scenario where one base station with N antennas serves simultaneously K single-antenna users which are uniformly distributed within the cell. Both N and K are asymptotically large with the ratio K/N being a constant. The minimum mean square error (MMSE) precoder has been shown to provide excellent performance in the asymptotic regime, where N and K are both large. However, MMSE precoding requires a matrix inversion which entails a high computational complexity especially for the large matrices typical for massive MIMO systems. To circumvent this problem, we propose a linear precoding scheme which avoids matrix inversion and is based on a matrix polynomial. Using results from random matrix theory, we derive a closed-form expression for the optimum coefficients of the precoder matrix polynomial. We also provide a solution to the power allocation problem in the asymptotic regime. Simulation results illustrate the excellent performance of the proposed power allocation and precoding scheme in terms of the achievable sum-rate.

Track B – MIMO Communications and Signal Processing

Session: MPb1 – Distributed Coherent MIMO

Chair: *Adam Margetts, MIT Lincoln Laboratory*

MP1b-1

3:30 PM

Optimal Training and Data Power Allocation for Distributed Transmit Beamforming

Adam R. Margetts, Rebekah Bartlett, Eric G. Torkildson, Shawn Kraut, Massachusetts Institute of Technology, United States

Performing distributed transmit beamforming across multiple cooperative radios can focus energy at a receiver to significantly improve the power, rate, and range tradeoff. In frequency division duplexed systems, the transmit beamformer is estimated at the receiver from a training signal and fed back to the transmitters. A caveat is that the training signal is typically not focused and as transmitters are added training may become a large fraction of the total transmit power. We determine the optimal allocation of power between training and data that minimizes the outage probability. Results depend on the target spectral efficiency, coherence time, SNR per receiver, and number of transmitters and receivers.

MP1b-2

3:55 PM

Distributed MIMO Channel Prediction

Patrick Bidigare, BBN Technologies, United States; D. Richard Brown III, Worcester Polytechnic Institute, United States; Shawn Kraut, MIT Lincoln Laboratory, United States; Upamanyu Madhow, University of California, Santa Barbara, United States

Receiver-coordinated distributed MIMO uses a network of disconnected co-channel radios to beamform a common data stream to a distant receiver. Independent local oscillators, radio motion and multipath cause the resulting aggregate MIMO channel to be highly non-stationary. This non-stationarity demands fast channel estimation and low-latency CSI feedback to maintain transmit coherence. In this paper we introduce models for the evolution of the distributed MIMO multipath channel. We use these to develop predictive filters that greatly relax the estimation and feedback latencies. Using data collected over-the-air we demonstrate $>2X$ relaxation in latency over conventional block stationary processing.

MP1b-3

4:20 PM

Outage Probability Analysis of Distributed Reception with Hard Decision Exchanges

Rui Wang, D. Richard Brown III, Min Ni, Worcester Polytechnic Institute, United States; Upamanyu Madhow, University of California, Santa Barbara, United States; Patrick Bidigare, BBN Technologies, United States

This paper analyzes the performance of a distributed reception technique in which receivers exchange hard decisions with other receivers in a fully connected receive cluster. These hard decisions are optimally combined with locally unquantized observations to maximize the local mutual information at each receiver. Upper and lower bounds on the outage probability performance gap of distributed reception with respect to ideal receive beamforming are developed. Simulation results verifying the bounds are also presented.

MP1b-4

4:45 PM

Receive Spatial Coding for Distributed Diversity

David Love, Purdue University, United States; Patrick Bidigare, BBN Technologies, United States

It is well known that centralized multiple antenna receivers can give a spatial diversity advantage. Distributed receive diversity systems, however, are studied much less frequently. In this paper, we consider the problem of diversity reception when distributed nodes can only pass a small, fixed number of bits per channel use to a fusion center. We concentrate on the particular case when each node can only pass one bit per channel use sample. Using insights from channel coding, we show how to provide increased spatial diversity.

Track A – Communications Systems

Session: MPa2 – Wireless Security

Chair: *Giuseppe Abreu, Jacobs University*

MP2a-1

1:30 PM

Secure Degrees of Freedom Region of Interference Channels with Confidential Messages

Jianwei Xie, Sennur Ulukus, University of Maryland, United States

We consider the Gaussian interference channel with confidential messages, where each user has a message for its receiver, which needs to be kept confidential from all other receivers. We consider the large signal to noise ratio regime, and determine the exact secure degrees of freedom region for this system.

MP2a-2

1:55 PM

The Effect of Channel Spatial Correlation on Physical Layer Security in Multi-antenna Scenarios

Gianni Pasolini, University of Bologna, Italy; Stefano Severi, Giuseppe Abreu, Jacobs University, Germany; Davide Dardari, University of Bologna, Italy

Information theoretic security at the physical-layer has been proposed to increase the privacy of wireless communications. Information-theoretic security is unbreakable, provable, quantifiable and can be achieved by exploiting physical layer characteristics such as the propagation reciprocity. An analytical framework aimed at deriving the achievable security level is presented. Its accuracy is assessed by comparison with simulations carried out in a narrowband fading scenario with multi-antenna transceivers. The impact on the achievable security level of a number of parameters, such as the signal-to-noise ratio, the channel reciprocity level and the number of antennas is finally discussed.

MP2a-3

2:20 PM

Random Puncturing for Secrecy

João Almeida, João Barros, Faculdade de Engenharia da Universidade do Porto, Portugal

The traditional framework under which error-correcting codes can enable secrecy involves the use of nested codes. While this structure provide us with means to achieve weak secrecy, it is not clear how these codes can be applied to varying wiretap channels. In the spirit of rate-compatible codes, we propose a new framework for coding for the wiretap channel. The proposed scheme is based on random-puncturing, where the puncturing pattern is kept secret from the eavesdropper. Our results indicate that such strategy can indeed achieve high equivocation-rates (even when the channel is degraded) without the need to re-design the underlying codes.

MP2a-4

2:45 PM

Interference Engineering for Heterogeneous Wireless Networks with Secrecy

Alberto Rabbachin, Massachusetts Institute of Technology, United States; Andrea Conti, ENDIF, Università di Ferrara, Italy; Jemin Lee, Moe Win, Massachusetts Institute of Technology, United States

Wireless secrecy is essential for information superiority, communication confidentiality, and economic advantage in modern information society. Contemporary security systems are based on cryptographic primitives and can be complemented by techniques that exploit the intrinsic properties of the wireless environment. We present foundations for design and analysis of heterogeneous wireless networks with intrinsic secrecy provided by nodes spatial distribution, wireless propagation medium, and aggregate network interference. Guided by our preliminary results, we envision that network interference can be engineered to provide beneficial effects to network secrecy opening to new perspectives for the coexistence of heterogeneous networks.

Track A – Communications Systems

Session: MPb2 – Energy Harvesting and Transfer

Chair: *Kaibin Huang, Hong Kong Polytechnic University*

MP2b-1

3:30 PM

Energy Harvesting Communications with Hybrid Energy Storage and Processing Energy Costs

Omur Ozel, Khurram Shahzad, Sennur Ulukus, University of Maryland, United States

We consider data transmission using an energy harvesting transmitter with hybrid energy storage in the presence of non-zero processing power. The hybrid storage consists of an efficient super-capacitor (SC) with finite storage space, and an inefficient battery with infinite storage. The transmitter can choose to store the harvested energy in the SC or the battery, while energy is drained from both the storage elements simultaneously. In an offline setting, we analyze the throughput maximization problem over a point-to-point static channel and find optimal transmission policies by applying directional glue pouring algorithm in multiple stages.

MP2b-2

3:55 PM

Multi-Pair and Multi-Way Communications Using Energy Harvesting Nodes

Aylin Yener, Burak Varan, Pennsylvania State University, United States

MP2b-3

4:20 PM

Wireless Info-Power Transfer: Theory and Practice

Pulkit Grover, Carnegie Mellon University, United States

We report the results of our experiments that test the models and theoretical results in simultaneous wireless information and power transfer. Understanding limitations of practical implementations can help direct theoretical research towards better guidance of such implementations.

MP2b-4

4:45 PM

Simultaneous Information-and-Power Transfer over Broadband Channels

Kaibin Huang, Hong Kong Polytechnic University, Hong Kong SAR of China; Erik G. Larsson, Linköping University, Hong Kong SAR of China

Far-field wireless recharging based on microwave power transfer (MPT) will free mobile devices from interruption due to finite battery lives. Integrating MPT with wireless communications to support simultaneous information-and-power transfer (SIPT) allows the same spectrum to be used for dual purposes without compromising the quality of service. A novel approach is presented in this paper for realizing SIPT in a broadband system where orthogonal frequency division multiplexing and transmit beamforming are deployed to create a set of parallel sub-channels for SIPT, which simplifies resource allocation. Supported by a proposed reconfigurable mobile architecture, different system configurations are considered by combining downlink/uplink information transfers and variable/fixed coding rates. Optimizing the power control for these configurations results in a new class of multiuser power-control problems featuring the circuit-power constraints, namely that the transferred power must be sufficiently large for operating receiver circuits. Solving these problems gives a set of power-control algorithms that exploit channel diversity in frequency for simultaneously enhancing the throughput and the MPT efficiency. For the system configurations with variable coding rates, the algorithms are variants of water filling that account for the circuit-power constraints. The optimal algorithms for those configurations with fixed coding rates are shown to sequentially allocate mobiles their required power for correctly decoding data streams in the ascending order till the budgeted power is exhausted. The required power for a mobile is derived as simple functions of the minimum signal-to-noise ratio for correct decoding, the circuit power and sub-channel gains.

Track D – Signal Processing and Adaptive Systems

Session: MPa3 – Blind Source Separation and Deconvolution

Chair: *Justin Romberg, Georgia Institute of Technology*

MP3a-1

1:30 PM

Recovery of Decision Factors from Incomplete Rankings

Laura Balzano, University of Michigan, United States

Recovery of Decision Factors from Incomplete Rankings

MP3a-2

1:55 PM

Blind Deconvolution with Subspace Constraints

Ali Ahmed, Justin Romberg, Georgia Institute of Technology, United States

Blind Deconvolution with Subspace Constraints

MP3a-3

2:20 PM

Nonlinear Basis Pursuit

Henrik Ohlsson, Allen Yang, Roy Dong, Shankar Sastry, University of California, Berkeley, United States

In compressive sensing, the basis pursuit algorithm aims to find the sparsest solution to an underdetermined linear equation system. In this paper, we generalize basis pursuit to finding the sparsest solution to higher order nonlinear systems of equations, called nonlinear basis pursuit. In contrast to the existing nonlinear compressive sensing methods, the new algorithm that solves the nonlinear basis pursuit problem is convex and not greedy. The novel algorithm enables the compressive sensing approach to be used for a broader range of applications where there are nonlinear relationships between the measurements and the unknowns.

MP3a-4

2:45 PM

The Sample Complexity of Independent Component Analysis

Santosh Vempala, Ying Xiao, Georgia Institute of Technology, United States

The Sample Complexity of Independent Component Analysis

Track D – Signal Processing and Adaptive Systems

Session: MPb3 – Distributed Signal Processing and Learning

Chair: *Alejandro Ribeiro, University of Pennsylvania*

MP3b-1

3:30 PM

Optimal Solutions to Distributed Finite Horizon Stochastic Team Problems

Ceyhun Eksin, Pooya Molavi, Ali Jadbabaie, Alejandro Ribeiro, University of Pennsylvania, United States

We consider a team problem with non-myopic agents. Each agent has a type indicating his preference. The stage team cost is quadratic in actions of agents and mean type of the population. A strategy is admissible for an agent if it is based on neighbors' actions of the past and his type. Hence, the information structure of agents is non-classic, that is, an individual's decision affects others' information while other agents cannot infer about decision maker's information fully. Since problems with non-classic information structure are notoriously hard to solve, we consider a relaxed version of the original team problem with delayed type sharing information structure where agents communicate their types with delays. In the relaxed problem agents' decisions do not affect each others' information in the future; as a result, the optimal policy to the relaxed problem is myopic. We leverage on the explicit characterization of the myopic policy for the relaxed problem together with the fact that optimal value for the relaxed problem is a lower bound on the original problem to show that for certain graph structures the original team problem with non-classic information structure has optimal admissible myopic policies. We provide explicit characterization of these optimal policies.

MP3b-2**3:55 PM****Distributed Kalman Filtering and Network Tracking Capacity**

Subhro Das, Jose M. F. Moura, Carnegie Mellon University, United States

In distributed parameter estimation and detection, global observability and mean connectedness of the network is sufficient for optimal asymptotic performance of (consensus + innovations) type algorithms. However, in distributed state estimation of dynamical systems, connectedness on average of the underlying network is enough only for stable systems. Distributed tracking of unstable systems requires stricter conditions on the network topology. It turns out that these are dependent on the specific class of distributed algorithms. Earlier references studied distributed state estimation of dynamical systems with Kalman filter type algorithms and introduced the concept of Network Tracking Capacity (NTC). NTC restricts the degree of instability of the dynamical systems that can be tracked by a distributed network of agents. For existing algorithms, NTC depends not only on the connectivity of the agent communication network but also on the local observation models. We propose and study a new distributed Kalman filter algorithm that can track unstable dynamics with bounded mean-squared error (MSE). NTC of this algorithm depends only on the diffusion rate of the network and is independent of the specifics of the local observation models, only requiring global observability.

MP3b-3**4:20 PM****Distributed Underwater Acoustic Source Localization and Tracking**

Jun Ye Yu, Deniz Ustebay, McGill University, Canada; Stephane Blouin, Defence Research and Development Canada, Canada; Michael Rabbat, McGill University, Canada

We consider the problem of localizing and tracking a noise source under water using bearings-only measurements taken from a small collection of distributed acoustic sensors. Nodes must cooperate in order to improve their estimates and overcome significant noise levels and spurious measurements from clutter. However the underwater communication channel is highly unreliable making coordination challenging. We evaluate the performance of distributed particle filtering methods in the setting where nodes communicate over unreliable links. Our results are validated using data from an experiment conducted at sea.

MP3b-4**4:45 PM****Distributed Sparse Canonical Correlation Analysis in Clustering Sensor Data**

Jia Chen, Ioannis Schizas, University of Texas at Arlington, United States

The problem of determining information-bearing sensors in the presence of multiple field sources and (non-)linear data models is considered. To this end, a novel canonical correlation analysis (CCA) framework combined with norm-one regularization is introduced to identify correlated measurements across the distributed sensors and cluster the sensor data based on their source content. A distributed algorithm is also put forth for informative sensor identification in nonlinear settings using the novel CCA approach. Toward this end, the sparsity-aware CCA framework is reformulated as a separable constrained minimization problem which is solved by utilizing block coordinate descent techniques combined with the alternating direction method of multipliers. Numerical tests demonstrate that the distributed sparse CCA scheme put forth outperforms existing alternatives when it comes to clustering the sensor data based on their source content.

*Track C – Networks***Session: MPa4 – Network Optimization and Control**Co-Chairs: *Chih-Ping Li, MIT and Eytan Modiano, MIT***MP4a-1****1:30 PM****Energy Trading in the Smart Grid: From End-User's Perspective**

Shengbo Chen, Ness Shroff, Prasun Sinha, The Ohio State University, United States

The smart grid is expected to be the next generation of electricity grid. It will enable numerous revolutionary features, that allow end-users, such as homes, communities, or businesses, to harvest renewable energy and store the energy in a local battery, which could act as a microgeneration unit. In addition, the customers could be provided with dynamic electricity pricing options under which the electricity price adjusts over a relatively small time scale, e.g., every hour, in response to the changing energy usage of the grid. Consequently, similar to the stock market, it presents an opportunity for an end-user to make profit by trading energy with the grid. More specifically, in this paper, we investigate the profit maximization problem for an end-user that is equipped with renewable energy harvesting devices and a battery, such that the user can buy/sell the energy from/to the grid by leveraging the varying price and the battery storage ability. The resulting algorithm performs arbitrarily close to the optimum without requiring future information of energy demands, electricity prices and the renewable energy arrival process. We validate our results through trace driven simulations.

MP4a-2

1:55 PM

Bayesian Congestion Control over a Markovian Network Bandwidth Process

Parisa Mansourifard, Bhaskar Krishnamachari, University of Southern California, United States; Tara Javidi, University of California, San Diego, United States

Abstract—We formulate a Bayesian congestion control problem in which a source must select the transmission rate over a network whose available bandwidth is modeled as a time-homogeneous finite-state Markov Chain. The decision to transmit at a rate below the instantaneous available bandwidth results in an under-utilization of the resource while transmission at rates higher than the available bandwidth results in a linear penalty. The trade-off is further complicated by the asymmetry in the information acquisition process: transmission rates that happen to be larger than the instantaneous available bandwidth result in perfect observation of the state of the bandwidth process. In contrast, when transmission rate is below the instantaneous available bandwidth, only a (potentially rather loose) lower bound on the available bandwidth is revealed. We show that the problem of maximizing the throughput of the source while avoiding congestion loss can be expressed as a Partially Observable Markov Decision Process (POMDP). We prove structural results providing bounds on the optimal actions. The obtained bounds yield tractable sub-optimal solutions that are shown via simulations to perform well.

MP4a-3

2:20 PM

Exploring the Tradeoff between Waiting Time and Service Cost in Non-Asymptotic Operating Regimes

Bin Li, Atilla Eryilmaz, The Ohio State University, United States

Motivated the problem of demand management in smart grids, we study the problem of minimizing the mean delay of user demands and the power generation cost, which increases with both the mean and the variance of power generations. The state-of-the-art algorithms for this problem are asymptotically optimal, i.e., they are optimal only when the mean delay of user demands increases to infinity. Yet, these algorithms may perform poorly for the moderate delay, which is the regime in which most applications operate. Hence, there is a pressing need for the design of algorithms that can operate efficiently in the moderate delay regime. We attack this challenging problem in a generic framework by first proposing a class of parameterized algorithms, which includes some existing policies as special instances. Then, we get the optimal algorithm within this class by explicitly characterizing the mean delay and the power generation cost as a function of the algorithmic parameters. The proposed algorithm with the optimal parameters is not only asymptotically optimal but also outperforms the existing algorithms uniformly for all cases.

MP4a-4

2:45 PM

Pricing and Bandwidth Optimization in Heterogeneous Wireless Networks

Cheng Chen, Randall Berry, Michael Honig, Vijay Subramanian, Northwestern University, United States

We consider a heterogeneous cellular network containing large (macro) and small (micro) cells, which serve two classes of users: highly mobile and fixed. The highly mobile users can be served only by the macro-cells, and the fixed users can be served by either the macro- or micro-cells. The service provider sets two prices for the mobile and fixed users, and partitions the available bandwidth across the macro- and micro-cells. We study the prices and allocation of bandwidth that maximize the total revenue.

Track C – Networks

Session: MPb4 – Network Coding and Compression

Chair: *Daniel Lucani, University of Aalborg*

MP4b-1

3:30 PM

Constructions of Fractional Repetition Codes from Combinatorial Designs

Oktay Olmez, Aditya Ramamoorthy, Iowa State University, United States

We consider regenerating codes for distributed storage systems that have the exact and uncoded repair property. Our codes leverage the properties of combinatorial designs based on affine geometries, Latin squares and lattices. Specifically, we propose a recursive construction where new codes can be generated from existing ones thus yielding an infinite family of codes that cover a larger range of parameters. Furthermore, we provide tighter estimates (than were known previously) on the file sizes that can be obtained using our codes.

MP4b-2**3:55 PM****Network Coded Storage with Multi-Resolution Codes**

Ulric Ferner, Tong Wang, Muriel Médard, Massachusetts Institute of Technology, United States

In this paper, we propose a network coded storage (NCS) system for data center video-streaming applications. In particular, files stored on drives are pre-network coded across multi-resolution (MR) layers. We explore the characteristics of this concept and compare it to a modern uncoded storage (UCS) scheme and to a classic scheme. We use Markov processes to model the transactions of different arrivals and departure types and show that the process structure is predominantly constrained by I/O access bandwidth limitations. We illustrate that the NCS scheme achieves a lower saturation probability than the UCS scheme under a large number of network conditions, including variations in server load, storage allocation between layers, and arrival request-type ratios. More specifically, we find that NCS can in some cases provide an order of magnitude in saturation probability gains over UCS systems. Finally, we show that NCS can be used to reduce required drive infrastructure in data centers.

MP4b-3**4:20 PM****Lattice Interference Alignment: State-of-the-Art and Challenges**

Vasilis Ntranos, University of Southern California, United States; Viveck Cadambe, Massachusetts Institute of Technology / Boston University, United States; Bobak Nazer, Boston University, United States; Giuseppe Caire, University of Southern California, United States

It is well known that lattice codes can enable alignment on the signal scale by allowing the receiver to treat the sum of several interfering terms as a single codeword. However, prior work on lattice codes has been limited to either the high SNR regime or to symmetric channel gains. As a result, lattice-based alignment is perceived to be brittle and ill-suited for the finite SNR regime. In this paper, we describe a lattice-based framework that can enhance the rates achievable via any beamforming solution for signal space alignment. We point out several open challenges, stemming both from the theoretical analysis of this framework and the optimization of the resulting rate region.

MP4b-4**4:45 PM****Bounds and Algorithms for Pliable Index Coding**

Siddhartha Brahma, Christina Fragouli, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Pliable index coding is a new formulation of the index coding problem we have recently introduced, where instead of demanding a specific bit (or message), clients are “pliable” and are happy to receive any one bit they do not have. As in index coding, the goal is to minimize the broadcast transmissions required to satisfy the clients. For example, the clients might be doing an internet search, have collected some information and are interested in receiving with low delay additional information on the subject they are searching; they do not care which specific piece of information they do receive, as long as it is something they do not already have. We present in this paper lower and upper bounds as well as construction algorithms for this problem.

*Track F – Biomedical Signal and Image Processing***Session: MPa5 – Extracting Information from Electrophysiology Data**Chair: *Christopher Rozell, Georgia Institute of Technology***MP5a-1****1:30 PM****Sparse Nonnegative Deconvolution of Compressive Calcium Imaging Data**

Eftychios A. Pnevmatikakis, Shyam S. Chandramouli, Liam Paninski, Columbia University, United States

Compressive fluorescence imaging has the potential to enable microscopy data acquisition at much higher temporal resolution than standard raster scanning approaches, by measuring a small set of random projections of each frame. Here we adapt this framework to the context of neuron population calcium imaging. We present efficient nonnegative deconvolution methods for extracting the neuronal calcium spiking time series. We consider both maximum-a-posteriori and MCMC approaches that scale linearly with the number of timesteps and thus are applicable to arbitrarily long experiments. By exploiting the sparsity of neural spiking we demonstrate that the number of measurements needed per timestep is significantly smaller than the total number of neurons, a result that can potentially enable imaging of larger neural populations at considerably faster imaging rates.

MP5a-2**1:55 PM****Schizophrenia Classification with Single-Trial MEG during Language Processing**

Tingting Xu, University of Minnesota, United States; Massoud Stephane, Oregon Health & Science University, United States; Keshab K. Parhi, University of Minnesota, United States

Language disorder is a core symptom associated with schizophrenia. This study investigates schizophrenia classification based on brain activity during language processing. 6 healthy controls and 6 schizophrenia patients were instructed to read words and sentences silently while 248 channel magnetoencephalography (MEG) signals were recorded. For each trial, power spectral features were extracted in 8 frequency bands from all channels which form a spectral-spatial feature set. Top features ranked by F-score were fed into machine learning based classifiers for patient and control classification. Following cross validation procedure, 98.94% and 99.78% accuracies were achieved in classifying 470 word trials and 450 sentence trials, respectively. The high accuracy indicates abnormalities of brain activity during language processing in patient group and show that MEG patterns reflecting such abnormalities can be used to discriminate schizophrenia patients from healthy subjects. The proposed scheme may have potential application in schizophrenia diagnosis and classifying other mental diseases.

MP5a-3**2:20 PM****Modeling Neural Population Data**

Urs Koster, Bruno Olshausen, University of California, Berkeley, United States; Charles Gray, Montana State University Bozeman, United States

A fundamental challenge in Neuroscience is to infer the emergent properties of networks of neurons. Our current understanding of neural processing is largely based on the response properties of single cells, but techniques to simultaneously record action potentials from populations of neurons are rapidly advancing. This provides new challenges for probabilistic models to characterize networks and to understand their connectivity as well as computational function. We present an overview of statistical models to describe the activity of simultaneously recorded neurons. These methods allow us to interpret the network activity in terms of underlying circuit structure and give insight into functional connectivity.

MP5a-4**2:45 PM****A Neuron as a Signal Processing Device**

Tao Hu, Janelia Farm, HHMI, United States; Alex Genkin, AVG Consulting, United States; Dmitri Chklovskii, Janelia Farm, HHMI, United States

A biological neuron is an elementary building block of the brain. While the physiology of a neuron has been studied extensively its computational role has until now remained a mystery. We propose to view a neuron as a signal processing device for extracting and tracking a non-Gaussian feature from its high-dimensional input. Such task can be accomplished collectively by two online algorithms: a slow time-scale algorithm which adjusts synaptic weights to extract the most non-Gaussian projection of the high-dimensional input, and a fast time-scale algorithm which tracks, or de-noises, the projection amplitude. Both online algorithms rely on sparsity-inducing regularizers and have provable performance bounds. The steps of these algorithms account for the salient physiological features of neurons such as leaky integration, non-linear output function, Hebbian synaptic plasticity rules, sparse connectivity and activity. Therefore, our work sets up a foundation for modeling biological neurons as adaptive signal processing devices.

Track F – Biomedical Signal and Image Processing

Session: MPb5 – Optimization in (Bio)Medical Imaging

Chair: *Roummel Marcia, University of California, Merced*

MP5b-1**3:30 PM****Parallel and Distributed Sparse Optimization**

Zhimin Peng, Ming Yan, Wotao Yin, University of California, Los Angeles, United States

This paper proposes parallel and distributed algorithms for solving very large-scale sparse optimization problems on computer clusters and clouds. Modern datasets usually have a large number of features or training samples, and they are usually stored in a distributed manner. Motivated by the need of solving sparse optimization problems with large datasets, we propose two approaches including (i) distributed implementations of prox-linear algorithms and (ii) GRock, a parallel greedy coordinate descent method. Different separability properties of the objective terms in the problem enable different data-distributed schemes along with their corresponding algorithm implementations. We also establish the convergence of GRock and explain why it often performs exceptionally well for sparse optimization. Numerical results on a computer cluster and Amazon EC2 demonstrate the efficiency and elasticity of our algorithms.

MP5b-2

3:55 PM

Nonconvex Compressive Sensing for X-ray CT: An Algorithm Comparison

Rick Chartrand, Los Alamos National Laboratory, United States; Emil Y. Sidky, Xiaochuan Pan, University of Chicago, United States

Compressive sensing makes it possible to reconstruct images from severely underdetermined linear systems. For X-ray CT, this can allow high-quality images to be reconstructed from projections along few angles, reducing patient dose, as well as enable other forms of limited-view tomography such as tomosynthesis. Many previous results have shown that using nonconvex optimization can greatly improve the results obtained from compressive sensing, and several efficient algorithms have been developed for this purpose. In this paper, we examine some recent algorithms for CT image reconstruction that solve nonconvex optimization problems, and compare their reconstruction performance and computational efficiency.

MP5b-3

4:20 PM

Computing Optimal Low-Rank Matrix Inverse Approximations for Image Processing

Julianne Chung, Matthias Chung, Virginia Tech, United States

In many applications such as biomedical imaging, the desired solution of an inverse problem can be well-represented using only a few vectors of a certain basis, e.g., the singular vectors. In this work, we design an optimal low-rank matrix inverse approximation by incorporating probabilistic information from training data and solving an empirical Bayes risk minimization problem. We propose an efficient update approach for computing a low-rank regularized matrix, and provide numerical results for problems from image processing.

MP5b-4

4:45 PM

Accurate and Fast Optimization for a Parameterized Diffuse Optical Tomography Problem

Eric de Sturler, Virginia Tech, United States; Misha Kilmer, Tufts University, United States; Christopher Beattie, Saifon Chaturantabut, Serkan Gugercin, Virginia Tech, United States

In diffuse optical tomography, the physics dictates that the spatial resolution of the recovered image is limited. Therefore, we use parametric level sets to represent the medium, which leads to a regularized problem, and solve a nonlinear least squares problem for a modest number of parameters. As the nonlinear function evaluation is expensive, solving a three-dimensional partial differential equation for many signals and frequencies, we use a special optimization method to reduce function evaluations and we reduce the cost of the forward problem by model reduction.

Track E – Array Signal Processing

Session: MPa6 – Smart Grid Signal Processing

Chair: *Rick Blum, Lehigh University*

MP6a-1

1:30 PM

Optimal Distributed Generation Placement in Smart Microgrids via Semidefinite Relaxation

Emiliano Dall’Anese, Georgios B. Giannakis, University of Minnesota, United States

Deployment of distributed generation (DG) units promises drastic performance enhancement of distribution systems in terms of power delivery efficiency, by bringing power generation closer to the end user, and by providing beneficial ancillary services such as reactive compensation. An optimal DG placement problem is formulated in this paper for three-phase smart microgrids, with the objective of minimizing the overall active power distribution loss, while effecting voltage regulation. Similar to various optimal DG placement renditions, nonlinear power flow relations and binary selection variables representing presence (absence) of DG, render the resultant optimization problem nonconvex and NP-hard. Nonetheless, a relaxed convex re-formulation is obtained by leveraging semidefinite relaxation techniques, and sparsity-promoting regularization approaches. It is shown that by adjusting a sparsity-tuning parameter, one can trade off attainable active power loss for the DG operation cost. The novel DG placement scheme is tested on the IEEE 37-node test feeder.

MP6a-2**1:55 PM****Clustering Consumption in Queues: A Scalable Model for Electric Vehicle Scheduling**

Mahnoosh Alizadeh, University of California, Davis, United States; George Kesidis, Pennsylvania State University, United States; Anna Scaglione, University of California, Davis, United States

In this paper, we introduce a scalable model for the aggregate electricity demand of a fleet of electric vehicles, which can provide the right balance between model simplicity and accuracy. The model is based on classification of tasks with similar energy consumption characteristics into a finite number of clusters. The aggregator responsible for scheduling the charge of the vehicles has two goals: 1) to provide a hard QoS guarantee to the vehicles at the lowest possible cost; 2) to offer load or generation following services to the wholesale market. In order to achieve these goals, we combine the scalable demand model we propose with two scheduling mechanisms, a near-optimal and a heuristic technique. The performance of the two mechanisms is compared under a realistic setting in our numerical experiments.

MP6a-3**2:20 PM****Forecasting Real-time Locational Marginal Price: A State Space Approach**

Yuting Ji, Jinsub Kim, Lang Tong, Cornell University, United States

The problem of forecasting the real-time locational marginal price (LMP) by a control center is considered. We propose an approach based on a geometric characterization of real-time LMP on the state space of the power grid. By incorporating state estimation in price forecasting, the proposed forecasting algorithm offers reduced complexity and enhanced performance. The proposed forecasting algorithm is tested against benchmark techniques using the IEEE 118-bus system.

MP6a-4**2:45 PM****Optimal Design of Sensor Networks for Enhanced Ocean Wave Energy Conversion**

Rick S. Blum, Basel Alnajjab, Lehigh University, United States

A multitude of sensor types are investigated for the short-term prediction of the exact time waveforms of ocean waves with numerical results concentrating on the estimation of wave elevation, a vital parameter for the optimal control of Wave Energy Converter (WEC) devices. Ocean waves are described as a sum of several plane waves of different frequencies and directions of travel while sensor measurements are assumed to be observed under Gaussian noise. A general expression for the Fisher Information Matrix is derived pertaining to the group of sensors analyzed in the paper. Based on the maximization of the determinant of the Fisher Information Matrix, optimal sensor types and sensor layouts are suggested and validated by numerical results based on the calculation of the Cramer Rao Bound of the estimates.

*Track E – Array Signal Processing***Session: MPb6 – Statistical Signal Processing**Chair: *Pramod Varshney, Syracuse University***MP6b-1****3:30 PM****Estimation with Correlated Additive Noise: Does Dependency Always Imply Redundancy?**

Fangrong Peng, Biao Chen, Syracuse University, United States

This paper revisits a simple parameter estimation problem in which the observations are corrupted by bivariate correlated Gaussian noises. We examine different correlation regimes when correlation may harm or benefit the underlying estimation problem. While it has been known that negatively correlated noises in additive models enjoy the inherent advantage of noise cancellation, this paper also identifies cases when positively correlated noises may also improve the inference performance compared with that of the independent observations. We then extend our work to a decentralized setting and study the impact of data correlation when each observation is subject to a one-bit quantization constraint.

MP6b-2**3:55 PM****Expected Likelihood Approach for Low Sample Support Covariance Matrix Estimation in Angular Central Gaussian Distributions**

Olivier Besson, University of Toulouse-ISA, France; Yuri Abramovich, W R Systems, Ltd., United States

We address the problem of estimating the covariance matrix from a complex central angular Gaussian distribution when the number of samples N is less than the size of the observation space M . As regularization is needed, we consider the expected likelihood (EL) approach as a means to set the regularization parameters. The EL principle, originally developed under the Gaussian assumption, relies on some invariance properties of the likelihood ratio (LR). In this paper, we show that

the LR, evaluated at the true covariance matrix, has a distribution that only depends on T and M . A simple representation as a product of beta distributed random variables is presented. This paves the way to EL-based regularized covariance matrix estimation, whose effectiveness is shown through simulations.

MP6b-3

4:20 PM

Compressive Recovery of 2-D Off-Grid Frequencies

Yuejie Chi, The Ohio State University, United States; Yuxin Chen, Stanford University, United States

We consider the problem of inverse scattering of a two-dimensional field from its Fourier samples, in particular we aim to estimate two-dimensional frequencies of a mixture of r complex sinusoids from a random subset of its regularly spaced samples of size n . We formulate an atomic norm minimization problem based on a generalization of the Caratheodory theorem for positive semidefinite block Toeplitz matrices, and show that a sample size of $\mathcal{O}(r \log r \log n)$ is sufficient to guarantee perfect recovery with high probability under a mild frequency separation condition. Our work extends the result in Tang et. al. to an arbitrary higher dimension by instantiating it in the two-dimensional scenario.

MP6b-4

4:45 PM

Efficient Approximation of Structured Covariance under Joint Toeplitz and Rank Constraints

Bosung Kang, Vishal Monga, Pennsylvania State University, United States; Muralidhar Rangaswamy, Air Force Research Laboratory, United States

The disturbance (clutter plus noise and jamming) covariance matrix which plays a central role in radar space time adaptive processing (STAP) should be estimated from sample training observations in practice. Traditional maximum likelihood (ML) estimators lead to degraded false alarm and detection performance in the realistic regime of limited training. Therefore constrained ML estimation has received much attention which exploits structure and other properties that a disturbance covariance matrix exhibits. In this paper, we derive a new covariance estimator for STAP that jointly considers a Toeplitz structure and a rank constraint on the clutter component. Past work has shown that in the regime of low training, even handling each constraint individually is hard and techniques often resort to slow numerically based solutions. Our proposed solution leverages a recent advance called rank constrained ML estimator (RCML) of structured covariances to build a computationally friendly approximation that involves a cascade of two closed form solutions. Experimental investigation shows that the proposed estimator outperforms state of the art alternatives in the sense of: 1.) normalized signal to interference and noise ratio (SINR), and 2.) probability of detection versus signal to noise ratio (SNR).

Track G – Architecture and Implementation

Session: MPa7 – Recent Progress in Computer Arithmetic

Chair: *Milos Ergecovac, University of California, Los Angeles*

MP7a-1

1:30 PM

Automated Circuit Elaboration from Incomplete Architectural Description

Andrew Becker, David Novo Bruna, Paolo Ienne, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

As design complexity continues to grow, there is an urgent need to ease designers' burden without sacrificing quality and performance of results. Raising the level of abstraction in the design process through high-level synthesis finally shows promise, but too often produces microarchitectural solutions significantly inferior to those an expert designer may find. We propose an alternative approach: the level of abstraction remains at the RTL level, but designers can focus on the big picture by leaving out small but essential details which can be discovered by an automated tool.

MP7a-2

1:55 PM

Avoiding Double Roundings in Scaled Newton-Raphson Division

Jean-Michel Muller, CNRS/ENSL/INRIA/UCBL, France

When performing divisions using Newton-Raphson (or similar) iterations on a processor with a floating-point fused multiply-add instruction, one must sometimes scale the iterations, to avoid over/underflow and/or loss of accuracy. This may lead to double-roundings, resulting in output values that may not be correctly rounded when the quotient falls in the subnormal range. We show how to avoid this problem.

MP7a-3**2:20 PM****Implementation of a High Speed Multiplier Using Carry Lookahead Adders**

Wesley Chu, Ali Unwala, Pohan Wu, Earl Swartzlander, University of Texas at Austin, United States

This paper examines a modification to the Dadda Multiplier to use carry lookahead adders instead of full adders to implement the reduction of the bit product matrix into the two numbers that are summed to make the product. Four bit carry lookahead adders are used in the reduction in place of individual full adders. Each carry lookahead adder reduces up to 9 partial product bits (instead of 3 with a full adder) while taking the same amount of time. This leads to fewer reduction stages being necessary when compared to a traditional Dadda Multiplier. The results show that 1 fewer stage is required for 8 by 8, 16 by 16, and 32 by 32 bit multipliers and 2 stages are saved for 24 by 24 bit multipliers.

MP7a-4**2:45 PM****Exhaustive Testing of Fused Multiply-Add RTL**

Neil Burgess, David Lutz, ARM Inc., United States

This paper describes the development and use of a short-wordlength (11-bit) Fused Multiply-Add (“FMA”) design. This “cut-down” design replicates the logic of our IEEE 754-2008 compliant FMA RTL, but the smaller size permits exhaustive testing. We present details of the complete test results and discuss the utility of the truncated FMA.

*Track H – Speech, Image and Video Processing***Session: MPb7 – 3D Content Processing**Chair: *Béatrice Pesquet-Popescu, Telecom ParisTech***MP7b-1****3:30 PM****A Distributed Video Coding System for Mmulti-view Video Plus Depth**

Giovanni Petrazzuoli, Institut Mines-Telecom, Telecom-ParisTech, France; Thomas Maugey, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Marco Cagnazzo, Béatrice Pesquet-Popescu, Institut Mines-Telecom, Telecom-ParisTech, France

Multi-view video plus depth (MVD) is gathering huge attention, as witnessed by the recent standardization activity, since its rich information about the geometry of the scene allows high-quality synthesis of virtual viewpoints. Distributed video coding of such kind of content is a challenging problem whose solution could enable new services as interactive multi-view streaming. In this work we propose to exploit the geometrical information of the MVD format in order to estimate inter-view occlusions without communication among cameras. This estimation can therefore be exploited to improve the side information generation and its correction. Experiments validate the feasibility of this novel approach.

MP7b-2**3:55 PM****Compact, Low-Power 3D Imaging of Simple Planar Scenes Using Parametric Signal Processing**

Jonathan Mei, Andrea Colaco, Ahmed Kirmani, Vivek Goyal, Massachusetts Institute of Technology, United States

We introduce a new architecture for optical sensing of 3D structure of simple scenes which is based on parametric modeling and processing of scene impulse responses. In contrast to conventional techniques, this framework offers simplicity of hardware, high frame rates, compact form factors, insensitivity to ambient light, and low power. It does not provide high resolution for general scenes, but rather high accuracy for simple features. In simulations, we apply our framework to two potential applications: localization of two hands for a gestural interface and estimation of plane position and pose for augmented reality.

MP7b-3**4:20 PM****Graph-Based Coding for Interactive Multi-view Navigation**

Thomas Maugey, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Antonio Ortega, University of Southern California, United States; Pascal Frossard, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

In this paper, we propose a new representation and coding method for multiview images in free-viewpoint applications. As an alternative to depth-based schemes, we propose a novel representation that captures the geometry and the dependencies between pixels in different frames in the form of connections in a graph. In our approach it is possible to directly perform compression of the geometry by removing connections in the graph, which provides a direct control of the effect of geometry approximation on view reconstruction. Our method leads to more accurate view synthesis, when compared to conventional lossy coding of depth maps operating at the same bit rate. We finally show the benefits of our representation in multiview navigation scenarios.

