THE ELISHA YEGAL BAR-NESS CENTER FOR WIRELESS COMMUNICATIONS AND SIGNAL PROCESSING RESEARCH ACTIVITY REPORT

2015-2016

NJIT
New Jersey Institute of Technology

ABOUT THE CENTER

The Elisha Yegal Bar-Ness Center for Wireless Communications and Signal Processing Research (CWCSPR) engages in a broad range of research areas ranging from wireless communications, radar, sensor networks, cloud radio, information theory, and signal processing. A unifying theme of CWCSPR is research on 5G wireless mobile networks. CWCSPR seeks new collaborations with the wireless communications industry as well as other academic institutions.

There are five faculty members associated with the Center and more than 20 graduate students, most of them pursuing their doctoral degrees.

CWCSPR routinely hosts visiting researchers, postdocs, and students from overseas. Several students pursue double Ph.D. programs as the result of agreements between NJIT and other universities.

For more information, please contact Alexander Haimovich, Director of CWCSPR, at 973-596-3534, or alexander.m.haimovich@njit.edu.

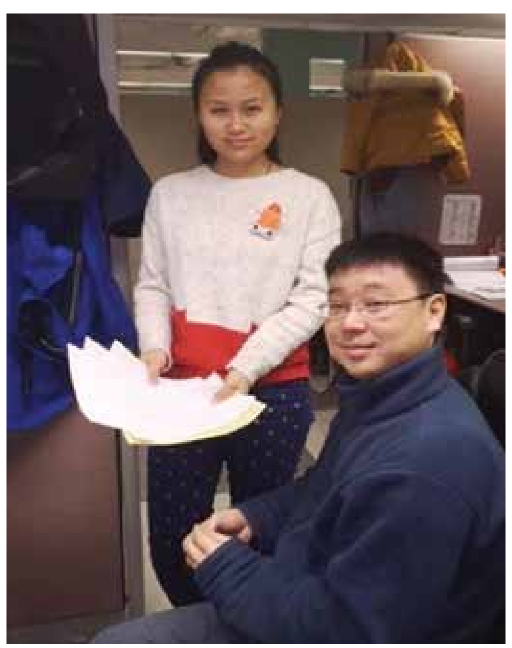
VISION OF THE CENTER

Primary Goal:

To serve as a focal point in the Department of Electrical and Computer Engineering for research on wireless, communications and signal processing.

Activities carried out by participating faculty:

- Initiate and pursue research in the fields of wireless communications and signal processing.
- Search collectively, as well as individually, for possible sources of financial research support for themselves and their affiliates (graduate students or visiting faculty).
- Establish contacts in the electronics industry in the Newark metropolitan area and New Jersey as a whole, learn about the industry's needs, and suggest methods of collaboration.
- Assume responsibility for teaching graduate courses in the fields of communications and signal processing, propose and plan new courses, and monitor graduate courses taught by adjunct faculty.
- Undertake initiatives to recruit highly qualified graduate students, research associates, and visiting faculty members, in addition to supporting the efforts of the department chairman to recruit new faculty.
- Suggest, design, prepare, and deliver short courses as part of the New Jersey Institute of Technology's continuing education program.
- Organize seminars on topics of interest to CWCSPR members, the Department of Electrical and
- Computer Engineering, and local industry.



RESEARCH INTERESTS OF CENTER FACULTY

Vector Acoustic Communication Technology for High-Speed Underwater Modems

Faculty: Ali Abdi
Graduate Student: Erjian (Eric) Zhang
Sponsor: NSF

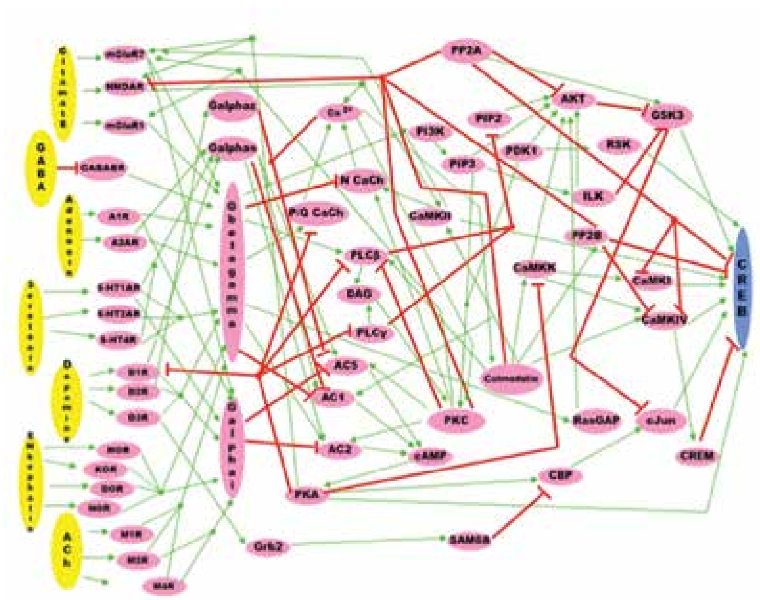
Innovative Communication and Signal Processing (iCASO) Lab setup at NJIT for underwater communication prototype test and development

More than 75 percent of the earth's surface is covered with water that overlays many resources upon which our lives depend. High speed wireless underwater data communication between underwater sensors, deepwater moored instruments, autonomous underwater vehicles, and surface vessels is of crucial importance in many applications of national interest. However, the achievable data rates by the conventional technologies are much smaller than what is needed for effective communication and management. To create high speed communication links in underwater environments, the transformative concept of communication via the vector components of the acoustic field was proposed and developed by A. Abdi in a prior NSF-supported project.

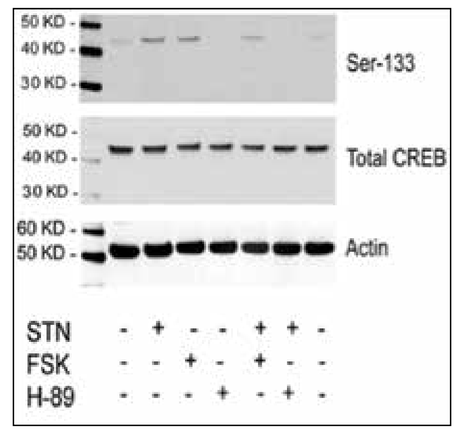
In this new project, a prototype modem will be developed, based on the vector field concept. The key difference between the new modem and other existing modems is that it uses vector transducers, which are compact multichannel devices, to transmit several data streams via multiple particle velocity vector channels. Other modems use scalar transducers, which can modulate the data only on the scalar acoustic pressure.

FAULT DIAGNOSIS AND THERAPEUTIC TARGET DISCOVERY IN HUMAN SIGNAL TRANSDUCTION NETWORKS

Faculty: Ali Abdi
Graduate Student: Iman Habibi (Ph.D. graduate)



