WiFiUS Summer School Tutorials

Please see the venue and times here:
http://209.140.21.224/~jwifiusa/summer-school-on-iot-2018

Tuesday, June 12, 2018

Session I. Riku Jantti, Aalto University, Finland
Title: Ambient and Quantum Backscatter Communications

Abstract: Low-power wireless communication has been identified as one of the key enabling technologies for the Internet of Things (IoT). The performance of the contemporary IoT connectivity solutions are mainly limited by congestion, interference, and limited operation time with battery. These limitations hamper the scaling of the IoT deployments. In this talk, we envision a new solution to the IoT connectivity combining existing and emerging wireless communication systems (hereafter legacy systems) with a new layer of ultra-low-power or passive ambient backscatter communication (AmBC). It can operate under very low signal-to-noise ratio conditions, share the spectrum with legacy systems without causing harmful interference to them, and scale to support large number of devices. We will also discuss how the emerging microwave quantum technology can be utilized to enhance the performance of backscatter communications beyond the limits of classical solutions.

Bio: Riku Jäntti is an Associate Professor (tenured) in Communications Engineering and the head of the department of Communications and Networking at Aalto University School of Electrical Engineering, Finland. He received his M.Sc (with distinction) in Electrical Engineering in 1997 and D.Sc (with distinction) in Automation and Systems Technology in 2001, both from Helsinki University of Technology (TKK). Prior to joining Aalto (formerly known as TKK) in August 2006, he was professor pro tem at the Department of Computer Science, University of Vaasa. Prof. Jäntti is a senior member of IEEE and associate editor of IEEE Transactions on Vehicular Technology. He is also IEEE VTS Distinguished Lecturer (Class 2016). The research interests of Prof. Jäntti include radio resource control and optimization for machine type communications, Cloud based Radio Access Networks, spectrum and co-existence management, and quantum communications.

Session II. Prof. Henning Schulzrinne, Columbia University
Title: Spectrum - the new "Buy land, they're not making it anymore"?

Abstract: Almost all IoT devices rely on radio spectrum, whether cellular licensed or various unlicensed bands. Starting in the 1980s, acquiring and managing spectrum has gotten far more sophisticated, with databases, sharing and two-sided auctions. In this tutorial, I will discuss how different parts of the radio spectrum are used for IoT, its properties, both technical and economical, and the regulatory and deployment issues of various existing and emerging frequency bands. As examples, I will discuss the 5.8 GHz band, the TV incentive auction, the 3.5 GHz band and emerging millimeter-wave bands, as well as the role of experimental licenses. No RF experience is assumed.

Bio: Prof. Henning Schulzrinne, Levi Professor of Computer Science at Columbia University, received his Ph.D. from the University of Massachusetts in Amherst, Massachusetts. MTS at AT&T Bell Laboratories; associate department head at GMD-Fokus (Berlin), before joining the Computer Science and EE departments at Columbia University. He served as chair of Computer Science from 2004 to 2009 and as Engineering Fellow, Technical Advisor and Chief Technology Officer of the Federal Communications Commission (FCC) from 2010 until 2017.

Protocol standards co-developed by him, including RTP, RTSP and SIP, are now used by almost all Internet telephony and multimedia applications. Fellow of the ACM and IEEE.

Session III. Pulkit Grover, Carnegie Mellon University, USA
Title: Ultra-Resolution EEG: A novel IoT platform for neural inference with applications to epilepsy and brain injuries.

Abstract: What are the fundamental limits on inferring information about the human brain through a noninvasive IoT system? Using this question as the intellectual motivation, I will discuss the theory, algorithms, implemented IoT systems, and clinical applications that we have obtained in the last 4 years. This work has led to a new technology for neural inference: "Ultra-Resolution EEG," which supersedes performance of existing technologies.

The main goals of this tutorial are to use this story:
1) to get researchers in IoT interested in neural monitoring, and providing them an shallow, non-comprehensive introduction to concepts and tools used to make inferences relevant for clinical, neuroscientific, and brain-machine interface applications.
2) to make a case that there is relevant and important theory needed in this area (namely, neuroengineering), that can revolutionize the set of emerging systems. This gives theorists an opportunity to learn about biological systems, as well as shape the development of this exciting area.

The work presented here is from ongoing collaborations of an information theorist (myself) with neuroscientists (Marlene Behrmann and Michael Tarr; CMU), hardware engineers (Shawn Kelly and Ashwati Krishnan; CMU) and clinicians (Drs. Mark Richardson, Lori Shutter, and Jonathan Elmer; University of Pittsburgh).