MP7b-4

4:45 PM

A Compression Method for Computer Generated Phase-shifting Holograms of Virtual 3D Objects

Yafei Xing, Béatrice Pesquet-Popescu, Frédéric Dufaux, TELECOM ParisTech, France

In phase-shifting digital holography (PSDH), three digital holograms are recorded to reconstruct the object. By shifting the phase of the reference wave, the holograms appear with phase difference. In this paper, a compression method for computer generated phase-shifting holograms (CGPSH) is proposed by using of the phase difference. The hologram of virtual three dimensional (3D) objects is generated by simulating the optical propagation in PSDH scheme. For compression, instead of compressing three holograms, coding techniques are only applied on the hologram recorded with zero phase. Other holograms for reconstructing the image of virtual objects can be obtained by multiplying the phase information.

Track D – Signal Processing and Adaptive Systems

Session: MPa8 – Distributed Signal Processing

1:30 PM–3:10 PM

Chair: *Weiyu Xu, University of Iowa*

MP8a1-1

Scaled Canonical Coordinates for Compression and Transmission of Noisy Sensor Measurements

Yuan Wang, Haonan Wang, Louis Scharf, Colorado State University, United States

This paper is motivated by sensing and wireless communication, where data compression or dimension reduction may be used to reduce the required communication bandwidth. High-dimensional measurements are converted into low-dimensional representations through linear compression. Our aim is to compress a noisy sensor measurement, allowing for the fact that the compressed measurement will then be transmitted over a noisy channel. We give the closed-form expression for the optimal compression matrix that minimizes the trace or determinant of the error covariance matrix. We show that the solutions share a common architecture consisting of a canonical coordinate transformation, scaling by coefficients which account for canonical correlations and channel noise variance, followed by a coordinate transformation into the sub-dominant invariant subspace of the channel noise.

MP8a1-2

Joint Recovery Algorithms Using Difference of Innovations for Distributed Compressed Sensing

Diego Valsesia, Giulio Coluccia, Enrico Magli, Politecnico di Torino, Italy

Distributed compressed sensing is concerned with representing an ensemble of jointly sparse signals using as few linear measurements as possible. Two novel joint reconstruction algorithms are presented in this paper. These algorithms are based on the idea of using one of the signals as side information; this allows to exploit joint sparsity in a more effective way with respect to existing schemes. They provide gains in reconstruction quality, especially when the nodes acquire few measurements, so that the system is able to operate with fewer measurements than is required by other existing schemes, hence achieving better performance with respect to the state-of-the-art.

MP8a1-3

Distributed Correlated Data Gathering in Wireless Sensor Networks via Compressed Sensing

Markus Leinonen, Marian Codreanu, Markku Juntti, University of Oulu, Finland

This paper addresses energy efficient data gathering methods for monitoring a data field of correlated sources in multi-hop wireless sensor networks (WSNs). We use compressed sensing (CS) as a signal compression/acquisition method that can exploit both temporal and spatial correlation among sensors (i.e., signal compressibility). As a result, different signal gathering methods are proposed, and their performance is numerically evaluated in terms of their capability of reducing and balancing the traffic load in WSNs.

MP8a1-4

Distributed Object Tracking Based on Cubature Kalman Filter

Venkata Pathuri Bhuvana, Melanie Schranz, Mario Huemer, Bernhard Rinner, Alpen-Adria Universität Klagenfurt, Austria

In this work, we propose the cubature Kalman filter (CKF) based distributed object tracking algorithm in a visual sensor network (VSN). A VSN consists of several distributed smart cameras having the ability to process and analyze the retrieved data locally. The first objective is to optimize the tracking process within the VSN through the CKF. Under the considered conditions, the CKF-based method shows two times better tracking accuracy than the extended Kalman filter (EKF) based method in terms of the average root mean square error (RMSE). A particle filter (PF) shows even better performance than the CKF, however, it is computationally very complex. The second proposal is to optimize the object tracking by aggregating the tracking results from multiple cameras. Assuming the VSN is a multi-camera network with overlapping field of views (FOVs), cameras having the same object in their FOV exchange their local estimates of the object's position and velocity. During the estimation process, each of the participating cameras aggregates the received states via a consensus algorithm. Thus, the resulting joint state has a much higher probability to be closer to the object's real state, than a single camera's observation would be.

MP8a1-5

Distributed Location Detection in Wireless Sensor Networks

Xue Zhang, Cihan Tepedelenlioglu, Mahesh Banavar, Andreas Spanias, Arizona State University, United States

A distributed location detection problem in wireless sensor networks (WSNs) with M anchors and one node is considered in this paper. In the presence of the transmitting node at a known location or region, each anchor receives the signal plus noise, and in the absence of the node, the anchors receive only noise. Each anchor makes a decision as to whether the node is present or not by using a Neyman-Pearson detector. The bit denoting the decision is transmitted to a fusion center. The fusion center will count the number of "1"s and "0"s, and declares the node present if it receives at least K "1"s from the anchors, where K is a design parameter. In comparison to the centralized location detection scheme, the distributed scheme benefits from both time and energy efficiency. Simulation results show that the choice of K depends on the requirement of the overall probability of false alarm PFA.

MP8a1-6

Max-Consensus using the Soft Maximum

Sai Zhang, Cihan Tepedelenlioglu, Mahesh Banavar, Andreas Spanias, Arizona State University, United States

A distributed consensus algorithm for estimating the maximum and the minimum of the initial measurements in a sensor network is proposed. Estimating the maximum and minimum values is useful in many applications such as temperature control. In the absence of communication noise, max estimation can be done by updating the state value with the largest received measurements in every iteration at each sensor. In the presence of communication noise, however, the maximum may incorrectly drift to a larger value at each iteration. As a result, a soft-max approach in conjunction with a consensus algorithm is introduced herein. A trade-off between the energy of the transmitted signal and the difference between the real max and the soft max is described and simulation results are provided.

MP8a1-7

Diffusion LMS Algorithm with Multi-Combination for Distributed Estimation over Networks

Jun-Taek Kong, Jae-Woo Lee, Woo-Jin Song, Pohang University of Science and Technology, Republic of Korea

We propose diffusion least-mean-square (LMS) algorithms utilizing multi-combination steps. Unlike conventional diffusion LMS, we allow each node in the network to use information from multi-hop neighbors to improve the approximation accuracy of a global cost function. In this manner, each node can also use information from non-adjacent nodes at each time instant, resulting in enhanced performance. The resulting distributed algorithms consist of adaptation and multi-combination steps. The simulation result indicates that the proposed algorithm outperforms the conventional diffusion LMS algorithm.

MP8a1-8

Exploiting Temporal and Spatial Correlation in Wireless Sensor Networks

Daniel Parker, Milica Stojanovic, Northeastern University, United States; Christopher Yu, Draper Laboratory, United States

Motivated by applications of wireless sensor networks to seismic field monitoring, we propose a method that integrates in-situ lightweight temporal compression with random access communication and compressive sensing for recovery of spatially-sparse phenomena. This method of spatio-temporal compression offers savings in terms of energy consumption and bandwidth usage,

does not require sensors to be synchronized, and requires minimal feedback from the fusion center. Furthermore, the method is robust to node failures and packet losses. Performance is quantified using both simulation and real data, showing significant improvements in energy and bandwidth efficiency over more conventional techniques.

Track C – Networks

Session: MPa8 – Wireless Sensor Networks

1:30 PM–3:10 PM

Chair: *Bernhard Etzlinger, Johannes Kepler University, Austria*

MP8a2-1

A Low-Complexity Particle-Based Belief Propagation Algorithm for Cooperative Simultaneous Localization and Synchronization

Florian Meyer, Vienna University of Technology, Austria; Bernhard Etzlinger, Johannes Kepler University, Austria; Franz Hlawatsch, Vienna University of Technology, Austria; Andreas Springer, Johannes Kepler University, Austria

We present a factor graph framework and a particle-based belief propagation algorithm for distributed cooperative simultaneous localization and synchronization (CoSLAS) in decentralized sensor networks. The proposed algorithm jointly estimates the locations and clock parameters of the network nodes in a fully decentralized manner while requiring time measurements and communications only between neighboring nodes and making only minimal assumptions about the network topology. A significant reduction of computational complexity is achieved by a novel particle-based scheme for message multiplication. Simulation results demonstrate the excellent performance of the proposed CoSLAS algorithm.

MP8a2-2

Effects of Approximate Representation in Belief Propagation for Inference in Wireless Sensor Networks

Yao Li, Lara Dolecek, University of California, Los Angeles, United States

Low-complexity inference in a range of wireless sensor networks can be achieved by modeling the sensor network as a loopy graphical model, and then developing a suitable belief propagation (BP) algorithm on this graphical model. To reduce the processing bandwidth of the BP algorithm, the propagated messages may be represented by their low-dimensional approximations. In this work, we investigate the effects of such approximations of message exchange on the performance of BP algorithm. It turns out that on a loopy graphical model, the quality of the inference is not a monotonic function of the chosen approximation. While high-precision approximation increases the quality of inference as long as the algorithm converges to the correct fixed point, under non-convergence and under convergence to an incorrect fixed point, the dependency on the granularity level of the employed approximation is not monotonic. This, in turn, causes the non-monotonicity in the quality of the resultant inference. Thus, the problem of picking the right approximation scheme becomes a non-trivial question in establishing the optimal complexity-performance tradeoff. In this work, we seek to address this question.

MP8a2-3

Collaborative Beamforming from Tethered Multirotor Aerial Vehicle Wireless Sensor Network

Tan Ngo, Murali Tummala, John McEachen, Naval Postgraduate School, United States

Collaborative beamforming on airborne wireless sensor networks can improve signal reception; however, this is difficult to implement due to power constraints. Recent developments in tethers for multirotor aerial vehicles (MAV) carrying data and power have alleviated this problem. This paper explores the feasibility of collaborative beamforming using a MAV network. We analyze the beam pattern fluctuations due to position errors from the MAV's unsteady station keeping. We show the effects of minor position errors are manageable. Finally, two constrained optimization methods for sidelobe suppression utilizing the MAVs mobility and station keeping capability are introduced. Simulations are used to support analysis.

MP8a2-4

Localization of Acoustic Beacons Using Iterative Null Beamforming over Ad-Hoc Wireless Sensor Networks

Vatsal Sharan, Sudhir Kumar, Rajesh Hegde, Indian Institute Of Technology Kanpur, India

In this paper an iterative method to localize and separate multiple audio beacon sources using the principles of null beamforming is proposed. In contrast to standard methods, the source separation is done optimally by putting a null on the other sources when obtaining an estimate for a particular source. Also, this method is not constrained by fixed sensor geometry as is

the case with general beamforming methods. The wireless sensor nodes can therefore be deployed in any random geometry as required. Experiments are performed to estimate the location and also the power spectral density of the separated sources. The experimental results indicate that the method can be used in ad-hoc, flexible and low-cost wireless sensor network deployment.

MP8a2-5

Limited-Feedback-Based Channel-Aware Power Allocation for Linear Distributed Estimation

Mohammad Fanaei, Matthew C. Valenti, Natalia A. Schmid, West Virginia University, United States

Most power-allocation schemes proposed in the literature for distributed estimation in wireless sensor networks require the feedback of the instantaneous channel state information from the fusion center (FC) to local sensors. This paper proposes a limited-feedback strategy in which the FC designs an optimal codebook containing the power-allocation vectors, based on the generalized Lloyd algorithm with modified distortion functions. Upon observing a realization of the channel vector, the FC finds the closest codeword to its corresponding optimal power-allocation vector and broadcasts the index of the codeword. Each sensor will then transmit its analog observations using its optimal quantized amplification gain.

Track E – Array Signal Processing

Session: MPa8 – Array Signal Processing

1:30 PM–3:10 PM

Chair: *D. Richard Brown III, Worcester Polytechnic Institute*

MP8a3-1

A Unified Detection Framework for Distributed Active and Passive RF Sensing

Daniel Hack, Lee Patton, Matrix Research, United States; Braham Himed, Air Force Research Laboratory, United States

This work considers centralized detection in distributed RF sensor networks. We present a comparative analysis of GLRT detection in active and passive networks including active multiple-input multiple-output (MIMO) radar (AMR), passive MIMO radar (PMR), and passive source localization (PSL). Our results demonstrate that PMR generalizes AMR and PSL in that PMR detection sensitivity may approximate that of AMR or PSL, depending on the direct-path-to-noise ratio (DNR). When the DNR is high, PMR detection approximates AMR detection. When the DNR is low, PMR detection approximates PSL detection. These low-DNR and high-DNR regimes are separated by a transition region, in which PMR detection sensitivity improves with increasing DNR. Thus, PMR bridges the gap between AMR and PSL, unifying them within a common theoretical framework.

MP8a3-2

Identifiability Analysis of Local Oscillator Phase Self-Calibration Based on Hybrid Cramer-Rao Bound in MIMO Radar

Peilin Sun, Jun Tang, Shuang Wan, Ning Zhang, Tsinghua University, China

The identifiability of phase perturbation self-calibration for MIMO radar is investigated. Both absolute phase perturbation (APP) and phase perturbation difference (PPD) are considered. The hybrid Cramer-Rao bound (HCRB) matrix of phase perturbation is derived and used to analyze the identifiability of phase perturbation. Under mild conditions, it is proved that only PPD is identifiable in co-located MIMO radar. Finally, the closed-form HCRB of PPD is obtained and verified by numerical simulations. In addition, the problem in this paper is a special case in which HCRB for joint estimation of deterministic and random parameters is asymptotically tight for nonlinear observation models.

MP8a3-3

Analysis of a Channel Model for Multipath-Assisted Indoor Localization Using UWB Signals

Erik Leitinger, Markus Fröhle, Paul Meissner, Klaus Witrisal, Graz University of Technology, Austria

Multipath-assisted indoor localization using ultra-wideband (UWB) signals exploit the geometric information contained in the deterministic multipath components (MPCs) from the channel measurements. A-priori available floorplan information allows robust localization independent of a line-of-sight (LOS) or non-LOS situation. In a recent work, the Cramer-Rao Lower Bound (CRLB) for a novel channel model, which explicitly models diffuse multipath as a stochastic noise process additionally to the present AWGN noise had been derived. In this paper, we adapt this model to real measurement data and evaluate the performance considering situations with and without path overlap. Performance results confirm the applicability of this novel channel model in a real world scenario.

MP8a3-4

Simultaneous Target and Multipath Positioning via Multi-Hypothesis Single-Cluster PHD Filtering

Li Li, Jeff Krolik, Duke University, United States

This work considers the problem of tracking a RF source in dense multipath environments using a uniform linear receiver array (ULA) where multipath propagation is modeled as specular reflections from planar reflectors. A single cluster process is formulated using a Bayesian estimation framework for Simultaneous Target and Multipath Positioning (STAMP) where target state is defined as a parent process and the reflector state is defined as the daughter process. A multi-hypothesis data association method is used with Probability Hypothesis Density (PHD) filtering when updating the parent process corresponding to the target state to improve the accuracy of the target state estimate. The Gaussian target state is updated based on classic multiple-scan maximum likelihood data association while the update of multipath parameters is based conventional Gaussian Mixture PHD filtering. Experimental results using real data for an indoor target positioning problem demonstrates substantial improvements in localization accuracy with this method.

MP8a3-5

Analysis of a Purina Fractal Beamformer

Philippos Karagiannakis, Stephan Weiss, University of Strathclyde, United Kingdom

This paper investigates the use of a Purina fractal array for beamforming. We compare the performance of this array to full lattice arrays of same aperture and element count in terms of beam pattern and complexity. Further, the array's sensitivity to element displacement and failure is investigated. Simulations indicate that the Purina array can offer significant advantages over its benchmarks particularly in the lower half of the spectrum.

MP8a3-6

Algebraic Confidence in Positioning Problems

Jani Saloranta, Davide Macagnano, University of Oulu, Finland; Giuseppe Abreu, Jacobs University, Germany

In this paper we provide the theoretical analysis on the confidence measures derived from Circular Interval-based scaling (CIS) algorithm previously proposed by the authors. The algebraic confidence is the output of the proposed optimization algorithm and does not rely on any a priori information of system statistics. It is shown that this measure captures the statistic of the set of measurements interesting the target and it is affected by the confidence of the neighbors connected to it. The confidence levels obtained via the CIS algorithm are shown to approximate the Fisher error ellipses derived from the Cramér-Rao lower bound (CRLB), corroborating the concept. In addition to the above the preliminary results in this extended abstract already shown that this confidence measure can be used inside the optimization process to dramatically improve the estimated targets' locations.

MP8a3-7

Root-MSE Geolocation Performance Using Angle-of-Arrival Measurements from a Moving Sensor System

Neda Adib, Scott Douglas, Southern Methodist University, United States

In this paper, we describe a procedure for evaluating the fundamental root-mean-square-error accuracy of a moving sensor system collecting angle-of arrival measurements of a stationary emitter. The procedure assumes a known probability density function for the azimuthal angles that are statistically-independent from each other. We construct the closed-form p.d.f. of the emitter position based on the motion of the sensor from which the root-MSE is numerically evaluated. The procedure has a number of uses, including performance assessment of geolocation algorithms; effects of trajectory speed, direction, and measurement rate on algorithm performance; and judging the benefits of various data processing strategies.

MP8a3-8

GPS AOA Selection Algorithm for Multiple GPS Signals

Suk-seung Hwang, Goo-Rak Kwon, Jae-young Pyun, Chosun University, Republic of Korea

The Global Positioning System (GPS) with various commercial and military applications is designed to estimate the location of the specific user or object. It requires at least four satellites to accurately estimate the location. Since GPS signals suffer from various high power interference signals and jammers, we employ efficient interference suppression techniques such as a minimum-variance distortionless-response (MVDR) beamformer or a generalized sidelobe canceler (GSC). Most of them require the GPS signal angle of arrival (AOA), and we utilize the Multiple Signal Classification (MUSIC) or Estimation of Signal Parameter via Rotational Invariance Techniques (ESPRIT) to estimate GPS AOA. However, they must choose the GPS AOAs from all estimated AOAs when existing high power interference signals, because they include AOAs of the interference signals. In this paper, we propose the AOA choosing algorithm for multiple GPS signals in the environment of high-power interference

signals. The proposed algorithm is based on the comparison of the estimated AOAs for the received signal before despreading and the output signal of the despreaders, for choosing GPS AOAs. A representative computer simulation example is presented to illustrate the performance of the AOA choosing algorithm for the multiple GPS signals.

Track H – Speech, Image and Video Processing

Session: MPa8 – Speech, Audio, Image, and Video Processing 1:30 PM–3:10 PM

Chair: *James Fowler, Mississippi State University*

MP8a4-1

Multi Channel Reverberant Speech Enhancement using LP Residual Cepstrum

Karan Nathwani, Harish Padaki, Rajesh M. Hegde, Indian Institute of Technology Kanpur, India

In this work, a method for multi channel speech enhancement using linear prediction (LP) residual cepstrum is proposed. The method performs deconvolution at each microphone output using cepstral domain. The deconvolution of acoustic impulse response from reverberated signal in each individual channel removes early reverberation. This dereverberated output from each channel is then spatially filtered using delay and sum beamformer (DSB). The late reverberation components are then removed by temporal averaging of the glottal closure instants (GCI) computed using the dynamic programming projected phase-slope algorithm (DYPSA). The GCI obtained herein correspond to the LP residual peaks. These residual peaks are excluded from the averaging process, since they have significant impact on speech quality and should remain unmodified. The experiments on subjective and objective evaluation are conducted on TIMIT and MONC databases for proposed method and compared with other methods. The experimental results of proposed method on speech dereverberation and distant speech recognition indicate reasonable improvement over conventional methods.

MP8a4-2

Phase Estimation for Signal Reconstruction in Dual-Channel Speech Enhancement

Pejman Mowlae, Graz University of Technology, Austria; Jalal Taghia, Ruhr University Bochum, Germany

The problem of recovering a desired speech signal from a number of speakers or background noise occurs in robust speech recognition or high quality speech communication. The conventional binaural noise reduction systems incorporate speech and noise power spectral densities to produce enhanced speech amplitude on the left and right channels, while they employ the noisy phase directly for signal reconstruction. In this paper, we propose a phase-aware binaural speech enhancement algorithm and estimate the speech phase spectrum at both channels. Comparing with benchmark systems, the proposed phase-aware approach improves the perceived speech quality of the enhanced signals.

MP8a4-3

Multipitch Estimation and Instrument Recognition by Exemplar-Based Sparse Representation

Ikuo Degawa, Kei Sato, Masaaki Ikehara, Keio University, Japan

This paper investigates the pitch estimation and the instrument recognition of music signals. A note exemplar is a spectrum segment of pitches of the specific instrument, stored as a dictionary in the form of logarithmic scale (dBFS) preliminarily. We describe the method of reconstructing a frame of musical signals as the linear combination of exemplars from the large exemplar dictionary with sparsity constraints. The proposed algorithm shows the ability to transcribe music pieces with relatively many notes per a frame and to explicitly determine the instrument through some examples.

MP8a4-4

Data Fusion of IR and Marine Radar Data

Golrokh Mirzaei, Mohsin M. Jamali, University of Toledo, United States; Peter V. Gorsevski, Joseph Firazado, Verner P. Bingman, Bowling Green State University, United States

Growth in the development of wind farms has contributed in an increase of birds/bats mortality. It has become a controversial public policy issue. An avian monitoring system based on acoustics, IR, and radar has been developed. The goal of this work is to fuse results from IR and radar. Data was collected near Lake Erie in Ohio during 2011 spring and fall migration periods. Data analysis was performed in accordance to needs of wildlife biologists.

MP8a4-5

Multimodal Aerial Image Registration Using Spatial Structure

Myra Nam, Rhonda Phillips, MIT Lincoln Laboratory, United States

Image registration is an important step prior to data fusion from multiple imaging sensors. However, it is challenging because the appearance of the same scene differs in multi-modal images. Such visual differences result in a high outlier environment, which may degrade the registration accuracy. We introduce a robust registration method that establishes correspondences when many outliers exist due to different image appearances in multi-modal images. The proposed matching method leverages the spatial order of detected landmarks that is preserved despite the non-linear deformation in remote-sensing data. We demonstrate that our matching algorithm is robust to outliers in real multi-modal image pairs.

MP8a4-6

Separating Temperature, Emissivity and Downwelling Radiance in Thermal Infrared Pure-Pixel Hyperspectral Images

Jake Gunther, Todd K. Moon, Matt Stites, Utah State University, United States; Gus Williams, Brigham Young University, United States

The identity of a material may be obtained by measuring its emissivity spectrum. Unfortunately, hyperspectral remote sensing instruments measure spectral radiance, which is a nonlinear function of the material's emissivity and temperature, and atmospheric downwelling radiance and other factors. Therefore, accurate interpretation of hyperspectral images requires estimation and separation of these quantities. By leveraging hyperspectral measurements spread across time, this paper develops a new algorithm for estimating temperature, emissivity and downwelling radiance. We show the results of applying this algorithm to real hyperspectral data. The estimated emissivity spectra are in good agreement with laboratory measured spectra, and estimated downwelling radiance agrees well with downwelling products computed using radiative transfer models.

MP8a4-7

User-Controlled Adaptive Video Streaming Framework for Healthcare Applications

Krupa Pranesh, Yusuf Ozturk, San Diego State University, United States

We propose a framework to support user-controlled two-way adaptive video telephony in healthcare applications. The user can vary the three basic settings of the encoder – bit rate, frame resolution and frame rate, dynamically, without having to tear down and recreate the session. In a video telemedicine scenario, user-controlled variation of the bit rate and resolution would help the doctor in better diagnosis. Further, the user could trade temporal resolution for a higher bit rate to achieve higher quality while maintaining the same average bit rate. An Android application has been developed to demonstrate the proposed scheme.

MP8a4-8

Low-Complexity Video Compression and Compressive Sensing

Salman Asif, Felix Fernandes, Samsung Research America, United States; Justin Romberg, Georgia Institute of Technology, United States

Compressive sensing (CS) provides a general signal acquisition framework that enables the reconstruction of sparse signals from a small number of linear measurements. To reduce video-encoder complexity, we present a CS-based video compression scheme. Modern video-encoder complexity arises mainly from the transform-coding and motion-estimation blocks. In our proposed scheme, we eliminate these blocks from the encoder, which achieves compression by merely taking a few linear measurements of each image in a video sequence. To guarantee stable reconstruction of the video sequence from only a few measurements, the decoder must effectively exploit the inherent spatial and temporal redundancies in a video sequence. To leverage these redundancies, we consider a motion-adaptive linear dynamical model for videos. Recovery process involves solving an L1-regularized optimization problem, which iteratively updates estimates for the video frames and motion within adjacent frames.

MP8a5-1

An Adaptive Power Amplifier and Control Subsystem for use in Space-Based Software Defined Radio Applications

Nehemya Cohen, James Whitney, II, Dontae Ryan, Michel Reece, Morgan State University, United States

Abstract—Software defined radios have been a major paradigm shift in the communications area. Similarly autonomous/cognitive operations are a further enhancement to SDR operation. In progressing these technologies, particularly in applications requiring high-efficiency, adaptable transmit amplifiers and associated cognitive control-systems can help. This is particularly true for regions where immediate battery replacement is difficult at best, or, impossible at worst, i.e., space applications. If autonomous control can be performed in a prescribed manner, the overall operating efficiency of the radio should be increased with a subsequent increase in battery life and radio operating ability.

MP8a5-2

Compressive Sensing Spectrum Analysis for Space Autonomous Radio Receivers

Gian Carlo Cardarilli, Marco Re, Ilir Shuli, University of Rome Tor Vergata, Italy; Lorenzo Simone, Thales Alenia Space, Italy

In space mission there are different scenarios where autonomous radio systems are very useful. In this paper we consider one of such scenarios, related to the communication infrastructure for the planet exploration (where different rovers communicate with an orbiter). One of the most critical functions to implement in autonomous radio is the reconstruction of the electromagnetic scenario, detecting the radio emission of the rovers (with the estimate of the frequency of the carrier, the power level and so on) present on the planet surface. In these deep space missions, it is often necessary to analyze a very large bandwidth signal (often more than 1 GHz) where only few small portions of the spectrum are used by narrow-band transmissions. This spectrum characteristic requires the use of high-resolution spectrum analysis, typically performed using FFT based algorithms. Even if this large bandwidth analysis is possible with actual (terrestrial) ADC technology, the space qualification and the constraints on the power consumption make this ADCs unsuitable for space applications. This paper shows as the new paradigm of Compressive Sensing -or Compressive Sampling- (CS) can be exploited to reduce the performance requirements of the ADC used for the spectrum analysis in autonomous radio

MP8a5-3

Analog-to-Information Converter Leveraging Diode Harmonics

Erica Daly, Jennifer Bernhard, University of Illinois at Urbana-Champaign, United States

This paper explores leveraging harmonic distortion generated by a varactor diode to extend the frequency range of a wideband spectrum sensing device. The varactor serves as a mixer that mixes the received signal with a wideband signal. The strongest harmonics generated by the varactor are treated as part of the mixing signal, which extends the frequency range of the sensing device. The nonlinear response of the Harmonic Analog-to-information Converter (HAIC) is derived and verified experimentally.

MP8a5-4

Performance and Complexity Comparison of Near-Optimal MIMO Decoders

Mohamed A. El-Aziz, Cairo University / Varkon Semiconductors, Egypt; Karim Seddik, Ayman Alezabi, American University in Cairo, Egypt; Mohamed Nafie, Cairo University / Varkon Semiconductors, Egypt

Wireless Communications standards increasingly use multiple antenna systems for increasing the throughput. We consider the Multiple Input Multiple Output (MIMO) system of the Long Term Evolution (LTE) Standard and provide comparisons in terms of performance and hardware complexity between two possible decoders for such a system. In particular we compare two sub-optimal decoders: the K-Best and the selective spanning fast enumeration (SSF), and provide block error rate comparisons and hardware implementation complexity of both decoders.

MP8a5-5

Locally-Connected Viterbi Decoder Architectures and their VLSI Implementation for LDPC and Convolutional Codes

Ahmed Refaey Hussein, University of Western Ontario, Canada; Sebastien Roy, Université de Sherbrooke, Canada; Isabelle Laroche, Benoit Gosselin, Université Laval, Canada

The applicability of the Viterbi add-compare-select (ACS) functional block to both convolutional and LDPC codes in various parallel implementations is investigated. To this end, a trellis representation for arbitrary LDPC codes must first be established. Then, a high-level architecture for a Viterbi-algorithm-based unified decoder is proposed. An in-depth exploration of the crucial path metrics (i.e ACS) functional block is then presented, where various locally-connected parallel structures at different speed-area points are explored. Some implementation results are provided, showing that the proposed structures offer high throughput, low latency, and a wide spectrum of speed-area trade-off point, depending on the specific topology that is chosen.

MP8a5-6

On the Tail-Biting Convolutional Code Decoder for the LTE and LTE-A Standards

Mohamed Omar, Cairo University / Varkon Semiconductors, Egypt; Ahmed El-Mahmoudy, Varkon Semiconductors, Egypt; Karim Seddik, Ayman Elezabi, American University in Cairo, Egypt

In this paper, we consider the design of the Tail- Biting Convolutional Code Decoder (TB-CCD) for the Long Term Evolution (LTE) system. Tail-biting convolutional coding is used for channel coding on two downlink channels, namely the Physical Broadcast Channel (PBCH) and the Physical Downlink Control Channel (PDCCH). The decoding in the latter channel occurs blindly, with the decoder having no prior knowledge of the location of the desired bits. The crucial constraint on the TB-CCD design will be the required decoding time and the exhaustive processing for the PDCCH blind decoding. The TB-CCD will be required to carry out at most 44 decoding attempts per LTE subframe, which has a duration of 1 ms. In this paper, we describe the various aspects of our design that result in savings in processing time and complexity while showing negligible performance degradation. We then provide a description of the implementation architecture for the selected TB-CCD design and briefly describe the verification process.

MP8a5-7

A Hardware Efficient Technique for Linear Convolution of Finite Length Sequences

Soumak Mookherjee, Linda DeBrunner, Victor DeBrunner, Florida State University, United States

In this paper, a hardware efficient convolution implementation is proposed which is based on the Hirschman Optimal Transform (HOT). Previously, it has been shown theoretically that convolution based on HOT has major cost advantage over FFT based convolution, since, a $K \times K$ point HOT is based on a K -point DFT. However, due to the complexity of the HOT convolution, it was not easily realizable on hardware. This paper first modifies the HOT based convolution technique to make it more suitable for hardware realization. Then, FFT based convolution and the proposed convolution are realized by using similar architectures. To evaluate the effectiveness of the implementation, we compare the proposed convolution with the FFT convolution for a length of 256. The Mean Square Error (MSE), space requirements, and maximum throughput are used in the analysis of the implementations. Field Programmable Gate Arrays (FPGAs) are used to implement the algorithms. We have shown almost 45% reduction in space compared to FFT convolution while maintaining similar MSE and slightly worse throughput.

MP8a5-8

Novel Architectures for Squares, and Sums of Squares, of Cross-correlations of Bipolar Sequences with Applications to CDMA

Ayman Elezabi, American University in Cairo, Egypt

This paper describes efficient architectures for computing squares, and sums of squares, of cross-correlations of bipolar sequences. These are sequences that takes values of $\pm n$ where n is typically equal to unity. Both metrics are used in improved decoder metrics for CDMA systems and appear in a variety of signal processing problems. We describe and compare several architectural variations including direct methods that circumvent intermediate computations. The techniques in this paper may also be applicable to binary sequences, i.e. that take values of 0 and 1, with some modifications. We also consider several special cases in the CDMA context including short codes on bit-asynchronous channels, chip-asynchronous multi-path fading channels, as well as uplink and downlink implementations.

Track B – MIMO Communications and Signal Processing

Session: TAa1 – MIMO Communications

Chair: *Joe Liberty, Applied Communication Sciences*

TA1a-1

8:15 AM

Bandwidth-Limited Cluster Networks for Distributed MIMO

Joseph Liberty, John Koshy, Applied Communication Sciences, United States

Distributed arrays provide a way to exploit MIMO and other array transmission and processing approaches using several single-antenna nodes connected via an Intra-Cluster Network (ICN). Subject to synchronization and coherence recovery, when the receive ICN (R-ICN) bandwidth is high, samples of the signals received at the distributed nodes can be forwarded to a combining node to achieve the performance of a connected array. Similarly, recruitment of nodes within the transmit cluster for relaying the distributed space-time block code (STBC) transmission can be coordinated by a source node. However, when ICN bandwidth is limited, the situation is more challenging. In this paper, methods for efficient combining of signals on the receive side as well as recruitment and relaying of the STBC on the transmit side in limited-bandwidth ICNs are discussed. Policy-based tuning of detection performance and receive ICN data rate requirements are also addressed.

TA1a-2

8:40 AM

Experimental Results of MIMO Enabled Tactical Mesh Networks

Babak Daneshrad, Silvus Technologies / University of California, Los Angeles, United States

Multi-Antenna, MIMO, techniques have been around for almost two decades and have inspired a great many academic papers. However, to date, field validated MIMO solutions have been by-and-large limited to the use of MIMO to increase spectral efficiency in civilian wireless systems such as WiFi, and WiMax among others. In contrast to civilian systems, the appeal of MIMO to tactical communications needs is not the improvement in spectral efficiency, rather it lies in the ability of multi antenna techniques to increase range, improve reliability, decrease transmit power, and suppress interference. In this paper we present a selected subset of the over 30 field trials carried out by the Silvus team that show 10x-50x reduction in the TX power for the same throughput, a 100x suppression of wideband interference, a 4.5x improvement in coverage area for urban comms, successful explorations of Culverts, the 1.8x range extension for air to ground links, and the ability to deliver high-def (in excess of 18 Mbps) video over a 44 Km range from a airborne asset.

TA1a-3

9:05 AM

Achieving Multiple Degrees of Freedom in Long-Range mm-Wave MIMO Channels Using Randomly Distributed Relays

Andrew Irish, Francois Quitin, Upamanyu Madhow, University of California, Santa Barbara, United States

Multi-Gbps, long-range wireless communication at millimeter wave frequencies is characterized by channels with strong line-of-sight signal components, with link budgets relying on highly directional and dense transmit and receive antenna arrays with sub-wavelength inter-element spacing. A natural method to further increase data rates over such channels is to spatially multiplex several data streams by providing additional antenna arrays at both ends of the communication system. However, at the link ranges of interest, the resulting MIMO channel rank, largely governed by the Rayleigh criterion, is deficient for inter-array spacings that can be realized with reasonable node size. One scalable approach to obtaining the maximum available degrees of freedom is to introduce relay nodes randomly distributed over a sufficiently large region that the effective inter-relay spacing satisfies the Rayleigh criterion. In this paper, quantitative conditions are presented which relate the achievable spatial degrees of freedom to the number of relays, the region size, the number of transmit/receive arrays, and the link range.

TA1a-4

9:30 AM

Experiment Results of Iterative Block-Based Decision Feedback Equalizer with Spatial Diversity in Underwater Acoustic Channels

Xiang Zou, James Ritcey, Daniel Rouseff, University of Washington, United States

The use of multiple hydrophones at the receiver brings several advantages to an underwater communication system, such as improved signal-to-noise (SNR) ratio and spatial diversity gain. Many existing array combining techniques have implicitly assumed that the channel undergoes flat fading, with either perfect time-domain equalization (TDE) or OFDM-based (Orthogonal Frequency Division Multiplexing) modulation. Unfortunately, direct applications of these methods to underwater acoustic (UWA) channels are severely limited by the long delay spread and the low dynamic range of hydrophones. In this paper, a receiver structure based on the recently developed iterative block (IB) decision-feedback equalization (DFE) with single-carrier

frequency domain equalization (SC-FDE) was applied to the real underwater acoustic data from CAPEX09. We investigated the performance improvement of this nonlinear equalizer with respect to the regular linear MMSE equalizer. Our results show that the IB-DFE are more immune to the noise contaminations compared with MMSE equalizer.

Track G – Architecture and Implementation

Session: TA1b – Implementation Aspects for Full-Duplex and Large-Scale MIMO Wireless Systems

Chair: *Christoph Studer, Rice University*

TA1b-1

10:15 AM

An Analog Baseband Approach for Designing Full-Duplex Radios

Brett Kaufman, Rice University, United States; Jorma Lilleberg, Renesas Mobile, Finland; Behnaam Aazhang, Rice University, United States

Recent wireless testbed implementations have proven that full-duplex communication is in fact possible and can outperform half-duplex systems. Many of these implementations modify existing half-duplex systems to operate in full-duplex. However, transmit and receive radios that were designed to be orthogonal to each other now interfere with each other. To realize the full potential of full-duplex, radios need to be designed with self-interference in mind. In our work, we use a wireless testbed to characterize the self-interference between radios. In doing so, we form an analytical model to design analog baseband cancellation techniques.

TA1b-2

10:40 AM

Characterizing Self-Interference in True Full-Duplex Radio Links

Alexios Balatsoukas-Stimming, Pavle Belanovic, Andreas Burg, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

True full-duplex communication capability not only enables more efficient medium access control procedures, but also almost doubles the capacity of conventional half-duplex wireless point-to-point links and that of more complex wireless systems (e.g., based on relaying). In a true full-duplex node, the quality of the self-interference cancellation determines its capability to lower the noise floor which ultimately limits the signal-to-noise-plus-interference ratio and therefore indirectly also determines the relationship between the maximum output power and the sensitivity. Unfortunately, predicting the quality of the self-interference cancellation by analytical means is very difficult due to the strong impact of hardware imperfections that are often only insciently well understood. In this paper, we characterize the operating region of an experimental full-duplex platform by analyzing the strength and characteristics of the residual self-interference. This analysis provides insight into the nature of the interference and the potential of hardware-modifications and better cancellation techniques to improve the interference rejection. Furthermore, the results allow to be more specific on the most promising operating region (e.g., distance and target spectral efficiency) of true full-duplex radio links.

TA1b-3

11:05 AM

Implementation of FD-MIMO in LTE

Yang Li, Yan Xin, Mian Dong, Gary Xu, Jianzhong (Charlie) Zhang, Samsung R&D Institute America-Dallas, United States; Younsun Kim, Juho Lee, Samsung Electronics, Co., Ltd., Republic of Korea

The rapid growth of mobile traffic driven by data-centric mobile devices poses challenges to the operators on the spectrum efficiency. Full Dimension MIMO (FD-MIMO) is a promising technique to significantly increase capacity, and has been proposed in LTE (Long Term Evolution) standard. FD-MIMO deploys a large number of active antenna elements in a 2-dimensional (2D) grid and can support many users on the same bandwidth simultaneously than currently deployed systems. This paper shows that based on system-level simulations, FD-MIMO attains 2-5 times cell average throughput gain and 5 times cell-edge throughput gain. In this paper, we also investigate algorithms for precoding, user scheduling and channel estimation in FD-MIMO systems. The complexity of different algorithms and practical implementation are studied.

TA1b-4

11:30 AM

Achievable Rates of ZF Receivers in Large MU-MIMO Systems with Phase Noise Impairments

Antonios Pitarokoilis, Linköping University, Sweden; Saif Mohammed, Indian Institute of Technology Delhi, India; Erik G. Larsson, Linköping University, Sweden

The effect of oscillator phase noise on the sum-rate performance of large multi-user multiple-input multiple-output (MU-MIMO) systems is studied. A Rayleigh fading MU-MIMO uplink channel is considered, where channel state information (CSI) is acquired via training. The base station (BS), which is equipped with an excess of antenna elements, M , uses the channel estimate

to perform zero-forcing (ZF) detection. A lower bound on the sum-rate performance is derived. It is shown that the proposed receiver structure exhibits an $O(M^{1/2})$ array power gain. Additionally, the proposed receiver is compared with earlier studies that employ maximum ratio combining and it is shown that it can provide significant sum-rate performance gains at the medium and high signal-to-noise-ratio (SNR) regime. Further, the expression of the achievable sum rate provides new insights on the effect of various parameters on the overall system performance.