The CREB signal transduction network



Western blot analysis for experimental verification

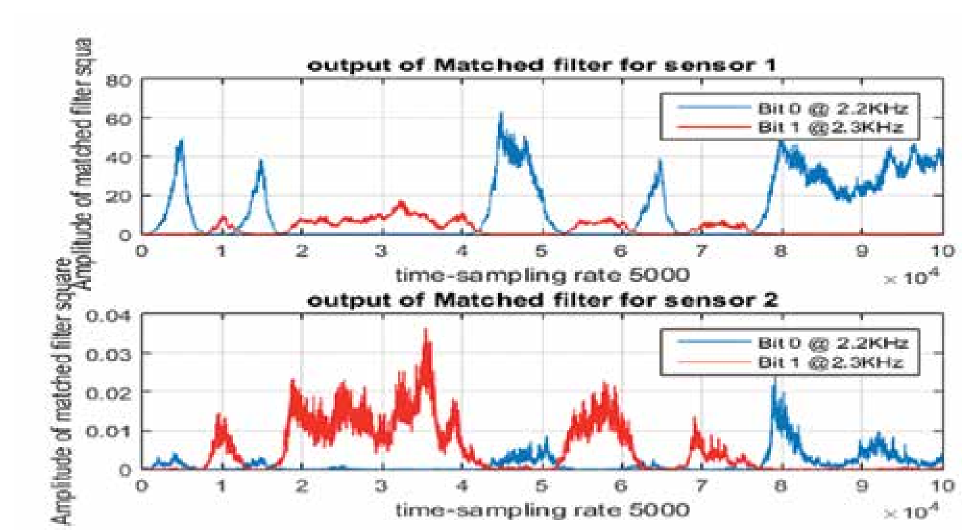
Failure analysis of signal transduction networks is an important topic in systems and molecular biology and has many applications in target discovery and drug development. In this work, some advanced methods for fault diagnosis in signaling networks are developed. The goal is to understand how, and to what extent, the dysfunction of molecules in a network contributes to the failure of the entire network. Network dysfunction is defined as failure to produce the expected outputs in response to the input signals. Vulnerability level of a molecule is defined as the probability of the network failure when the molecule is dysfunctional. In this study, a method to calculate the vulnerability level of single molecules for different combinations of input signals is developed. Furthermore, a more complex yet biologically meaningful method for calculating the multi-fault vulnerability levels is suggested, in which two or more molecules are simultaneously dysfunctional. Additionally, a method is developed for fault diagnosis of networks based on a ternary logic model, which considers three activity levels for a molecule, instead of the previously published binary logic model. This study suggests that by increasing the number of activity levels the complexity of the model grows; however, the predictive power of the ternary model does not appear to be increased proportionally.

BOREHOLE COMMUNICATION VIA STEEL PIPES IN OIL WELLS

Faculty: Ali Abdi
Graduate Student: Ali Alenezi
Sponsor: NSF

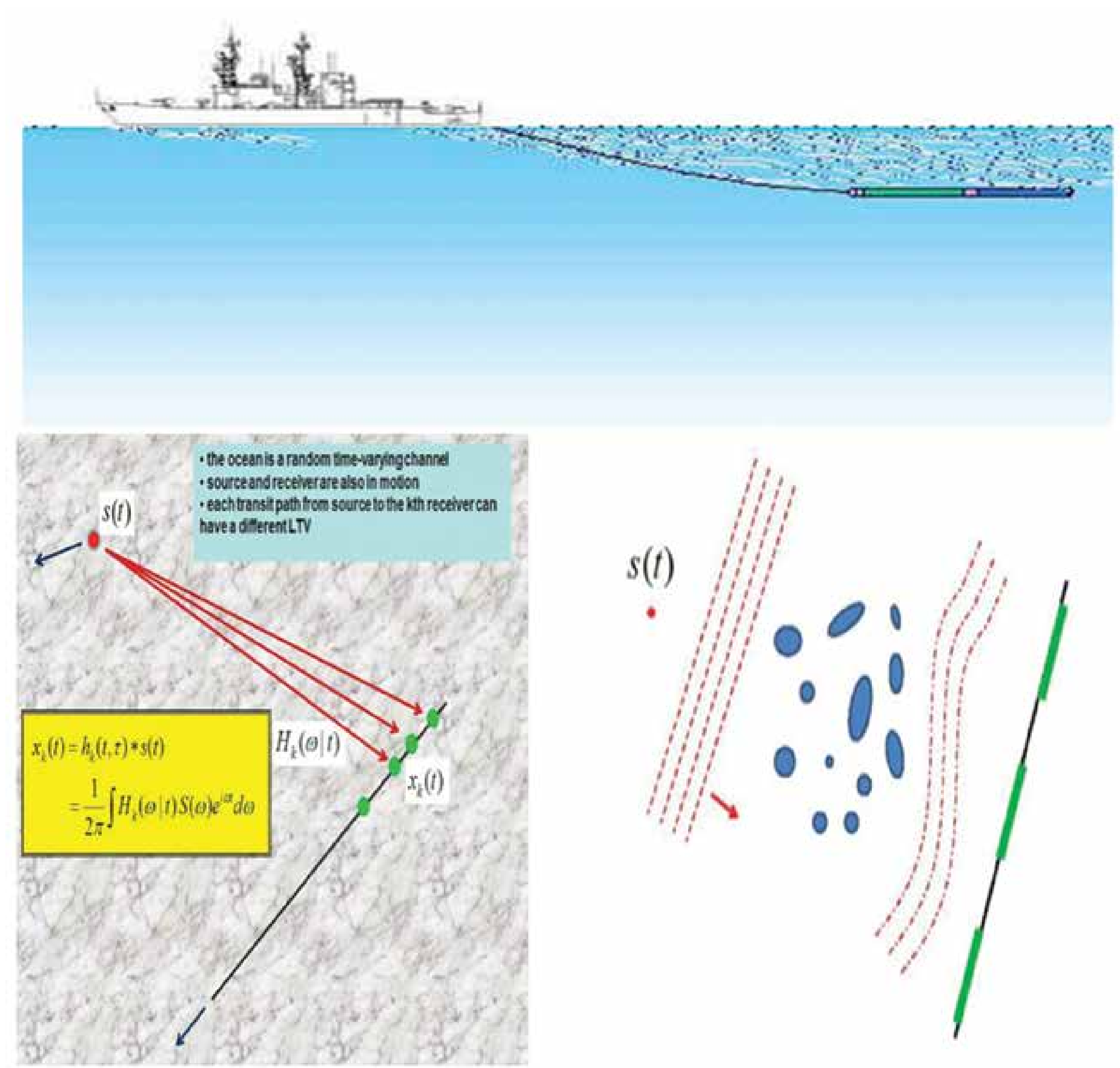
Since boreholes in oils wells are typically several thousand feet deep or more, wired communication is very expensive and prone to failure. Wireless electromagnetic-based and mud-based methods can provide only very low data rates, typically few bits per second. Acoustic transmission, however, offers higher data rates. In this research, new high-rate communication schemes will be developed by using the physics of sound propagation in steel pipes.

Innovative Communication and Signal Processing (iCASP) Lab testbed at NJIT for communi



PASSIVE RANGING USING DISTRIBUTED ARRAYS IN UNDERWATER ACOUSTIC ENVIRONMENTS SUBJECT TO SPATIAL COHERENCE LOSS

Faculty: Hongya Ge
Collaborators: Ivars P. Kirsteins (Naval Undersea Warfare Center (NUWC) Newport, RI
Sponsor: U.S. Office of Naval Research (ONR), Naval Sea Systems Command (NAVSEA and NUWC



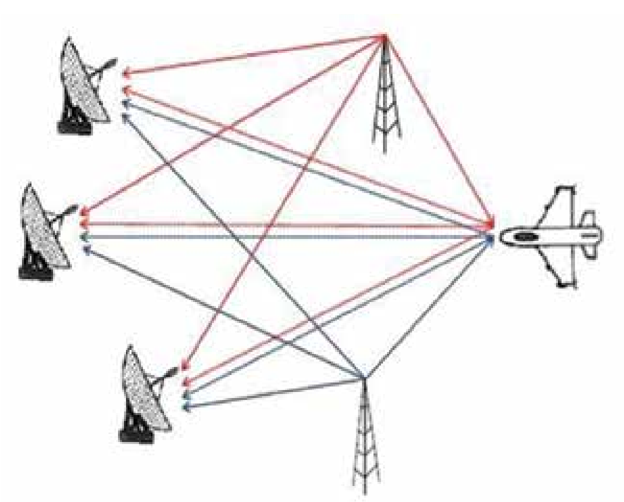
Passive ranging in challenging underwater environments is an important problem in many naval applications, ranging from national defense to disaster recovery and environmental monitoring. Large aperture and/or moving aperture array systems has been designed and redesigned to enable the performance gain in passive methods to source detection, localization and tracking.