Bio: Pulkit Grover (Ph.D. UCB) is an assistant professor at CMU (2013-). His main contributions to science are towards developing and experimentally validating a new theory of information (fundamental limits, practical designs) for efficient communication, computing, and control, e.g. by incorporating novel circuit-energy models. To apply these ideas to a variety of problems including novel biomedical systems, his lab works extensively with system and device engineers, neuroscientists, and doctors. Pulkit received the 2010 best student paper award at IEEE CDC; the 2011 Eli Jury Dissertation Award from UC Berkeley; the 2012 Leonard G. Abraham best journal paper award from the IEEE ComSoc; a 2014 NSF CAREER award; a 2015 Google Research Award; and a 2018 inaugural award from the Chuck Noll Foundation for Brain Injury Research. He presented an ISIT’17 tutorial on "coded computing," an emerging science of computing in presence of faults, delays, errors.

Wed, June 13, 2018

Session I. Robert Heath and Nuria González-Prelcic, The University of Texas at Austin, USA

Title: Sparse Signal Processing in Millimeter Wave MIMO Systems

Abstract: Sparsity is a new feature of large millimeter wave communications, a key technologies for 5G cellular networks. In such systems, antenna arrays with hundreds of antennas (versus two-eight for conventional systems) provide beamforming gain, spatial multiplexing capability, or separation for multiple users. The large numbers of antennas expose spatial sparsity in the channel, which naturally complements other forms of sparsity introduced for example by the larger bandwidths. This tutorial explains the sparse channel model in millimeter wave communication systems, and highlights different approaches for leveraging that sparsity.

Bio: Robert W. Heath Jr. is a Cullen Trust Endowed Professor in the Department of Electrical and Computer Engineering at The University of Texas at Austin and a Fellow of the IEEE. Prof. Heath is a recipient of several best paper awards including the 2012 Signal Processing Magazine best paper award, a 2013 Signal Processing Society best paper award, the 2016 IEEE Communications Society Fred W. Ellersick Prize, and the 2016 IEEE Comm. Society and Info. Theory Society Joint Paper Award. He authored "Introduction to Wireless Digital Communication” and "Digital Wireless Communication: Physical Layer Exploration Lab Using the NI USRP" (National Technology and Science Press, 2012). He co-authored "Millimeter Wave Wireless Communications" (Prentice Hall, 2014). He has been working on MIMO communication for almost 20 years, since the beginning of his PhD, and was part of the finalist team for the 2016 European Inventor Awards (with Paulraj) for the invention of MIMO.

Nuria González-Prelcic is Senior Research Scientist at The University of Texas at Austin, and an Associate Professor in the Signal Theory and Communications Department, University of Vigo, Spain. She has co-authored more than 30 journal and conference papers in the last two years in the topic of signal processing for MIMO communication, especially mmWave communication. She has also co-authored a tutorial IEEE Journal of Selected Topics in Signal Processing on mmWave MIMO and was also a guest editor for the same special issue. She is an associate editor for the IEEE Transactions on Wireless Communications. She has co-organized several special sessions on mmWave communications at conferences, and delivered tutorials on millimeter wave MIMO and compressed sensing.

Session II: Pasi Liljeberg, University of Turku, Finland
Title: Internet of Cognitive Things for Personalised Healthcare

Abstract: Internet-of-Things (IoT) is a paradigm that envisions a near future in which the objects of everyday life will be equipped with microcontrollers, transceivers, and protocol stacks that will make them able to communicate with one another and with users, becoming an integral part of the Internet. The IoT is remodeling the healthcare sector in terms of social benefits and penetration as well as economics. Enabled by ubiquitous computing, all the healthcare system entities can be monitored and managed continuously. IoT allows remote monitoring and tracking of patients living alone at home or treated in hospitals. Data generated from sensors attached to patients is made available to doctors, family and interested parties giving them the ability to check the subject's vital signs and contextual information from anywhere at any time as well as performing intelligent decision making to assist healthcare workers. However, IoT-based healthcare systems necessitate a higher degree of dependability, accessibility, efficiency, and robustness, compared to the IoT applications in other sectors. The talk aims at covering different key aspects of general-purpose IoT technologies as well as the recent achievements in the context of e-health systems including low-latency and real-time application requirements, interoperability, reliability, federation, energy efficiency, mobility, hierarchical Fog-assisted computing and data analytics, geo-distribution and context awareness, and the notion of Internet-of-Cognitive-Things (IoCT).