Track A – Communications Systems

Session: TAa2 – Stochastic Geometry and Random Networks

Chair: *Xiangyun Zhou, Australian National University*

TA2a-1

8:15 AM

On Decoding the kth Strongest User in Poisson Networks with Arbitrary Fading Distribution

Xinchen Zhang, Martin Haenggi, University of Notre Dame, United States

Consider a d-dimensional network whose transmitters form a non-uniform Poisson point process and whose links are subject to arbitrary fading. Assuming interference from the k-1 strongest users is canceled, we derive the probability of decoding the k-th strongest user. For k=1, this probability is the standard coverage probability and can be expressed in closed form. For general k, a closed-form expression exists in some special cases. This general result has immediate applications in networks with successive interference cancellation (SIC) capability. We use it to find closed-form upper and lower bounds on the probability of decoding at least k users and the mean number of successively decodable users. These bounds show that transmitter clustering is beneficial in exploiting SIC.

TA2a-2

8:40 AM

A Unified Approach to SINR-Based Performance Metrics with Application to D2D and Carrier Aggregation

Xingqin Lin, Jeffrey Andrews, University of Texas at Austin, United States

This paper develops a unified approach to evaluating SINR-based performance metrics like coverage, throughput, or bit error rate for arbitrary signal and interference distributions. Specifically, we propose using weighted Gamma random variables to approximate an arbitrary signal distribution. Then, along with the Laplace transform of the interference, the derived result can be used to compute any performance metric that is a function of SINR, provided some mild conditions on the mapping are satisfied. We apply this technique to compute the mean throughput of device-to-device (D2D) communication using an unlicensed band and then to the mean downlink throughput of multi-band (i.e. carrier aggregated) heterogeneous cellular networks.

TA2a-3

9:05 AM

Secrecy Transmission Capacity of Random Networks

Satyanarayana Vuppala, Giuseppe Abreu, Jacobs University, Germany

We investigate the secrecy transmission capacity of random networks with Nakagami-m fading. Using a model that accounts for uncertainties both in node locations (distances) and channel coefficients (fading), we derive the path-gain distributions of individual nodes and collusion of nodes, as well as the corresponding outage secrecy capacities and secrecy capacity distribution. These results are then used to obtain the secrecy transmission capacity of the network. The results are useful in quantifying the impact of fading and relative density of legitimate/eavesdropping nodes, onto the performance of random networks subject to fading and eavesdropping threats.

TA2a-4

9:30 AM

Coverage by Pairwise Base Station Cooperation under Adaptive Geometric Policies

Francois Baccelli, University of Texas at Austin, United States; Anastasios Giovanidis, INRIA, France

We study a cooperation model where the positions of base stations follow a Poisson point process distribution and where Voronoi cells define the planar areas associated with them. For the service of each user, either one or two base stations are involved. If two, these cooperate by exchange of user data with conferencing over some backhaul link. The total user transmission power is split between them and a common message is encoded. The decision for a user to choose service with or without cooperation is directed by a family of geometric policies. The suggested policies further allow the control of the shape of coverage contours in favor of cell-edge areas. Analytic expressions based on stochastic geometry are derived for the coverage probability in the network under a variety of assumptions on channel knowledge.

TA2b-1

10:15 AM

Decentralized Eigenvalue Algorithms in Wireless Sensor Networks with Limited Energy Supply

Jafar Mohammadi, Federico Penna, Slawomir Stanczak, Fraunhofer Heirinch Hertz Institute, Germany

Decentralized computation of the eigenvalues of sample covariance matrices in large-scale sensor networks is a central problem for a variety of applications, such as cooperative spectrum sensing, signal feature estimation, and traffic anomaly detection. Solutions to this problem based on iterative consensus algorithms have been recently proposed. In this paper we discuss the impact of limited energy supply on such methods. In particular, we consider the case of sensor nodes powered with energy harvesting and characterized by a stochastic recharge process. This contribution is meant as a first step towards the development of an energy-aware, cross-layer framework for distributed computation in wireless networks.

TA2b-2

10:40 AM

Analysis of Blind Pilot Decontamination

Ralf Müller, University of Erlangen-Nuremberg, Germany; Laura Cottatellucci, Institute Eurecom, France; Mikko Vehkaperä, Aalto University, Finland

Blind pilot decontamination is based on separation of the eigenvalue spectra of the signal of interest and the interference. We provide an analysis of the boundaries of the eigenvalue spectra in massive MIMO systems. The analysis is exact after letting the number of antennas and the coherence time grow to infinity, but assume that the number of antennas at the base station outnumbers the number of antennas at the terminals. The results suggest that pilot contamination in cellular systems can be overcome by means of power-controlled hand-off.

TA2b-3

11:05 AM

Ocean Bottom Sensing using Random Matrix Models for Ocean Noise

Ravi Menon, Peter Gerstoft, William Hodgkiss, University of California, San Diego, United States

Cross-correlations of diffuse ocean noise provide travel time information between different sensors, which correspond to the various propagation paths in the environment. We use random matrix theory to model the diffuse component of the ocean noise field and distinguish statistically, the outliers which are due to anthropogenic sources (such as ships). This approach improves the “diffusivity” of the noise field by selective removal of outlier eigenvalues. We demonstrate its application in sensing the ocean sub-bottom structure using a vertical line array (passive fathometer) and compare the results obtained to those from standard techniques.

TA2b-4

11:30 AM

Degrees of Freedom in Line-of-Sight MIMO Systems

Marc Desgroseilliers, Olivier Lévêque, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Emmanuel Preissmann, Université de Lausanne, Switzerland

While the efficiency of MIMO transmissions in a rich scattering environment has been demonstrated, less is known about the situation where the fading matrix coefficients come from a line-of-sight model. We study a matrix model obtained by approximating the coefficients of the line-of-sight channel matrix. Our results relate to the number of significant eigenvalues of this new matrix model.

Track D – Signal Processing and Adaptive Systems

Session: TAa3 – Active Sensing and Learning

Chair: *Jarvis Haupt, University of Minnesota*

TA3a-1

8:15 AM

Quick Search for Rare Events through Sequential Group Sampling

Ali Tajer, Wayne State University, United States; H. Vincent Poor, Princeton University, United States

Rare events can potentially occur in many applications and when model transient opportunities or costly risks should be detected quickly. Due to their sporadic nature, the information-bearing signals associated with rare events often lie in a large set of irrelevant signals and are not easily accessible. This paper provides a sequential search framework that initially takes rough mixed measurements from a group of events. The groups of events that are deemed to be including one or more rare events are retained for further scrutiny and the individual events in such groups are processed sequentially in order to identify a rare event with the shortest delay. Particular focus is placed on Gaussian signals with the aim of detecting signals with rare mean and variance values.

TA3a-2

8:40 AM

A Game Theoretic Approach to Adaptive Compressive Imaging

Amit Ashok, James Huang, Mark Neifeld, University of Arizona, United States

Structured sparsity signal priors have been successfully used for static compressive kernel design, which does not change during the measurement process and outperforms random measurements. However, a static design is unable to exploit the structure of a signal realization during the measurement process. In contrast, an adaptive compressive design approach attempts to learn this signal structure from the past measurements to design the next measurement(s), thereby achieving further performance improvements relative to static design. Prior research in adaptive compressive sensing has solely focused on the optimal design of the next measurement(s) using a greedy approach, which leads to sub-optimal performance. In this work, we adopt a game-theoretic approach to adaptive compressive measurement design with a goal of maximizing the performance over all measurements (i.e. a sequential game of adaptive measurements for a fixed measurement energy budget). We analyze the resulting performance improvements with respect to the state-of-the-art greedy adaptive measurement designs in the literature.

TA3a-3

9:05 AM

On the Query Complexity of the Best-Arm Problem

Matthew Malloy, Kevin Jamieson, Robert Nowak, Sebastien Bubeck, University of Wisconsin, United States

TA3a-4

9:30 AM

Recovering Graph-Structured Activations using Adaptive Compressive Measurements

Akshay Krishnamuthy, James Sharpnack, Aarti Singh, Carnegie Mellon University, United States

We study the localization of a cluster of activated vertices in a graph, from adaptively designed compressive measurements. We propose a hierarchical partitioning of the graph that groups the activated vertices into few partitions, so that a top-down sensing procedure can identify these partitions, and hence the activations, using few measurements. By exploiting the cluster structure, we are able to provide localization guarantees at weaker signal to noise ratios than in the unstructured setting. We complement this performance guarantee with an information theoretic lower bound, providing a necessary signal to noise ratio for any algorithm to successfully localize the cluster. We verify our analysis with some simulations, demonstrating the practicality of our algorithm.

Track D – Signal Processing and Adaptive Systems

Session: TAb3 – Optimization in Signal Processing

Chair: *Wotao Yin, Rice University*

TA3b-1

10:15 AM

Limited Memory Quasi-Newton Methods for Sparse Optimization

Roummel Marcia, University of California, Merced, United States

We investigate fast direct methods for solving linear systems in limited-memory quasi-Newton methods for solving large-scale sparse recovery problems. These systems arise in trust-region methods and preconditioning techniques for interior-point methods in optimization. We show that under mild assumptions, these linear system can be solved in an efficient and stable manner via a recursion that requires only vector inner products. We consider various settings and demonstrate the effectiveness of the recursion methods in numerical experiments.

TA3b-2

10:40 AM

New Algorithms for Verifying the Null Space Conditions in Compressed Sensing

Myung Cho, Weiyu Xu, University of Iowa, United States

In this paper, we propose new algorithms to verify the null space conditions in compressed sensing. Empirical results show the performance improvements of new algorithms over existing methods.

TA3b-3

11:05 AM

Sparse Dictionary Recovery with Noise

John Wright, Columbia University, United States

Stable Dictionary Recovery under Noise Learning a signal model from sample data is a key step in many modern algorithms for image processing. Algorithms based on learned dictionaries often outperform their fixed-dictionary counterparts. However, the problem of learning the dictionary from observation data is very challenging. Most natural heuristics are based on alternating directions, and are difficult to analyze theoretically. Recently, Spielman, Wang and Wright [COLT '12] showed that it was possible to provably learn complete (square) dictionaries under certain sparse coefficient models, using convex programming. These results pertain to an exact (noise-free) observation model, which limits their practical applicability. In this talk, we discuss stable extensions of this approach, which have bounded estimation error under Gaussian noise. We discuss applications of this approach in imaging problems, as well as some novel related results on learning task-specific dictionaries for visual object detection.

TA3b-4

11:30 AM

Sparse Recovery over Continuous Dictionaries: Just Discretize

Gongguo Tang, Badri Narayan Bhaskar, Benjamin Recht, University of Wisconsin-Madison, United States

We consider the problem of estimating signals having sparse representations with respect to dictionaries whose elements are continuously parameterized. Signals of this nature arise frequently in applications such as imaging, radar, sonar, sensor array, communication, seismology, and remote sensing. We use atomic norm minimization as a general convex approach to directly enforce sparsity in the continuous dictionary, coupled with discretization as a universal computational scheme to approximate the atomic norm solution. We demonstrate that as we discretize finer, the solutions of the discretized system converge to the solution of the original atomic minimization problem. We also explicitly establish the rate of convergence under mild smoothness conditions. We validate the convergence results by extensive numerical experiments.

Session: TAa4 – Cooperation Techniques for Wireless Networks

Co-Chairs: *Michele Zorzi, University of Padova and Leonardo Badia, University of Padova*

TA4a-1

8:15 AM

Analysis and Management of Heterogeneous User Mobility in Large-Scale Downlink Systems

Axel Müller, Supélec, France; Emil Björnson, KTH Royal Institute of Technology, Sweden; Romain Couillet, Mérouane Debbah, Supélec, France

Modern multi-user communication systems need to serve user terminals with large disparities in mobility. This incurs different accuracy and coherence times on the channel estimation depending on each user's mobility. In this paper, we consider the single-cell downlink. The system is large in the sense that the number of transmit antennas and user terminals go to infinity at a fixed ratio. We show that even a small fraction of low-quality channel estimates severely diminishes system performance, since the misinformed precoding harms all users. Simulations are used to verify the applicability of our large-scale approximations for systems of practical size and to introduce possible solutions to the new mobility challenge.

TA4a-2

8:40 AM

Energy Efficiency Optimization in Relay-Assisted Multi-User MIMO Systems

Alessio Zappone, Pan Cao, Eduard Jorswieck, Dresden University of Technology, Germany

The issue of energy-efficient resource allocation in a multi-user, amplify-and-forward, relay-aided MIMO system is considered. The transmit covariance matrices and the relay amplification matrix are optimized in order to maximize the system's global energy efficiency, defined as the ratio between the system achievable sum-rate and the total consumed power. In the definition of the consumed power, both the transmit power and the circuit power needed to operate the terminal are accounted for. The considered performance metric is measured in bits/Joule thus representing a natural measure of the efficiency with which each Joule of energy is employed. The tools of fractional programming and alternating maximization are employed to come up with a resource allocation algorithm which also considers QoS constraints.

TA4a-3

9:05 AM

Performance Evaluation of Coded Meshed Networks

Morten V. Pedersen, Daniel E. Lucani, Frank H. P. Fitzek, Aalborg University, Denmark

We characterize the performance of intra- and inter-session network coding (NC) in wireless networks using real-life implementations. We compare this performance to a recently developed hybrid approach, called CORE, which combines intra- and inter-session NC exploiting the code structure of the former to enhance the gains of the latter. We first motivate our work through measurements in WiFi mesh networks. Later, we compare state-of-the-art approaches, e.g., COPE, RLNC, to CORE. Our measurements show the higher reliability and throughput of CORE over other schemes, especially, for asymmetric and/or high loss probabilities. We show that a store and forward scheme outperforms COPE under some channel conditions, while CORE yields 3dB gains.

TA4a-4

9:30 AM

MAC Design for Full-Duplex Relaying

Sanjay Goyal, Polytechnic Institute of New York University, United States; Ozgur Gurbuz, Sabanci University, United States; Elza Erkip, Shivendra Panwar, Polytechnic Institute of New York University, United States

This paper provides an IEEE 802.11 based MAC protocol design that enables full-duplex relaying. More specifically, the proposed MAC protocol allows for streaming data over two hops while efficiently utilizing the full-duplex capability. Performance comparisons with direct transmission and half-duplex relaying are provided by taking into account the residual self-interference at the relay due to the full-duplex operation and the additional resources (such as antennas or RF chains) used at the relay for enabling full-duplex.

Session: TAb4 – Body Area Nanonetworks

Chair: *Josep Miquel Jornet, University at Buffalo, The State University of New York*

TA4b-1

10:15 AM

A Molecular Communication Framework for Targeted Drug Delivery Systems

Youssef Chahibi, Massimiliano Pierobon, Georgia Institute of Technology, United States; Sang Ok Song, Samsung Electronics, Co., Ltd., Republic of Korea

Targeted Drug Delivery Systems (DDS) aim to selectively deliver medication to the cause of the disease while minimizing the effects on healthy parts of the body. The Molecular Communication (MC) paradigm, which abstracts the exchange of information through molecules, underlies many biological pathways naturally present inside the human body, such as the hormonal signaling in the endocrine system. In this paper, the MC paradigm is used as a framework to study and design targeted DDS by modeling the drug particles transport throughout the body as a communication system, where the drug injection is the transmission process, the drug absorption is the reception process, and the human body represents the channel. The performance metrics of the communication system are related to critical objectives in DDS, such as optimal biodistribution and pharmacokinetics.

TA4b-2

10:40 AM

Error Control for Calcium Signaling Based Molecular Communications

Michael Barros, Brendan Jennings, Telecommunication Software and Systems Group, Ireland; Sasitharan Balasubramaniam, Tampere University of Technology, Finland

Calcium Signaling is one of the most widely studied means of providing for molecular communications in nano-networks. In this paper we investigate the issue of error control for Calcium Signaling. Taking an information theoretic approach we show, using a stochastic simulation model, how error conditions such as signal fading, information memory and multipath propagation can affect the communication rate. We analyse potential techniques to mitigate these effects, including modulation, coding, relay nodes and cooperative transmission.

TA4b-3

11:05 AM

Nanoscale Magneto-Inductive Communication

Deniz Kilinc, Ozgur B. Akan, Koç University, Turkey

The wireless nanonetworks allow nanodevices to perform more complex functions. In this paper, we introduce Nanoscale Magneto-Inductive (NMI) communication for the first time. The coupling between nanocoils establishes a communication channel. The novel NMI communication solves the problems of the electromagnetic communication by introducing low absorption losses and flat channel characteristics. We present the physical models of both the point-to-point and waveguide NMI communication techniques and derive path loss expressions for both methods. Waveguide technique communication significantly reduces the path loss and increases feasible communication range. The NMI communication stands as a promising solution to nanoscale communication between nanodevices.

TA4b-4

11:30 AM

Opto-Ultrasonic Communications in Wireless Body Area Nanonetworks

G. Enrico Santagati, Tommaso Melodia, State University of New York at Buffalo, United States

Wirelessly interconnected nanorobots, devices with sizes ranging from one to a few hundred nanometers, represent a promising solution for remote and distributed medical diagnosis and treatment of major diseases within the human body. Each nanorobot is usually designed to perform a set of basic tasks such as sensing and actuating. However, a dense wireless interconnection between these nano-deceives, i.e., a nanonetwork, could potentially accomplish new and more complex functionalities, thus enabling revolutionary nano-medicine applications. Several innovative communication paradigms have been proposed during the last decade, including electromagnetic communications in the Terahertz Band and Molecular Communications. In this paper, we propose and discuss a different solution based on establishing in-body opto-ultrasonic communications between nano-robots. Opto-ultrasonic communications are based on the optoacoustic effect, which enables the generation of high-frequency acoustic waves by irradiating the medium with electromagnetic energy in the optical frequency range. We first discuss the fundamentals of the nanoscale opto-ultrasonic communication in biological tissues. Then, we model and simulate the opto-ultrasonic propagation in the human body. Finally we discuss possible transmission schemes based on impulsive transmissions.

TA5a-1

8:15 AM

Hierarchical Probabilistic Models for M/EEG Imaging

Srikantan Nagarajan, University of California, San Francisco, United States

A new approach is presented for the M/EEG inverse problem, formulated in the framework of probabilistic modeling. We define hierarchical models for brain activity that include spatial and temporal correlations across brain regions, uncorrelated voxel activity, interference and sensor noise. Fast algorithms are then derived to learn optimal values of parameters for these models. This framework allows for generalization of many existing algorithms, and also enables extensions to new formulations, such as novel algorithms for fusion of fMRI with MEG and EEG data. Robust reconstructions of current distributions are found in realistic simulation and real datasets.

TA5a-2

8:40 AM

EEG Source Imaging and Connectivity Analysis in Epilepsy Patients

Yunfeng Lu, University of Minnesota, United States; Gregory Worrell, Mayo Clinic, United States; Bin He, University of Minnesota, United States

EEG represents a useful tool to study the electrophysiological brain activity. EEG has also been widely used to help diagnose the epilepsy and study the underlying brain sources of epileptic activity. Here, we present a study of imaging the seizure activity of epilepsy patients from noninvasive scalp EEG. A spatio-temporal EEG source localization approach (FINE) was firstly applied to localize the active sources during ictal period. Functional connectivity analysis of directed transfer function (DTF) was then utilized to identify the primary source of seizure onset. Computer simulation was performed to study the source localization in dipolar sources. The method was also applied in medically intractable epilepsy patients to localize the seizure onset zone and the results were evaluated by comparing with the surgical resection of the patients.

TA5a-3

9:05 AM

Causality in Variance in Electrophysiological Data Using the GARCH Model

Syed Ashrafulla, University of Southern California, United States; John C Mosher, Cleveland Clinic, United States; Richard M Leahy, University of Southern California, United States

In human brain electrophysiological data, such as that recorded from electroencephalography (EEG) or magnetoencephalography (MEG), causation in variance can arise when the activation of electrical signals in one area of the brain modulates the strength of activation in a second area of the brain. In this paper we use the concept of generalized autoregression with conditional heteroscedasticity (GARCH) to model causality in variance for brain activity during nominally steady state periods in which the subject is either at rest or listening to music. In simulation and continuously measured MEG data, we use GARCH modelling to show how causality in variance, along with causality in mean, can provide additional insight into the dynamics of brain activity.

TA5a-4

9:30 AM

Sparse Multivariate Autoregressive Models with Exogenous Inputs for Modeling Intracerebral Responses to Direct Electrical Stimulation of the Human Brain

Jui-Yang Chang, University of Wisconsin, United States; Andrea Pigorini, Francesca Seregini, Marcello Massimini, University of Milan, Italy; Lino Nobili, Niguarda Hospital, Italy; Barry Van Veen, University of Wisconsin, United States

The self-connected group lasso is used to estimate sparse multivariable autoregressive with exogenous (MVARX) input models of the cortical interactions excited by direct current stimulation of the cortex. The group lasso criterion introduces a direct network connection between two sites only if the presence of the connection significantly reduces the mean-squared error of the model. This method is applied to intracranial recordings of the human brain to direct electrical stimulation. Excellent agreement between measured and model-predicted average responses across all data sets is obtained. One-step prediction of the recordings is also used to demonstrate that the model describes the dynamics in individual responses. We study the similarity of network models for a given set of channels when the electrical stimulation is applied at different locations in both wakefulness and non-rapid eye movement (NREM) sleep to identify common network characteristics.

TA5b-1

10:15 AM

A Temporal Superresolution Method Applied to Low-Light Cardiac Fluorescence Microscopy

Kevin Chan, University of California, Santa Barbara, United States; Le A. Trinh, University of Southern California, United States; Michael Liebling, University of California, Santa Barbara, United States

In biomicroscopy, fluorescent samples emit very little light, and imaging requires a long camera integration time to acquire an adequate number of photons. However, when imaging live, dynamic biological processes, a long integration time results in motion blur, and a low sampling rate results in temporal aliasing. To reduce these unwanted artifacts, we utilize a temporal superresolution algorithm to reconstruct a high temporal resolution image sequence from multiple low temporal resolution acquisitions. Each acquisition is temporally shifted by a subframe shift, and an l1 cost minimization is used to reconstruct the high temporal resolution sequence. This paper describes the acquisition and reconstruction algorithm, evaluates its performance, and demonstrates its application in live fluorescence bioimaging of the embryonic zebrafish heart. Our temporal superresolution algorithm increases the bandwidth by a factor of 1.5 and shows that temporal super-resolution can be a valuable tool to quantify fast dynamic processes in biomicroscopy.

TA5b-2

10:40 AM

Neuron Tracing from Confocal Stacks Using Automated Seed Selection

Suvadip Mukherjee, Barry Condron, Scott Acton, University of Virginia, United States

The massive volume of biological image data generated using the state of art imaging techniques like confocal microscopy, EM, etc., has encouraged researchers to develop robust, automated tools for bio-image analysis. Building a neurome or the neural connectivity map for a species in complexity beyond the worm is still an open problem. With more than 20,000 neurons to analyze in an adult fruit fly, five million neurons in a mouse and about 1012 neurons in a human brain, developing an automated neuron tracing tool is both challenging and a daunting task. Segmentation quality is largely hampered by the low SNR of the confocal stacks, while the disconnected structure of the neurites pose challenge to obtain the neural connectivity information. A majority of the neuron tracing tools depend on an initial segmentation of the confocal stack to separate the foreground from the background. Successful tracing depends on the quality of the initial segmentation, which is limited by the presence of noise and clutter in the image. In this report, we present a neuron tracing scheme that automatically selects a set of candidate neuron points by analyzing a neuron medialness map, generated using vector field convolution. A global graph is constructed with the auto-generated seeds as nodes in which the obtained neuronal tree maximizes the probability of belonging to the actual neuron by way of iterative optimization. The proposed method is completely automated and requires no human interaction to generate the final trace.

TA5b-3

11:05 AM

Quantitative Tissue Characterization in Fluorescence Microscopy

Jenna Mueller, Albert Oh, Duke University, United States; J. Quincy Brown, Tulane, United States; Nimmi Ramanujam, Rebecca Willett, Duke University, United States

Diagnosis of many cancers depends on the detection of pockets of microscopic tumor cells and accurate inference of its context, or the characteristics of the surrounding tissue. This paper describes the application of sparse coding methods to real fluorescence microscopy data and assesses their diagnostic potential. Results show that sparse coding methods not only allow tumor locations, sizes, and densities to be accurately estimated, but also reveal whether tumors are embedded in muscle or fat tissue – an important indicator of the malignancy of tumor cells.

TA5b-4

11:30 AM

Analysis of Spatial Clustering with Robust Statistics

Thibault Lagache, Institut Pasteur, France; Gabriel Lang, AgroParisTech, France; Nathalie Sauvonnet, Jean-Christophe Olivo-Marin, Institut Pasteur, France

Spatial organization of objects is essential in many scientific areas because it brings information about objects interactions and their interplay with the environment. Objects organization can be studied at different scales, ranging from country size in epidemiology to atomic structures in physics. Objects are represented as points in a restricted field of view (country, forest, cell) and quantitative methods are used to extract features about spatial point distributions. Here, we propose a closed-form expression

of critical quantiles of Ripley's K function which alleviates the need for Monte-Carlo simulations and gives rise to a fast, robust and analytical method that is implemented and available freely in Icy (<http://icy.bioimageanalysis.org>). To illustrate the capabilities of our method, we used it to analyze the spatial organization of endocytosis at cell membrane.

Track H – Speech, Image and Video Processing

Session: TAa6 – Geospatial Image Processing

Chair: *Saurabh Prasad, University of Houston*

TA6a-1

8:15 AM

Sparsity and Structure in Hyperspectral Imaging: Sensing, Reconstruction, and Target Detection

Rebecca Willett, Duke University, United States; Mark Davenport, Georgia Institute of Technology, United States; Marco Duarte, University of Massachusetts Amherst, United States; Richard Baraniuk, Rice University, United States

New sparse and low-dimensional models of hyperspectral images provide novel ways and means for the joint design of inference algorithms and hyperspectral imaging hardware. We will first provide an overview of how the richness and complexity of real-world hyperspectral images can be captured with tractable mathematical models. These models can be used to help navigate the complex interplay among various hardware design choices. Concepts related to compressive sensing (CS) play an important role but the physics of linear optical systems constrain our choice of sensing matrices and thus introduce new challenges not considered in the majority of the CS literature.

TA6a-2

8:40 AM

Sparse Representations for Classification of High Dimensional Multi-sensor Geospatial Data

Saurabh Prasad, Minshan Cui, University of Houston, United States

Sparse representation has been an active research area in the signal processing and machine learning community in recent years. Recently, sparse representation classifier was proposed for challenging classification tasks --- it entails representing a testing sample as a linear combination of all training samples which form an over-complete dictionary. In this paper, we demonstrate that for challenging high-dimensional classification tasks, an appropriate feature-space reconditioning by means of a suitable dimensionality reduction projection is beneficial for sparse representation classifiers and its variants --- especially when some features are redundant and/or lack discriminatory power. We propose a new dimensionality reduction algorithm to optimize the performance of greedy pursuit algorithms (required in sparse representation classifiers) by projecting the data into a space where the ratio of intra-class to inter class inner products are maximized. We also propose and present a multi-scale extension of this approach for geospatial data. We demonstrate the superiority of the proposed method with geospatial (hyperspectral and LiDAR) image analysis tasks, both in single-sensor and multi-sensor settings, in terms of improved classification performance and a speed-up in the run-time.

TA6a-3

9:05 AM

Adaptive Compressive Sensing for Wide Area Surveillance and Imaging

Abhijit Mahalanobis, Lockheed Martin, MFC, United States

The goal of a target detection system is to determine the location of potential targets in the field of view of the sensor. Traditionally, this is done using high quality images from a conventional imager. For wide field of view scenarios, this can pose a challenge for both data acquisition and system bandwidth. In this paper, we discuss a compressive sensing techniques for target detection that dramatically reduce the number of measurements that are required to perform the task, as compared to the number of pixels in the conventional images. This in turn can reduce the data rate from the sensor electronics, and along with it the cost, complexity and the bandwidth requirements of the system. Specifically, we discuss a two-stage approach that first adaptively searches a large area using shift-invariant masks to determine the locations of potential targets (i.e. the regions of interest), and then re-visits each location to discriminate between target and clutter using a different set of specialized masks. We show that the overall process is not only highly efficient (i.e dramatically reduces the number of measurements as compared to the number of pixels), but does so without appreciable loss in target detection performance.

TA6a-4

9:30 AM

Context-based Unmixing and Detection Using Co-registered Hyperspectral and LiDAR Sensors

Paul Gader, Taylor Glenn, University of Florida, United States

The paper describes a method for sub-pixel target detection using hyperspectral and LiDAR sensors. The method uses clustering algorithms that incorporate spatial, spectral, and elevation information to define contexts. Backgrounds within each context are represented using linear and/or nonlinear mixing models. Targets are found by comparing unmixing with a target pixel and the background to unmixing with the background alone. Two methods are used for comparison: a hybrid sub-pixel detection and abundance estimates. Results are provided on hyperspectral and LiDAR data collected over the same scene at the same time.

Track E – Array Signal Processing

Session: TA6 – Control and Signal Processing for Information Fusion

Chair: *Prakash Ishwar, Boston University*

TA6b-1

10:15 AM

Adaptive Non-myopic Quantizer Design for Target Tracking in Wireless Sensor Networks

Sijia Liu, Syracuse University, United States; Engin Masazade, Yeditepe University, Turkey; Xiaojing Shen, Sichuan University, China; Pramod K. Varshney, Syracuse University, United States

In this paper, we investigate the problem of non-myopic (multi-step ahead) quantizer design for target tracking using a wireless sensor network. Adopting the alternative conditional posterior Cramer-Rao lower bound (A-CPCRLB) as an optimization metric, we theoretically show that this problem can be temporally decomposed over a certain time window. Based on sequential Monte-Carlo methods for tracking, i.e., particle filters, we design the local quantizer adaptively by solving a particle-based non-linear optimization problem which is well suited for the use of interior point algorithm and easily embedded in the filtering process. Simulation results are provided to illustrate the effectiveness of our proposed approach.

TA6b-2

10:40 AM

Are Global Sufficient Statistics Always Sufficient: The Impact of Quantization on Decentralized Data Reduction

Shengyu Zhu, Ge Xu, Biao Chen, Syracuse University, United States

The sufficiency principle is the guiding principle for data reduction for various statistical inference problems. There has been recent effort in developing the sufficiency principle for decentralized inference with a particular emphasis on studying the relationship between global sufficient statistics and local sufficient statistics. We consider in this paper the impact of quantization on decentralized data reduction. The central question we intend to ask is: if each node in a decentralized inference system has to summarize its data using a finite number of bits, is it still sufficient to implement data reduction using global sufficient statistics prior to quantization? We show that the answer is negative using a simple example and proceed to identify conditions when global sufficient statistics based data reduction is indeed optimal. They include the well known case when the data at decentralized nodes are conditionally independent as well as a class of problems with conditionally dependent data.

TA6b-3

11:05 AM

Controlled Sensing for Sequential Multihypothesis Testing with Non-Uniform Sensing Cost

Sirin Nitinawarat, University of Illinois, United States; Venugopal V. Veeravalli, University of Illinois at Urbana-Champaign, United States

A new model for controlled sensing for sequential multihypothesis testing is proposed and studied. This new model generalizes the existing model in two aspects. First, it exhibits a more complicated memory structure in the controlled observations than that in the existing model. Second, it is applicable to the situation with a very general sensing cost that can depend on realizations of both the observations and control values up to a stopping time. An asymptotically optimal sequential test is proposed and is proven to enjoy a strong asymptotic optimality condition pertaining to a tradeoff between error probabilities and cost.

TA6b-4

11:30 AM

Dynamic Topic Discovery through Sequential Projections

Weicong Ding, Mohammad Rohban, Prakash Ishwar, Venkatesh Saligrama, Boston University, United States

We propose algorithms for discovering topics in a dynamically evolving document corpus by tracking the geometry of cross-document word-frequency patterns. This is based on efficiently identifying novel words that are unique to each topic through a sequence of data-dependent and random projections of word-frequency patterns. We present experiments on synthetic and real-world datasets to demonstrate qualitative and quantitative merits of our scheme.

Track G – Architecture and Implementation

Session: TAa7 – Heterogenous and Reconfigurable Computing

Chair: *Joe Cavallaro, Rice University*

TA7a-1

8:15 AM

Heterogeneous Processors for Exascale Systems

Michael Schulte, AMD, United States

Exascale computing systems that can perform over 10^{18} operations per second are needed to solve some of the world's most important physical simulation and modeling problems. These systems also need to be very power efficient to avoid high operating expenses. Heterogeneous processors that combine general-purpose processing cores, graphics processing vector engines, specialized accelerators, high-speed communications mechanisms, and advanced memory systems provide a potential solution for meeting the performance and power-efficiency goals of exascale computing systems. This paper provides an overview of some of the key challenges of exascale computing systems, and discusses the use of heterogeneous processors to overcome these challenges.

TA7a-2

8:40 AM

Autocoded Dataflow Synthesis for Heterogeneous Embedded Targets

Mohammad Hosseinabady, John McAllister, Queen's University Belfast, United Kingdom

Dataflow application modeling has been widely exploited in recent years for synthesis and optimization of embedded streaming systems. However, whilst the expressive power and capabilities for dataflow dialects such as Synchronous dataflow (SDF), Multidimensional SDF (MSDF) and Cyclo-static Dataflow (CSDF) are well know and demonstrated, choosing the appropriate proper model of computation (MoC) for an application at hand is a challenge which directly impacts upon the potential quality of the final implementation, yet is an ad-hoc manual process at present. This paper proposes a high-level programming approach which, as far as the authors are aware, is the first recorded autocoding approach which synthesizes dataflow application models themselves, rather than synthesizing embedded code from those models. It is used to autogenerate SDF, MSDF and CSDF models from a single source, and generate realisations on heterogeneous embedded platforms.

TA7a-3

9:05 AM

Efficient Reconfiguration Methods to Enable Rapid Deployment of Runtime Reconfigurable Systems

Roman Lysecky, Nathan Sandoval, Sean Whitsitt, Casey Mackin, Jonathan Sprinkle, University of Arizona, United States

Today's data streams are encoded or compressed to maximize throughput or minimize information loss, but not always using the same algorithms or compression schemes. In response, embedded computing applications require a large degree of configurability and adaptability to operate on a variety of data inputs where the characteristic of the data inputs may also change over time. To address these challenges, runtime reconfigurable systems can enable efficient implementations in which hardware accelerators can be reconfigured in response to the characteristics of an incoming data stream. In this paper, we present an overview of the framework and runtime reconfiguration methods developed in the data-adaptable reconfigurable embedded systems (DARES) project. We provide an overview our rapid deployment and runtime reconfiguration capabilities with an adaptable implementation of JPEG2000 image compression, and its large parameterization space.

TA7a-4**9:30 AM****Multimode Turbo Decoder on GPU**

Michael Wu, Guohui Wang, Bei Yin, Christoph Studer, Joseph R. Cavallaro, Rice University, United States

This paper proposes a massively parallel implementation of a high throughput reconfigurable Turbo decoder on NVIDIA Kepler graphics processing unit (GPU). The implementation supports Max-Log-MAP and Log-MAP decoding algorithms and various code rate and length specified by HSPA and LTE standards. To improve performance, we take advantage of WARP shuffle instruction and the larger number of maximum available registers per thread on Kepler architecture. In addition, we reduce device memory bandwidth requirement through LLR compression. We show that this implementation can achieve high throughput with a reasonable number of concurrent codewords and higher throughput than existing software based turbo decoder on general purpose processors.

*Track H – Speech, Image and Video Processing***Session: TAb7 – High Efficiency Video Coding**Chair: *Marios Pattichis, University of New Mexico***TA7b-1****10:15 AM****On the Use of SSIM in HEVC**

Tiesong Zhao, Zhou Wang, University of Waterloo, Canada

The structural similarity index (SSIM) has been attracting an increasing amount of attention recently in the video coding community as a potential criterion for perceptual optimization. Meanwhile, the arrival of the new high efficiency video coding (HEVC) scheme creates new opportunities and challenges in perceptual video coding. In this paper, we address several essential issues on the use of SSIM in HEVC. These include the tradeoff between efficient computation and accurate approximation of SSIM, the estimation of rate-SSIM curves from a small number of samples, and the evaluation of perceptual coding gain based on rate-SSIM performance and user-defined target rate and quality.

TA7b-2**10:40 AM****A Layer-Adaptive Approach to Screen Content Coding for HEVC Application Range Extensions**

Chun-Chi Chen, Hung-Cheng Jhu, Tsui-Shan Chang, Wen-Hsiao Peng, National Chiao Tung University, Taiwan

Screen content coding (SCC), which finds applications in emerging video streaming services such as cloud gaming and desktop air mirroring, has recently attracted wide attention in the video standards community. The screen content, generally including a mixture of text, graphics, and nature scene images, exhibits very different characteristics from camera-captured video. Conventional coding techniques have proved extremely inefficient in representing such signals with high dynamics, while most prior works for SCC often incur a large coding delay in attempting to differentiate the various components based on iterative algorithms for separate coding. Constrained by low-complexity and low-latency requirements, we propose in this paper a layer-adaptive approach to screen content coding. It begins with block pixels classification into layers using an one-pass scheme, followed by an adaptive coding of intra prediction residuals or pulse code modulation samples in each layer with transform, palette, or lossless representation. Significant efforts have been made to minimize the changes to the current HEVC architecture and the impact on both encoding and decoding complexities. Preliminary results show that with All-Intra Main configuration, our approach achieves, on average, a 19.4% BD-rate saving over the HM-7.0 anchor in common test conditions.

TA7b-3**11:05 AM****Dynamically Reconfigurable Architecture System for Time-Varying Image Constraints (DRASTIC) for HEVC Intra Encoding**

Yuebing Jiang, Gangadharan Esakki, Marios Pattichis, University of New Mexico, United States

We introduce the use of a dynamically reconfigurable architecture system for time-varying image constraints (DRASTIC) and consider its application in HEVC intra encoding. DRASTIC provides a framework for jointly optimizing energy-rate-distortion for different operating modes. DRASTIC optimization involves dynamically reconfiguring parameters (e.g., the quantization parameter, prediction modes), software and hardware cores. However, in this paper, we will not consider the use of hardware cores. DRASTIC implementations for HEVC intra-encoding require limited computing resources while providing fast random access. We provide a list of Pareto-optimal configurations and demonstrate performance on time-varying constraints.

TA7b-4

11:30 AM

High Efficiency Video Coding (HEVC) for Reproducible Medical Ultrasound Video Diagnosis

Andreas Panayides, Imperial College London, United Kingdom; Marios Pattichis, University of New Mexico, United States; Constantinos Pattichis, University of Cyprus, Cyprus

The emerging HEVC standard allows archiving of clinical ultrasound video at the original acquisition resolution. This capability supports the development of a reproducible protocol that requires that the diagnosis based on the HEVC archived video be equivalent to the in-clinic diagnosis. We present a full-reference video quality assessment system for assessing structure, texture, and motion of atherosclerotic plaque ultrasound used in the diagnosis of stroke. The system is based on multi-objective optimization and regression for predicting clinical ratings. We make our clinical ultrasound video database and clinical ratings open to the community to support further research in this area.

Track E – Array Signal Processing

Session: TAA8 – Radar and Sonar Signal Processing

8:15 AM–9:55 AM

Chair: *Pu Wang, Schlumberger-Doll Research Center*

TA8a1-1

A Novel Target Motion Compensation Method for Randomized Stepped Frequency ISAR

Peng Song, Huadong Meng, Tianyao Huang, Yimin Liu, Tsinghua University, China

In this paper, we focus on motion compensation of moving target with a constant acceleration in randomized stepped frequency inverse synthetic radar (RSF ISAR). A novel target motion compensation method called minimum entropy of accumulated Doppler spectrum method is proposed. The method compensates the second-order phase first, and then estimates radial velocity. The method can overcome the influence on radial velocity estimation caused by radial acceleration, and keep the benefit of overcome range profile de-focus problem. Simulation results show that the proposed method is effective for motion compensation and robust to the signal-noise ratio (SNR).

TA8a1-2

SAR Imaging Using Sparse ML Approaches

George-Othon Glentis, University of Peloponnese, Greece; Kexin Zhao, University of Florida, United States; Andreas Jakobsson, Lund University, Sweden; Habti Abeida, University of Taif, Saudi Arabia; Jian Li, University of Florida, United States

High-resolution spectral estimation techniques are of notable interest for synthetic aperture radar (SAR) imaging. Typically, SAR images are formed using periodogram-based estimators, thereby suffering from the well-known limitations in resolution and high leakage levels. Several sparse estimation techniques have been shown to provide significant performance gains as compared to conventional approaches. In this work, we continue this development, considering efficient implementation of the recent iterative sparse maximum likelihood-based approaches (SMLA). Furthermore, we present approximative fast SMLA formulations using the Quasi-Newton approach, as well as consider hybrid SMLA-MAP algorithms. The effectiveness of the discussed techniques are illustrated using numerical and experimental examples.