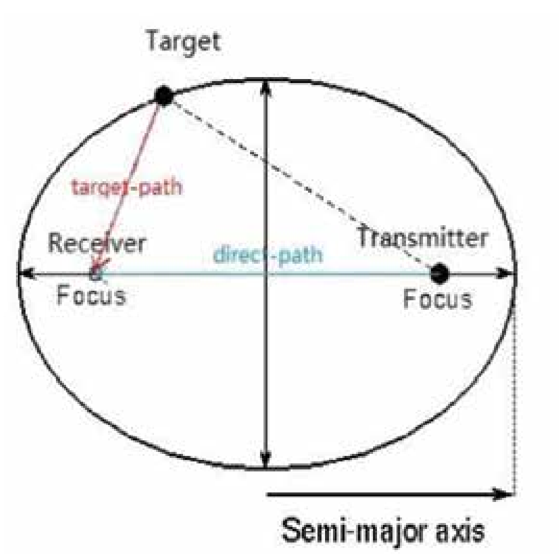
Through data-driven adaptive signal processing, our research explores statistical as well as tempo-spatial-spectral features of acoustic data collected by towed array systems comprised of multiple distributed volumetric array modules. The large amounts of space-time data are collected during different sea trials under the sponsorship of ONR, NAVSEA and NUWC. The goal is to design real-time solutions to passively localize (detection and estimation), classify, and track distant emission sources undersea. Due to the turbulent nature and random media effects of underwater acoustic channels, an emission source's spherical or plane wavefronts are partially distorted when arriving at the receiving arrays of large/moving aperture. The relative motion between the source of interest and receiving arrays makes data and the associated parameters highly variable by time (a typical high-dimension and sample-poor scenario). These factors result in performance degradation to the wavefront curvature ranging systems equipped with very long aperture. We developed maximum likelihood multi-stage and multi-rank wavefront curvature passive ranging solutions to the problem of localizing and tracking distant sources of interest.

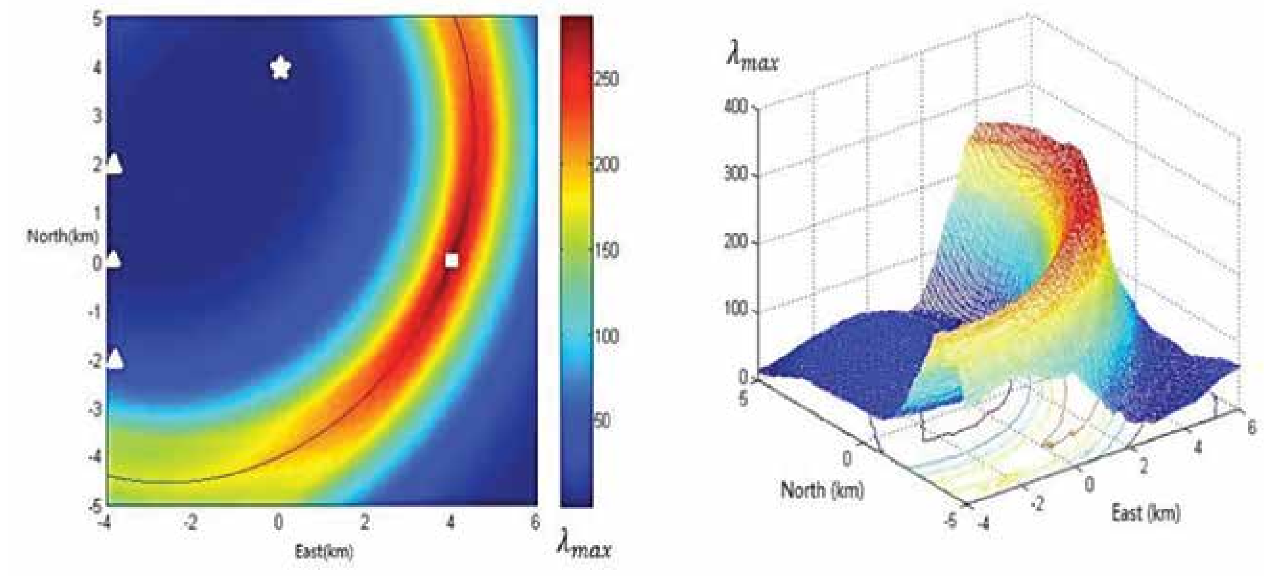
PASSIVE MIMO-RADAR FOR TARGET DETECTION

Faculty: Hongya Ge
Graduate Student: Enlong Hu

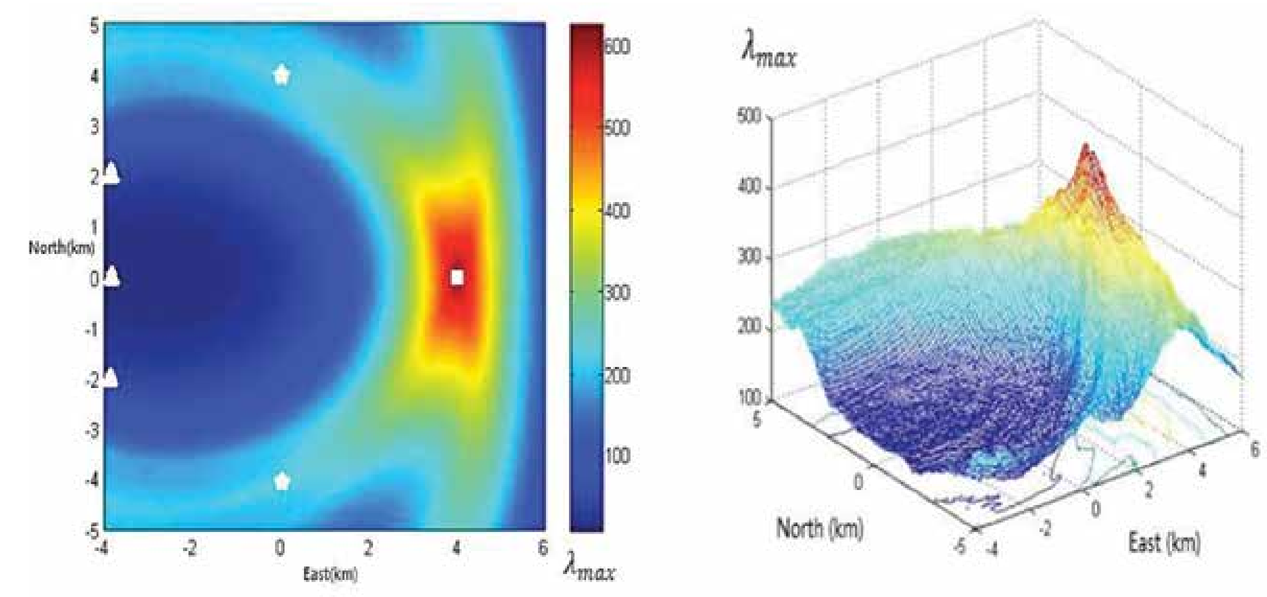
In passive MIMO-Radar system, the RF transmission from existing radio towers along with the reflected RF signals from a target are used by low-cost radar antennas. Such primary and secondary multi-channel data can be used to build low-cost MIMO radars for surveillance applications. We studied the performance gain in detection using multiple RF towers as well as reference channel data.