Bio: Pasi Liljeberg received the MSc and PhD degrees in electronics and information technology in 1999 and 2005, respectively. He received Adjunct professorship in embedded computing architectures in 2010. Currently he is working as full professor at University of Turku in the field of Embedded Systems and Internet of Things. At the moment his research is focused on Internet of Things, self-aware computing, biomedical engineering and health technology, approximate computing and Fog computing. In that context he has established and leading the Internet-of-Things for Healthcare, IoT4Health, (http://iot4health.utu.fi) research group. Liljeberg is the author of more than 280 peer-reviewed publications.

Session III: Alexander M Wyglinski, Worcester Polytechnic Institute, USA
Title: Bumblebees and Beamforming -- Enabling the Vehicular Internet-of-Things

Abstract: Wireless connectivity is quickly becoming a critical element in future transportation systems, especially with respect to self-driving cars and various levels of vehicular autonomy. Given the complex and highly time-varying environments existing on busy roadways, having each vehicle possessing real-time situational awareness is essential for performing complex functions, such as autonomous lane-changing, traffic intersection management, and platooning. Although there already exists a variety of different sensors that can gather data about the vehicular environment in order to obtain real-time situation awareness, such as LIDAR, RADAR, and vision systems, these sensors can only collect this data via line-of-sight (LOS). On the other hand, wireless connectivity is not constrained to LOS data gathering and can greatly increase the real-time situational awareness of each vehicle on the road, enhancing its performance and

increasing driver/passenger safety. As the number of vehicles on the road become connected to each other, this information sharing will evolve into a Vehicular Internet-of-Things (VIOT) environment.

To support the VIOT ecosystem, adequate wireless spectrum is needed to enable this connectivity between vehicles in real-time as they are operating on the road in complex conditions. To achieve this, two techniques can be used in order to facilitate wireless connectivity in the VIOT environment:

(1) Vehicular Dynamic Spectrum Access, or VDSA, is a technique where unoccupied wireless spectrum can be temporarily accessed by non-licensed users in order to support data communications during that time interval. Compared to conventional DSA techniques, VDSA needs to be capable of handling significant spectral availability variations during a transmission. Past research has explored the use of VDSA in television white space spectral environments as well as the implementation of VDSA algorithms using machine learning techniques. However, recently a new approach to VDSA has been proposed where each vehicle performs VDSA using an algorithm based on bumblebee-inspired resource foraging. In the first part of this lecture, the fundamentals of how bumblebee-inspired VDSA will be presented, with several examples shown in order to demonstrate the performance of this approach.

(2) Spatial filtering has often been used in order to increase user capacity within a geographical region by exploiting the physics of phasing multiple antennas to convey electromagnetic energy in order direction and not in others. Although frequently used in cellular environments to support multiple users supported by a single base station, the concept of using beamforming in vehicular networks is only beginning to receive significant attention due to the ability of such vehicle networks to support large scale connectivity using limited amounts of wireless spectrum. However, unlike cellular applications of beamforming, where the mobile users move relatively slow, in vehicular applications the beamforming needs to be performed with sufficient accuracy and speed in order to support link connectivity without any interruptions. In the second part of this lecture, we present the fundamentals of performing beamforming in vehicular wireless environments using several signal processing techniques in order to mitigate link failure due to the high level of mobility present on the road.

Bio: Dr. Alexander M. Wyglinski is a Professor of Electrical & Computer Engineering and a Professor of Robotics Engineering at Worcester Polytechnic Institute (WPI), as well as Director of the Wireless Innovation Laboratory (WI Lab, http://www.wireless.wpi.edu/). His research interests are in the area of wireless communications, connected vehicles, cognitive radios, autonomous/self-driving cars, and dynamic spectrum access networks. Dr. Wyglinski received his Ph.D. degree from McGill University in 2005, M.S. degree from Queens University at Kingston in 2000, and B.Eng. degree from McGill University in 1999, all in Electrical Engineering. Dr. Wyglinski is very actively involved in the research community. He currently serves on the editorial board of the IEEE Communications Magazine. He has previously served as the general co-chair of the 82th IEEE Vehicular Technology Conference (IEEE VTC 2015