TA8a1-3

Direction Estimation Using Compressive Sampling Array Processing with Reconfigurable Antennas

Erica Daly, Kurt Schab, Jennifer Bernhard, University of Illinois at Urbana-Champaign, United States

The importance of antenna design on direction finding using compressive sensing array processing is explored. A method for reducing the complexity of the receiver necessary for accurate direction of arrival estimation by using pattern reconfigurable antennas is investigated.

TA8a1-4

Radar Modeling and Validation of Human Gaits Using Joint Motion Capture and Radar Data Collections

Ryan Hersey, Georgia Tech Research Institute, United States; David Bowden, Dustin Bruening, Lamar Westbrook, Air Force Research Laboratory, United States

Prior radar modeling of the human gait has implemented radar models of a human gait with motion defined by a kinematic walking model. While this model captures the fundamental walking characteristics, it is limited in practical application due to the generality of its definition. To increase the fidelity and realism of human gait modeling, we utilize motion capture and radar data measurements that are collected simultaneously. We utilize the motion capture data collections to provide accurate body segment locations over time. We incorporate this information into a radar model that calculates the coherent radar return from each segment over time. We validate this model with measured X-band and Ku-band radar data.

TA8a1-5

On the Effect of Reconfigurable Antenna Radiation Patterns on Outdoor Channel Characteristics

Hassan El-Sallabi, Mohamed Abdallah, Texas A&M University at Qatar, Qatar; Jean-Francois Chamberland, Texas A&M University, United States; Khalid Qaraqe, Texas A&M University at Qatar, Qatar

In this paper, using simulation based on multi-ray multi-dimensional multi-state RF model, we investigate the radiation patterns of the reconfigurable antenna for different states determined by the antenna rotation angle and show its effect on the outdoor channel characteristics in terms of its temporal and spatial variability. We also show, via simulation of a coded communication system, the bit-error-rate performance benefits attained using the best antenna state defined by the average channel gain per codeword.

TA8a1-6

Target Detection and Classification Against Non-stationary Interference Using Dynamic Time-Frequency Localization

Ananya Sen Gupta, University of Iowa, United States; Ivars Kirsteins, Naval Undersea Warfare Center, United States

We address the well-known challenge of detecting a target in non-stationary clutter in active sonar using dynamic time-frequency localization. The challenge is to track the target against non-stationary interferers, anthropogenic or biological, as well as environmental backscatter from the sea surface and bottom. Definition of “target” is application-specific, e.g. in a naval application the target would typically be a submarine or mine, in another application the target is an environmental AUV sensor tracing pollutant flow along the coast. Examples of non-targets include bathymetric features, fish, wrecks, other AUVs, etc. We present an adaptive subspace-tracking algorithm that navigates the time-frequency space dynamically using non-uniform sampling and mixed norm optimization to provide enhanced target detection and classification.

TA8a1-7

Passive Radar Detection Using Multiple Transmitters

Stephen Howard, Songsri Sirianunpiboon, Defence Science and Technology Organisation, Australia

Target detection for a multi-static passive radar, in which the radar uses multiple illuminators of opportunity, as well as multiple target surveillance receivers, is considered. It is shown that this detection problem can be formulated as a statistical test of whether a signal of known rank is present in both the reference and target surveillance channels or only in the reference channels, in the presence of independent gaussian white noise across all channels. Bayesian and generalized likelihood ratio tests for target detection are derived for both known and unknown receiver noise variances and are compared through simulation.

TA8a1-8

Optimal Beam Pattern Design For Very Large Sensor Arrays With Sparse Sampling

Yenming Lai, Radu Balan, University of Maryland, United States; Heiko Claussen, Justinian Rosca, Siemens Corporation, United States

Consider a sensing system using a large number of N microphones placed in multiple dimensions to monitor an acoustic field at multiple frequencies. Using all the microphones at once is impractical because the sheer amount of data is staggering. Instead we choose a subset of D sensors to be active. A direct, combinatorial approach to select the active sensors is often impractical because of problem size (N choose D) so instead we define an optimization criterion of interest, to minimize the largest interference gain, whose solution can drive the selection of a subset of microphones. This paper discusses the properties

of a convex optimization technique to solve this problem at multiple frequencies simultaneously, which induces sparsity in determining a small subset of microphones to monitor the target location while suppressing a large number of interferences. We test the robustness of the convex solution through simulated annealing and compare its performance against a classical beamformer which maximizes SNR.

Track A – Communications Systems

Session: TAA8 – Communication Systems I

8:15 AM–9:55 AM

Chair: *Ralf Muller, University of Erlangen-Nuremberg*

TA8a2-1

Low Latency T-EMS Decoder for NB-LDPC Codes

Erbao Li, David Declercq, ETIS ENSEA/univ. Cergy-Pontoise/CNRS, France; Kiran Gunnam, Nvidia Corporation, United States; Francisco Garcia, Jesus Omar, Javier Valls, Universidad Politecnica de Valencia, Spain

Check node update processing for non-binary LDPC (NB-LDPC) architectures requires a large number of clock cycles, which reduces the achievable throughput to tens of Mbps for high rate codes. We propose a new NB-LDPC architecture based on the Trellis-EMS (T-EMS) algorithm that reduces the number of clock cycles by a factor of dc, by adding an extra column to the trellis. The proposed architecture applied to a high-rate ($N=3888, K=3456$) code over GF(4) achieves a throughput of 3.2 Gbps with an area of 0.8 mm² on a 40nm CMOS process.

TA8a2-2

On Polarization for the Linear Operator Channel

Cesar Brito, Joerg Kliewer, New Mexico State University, United States

We address the problem of reliably transmitting information over a multiplicative and additive matrix channel which is a good model for networked transmission with random linear network coding under the action of an adversary. We show that this channel behaves like a subspace-based symmetric discrete memoryless channel (DMC) under subspace insertions and deletions and typically has an input alphabet with non-prime cardinality. Based on these observations we show that polarization for this adversarial linear operator channel can be achieved via an element-wise encoder mapping for the input matrices.

TA8a2-3

Quickness of the Instantaneous Frequency Based Classifier Distinguishing BFSK from QAM and PSK Modulations

Mohammad Bari, Miloš Doroslovacki, George Washington University, United States

In this paper we study the quickness of a classifier based on simple features that we have previously proposed to distinguish frequency from amplitude-phase digital modulations. The feature is based on the product of two consecutive signal values and on time averaging of the imaginary part of the product. First, the conditional probability density functions of the feature given the present modulation are determined. The central limit theorem for strictly stationary m -dependent sequences is used to obtain Gaussian approximations. Then thresholds are determined based on the minimization of the total probability of misclassification. Following that effects of carrier offsets, effects of fast fading, and of the symbol period and time delay being non-integer multiples of sampling period on the performance are studied. In the course of doing that, the proposed classifier is compared to the maximum likelihood classifier and the wavelet based classifier using support vector machine.

TA8a2-4

Coalition Formation for Uplink Device to Device Coordination with Cooperation Costs

Srinivas Yerramalli, Rahul Jain, Urbashi Mitra, University of Southern California, United States

Cooperation in the uplink of wireless networks allows users to form coalitions and improve their throughput by jointly transmitting to the base station. As the users are geographically separated, they must first share the information to be transmitted, among themselves, before joint encoding can be performed. In this paper, we propose a framework to maximize the throughput of each coalition by optimizing the fraction of time and energy spent in sharing data between the coalition members in comparison to the time spent in subsequent joint transmission to the base station. Using the throughput obtained from this framework, we model the problem of determining which users should cooperate as a coalitional game with non-transferable utility and propose a coalition formation algorithm which determines an optimal coalition structure using a Pareto improvement criterion. Numerical simulations show that while users close to the base station obtain little benefit from cooperation, the throughput of cell edge users more than doubles, showing the benefits of cooperation even with significant cooperation costs.

TA8a2-5

A Probabilistic Framework for Global Navigation Satellite System Signal Timing Assurance

Kyle Wesson, Brian Evans, Todd Humphreys, University of Texas at Austin, United States

Global Navigation Satellite System (GNSS) signals serve as a worldwide timing reference in numerous technological sectors. Yet GNSS receivers are vulnerable to so-called spoofing attacks that can manipulate the time reference. We illustrate the need for a probabilistic security model in the context of authenticating a timing signal as opposed to the traditionally non-probabilistic security models of message authentication and cryptography. Our primary contribution is establishing the necessary conditions for timing assurance in the context of security-enhanced GNSS signals. In addition, we formulate a probabilistic framework for timing assurance that combines cryptography and statistical signal processing across multiple network layers.

TA8a2-6

Channel-Optimized Vector Quantization with Mutual Information as Fidelity Criterion

Andreas Winkelbauer, Gerald Matz, Vienna University of Technology, Austria; Andreas Burg, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

We consider the problem of channel-optimized vector quantizer (COVQ) with mutual information as fidelity criterion. This problem is relevant in a communications context, where the goal is to maximize the end-to-end rate. We propose an algorithm which is similar to the information bottleneck method and solves the considered COVQ design problem. In contrast to conventional COVQ design algorithms, the proposed algorithm implicitly optimizes the labels of the quantizer outputs. Thus, the NP-hard label optimization is avoided and the optimal performance is achieved without additional computational complexity. Finally, we provide application examples which confirm the usefulness of the proposed algorithm.

TA8a2-7

Exploiting Spectral Leakage for Spectrogram Frequency Super-Resolution

Ray Maleh, Frank Boyle, L-3 Communications Mission Integration, United States

The spectrogram is a classical DSP tool used to view signals in both time and frequency. Unfortunately, the Heisenberg Uncertainty Principle limits our ability to use them for detecting and measuring narrowband signal modulation in wideband environments. On a spectrogram, instantaneous frequency can only be measured to the nearest bin without additional interpolation. This work presents a novel technique for extracting higher accuracy frequency estimates. Whereas most practitioners seek to suppress spectral leakage, we use mismatched windows to exploit such artifacts in order to produce super-resolved spectral displays. We present a derivation of our methodology and exhibit several interesting examples.

TA8a2-8

Constraint-Based Adaptive OFDM Transmission with Signaling-Assisted Modulation Classification

Lars Häring, Christian Kisters, University Duisburg-Essen, Germany

This paper proposes a novel adaptive Orthogonal Frequency Division Multiplexing (OFDM) transmission scheme in which adaptive coding and modulation (ACM) and the required signaling overhead is jointly optimized to maximize the effective data rate. In the considered time-division duplex (TDD) system, the transmitter signals only the most important ACM parameters to the receiver which classifies the modulation schemes based upon a novel maximum-a-posteriori (MAP) algorithm. Simulations results for indoor propagation scenarios show a superior effective bandwidth efficiency of the new technique which can be regarded as a combination of automatic modulation classification (AMC) and a pure signaling-based transmission concept.

TA8a2-9

Analysis of Min-Sum based Decoders Implemented on Noisy Hardware

Christiane Ngassa, Valentin Savin, CEA-LETI, MINATEC campus, France; David Declercq, ETIS ENSEA/univ. Cergy-Pontoise/CNRS, France

In this paper, we investigate the performance of two Min-Sum based LDPC decoders on noisy hardware. We derive density evolution equations for the noisy Min-Sum decoder, and analyze the useful regions of noise probabilities to achieve a target bit-error rate (BER). We also present finite length performance of the Min-Sum based decoders, and point out the excellent performance of the Self-Corrected Min-Sum decoder, which comes from its intrinsic ability to detect and discard unreliable messages during iterations. This work serves as a first step for the design of robust noisy arithmetic components in LDPC decoders.

TA8a2-10

Sum-Rate Maximization for Active Channels: Unequal Noise Power over Different Subchannels

Javad Mirzaee, Shahram ShahbazPanahi, University of Ontario Institute of Technology, Canada

We study the sum-rate maximization for an active channel subject to two constraints, one on the source total transmit power and one on the channel energy. Here, active channel refers to a parallel channel where gains of the subchannels can be adjusted. In spite of non-convexity of the sum-rate maximization problem of such channels, using Karush-Kuhn-Tucker (KKT) conditions, we propose a semi-closed form solution to sum-rate maximization where the optimal solution can be obtained by comparing a finite number of points in the feasible set and by choosing the point which yields the best sum-rate performance. We prove that, at the optimum, half of the total power should be allocated to the channel while the remaining half should be assigned to the source. Our results show that active channels can offer significantly higher sum-rate compared to their passive counterpart which rely on water-filling power allocation scheme.

Track D – Signal Processing and Adaptive Systems

Session: TAA8 – Machine Learning and Statistical Signal Processing I 8:15

AM-9:55 AM

Chair: *Mauro Maggioni, Duke University*

TA8a3-1

On the Periodogram Estimator of Period from Sparse, Noisy Timing Data

Barry Quinn, Macquarie University, Australia; Vaughan Clarkson, University of Queensland, Australia; Robby McKilliam, University of South Australia, Australia

The problem discussed is that of estimating the period of a sequence of periodic events when the occurrence time measurements are noisy and sparse. The problem arises in signal processing applications such as baud estimation from zero-crossings in telecommunications and in pulse repetition interval estimation in electronic support measures. Estimation techniques have been based on periodogram maximisation, Euclidean algorithms, least squares line search, lattice line search, Gaussian maximum likelihood and least squares. Aside from one paper, there has been no rigorous statistical analysis. In this paper, we show that the periodogram maximiser has excellent (theoretical) asymptotic statistical properties, illustrating them via simulation.

TA8a3-2

Random Matrix Theory in Pattern Classification: An Application to Error Estimation

Amin Zollanvari, Edward R. Dougherty, Texas A&M University, United States

We employed the Random Matrix Theory (RMT) to construct a nearly unbiased estimator of true error rate of linear discriminant analysis (LDA) with ridge estimator of inverse covariance matrix in the multivariate Gaussian model and in small-sample situation. In such a scenario, the performance of the constructed estimator, as measured by Root-Mean-Square (RMS) error, shows consistent improvement over well-known estimators of true error.

TA8a3-3

Hierarchical Bayesian Sparse Source Separation of Hyperspectral Signals

Todd K. Moon, Jacob H. Gunther, Utah State University, United States; Candace Berrett, Gustavious P. Williams, Brigham Young University, United States

We consider the separation of signals having a simplex constraint based on observations of noisy data using a fully Bayesian result. A joint density for the abundances (the simplex-constrained signal) is established. To specifically allow for the abundances to be sparse, this joint density is endowed with a parameter which is hyperparameterized to encourage sparseness. Learning is by Gibbs sampling. Sampling is complicated in this case, but is efficiently achieved using the Metropolis algorithm using a Gaussian mixture as the sampling density.

TA8a3-4

Bayes Clustering Operators for Known Random Labeled Point Processes

Lori Dalton, The Ohio State University, United States; Marco Enrique Benalcázar Palacios, Marcel Brun, Universidad Nacional de Mar del Plata, Argentina; Edward R. Dougherty, Texas A&M University, United States

There is a widespread belief that clustering is inherently subjective. To quote A. K. Jain, "As a task, clustering is subjective in nature. The same dataset may need to be partitioned differently for different purposes." One is then left with a number of questions: Where do clustering algorithms account for statistical properties of the sampling procedure? How can one address the ability of a clusterer to make inferences without a definition of its predictive capacity? This work develops a probabilistic theory of clustering that fully parallels the well-developed Bayes decision theory for classification, making it possible to address these questions and transform clustering from a subjective activity to an objective operation.

TA8a3-5

A Particle-Based Search Strategy for Improved Space Situational Awareness

Tyler A. Hobson, Vaughan Clarkson, University of Queensland, Australia

In certain tracking applications, it is not sufficient to assume that the measurement of a target's state can be made whenever a sensor is tasked to do so. For example, the target's position may lie outside the sensor's limited field of view. Nevertheless, failure of this sort still yields some information. It tells us where the target is not. This information is difficult to capture in conventional filtering. In the context of catalogue maintenance of resident space objects, a central task in Space Situational Awareness, we demonstrate how the particle filter may be adapted to account for occasional failed observations and to guide the process of target reacquisition while maintaining a high quality track at other times. The results of a numerical simulation show that while an Unscented Kalman Filter can lose track of objects in more challenging circumstances, the proposed particle method consistently reacquires and tracks all objects.

TA8a3-6

Closed-Form CRLBs for CFO and Phase Estimation from Turbo-Coded Square-QAM-Modulated Signals

Achref Methenni, Faouzi Bellili, Sofiène Affès, Institut National de la Recherche Scientifique, Canada

In this paper, we derive for the first time the closed-form expressions for the Cramér-Rao lower bound (CRLB) of the joint phase and carrier frequency offset (CFO) estimation from square-QAM modulated signals over turbo-coded transmissions. These analytical expressions corroborate the previous attempts to evaluate the considered CRLBs empirically. In the low-to-medium SNR regions, the CRLB for code-aided estimation lies between the bounds for completely blind (non-code-aided) and data-aided estimation schemes, thereby highlighting the effect of the coding gain. At high SNR values, the three CRLBs coincide.

TA8a3-7

Comparisons of Particle Swarm and CAT Swarm Optimization Algorithms for IIR Adaptive Filtering

Jinhyun So, William Jenkins, Pennsylvania State University, United States

In the recent past the Particle Swarm Optimization (PSO) algorithms have been researched for use in adaptive filtering problems where the mean squared error (MSE) surface is ill-conditioned. Recently a related bio-inspired optimization algorithm called the Cat Swarm Optimization (CSO) algorithm appeared in the literature for IIR adaptive filtering. The research to be reported in this paper presents analytical and experimental comparisons in an attempt to determine the similarities and differences between the PSO and CSO algorithms. The analyses include learning rate and computational complexity comparisons and an attempt to determine which algorithm is best suited for IIR adaptive filtering.

TA8a3-8

Automated Human Behavioral Analysis Framework using Facial Feature Extraction and Machine Learning

Demiyan Smirnov, Sean Banger, Sara Davis, Rajani Muraleedharan, Ravi Ramachandran, Rowan University, United States

Emotional intelligence is essential in understanding and predicting human behavior. Although human emotion is best captured using non-intrusive methods, due to factors such as system complexity, computation time and decision response time, the reality of automated behavioral analysis is hindered. In this paper, we propose a behavioral analysis framework capable of recognizing

emotions of an individual to identify any suspicious behavior. Our research shows 91.1% of emotion classification accuracy for cooperative individuals using facial feature extraction and machine learning techniques, thus outperforming existing state-of-the-art approaches.

Track F – Biomedical Signal and Image Processing

Session: TAa8 – Machine Learning for Biological Signals

8:15 AM–9:55 AM

Chair: *Scott Acton, Virginia Tech*

TA8a4-1

Projection Operator Based Removal of Baseline Wander Noise from ECG Signals

Sakshi Agrawal, Anubha Gupta, International Institute of Information Technology-Hyderabad, India

In this paper, we propose a novel method for baseline wander removal from a noisy ECG signal. We use projection operator based approach to remove baseline wander noise from the ECG signal. The noise subspace is generated using sample functions of the first order fBm processes characterizing baseline wander noise. The orthogonal projection of noisy ECG signal onto the noise subspace provides an estimate of baseline wander noise. The estimated noise is subtracted from the noisy input signal to obtain noise-free ECG signal. Performance comparison with other baseline wander removal methods shows the efficacy of the proposed method.

TA8a4-2

A Multi-Scale Energy Detector For Anomaly Detection in Dynamic Graphs

Arash Golibagh Mahyari, Selin Aviyente, Michigan State University, United States

Complex networks provide natural structure to represent relational data that arise in a variety of areas including social and biological sciences. The weight associated with each edge in the graph often represents the similarity between the two vertices it connects. In many real life scenarios, these relationships vary over time yielding dynamic graphs. Although the problem of anomaly detection has been addressed for static graphs, the extensions to dynamic graphs have been limited. In this paper, we propose a multiscale decomposition and detection framework to identify edges with unusual activity and the time points where this activity occurred.

TA8a4-3

Virtual Inertial Measurements for Motion Inference in Wireless Health

Xiaoxu Wu, Hua-I Chang, Chu-Hsiang Huang, Yan Wang, Lara Dolecek, Greg Pottie, University of California, Los Angeles, United States

Human motion monitoring plays an important role in many medical applications. We propose a framework for robust inference of human motion trajectory via low-cost noisy inertial sensors. We focus on the motion data processing and sensor measurement with impairment modeling to enable the generation of low-cost virtual inertial sensor measurements from existing motion databases. Experimental results show that our data processing algorithms successfully produced the virtual sensor data that captures the characteristics of real experiment data. The measurement modeling and virtual sensor data generation serve as an indispensable basis to efficiently develop robust inference algorithm for human motion trajectory estimation.

TA8a4-4

Shape Descriptors Based on Compressed Sensing with Application to Neuron Matching

Suvadip Mukherjee, Rituparna Sarkar, Scott Acton, University of Virginia, United States

In this paper we propose a novel compressed sensing based Fourier shape descriptor method to compute the shape feature vector of an arbitrary object. First, the object contour obtained via segmentation is represented as a complex signal. We then formulate an optimization problem that exploits the sparsity of the shape feature of the contour. This results in a reduced size feature vector, which can efficiently represent the shape of an object as illustrated by the reconstruction results. Appropriate for general shape retrieval problems, we demonstrate the efficacy of our algorithm by retrieving structurally similar neurons from a database. Currently, the representation and matching of neurons, given the heterogeneous nature of the neuronal morphology and the characteristically complex branching patterns, is an open problem. Retrieval of structurally similar neurons will potentially enable classification of neurons imaged. The retrieval results obtained using our method provide evidence of efficacy with a 27% improvement over Sholl analysis, which is a standard shape descriptor used in neuroscience.

TA8a4-5

Multi-view Network Module Detection

Yu-Teng Chang, Dimitrios Pantazis, McGovern Institute for Brain Research, Massachusetts Institute of Technology, United States

Fundamental to the identification of the architecture and organization of complex systems is the detection of modules, also called communities or clusters. By combining multi-view clustering and modularity-based partitioning, we propose a new method to identify the joint community structure of multiple realizations of networks. Our method finds clustering patterns that agree across all network views and is ideal for multi-modal data, such as coupled analysis of anatomical and functional brain connectivity networks, or inter-subject network analysis.

TA8a4-6

Bayesian Optimal Control of Markovian Genetic Regulatory Networks

Mohammadmahdi Rezaei Yousefi, Edward R. Dougherty, Texas A&M University, United States

Finding the optimal control policy for a Markovian genetic regulatory network requires that the transition probabilities be known precisely. In practice, due to practical limitations and complex nature of the underlying system, this knowledge may be inaccurate or incomplete. To address this difficulty, we construct an uncertainty class corresponding to the unknown network and define the objective function with respect to the probability distribution over the uncertainty class. We formulate the optimal control policy minimizing this cost function relative to our present knowledge of the process, which simultaneously provides an adaptive framework, resulting in an intrinsically robust Bayes-adaptive policy.

Track A – Communications Systems

Session: TA8 – Communications Systems II

10:15 AM–11:55 AM

Chair: *Vaughan Clarkson, University of Queensland*

TA8b1-1

Computing the Multiple Access Rate Region for Real-World Signals

Bruce MacLeod, MIT Lincoln Laboratory, United States

In this correspondence, we address the problem of predicting the usable rates of a multiple access communications channel under real world conditions. In particular, we are interested in channels and communications signals that cannot be easily modeled by the usual Gaussian assumptions, and call for alternative methods of analysis. The examples we use in our development typically involve two communicators, facilitating visualization of the rate regions. These results would be immediately applicable to the situation where a new communicator wishes to enter a channel where another link may be in progress, and needs to devise a strategy to allow each to operate normally. Our results should benefit both the system design of multiple access systems, especially adaptive or cognitive communications systems operating in an ad-hoc multiple access scheme.

TA8b1-2

Extraction of a Weak Co-channel Interfering Communication Signal using Complex Independent Component Analysis

Matthew Hagstette, Monique Fargues, Roberto Cristi, Naval Postgraduate School, United States

Independent Component Analysis (ICA) algorithms taking advantage of the potential non-circular property of complex signals have been recently derived and shown to lead to improved performances. We investigate the performance of three ICA approaches to extract a weak co-channel interfering communications signal from a television broadcast signal over varied interference-to-noise ratios: complex maximization of non-Gaussianity by Novey et al., RobustICA by Zarzoso et al., and complex fixed-point algorithm by Douglas. Findings show improved performance and sensitivity to the prewhitening step as the number of sensors increases.

TA8b1-3

Resource Allocation for Mobile Video Conferencing

Chao Yang, Scott Jordan, University of California, Irvine, United States

We consider resource allocation for mobile video-conferencing applications. We represent the performance of a session by a sigmoid utility function of the average bit rate over one or more groups of pictures, subject to an outage constraint. The goal is to maximize the total expected utility of all active video-conferencing users. We propose that resources can be allocated if the base

station chooses a price per unit rate based on total demand and the users respond by choosing rates. Since video-conferencing is interactive, an outage constraint requires that resources be assigned based on a user's channel. We suggest that prices should be set to statistically guarantee a minimum rate for users with poor combined pathloss and shadowing.

TA8b1-4

Multi-User Real-Time Wireless Video with Perceptual Constraints

Andrew Thornburg, Alan Bovik, Robert W. Heath, Jr., University of Texas at Austin, United States

Real-time wireless communication in civil and military applications is becoming increasingly prolific. Networks of Systems capture the complexity of such systems using tools from wireless engineering and control theory. We investigate the role of perceptual quality constraints on real-time multi-user wireless video. We propose an algorithm to determine the optimal feasible set of users, given their perceptual constraints and channel qualities. The H.264/SVC codec is used for compression, and the visual information fidelity pixel-domain (VIFP) full-reference image quality assessment model is used to measure perceptual quality. Initial results indicate such is an algorithm can maximize the utility of a video network while meeting target video quality.

TA8b1-5

Cross Layer Link Adaptation in Time Varying Mobile Satellite Channels with Outdated and Statistical CSIT

Alberto Rico-Alvarino, Jesus Arnau, Carlos Mosquera, University of Vigo, Spain

The inherently large propagation delay present in satellite communications makes link adaptation procedures difficult to apply. Particularly, channel state information at the transmitter (CSIT) can be completely outdated after a round-trip time for high-speed receivers. For moderate speeds, some correlation is expected between the current channel and the CSIT. In this paper we present a link adaptation procedure that uses both CSIT and statistical information about the channel variation. We exploit the use of retransmissions to alleviate the rate backoff induced by the outage constraint. The link adaptation procedure is stated as the maximization of the $\text{E}\{\text{goodput}\}$ subject to a packet error probability constraint, and the channel variation is captured by a time-homogeneous Markov chain.

TA8b1-6

Cancellation of Power Amplifier Induced Nonlinear Self-Interference in Full-Duplex Transceivers

Lauri Anttila, Dani Korpi, Ville Syrjälä, Mikko Valkama, Tampere University of Technology, Finland

Recently, full-duplex (FD) communications with simultaneous transmission and reception on the same channel has been proposed. The FD receiver, however, suffers from inevitable self-interference (SI) from the much more powerful transmit signal. Analogue radio-frequency (RF) and baseband, as well as digital baseband, cancellation techniques have been proposed for suppressing the SI, but so far the inherent nonlinearities of the transmitter and receiver front-ends have not been considered in the SI mitigation literature. To fill this gap, this article proposes a novel digital nonlinear interference cancellation technique to mitigate the power amplifier (PA) induced nonlinear SI in a FD transceiver. The technique is based on modeling the nonlinear SI channel, which is comprised of the nonlinear PA and the linear multipath SI channel, with a parallel Hammerstein nonlinearity. Stemming from the modeling, and appropriate parameter estimation, the known transmit data is then processed with the developed nonlinear parallel Hammerstein structure and suppressed from the receiver path at digital baseband. The results illustrate that with a given IIP3 figure for the PA, the proposed technique enables higher transmit power to be used compared to existing linear SI cancellation methods. Alternatively, for a given maximum transmit power level, a lower-quality PA (i.e., lower IIP3) can be used.

TA8b1-7

Self-Interference Cancellation with Nonlinear Distortion Suppression for Full-Duplex Systems

Elsayed Ahmed, Ahmed Eltawil, University of California, Irvine, United States; Ashutosh Sabharwal, Rice University, United States

In full-duplex systems, due to the strong self-interference signal, system nonlinearities become a significant limiting factor that bounds the possible cancellable self-interference power. In this paper, a self-interference cancellation scheme for full-duplex orthogonal frequency division multiplexing systems is proposed. The proposed scheme increases the amount of cancellable self-interference power by suppressing the distortion caused by the transmitter and receiver nonlinearities. An iterative technique is used to jointly estimate the self-interference channel and the nonlinearity coefficients required to suppress the distortion signal. The performance is numerically investigated showing that the proposed scheme achieves a performance that is less than 0.5dB off the performance of a linear full-duplex system

TA8b1-8

A Physical Layer Framework for Interference Analysis of LTE and Wi-Fi Operating in the Same Band

Rafael C. D. Paiva, Nokia Institute of Technology, Brazil; Panayiotis Papadimitriou, Sayantan Choudhury, Nokia Research Center, Finland

The recent digital transition of TV broadcasting has created new opportunities for wireless usage for voice, video and data services in these newly released bands (known as TV Whitespaces). Some possible wireless technologies that can be used in this new spectrum are LTE and Wi-Fi. In this paper, we conduct an in-depth analysis of the physical layer performance of LTE (Wi-Fi) in the presence of cross-technology interference. We propose a methodology in order to co-simulate the link level performance of LTE and Wi-Fi and show the impact of different interference patterns on the error rate. Our results show that the Wi-Fi performance is slightly exacerbated (compared to similar Wi-Fi interference) in the presence of LTE interference. We also show that LTE pilot boosting has negligible impact on Wi-Fi performance. Finally, we also show the impact of Wi-Fi interference on LTE performance.

Track G – Architecture and Implementation

Session: TA8 – Computer Arithmetic

10:15 AM–11:55 AM

Chair: *Earl Swartzlander, University of Texas at Austin*

TA8b2-1

A Partially-Adiabatic Energy-Efficient Logic Family as a Power Analysis Attack Countermeasure

Mihail Cutitaru, Lee A. Belfore, II, Old Dominion University, United States

This paper investigates attempts at securing physical implementation of circuits and analyzes the security of a new partially-adiabatic energy-efficient family through implementation of a AND/NAND gate. Previous proposals to implement power analysis resistant circuits consumed more power and used more transistors than their CMOS equivalents. In this paper we analyze the ability of adiabatic logic to implement secure circuits and propose a new energy-efficient logic family that reduces peak current in a circuit by a factor of almost four and has lower variation of peak current between different inputs. Circuits built using the proposed family can have increased resistance to power analysis attacks and reduced energy consumption.

TA8b2-2

Arithmetic with Binary-Encoded Balanced Ternary Numbers

Behrooz Parhami, Michael McKeown, University of California, Santa Barbara, United States

Ternary number representation and arithmetic, based on the radix-3 digit set $\{-1, 0, +1\}$, has been studied at various times in the history of digital computing. Some such studies concluded that we should abandon ternary in favor of binary computation. Others, demonstrated promise and potential advantages, but, for various reasons, including inertia, did not lead to widespread use. By proposing an efficient binary encoding for balanced ternary numbers, along with the corresponding arithmetic circuits, we argue that a reexamination of the decision against using ternary arithmetic might be in order.

TA8b2-3

Design and Implementation of Radix-10 Algorithm for Cube Root with Limited Precision Primitives

Milos Ercegovic, University of California, Los Angeles, United States; Robert McIlhenny, California State University, Northridge, United States

We present a radix-10 fixed-point digit-recurrence algorithm for cube 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 8 (single-precision) and 16 (double-precision) decimal digits. The proposed scheme uses limited precision operators which leads to compact modules, reduced interconnections and has an advantage at the layout level as well as in power optimization.

TA8b2-4

Radix Conversion for IEEE754-2008 Mixed Radix Floating-Point Arithmetic

Olga Kupriianova, Christoph Lauter, Université Pierre et Marie Curie Paris 6, France; Jean-Michel Muller, Centre National de Recherche Scientifique - Ecole Normale Supérieure de Lyon, France

Conversion between decimal and binary floating-point representations on I/O is ubiquitous. The advent of decimal floating-point arithmetic in IEEE754-2008 makes radix conversion even more pervasive, especially in mixed radix algorithms. Floating-point radix conversion means converting both the exponent and the significand. This work presents novel, straight-line algorithms for both quantities, suitable for hardware integration. Exponent conversion is performed with a small multiplication and a table lookup. It yields the correct result without error. Significand conversion uses a few multiplications and a small lookup table that is shared amongst all types of conversions. Accuracy can be adapted by adjusting the computing precision.

TA8b2-5

Logarithmic Arithmetic as an Alternative to Floating-Point: A Review

Manik Chugh, Behrooz Parhami, University of California, Santa Barbara, United States

The logarithmic number system (LNS) has found appeal in digital arithmetic because it allows multiplication and division to be performed much faster and more accurately than with widely used floating-point (FP) number formats. We review the sign/logarithmic number system and present a comparison of various techniques and architectures for performing arithmetic operations efficiently in LNS. As a case study, we describe the European logarithmic microprocessor, a device built in the framework of a research project launched in 1999. Comparison of the arithmetic performance of this microprocessor with that of a commercial superscalar pipelined FP processor leads to the conclusion that LNS can be successfully deployed in general-purpose systems.

TA8b2-6

Comparison of Parallelized Radix-2 and Radix-4 Scalable Montgomery Multipliers

Andrew Carter, Paula Ning, William Koven, David Harris, Michael Braly, Nathan Jones, Julien Massas, Alexandra Simoni, Harvey Mudd College, United States

This paper compares 130nm custom silicon implementations of three scalable Montgomery multiplier architectures to previously published FPGA implementations of the same architectures. It investigates the delay, energy, and area tradeoffs of parallelized left-shifting radix-2, radix-4, and Booth encoded radix-4 architectures. The radix-4 architecture is most efficient, performing 256 256-bit modular multiplication in 453ns while consuming 15.7nJ of energy and occupying an area of 0.141mm². The radix-2 architecture is a close second, with an energy-delay product (EDP) 0.8% higher and an area delay product (ADP) 3.1% higher. The Booth-encoded radix-4 architecture eliminates the need for an adder generating a 3 multiple, but comes at a cost of 36% in EDP and 34% in ADP relative to the conventional radix-4 architecture. The relative efficiencies of the silicon implementations are consistent with the FPGA implementations.

TA8b2-7

Implementation of a 64-Bit Jackson Adder

Andrew Carter, Tynan McAuley, William Koven, Paula Ning, David Harris, Harvey Mudd College, United States

In 2004, Robert Jackson and Sunil Talwar published a novel method of decomposing binary prefix addition. Their work sought to balance the complexity of the generate and propagate terms that bear the computational load in parallel prefix adders. This paper presents an implementation of a 64-bit adder based on this method, as well as an improved method of expressing this complex decomposition. This adder is compared to the optimized Sklansky architecture produced by Design Compiler in a 45 nm process. The 64-bit Jackson adder is 5% faster than the DesignWare adder, but uses 80% more energy.

TA8b2-8

Fast modulo $2n-1$ and $2n+1$ Adder Using Carry-Chain on FPGA

Laurent-Stephane Didier, Université de Toulon, France; Luc Jaulmes, Ecole Polytechnique, France

Modular addition is a widely used operation in Residue Number System applications. Specific sets of moduli allow fast RNS operations such as binary conversions and multiplications. Most of them use modulo 2^n-1 and 2^n+1 additions. This paper presents four fast and small architectures for these specific moduli targeting modern FPGAs with fast carry chains. The use of this arithmetic dedicated feature allows fast and small modular adders. Our modulo 2^n-1 adders have a single zero representation. Our modulo 2^n+1 adders are designed for binary and diminished-one representation with and without zero value management.

TA8b3-1

Some Fundamental Limits on Synchronization in Massive MIMO

Hei Victor Cheng, Erik G. Larsson, Linköping University, Sweden

The effect of frequency offsets on the uplink sum-rate performance of massive MIMO systems is studied in the case of flat fading with pilot assisted estimation. The specific goal of this work is to determine whether the same attractive array gain can be achieved as in the synchronous systems. Both collocated and distributed antenna architectures will be studied to determine if there is a fundamental preference for collocated or distributed antenna architectures from the perspective of frequency synchronization and its effect on the rate performance in a high mobility environment.

TA8b3-2

Massive MIMO with Clustered Pilot Contamination Precoding

Mahmood Mazrouei-Sebdani, Witold Krzymien, University of Alberta / Telecommunications Research Laboratories, Canada

In this paper, a practical approach to pilot contamination precoding (PCP) for massive MIMO is proposed through a joint clustering and pilot reuse scheme. We also introduce power scaling to enforce per-base station (BS) power constraints. We consider a massive MIMO system, where uncoordinated conventional beamforming is implemented in each cell. PCP acts as outer linear precoding prior to conventional beamforming through a cooperative transmission scheme with 3 base stations (BSs) involved. We partition each cell into 3 sectors and assign pilot sequences in a suitable way in order to perform PCP. In order to characterize performance and avoid time-consuming simulations, we employ large system analysis and random matrix theory. Numerical results show that the superiority of the clustered PCP is marginal for the moderate number of transmit antennas, but it becomes more significant in a massive MIMO mode. In addition, depending on user location, some users may experience a two-fold increased spectral efficiency after applying clustered PCP in the massive MIMO mode.

TA8b3-3

Second-Order Analysis of the Joint SINR Distribution in Rayleigh Multiple Access and Broadcast channels

Adrien Pelletier, Romain Couillet, Supélec, France; Jamal Najim, Université Paris-Est, France

This article studies the distribution of the signal-to-interference-plus-noise ratios (SINR) of users in a Rayleigh multi-user channel, using large dimensional random matrix theory. It is shown that the empirical distribution of the SINRs of the users in a Rayleigh multiple access channel (MAC) with minimum mean square error (MMSE) decoding behaves asymptotically as a Gaussian, with identified mean and variance. The result is applied to the estimation of the proportion of users in outage for a given target rate. The theoretical approach used is extended to broadcast channels in the full version of the article.

TA8b3-4

Power-Throughput Tradeoff in MIMO Heterogeneous Networks

Shashika Manosha Kapuruhamy Badalge, Satya Joshi, Marian Codreanu, Nandana Rajatheva, Matti Latva-aho, Centre for Wireless Communications, Finland

We consider a heterogeneous multiple-input multiple-output network, where the macrocell shares the same frequency band with the femto network. The interference power to the macro users from the femto base stations are kept below a threshold to guarantee that the performance of the macro users do not degrade due to femto network. We consider the power-throughput trade-off problem for this setting, which is formulated as a vector optimization problem. We further simplify the problem by using the scalarization method. Finally, we propose a linear transceiver design algorithm to solve the problem, and then, construct the optimal trade-off curve.

TA8b3-5

Decentralized Joint Beamforming and Scheduling for Weighted Sum Rate Maximization

Jarkko Kaleva, Antti Tölli, Markku Juntti, University of Oulu, Finland

Weighted sum rate maximization with general convex transmit power constraints is considered for multi-cell multi-user multiple-input multiple-output systems. We show that conventional gradient based approximation methods have high probability of achieving inefficient solutions and low rate of convergence as the complexity of the systems is increased. The proposed method

provides more effective definition of efficient solutions, and, additionally, provides better convergence properties. These solutions are shown support the number of active spatial data streams closer to the optimal value. This effectively translates into more efficient spatial data stream scheduling.

TA8b3-6

Performance Comparison of ZF-DPC to Block Diagonalization for Quantized Feedback

Joydeep Acharya, Long Gao, Sudhanshu Gaur, Hitachi America Ltd, United States

Multuser multiple-input multiple-output (MU-MIMO) systems can achieve higher data rates compared to single user (SU-MIMO) by exploiting multi-user diversity. The capacity bound for MU-MIMO systems is given by the MIMO broadcast channel (BC) capacity. Dirty paper coding (DPC) is a well-known non-linear precoder to achieve this bound. Zero forcing DPC (ZF-DPC) is a sub-optimal way to achieve DPC by triangularizing the channel which still performs better than linear precoders such as Block Diagonalization with complete channel knowledge at the transmitter. In practice complete channel knowledge is not possible at the transmitter and the precoder is designed based on quantized channel feedback from the receiver. In this paper, we establish a comparison of ZF-DPC to Block Diagonalization for quantized channel feedback. In order to do this, we first derive the framework for operating ZF-DPC with quantized feedback. Next we compare the performance of ZF-DPC over Block Diagonalization with a well-known quantized feedback structure (LTE Release 8 codebook) and demonstrate that the ZF-DPC still performs better.