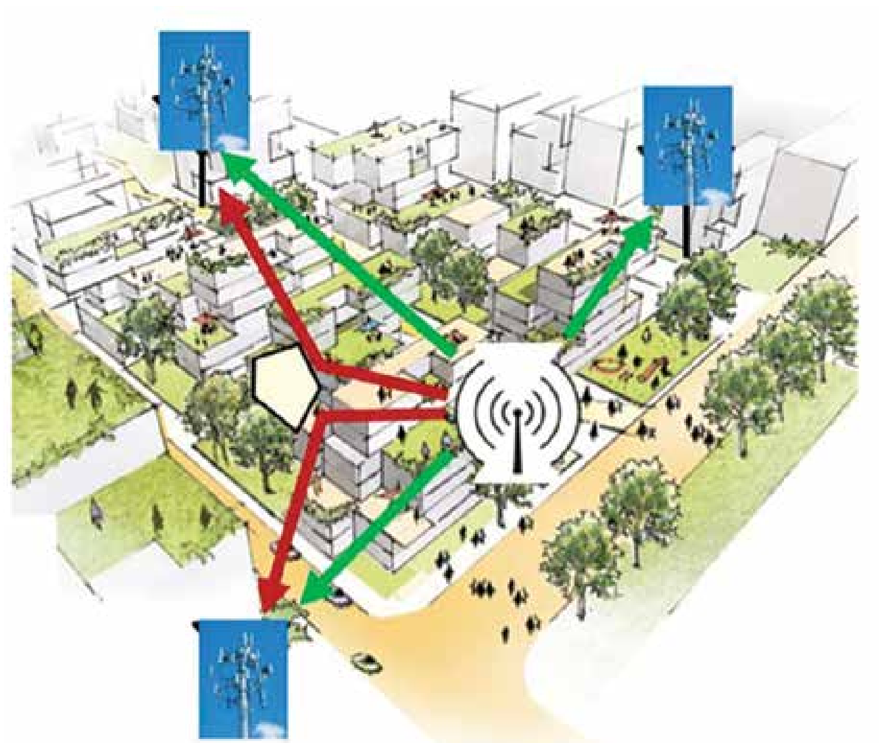
Results obtained by using the transmission from a single RF tower and the target reflection



Results obtained by the using transmissions from two RF towers and the target reflection

DIRECT LOCALIZATION OF RF SOURCES IN MULTIPATH CHANNELS

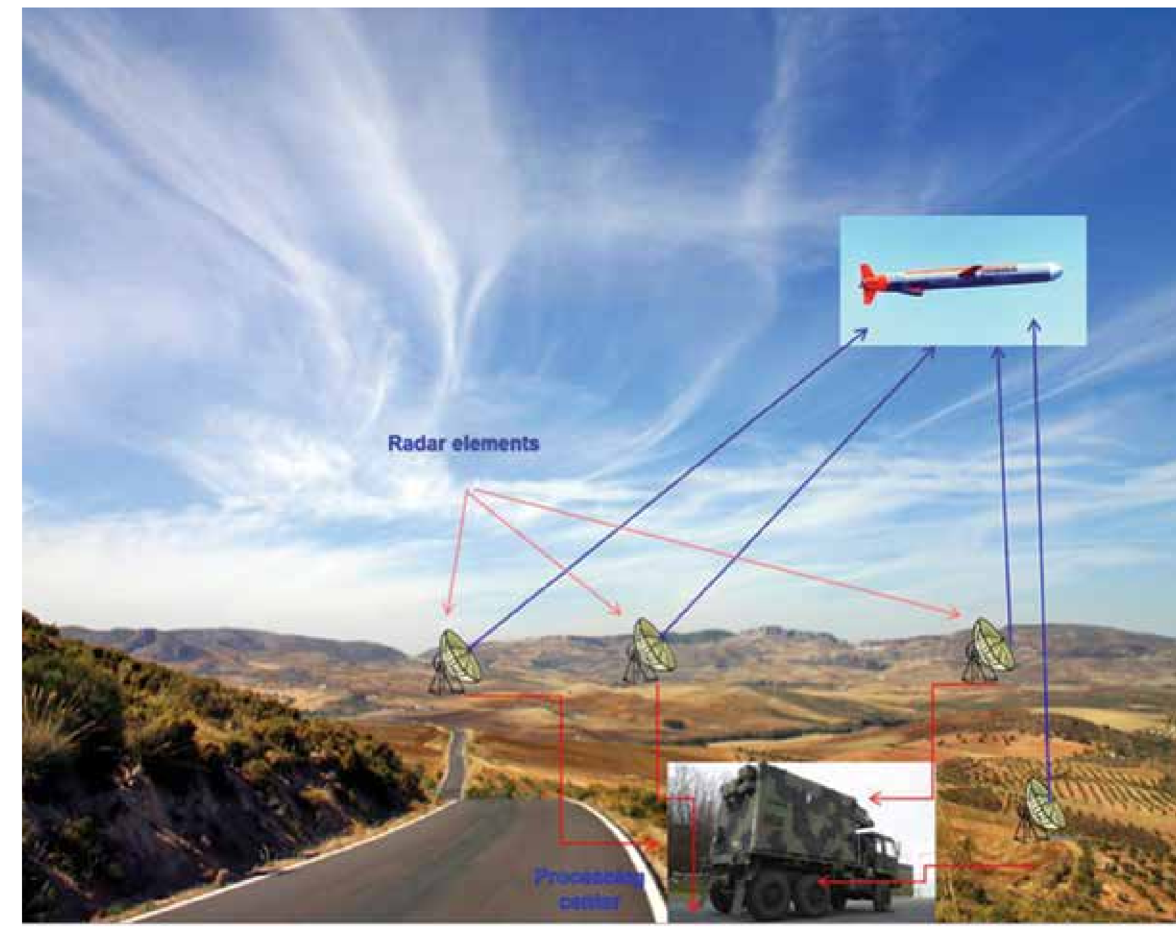
Faculty: Alexander Haimovich
Graduate Student: Annan Dong
Collaborators: Martial Coulon (University of Toulouse), Jason Dabin (U.S. Navy)
Sponsor: Battelle/ARO



The problem of localizing multiple emitters using widely spaced sensors is most commonly solved by estimating some parameters such as time of arrival (TOA), time difference of arrivals (TDOA), or received signal strengths (RSS). Subsequently, the emitters are located by multilateration. Such techniques estimate the intermediate parameters independently and therefore are suboptimal in comparison to direct localization techniques, in which emitter locations are estimated jointly. The literature on direct localization in the presence of frequency-selective multipath is scarce. To fill this gap, we propose a direct localization technique designed to work in the presence of flat or frequency-selective multipath, for known signals. A common approach in localization is to assume that the first arrival at each sensor corresponds to the line of sight (LOS) path; however, such an approach can lead to large errors if the L OS path is blocked or confused with secondary lobes from other arrivals. Our approach divides the search area of the emitters in a grid of points. Since the number of emitters is sparse compared to the number of grid points, it leads naturally to a compressive sensing problem, which can be solved by sparse recovery techniques. Moreover, we show how such a framework enables us to distinguish between LOS and NLOS paths. Our technique has the advantage of direct localization techniques, i.e., superior accuracy, while being especially sensitive to strong NLOS signals, and to some extent, to sensors with blocked LOS. Subsequently, we will address the problem of localizing RF sources whose waveforms are unknown.