Fall), co-chair of the Cognitive Radio Symposium of the 2015 IEEE International Conference on Communications (IEEE ICC 2015), and general co-chair of the 2013 IEEE Vehicular Networking Conference (IEEE VNC 2013). Dr. Wyglinski has been or is currently a technical program committee member on numerous IEEE and other international conferences in wireless communications and connected vehicles. Finally, Dr. Wyglinski is serving as the President of the IEEE Vehicular Technology Society (an IEEE VTS Board of Governors position), as well as a speaker for the IEEE VTS Distinguished Lecturer Series. In addition to authoring/co-authoring over 100 peer-reviewed journal articles and conference papers, Dr. Wyglinski is the co-author of the first textbook on cognitive radio and dynamic spectrum access, entitled Cognitive Radio Communications and Networks: Principles and Practice (Academic Press, December 2009), as well as a co-author of the first textbook on digital communication systems engineering using software-defined radio technology, entitled Digital Communication Systems Engineering Using Software Defined Radio (Artech House, January 2013). Dr. Wyglinski is currently or has been sponsored by organizations such as the Defense Advanced Research Projects Agency (DARPA), Naval Research Laboratory (NRL), MIT Lincoln Laboratory, Raytheon, MITRE, Office of Naval Research (ONR), Air Force Research Laboratory (AFRL) - Space Vehicles Directorate, The MathWorks, Toyota InfoTechnology Center U.S.A., and the National Science Foundation. Dr. Wyglinski is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), as well as a member of Sigma Xi, Eta Kappa Nu, and the American Society of Engineering Education (ASEE).

Thu, June 14, 2018

Session I. Rick Blum, Lehigh University, USA
Title: Attacks Against Sensor Systems for Estimation for Internet of Things and Cyber Physical Systems Applications

Abstract: Estimation of an unknown deterministic vector from quantized sensor data is considered in the presence of spoofing and man-in-the-middle attacks which alter the data presented to several sensors. First, asymptotically optimum processing, which identifies and categorizes the attacked sensors into different groups according to distinct types of attacks, is outlined in the face of man-in-the-middle attacks. Necessary and sufficient conditions are provided under which utilizing the attacked sensor data will lead to better estimation performance when compared to approaches where the attacked sensors are ignored. Next, necessary and sufficient conditions are provided under which spoofing attacks provide a guaranteed attack performance in terms of the Cramer-Rao Bound (CRB) regardless of the processing the estimation system employs, thus defining a highly desirable attack. Interestingly, these conditions imply that, for any such attack when the attacked sensors can be perfectly identified by the estimation system, either the Fisher Information Matrix (FIM) for jointly estimating the desired and attack parameters is singular or the attacked system is unable to improve the CRB for the desired vector parameter through this joint estimation even though the joint FIM is nonsingular. It is shown that it is always possible to construct such a highly desirable attack by properly employing an attack vector parameter having a sufficiently large dimension

relative to the number of quantization levels employed, which was not observed previously. For unattacked quantized estimation systems, a general limitation on the dimension of a vector parameter which can be accurately estimated is uncovered. Application to IEEE 1588 clock synchronization will be described.

Bio: Rick S. Blum received a B.S.E.E from Penn State in 1984 and an M.S./Ph.D in EE from the University of Pennsylvania in 1987/1991. From 1984 to 1991 he was with GE Aerospace. Since 1991, he has been at Lehigh. His research interests include signal processing for smart grid, communications, sensor networking, radar and sensor processing. He was an AE for IEEE Trans. on Signal Processing and for IEEE Communications Letters. He has edited special issues for IEEE Trans. on Signal Processing, IEEE Journal of Selected Topics in Signal Processing and IEEE Journal on Selected Areas in Communications. He was a member of the SAM Technical Committee (TC) of the IEEE Signal Processing Society. He was a member of the Signal Processing for Communications TC of the IEEE Signal Processing Society and is a member of the Communications Theory TC of the IEEE Communication Society. He was on the awards Committee of the IEEE Communication Society. Dr. Blum is a Fellow of the IEEE, a former IEEE Signal Processing Society Distinguished Lecturer (twice), an IEEE Third Millennium Medal winner, a member of Eta Kappa Nu and Sigma Xi, and holds several patents. He was awarded an ONR Young Investigator Award and an NSF Research Initiation Award.

Session II: Shiwen Mao, Auburn University, USA
Title: On CSI based Vital Sign Monitoring in Healthcare IoT

Abstract: Vital signs, such as breathing and heartbeat, are useful to health monitoring since such signals provide important clues of medical conditions. Effective solutions are needed to provide contact-free, easy deployment, low-cost, and long-term vital sign monitoring. Exploiting wireless signals for contact-free vital sign monitoring will be an important part of the future healthcare Internet of Things (IoT). In this talk, we present our recent work on contact-free vital sign monitoring. The first part is to exploit channel state information (CSI) phase difference data to monitor breathing and heartbeat with commodity WiFi devices. We will present PhaseBeat, a discrete wavelet transform based design, and TensorBeat, a tensor decomposition based design, as well as our experimental study to validate their performance. The second part of this talk is to exploit a 20KHz ultrasound signal for breathing rate detection. We will present our smartphone App based implementation. Our experimental study shows that the proposed systems can achieve high accuracy under different environments for vital sign monitoring.