TA8b3-7

Iterative MMSE-DFE Equalizer for the High Data Rates HF Waveforms in the HF Channel

Mahmoud Elgenedy, VarkonSemiconductors, Egypt; Essam Sourour, Alexandria University, Egypt

several researches investigate the performance of the conventional equalizers based on adaptive equalization in the single carrier medium data rates HF waveforms (up to 8 PSK) and show that they are suitable for mitigating the HF channel; however, the performance of these types of equalizers is very bad when used with the high data rates HF waveforms (up to 64QAM). Most of the later researches in the high data rates HF waveforms are based on the soft turbo equalizers which are very complicated. In this paper, we try to get the lowest complex equalizer can mitigate the HF channel for the high data rates waveforms. We investigate the performance of the minimum mean square error decision feedback equalizer (MMSE-DFE) indirectly adaptive through channel estimation based on least square estimation (LS) during the training sequences and linear interpolation between estimates. The basic performance of the equalizer is not enough to satisfy the standard requirements and hence we introduce two enhancements. First, an effective channel estimation technique (double estimation) is proposed. The new estimator shows a valuable performance enhancement over simple least square estimation with linear interpolation (about 3 dB gain at $1e-5$ BER for the 64QAM). The second enhancement is to use the iterative structure through decoder using the same conventional equalizer and decoder and this gives another 3 dB gain at $1e-5$ BER for the 64QAM. Iterative structure is less complicated than turbo equalizers for sure, as turbo equalizers require a lot of changes in the equalizer, decoder and demapper blocks to be SISO modules. Final equalizer model satisfies all the strict requirements of both STANAG 4539 annex B and MIL-STD-188-110B app. C standards under the ITU-R Poor channel conditions. In addition, we compare our performance with two different vendors of HF modems and two different researches and show that our performance is very competitive.

TA8b3-8

Worst-Case Weighted Sum-Rate Maximization for MISO Downlink Systems with Imperfect Channel Knowledge

Uditha Wijewardhana, Satya Joshi, Marian Codreanu, Matti Latva-aho, Centre for Wireless Communications, Finland

We consider the worst-case weighted sum-rate maximization (WSRMax) problem under imperfect channel state information in multicell downlink multi-input single-output systems. The problem is known to be NP-hard. We propose a solution method, based on semi-definite relaxation and branch and bound technique, which solves globally the nonconvex robust WSRMax problem with an optimality certificate. Novel bounding technique based on semi-definite relaxation is proposed.

TA8b3-9

Splitting Source Power for a Multicarrier Relay System with Direct Link

Yiming Ma, Yingbo Hua, University of California, Riverside, United States

We present optimization algorithms for source and relay power allocations for a multicarrier three-node relay system with direct link. We show that there is a benefit to the system capacity by allowing the source power to be split in both phases in a two-phase relay scheme. While the source power allocation problem is convex, the relay power allocation problem is not. But in both cases, we present efficient algorithms that yield the exact optimal solutions.

TA8b3-10

Channel Estimation Using Time-Shifted Pilot Sequences in Non-Cooperative Cellular TDD Networks with Large Antenna Arrays.

José Luis Lagunas-Morales, Sébastien Roy, University of Sherbrooke, Canada

Fernandes, Ashikhmin and Marzetta proposed a time-shifted scheme for large antenna arrays at the BTS in which the transmission of pilots is shifted in time, completely cancelling interference from inter-cell users. A specific question was raised by the authors: Can a BTS obtain an accurate estimate of the channel vector in the presence of strong downlink signals from adjacent cells? We answer positively by proposing a modification to their proposed scheme to obtain a robust estimation technique which uses both the pilot sequence and the uplink information to find the desired channel coefficients. Secondly, we assess the sensitivity of the system to the received downlink signals of the interferers and to the length of the training sequence.

TA8b3-11

Blind Separation for Precoding-Based Blind Channel Estimation for MIMO-OFDM Systems

Song Noh, Michael D. Zoltowski, Purdue University, United States

In this paper, the problem of blind channel separation for precoding-based blind channel estimation is considered in multiple-input multiple-output (MIMO) orthogonal frequency-division multiplexing (OFDM) systems. In the new scheme, blind separation is achieved by implicitly “marking” the respective signal sent by each transmitter with a unique (known) circular time-shift during even-valued time slots. Separation of the blindly obtained channel mixtures is achieved through a combination of subspace alignment followed by SVD based computation of the intersection of two subspaces. Separability conditions required for the proposed precoding-based blind channel estimation are established. Numerical results are presented demonstrating the efficacy of the proposed algorithm.

TA8b3-12

On the Jamming Power Allocation and Signal Design in DF Relay Networks

Xiangyun Zhou, Min Qiu, Australian National University, Australia; Shih-Chun Lin, National Taiwan University of Science and Technology, Taiwan; Y.-W. Peter Hong, National Tsing Hua University, Taiwan

This paper studies a simple decode-and-forward (DF) relay network in the presence of a jammer. The jammer is able to send noise-like signals to interfere with the signal reception at both the relay and the destination. From the attacker’s point of view, we investigate the following two design problems: i) What is the optimal probability distribution of the random jamming signals? ii) Given a total jamming power budget, how to optimally allocate the power between attacking the relay and attacking the destination? We provide analytical solutions to these design problems for both quasi-static and ergodic fading channels.

TA8b3-13

Soft-Input Soft-Output Linear Programming Decoding for Spread Spectrum Underwater Acoustic Communications

Erica Daly, University of Illinois at Urbana-Champaign, United States

This paper presents the soft-input soft-output (SISO) linear programming (LP) decoder. It is shown that the soft information gleaned from a pseudo-codeword solution to the LP optimization is not only useful, but that it can be used to form a superior channel estimate compared to the output from a SISO belief propagation (BP) decoder in certain situations.

AM

Chair: *Ric Romero, Naval Postgraduate School*

TA8b4-1

Information Theoretic Upper Bounds on the Number of Distinguishable Classes

C. M. Keller, M. Ho, P. Basu, MIT Lincoln Laboratory, United States; G. H. Whipple, Laboratory for Telecommunications Sciences, United States

This paper examines data driven information theoretic upper bounds on the number of classes that can be distinguished by a machine-learning classification system as a function of the signal-to-noise ratio (SNR) of the features. Fano upper bounds are derived with desired classification error as a parameter. A simulation example is used to explore the bounds. The final paper will include a result exploring the bounds using experimental data generated with USRP radios.

TA8b4-2

Direct Learning Adaptation of Power Amplifier Pre-distortion Based on Wirtinger Calculus

Navid Lashkarian, Jun Shi, Marcellus Forbes, Broadcom, United States

To improve efficiency of power amplifiers (PA), linearity of PA is often compromised when targeting lower power consumption (class B). Moreover, sophisticated PA efficiency improvement schemes such as envelope tracking tend to further boost the nonlinear characteristics of the PA. Digital pre-distortion (DPD) is a technique to improve the linearity of a power amplifier (PA) at expense of extra processing in the base-band. Derivation of optimal DPD adaptive filters involves optimization of real-valued objective functions of complex variables, whose derivative or gradient does not exist in the standard complex-analysis sense, due to nonholomorphic nature of the function. This is often overlooked in the literature and results in erroneous results. For instance, the methodology presented in [3] computes the gradient with respect to the variable to compute the updates. However, as discussed in [1] and [2], it is the gradient with respect to the conjugate of the variable (and not the variable) that leads to the nonpositive increment of the objective function. We resort to the theory of Wirtinger calculus to derive the proper first and second-order derivatives (gradient and Hessian operators) of the non-holomorphic objective function and extend the results to optimization methodologies such as Newton, Gauss-Newton, and their quasi-variants. Results are assessed through experimental validation of the proposed methods on WLAN PAs.

TA8b4-3

Adaptive Signal Classification of Satellite-Based Recordings of Radiofrequency (RF) Transients Using Learned Dictionaries

Daniela Moody, David Smith, Tess Light, David Suszcynsky, Los Alamos National Laboratory, United States

Los Alamos National Laboratory's FORTE satellite provided a rich lightning database that has been used to study the Earth's radiofrequency background. We develop new classification capability on FORTE data using adaptive signal processing combined with machine learning techniques. The focus is improved feature extraction using sparse representations over learned dictionaries. We compare classification scenarios designed to identify the presence and capture the dynamic behavior of standard lightning event types, while remaining robust to changes in background clutter and noise levels. In addition to time-domain RF dictionary learning, this paper brings a new contribution in time-frequency domain dictionary learning.

TA8b4-4

Reduced-Complexity Binary Search for Doppler Estimation in GNSS Receivers

Baharak Soltanian, Tampere University of Technology, United States; Murat Demirtas, University of California, Irvine, United States; Moncef Gabbouj, Tampere University of Technology, Finland

Abstract—In this article, we introduce a variation of binary search algorithm for the estimation of Doppler frequency shift in the acquisition stage of a GNSS receivers. It is shown in this article that the proposed modified binary search on average reduces the number of search steps by 25% in compare to traditional sequential search which is conventionally used in this context. This saving for the worst case scenario is as high as 100%.

TA8b4-5

Adaptive Learning of Immunosignaturing Features for Multi-Disease Pathologies

Anna Malin, Narayan Kovvali, Antonia Papandreou-Suppappola, Brian O'Donnell, Stephen Johnston, Phillip Stafford, Arizona State University, United States

Previously, adaptive learning algorithms have been used with immunosignaturing in order to identify single disease states in patients. In previous algorithms, a single disease state presence is assumed, although in a clinical setting this may not be the case. We propose a novel algorithm that is based on feature identification using BPFA, whose feature matrix is then modified and patient-wise comparisons are used to identify possible disease states. This algorithm is verified using combinations of actual patient immunosignaturing data. This has a variety of uses including multi-disease state diagnosis in the clinical setting, multi-biothreat detection in the field, and separation of co-contaminated biological samples in a research setting.

TA8b4-6

Hirschman Uncertainty with the Discrete Fractional Fourier Transform

Kirandeep Ghuman, Victor DeBrunner, Florida State University, United States

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]. We have seen that a basis can be constructed from signals with minimum Hirschman Uncertainty in that paper, leading to a transform we called the Hirschman Optimal Transform. Recently, we showed that the minimizers, and thus the uncertainty, are invariant to the Rényi entropy order [3]. This characteristic strongly suggests that Hirschman Uncertainty is a fundamental characteristic of digital signals. In this paper, we study the effect of incorporating the discrete fractional Fourier transform (discrete FRT) instead of the DFT and develop a new uncertainty measure denoted by $U_{a1/2}(x)$.

Track B – MIMO Communications and Signal Processing

Session: TP1 – Advanced MIMO Networking

Chair: *Sidhartan Govindasamy, Olin College*

TP1a-1

1:30 PM

Asymptotic Spectral Efficiency of Limited-Rank MIMO Transmissions in Wireless Networks with Nodes at Correlated Locations

Sidhartan Govindasamy, F. W. Olin College of Engineering, United States; Daniel Bliss, Arizona State University, United States

The spectral efficiency of a MIMO link with interferers at correlated positions is shown to approach an asymptote in probability as the number of interferers and antennas per node increase. The ranks of transmit covariance matrices are assumed to be limited and the spatial correlation between transmitters is assumed to satisfy a certain asymptotic independence property. This finding is applied to a variety of network models including analogs to Matern type-I and II networks, and others. These findings generalize previously derived results for MIMO links in networks with spatially independent users to networks with spatially correlated users.

TP1a-2

1:55 PM

Impact of Spatial Correlation and Distributed Antennas for Massive MIMO systems

Kien Truong, MIMO Wireless Inc., United States; Robert W. Heath, Jr., University of Texas at Austin, United States

Massive MIMO is a new breakthrough communication technique. The key ideas are to deploy a very large number of antennas at each base station and to use multiuser MIMO transmission to serve a much smaller number of users. The large arrays of massive MIMO are likely to be closely spaced, leading to correlation in the channel. This paper investigates the impact of spatial correlation and distributed antennas on pilot-based massive MIMO communication. Using a single cluster channel model, numerical results show that distributed antennas improve rate distribution of massive MIMO communication.

TP1a-3**2:20 PM****Impact of Training on Multiple-Antenna Communications in Wireless Ad Hoc Networks**

Yueping Wu, Raymond Louie, Matthew McKay, Hong Kong University of Science and Technology, Hong Kong SAR of China

We investigate the impact of channel estimation error on the transmission capacity of a multiple-input multiple-output singular value decomposition scheme in wireless ad hoc networks. We first investigate the feasible-range of pilot-training lengths which yield a positive transmission capacity. We then prove that the transmission capacity scales linearly with the number of antennas, subject to some mild technical conditions. Finally, we investigate the optimal pilot-training length which maximizes the transmission capacity.

TP1a-4**2:45 PM****Area Spectral and Energy Efficiency in Multi-antenna Cognitive Underlay Networks**

Syed Ali Raza Zaidi, Mounir Ghogho, Desmond C. McLernon, University of Leeds, United Kingdom; Ananthram Swami, US Army Research Laboratory, United States

Growing energy consumption and diminishing bandwidth are two key artefacts of the ever-increasing consumer demand. Cognitive Radios (CRs) are envisioned as key enablers for addressing the spectrum scarcity problem. While spectral efficiency gains provided by CRs are well explored, the energy consumption issue largely remains un-addressed. In this article, we present a comprehensive statistical framework to quantify both the energy and spectral efficiency of a large scale Poisson CR network (CRN). We consider that CRs are furnished with multiple antennas and communicate with their destinations in a multi-hop manner. Spectrum sharing between the legacy and the cognitive user is provisioned by adopting the underlay access mechanism. Considering both the node and the network level dynamics, we explore the design space of MIMO underlay CRNs. More specifically, the available degrees of freedom are identified and their optimal exploitation is presented.

*Track B – MIMO Communications and Signal Processing***Session: TPb1 – Full-Duplex MIMO Communications II**Chair: *Yingbo Hau, University of California, Riverside***TP1b-1****3:30 PM****Diversity-Multiplexing Tradeoff Analysis of MIMO Relay Networks with Full-Duplex Relays**

Qiang Xue, University of Oulu, Finland; Anna Pantelidou, Renesas Mobile Europe, Finland; Behnaam Aazhang, Rice University, United States

A 2-hop MIMO relay network, where the relay can switch between half-duplex (HD) mode and full-duplex (FD) mode is studied. We investigate three practical FD techniques that have attracted a lot of attention recently and analyze their impact on the diversity-multiplexing tradeoff (DMT) of the network. Specifically, we derive the DMT functions of the network under three practical FD techniques applied at the relay. We show that HD may achieve better performance than FD especially at the low multiplexing gain regime. In some cases, HD even achieves strictly better DMT than FD at all regimes. However, there are also other cases, where FD achieves strictly better performance than HD. Generally, if the optimal multiplexing gain that FD achieves is better than that of HD, we observe that FD is always a better choice at the high multiplexing gain regime.

TP1b-2**3:55 PM****Ergodic Mutual Information of Full-Duplex MIMO Radios with Residual Self-Interference**

Ali Cagatay Cirik, University of California, Riverside, United States; Yue Rong, Curtin University, Australia; Yingbo Hua, University of California, Riverside, United States

We study the theoretical performance of a full-duplex multiple-input multiple-output (MIMO) bi-directional communication system. We focus on the effect of the residual self-interference due to channel estimation errors and transmitter impairments. We assume that the instantaneous channel state information (CSI) at the transmitting nodes is not known and the CSI at the receiving nodes is imperfect. To maximize the system ergodic mutual information, which is a non-convex function of power allocation vectors at the nodes, a gradient projection (GP) algorithm is developed to optimize the power allocation vectors. This algorithm exploits both spatial and temporal freedoms of the source covariance matrices of the MIMO links between the nodes to achieve higher sum ergodic mutual information. It is observed through the simulations that the algorithm reduces to a full-duplex scheme when the nominal residual self-interference is low, or to a half-duplex scheme when the nominal residual self-interference is high.

TP1b-3**4:20 PM****Full-Duplex in Large-Scale Wireless Systems**

Bei Yin, Michael Wu, Christoph Studer, Joseph R. Cavallaro, Rice University, United States

The combination of full-duplex wireless communication with large-scale multiple-input multiple-output (MIMO) technology enables the design of a bidirectional wireless communication systems requiring low power consumption and achieving high spectral efficiency. Self interference caused by full-duplex technology, however, necessitates sophisticated interference cancellation schemes, which either require high circuit complexity (if done directly in the analog or radio-frequency domain) or rather expensive (passive) shielding between the antennas. In order to solve the fundamental issue of self-interference cancellation in full-duplex communication systems, we propose two schemes that exploit the excess of antennas present in large-scale MIMO systems. We investigate the associated sum-rate and bit error-rate system performance and show that by carefully selecting the number of transmit and receive antennas, one is able to maximize the system capacity. We further investigate the impact of channel-estimation errors, transmit radio-frequency (RF) impairments, and inter-user interference existed in multi-user scenarios. Our analysis shows that inter-user interference heavily affects the overall system performance, whereas the effects of channel-estimation errors or transmit-RF impairments can be mitigated well by means of passive antenna shielding.

TP1b-4**4:45 PM****Full-Duplex Communication via Adaptive Nulling**

Scott Johnston, Paul Fiore, Massachusetts Institute of Technology, United States

Simultaneous communication in the same frequency band is gaining interest as an approach to increasing spectral efficiency. This functionality is usually prevented by the close proximity of the transmit and receive antennas, resulting in interference at the receiver. In this paper, we develop an uncooperative wide-band MIMO adaptive channel estimation and nulling approach for simultaneous transmit and receive on the same channel. Low-power training waveforms are used to estimate the time-varying MIMO interference channel. Transmit beamforming weights that span the null space of the interference channel are then calculated via an algebraic approach. Results are reported, which show null depths at the receive antennas of greater than 40dB.

TP1b-5**5:10 PM****Weighted-Sum-Rate Maximization for Bi-directional Full-Duplex MIMO Systems**

Ali Cagatay Cirik, University of California, Riverside, United States; Rui Wang, Shanghai Jiao Tong University, China; Yingbo Hua, University of California, Riverside, United States

We consider a full-duplex bi-directional communication system between two nodes that suffer from self-interference, where the nodes are equipped with multiple antennas and instantaneous channel state information (CSI) at the nodes is imperfect. We focus on the effect of the residual self-interference due to channel estimation errors and limited dynamic ranges of the transmitters and receivers. We consider the transmit filter design for Weighted Sum-Rate (WSR) maximization problem subject to total power constraint of the full-duplex system. Based on the relationship between WSR and Weighted Minimum Mean Square Error (WMMSE) problems for bi-directional full-duplex systems, we propose a low complexity alternating algorithm which converges to a local WSR optimum point. This algorithm exploits both spatial and temporal freedoms of the source covariance matrices of the multiple-input multiple-output (MIMO) links between the nodes to achieve higher WSR.

*Track H – Speech, Image and Video Processing***Session: TPa2 – Multimedia Quality Assessment**Chair: *Patrick Le Callet, IRCCyN/Université de Nantes***TP2a-1****1:30 PM****On the Effectiveness of Natural Videos in Masking Dynamic DCT Noise**

Jeremy Evert, Damon Chandler, Oklahoma State University, United States

A fundamental understanding of what makes distortions harder to detect in videos can benefit efforts in video processing. We present the results of a study which extends the work of Watson et al. [J. Electronic Imaging, 2001], to investigate masking of dynamic DCT distortions by eight natural videos. Distortions ranged from 0-60 Hz in temporal frequency and from 2-22.6 c/deg in spatial frequency. Our results revealed that detection thresholds are jointly influenced by the spatiotemporal characteristics of the distortion and by the spatiotemporal characteristics of the video. We discuss the implications of these results for video coding and quality assessment.

TP2a-2

1:55 PM

Investigating Electrophysiology for Measuring Emotions Triggered by Audio Stimuli

Filippo Mazza, IRCCyN, France; Matthieu Perreira Da Silva, Patrick Le Callet, IRCCyN/University of Nantes, France

Multimedia quality evaluation recently started to take into account also analysis of emotional response to audio-visual stimuli, especially for quality of experience evaluation. Self-assessed affective reports are commonly used for this purpose. Nevertheless, measuring emotions via physiological measurement might be also considered as it could limit the effects of cognitive bias due to self-report following the rule that “your body cannot lie”. In this paper we first review in the context of emotion assessment, common physiological measurements such as cardiac and respiratory rhythms, Electroencephalography (EEG) and Galvanic Skin Resistance (GSR); more advanced techniques as infrared thermography or blood perfusion with laser Doppler flowmetry. Then we present some results of electrophysiological measures related to the evaluation of emotions triggered by sounds.

TP2a-3

2:20 PM

Perceptual Evaluation of Image Denoising Algorithms

Kai Zeng, Zhou Wang, University of Waterloo, Canada

Denoising is a fundamental image processing problem that has been widely studied in the past decades. Nevertheless, methods dedicated to evaluate the perceptual quality of denoised images and to compare different denoising algorithms have yet to be developed. In this work, we first build an image database that contains diverse types of images contaminated by different levels of noise and denoised by eight denoising algorithms selected to represent both classical and state-of-the-art denoising algorithms. We then carry out subjective tests to evaluate and compare the quality of the denoised images. Our data analysis not only provides useful information about the relative performance of current image denoising algorithms, but also suggests new insights into the development of effective objective image quality assessment algorithms for denoised images.

TP2a-4

2:45 PM

Coding of 3D Videos based on Visual Discomfort

Dogancan Temel, Ghassan AlRegib, Georgia Institute of Technology, United States

We propose a rate-control algorithm for 3D videos based on visual discomfort. We estimate visual discomfort in the encoded depth maps using three indexes: temporal outliers (TO), temporal inconsistencies (TI), and spatial outliers (SO). These three indexes are used to measure the difference between the processed depth map and the ground truth depth. Moreover, these indexes implicitly depend on the amount of edge information within a frame and on the amount of motion between frames. We test the proposed algorithm on a number of videos and compare the results with the default rate-control algorithm in the H.264/HEVC encoders. We base our comparison on the achieved bit rate and the perceived quality of the synthesized view measured by SSIM and PSNR.

Track A – Communications Systems

Session: TPb2 – PHY Performance Abstraction Techniques

Chair: *Carlos Mosquera, University of Vigo*

TP2b-1

3:30 PM

Stochastic Dynamic Models in PHY Abstraction

Francesc Rey, Josep Sala-Alvarez, Technical University of Catalonia, Spain

Physical Layer (PHY) abstraction aims to model the link performance and accelerate the system-level analysis of communication systems by reducing simulation complexity and its associated computational costs. In this paper, we examine a PHY abstraction approach based on stochastic dynamic system models for easing the requirement of expensive Monte Carlo system-level evaluations. First, we introduce the framework, which has been recently applied in simplified models for successive interference cancellation receivers in the finite and large user limit and then go on to examine some communication systems whose operation can be formulated in terms of stochastic dynamic models and with the objective of evaluating performance measures such as the Packet Error Rate. Our approach is exploratory and example-driven so as to draw conclusions on the standing challenges toward a broader applicability of such methods.

TP2b-2**3:55 PM****On Scalability, Robustness and Accuracy of Physical Layer Abstraction for Large-Scale System Level Evaluations of LTE networks**

Florian Kaltenberger, Imran Latif, Raymond Knopp, Eurecom, France

We present an in-depth performance analysis of the gains of physical layer abstraction when compared to a full implementation of the physical layer. The abstraction model uses either effective SINR mapping or mutual information effective SINR mapping and covers different transmission modes as well as support for hybrid automatic repeat request. Using the OpenAirInterface LTE system level simulator we show that for a simple network with one base station and two user equipments these physical layer abstraction techniques decrease the simulation time by a factor of 30 while providing the same accuracy as with the full PHY implementation.

TP2b-3**4:20 PM****Link Adaptation in MIMO-OFDM with Practical Impairments**

Alberto Rico-Alvarino, University of Vigo, Spain; Robert W. Heath, Jr., University of Texas at Austin, United States

Performing link adaptation in coded multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) systems is challenging due to the difficulty of mapping the channel state information to a frame error rate (FER) value. Moreover, system model imperfections can severely affect the adaptation performance in realistic scenarios. For example, impulsive noise can be generated from electronic devices in indoor environments. Also, the variation of the temperature can affect the non-linearity of power amplifiers, which is very harmful to OFDM systems. Other system-related features, like variable frame size, can severely increase the complexity of link adaptation if non handled properly. In this paper, we study the performance of different FER prediction techniques under these practical impairments, and compare the achieved throughput when used in conjunction with machine learning-based link adaptation algorithms.

TP2b-4**4:45 PM****Digital Pre-distortion of Radio Frequency Front-end Impairments in the Design of Spectrally Agile Multicarrier Transmission**

Zhu Fu, Alexander Wyglinski, Worcester Polytechnic Institute, United States

In this paper, we analyze the impact of Radio Frequency (RF) front-end component impairments of cognitive radio (CR) transceivers on spectrally agile multi-carrier waveform transmission, and then propose a digital pre-distortion (PD) approach to effectively correct associated non-ideal behaviors. Although there has been a substantial amount of research conducted into reduction of OOB radiation caused by multi-carrier signal forming, spectrum regrowth can be reproduced when signal goes through RF front end components, and thus potentially deteriorates liability of DSA network. Our goal is to mitigate out-of-band (OOB) interference produced by RF front-end impairments between primary users (PU) and secondary users (SU) in Dynamic Spectrum Access (DSA) networks. The digital PD algorithm we propose uses indirect learning architecture (ILA) together with least square (LS) estimation for PD system identification. The results show that the proposed algorithm is able to evidently alleviate distortions such as non-linearity and memory effects caused by RF front-end components like power amplifier (PA), which translate to mitigation of OOB leakage in spectrum with non-contiguous multi-carrier modulation (NC-MCM) employed.

TP2b-5**5:10 PM****System-Level Interfaces and Performance Evaluation Methodology for 5G Physical Layer Based on Non-orthogonal Waveforms**

Gerhard Wunder, Martin Kasparick, Fraunhofer Heinrich Hertz Institute, Germany; Stephan ten Brink, Frank Schaich, Thorsten Wild, Bell Labs, Alcatel-Lucent, Germany; Ivan Gaspar, Nicola Michailow, Gerhard Fettweis, Technische Universität Dresden, Germany; Nicolas Cassiau, Commissariat à l'énergie atomique et aux énergies alternatives, France; Marcin Dryjanski, Slawomir Pietrzyk, IS-Wireless, Poland; Bertalan Eged, National Instruments, Hungary

5GNOW is an European collaborative research project questioning the design targets of LTE and LTE-Advanced, in particular the obedience to strict synchronism and orthogonality. Introducing new waveforms, it fosters a re-design of physical and partially MAC layers to support heterogeneous traffic (high rate, sporadic access, carrier aggregation). For system-level performance evaluations of the non-orthogonal waveforms (together with key radio resource management algorithms) an abstract view of physical layer with analytical models going beyond standard OFDM performance evaluation (i.e. dependencies between resource blocks) are needed. A system-level simulation platform is provided addressing, based on the developed abstractions, the trade-off between simulation granularity and speed.

Track D – Signal Processing and Adaptive Systems

Session: TPa3 – New Geometric Models for Processing in Big-Data World

Chair: *Waheed Bajwa, Rutgers University*

TP3a-1 **1:30 PM**

Robust Subspace Clustering

Mahdi Soltanolkotabi, Emmanuel Candes, Stanford University, United States

N/A

TP3a-2 **1:55 PM**

Geometric Estimation of Probability Measures in High-Dimensions

Mauro Maggioni, Duke University, United States

N/A

TP3a-3 **2:20 PM**

Change-point Detection for High-Dimensional Data

Yao Xie, Rebecca Willett, Duke University, United States

N/A

TP3a-4 **2:45 PM**

Image Analysis with Transformation-Invariant Group Sparsity

Alhussein Fawzi, Pascal Frossard, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

N/A

Track D – Signal Processing and Adaptive Systems

Session: TPb3 – Low-Dimensional Signal Models

Chair: *John Wright, Columbia University*

TP3b-1 **3:30 PM**

Nearest Subspace Classification with Missing Data

Yuejie Chi, The Ohio State University, United States

We consider the problem of multi-class classification when there are missing entries in both the training samples and the test samples. A robust version of the nearest subspace classifier is proposed and analyzed to handle missing data. We show the performance of the nearest subspace classifier is close to its counterpart when no missing data are present as long as the probability of observing each entry in the training set is $\delta \gtrsim \mathcal{O}((\log M/n_i)^{1/2})$, where M is the sample dimension and $n_i \gtrsim \mathcal{O}(\log M)$ is the training size. Finally, numerical results are provided for digit recognition when only a subset of the pixels are observed.

TP3b-2 **3:55 PM**

Reflections on Sampling-Filters for Compressive Sensing and Finite-Innovations-Rate Models

P. P Vaidyanathan, California Institute of Technology, United States

This paper revisits sampling-filters for signals having a finite rate of innovations. Such filters arise in many applications including digital communications and compressive sensing, and multichannel versions of these systems have been considered in the past. The main focus of this paper is on sampling-filters that result in perfect reconstruction (PR), or zero-forcing (ZF). Conditions for existence of these filters are expressed both in terms of bandwidth requirement and in the framework of Riesz basis. Many practical advantages induced by the Riesz basis property are also pointed out. When the sampling filters for PR exist, they are in general not unique. Optimum filters that minimize the effect of noise are discussed and compared with energy compaction filters, which in general are not optimal.

TP3b-3**4:20 PM****Identifiability Bounds for Bilinear Inverse Problems**

Sunav Choudhary, Urbashi Mitra, University of Southern California, United States

A number of important inverse problems in signal processing, including blind deconvolution, dictionary learning and matrix factorization, are instances of bilinear inverse problems. This paper shows that bilinear inverse problems are identifiable with probability close to one for random inputs provided that the number of rank-2 matrices in the null space grows as $o(mn)$ for key applications.

TP3b-4**4:45 PM****Load Forecasting via Low Rank and Sparse Matrix Factorization**

Seung-Jun Kim, Georgios B. Giannakis, University of Minnesota, United States

A key aspect of the smart power grid under active research and development is to incorporate pervasive sensing, communication, and control capabilities to make the grid more efficient, reliable, and sustainable. Major computational intelligence is thus required to solve associated big data analytics problems. In this work, load forecasting is studied, which is an important prerequisite for various smart grid management tasks, including demand response. Departing from conventional load forecasting setups, the goal here is to obtain a fine-grained characterization of energy consumption, even to the different types of loads due to different consumers, by capturing their preferences and decision patterns. Inspired by recent advances in compressive sensing and recommender systems, a joint low-rank and sparse matrix factorization model is put forth, where the low rank component captures the global trend, while the sparse matrix factors target locally clustered patterns.

TP3b-5**5:10 PM****Semi-Blind Source Separation via Sparse Representations and Online Dictionary Learning**

Sirisha Rambhatla, Jarvis Haupt, University of Minnesota, United States

This work examines a semi-blind single-channel source separation problem. Our specific aim is to separate one source whose local structure is approximately known, from another a priori unspecified background source, given only a single linear combination of the two sources. We propose a separation technique based on local sparse approximations along the lines of recent efforts in sparse representations and dictionary learning. A key feature of our procedure is the online learning of dictionaries (using only the data itself) to sparsely model the background source, which facilitates its separation from the partially-known source. Our approach is applicable to source separation problems in various application domains; here, we demonstrate the performance of our proposed approach via simulation on a stylized audio source separation task.

*Track C – Networks***Session: TPa4 – Power Networks**Chair: *Edmund Yeh, Northeastern University***TP4a-1****1:30 PM****Convex Relaxation for Optimal Power Flow Problem: Mesh Networks**

Ramtin Madani, Columbia University, United States; Somayeh Sojoudi, California Institute of Technology, United States; Javad Lavaei, Columbia University, United States

This paper is concerned with a fundamental resource allocation problem for electrical power networks. This problem, named optimal power flow (OPF), is nonconvex due to the nonlinearities imposed by the laws of physics, and has been studied since 1962. We have recently shown that a convex relaxation based on semidefinite programming (SDP) is able to find a global solution of OPF for IEEE benchmark systems, and moreover this technique is guaranteed to work over acyclic (distribution) networks. This work studies the potential of the SDP relaxation for OPF over cyclic (transmission) networks. Given an arbitrary weakly-cyclic network, it is shown that the injection region is convex in the lossless case and that the Pareto front of the injection region is convex in the lossy case. Second, it is proved that the SDP relaxation is exact for this type of network. Moreover, it is shown that if the SDP relaxation is not exact, it still has a low rank solution whose rank depends on the structure of the network. Finally, a heuristic method is proposed to recover a rank-1 solution for the SDP relaxation whenever the relaxation is not exact.

TP4a-2**1:55 PM****Nonstationary Demand-Side Management**

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

In future smart grids, demand-side management is a key technology aimed at shaping the electricity usage patterns of households. Most existing works study demand-side management within a one-day time horizon, and aim to induce a desirable one-day electricity usage pattern that is repeated everyday, such that the one-day social welfare (or payment) is maximized (or

minimized). We call such demand-side management schemes stationary. However, since the households use electricity for a long period of time, each household may want to optimize its long-term discounted sum utility, and adopt different electricity usage patterns across different days. Nonstationary usage patterns may be more desirable in terms of long-term total electricity payments or social welfare, when there are negative externalities among the households. In this paper, we derive analytical conditions on the pricing and utility functions under which nonstationary electricity usage patterns outperform stationary usage patterns. We build a unified design framework for nonstationary demand-side management. Despite the analysis of such schemes being very challenging, we are able to develop a low-complexity algorithm that can be run by each household in a decentralized fashion to determine its optimal nonstationary electricity usage pattern. Our results can be extended to the cases in which the households have imperfect pricing information and discount future utilities differently.

TP4a-3

2:20 PM

Framing Attack on State Estimation

Jinsub Kim, Lang Tong, Robert J. Thomas, Cornell University, United States

Framing attack is a new strategy aimed at misleading the control center that certain normally operating meters are responsible of generating bad data. As part of the bad data removal procedure, the data from these meters are removed from system state estimation, causing performance degradation and, in some instances, making an observable system unobservable. The optimal design of framing attack is formulated as a quadratically constrained quadratic program (QCQP). It is shown that the adversary needs to modify only half of the critical set of measurements to make the power system unobservable. Implications of this attack on power system operations are discussed and the attack performance is evaluated using benchmark systems.

TP4a-4

2:45 PM

Power System Dynamics as Primal-Dual Algorithm for Optimal Load Control

Changhong Zhao, California Institute of Technology, United States; Ufuk Topcu, University of Pennsylvania, United States; Lina Li, Steven Low, California Institute of Technology, United States

We formulate an optimal load control (OLC) problem in power networks, where the objective is to minimize the aggregate disutility of tracking an operating point subject to power balance over the network. We prove that the swing dynamics and the branch power flows, coupled with frequency-based load control, serve as a distributed primal-dual algorithm to solve OLC. Even though the system has multiple equilibrium points, we prove that it nonetheless converges to an optimal point. This result implies that the local frequency deviations at each bus convey exactly the right information about the global power imbalance for the loads to make individual decisions that turn out to be globally optimal. It allows a completely decentralized solution without the need for explicit communication among the buses. Simulations show that the proposed OLC mechanism can resynchronize bus frequencies with significantly improved transient performance.

Track C – Networks

Session: TPb4 – Location-Aware Networking

Chair: *Henk Wymeersch, Chalmers University*

TP4b-1

3:30 PM

Robust Link Scheduling with Channel Estimation and Location Information

Srikar Muppirisetty, Rocco Di Taranto, Henk Wymeersch, Chalmers University of Technology, Sweden

We study the robust link scheduling problem (RLSP) based on a physical interference model with errors in channel state information. The objective of RLSP is to find a robust minimum length schedule using spatial time division multiple access. We compare two approaches to RLSP, one using channel gain estimates and the other using location information. In both cases, we formulate the RLSP as a binary integer program and solve it by a classical column generation technique. Our comparison reveals that both approaches yield similar performances, but with different overhead.

TP4b-2

3:55 PM

Simultaneous Routing and Power Allocation using Location Information

Rocco Di Taranto, Henk Wymeersch, Chalmers University of Technology, Sweden

To guarantee optimal performance of wireless networks, simultaneous optimization of routing and resource allocation is needed. Optimal routing of data depends on the link capacities which, in turn, are determined by the allocation of communication resources to the links. Simultaneous routing and resource allocation (SRRA) problems have been studied under the assumption that (global) channel state information (CSI) is collected at a central node. This is a drawback as SRRA depend on channels between all pairs of nodes in the network, thus leading to poor scalability of the CSI-based approach. In this paper, we first investigate to what extent it is possible to rely solely on location information (i.e., position of nodes) when solving the SRRA problem. We propose a heuristic based on which nodes can adjust their rate (obtained by solving the SRRA problem using

location information) by locally estimating the CSI with respect to their neighbors (i.e., nodes in the network with an active link toward them). Our numerical results show that the proposed heuristic achieves near-optimal flow in the network under different shadowing conditions.

TP4b-3

4:20 PM

Location Aware Training Scheme for D2D Networks

Daoud Burghal, Andreas F. Molisch, University of Southern California, United States

We consider the problem of acquiring channel state information (CSI) in base-station (BS) controlled Device To Device (D2D) networks. Obtaining high-quality CSI requires a trade-off between interference, outdatedness of CSI, and noise. We present the Location Aware Training Scheme (LATS) as simple yet efficient training technique. In the proposed scheme, the BS utilizes the location information about the devices to group devices into training sets and schedule the transmission of the training sequences accordingly. To define the clusters we use the Mean Square Error (MSE) as a metric that combines the outdatedness, noise, and interference, and solve an optimization problem over two variables numerically. Simulations shows that LATS significantly outperforms other schemes.

TP4b-4

4:45 PM

Cooperative High-Accuracy Localization Algorithms for Improved Road Workers' Safety

Sankalp Dayal, Khanh H. Huynh, Adam Mortazavi, University of California, Santa Barbara, United States; Ramez L. Gerges, California Department of Transportation, United States; John J. Shynk, University of California, Santa Barbara, United States

This paper describes high-accuracy localization algorithms to improve the safety of highway workers and the driving public approaching work-zone lanes in urban and rural settings. The proposed system involves two different cooperative subsystems. The first subsystem concerns a wireless sensor network of smart cones which includes a centralized master node, and are used in work zones to control traffic flow and protect construction workers. The second subsystem considers the localization of vehicles at normal highway speeds using cooperative techniques only between "connected vehicles" that form an ad hoc network, and without any fixed road-side nodes. The two subsystems are integrated such that the low-mobility smart cone network will detect a vehicle intruding on a work zone and will alert the working crew, and in turn the master node will alert high-mobility vehicles approaching a specific lane. The two subsystems use different localization techniques because the communication signals encounter different types of impairments, since vehicles and nodes have different mobility. The localization algorithms also use different sets of sensor data from the cones and vehicles. The algorithms for low-mobility nodes (cones and workers) require decimeter accuracy, while lane-level sub-meter accuracy is needed for high-mobility vehicles. From these high-accuracy localization results, it is possible to detect vehicle lane changes and any sudden movement of smart cones.

TP4b-5

5:10 PM

Real-Time Energy Storage Management with Renewable Energy of Arbitrary Generation Dynamics

Tianyi Li, Min Dong, University of Ontario Institute of Technology, Canada

We design a real-time control policy for energy storage management with renewable energy integration, where the renewable energy has arbitrary sample path statistics and may be non-ergodic over time. We formulate the control optimization problem to minimize the cost over a finite time horizon. By relaxation and reformulation, we apply the Lyapunov optimization technique to design the real-time control algorithm that jointly optimizes the decisions for storage from two energy sources and supply to the consumer. We bound the performance of the proposed algorithm to that under the optimal non-causal T-slot lookahead control policy. We provide a close-form solution to our control optimization which renders our policy implementation with minimum complexity.