MIMO RADAR: COMPRESSIVE SENSING TECHNIQUES FOR LOCALIZATION

Faculty: Alexander Haimovich
Graduate Student: Haley Kim
Sponsor: Air Force Office of Scientific Research

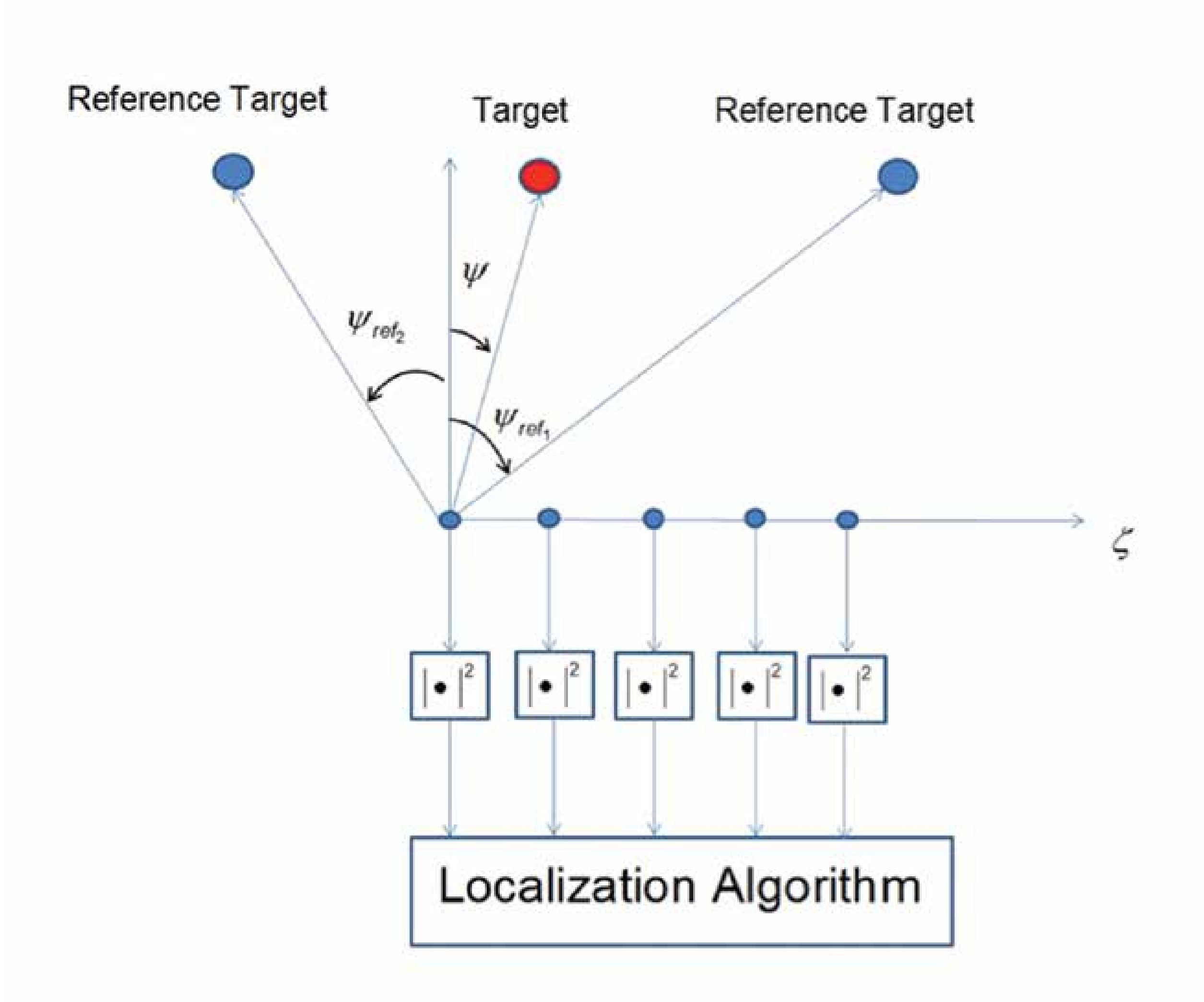


Multiple-input, multiple-output (MIMO) radar is a sensing paradigm in which multiple transmitters and receivers have the ability to jointly plan transmissions and to process received signals in order to detect, localize and track targets. Compressive sensing is an emerging field in which performance of sensing systems is maintained even when observed signals are undersampled. Compressive sensing algorithms are designed to cope with ambiguities introduced by undersampling.

Large random arrays are undersampled adaptive arrays that support improved angle-Doppler resolution and lower minimum detectable velocity (MDV), at the cost of higher sidelobes. Even though random arrays were studied as early as the 1970s, new results reveal interesting links to the emerging field of compressive sensing. MIMO provides further improvements in angular resolution and MDV, while supporting waveform diversity and additional savings in the number of sensors. Compressive sensing algorithms are designed to cope with ambiguities introduced by undersampling. We develop methods involving MIMO radar and compressive sensing that enable to localize radar targets with high accuracy.

NON-COHERENT DIRECTION OF ARRIVAL ESTIMATION

Faculty: Alexander Haimovich
Graduate Student: Wei Jiang



We study the classical direction of arrival (DOA) estimation problem in the presence of random sensor phase errors present at each sensor. To eliminate the effect of these phase errors, we propose a DOA recovery technique that relies only on magnitude measurements. This approach is inspired by phase retrieval for applications in other fields. Ambiguities typically associated with phase retrieval methods are resolved by introducing reference targets with known DOA. The DOA estimation problem is formulated as a nonlinear optimization in a sparse framework, and is solved by the recently proposed GESPAR algorithm modified to accommodate multiple snapshots. Numerical results demonstrate good DOA estimation performance. For example, the probability of error in locating a single target within 2 degrees is less than 0.1 for SNR ≥ 15 dB and one snapshot, and negligible for SNR ≥ 10 dB and five snapshots.

MEASURING AND MODELING INFORMATION FLOW ON THE BRAIN-RESPONSE CHANNEL

Faculty: Joerg Kliewer
Graduate Student: Ketan Mehta, New Mexico State University (NMSU)
Sponsor: NSF
Collaborators: Chuck Creusere (NMSU), Jim Kroeger (NMSU)

We use mutual information (MI) as a measure to quantify the subjective perception of audio quality by directly measuring the brainwave responses of human subjects using a high resolution electro-encephalogram (EEG). Specifically, we propose an information theoretic model to interpret the entire "transmission chain" comprising stimulus generation, brain processing by the human subject, and EEG measurements as a nonlinear, time-varying communication channel with memory. In the conducted experiments at NMSU, subjects were presented with audio whose quality varies between two quality levels. The recorded EEG measurements can be modeled as a multidimensional Gaussian mixture model (GMM). In order to make the computation of the MI feasible, we have derived a novel approximation technique for the differential entropy of the multidimensional GMM. This work was published in the June 2015 issue of the *IEEE Transactions on Molecular, Biological, and Multiscale Communications.*

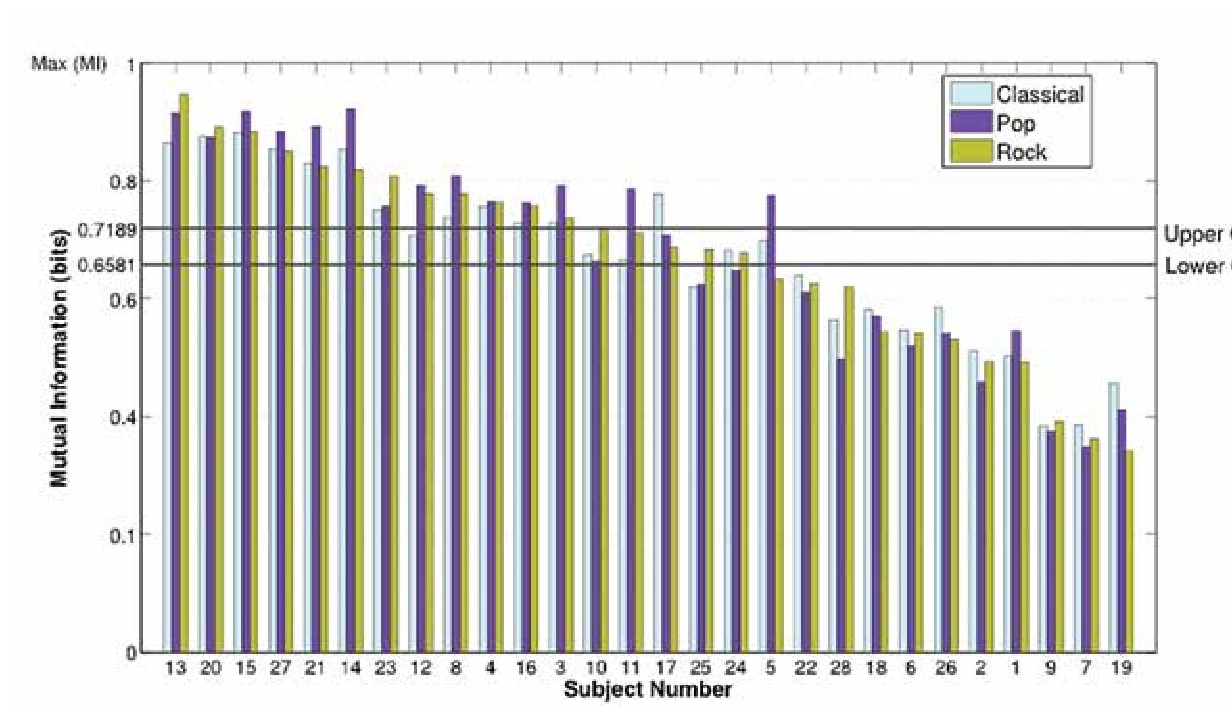


Figure: The median mutual information estimates for each of the 19 test subjects when presented with the same set of trial-sequences, across the two different distortion-types.