Bio: Shiwen Mao received his Ph.D. in electrical and computer engineering from Polytechnic University (now NYU Tandon School of Engineering), Brooklyn, NY in 2004. He is the Samuel Ginn Distinguished Professor and Director of the Wireless Engineering Research and Education Center (WEREC) at Auburn University, Auburn, AL. His research interests include wireless networks and multimedia communications. He is a Distinguished Speaker of the IEEE Vehicular Technology Society (VTS). He is on the Editorial Board of IEEE Transactions on Mobile Computing, IEEE Transactions on Multimedia, IEEE Internet of Things Journal, IEEE

Multimedia, ACM GetMobile, among others. He is a TPC/Symposium Co-Chair of IEEE INFOCOM 2018, IEEE ICC 2017, IEEE WCNC 2017, among others. He received the 2017 IEEE ComSoc ITC Outstanding Service Award, the 2015 IEEE ComSoc TC-CSR Distinguished Service Award, the 2013 IEEE ComSoc MMTC Outstanding Leadership Award, and the NSF CAREER Award in 2010. He is a co-recipient of the IEEE ComSoc MMTC 2017 Best Conference Paper Award, Best Paper Awards from IEEE GLOBECOM 2016 & 2015, IEEE WCNC 2015, and IEEE ICC 2013, and the 2004 IEEE Communications Society Leonard G. Abraham Prize in the Field of Communications Systems.

Fri, June 15, 2018

Session I. Teemu Roos, University of Helsinki, Finland
Title: title: Approximate methods for fast nearest neighbor search

Abstract: Nearest neighbor search is a fundamental building block in many applications of great practical importance. Examples include information retrieval, recommendation systems, supervised machine learning, and data visualization. As the size of the data grows, brute force search may become infeasible. Significant speed-ups can be achieved by constructing a index structure and if a reasonable level of approximation error is allowed. There are a number of approaches to construct index structures for approximate nearest neighbor search that each have their pros and cons. We will briefly review the main approaches, including space partitioning trees, locality-sensitive hashing, and graph-based techniques. We will focus in particular on recent methods based on random projection trees which can be shown to lead to simple, robust, and fast queries, and moreover, which can be efficiently parallelized. I will present new results from work-in-progress with CMU (ongoing WiFiUS project with Pulkit Grover's group) on fault-tolerant distributed nearest neighbor search on unreliable hardware.

Bio: Teemu Roos is an Associate Professor at the Department of Computer Science, University of Helsinki. He received a PhD degree in computer science from the University of Helsinki in 2007. Prof Roos's research interests include the theory and applications of artificial intelligence, machine learning, and data science. He also teaches introductory courses on these topics on-campus as well as online (see www.elementsofai.com). He has developed applications in areas such as mobile computing, genomics, epidemiology, quantum physics, and digital humanities.

Session II: Randall Berry, Northwestern University, USA
Title: Wireless Network Economics

Abstract: The continued growth and evolution of wireless networks in part economic incentives. This includes the incentives of users to adopt new technologies and the incentives of firms to invest in and deploy these technologies. There are complex interactions between these economic incentives and the underlying wireless technologies used. This tutorial will survey several approaches for modeling such interactions.

Bio: Randall Berry joined Northwestern University in 2000, where he is currently the Lorraine Morton Professor in the Department of Electrical Engineering and Computer Science. He received the M.S. and PhD degrees in Electrical Engineering and Computer Science from MIT in 1996 and 2000, respectively. Dr. Berry is the recipient of a 2003 CAREER award from the National Science Foundation and is an IEEE Fellow. Along with his students, he has won several best paper awards including including at the 2017 IEEE Smart Data Pricing Workshop and the 2016 WiOPT conference. He was an IEEE Communications Society Distinguished Lecturer for 2013-14. He has served as an Editor for the IEEE Transactions on Wireless Communications from 2006 to 2009, and an Associate Editor for the IEEE Transactions on Information Theory from 2009 to 2011, in the area of communication networks. He has served on the program and organizing committees of numerous conferences including serving as a TPC co-chair for ACM Mobihoc 2018 and chair of the 2012 IEEE Communication Theory Workshop.