TP5a-1

1:30 PM

Predicting Responsiveness of Ovarian Cancer Patients to Platinum Chemotherapy Using Differentially Weighted Lone Star Algorithm

Eren Ahsen, Burook Misganaw, Nitin Singh, Mathukumalli Vidyasagar, University of Texas at Dallas, United States; Michael White, University of Texas Southwestern Medical Center, United States

Ovarian cancer afflicts roughly 22,000 American women per year, and results in roughly 15,500 deaths per year. The standard (or “front line”) therapy is to administer taxane plus cisplatin, that is, a cytotoxic drug and platinum. About 10% of women do not respond at all or respond poorly, while at the other end, about 10% of women respond extremely well, enjoying relapse-free survival of three years or more. In earlier work, the authors had used the so-called “lone star” algorithm invented by them to identify a small panel of indicative genes to predict whether a patient is a normal responder, a super-responder, or a non-responder, to platinum chemotherapy. In this paper, we modify the lone star algorithm to “favor” a prespecified set of genes, which according to the literature may play a role in the onset and/or progress of ovarian cancer, and see whether any of these genes actually have a role in determining the responsiveness of patients. Preliminary indications suggest that the answer is “no” -- responsiveness to platinum chemotherapy depends on previously unsuspected sets of genes.

TP5a-2

1:55 PM

Classifier Risk Analysis under Bayesian Uncertainty Models

Lori Dalton, The Ohio State University, United States

There are a number of important small-sample phenotype discrimination problems in biomedicine, typically based on classifying between types of pathology, stages of disease, response to treatment or survivability. In contrast to the usual heuristic classifier and error estimation rules, recent work proposes a Bayesian modeling framework over an uncertainty class of feature-label distributions, which when combined with data facilitates optimal MMSE error estimation, optimal classifier design and sample-conditioned MSE error estimation analysis, all relative to the true classification error. Here, we extend Bayesian classifier learning theory beyond simple classification error to a risk based analysis more suitable for medical applications.

TP5a-3

2:20 PM

Reconstruction of Novel Transcription Factor Regulons through Inference of their Binding Sites

Abdulkadir Elmas, Xiaodong Wang, Columbia University, United States; Michael Samoilov, University of California, United States

In most sequenced organisms the number of known regulatory genes (e.g., transcription factors (TFs)) vastly exceeds the number of experimentally-verified regulons which could be associated with them. At present, identification of TF regulons is mostly done through comparative genomics approaches. The nature of such methods causes them to frequently miss organism-specific regulatory interactions and often requires expensive and time-consuming experimental techniques to generate the underlying data. One approach to computationally addressing these problems is through discovery of transcription factor binding sites (TFBSs) and inference of corresponding regulons based on the location of such motifs across the genome. In this work, we present an efficient algorithm that aims to identify a given transcription factor’s regulon through inference of its unknown binding sites, based on the discovery of its binding motif, which is also unknown and is estimated within the algorithm framework. The proposed approach relies on computational methods that utilize microarray gene expression data sets and fitness data sets which are available or may be straightforwardly obtained for many organisms. We computationally constructed the profiles of putative regulons for the TFs LexA and PurR in *E. coli* K12 and identified their binding motifs. Comparisons with an experimentally-verified database showed high recovery rates of the known regulon members (93% recovery for LexA regulon), and indicated good predictions for the newly found regulon genes with high biological significances. The results also show that the algorithm can predict genome-wide transcription factor binding motifs, which display high homology to their known consensus binding sites. The proposed approach is also applicable to novel organisms for predicting unknown regulons of the transcriptional regulators.

TP5a-4**2:45 PM****Sample-Based Prior Construction Using Biological Pathway Knowledge**

Mohammad Shahrokh Esfahani, Edward R. Dougherty, Texas A&M University, United States

Phenotype classification using high-throughput biological data such as gene/protein expression face the ubiquitous problem of very high dimension and small samples, a consequence of which is that it is usually impossible to obtain validated models via distribution-free methods. Bayesian frameworks, despite their rigorous statistical foundations, face the difficulty of determining a prior distribution consistent with prior knowledge. Utilizing prior knowledge in the form of biological pathways, we propose an optimization paradigm for prior-distribution construction for phenotype classification utilizing information from biological pathways. The proposed paradigm, called regularized expected mean log-likelihood (REML), builds the prior-expected mean log-likelihood function (using a small number of feature-label sample points) and then regularizes it with slackness variables bounding conditional entropy functions induced by the dependencies demonstrated in the pathways. With a Normal-Wishart prior distribution on the mean and inverse covariance matrix (precision matrix) of a Gaussian distribution, these optimization problems become convex.

*Track F – Biomedical Signal and Image Processing***Session: TPb5 – Analysis of Complex Biological Systems and Omics Data II**Chair: *Byung-Jun Yoon, Texas A&M University***TP5b-1****3:30 PM****Characterizing Functions in Uncertain Signaling Network Topologies**

Haitham Gabr, Tamer Kahveci, University of Florida, United States

Extracellular molecules trigger a response inside the cell by initiating a signal at special membrane receptors which is then transmitted to reporters through various chains of interactions among proteins. Interactions are uncertain events that may or may not take place. In this study, we describe a novel strategy to characterize the possible spectrum of functions a signaling network can serve in the presence of uncertain interactions. We demonstrate the usefulness strategy at various granularities of functional analysis of signaling networks. First, we measure the centrality of individual proteins. Second, we quantify the robustness of the entire network. Finally, we compute the functions that are most likely to be served by the underlying network.

TP5b-2**3:55 PM****Statistical Validation of Parametric Approximations to the Chemical Master Equation**

Garrett Jenkinson, John Goutsias, The Johns Hopkins University, United States

A number of analytical and Monte Carlo sampling algorithms have been proposed to provide approximate solutions to the master equation. Unfortunately, these algorithms usually require a well-chosen parameter set to maintain accuracy and computational efficiency. We have recently developed a rigorous statistical hypothesis-testing framework that is capable of determining the validity of a given approximation method with a specified choice of parameters. In this paper, we extend this technique to address the “multiple-testing” problem where an array of parameter values is tested simultaneously. This allows for effective tuning of approximation algorithms and for an empirical study of the range of validity of a given approximation method.

TP5b-3**4:20 PM****Objective-Based Experimental Design for Optimal Reduction of Model Uncertainty**

Byung-Jun Yoon, Texas A&M University, United States

In this work, we propose a novel method for designing optimal experiments that can effectively reduce the uncertainty present in a complex dynamical model. Many real-world problems require handling complex systems that cannot be perfectly modeled due to various factors, including complexity and randomness. A typical engineering solution involves constructing a mathematical model based on the available training data and building optimal operators based on this model. Naturally, the performance of the resulting operator depends on the quality of the estimated model, which again depends on the available data. Suppose we want to perform additional experiments to obtain more data with the goal of improving the model. How should we design these experiments in order to reduce the model uncertainty and improve the operator performance in a most effective manner? To address this question, we adopt a recently proposed objective-based uncertainty quantification (UQ) framework and show how it can be used to design experiments that can optimally reduce the operational cost that arises from model uncertainty.

TP5b-4

4:45 PM

A Message-Passing Algorithm for Haplotype Assembly

Zrinka Puljiz, Haris Vikalo, University of Texas at Austin, United States

A haplotype is an ordered sequence of single nucleotide polymorphisms on a pair of chromosomes that vary from one individual to another. The haplotype of a single individual can be inferred using overlapping DNA fragments provided by high-throughput sequencing platforms. These fragments are short and the information about them potentially erroneous, which renders the haplotype inference challenging. We consider a binary formulation of the haplotype inference problem and propose a message-passing scheme for solving it. The proposed solution is fast and scalable, and compares favorably with state-of-the-art methods.

Track E – Array Signal Processing

Session: TPa6 – MIMO Radar

Co-Chairs: *Jian Li, University of Florida and Dan Bliss, Arizona State University*

TP6a-1

1:30 PM

Ziv-Zaikai Bound for Target Location and Velocity Estimation using Noncoherent MIMO Radar

Vlad Chiriac, New Jersey Institute of Technology, United States; Qian He, University of Electronic Science and Technology of China, China; Alexandra Haimovich, New Jersey Institute of Technology, United States; Rick Blum, University of Electronic Science and Technology of China, United States

Bayesian bounds incorporate prior knowledge on parameters of interest, and can provide a tighter prediction of the performance of estimators than non-Bayesian bounds, such as the Cramer-Rao bound (CRB), especially under low signal-to-noise ratio (SNR) conditions. In this paper, we derive the ZivZakai bound (ZZB) for joint location and velocity estimation for noncoherent, multiple-input multiple-output (MIMO) radar. We show that the ZZB is a comprehensive metric that captures the effect of the SNR and the auto- and cross- ambiguity functions of the waveforms used by the radar. The ZZB is shown to display three SNR operating regions, namely the noise, ambiguity, and asymptotic regions. The effects of different waveforms and system configurations are explored through numerical studies.

TP6a-2

1:55 PM

Parametric Moving Target Detection with MIMO Radar in Non-Homogeneous Environments

Pu Wang, Hongbin Li, Stevens Institute of Technology, United States; Braham Himed, Air Force Research Laboratory / RYMD, United States

Moving target detection (MTD) with distributed multi-input multi-output (MIMO) radars in non-homogeneous environments is considered, where the disturbance signal (clutter and noise) exhibits non-homogeneity in not only power but also covariance structure from one transmit-receive (TX-RX) antenna pair to another as well as across different test cells. We propose a parametric approach by employing a set of distinctive auto-regressive (AR) models, one for each TX-RX pair, to model the non-homogeneous disturbance signals, and develop a parametric generalized likelihood ratio test (PGLRT). The underlying parameter estimation problem, along with the Cramer-Rao bound, is examined to shed additional light to the problem.

TP6a-3

2:20 PM

The MIMO radar MIRA-CLE Ka

Jens Klare, Fraunhofer FHR, Germany

This paper focuses on the co-located MIMO radar MIRA-CLE Ka which is a highly flexible radar working in Ka band. MIRA-CLE Ka consists of 16 transmitters and 16 receivers that are organized in a minimum redundant way. Currently, the TX elements are activated subsequently while always four RX elements receive the reflected signals at the same time. In the next development stage, MIRA-CLE Ka will be able to transmit and receive with more elements at the same time using waveform diversity and frequency diversity. The system can be used for diverse applications like imaging, change detection, and 3D MIMO SAR. This paper analyzes the multi-dimensional ambiguity function for different modes and compares the theoretical achievable image quality with field measurements.

TP6a-4**2:45 PM****Joint Estimation of Non-Coherent Returns for MIMO Radar**

William Rowe, Ode Ojowu, University of Florida, United States; Petre Stoica, Uppsala University, Sweden; Jian Li, University of Florida, United States

In active sensing applications such as radar, the echo signal power is proportional to the target radar cross section (RCS). The RCS is a function of aspect angle and wavelength. When spatial diversity or frequency diversity are utilized then non-coherent signal integration must be performed in multiple-input, multiple-output radar applications. If a target is present, the target's RCS should occur in groups for the corresponding delay and Doppler bins. The traditional method is to estimate the RCS independently for each bin and then non-coherently add the signal power together which provides non-ideal noise suppression. In this work we present Group Iterative Adaptive Approach to jointly estimate the average RCS from multiple non-coherent returns. We examine the performance using numerical simulations.

*Track E – Array Signal Processing***Session: TPb6 – Target Tracking I**

Chair: *Peter Willett, University of Connecticut*

TP6b-1**3:30 PM****Track State Augmentation for Feature-Aided Active Sonar Tracking**

Evan Hanusa, David Krout, University of Washington, United States

This work explores the effects of including features in a JPDA-based tracker. The primary focus will be the augmentation of the state vector with several features and including them in the calculation of the JPDA association weights. A state augmentation approach can also be used to affect the gating process in order to control the ingestion of false contacts to the tracking algorithm. The effects on target state vector augmentation will be explored in the context of multistatic active target tracking.

TP6b-2**3:55 PM****Hypothesis Structure in Enhanced Multiple-Hypothesis Tracking**

Stefano Coraluppi, Craig Carthel, Compunetix Inc., United States

Multiple-hypothesis tracking (MHT) is a powerful approach to multi-target tracking (MTT). A well-known challenge with this approach is the need for efficient hypotheses management [1]. Lesser-known issues include: (1) the sub-optimality of the maximum a posteriori (MAP) criterion with respect to target tracking metrics [2]; (2) the sub-optimality (and potential degeneracy) in the usual decoupling of data-association and track-extraction functions; and (3) the sub-optimality of neglecting undetected target births [3-4]. This paper examines these issues and provides structural results that enable an efficient, enhanced MHT approach to address (3) that does not increase the number of relevant track hypotheses with respect to classical MHT. We provide simulation results that show improved tracking performance with respect to the MAP criterion and relevant MTT metrics. Finally, we propose an approach to performance evaluation that will enable a principled comparison to label-free trackers (see [5] and references therein). [1] S. Blackman and R. Popoli, *Design and Analysis of Modern Tracking Systems*, Artech House, 1999. [2] Braca, M. Guerriero, S. Marano, V. Matta, and P. Willett, *Selective Measurement Transmission in Distributed Estimation with Data Association*, in *IEEE Transactions on Signal Processing*, vol. 58(8), August 2010. [3] S. Coraluppi and C. Carthel, *Optimality and Ghosting Phenomena in Multi-Target Tracking*, in *Proceedings of the 15th International Conference on Information Fusion*, Singapore, July 2012. [4] S. Coraluppi and C. Carthel, *Undetected Target Births in Multiple-Hypothesis Tracking*, submitted to the *16th International Conference on Information Fusion*, Istanbul, Turkey, July 2013. [5] O. Erdinc, P. Willett, and Y. Bar-Shalom, *The Bin-Occupancy Filter and Its Connection to the PHD Filters*, *IEEE Transactions on Signal Processing*, vol. 57(11), November 2009.

TP6b-3**4:20 PM****The Spline Probability Hypothesis Density Filter for Maneuvering Target Tracking**

Rajiv Sithravel, Xin Chen, Thia Kirubarajan, McMaster University, Canada; Mike McDonald, Defence Research and Development Canada, Canada

The Probability Hypothesis Density (PHD) filter is an efficient algorithm for multitarget tracking in the presence of nonlinearities and/or non-Gaussian noise. The Sequential Monte Carlo (SMC) and Gaussian-Mixture (GM) techniques are commonly used to implement the PHD filter. Recently, a new implementation of the PHD filter using B-splines with the capability to model any arbitrary density functions using only a few knots was proposed. The Spline PHD (SPHD) filter was found to be more robust than the SMC-PHD filter since it does not suffer from degeneracy and it was better than the GM-PHD implementation in terms of accuracy. In this paper, we propose a Multiple Model (MM) extension to the SPHD filter to track multiple maneuvering. Simulations results are presented to demonstrate the effectiveness of the new filter.

TP6b-4**4:45 PM****Performance Analysis of the Converted Range Rate and Position Linear Kalman Filter**

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

In active sonar and radar applications measurements consist of range, bearing and often range rate - all nonlinear functions of the target state (usually modeled in Cartesian coordinates). The converted measurement Kalman filter (CMFK) first converts the range and bearing measurements into Cartesian coordinates to allow for the use of a linear Kalman filter. The extension of the CMKF to use range rate as a linear measurement however has been limited to cases with small bearing errors. The use of range rate as a nonlinear measurement requires the use of a nonlinear filter such as the extended Kalman filter (EKF). Due to the poor performance of the EKF, various modifications have been proposed, including use of a pseudo measurement, an alternative linearization of the measurement prediction function, and sequentially processing the converted position and range rate measurements (applied to the EKF and the Unscented Kalman Filter). Common to these approaches is that the measurement prediction function remains nonlinear. A measurement conversion from range, bearing and range rate to Cartesian position and velocity has recently been proposed [original 2012 Asilomar paper]. This manuscript expands the evaluation of the new approach by comparing to the EKF, the Sequential UKF and the posterior Cramer-Rao lower bound (PCRLB). The new method is shown to have improved mean square error performance and exhibits improved constancy over the previously proposed methods, especially in cases with poor bearing accuracy.

TP6b-5**5:10 PM****MAP-PF Multitarget Tracking with Propagation Modeling Uncertainties**

Kristine Bell, Robert Zarnich, Metron, United States

We consider the problem of multi-target tracking using the Maximum a Posteriori Penalty Function (MAP-PF) technique under propagation modeling uncertainties. We assume that the propagation model, which describes how the target state is perceived at the sensor, is a function of one or more parameters that are not known exactly, but are characterized statistically by a probability distribution. Under this model, the penalty function in the standard MAP-PF tracker becomes a robust penalty function (RPF), averaged over the propagation parameter distribution. Performance is demonstrated on a simulated underwater acoustic scenario with uncertainty in sound speed.

*Track G – Architecture and Implementation***Session: TPa7 – Algorithm/Architecture Co-design**Chair: *Gunar Schirner, Northeastern University***TP7a-1****1:30 PM****Using Stream Rewriting for Mapping and Scheduling Data Flow Graphs onto Many-Core Architectures**

Christian Haubelt, Lars Middendorf, Christian Zebelein, University of Rostock, Germany

Data flow graphs, consisting of actors and communication channels, provide a high-level model of multimedia applications on many-core architectures. However, in case of varying and unpredictable workloads, a static mapping is often infeasible but a dynamic approach becomes challenging due to the numerous amount of tasks. Our concept of stream-rewriting represent a novel execution semantics for data flow graphs on many-core architectures, which describes actor states as a token stream and transitions as rewriting rules. We present a distributed scheduling mechanism, global resource sharing and lightweight lock-free synchronization based on pattern matching. Moreover, an optimized architecture for stream-rewriting is prototyped and evaluated.

TP7a-2**1:55 PM****A System-Level Design Approach for Dynamic Resource Coordination and Energy Optimization in Sensor Network Platforms**

Inkeun Cho, Chung-Ching Shen, University of Maryland at College Park, United States; Jonathan McGee, Laboratory for Physical Sciences, United States; Shuvra Bhattacharyya, University of Maryland at College Park, United States

Wireless sensor network (WSN) application software needs to be co-designed carefully with optimized methods for dynamic resource coordination and utilization of power-aware processing modes. In this paper, we present a system-level design method for WSN applications to address this problem. Our method is based on a new application modeling approach using interrupt-driven parameterized synchronous dataflow (PSDF) graphs. We demonstrate our new PSDF-based design method

by implementing an application subsystem for distributed speech recognition on a state-of-the-art sensor node platform. Experimental results using this demonstration system show how our proposed techniques can effectively optimize energy consumption and buffer management.

TP7a-3

2:20 PM

Architecture/Algorithm Codesign in Molecular Dynamics Processors

Martin Herbordt, Boston University, United States; Md. Ashfaquzzaman Khan, Intel, United States

Molecular Dynamics is unique in High Performance Computing in that it is both sufficiently critical and not well-enough served by off-the-shelf processors that it has been continually targeted with domain-specific architectures. These range from the common, i.e., use of accelerators, to FPGA-centric servers, to full-scale ASIC-based systems (e.g., the Anton processor). The strict constraints on achieving strong scaling lead to novel designs, which in turn suggest restructurings of the underlying algorithms. We discuss the technological issues involved, the implications of various approaches on architecture/algorithm codesign, and how these are likely to affect future high-end processors, both domain-specific and off-the-shelf.

TP7a-4

2:45 PM

Flexible Function-Level Acceleration of Embedded Vision Applications using the Pipelined Vision Processor

Robert Bushey, Analog Devices Inc., United States

Embedded computer vision is a very hot topic driven largely by the automotive advanced driver assistance and industrial IP camera markets. Vision demands computationally intense real-time safety critical processing for object detection, object classification/tracking, and object verification. These applications present challenging constraints and features including low power consumption (<1W), very high DSP performance (many billions of pixel operations per second), pixel pipeline enabled low memory bandwidth, and low cost thermal efficient packaging. This paper discusses algorithm and architecture co-development aspects underlying Analog Devices' BF609 video and vision digital signal processing SoC including its Pipelined Vision Processor. The BF609, implemented in TSMC's 65nm low power process, computes >25GOPS of vision and video analytics processing while consuming <100mW.

Track D – Signal Processing and Adaptive Systems

Session: TPb7 – Machine Learning and Statistical Signal Processing II

Chair: *Yao Xie, Georgia Institute of Technology*

TP7b-1

3:30 PM

Forward/Back State and Model Parameter Estimation for Continuum-State Hidden Markov Models (CHMM) with Dirichlet State Distributions

Todd K. Moon, Jacob H Gunther, Utah State University, United States

In this paper, the foundations of the theory of the continuum state HMM (cHMM) are extended to include a forward/ backward algorithm producing probability densities analogous to those in conventional HMMs, and algorithms for estimating the parameters of the state transition density and the constituent output densities. The π and λ densities are approximated as Dirichlet distributions, providing for nearly closed form, "closed" operations. The EM algorithm is extended to apply to the parameter estimation problem.

TP7b-2

3:55 PM

Low-Rank Kernel Learning for Electricity Market Inference

Vassilis Kekatos, Yu Zhang, Georgios B. Giannakis, University of Minnesota, United States

Recognizing the importance of smart grid data analytics, modern statistical learning tools are applied here to whole-sale electricity market inference. Market clearing congestion patterns are uniquely modeled as rank-one components in the matrix of spatiotemporally correlated prices. Upon postulating a low-rank matrix factorization, kernels across pricing nodes and hours are systematically selected via a novel methodology. To process the high-dimensional market data involved, a block-coordinate descent algorithm is developed by generalizing block-sparse vector recovery results to the matrix case. Preliminary numerical tests on real data corroborate the prediction merits of the developed approach.

TP7b-3

4:20 PM

Hierarchical Clustering Methods and Algorithms for Asymmetric Networks

Gunnar Carlsson, Stanford University, United States; Facundo Mémoli, University of Adelaide, Australia; Alejandro Ribeiro, Santiago Segarra, University of Pennsylvania, United States

Three different families of hierarchical clustering methods satisfying the axioms of value – in a network with two nodes the nodes cluster together at resolutions at which both can influence each other – and transformation – when we reduce some pairwise dissimilarities and increase none, the resolutions at which nodes cluster together may decrease but not increase – are introduced. The grafting family exchanges branches between dendrograms generated by different admissible methods. The convex combination family combines admissible methods using a convex operation in the space of dendrograms. The semi-reciprocal family is related to the reciprocal and nonreciprocal clustering methods introduced in previous literature. Algorithms for the computation of hierarchical clusters generated by reciprocal and nonreciprocal clustering as well as the grafting, convex combination, and semi-reciprocal families are derived using matrix operations in a dioid algebra.

TP7b-4

4:45 PM

Maximum Likelihood SNR Estimation over Time-Varying Flat-Fading SIMO Channels

Faouzi Bellili, Rabii Meftahi, Sofiène Affes, Institut National de la Recherche Scientifique, Canada

In this paper, we propose a new signal-to-noise-ratio (SNR) maximum likelihood (ML) estimator over time-varying single-input multiple-output (SIMO) channels, for both data-aided (DA) and non-data-aided (NDA) cases. Unlike the classical techniques which assume the channel to be slowly time-varying, and therefore considered as constant during the observation period, we address the more challenging problem of instantaneous SNR estimation over fast time-varying channels. The channel variations are locally tracked using a polynomial-in-time expansion. In the DA scenario, the ML estimator is developed in closed-form expression. In the NDA scenario, however, the ML estimates of the per-antenna SNRs are obtained iteratively, with very few iterations, using the expectation-maximization (EM) procedure. Our estimator is able to accurately estimate the instantaneous SNRs over a wide range of average SNR. We show through extensive Monte-Carlo simulations that the new estimator outperforms previously developed solutions.

TP7b-5

5:10 PM

Achieving Complete Learning in Multi-Armed Bandit Problems

Sattar Vakili, Qing Zhao, University of California, Davis, United States

In the classic Multi-Armed Bandit (MAB) problem, there is a given set of arms with unknown reward distributions. At each time, a player selects one arm to play, aiming to maximize the total expected reward over a horizon of length T . The so called regret has a logarithmic order with time for this problem. Also it is known that when one knows the value of the largest reward mean and the difference between the largest and second largest reward mean, a regret uniformly bounded over time is achievable. In this paper we show that if only a value ϵ between the largest and second largest reward mean is known, the uniformly bounded regret over time can be achieved (thus achieving complete learning). The reward distributions on arms can be any set of light-tailed distributions or heavy-tailed distributions with p th moment ($p > 1$).

Track A – Communications Systems

Session: TPa8 – Spectrum Sensing and Sharing

1:30 PM–3:10 PM

Chair: *Geert Leus, Delft University of Technology (TU Delft)*

TP8a1-1

Cognitive Coexistence: A Throughput Study of MUD-Enhanced Opportunistic Spectrum Access

Rachel Learned, Scott Johnston, Massachusetts Institute of Technology, United States

A new dynamic spectrum access paradigm for enabling heterogeneous wireless networks of primary and secondary users to coexist on the same frequency in the same geographic location is proposed and evaluated. In this new paradigm secondary nodes operate without overt coordination with primary nodes. Instead, the secondary nodes monitor their local environment and their effect upon it to determine acceptable channels for coexistence. Combining the proposed cognitive coexistence paradigm with multiuser detection in some or all of the secondary nodes enables high rate links in the presence of even the most severe primary interference. The result is a backward compatible coexistence of primary and secondary nodes with high throughput for both networks.

TP8a1-2

Throughput Maximization in Multichannel Cognitive Radio Systems with Delay Constraints

Ahmed Ewaisha, Cihan Tepedelenlioglu, Arizona State University, United States

We study the throughput-vs-delay trade-off in a multichannel cognitive radio system. Due to the limited sensing capabilities of the cognitive radio user, channels are sensed sequentially. Maximizing the throughput in such a problem is well-studied in the literature. In real-time applications, we may have hard delay constraints. Thus, we propose an optimization problem that maximizes the secondary user's throughput, such that the delay does not exceed a pre-specified upper bound. We provide a closed-form expression to the optimal solution of this problem. Simulation results show that this solution allows the secondary user to meet the delay constraint without sacrificing throughput significantly.

TP8a1-3

Joint Random Beam and Spectrum Selection for Spectrum Selection with Partial Channel State Information

Mohamed Abdallah, Mostafa Sayed, Texas A&M University at Qatar, Qatar; Mohamed-Slim Alouini, King Abdullah University of Science and Technology, Saudi Arabia; Khalid Qaraqe, Texas A&M University at Qatar, Qatar

In this work, we develop joint interference-aware random beam and spectrum selection scheme that provide enhanced performance for the secondary network under the condition that the interference observed at the primary receiver is below a predetermined acceptable value. We consider a secondary link composed of a transmitter equipped with multiple antennas and a single-antenna receiver sharing the same spectrum with a set of primary links composed of a single-antenna transmitter and a single-antenna receiver. The proposed schemes jointly select a beam, among a set of power-optimized random beams, as well as the primary spectrum that maximizes the signal-to-interference-plus-noise ratio (SINR) of the secondary link while satisfying the primary interference constraint. In particular, we consider the case where the interference level is described by a q -bit description of its magnitude, whereby we propose a technique to find the optimal quantizer thresholds in a mean square error (MSE) sense.

TP8a1-5

Signal Detection for Dynamic Spectrum Access

Jim Schroeder, Dave Chester, Jerry Sonnenberg, Bryan Hehn, Steve Andrews, Nick Van Stralen, Ihsan Akbar, Harris Corporation, United States

Both cyclostationary signal detection algorithms and temporal or spatial covariance matrix-based detections algorithm are well known. The cyclostationary detection algorithm is computationally expensive, however does also provides signal features useful for signal classification. In this paper we consider a frequency domain covariance matrix detection algorithm that achieves good detection performance down to SNR = - 5 dB and is computationally efficient. We compare signal detection performance to two standard detection algorithms: Cyclostationary and Covariance Matrix-based.

TP8a1-6

Multi-Bit Cooperative Spectrum Sensing Strategy in Closed Form

Xiaoyuan Fan, Dongliang Duan, University of Wyoming, United States; Liuqing Yang, Colorado State University, United States

Spectrum sensing is one of the most important tasks in cognitive radio system. In order to combat fading, cooperation among different sensing users is adopted. In our previous work, we quantified the performance gain of cooperative spectrum sensing by diversity. In addition, we have shown that even with local binary decisions, the cooperative spectrum sensing can achieve the maximum diversity by appropriately selecting local and fusion rules. However, there is a significant signal-to-noise ratio (SNR) loss compared with the soft information fusion scenario due to local binary quantizations. Intuitively, increasing the number of bits of local quantizations will improve the sensing performance. Most work in the literature on multi-bit cooperative sensing are mathematically intractable and can only be solved numerically with high complexity. In this paper, by jointly maximizing diversity and SNR gain, we provide a generalized multi-bit cooperative sensing strategy with the local and fusion decision rules in explicit closed form. Simulations show that even with small number of bits, our proposed cooperative sensing strategy can significantly improve the sensing performance.

TP8a1-7

Identifying Statistical Mimicry Attacks in Distributed Spectrum Sensing

Mihir Laghate, Chu-Hsiang Huang, Chung-Kai Yu, Lara Dolecek, Danijela Cabric, University of California, Los Angeles, United States

In this work, we consider the spectrum sensing problem in cognitive radio applications where a fusion center collects reports from secondary users (SUs) and fuses them to estimate spectrum occupancy. Malicious SUs may provide false reports, e.g. by mimicking other SUs. We prove that when the identity of mimic SUs is known, the sufficient test statistic for the optimal fusion rule ignores the mimics' reports, thus reducing the dimensionality of the test statistic. Identifying the mimic SUs hence reduces, by orders of magnitude, the time and storage complexity of the online algorithms proposed in literature to estimate the sufficient test statistic of the optimal fusion rule. As a step towards improving the estimation rate, we propose a method to identify mimic SUs in the system, and thus counteract mimicry attacks. Our method uses observed reports to learn the Markov network underlying the SU reports. We identify the mimic SUs by using the tree structure they form in the inferred Markov network. We verify the performance of the proposed algorithm by simulations and demonstrate that it can reliably identify mimic SUs.

TP8a1-8

An Amplify and Forward Scheme for Cognitive Radios

Francesco Verde, University Federico II of Naples, Italy; Anna Scaglione, University of California, Davis, United States; Donatella Darsena, Parthenope University of Naples, Italy; Giacinto Gelli, University Federico II of Naples, Italy

In this paper, we propose an opportunistic amplify-and-forward relaying scheme for a cognitive radio network, which is aimed at allowing a secondary user (SU) to transmit over the same time-frequency slot of a primary user (PU). In our scheme, the SU amplifies and transmits the PU signal it receives, by using as relaying gain the information symbols that the SU wishes to transmit towards its own secondary receiver. The information theoretic limits of the proposed protocol are investigated by showing that, in some operative conditions of practical interest, the SU can use the same time-frequency slot allocated for the PU, thus attaining reasonable transmission rates, without remarkably adding interference, therefore the cognitive radio principle of protecting the PU transmission is not violated.

TP8a1-9

Non-Compressive Wideband Spectrum Sensing with Sub-Nyquist Sampling Rates

Mustafa Al-Ani, University of Westminster, United Kingdom; Bashar Ahmad, University of Cambridge, United Kingdom; Andrzej Tarczynski, University of Westminster, United Kingdom

We introduce a reliable wideband spectrum sensing technique that operates at remarkably low sub-Nyquist sampling rates. Unlike the majority of the sub-Nyquist algorithms which are based on compressive sensing, the proposed method adopts the alias-free sampling approach. It does not entail solving any optimisation problem as in the compressive case and relies on novel sampling schemes to suppress aliasing. The developed technique is characterised by simplicity and low computational complexity; it delivers superior performance when significant reductions on the acquisition rates are sought. The reliability guidelines of the non-compressive method are derived and simulations are provided to demonstrate its performance.

TP8a1-10

Opportunistic Transmitter Selection for Selfless Overlay Cognitive Radios

Mohammad Shaqfeh, Texas A&M University at Qatar, Qatar; Ammar Zafar, King Abdullah University of Science and Technology, Saudi Arabia; Hussein Alnuweiri, Texas A&M University at Qatar, Qatar; Mohamed-Slim Alouini, King Abdullah University of Science and Technology, Saudi Arabia

We propose an opportunistic strategy to grant channel access to the primary and secondary transmitters in causal selfless overlay cognitive radios over block-fading channels. The secondary transmitter helps the primary transmitter by relaying the primary messages opportunistically, aided by a buffer to store the primary messages temporarily. The optimal channel-aware transmitter-selection strategy is the solution of the maximization of the average secondary rate under the average primary rate requirement and the buffer stability constraints. Numerical results demonstrate the gains of the proposed opportunistic selection strategy.

TP8a1-11

A Game Theoretic Power Control Framework for Spectrum Sharing in Competitive Environments

Raghd El-Bardan, Swastik Brahma, Pramod K. Varshney, Syracuse University, United States

This paper presents a Game Theoretic framework for the analysis of distributed spectrum sharing in a Cognitive Radio Network (CRN). We consider competitive interactions among selfish secondary users (SUs) under realistic physical interference constraints. Subject to a per-user average power budget, SUs choose their transmission powers with the objective of satisfying minimum signal-to-interference plus noise ratio (SINR) constraints at the intended receivers. We investigate self-enforcing spectrum sharing strategies of the SUs which correspond to Nash Equilibria (NE) points in a single shot scenario. We carry out an equilibrium analysis by considering the mixed strategy space and provide closed form expressions of the equilibria points. Numerical examples are further presented for illustration.

TP8a1-12

Cognitive Radio Transmission Strategies for Primary Erasure Channels

Ahmed ElSamadony, Mohammed Nafie, Ahmed Sultan, Nile University, Egypt

We consider a secondary cognitive radio that can eavesdrop on the ACK/NACK Automatic Repeat reQuest (ARQ) fed back from the primary receiver to the primary transmitter. Based on the ACK/NACK received, we fully characterize an optimal achievable scheme that spans the boundary of the primary-secondary rate region for a two state erasure primary channel. Our scheme maximizes a weighted sum of primary and secondary throughput. The actual weight used during network operation is determined by the degree of protection afforded to the primary link. Moreover, we study a three-state model where we derive the optimal transmission strategy using dynamic programming.

Track B – MIMO Communications and Signal Processing

Session: TPa8 – Relays in Communications

1:30 PM–3:10 PM

Chair: *Cihan Tepedelenlioglu, Arizona State University*

TP8a2-1

Optimized Receiver Design for Decode-and-Forward Relays using Hierarchical Modulation

Tu Nguyen, Pamela Cosman, Laurence Milstein, University of California, San Diego, United States

We consider a wireless relay network with a single source, a single destination, and multiple relays. The relays are half-duplex and use the decode-and-forward protocol. The transmit source is a layered bitstream, which can be partitioned into a base layer (BL) and an enhancement layer (EL). The source broadcasts both layers to all the relays and the destination using hierarchical 16-QAM. Each relay detects and transmits successfully decoded layers to the destination using either hierarchical 16-QAM or QPSK. We derive the optimal linear combining method at the destination, where the uncoded bit error rate is minimized. We also present a suboptimal combining method with a closed-form solution, which performs very close to the optimal. Numerical results show that the two-layer scheme outperforms the classical one-layer scheme using conventional modulation.

TP8a2-2

Optimal Linear-combining Receiver for Decode-and-Forward Relays using Superposition Coding

Tu Nguyen, Laurence Milstein, University of California, San Diego, United States

We consider a relay network with a single source, a single destination, and multiple relays. The relays are half-duplex and use the decode-and-forward protocol. A successively refinable Gaussian source partitioned into two layers is transmitted. The source broadcasts a message consisting of two layers to all the relays using superposition coding. Each relay re-encodes and forwards all its successfully decoded layers to the destination using an orthogonal channel. Superposition coding is used only if both layers are forwarded. We propose a novel approach to derive the optimal linear-combining receiver at the destination. Numerical results show that the two-layer scheme using superposition coding outperforms a conventional one-layer scheme in terms of average throughput and expected distortion.

TP8a2-3

Alternate Relaying and the Degrees of Freedom of One-Way Cellular Relay Networks

Aya Salah, Amr El-Keyi, Mohammed Nafie, Nile University, Egypt

A two-hop cellular relay network consisting of two source-destination pairs is considered where each source is assisted by two decode-and-forward relays operating in half-duplex mode and all nodes are equipped with N antennas. In order to compensate for the loss of capacity pre-log factor $1/2$ due to the half-duplex mode, an alternate transmission protocol is proposed. An outer bound on the degrees of freedom (DoF) of this setting is developed. A constructive proof of achievability based on two different schemes is provided. The feasibility of the IA problem in the case of a K -user setting is also studied using an iterative distributed algorithm.

TP8a2-4

Distributed AF Beamforming Relay Networks under Transmit Power Constraint

Kanghee Lee, Hyuck M. Kwon, Edwin M. Sawan, Wichita State University, United States; Hyuncheol Park, Korea Advanced Institute of Science and Technology, Republic of Korea

This paper investigates minimum mean square error (MMSE)-based amplify-and-forward (AF) relay amplifying matrices and source/destination beamforming vectors under perfectly known channel state information by imposing constraints on the transmit power of source and relays, separately and individually. The main contribution of this paper is the derivation of a set of relay amplifying matrices and source/destination beamforming vectors under transmit power constraints on the source and relay. Additionally, the SNR and the MMSE cost function behaviors will be investigated numerically and analytically.

TP8a2-5

Joint Transmit Design and Node Selection for One-Way and Two-Way Untrusted Relay Channels

Jing Huang, A. Lee Swindlehurst, University of California, Irvine, United States

We investigate a relay network where the source and destination select one relay out of a group of untrusted relay nodes to establish a reliable and confidential connection. We assume there is no direct link between them, and the users have to employ an untrusted relay while simultaneously protecting the confidential data from it. We study joint transmit design and node selection strategies for both one-way relaying with the help of cooperative jamming from the destination, and two-way relaying. We first derive optimal algorithms through numerical methods for secrecy rate maximization, and then we propose closed-form suboptimal solutions with reduced complexity. Simulation results show that unlike the conventional relay channels, when untrusted relays are used, one-way relaying with cooperative jamming is more efficient than the two-way relaying scheme in terms of secrecy rate.

TP8a2-6

Wireless Physical Layer Security Enhancement with Buffer-Aided Relaying

Jing Huang, A. Lee Swindlehurst, University of California, Irvine, United States

We consider utilizing a buffer-aided relay to enhance security for two-hop half-duplex relay networks with an external eavesdropper. We propose a link selection scheme that adapts reception and transmission time slots based on the channel quality, while considering both the two-hop transmission efficiency and the security. Closed-form expressions for the secrecy throughput and the secrecy outage probability (SOP) are derived, and the selection parameters are optimized to maximize the secrecy throughput or minimize the SOP. We also study two sub-optimal link selection schemes that only require a line search to solve the optimization problem. Numerical results show that buffer-aided relaying provides a significant improvement in security compared to conventional unbuffered relaying.

TP8a2-7

Training Slot Allocation for Mitigating Estimation Error Propagation in a Two-Hop Relaying System

Qian Gao, Gang Chen, Yingbo Hua, University of California, Riverside, United States

This paper analyzes a channel estimation error propagation problem for a two-hop amplify-and-forward (AF) relaying system using two-phase. Channel estimator in each phase is obtained by the linear minimum mean squared error (LMMSE) method. The inaccuracy of estimation of the relay-to-destination (RtD) channel in the first phase affects the estimation of the source-to-relay (StR) channel in the second phase, making it more erroneous than the first phase. We derive an close-form expression for the averaged Bayesian mean-square estimation error (ABMSE) of both phases in terms of the length of source and relay training slots, based on which an iterative searching algorithm is then proposed which optimally allocates the training slots to each phase

such that the estimation errors are balanced for both phases. Analysis shows how the ABMSE of StD channel estimation varies with the length of relay training slots, the length of source training slots, the relay amplification gain, and the channel prior information respectively. This scheme is shown to be substantially better than a random allocation scheme.