Current research focuses on extending the results shown above to analyzing directed MI measures between different regions of EEG sensors and to determine whether these measures are useful to Illustrate different information flows for different audio stimuli between these regions.

LOW-COMPLEXITY WIRELESS SENSOR ARCHITECTURES BASED ON ASYNCHRONOUS PROCESSING

Faculty: Joerg Kliewer Graduate
Student: Chen Yi Chen
Sponsor: NSF
Collaborators: Wei Tang, New Mexico State University (NMSU)

In recent years integrated wireless sensors have emerged in a wide range of applications including health care, surveillance, smart buildings, disaster mitigation, and environmental monitoring. These applications have significantly benefited society by alleviating certain monitoring tasks. However, new applications, such as implantable biopotential sensors or submersible sensors, for measuring mechanical stress require further miniaturization of existing state-of-the-art sensor hardware. This is because of a significantly increased transmission data rate due to the need to perform multichannel processing, i.e., to aggregate the data of multiple single sensors on the same chip over a single communication link. Thus, these approaches require the design of very low-power sensor hardware architectures including novel low-complexity modulation and coding schemes which can support reliable and secure transmission over these high-speed data links.

The goal of this project is find and study novel designs and strategies that are tailored to this emerging class of low-power integrated wireless sensor nodes. We analyze a systematic solution for integrated wireless sensors by devising asynchronous delta modulation on the sensor interface in combination with asynchronous ultra-wideband transmission on the wireless radio interface in order to significantly decrease the power consumption of the sensor hardware. Further, to ensure that the sensor operates with guaranteed reliability over the noisy communication link, new non-binary FEC schemes with a low complexity encoding are analyzed, whose data symbols consist of both asynchronous timing information and pulse signs.

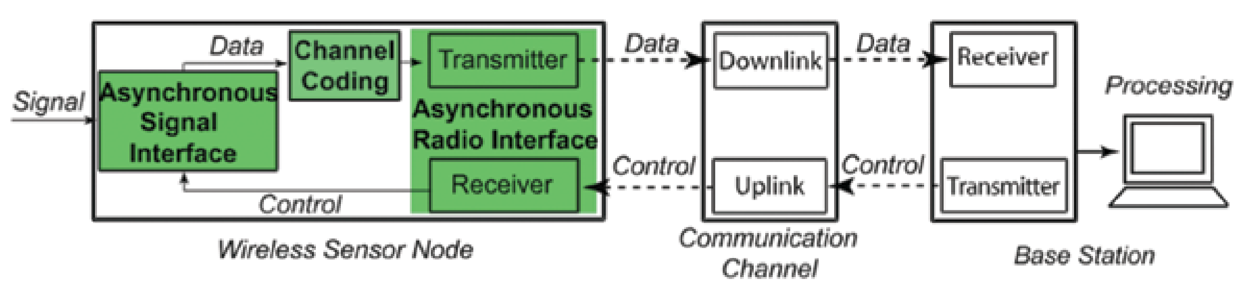
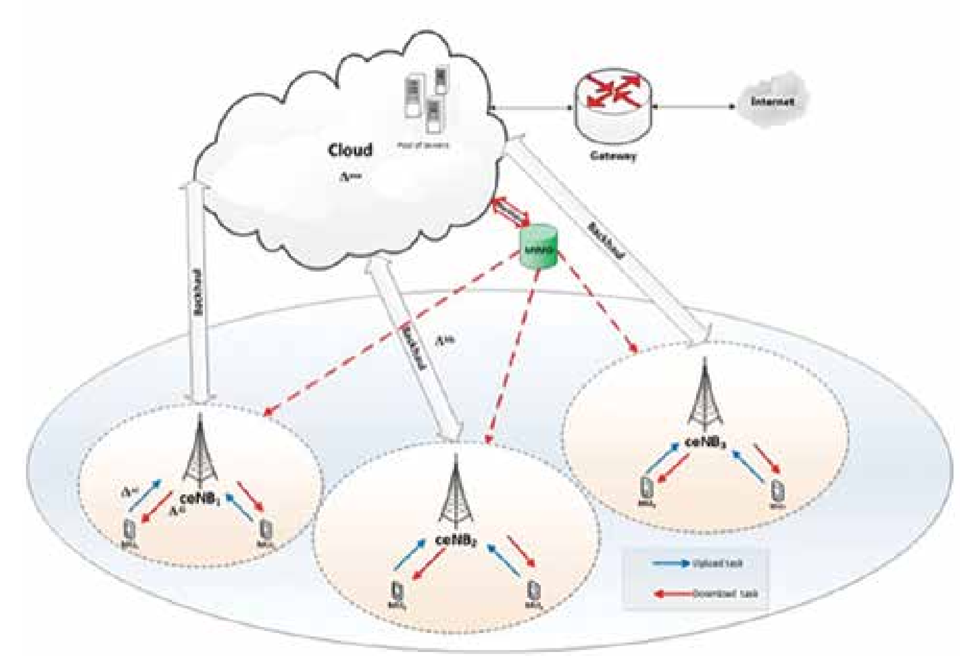


Figure: Block diagram of the wireless sensing system.

MOBILE FOG COMPUTING

Faculty: Osvaldo Simeone
Graduate Students: Alireza Bagheri, Ali Najdi
Collaborator: Gesualdo Scutari (Purdue University)
Sponsor: NSF

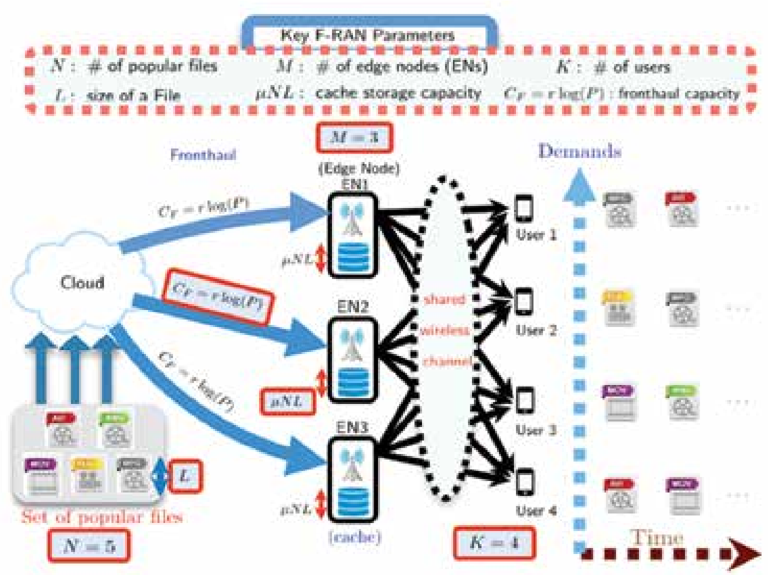


While the number of computation-intensive applications that users expect to run on mobile devices—including video processing, object recognition, gaming, automatic translation and medical monitoring—continues to grow, the devices' computing capabilities are ultimately limited by the battery lifetime. Barring breakthroughs in battery technology, the only potential solution to this challenge appears to be mobile cloud computing, that is, the offloading of computation-intensive tasks to a cloud service provider, such as speech recognition on Google Voice Search and Apple Siri. However, accessing the cloud through a wireless network entails the energy and latency required for uplink and downlink transmissions, as well as the delay caused by routing on the backhaul network, hence potentially offsetting the gains of mobile cloud computing.

This research project proposes to tackle the above problem by introducing fog mobile computing architecture, in which the small-cell base stations of a cellular system are endowed with computing capabilities to offer proximate wireless access and computing. The key objective of the project is to develop effective, low-complexity, scalable and flexible offloading strategies based on the inter-layer optimization of computation and communication resources, with the aim of ensuring Quality of Experience (QoE) constraints in terms of minimal mobile energy expenditure and latency.

FOG RADIO ACCESS NETWORKS: CLOUD AND CACHE-AIDED WIRELESS SYSTEMS

Faculty: Osvaldo Simeone
Graduate Students: Mohammadreza Azimi, Avik Sengupta (Virginia Tech)
Collaborator: Ravi Tandon (University of Arizona)
Industrial Partners: Globalwirelesstech, Huawei

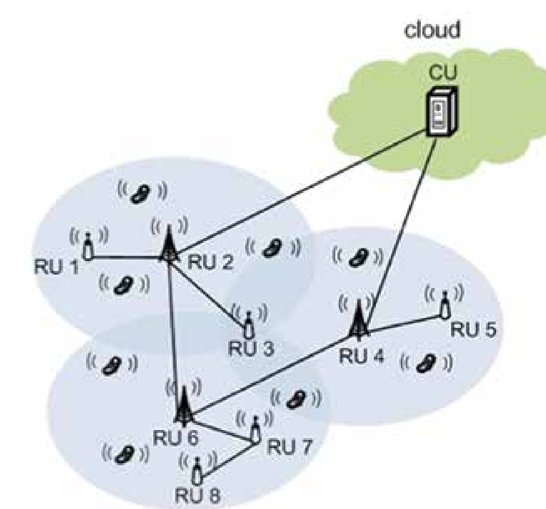


Virtualization and edge processing are among the most promising and transformative trends in the evolution of wireless network architectures. Virtualization of radio access, also known as Cloud Radio Access Network (C-RAN), prescribes the centralization of baseband and higher-layer processing, with the aim of boosting spectral and cost efficiency in interference-limited, dense wireless deployments. Edge processing leverages local content reuse by means of edge-caching, with the goal of catering to hot-spot or proximate traffic of popular multimedia content. In order to accommodate the broad range of use cases that are envisioned to be within the scope of 5G systems and beyond, we propose a hybrid architecture, referred to as Fog-RAN (F-RAN), that harnesses the benefits of, and the synergies between, both technologies. In an F-RAN, edge nodes may be endowed with caching capabilities, so as to serve local data requests of popular content with low latency, while at the same time being controllable from a central cloud processor, in order to serve arbitrary data requests with stronger interference management properties and less stringent delay constraints.

The optimal operation of an F-RAN architecture poses a complex design problem that is characterized by the interaction between the policies used for caching, for transmission over the fronthaul links connecting cloud and edge nodes, and for wireless delivery. The policies operate at heterogeneous time scales and under different conditions in terms of channel state information and knowledge of users' requests. In order to tackle this complex design problem and obtain insights into the main trade-offs between performance and resources, namely caching and fronthaul capacities, a novel information-theoretic model for F-RAN is introduced along with a fundamental performance metric that quantifies the worst-case delivery latency needed to support the users' requests. The delivery latency encompasses the delays associated with the transfer of information on the fronthaul network and on the wireless segment. Novel information-theoretic achievability and converse arguments will be developed to obtain tight characterizations of the tradeoff between latency, on the one hand, and fronthaul and edge-caching capacities, on the other. Through this information-theoretic analysis, fundamental insights into optimal design choices will be revealed. The theory will be complemented by means of system-level simulations that will be carried out in collaboration with industrial and academic partners.

CLOUD RADIO ACCESS NETWORKS

Faculty: Osvaldo Simeone
Graduate Students: Jinkyu Kang Korea Advanced Institute of Science and Technology (KAIST), Seongah Jeong (KAIST), Eunhye Heo (KAIST), Wonju Lee (KAIST)
Collaborators: Shlomo Shamai (Technion), Onur Sahin (InterDigital), Joonhyuk Kang (KAIST), Marco Levorato (University of California, Irvine), Wei Yu (University of Toronto)
Support: Vienna Science and Technology Fund



Next-generation wireless cellular systems are expected to undergo a radical paradigm shift, which is akin to the revolution of cloud computing in computer networks. Cloud computing prescribes the physical separation of user-centric data input/output and remote computing; cloud radio access networks (C-RANs) separate distributed and localized radio transmission/reception units from centralized information processing nodes.

In basic C-RAN, radio units (RUs), such as macro-, pico- and home-base stations, provide the wireless interface between the operator's network and the mobile devices. However, unlike conventional cellular systems, RUs do not implement the information processing functionalities needed to encode and decode information on the wireless channel. Instead, information processing is carried out remotely within the "cloud" of the operator's network. This migration of computing to the cloud is enabled by a network of backhaul links that connect the radio units both among themselves and also to control units (CUs) within the cloud.

The centralization of information processing afforded by C-RANs enables effective interference management at the geographical scale covered by the distributed radio units. Moreover, C-RANs in principle, simplify the deployment of dense heterogeneous networks. Both advantages promise to be key components of the solution to the so-called spectrum crunch problem. However, the main roadblock to the realization of possibility of C-RANs for this use hinges on the effective integration of the wireless interface provided by the radio units with the backhaul network that links the radio units and information processing nodes within the cloud. The goal of this research is to investigate advanced integration strategies based on network information theoretical principles.

CENTER PH.D. STUDENTS AND VISITING SCHOLARS:

First	Last	Advisor
Ali	Alenezi	Abdi
Erjian (Eric)	Zhang	Abdi
Enlong	Hu	Ge
Annan	Dong	Haimovich
Haley	Kim	Haimovich
Pelin	Salem	Haimovich
Phuoc	Vu	Haimovich
Wei	Jiang	Haimovich
Chen	Yi	Kliewer
Shahrouz	Khalili	Simeone
Ali	Al-Shuwaili	Simeone
Alireza	Bagheri	Simeone
Seyyed Mohammadreza	Azimi	Simeone

CENTER MASTER'S DEGREE AND BACHELOR'S DEGREE STUDENTS WORKING ON PROJECTS:

First	Last	Advisor
Sudha	Namburi	Abdi
Jinzhen	Wang	Abdi
Yichen	Lin	Abdi
Sarah	Obead	Kliewer
Salman	Habibi	Kliewer
Xiangyi	Yu	Kliewer

CENTER FACULTY AND STAFF:

First	Last	Advisor
Ali	Abdi	Faculty
Yeheskel	Bar-Ness	Faculty Emeritus
Hongya	Ge	Faculty
Alexander	Haimovich	Faculty
Joerg	Kliewer	Faculty
Osvaldo	Simeone	Faculty
Kathy	Bosco	Staff

LIST OF PROJECTS AND FUNDING

Haimovich, Alexander M. (PI), "GMTI by Multi-Platform Airborne Distributed MIMO," US Air Force/ Matrix Research, $307,767.00. (August 2015 – August 2018).

Haimovich, Alexander M. (PI), Simeone, Osvaldo (Co-PI), "MIMO Signal Classification Models," Sponsored by Aspen Consulting, $115,000.00. (August 2014 – August 2015).