TP8a2-8

Transmit Outage Pre-equalization for Amplify-and-Forward Relay Channels

Fernando Sanchez, Gerald Matz, Vienna University of Technology, Austria

We consider amplify-and-forward (AF) on the relay channel without direct source-destination link. In contrast to existing scheme, we propose to perform pre-equalization at the source, which entails a channel-independent gain at the relay. If the power constraint does not allow for pre-equalization, the source refrains from transmitting and declares a transmit outage. Channel state information is acquired at the source and at the destination based on a single pilot transmission from the relay. The advantages of the proposed method are an extremely simple relay, a reduced pilot overhead, huge power savings at the source, and high robustness against imperfect CSI.

Track C – Networks

Session: TPa8 – Cellular and Heterogeneous Networks

1:30 PM–3:10 PM

Chair: *Sundeep Rangan, NYU Poly*

TP8a3-1

Downlink Coverage Analysis of N-Tier Heterogeneous Cellular Networks Based on Clustered Stochastic Geometry

Chunlin Chen, Robert Elliott, Witold Krzymien, University of Alberta / Telecommunications Research Laboratories, Canada

Assuming a desired base station (BS) at the point of reference (origin) in the tier of interest, we derive an expression for the downlink coverage probability over a heterogeneous network, wherein the BS locations result from different point processes, such as Poisson point and Poisson cluster processes. Simulation results show increasing the BS density in each tier lowers the coverage probability, but not as much as increasing the coverage threshold does. We also provide lower and upper bounds for the coverage probability in a two-tier heterogeneous network modelled with Poisson point and cluster processes, which are of potential use for network design.

TP8a3-2

System-Level Performance of the MIMO-OFDM Downlink with Dense Small Cell Overlays

Thomas Wirth, Bernd Hofeld, Fraunhofer Heinrich Hertz Institute, Germany

Multi-tier heterogeneous networks based on MIMO-OFDM are a promising approach to enhance coverage and capacity in next generation cellular networks. We investigate the downlink performance of such a small cell deployment based on a system-level model of a 4G network. The parameters are based on 3GPPs latest long term evolution (LTE) standard. The co-existence of a set of Macrocells with a dense small cell deployment is modelled by using statistical channel models. Since all cells operate on the same frequency as in a single frequency network (SFN), the system is interference limited. First, the number of small cell nodes operated in a Macro cell-of-interest is increased, in order to evaluate the effect of small cell densification on the Macro cell as well as on the overall performance. Next, mechanisms are introduced which allow enhanced inter-cell interference coordination (eICIC). The trade-off by introducing such coordination techniques is shown by evaluating physical layer (PHY) system throughput results.

TP8a3-3

Adaptive HARQ and Scheduling for Video over LTE

Avi Rapaport, Weimin Liu, Liangping Ma, Gregory S. Sternberg, Ariela J. Zeira, Anantharaman Balasubramanian, InterDigital, United States

This paper proposes a cross-layer approach to the delivery of real-time video streams over LTE cellular systems. The objective is to maximally improve video quality by adapting the wireless system (specifically, HARQ retransmission and scheduling rules) to video packet importance. Complying with the LTE framework, video packets are given priorities and assigned to different radio bearers or logical channels based on their importance. Applicable to both uplink (UL) and downlink (DL), the adaptive HARQ minimizes the effect of transmission errors by performing potentially more HARQ retransmissions for high-priority video packets while the scheduling algorithm deals with congestion by giving high priority to important packets to minimize their transmission timeout. We show that the combination of adaptive HARQ and priority-based scheduling offers significant gains in video quality by enabling the wireless system to handle congestion and transmission errors, two of the main challenges to cellular delivery of real-time video.

TP8a3-4

Novel Partial Feedback Schemes and Their Evaluation in an OFDMA System with CDF Based Scheduling

Anh Nguyen, University of California, San Diego, United States; Yichao Huang, Qualcomm Technologies, Inc., United States; Bhaskar Rao, University of California, San Diego, United States

In an Orthogonal Frequency Division Multiple Access (OFDMA) system, cumulative distribution function (CDF) based scheduling can be applied to prioritize users. In such a wideband multiuser system, it is essential to reduce the typically very large feedback requirement. Herein, we consider a system in which several adjacent highly correlated subcarriers are grouped into a resource block. Then, the formed resource blocks can be further combined to form subbands, each consisting of a certain number of resource blocks. To reduce feedback, three feedback schemes, which include two new schemes, are considered and compared. They are a novel CDF based opportunistic scheme, the best M feedback scheme and a hybrid scheme. We provide analytical results which are used to optimally set feedback parameters to best exploit system resource while still maintaining fairness among users. In addition, the convergence behaviors of the total feedback requirement of the schemes are also provided. Simulation are conducted to verify the tradeoff between feedback reduction and system performance. The experiments also show the optimal hybrid and opportunistic schemes are identical and result in the least feedback requirement.

TP8a3-5

Opportunistic Third-Party Backhaul for Cellular Wireless Networks

Russell Ford, Changkyu Kim, Sundeep Rangan, Polytechnic Institute of New York University, United States

To reduce growing backhaul costs in cellular networks, this paper presents an opportunistic backhaul model where third parties install open access femtocells and lease out excess capacity in their networks to the cellular provider, presumably at significantly lower costs than guaranteed connections that operators currently purchase. The paper discusses both network architectural issues as well the mathematical optimization for the carrier that must assign mobiles between third-party and operator-controlled cells based on channel conditions, loading and access pricing. Simulations, based on reported base stations and WiFi locations, suggest significant potential capacity increases with this model.

TP8a3-6

Proactive User Association in Small Cell Networks via Collaborative Filtering

Francesco Pantisano, Mehdi Bennis, Centre for Wireless Communications, Finland; Walid Saad, University of Miami, United States; Stefan Valentin, Bell Labs, Alcatel-Lucent, Germany; Mérouane Debbah, Supelec, France; Alessio Zappone, Technische Universität Dresden, Germany

In this paper, we propose a proactive cell association framework for small cell networks, based on content recommendations. We focus on multimedia data services and characterize the user's quality of service (QoS) in terms of mean opinion scores (MOSs) that accurately reflect the characteristics of wireless transmissions and data applications. Based on such information, we propose a collaborative filtering approach that enables the small base stations to extract user information from large data sets, predict user-specific QoS characteristics, and ultimately devise better-informed cell association decisions. Results show that the proposed solution yields 19% spectrum savings improvement compared to traditional reactive approaches.

TP8a3-7

Interference Analysis of Multi-hop Cellular Networks

Yeashfi Hasan, R. Michael Buehrer, Virginia Polytechnic Institute and State University, United States

In conventional single-hop cellular networks, cell size is limited by the fact that users located far from the base station transmit at high power, generating high levels of interference for co-channel users in neighboring cells. Decreasing the cell size, however, requires the installation of more base stations for the same coverage area, increasing overall costs. In this paper, we propose a multi-hop architecture for cellular networks for sensor applications as an alternative. We present an interference analysis for our multi-hop network and compare the uplink outage capacity for different number of hops. We show that, for the same outage probability, spread spectrum multi-hop networks can greatly increase capacity compared to single hop networks, however the incremental capacity improvement diminishes as the number of hop increases. Additionally, we examine the impact of different network parameters on the statistics and distribution of the total uplink interference power and provide recommendations for network design.

TP8a4-1

A Gradient-Controlled Improved Proportionate Multi-Delay Filter

Jie Yang, Texas Instruments, United States; Sobelman Gerald, University of Minnesota, United States

As an attractive alternative to time domain solutions, the frequency domain multi-delay filter has gained attention in acoustic echo cancellation (AEC) because of its efficient implementation. This paper proposes a new gradient-controlled improved proportionate multi-delay filter (GC-IPMDF) for AEC. It uses the magnitude of a time-averaging gradient estimate as the step size distribution vector instead of the magnitude of the current coefficients estimate that is used in the existing improved proportionate multi-delay filter (IPMDF). Simulation results demonstrate that it can speed up the convergence process while maintaining the same steady-state error performance as compared with the previously proposed approach.

TP8a4-2

Complex Proportionate-Type Affine Projection Algorithms

Kevin Wagner, Naval Research Laboratory, United States; Miloš Doroslovacki, George Washington University, United States

An extension of complex proportionate-type normalized least mean square algorithms is proposed and derived. This new algorithm called the complex proportionate-type affine projection algorithm helps the estimation of unknown impulse responses when the input signal is colored. The derivation of the complex proportionate-type affine projection algorithm is performed by minimizing the second norm of the weighted difference between the current estimate of the impulse response and the estimate at the next time step under constraints that multiple a posteriori output errors are zero. Several variants of the algorithm are obtained as in the case of the complex proportionate-type normalized least mean square algorithm. The learning curves of the algorithms are compared for several standard gain assignment laws for colored and speech input. Through simulation it was demonstrated that the complex proportionate-type affine projection algorithm offers superior convergence performance for colored input signals relative to complex proportionate-type normalized least mean square algorithms and that using separate gains to update the real and imaginary parts of the estimated impulse response, as opposed to the same gain, improves the convergence performance.

TP8a4-3

Radar Waveform Design in Active Communications Channel

Kevin Shepherd, Ric Romero, Naval Postgraduate School, United States

In this paper, we investigate adaptive radar transmit waveform design and its effects on an active communication system. We specifically look at waveform design for point targets with infinite frequency response. The transmit waveform is optimized by accounting for the modulation spectrum of the communication system while trying to efficiently use the remaining spectrum. With the use of adaptive radar waveform, we show that the SER detection performance of the communication system is minimally affected compared to the SER performance with a classical non-adaptive pulsed radar waveform. Moreover, we show the detection performance of the adaptive waveform is less impacted by the active communication compared to that of the pulsed radar waveform design. In other words the radar is able to coexist with a friendly communication systems.

TP8a4-4

The Leaky Least Mean Mixed Norm Algorithm

Mohammed Abdul Nasar, Azzedine Zerguine, King Fahd University of Petroleum & Minerals, Saudi Arabia

In this work, a leakage-based variant of the Least Mean Mixed Norm (LMMN) algorithm, the leaky Least Mean Mixed Norm (LLMMN) algorithm, is derived. The proposed algorithm will help mitigate the weight drift problem experienced in the conventional Least Mean Square (LMS) and Least Mean Fourth (LMF) algorithms. The main aim of this work is to derive the LLMMN adaptive algorithm and conduct transient analysis using the energy conservation relation framework. Finally, a number of simulation results are carried out to corroborate the theoretical findings, and show improved performance obtained through the use of LLMMN over the conventional LMMN algorithm in a weight drift environment.

TP8a4-5

A New Variable Step-Size Zero-Point Attracting Projection Algorithm

Jianming Liu, Steven Grant, Missouri University of Science and Technology, United States

This paper proposes a new variable step-size (VSS) scheme for the recently introduced zero-point attracting projection (ZAP) algorithm. The proposed variable step-size ZAPs are based on the gradient of sparseness which is approximated by the difference between the sparseness measure of current filter coefficient and an averaged sparseness measure. Simulation results demonstrate that the proposed approach provides both faster tracking ability and lower steady-state misalignment than previous ones.

TP8a4-6

Reliable and Low Power Least Squares Lattice Filtering

Chandrasekhar Radhakrishnan, Andrew Singer, University of Illinois at Urbana-Champaign, United States

Power efficiency and reliability are two issues facing digital signal processing (DSP) systems designed using CMOS and nanoscale process technologies. Power saving techniques like voltage overscaling (VOS) in CMOS technologies and the reliability issues in nanoscale processes make these systems susceptible to transient errors. These errors often manifest themselves as large magnitude errors at the application level and are usually mitigated using a reduced-precision replica of the main computational unit. In this work we exploit the order recursive nature of the lattice structure to design reliable lattice filters. We use a structure in which the higher orders of the lattice filter are susceptible to errors. The lower orders of the lattice structure compensate for the potentially erroneous output of the successive stages of the lattice by providing an approximate result.

Track F – Biomedical Signal and Image Processing

Session: TPb8 – Electrophysiology and Brain Imaging

3:30 PM–5:10 PM

Chair: *Behnaam Aazhang, Rice University*

TP8b1-1

Joint Compression of Neural Action Potentials and Local Field Potentials

Sebastian Schmale, Benjamin Knoop, Janpeter Hoeffmann, Dagmar Peters-Drolshagen, Steffen Paul, University of Bremen, Germany

Brain research deals with two types of electrophysiological signals: neural action potentials (AP) and local field potentials (LFP). The demand for a increased spatial and temporal resolution leads to an enlarged data rate which has to be handled by an assumed wireless link in between the signal sources and the recording hardware. The theory of Compressed Sensing (CS) can be utilized to perform data compression right after or during acquisition of the neural raw data. In order to apply a joint CS infrastructure for LFPs and APs, a common basis in which both signal types can be characterized as sparse has to be found. We compare four different bases for the joint processing of LFPs and APs, of which the DCT turns out to be best suited.

TP8b1-2

Reducing the Effect of Correlated Brain Sources in MEG Using a Linearly Constrained Spatial Filter Based on Minimum Norm

Jose Alfonso Sanchez De Lucio, David M. Halliday, University of York, United Kingdom

Magnetoencephalogram (MEG) studies rely on the use of spatial filters to find and extract the brain activity generated by neuronal currents. Two of the most used spatial filters are the Linearly Constrained Minimum Variance Beamformer (LCMV) and the Minimum Norm Estimate (MNE). These have different properties that can increase or decrease their performance depending on the correlation between brain sources and sensitivity of the sensors. This study introduces a spatial filter as a benchmark to decide when to apply the LCMV or the MNE spatial filters, in order to have results unaffected by correlated brain sources

TP8b1-3

Online Bayesian Change Point Detection Algorithms for Segmentation of Epileptic Activity

Rakesh Malladi, Behnaam Aazhang, Rice University, United States; Giridhar P Kalamangalam, University of Texas Health Science Center, United States

Epilepsy is a dynamic disease in which the brain transitions between different states. In this paper, we focus on the problem of identifying the time points, referred to as change points, where the transitions between these different states happen. A Bayesian change point detection algorithm that does not require the knowledge of the total number of states or the parameters of the probability distribution modeling the activity of epileptic brain in each of these states is developed in this paper. This algorithm works in online mode making it amenable for real-time monitoring. To reduce the quadratic complexity of this algorithm, an

approximate algorithm with linear complexity in the number of data points is also developed. Finally, we use these algorithms on ECoG recordings of an epileptic patient to locate the change points and determine segments corresponding to different brain states.

TP8b1-4

Spiking Neural Networks based on LIF with Latency: Simulation and Synchronization Effects

Gian Carlo Cardarilli, Alessandro Cristini, Marco Re, Mario Salerno, Gianluca Susi, University of Rome Tor Vergata, Italy

In this paper, a work on spiking neural networks based on a model of a kind of Leaky Integrate-and-Fire (LIF) neuron with latency is presented. Efficient simulations are carried out through an ad hoc event-driven approach, highlighting some particular effects of synchrony in a simple feedforward network topology. These results are consistent with literature research and, thanks to the implementation of the biologically plausible latency effect in the model, new results have emerged from the simulations. The authors plan to apply these results in the near future to applications in which this kind of neural networks and Digital Signal Processing (DSP) applications can be merged to obtain powerful nonlinear DSP techniques [15]. In the plan of the authors is also the definition of a hardware prototype of the network based on digital techniques [34-35]

TP8b1-5

Time-Frequency Analysis of Brain Electrical Signals for Behaviour Recognition in Patients with Parkinson's Disease

Huaiguang Jiang, Jun Jason Zhang, University of Denver, United States; Adam Hebb, Colorado Neurological Institute, United States; Mohammad Mahoor, University of Denver, United States

A behaviour recognition method is proposed based on time-frequency analysis and machine learning techniques to identify Parkinson's disease (PD) patients' behaviours from local field potential (LFP) and electrocorticography (ECoG) signals obtained from a deep brain stimulation (DBS) system. Specifically, the amplitude-time-frequency-variance features are extracted by Matching Pursuit Decomposition (MPD) from LFP signals, which are sampled by the DBS lead from the PD patients' brain. Using the feature vectors, different Hidden Markov Models (HMMs) are trained and then used to recognize different human behaviours. The experiment results demonstrate the feasibility, effectiveness and accuracy of our proposed method.

TP8b1-6

Modified Hodgkin-Huxley Model using Fractional Differential Equation

Harsh Wardhan, Anubha Gupta, Shubhajit Roy Chowdhury, International Institute of Information Technology-Hyderabad, India

This paper proposes a modification to the existing Hodgkin-Huxley model that is an electrical abstraction of a biological neuron. The Hodgkin-Huxley model explains ion transport mechanism across membrane of a neuron via linear ordinary differential equation. Hodgkin-Huxley model suffers with two major drawbacks: 1) it does not take into account the dielectric losses in the cell membrane and 2) it models charge separation across membrane by an ideal capacitor. The proposed model addresses these shortcomings by utilizing fractional order differential equations and is called modified Hodgkin-Huxley model. The proposed model has been validated by comparing results with findings in literature.

TP8b1-7

A Measure of Connectivity in the Presence of Crosstalk

Sergul Aydore, Syed Ashrafulla, Anand Joshi, Richard Leahy, University of Southern California, United States

Analyses between brain electrophysiological signals are often affected by crosstalk, in which the sensitivity of each sensor to every brain signal leads to spurious correlations. We analyze a measure of connectivity, termed orthogonalized coherence, that is robust to crosstalk. This coherence is derived by projecting a component of one signal away from the second, effectively removing the part of the cross-spectrum between the two signals that is affected by crosstalk. We show its relationship with other well-known measures of connectivity such as coherence and imaginary coherence. We also propose a multivariate extension to orthogonalized coherence in the case of multiple sensors, providing a connectivity measure that is less affected by crosstalk than current connectivity measures.

TP8b2-1**Multi-User MIMO Scheduling in the Fourth Generation Cellular Uplink**

Narayan Prasad, Honghai Zhang, NEC Laboratories America, Inc., United States; Hao Zhu, University of Minnesota, United States; Sampath Rangarajan, NEC Laboratories America, Inc., United States

In this paper, we consider Multi-User MIMO (MU-MIMO) scheduling in the 3GPP LTE-Advanced (3GPP LTE-A) cellular uplink. The 3GPP LTE-A cellular network is expected to be the most widely deployed fourth generation (4G) cellular network. It allows for precoded multi-stream (precoded MIMO) transmission from each scheduled user in the uplink along with flexible multi-user (MU) scheduling, wherein multiple users can be assigned the same time-frequency resource. However, exploiting these features is made challenging by certain practical constraints that have been imposed in order to maintain a low signaling overhead. We show that while the scheduling problem in the 3GPP LTE-A cellular uplink is NP-hard, it can be formulated as the maximization of a monotonic submodular set function subject to one matroid and multiple knapsack constraints. We then propose constant-factor polynomial-time approximation algorithms and demonstrate their superior performance via simulations.

TP8b2-2**Optimal DoF Region of the Two-User MISO-BC with General Alternating CSIT**

Jinyuan Chen, Petros Elia, Eurecom, France

In the setting of the time-selective two-user multiple-input single-output (MISO) broadcast channel (BC), recent work by Tandon et al. considered the case where - in the presence of error-free delayed channel state information at the transmitter (delayed CSIT) - the current CSIT for the channel of user 1 and of user 2, alternate between the two extreme states of perfect current CSIT and of no current CSIT. Motivated by the problem of having limited-capacity feedback links which may not allow for perfect CSIT, as well as by the need to utilize any available partial CSIT, we here deviate from this 'all-or-nothing' approach and proceed - again in the presence of error-free delayed CSIT - to consider the general setting where current CSIT now alternates between any two qualities. Specifically for I_1 and I_2 denoting the high-SNR asymptotic rates-of-decay of the mean-square error of the CSIT estimates for the channel of user-1 and of user-2 respectively, we consider the case where $I_1, I_2 \in \{\gamma, \alpha\}$ for any two positive current-CSIT quality exponents γ, α ; as a result, the overall current CSIT - for both users' channels - alternates between any four states $I_{1,2} \in \{\gamma, \alpha, \alpha\gamma, \alpha\alpha\}$. In a fast-fading setting where we consider communication over any number of coherence periods, and where each CSIT state $I_{1,2}$ is present for a fraction $\lambda_{I_{1,2}}$ of this total duration (naturally forcing $\lambda_{\alpha\gamma} + \lambda_{\alpha\alpha} + \lambda_{\gamma\alpha} + \lambda_{\gamma\gamma} = 1$), we focus on the symmetric case of $\lambda_{\alpha\gamma} = \lambda_{\gamma\alpha} = \lambda_{\alpha\alpha} = \lambda_{\gamma\gamma}$, and derive the optimal degrees-of-freedom (DoF) region to be the polygon with corner points $\{(0,0), (0,1), (\bar{\lambda}, 1), (\frac{2+\bar{\lambda}}{3}, \frac{2+\bar{\lambda}}{3}), (1, \bar{\lambda}), (1, 0)\}$, for some $\bar{\lambda} \stackrel{\text{def}}{=} (\lambda_{\gamma\alpha} + \lambda_{\gamma\gamma})\gamma + (\lambda_{\alpha\gamma} + \lambda_{\alpha\alpha})\alpha$, representing a measure of the average CSIT quality. The result, which is supported by novel communication protocols, naturally incorporates the aforementioned 'Perfect current' vs. 'No current' setting by limiting $I_1, I_2 \in \{0,1\}$, as well as the Yang et al. and Gou and Jafar setting by forcing $\alpha = \gamma$. Finally, motivated by recent interest in frequency correlated channels with unmatched CSIT, we also analyze the setting where there is no delayed CSIT.

TP8b2-3**Exploiting Spatial Spectrum Holes in Multiuser MIMO systems**

Feeby Salib, Karim Seddik, American University in Cairo, Egypt

In this paper, a modified spectrum sensing algorithm for Cognitive Radio is proposed for the detection of spatial spectrum holes. We consider two scenarios, namely, the static and the dynamic scenarios. In both scenarios, by exploiting a priori information about primary users (PUs) activity, a better sensing for spatial spectrum holes in MU-MIMO can be achieved. A Maximum A Posteriori (MAP) detector with relaxed constraints is considered where both the block sparsity structure of the signal being sensed and the knowledge of a priori information about the PUs activity are considered. In the dynamic case, the PUs activity is modeled as a two-state Markov chain.

TP8b2-4

Achievable Degrees of Freedom of Three-Cell MIMO Cellular Networks Using Subspace Alignment Chains

Gokul Sridharan, Wei Yu, University of Toronto, Canada

In this paper we extend the notion of subspace alignment chains for the 3-user MIMO interference channel to 3-cell MIMO cellular networks. We show that if $d=ab$, with $a, b \in \mathbb{Z}^{++}$, degrees of freedom per user are achievable in a 3-user interference channel with M antennas at each transmitter and N ($M \leq N$) antennas at each receiver without the need for symbol extensions, then a degrees of freedom per user are achievable without any symbol extensions in a 3-cell MIMO cellular network with b users per cell having M antennas per user and N antennas per base station. This result provides a constructive proof for feasibility of linear interference alignment without symbol extensions for certain MIMO cellular networks. Further, it highlights the significant ease with which aligned beamformers can be computed when there is redundancy in the number of transmit or receive antennas.

TP8b2-5

Interference Alignment for MISO Broadcast Channels under Jamming attacks

SaiDhiraj Amuru, Ravi Tandon, R. Michael Buehrer, T. Charles Clancy, Virginia Tech, United States

Jamming attacks can significantly impact the performance of wireless communication systems, and lead to insurmountable overhead in terms of re-transmissions and increased power consumption. In this paper, we consider the two-user multiple-input single-output (MISO) broadcast channel (BC) in the presence of a jamming attack in which either one, or both or none of the users can be jammed or interfered at any given time. We present countermeasures for mitigating the effects of such jamming attacks. The effectiveness of anti-jamming countermeasures is quantified in terms of the degrees-of-freedom (DoF) of the MISO BC under various assumptions regarding the availability of the channel state information (CSIT) and the jammer state information at the transmitter (JSIT).

TP8b2-6

Performance Study of MRC and IRC Weights In LTE/LTE-A Systems With Interference Management

Thomas Svantesson, ArrayComm, United States

An inter-cell interference coordination (ICIC) interference management technique that recently has attracted interest is to create protected subframes to reduce inter-cell interference. This technique can under some circumstances lead to almost blank subframes (ABS) where there is interference on only the pilots but no interference on the data. This paper analyzes the performance of traditional MRC and IRC receivers for ABS subframes both analytically and through simulations. It is found that IRC often yields better performance than MRC even in the absence of interference on data making the IRC receiver an interesting receiver in practice.

TP8b2-7

MIMO Broadcast Channels with Partial CSIT and Application to Location based CSIT

Habib Chabbi, Yohan Lejosne, Dirk Slock, Eurecom, France; Yuan-Wu Yi, Orange Labs, France

Channel State Information at the Transmitter (CSIT), which is crucial in multi-user systems, is always imperfect in practice. In this paper we focus on the optimization of beamformers for the expected sum rate in the MIMO Broadcast Channel (multi-user MIMO downlink). We first review some beamformer designs for the perfect CSIT case, such as Weighted Sum MSE and convexified linearization. The discussion then turns to mean and covariance CSIT, and the special case of location aided CSIT. We then review an exact Monte Carlo based approach and a variety of approximate techniques and bounds that all reduce to problems of the (deterministic) form of perfect CSIT. Other simplified exact solutions can be obtained through massive MIMO asymptotics, or the more precise large MIMO asymptotics. The complexity and relative performance of the in the end many possible approaches are then compared.

TP8b2-8

A System-Level Study on Multi-User MIMO Transmission for Ultra Dense FDD Networks

Lars Thiele, Martin Kurras, Kai Börner, Fraunhofer Institute, Germany

TP8b2-9

Diversity-Multiplexing Tradeoff of MIMO Linear Precoding

Ahmed Mehana, Samsung Electronics, Co., Ltd., United States; Aria Nosratinia, University of Texas at Dallas, United States

This work characterizes the diversity-multiplexing tradeoff (DMT) of MIMO systems with linear precoders. We analyze the cases of zero-forcing (ZF), regularized ZF (RZF), matched filtering and Wiener filtering precoded MIMO systems. We show that MIMO systems with ZF precoding achieve the same DMT as that of MIMO systems with ZF equalizer. When a regularized ZF (RZF) or Matched filter (MF) precoder is used, the DMT implies an error floor at all rates. However, we observe that in the fixed rate regime (i.e. zero multiplexing gain) both RZF and the MF precoded systems can sometimes achieve the maximum spatial diversity. When the regularization factor in the RZF precoder is optimized in the MMSE sense, the DMT implies low diversity gain in the fixed rate regime; however the diversity in this regime is function of the spectral efficiency and can be as large as the maximum spatial diversity.

Track G – Architecture and Implementation

Session: TPb8 – Design Automation

3:30 PM–5:10 PM

Chair: *Christian Haubelt, University of Rostock*

TP8b3-1

MPMAP: A High Level Synthesis and Mapping Tool for MPSoCs

Amr Hussien, Ahmed Eltawil, University of California, Irvine, United States; Rahul Amin, Jim Martin, Clemson University, United States

The design of efficient multiprocessor systems on chip (MPSoC) is challenging, especially with the increasing demand in high performance, low power, and reconfigurable applications. This paper proposes a tool for high level MPSoC generation with joint task and core mapping (MPMAP) with the objective of minimizing the average power consumption considering static, dynamic, configuration and communication powers. MPMAP provides a flexible XML interface with a high level description of different PU architectures, and applications. Additionally, the paper presents a case study of real-life applications that can be adopted in future heterogeneous wireless systems.

TP8b3-2

Software Tool for FPGA Based MIMO Radar Applications

Amin Jarrah, Mohsin M. Jamali, University of Toledo, United States

Direct Data Domain (D3) algorithm is very useful in Space-Time Adaptive Processing (STAP) algorithms to mitigate the effects of multipath and interference. However, the computation of D3 is computationally intensive. A software tool is developed that is capable of auto-generating a fully optimized VHDL. The tool is written in Java and utilizes Vivado High Level Synthesis Tool. The tool receives user specified input and produces various performance parameters. It is a rapid prototyping environment and allows the designer to focus on the overall SoC performance and make adjustments as necessary. It utilizes many optimization techniques to improve throughput and latency.

TP8b3-3

Multi-Clock Domain Optimization for Reconfigurable Architectures in High-Level Dataflow Applications

Simone Casale Brunet, Endri Bezati, Claudio Alberti, Marco Mattavelli, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Edoardo Amaldi, Politecnico di Milano, Italy; Jörn Janneck, Lund University, Sweden

A new design methodology is proposed to partition dataflow applications on a multi clock domain architecture. This work shows how starting from a high level dataflow representation of a dynamic program it is possible to reduce the overall power consumption without impacting the performances. The objective is to optimize the mapping of the application into multiple clock domains. In this way, a different clock frequency is assigned to each clock domain in order to reduce the overall power consumption, but with the purpose to not reduce the overall design performance requirements. Two different approaches are illustrated, both based on the post-processing and analysis of the causation trace of a dataflow program. Methodology and initial experimental results are demonstrated in an at-size scenario using an MPEG-4 Simple Profile decoder.

TP8b3-4

Actor Classification using Actor Machines

Gustav Cedersjö, Jörn Janneck, Lund University, Sweden

Recently, computers with parallel processing capabilities have become more popular as a consequence of the no longer increasing clock speeds of new processors. Together with the need for processing streams of data in many applications today, this has renewed the interest in dataflow programming. New languages (such as CAL and RVC-CAL) that can express large classes of dataflow programs have been developed. In this paper we present static analyses to help programmers to write efficient and correct programs, by classifying the actors of a dataflow program (expressed as actor machines) by schedulability and other interesting properties.

TP8b3-5

Systems Design Space Exploration by Serial Dataflow Program Executions

Simone Casale Brunet, Marco Mattavelli, Claudio Alberti, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Jörn Janneck, Lund University, Sweden

Heterogeneous parallel systems are becoming mainstream computing platforms nowadays. One of the main challenges the development community is facing consists in fully exploiting the available computational power when porting existing programs or developing new ones with available techniques. In this direction, several design space exploration methods have been presented and extensively adopted. However, defining the feasible design space of a dynamic dataflow program still remains an open issue. This paper proposes a novel methodology for defining such a space through a serial execution. Homotopy theoretic methods are used to demonstrate how the design space of a dynamic dataflow program can be reconstructed from its serial execution trajectory.

TP8b3-6

Porting an MPEG-HEVC Decoder to a Low-Power Many-Core Platform

Damien de Saint-Jorre, Claudio Alberti, Marco Mattavelli, Simone Casale Brunet, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

After several generations of video coding standards, MPEG High Efficient Video Coding (HEVC) is likely to emerge as the video coding standards for HD and Ultra-HD TV. HEVC decoding is expected to be less computationally demanding and to provide a higher level of potential intrinsic parallelism. A many-core platform such as the STM STHORM appears to be a very good candidate for supporting low-power HEVC implementations capable of exploiting the different intrinsic parallelization options. This work explores the potential of HEVC wavefront and tiles algorithms implementation on the STHORM. Different partitioning options of an HEVC specified at high level using the standard RVC-CAL dataflow language are presented. Performances are measured and profiled on the STHORM platform by repartitioning and refactoring the dataflow software according to performance objectives.

TP8b3-7

Real-time Radar Signal Processing on Massively Parallel Processor Arrays

Zain Ul-Abdin, Halmstad University, Sweden; Anders Åhlander, Saab AB, Sweden; Bertil Svensson, Halmstad University, Sweden

The next generation radar systems have high performance demands on the signal processing chain. Among these are advanced image creating sensor systems in which complex calculations are to be performed on huge sets of data in real-time. Massively Parallel Processor Arrays (MPPAs) are gaining attention to cope with the computational requirements of complex radar signal processing by exploiting massive parallelism inherent in the algorithms in an energy efficient manner. In this paper, we evaluate two such massively parallel architectures, namely, Ambric and Epiphany, by implementing a significantly large case study of autofocus criterion calculation, which is a key component in future synthetic aperture radar systems. The implementation results from the two case studies are compared on the basis of achieved performance, energy efficiency, and programmability.

TP8b3-8

Algorithm and Architecture Co-design of Mixture of Gaussian (MoG) Background Subtraction for Embedded Vision

Hamed Tabkhi, Northeastern University, United States; Robert Bushey, Analog Devices Inc., United States; Gunar Schirner, Northeastern University, United States

Embedded vision has emerged as a rapidly growing and challenging market demanding high computation with low power consumption as primary requirements. To achieve efficient realizations, vision algorithms and architectures are required to be developed and tuned in conjunction. This article demonstrates a co-design possibility focusing on Mixture of Gaussian (MoG)

for background subtraction. Through joint algorithm tuning and system-level exploration, we propose a HW-based architecture for MoG with sufficient flexibility to adjust to scene complexity and navigating the bandwidth/quality trade-off. Through compression of Gaussian parameters, our solution reduces the memory bandwidth by 63% with limited loss in quality

Track B – MIMO Communications and Signal Processing

Session: WAa1 – MIMO Interference Management

Chair: *Rachel Learned, MIT Lincoln Laboratory*

WA1a-1

8:15 AM

Degrees of Freedom for the Constant MIMO Interference Channel with CoMP

Transmission

Craig Wilson, Venugopal V. Veeravalli, University of Illinois at Urbana-Champaign, United States

This work considers the MIMO interference channel (IC) with constant channel coefficients, N transmit and receive antennas at each user, and cooperative multipoint (CoMP) transmission, in which each message is jointly transmitted by M_t successive transmitters. It is shown that the degrees of freedom with CoMP using a two stage scheme involving both zero forcing (ZF) and interference alignment (IA) can be significantly greater than without CoMP. In particular, all users can achieve d degrees of freedom almost surely if $d \leq \lfloor \frac{2N}{K-M_t+1} \rfloor$ and $M_t \leq K-2$. Additionally, the first M_t-1 users can achieve d_1 degrees of freedom and the last $K-M_t+1$ users can achieve d_2 degrees of freedom almost surely if $d_2 \leq \lfloor \frac{2N}{K-M_t+1} \rfloor$, $M_t \leq K-2$, and $d_1+(K-M_t+1)d_2 \leq 2N$.

WA1a-2

8:40 AM

Dynamic Interference Management

Aly El Gamal, Venugopal V. Veeravalli, University of Illinois at Urbana-Champaign, United States

A linear interference network is considered. Long-term fluctuations (shadow fading) in the wireless channel can lead to any link being erased with probability p . Each receiver is interested in one unique message that can be available at M transmitters. In a cellular downlink scenario, the case where $M=1$ reflects the cell association problem, and the case where $M>1$ reflects the problem of setting up the backhaul links for Coordinated Multi-Point (CoMP) transmission. In both cases, Degrees of Freedom (DoF) optimal schemes for the case of no erasures are analyzed, and new schemes are proposed with better average DoF performance at high probabilities of erasure.

WA1a-3

9:05 AM

A MUD/Rate Selection Tool for Cognitive Radios in Packet Based Asynchronous Gaussian Multiple Access Channels

Prabahan Basu, Rachel Learned, MIT Lincoln Laboratory, United States

Abstract—In this work, we develop a tool to predict the performance, for a given rate, of cognitive radios equipped with Multi User Detection (MUD), thereby helping to enable communications in the face of co-channel interference from packet based transmission networks. Existing approaches to the problem of predicting performance across an asynchronous Gaussian multiple access channel rely on loose upper bounds on the probability of transmission error. Here, we explore an alternative approach wherein the notion of rate regions from multi-user Information Theory is modified for use as a performance prediction tool in the packet based transmission setting. In the submitted extended abstract, we detail the context for this problem, present the relevant signal model and outline a monte-carlo based approach that makes use of a simplified tractable model. In the final submission, we will relax these simplifications and provide closed-form approximations of the proposed performance score.

WA1a-4

9:30 AM

Precoder Design for Fractional Interference Alignment

Hari Ram Balakrishnan, Giridhar K, Indian Institute of Technology Madras, India

In this work, we consider a K -user Interference Channel (IC), where all the transmitters employ Finite Alphabet (FA) signals. With M antennas at both transmitter and receiver nodes, the Interference Alignment (IA) scheme [1] was shown to provide $1/2$ SpAC (Symbols transmitted per transmit Antenna per Channel use) per user, whereas, the Fractional Interference Alignment (FIA) scheme [2] provides a value of SpAC in the range $[0,1]$. When FA signals are used, the IA technique which uses a fixed value of SpAC = $1/2$ is sub-optimal, and therefore will not provide the best possible rate and/or bit error rate (BER). Instead, the FIA scheme explicitly computes the maximum SpAC that can be supported for a given measurement model (assuming that accurate knowledge of the channel state information is available for the desired and the interfering signals). Hence, based on two different optimization criteria, namely (a) Coding Gain-(CG) maximization, and (b) Goodput-(GP) maximization, we use

a simple conjugate gradient search approach to compute the sub-optimal SpAC value and the corresponding precoders for the FIA scheme. Numerical results show that for a 3-user IC, even at finite signal-to-interference ratio (SIR), $(M-1)/M$ SpAC (upper bound in FIA scheme) is achieved, as signal-to-noise ratio (SNR) tends to infinity. The BER performance is also compared between CG and GP maximization problems. Finally, the BER performance of these two optimization schemes are compared with the IA scheme, where it is shown that with the proposed FIA CG criterion will outperform the IA scheme, and will provide 0.7dB SNR gain for the same rate.

Track B – MIMO Communications and Signal Processing

Session: WAb1 – MIMO Processing

Chair: *David Love, Purdue University*

WA1b-1

10:15 AM

MMSE Receive Filtering for Precoded MIMO Systems

Ahmed Mehana, Samsung Electronics, Co., Ltd., United States; Aria Nosratinia, University of Texas at Dallas, United States

MIMO precoding matches the transmission to channel conditions in order to reduce or eliminate interference at the receiver. We consider the case where the precoder has been designed without the assumption of receiver-side equalization. However, this does not preclude receiver-side equalization. This paper analyzes the impact of MMSE receive filters on the performance of pre-designed MIMO precoders that are not optimized jointly with the receive filter. We show that receive-side MMSE equalization removes the error floors that can appear with regularized zero-forcing precoding and matched-filter precoding. We also show that using MMSE filters at both the transmitter and receiver can achieve the full spatial diversity when the spectral efficiency \mathcal{R} (b/s/Hz) is below a certain value.

WA1b-2

10:40 AM

Multiuser Hybrid Precoding for Millimeter Wave Cellular Systems

Ahmed Alkhateeb, Omar El Ayach, Robert W. Heath, Jr., University of Texas at Austin, United States

Ultra high data rates for cellular systems are possible by communicating over the large bandwidth available at millimeter wave (mmWave) frequencies. Realizing this technology, however, requires developing mmWave suitable precoding schemes that can overcome the associated hardware limitations, and meet the operating link budgets. Hybrid precoding with large antenna systems, that divides needed processing between analog and digital domains, has been recently shown to achieve a near-optimal performance in single-user mmWave channels [1], [2]. In this paper, we focus on the multi-user case, and design low-complexity yet highly-efficient hybrid precoding/combining algorithms by exploiting the sparse nature of the mmWave channel. Simulation results show that the proposed algorithms can approach the sum-rate achieved by unconstrained digital beamforming solutions, and offer substantial gains over analog-only precoders.

WA1b-3

11:05 AM

Linear Precoding for MIMO with LDPC Coding and Reduced Receiver Complexity

Thomas Ktseoglou, California State University, Pomona, United States; Ender Ayanoglu, University of California, Irvine, United States

In this paper, the problem of designing a linear precoder for Multiple-Input Multiple-Output (MIMO) systems employing Low-Density Parity-Check (LDPC) codes is addressed under the constraint of minimizing the dependence between the system's receiving branches, thus reducing the corresponding receiver complexity. The proposed approach constitutes an interesting generalization of Bit-Interleaved Coded Modulation with Multiple Beamforming (BICMB) which has shown many benefits in MIMO systems, while it keeps receiver complexity to a minimum due to receiving branch independence. Based on a Pareto optimal surface modeling of the system we show multiple properties regarding the desired precoder design, including optimality conditions, as well as the difficulty involved in the corresponding optimization problem. It is also shown that BICMB and Mercury Water Filling (MWF) constitute special cases on the overall Pareto optimal surface. We then propose an alternative, practical technique called Per-Group Precoding (PGP) which groups together multiple input symbol streams and corresponding receiving branches and then it precodes inputs from each group separately. Thus, PGP results into independent receiving streams between groups, while the precoding complexity per group is much lower due to the smaller dimensions involved. Under PGP, both the precoding and reception problems are converted into a multiple number of smaller dimension problems that are easier to solve.

WA1b-4

11:30 AM

Optimal Pilot Beam Pattern Design for Massive MIMO Systems

Song Noh, Michael D. Zoltowski, Purdue University, United States; Youngchul Sung, Korea Advanced Institute of Science and Technology, Republic of Korea; David J. Love, Purdue University, United States

In this paper, channel estimation for massive multiple-input multiple-output (MIMO) systems with a large number of transmit antennas at the base station is considered, and a new algorithm for pilot beam pattern design for optimal channel estimation under the assumption of Gauss-Markov channel processes is proposed. The proposed algorithm designs the optimal pilot beam pattern sequentially by exploiting the statistics of channel, antenna correlation, and temporal correlation, and the algorithm provides a sequentially optimal sequence of pilot beam patterns for a given set of system parameters. Numerical results show the effectiveness of the proposed algorithm.

Track A – Communications Systems

Session: WAa2 – OFDM

Chair: *Marko Kocic, MIT Lincoln Laboratory*

WA2a-1

8:15 AM

MIMO-OFDM Outage Channel Capacity With Practical Imperfect CSI

Marko Kocic, MIT Lincoln Laboratory, United States; Nicholas Chang, Applied Communication Sciences, United States; David Romero, Matthew Ferreira, MIT Lincoln Laboratory, United States

Link adaptation is one of key features of modern 3G and 4G communication systems, enabling significant boost in achievable throughput. Accurate link error prediction (equivalent to channel capacity estimation) is required for implementation of link adaptation. Practical link capacity algorithms almost universally require extensive simulation effort. On the other hand, research based on information theory, while considering no-ideal Channel State Information (CSI), has been limited to MMSE estimation algorithms, which are frequently not used in practice. In this paper we attempt to bridge the gap between these two approaches by extending the MIMO-OFDM outage capacity lower bound to practical CE algorithms, such as Least Squares (LS) estimation combined with linear interpolation, and most important RF imperfections, such as frequency offset. Numerical results show significant impact of practical CE methods on outage capacity in both low and high SNR region. Conversely, frequency offset is shown to have relatively small impact at low SNR, while limiting outage capacity at high SNR. In the final version of the paper we will compare effectiveness of lower outage capacity bounds as a link error prediction metric with the currently customary approach based on simulations. A MIMO-OFDM communication system that uses adjustable code rate GF(q) LDPC codes will be used for this comparison.

WA2a-2

8:40 AM

Biased Estimation of Symbol Timing Offset in OFDM Systems

Rohan Ramlall, University of California, Irvine, United States

For orthogonal frequency division multiplexing (OFDM) receivers, the mutual orthogonality of the subcarriers is preserved only if the estimated symbol timing error lies in the lock-in region. This paper is the first to investigate adding a bias to blind, unbiased coarse symbol time estimators, and analyze its performance in terms of the lock-in probability. The optimal value for the bias term is derived, and it is shown through simulation that the biased estimator achieves a significantly higher lock-in probability than the unbiased estimator.

WA2a-3

9:05 AM

A Factor-Graph Approach to Joint OFDM Channel Estimation and Decoding in Impulsive Noise Channels

Marcel Nassar, University of Texas at Austin, United States; Philip Schniter, The Ohio State University, United States; Brian Evans, University of Texas at Austin, United States

We propose a factor-graph-based approach to joint channel/noise-estimation-and-decoding (JCNE) of LDPC-coded orthogonal frequency division multiplexing (OFDM) systems in impulsive noise environments. Impulsive noise arises in many modern wireless and wireline communication systems, such as cellular LTE and powerline communications, due to uncoordinated interference that is much stronger than thermal noise. Our receiver merges prior knowledge of the impulsive noise models with the recently proposed “generalized approximate message passing” (GAMP) algorithm, and soft-input soft-output decoding through the sum-product framework. Unlike the prior work, we explicitly consider channel estimation in the problem formulation. For N subcarriers, the resulting receiver has a complexity of $O(N \log N)$, comparable to a typical DFT receiver. Numerical results indicate that the proposed receiver outperforms all prior impulsive noise OFDM decoders with improvements that reach 13dB when compared to the commonly used DFT receiver.

WA2a-4

9:30 AM

Widely Linear Data Estimation for Unique Word OFDM

Mario Huemer, Alexander Onic, Christian Hofbauer, Stefan Trampitsch, Alpen-Adria-Universität Klagenfurt, Austria

Unique word - orthogonal frequency division multiplexing (UW-OFDM) is known to feature an excellent bit error ratio performance when compared to conventional OFDM using cyclic prefixes (CP). Up to now linear and non-linear UW-OFDM receivers have been investigated and compared for proper data symbol constellations. However, strictly linear receivers are not able to exploit the whole potential for improper constellations like e.g. M-ASK (amplitude shift keying). In this work we will derive the widely linear minimum mean square error (WLMSE) estimator for the application to UW-OFDM in order to regain the wasted potential. We recognize a significant gain of the widely linear estimator over strictly linear methods, when using improper data symbol constellations.

Track A – Communications Systems

Session: WAb2 – Advances in Coding and Decoding

Chair: *Ashish Khisti, University of Toronto*

WA2b-1

10:15 AM

Efficiently Encodable Non-Binary Generalized LDPC Codes

Nicholas Chang, Applied Communication Sciences, United States; Marko Kocic, MIT Lincoln Laboratory, United States

This writeup examines the construction and performance of non-binary generalized low-density parity-check (GLDPC) codes. Recently, binary GLDPC coding techniques have been shown to improve upon conventional low-density parity-check (LDPC) codes by increasing the minimum codeword length, reducing error floors, and improving performance at lower coding rates. GLDPC codes replace the parity-check constraints of a standard LDPC code with stronger codes, e.g. short linear block codes. At the same time, non-binary LDPC codes have been shown to outperform their binary LDPC counterpart for shorter codeword lengths and for space-time coding applications in multiple-input multiple-output (MIMO) systems. Therefore, in contrast to previous works which have examined binary GLDPC codes, this paper explores non-binary GLDPC codes to combine all of the aforementioned benefits of non-binary LDPC and binary GLDPC codes. Additionally, nonbinary GLDPC codes can attain higher coding rates than the counterpart binary GLDPC codes. We first propose a class of GLDPC codes with low encoding complexity, where the number of encoding operations scales linearly with the codeword length. An example is provided to illustrate the performance and complexity benefits of GLDPC codes over non-binary LDPC codes at lower coding rates. In particular, a GF(4) GLDPC code is shown to outperform a strong GF(256) LDPC code while requiring approximately 9x less operations per information bit. It is also demonstrated that with the appropriate parameters, the non-binary GLDPC codes outperform non-binary LDPC codes with respect to both the error floor and waterfall performance. Furthermore, it is shown that performance remains strong for the same coding rate as the constellation changes; this result contrasts previous works which have demonstrated that for non-binary LDPC codes, optimal parameters such as the column weight need to be adjusted for different constellations. The final version will contain a more detailed description and results on parameter optimization for code construction and performance analysis.

WA2b-2

10:40 AM

Practical Non-Binary Rateless Codes for Wireless Channels

David Romero, Massachusetts Institute of Technology, United States; Nicholas Chang, Applied Communication Sciences, United States; Adam Margetts, Massachusetts Institute of Technology, United States

Modern wireless communication systems employ a variety of methods to help ensure reliable data transmission in challenging environments. One method uses a channel code designed such that a given transmission can be decoded by the receiver as soon as a sufficient number of symbols is received. Such a scheme is referred to as rateless coding. Rateless codes are well known for their application to erasure channels and there has recently been a growing interest in their use for physical-layer channels, such as additive white Gaussian noise and fading channels. For these kinds of channels, rateless codes are particularly useful in situations where the transmitter has little or no prior channel state information or when the channel is not stationary. In this paper, we study the performance of a rateless coding scheme which uses a combination of direct modulation and a novel, rate compatible, non-binary, LDPC code that is capable of excellent performance at many different code rates. We compare the performance and complexity of this method to other rateless schemes.

WA2b-3**11:05 AM****On the Optimality of Polar Codes for the Deterministic Wiretap Channel**

Ali Fakoorian, A. Lee Swindlehurst, University of California, Irvine, United States

Wiretap channel introduced by Wyner [1] in 1975, consists of a transmitter with a confidential message for the intended receiver which needs to be kept secret from the eavesdropper. While the perfect secrecy capacity of the wiretap channel, which quantifies the maximum rate at which a transmitter can reliably send a secret message to its intended recipient without it being decoded by an eavesdropper, is achievable based upon a random-coding argument, constructing channel coding schemes that achieve the secrecy capacity of a general wiretap channel is still an open problem. In this paper, we show that polar coding is an optimal coding scheme in achieving the secrecy capacity for the deterministic wiretap channel, where the channel between the transmitter and the intended receiver and the channel between the transmitter and the eavesdropper are arbitrary deterministic.

WA2b-4**11:30 AM****Delay-Optimal Streaming Codes under Source-Channel Rate Mismatch**

Pratik Patil, Ahmed Badr, Ashish Khisti, University of Toronto, Canada; Wai-Tian Tan, Hewlett-Packard Labs, United States

We study low-delay error correction codes for streaming-recovery over a class of packet-erasure channels. In our setup, the encoder observes one source frame every M time slots, but is required to transmit a channel packet in each time slot. The decoder is required to reconstruct each source frame within a playback delay of T source frames. The collection of M transmitted channel packets between successive source frames is called a (channel) macro-packet. For a certain class of burst-erasure channels, we characterize the associated capacity and develop explicit codes that attain the capacity. We recover as a special case, the capacity when $M=1$, studied in earlier works. Our proposed code constructions involve splitting each source frame into two groups of sub-symbols, applying unequal error protection and carefully allocating source and parity-check sub-symbols within each (channel) macro-packet. Our constructions are a non-trivial extension of the previously proposed codes for $M=1$. Simulation results indicate significant gains over baseline error correction codes for the Gilbert model for burst erasures.

*Track D – Signal Processing and Adaptive Systems***Session: WAa3 – Adaptive Filtering**Chair: *Ric Romero, Naval Postgraduate School***WA3a-1****8:15 AM****A Gradient-Controlled Proportionate Technique for Acoustic Echo Cancellation**

Jie Yang, Texas Instruments, United States; Gerald Sobelman, University of Minnesota, United States

In acoustic echo cancellation (AEC), the echo paths are often long, sparse and rapidly changing. In this paper, a new gradient controlled proportionate adaptation technique is proposed for AEC, where a time-averaging gradient estimate is assigned as the gain distribution vector to update filter taps proportionally to the magnitude of the mean of the gradient vector. Based on this technique, we propose the gradient-controlled improved proportionate affine projection algorithm (GC-IPAPA), and gradient-controlled improved proportionate normalized least mean square algorithm (GC-IPNLMS). Simulation results demonstrate significant improvements in convergence rate and a more robust performance compared with traditional proportionate algorithms for AEC.

WA3a-2**8:40 AM****Interference Identification in Cellular Networks via Adaptive Projected Subgradient Methods**

Konstantin Oltmann, Renato L. G. Cavalcante, Slawomir Stanczak, Martin Kasparick, Fraunhofer Heirinch Hertz Institute, Germany

We develop an adaptive algorithm to estimate a channel gain matrix in cellular heterogeneous networks. This algorithm has the objective of providing important information to interference coordination and management schemes, a crucial functionality of “beyond 2020 networks”. In more detail, we pose the estimation problem as a set-theoretic adaptive filtering problem. In the proposed scheme, the channel gain matrix is tracked with the adaptive projected subgradient method (APSM), a powerful iterative tool that can seamlessly use prior information and information gained by measurements. More precisely, we construct multiple closed convex sets, each of which containing estimates that are consistent with a piece of information about the channel gain matrix. The intersection of these sets corresponds to estimates that are consistent with all available information. In particular, we use the following information to construct the sets: i) physical upper and lower bounds of the path gains, ii) interference bounds for the downlink and uplink communication, and iii) received signal received power (RSRP) measurements.

The algorithm produces a sequence of estimates where each term is an estimate that approaches the intersection of the multiple sets available at a given time instant. Simulations show that the proposed algorithm is able to track the channel gain matrix in scenarios with mobile users, and it significantly outperforms standard adaptive filters that do not use prior information.

WA3a-3

9:05 AM

A Reconsideration of Improved PNLMS Algorithm From Metric Combining Viewpoint

Osamu Toda, Masahiro Yukawa, Keio University, Japan

In this paper, we show the importance of considering metric in adaptive filtering through a reconsideration of the improved proportionate normalized least mean square (IPNLMS) algorithm for sparse systems from a viewpoint of metric combining. IPNLMS convexly combines a positive-definite diagonal matrix (whose diagonal elements are proportional to the absolute values of the adaptive filter to reflect the system sparsity) with the identity matrix. We present the metric-combining NLMS (MC-NLMS) algorithm and derive, as its special example, the natural PNLMS (NPNLMS) algorithm. NPNLMS can be regarded as a modified version of IPNLMS and we show that NPNLMS is more natural (and performs better) than IPNLMS.

WA3a-4

9:30 AM

Detection Performance of Matched Transmit Waveform for Moving Extended Targets

Ric Romero, Naval Postgraduate School, United States

Depending on the radar-target dynamics, the time extent and amplitude of a moving extended target from a radar's perspective may actually change as a function of relative motion. It follows that waveform design should accommodate for the increase or decrease of a target's time extent and changes in amplitude as the target moves towards or away from a radar or vice versa. This paper shows the performance gain and/or degradation of both matched transmit waveform (called eigenwaveform) and the classical wideband pulsed transmit waveform when the effect of motion on target's time extent and amplitude changes are considered.

Track A – Communications Systems

Session: WAb3 – Detection

Chair: *Wei Zhang, University of New South Wales*

WA3b-1

10:15 AM

Asynchronous Signal Detection in Frequency-Selective Non-Gaussian Channels

SaiDhiraj Amuru, Daniel Jakubisin, R. Michael Buehrer, Virginia Tech, United States; Claudio da Silva, Samsung Electronics, Co., Ltd., United States

We present a signal detection algorithm for digital amplitude-phase modulated signals in frequency-selective fading channels with non-Gaussian noise. We consider an asynchronous scenario in which the timing (symbol transition epochs) is unknown and a symbol rate offset is present due to clock drift. A Gibbs sampling-based algorithm is proposed to estimate the unknown parameters and signal detection is performed using a maximum-likelihood procedure. The additive noise is modeled by a Gaussian mixture distribution, a well-known model for man-made and natural noise. Numerical results are presented to characterize the performance of the proposed algorithm.

WA3b-2

10:40 AM

An Information Theoretic Characterization of the Channel Shortening Receiver

Fredrik Rusek, Lund University / Huawei, Sweden; Ove Edfors, Lund University, Sweden

Channel shortening detection (CSD) has been studied for 40 years since Falconer and Magee's original 1973 paper. However, CSD was first optimized for mutual information in 2012. In this paper we study achievable rates of optimized CS detectors for MIMO and discovers that the rates can be written on exactly the same form, but more general, as the achievable rate of an MMSE receiver. The MMSE-rate framework was recently developed by McKay, Collings, and Tulino and by our discovery it follows that all their results can be carried over to the case of CS. In fact, the results of [MCT] become special cases of the CS results when the detector memory is set to 0.

WA3b-3**11:05 AM****Iterative MMSE-SIC Receiver with Low-Complexity Soft Symbol and Residual Interference Estimations**

Guosen Yue, Sampath Rangarajan, NEC Laboratories America, Inc., United States

In this paper, we develop low-complexity methods to compute the soft symbol and interference estimations for QAM constellations with applications to iterative MMSE-SIC receivers. In particular, we propose a bit flipping based estimation scheme. With Gray mapping, we derive efficient approaches for both soft symbol and variance estimations with the complexities of $O(\log N)$ and $O((\log N)^2)$, respectively, for an N-QAM constellation. We also present an improved approach which completely removes the multiplication operations at a cost of a slight performance degradation. We also extend the proposed methods to the non-squared QAM.

WA3b-4**11:30 AM****New Results in the Analysis of Decision-Feedback Equalizers**

Ahmed Mehana, Samsung Electronics, Co., Ltd., United States; Aria Nosratinia, University of Texas at Dallas, United States

This paper considers the decision feedback equalizers (DFE) with finite impulse response (FIR). Although they have been the subject of a number of studies, several long-standing problems in the analysis of these equalizers remained open. For the most part, the problems addressed in this paper are in the domain of high-SNR analysis, including the Diversity-Multiplexing Tradeoff (DMT) for DFE. We find that the DFE fixed-rate diversity follows the DMT analysis, unlike several examples from linear equalization in the recent literature where the fixed-rate diversity departed from the DMT expression. As part of the developments of this paper, the notion of the $\{\text{em spectral representation}\}$ of random processes is used to remove complications that existed in the analysis of the DFE.

*Track C – Networks***Session: WAa4 – Relaying and Cooperation**Chair: *Hieu Do, KTH Royal Institute of Technology***WA4a-1****8:15 AM****Two-Way Amplify-and-Forward Relay Strategies under Relay Power Constraint**

Kanghee Lee, Hyuck M. Kwon, Edwin M. Sawan, Wichita State University, United States; Hyuncheol Park, Korea Advanced Institute of Science and Technology, Republic of Korea

This paper proposes a two-way amplify-and-forward (AF) wireless relay network consisting of two sources with a single antenna and one relay with multiple antennas. The relay amplifying matrix under a power constraint at the relay is presented. The minimum mean square error (MMSE) criterion with self-interference cancelation is employed using vectorization and singular value decomposition (SVD) methods, while the MMSE and matched-filter (MF) criteria without self-interference cancelation are implemented. Using the derived optimal relay amplifying matrix, the average bit error rate (BER) and average mean square error (MSE) behaviors are evaluated.

WA4a-2**8:40 AM****Gaussian Interfering Relay Channels**

Hieu T. Do, Tobias J. Oechtering, Mikael Skoglund, KTH Royal Institute of Technology, Sweden; Mai Vu, Tufts University, United States

We extend the primitive relay channel (PRC) introduced by Cover and Kim to a more general scenario where two Gaussian PRC's cause interference to each other. We show that extended hash-and-forward relaying with proper power allocation can achieve a bounded gap to the capacity region, as long as the interference each transmitter induces at the neighboring relay is not unboundedly stronger than the interference induced at the neighboring receiver.

WA4a-3**9:05 AM****Throughput Improvements for Cellular Systems with Device-to-Device Communications**

PhuongBang Nguyen, Bhaskar Rao, University of California, San Diego, United States

We consider the resource allocation problem in cellular networks which support Device-to-Device Communications (D2D) under the orthogonal resource sharing setting. We propose and analyze two resource allocation schemes that guarantee perfect access fairness among all users, regardless of whether they are cellular or D2D, while taking advantage of multi-user diversity and local

D2D communications to provide marked improvements over existing cellular-only schemes. The first scheme, Cellular Fairness Scheme, provides the simplest D2D extension to existing cellular systems, while the second scheme, D2D Fairness Scheme, harnesses maximal performance from D2D enabled systems under the orthogonal sharing setting.

WA4a-4

9:30 AM

Cooperative Simultaneous Localization and Synchronization: A Distributed Hybrid Message Passing Algorithm

Bernhard Etzlinger, Johannes Kepler University, Austria; Florian Meyer, Vienna University of Technology, Austria; Andreas Springer, Johannes Kepler University, Austria; Franz Hlawatsch, Vienna University of Technology, Austria; Henk Wymeersch, Chalmers University of Technology, Sweden

Localization and synchronization in wireless networks are strongly related when they are based on inter-node time measurements. We leverage this relation by presenting a message passing algorithm for cooperative simultaneous localization and synchronization (CoSLAS). The proposed algorithm jointly estimates the locations and clock parameters of the network nodes in a fully decentralized manner while requiring time measurements and communications only between neighboring nodes and making only minimal assumptions about the network topology. Low computation and communication requirements are achieved by a hybrid use of sample-based and Gaussian belief propagation. Our simulations demonstrate performance advantages of the proposed CoSLAS algorithm over separate state-of-the-art localization and synchronization algorithms.

Track H – Speech, Image and Video Processing

Session: WAa5 – Image Analysis and Processing

Chair: *Marios Pattichis, University of New Mexico*

WA5a-1

8:15 AM

Multiscale AM-FM Image Reconstructions Based on Elastic Net Regression and Gabor Filterbanks

Ioannis Constantinou, University of Cyprus, Cyprus; Marios Pattichis, University of New Mexico, United States; Constantinos Pattichis, University of Cyprus, Cyprus

Current multi-scale AM-FM image analysis methods are based on the use of Dominant Component Analysis (DCA), multi-scale DCA, and Channel Component Analysis (CCA). In this paper, we introduce a new AM-FM component selection method based on elastic net regression. The new approach is implemented using a family of Gabor filterbanks, each of them based on different filter scale overlap characteristics. The results show that the elastic net regression component selection algorithm performs better than all other methods.

WA5a-2

8:40 AM

Colorization Based on Piecewise Autoregressive Model

Yasuhiro Nakajima, Takashi Ueno, Taichi Yoshida, Masaaki Ikehara, Keio University, Japan

Colorization is a technique to produce color components for grayscale images with color assigned information provided by the user. The conventional method colorizes via propagating the assignments with weights of neighborhood pixels. In this paper, we propose the colorization method based on the piecewise autoregressive (AR) model. The proposed method calculates weights considering an image structure, and improves objective and perceptual qualities of colorized images compared with the conventional method.

WA5a-3

9:05 AM

Image Denoising by Adaptive Directional Lifting-Based Discrete Wavelet Transform and Quantization

Naoki Furuhashi, Azusa Oota, Taichi Yoshida, Masaaki Ikehara, Keio University, Japan

In this paper, we propose the non-local method for image denoising via adaptive directional lifting-based discrete wavelet transform (ADL) and quantization. The non-local methods such as non-local means are interested in image denoising based on the self-similarity. They search similar blocks and estimate the original value. The proposed method doesn't search but generates new similar blocks by ADL with multiple directions, and quantization to denoise. It improves the denoising quality and reduces the computational complexity. Finally, we compare the proposed and conventional method, and show an advantage of them.

WA5a-4

9:30 AM

Introducing Diversity to Normalized Cross Correlation for Dense Image Registration

Nafise Barzigar, Aminmohammad Roozgard, Pramode Verma, Samuel Cheng, University of Oklahoma, United States

Normalized Cross Correlation (NCC) has been extensively used for image registration, but applying NCC alone does not result in sufficient accuracy for many scenarios. In this paper, we propose a simple yet accurate dense image registration method by introducing diversity to “candidates” of NCC matches. We then select the best match using Belief Propagation (BP) to incorporate non-local geometric information into the calculation. We compared our proposed method with a control method when diversity is not incorporated and a state-of-the-art image registration method, SCoBeP.

Track E – Array Signal Processing

Session: WAb5 – Target Tracking II

Chair: *Peter Willett, University of Connecticut*

WA5b-1

10:15 AM

Posterior Distribution Preprocessing for Passive DTV Radar Tracking: Simulated and Real Data

Evan Hanusa, Laura Vertatschitsch, David Krout, University of Washington, United States

This work presents the results of a multistage tracking framework on two types of passive radar data. The framework consists of three stages: range/range rate tracking to reject clutter, a posterior distribution transmitter fusion step, and a JPDA-based tracker. The overall system is applied to a simulated passive DTV radar dataset which contains two sets of SFN transmitters. The simulated dataset includes range, range rate, and azimuth measurements. We also present results on a new passive DTV radar dataset, which includes multiple transmitters on different frequencies.

WA5b-2

10:40 AM

Depth-Based Passive Tracking of Submerged Sources in the Deep Ocean Using a Vertical Line Array

Lisa Zurk, Jordan Shibley, Portland State University, United States

Underwater sources detected on vertical line arrays (VLAs) deployed below the critical depth in deep ocean environments can travel via the reliable acoustic path (RAP), with minimal transmission loss. However, VLAs have no horizontal aperture to reject loud nearby shipping noise that also arrives via RAP propagation. In this paper a new technique of depth-based tracking is used to discriminate surface versus submerged sources. The depth-based tracking exploits the harmonic modulation of the received energy caused by the interference between direct and surface-bounce arrivals. Results are shown for submerged sources in the presence of surface interferers.

WA5b-3

11:05 AM

Generalized Linear Minimum Mean-Square Error Estimation with Application to Space-Object Tracking

Yu Liu, X. Rong Li, Huimin Chen, University of New Orleans, United States

The linear minimum mean-square error (LMMSE) estimation has been shown to provide a good tradeoff between the computational requirement and estimation accuracy in nonlinear point estimation. However, the best estimator within linear class may not be adequate to provide acceptable accuracy when dealing with a highly nonlinear system. We propose a generalized LMMSE (GLMMSE) estimation framework that searches for the best estimator among all the estimators that are linear in a vectorvalued function (namely, measurement transform function) of data. The measurement transform function may convert or augment the original measurement model. General guidelines for designing the GLMMSE estimator are discussed based on a numerical example. With properly designed measurement transform function, GLMMSE estimation should perform no worse than LMMSE estimation if the moments involved can be computed exactly. We apply the GLMMSE estimation to a spaceobject tracking problem and its performance is compared with the conventional LMMSE estimators.

WA5b-4

11:30 AM

Feature-Aided Initiation and Tracking via Tree Search

Hossein Roufardshbaf, Jill Nelson, George Mason University, United States

We present a feature-aided approach to multiple-target tracking based on the tree-search tracker. Using a tree to represent sample paths through the target state space, the tracker navigates the tree in search of the most likely sequence of states visited by the targets. The search for new targets and for new states of existing targets is governed by path metrics that are proportional to the posterior state distribution and incorporate the likelihood of observed feature values. Features may be assumed to follow a given statistical model, or their probability density function may be estimated empirically using the feature history stored within each path in the tree. The performance of the feature-aided tracker with respect to target detection/tracking and clutter rejection is evaluated using the CLUTTER'09 dataset.

Track E – Array Signal Processing

Session: WAa6 – Multi-Sensor Signal Processing

Chair: *Shawn Kraut, MIT Lincoln Laboratory*

WA6a-1

8:15 AM

Why Does Direct-MUSIC on Sparse-Arrays Work?

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

The nested and coprime arrays have recently been introduced as systematic structures to construct difference coarrays with $O(m^2)$ elements, where m is the number of array elements. They are therefore able to identify $O(m^2)$ sources (or DOAs) under the assumption that the sources are uncorrelated. In view of their larger aperture compared to uniform linear arrays (ULAs) with the same number of elements, these arrays have some advantages over conventional ULAs even in the cases where the number of sources is less than m , such as improved Cramer-Rao bounds and improved resolvability for closely spaced sources. It has recently been shown that in such situations and under mild assumptions on source locations, it is possible to use subspace techniques such as the MUSIC algorithm directly on these sparse arrays, instead of on the coarrays, thereby making the resulting algorithms simpler. Thus the ambiguity introduced by the sparsity of the arrays is overcome with the help of extra elements with coprime spacing, even if there are multiple sources. The purpose of this paper is to give the theoretical justification for this.

WA6a-2

8:40 AM

Asymptotically Optimal Truncated Hypothesis Test for a Large Sensor Network Described by a Multivariate Gaussian Distribution

Jiangfan Zhang, Rick Blum, Lehigh University, United States

While recent advances have provided extremely efficient distributed methods for computing optimum test statistics for many hypothesis testing problems occurring in large sensor networks, the popular multivariate Gaussian hypothesis testing problem involving a change in both the mean vector and covariance matrix is not one of these. The difficulty is that these test statistics generally require long range communications. A truncated test is studied which only requires that each sensor shares information with k neighboring sensors out of a set of L total sensors. Sufficient conditions are given on truncation rules, k as a function of L , and sequences of hypothesis testing problems to ensure no loss in deflection performance as L approaches infinity when compared to the optimum untruncated detector. For several popular classes of limiting covariance matrix models, including observations from wide-sense stationary limiting processes, the sufficient conditions are shown to be satisfied for truncation rules which increase very slowly compared to L even when the difficulty of the hypothesis testing problem scales in the least favorable manner. Numerical results imply the fixed-false-alarm-rate detection probability of the truncated detector converges rapidly to the detection probability of the optimum untruncated detector.

WA6a-3

9:05 AM

A Joint Localization and Synchronization Technique Using Time of Arrival at Multiple Antenna Receivers

Siamak Yousefi, Xiao-Wen Chang, Benoit Champagne, McGill University, Canada

In this work, a system scheme is proposed for tracking a radio emitting target moving in two-dimensional space. The localization is based on the use of biased time-of-arrival (TOA) measurements obtained at two asynchronous receivers, each equipped with two closely spaced antennas. By exploiting the multi-antenna configuration and using all the TOA measurements up to current time step, the relative clock bias at each receiver and the target position are jointly estimated by solving a nonlinear least-squares (NLS) problem. To this end, a novel time recursive algorithm is proposed which fully takes advantage of the problem structure to

achieve computational efficiency while using orthogonal transformations to ensure numerical reliability. The Cramer-Rao lower bound (CRLB) is also derived as a lower bound on the error in estimating the position and biases. Simulation results show that the mean-squared error (MSE) of the proposed method approaches the CRLB closely.

WA6a-4

9:30 AM

Reducing the Fractional Rank of Interference with Space-Time-Frequency Adaptive Beamforming

Shawn Kraut, Adam Margetts, MIT Lincoln Laboratory, United States; Daniel Bliss, Arizona State University, United States

When wideband interference is subject to multi-path, the rank of the interference component sensed at a receive-antenna array increases. In a MIMO communications system, this makes it more challenging to suppress the interference and close the link. In this paper we investigate the use of adaptive filters to suppress interference, by quantifying the impact of multiple time taps and frequency ``taps'' on the rank of the interference. We show that as the number of taps increases, the relative rank of the interference decreases asymptotically to one over the number of receive antennas. We verify this with measurements of a broadcast interference source.

Track E – Array Signal Processing

Session: WAb6 – Direction of Arrival Estimation

Chair: *Mark Fowler, SUNY Binghamton*

WA6b-1

10:15 AM

A Self-Calibration Technique for Direction Estimation with Diversely Polarized Arrays

Benjamin Friedlander, University of California, Santa Cruz, United States

A self-calibration algorithm is presented for direction finding using diversely polarized arrays in the presence of sensor gain and phase uncertainties. The method jointly estimates the directions of arrival of all the sources as well as the gain and phase of each sensor in the array. The technique is based on iterating between direction estimation and gain/phase estimation. The first is accomplished by the MUSIC algorithm and the latter by the calculation of the smallest eigenvalue of a certain matrix. A key feature of this approach is that the computation of the gain/phase coefficients does not involve search and is computationally efficient. The performance of the algorithm is illustrated by numerical examples and is shown to be close to the Cramer-Rao bound for the joint estimation problem.

WA6b-2

10:40 AM

Cramer-Rao Performance Bounds for Simultaneous Target and Multipath Positioning

Li Li, Jeff Krolik, Duke University, United States

This work considers the performance of none-light-of-sight (NLOS) target localization method using a distributed receiver array. The multipath propagation is modeled with single bounce reflection from unknown random scatters. A Simultaneous Target and Multipath Positioning (STAMP) method is proposed for jointly estimating the target and scatter positions given Time-of-Arrival (TOA) observations. The Cramer-Rao Lower Bound (CRLB) is derived for the STAMP method and analyzed to establish the identifiability of this joint estimation problem. The CRLB is also extended to the case of data association uncertainty in term of the Fisher Information Reduction Matrix, which is illustrated and further more discussed using numerical examples

WA6b-3

11:05 AM

Copy Correlation Direction-of-Arrival Estimation Performance with a Stochastic Weight Vector

Christ Richmond, Keith Forsythe, MIT Lincoln Laboratory, United States; Christopher Flynn, Stevens Institute of Technology, United States

Copy-aided direction finding of co-channel signals with known structure is an effective method of angle estimation applicable to any blind or non-blind frontend signal processing. The frontend processing yields for each emitter a copy weight vector that can be correlated with an angle dependent hypothesized adaptive beamformer to extract direction-of-arrival (DOA). The mean squared error (MSE) performance of this method is extended to include the stochastic nature of the copy weight vectors. Prediction of the DOA MSE performance of copy weights derived from the well-known constant modulus algorithm is explored as an application of the results.

WA6b-4

11:30 AM

Locating Closely Spaced Coherent Emitters Using TDOA Techniques

Jack Reale, Lauren Huie, Air Force Research Laboratory, United States; Mark Fowler, State University of New York at Binghamton, United States

This paper considers the problem of locating closely-spaced coherent emitters. Classical TDOA-based emitter location methods assume only a single emitter is being estimated. As a result, when multiple emitters that cannot be resolved during detection exist, the MSE performance is significantly degraded. These errors are due to the fact that the TDOA observation model does not account for multiple transmissions. We propose a new TDOA observation model that can resolve multiple emitted signals. We show a significant improvement in MSE when locating multiple emitters using our new model as compared with the classical one-emitter assumption TDOA model.

Track G – Architecture and Implementation

Session: WAa7 – Communication System Design

Chair: *Jorn Janneck, Lund University*

WA7a-1

8:15 AM

Implementation of Selective Packet Destruction on Wireless Open-Access Research Platform

Stephen Hughes, Bosheng Zhou, Roger Woods, Alan Marshall, Queen’s University Belfast, United Kingdom

Interesting wireless networking scenarios exist wherein network services must be guaranteed for priority users in a dynamic fashion, such as in disaster recovery where members must quickly block other users’ transmissions in order to gain sole use of the Wi-Fi channel. As it is not always feasible to physically switch off users, a selective packet destruction (SPD) solution is proposed that ensures priority service. This paper describes a test-bed for SPD destruction that is based on the Wireless open-Access Research Platform. Extensive measurements between performance and acknowledgement destruction rate were performed and show a 70% reduction in TCP traffic for a 50% MAC ACK destruction rate can be achieved.

WA7a-2

8:40 AM

Efficient Error-Aware Power Management for Memory Dominated OFDM Systems

Muhammad S. Khairy, Ahmed M. Eltawil, Fadi J. Kurdahi, University of California, Irvine, United States; Amin Khajeh, Intel labs, United States

In this paper, we exploit the dynamic and statistical nature of wireless signals to aggressively scale the supply voltage of buffering memory modules using Voltage over Scaling (VoS) to save power. VoS introduces a controlled amount of spatially random errors in embedded memory modules. This paper presents a novel approach to model VoS induced noise as Gaussian noise that can be analytically described to obtain the system performance in terms of PER. Finally, power management policies are presented that utilize the available slack in the received SNR to minimize power consumption, while keeping performance within normative margins.

WA7a-3

9:05 AM

FPGA Implementation of a Message-Passing OFDM Receiver for Impulsive Noise Channels

Karl Nieman, Marcel Nassar, Jing Lin, Brian Evans, University of Texas at Austin, United States

Conventional orthogonal frequency division multiplexing (OFDM) communication systems are typically designed assuming additive white Gaussian noise and interference statistics. However, in many applications, such as Wi-Fi and powerline communications (PLC), impulsive statistics are often observed. Impulsive noise can degrade the signal-to-noise ratio (SNR) of all subcarriers and impair communication performance. In this work, we design and implement a real-time OFDM receiver with approximate message passing (AMP) to estimate and mitigate impulsive noise. The goal is to meet throughput and latency requirements while guaranteeing improved communication performance in impulsive noise. Our contributions include (i) modeling functional parallelism in an AMP OFDM receiver in synchronous dataflow, (ii) converting an AMP OFDM PLC receiver to using only fixed-point data and arithmetic, and (iii) mapping the receiver in fixed-point onto a Field Programmable Gate Array (FPGA) target using a high-level graphical synthesis tool. Our FPGA OFDM transceiver testbed achieves full streaming throughput at G3-PLC rates and recovers up to 8 dB SNR of impulsive noise over a wide SNR range.

WA7a-4**9:30 AM****Mobile Transmitter Digital Predistortion: Feasibility Analysis, Algorithms and Design Exploration**

Mahmoud Abdelaziz, Tampere University of Technology, Finland; Amanullah Ghazi, University of Oulu, Finland; Lauri Anttila, Tampere University of Technology, Finland; Jani Boutellier, University of Oulu, Finland; Toni Lähteensuo, Tampere University of Technology, Finland; Xiaojia Lu, University of Oulu, Finland; Joseph R. Cavallaro, Rice University, United States; Shuvra Bhattacharyya, University of Maryland, United States; Markku Juntti, University of Oulu, Finland; Mikko Valkama, Tampere University of Technology, Finland

This article addresses intermodulation challenges in carrier aggregation and multicarrier type transmission scenarios in mobile transmitters. In such transmission schemes, emerging in 3GPP LTE-Advanced mobile cellular radio evolution, the spectrum of the signal entering the transmit power amplifier (PA) is of non-contiguous nature and thus severe intermodulation is created. To satisfy the stringent emission requirements and limits, devices may need to considerably back off their transmit power, compared to nominal value of +23dBm, but this then also heavily impacts the uplink coverage. As an alternative, feasibility of digital predistortion (DPD) is explored in this article. Specifically tailored algorithm solutions, with reduced complexity, to control the most critical intermodulation components from terminal emission mask perspective are developed. Furthermore, digital design exploration is carried out, implying that the needed computational resources are close to what is already available in most advanced mobile platforms and chipsets in the market. To complement the cross-disciplinary contributions, we also provide uplink system performance results where the impact of linearization is assessed at cellular system level.

*Track G – Architecture and Implementation***Session: WAb7 – Energy- and Reliability-Aware Design**

Chair: *Neil Burgess, ARM*

WA7b-1**10:15 AM****Low-Energy Architectures for Support Vector Machine Computation**

Manohar Ayinala, Keshab K. Parhi, University of Minnesota, United States

This brief presents a novel architecture for Support Vector Machines (SVMs), a machine learning algorithm that performs classification tasks. SVMs achieve very good classification accuracy at the cost of high computational complexity. We propose a low-energy architecture based on approximate computing by exploiting the inherent error resilience in the SVM computation. We present two design optimizations, fixed-width multiply-add and non-uniform look-up table (LUT) for exponent function to minimize power consumption and hardware complexity while retaining the classification performance. A novel non-uniform quantization scheme is proposed for implementing the exponent function which reduces the size of the look-up table by 50%. The proposed non-uniform look-up table reduces the power consumption by 35% using 10-bit quantization. The proposed architecture is programmable and can evaluate three different kernels (linear, polynomial, radial basis function (RBF)). The proposed design consumes 31% less energy on average compared to a conventional design. We estimate that SVM computation using RBF kernel can be performed in 382.2nJ for 36 features and 5000 support vectors using 65nm technology.

WA7b-2**10:40 AM****Truncated Multipliers through Power-Gating for Degrading Precision Arithmetic**

Pietro Albicocco, Gian Carlo Cardarilli, Univ Roma Tor Vergata, Italy; Alberto Nannarelli, Technical University of Denmark, Denmark; Massimo Petricca, Politecnico di Torino, Italy; Marco Re, Univ Roma Tor Vergata, Italy

When reducing the power dissipation of resource constrained electronic systems is a priority, some precision can be traded-off for lower power consumption. In signal processing, it is possible to have an acceptable quality of the signal even introducing some errors. In this work, we apply power-gating to multipliers to obtain a programmable truncated multiplier. The method consists in disabling the least-significant columns of the multiplier by power-gating logic in the partial products generation and accumulation array.

WA7b-3**11:05 AM****A Logarithmic Approach to Energy-Efficient GPU Arithmetic for Mobile Devices**

Miguel Lastras, Behrooz Parhami, University of California, Santa Barbara, United States

Graphic processing units (GPUs) have emerged as useful components in the realization of high-performance and cost-effective digital systems for numerically intensive applications, from simple personal devices to large-scale supercomputers. In this paper, we consider GPUs that incorporate energy-efficient logarithmic arithmetic units. After analyzing numerical errors arising from such an implementation scheme, we present a simple fine-tuning of the design to reduce the worst-case error.

On Separable Error Detection for Addition

Michael Sullivan, Earl Swartzlander, University of Texas at Austin, United States

Addition is ubiquitous in computer systems, and rising error rates make error detection within adders increasingly important. This paper considers the best way to introduce strong, non-intrusive error detection to fixed-point addition within an existing, optimized machine datapath. A flexible family of separable error detection techniques is presented that offer superior error detection efficiency for a variety of adders.

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