Haimovich, Alexander M. (PI), "Compressive Sensing for Target Localization with MIMO Radar and Passive Methods," AFOSR, Federal, $454,499.00. (August 1, 2012 – July 31, 2015).

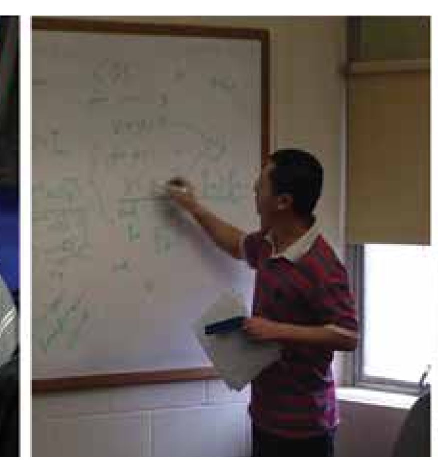
Haimovich, Alexander (PI), "Precision Source Localization in Multipath Environment," U.S. Army/ Battelle Memorial, Federal, $199,977.00. (June 2014 – December 2015).

Kliewer, Joerg (PI), "Collaborative Research: Coordination and Cooperation in Networked Multi-Agent Systems," NSF, Federal, $246,157. (Sept. 2014- Aug. 2017). Awarded to New Mexico State University, transferred to NJIT.

Kliewer, Joerg (PI), "Collaborative Research: Spatially Coupled Sparse Codes on Graphs—Theory, Practice, and Extensions," NSF, Federal, $153,989. (July 2012-June 2015). Awarded to New Mexico State University, transferred to NJIT.

Kliewer, Joerg (PI), "Collaborative Research: New Approaches to the Design of Joint Source Channel Codes," NSF, Federal, $177,193. (September 2011 – August 2015). Awarded to New Mexico State University, transferred to NJIT.

Kliewer, Joerg (PI), "Collaborative Research: Low-Complexity Wireless Sensor Architectures Based on Asynchronous Processing," NSF, $194,898. (September 2014 – August 2017).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Kliewer, Joerg (PI), "Assessment and Modeling of Temporal Variation in Perceived Audio and Video Quality using Direct Brainwave Measurements," NSF, Federal (sub-award from New Mexico State University), $53,741. (June 2014 – May 2015).

Kliewer, Joerg (PI), "TWC: Small: Communication Under Adversarial Attacks in Complex Networks—Fundamental Limits and Secure Coding Strategies," NSF, Federal, $338,193. (September 2015 – August 2018).

Simeone, Osvaldo (Co-PI), "TINCOIN," Vienna Science and Technology Fund, $50,000. (November 2012 – Present).

Matz, G. (TU Wien) (PI), Simeone, Osvaldo (Co-PI), "TINCOIN," Vienna Science and Technology Fund, $40,000. (March 2014 – March 2017).

Simeone, Osvaldo (PI), "CIF: Small : Collaborative Research: Communicating While Computing: Mobile Fog Computing Over Wireless Heterogeneous Networks," NSF, Federal, $249,848.00. (September 2015 – August 2018).

Abdi, Ali (PI) "PFI: AIR – TT: A Novel Vector Acoustic Communication Technology for High Speed Underwater Modems," NSF, Federal, $199,985. (August 2015 – January 2017).

Abdi, Ali (PI) "I-Corp: Data Communication via the Vector Components of the Acoustic Field," NSF, Federal, $50,000. (May 2013 – November 2015).

PUBLICATIONS

Refereed Journal Articles Published:

Mehta, K., Kliewer, J., "An Information-Theoretic Approach Towards Assessing Perceptual Audio Quality Using EEG," *IEEE Transactions on Molecular, Biological, and Multi-Scale Communications*, December 2015 (DOI: 10.1109/TMBMC.2015.2501744).

Jeong, S., Simeone, O., Haimovich, A., and Kang, J., "Beamforming Design for Joint Localization and Data Transmission in Distributed Antenna System," *IEEE Trans. Veh.* Techn., vol. 64, no. 1, pp. 62 – 72, Jan. 2015.

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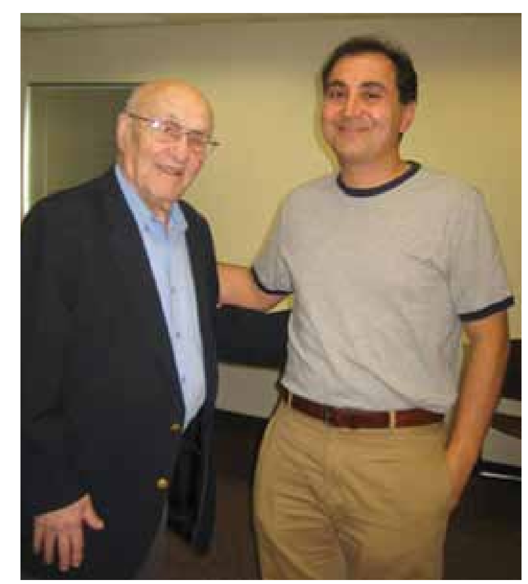

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NEWS

Annual Research Day

The Elisha Yegal Bar-Ness Center for Wireless Communications and Signal Processing Research (CWCSPR) presented faculty research addressing the challenges posed by the next generation of mobile networks at its annual Research Day showcase on March 24, 2015. Presentations focused on error control strategies, cloud processing, geolocation, lightwave communications and data hiding, among other areas.

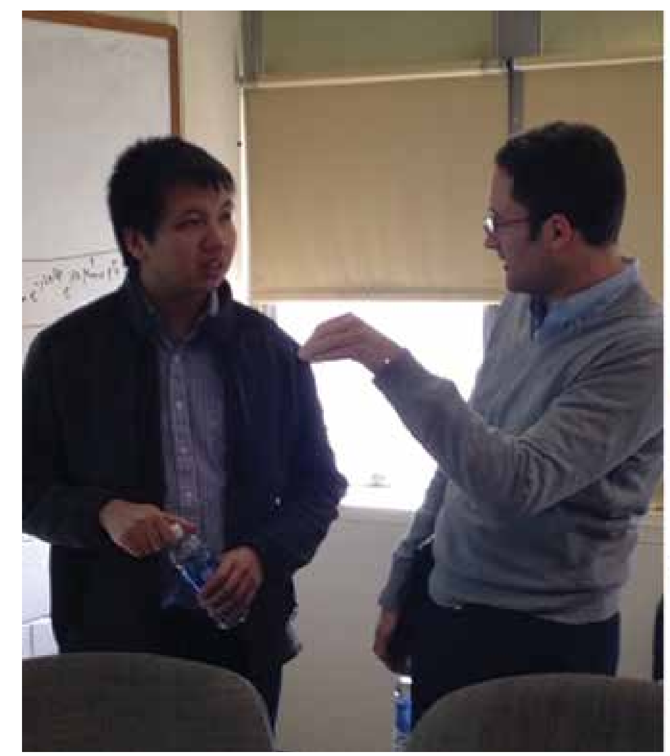
Four Doctoral Students Present Research at Annual Elisha Yegal Bar-Ness CWCSPR Showcase

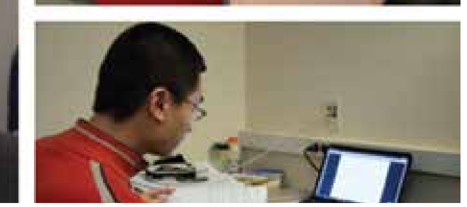
NJIT's Elisha Yegal Bar-Ness Center for Wireless Communications and Signal Processing Research recently showcased the research of four doctoral students. The students' work was featured in presentations and posters displayed in the area. The annual event aims to give doctoral students and their professors from the center a chance to exchange information from a year's worth of work.

Patents Awarded/Filed

Provisional Application Filed:

Communication Efficient Secret Sharing. Inventors: Wentao Huang, Michael Langberg, Joerg Kliewer, Jehoshua Bruck. May 2015





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