Celebrating our 20th Anniversary

20TH Virginia Tech Symposium on

Wireless personal Communications

6TH Annual

Wireless Summer School

June 2-4, 2010

Virginia Polytechnic Institute and State University
The Inn at Virginia Tech and Skelton Conference Center • Blacksburg, Virginia

Sponsored by

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Symposium Highlights

Wireless technology continues its unrelenting quest for innovation and expansion. To assist professionals and academics stay abreast of the latest research, Wireless @ Virginia Tech will host its 20th annual symposium and 6th annual summer school on wireless communications June 2-4, 2010.

This year's symposium includes our strongest ever collection of technical presentations and posters. The technical program held on Wednesday has been expanded and consists of concurrent oral presentation sessions and a separate poster spotlight session. To facilitate expanded interaction, the posters will remain up for the duration of the symposium and summer school. The paper and poster presentations from researchers around the world discuss the latest breakthroughs in wireless communications and networking research.

The annual summer school, which kicks off on Wednesday afternoon, offers 14 half-day tutorials in key areas of wireless communications and networks. The full list of tutorial descriptions is provided in this brochure. These tutorials provide an excellent opportunity for wireless professionals to learn about both the basics of each technology and recent breakthroughs in each area.

Distinguished keynote speakers this year include Dr. Bruce Fette, DARPA, Dr. Barry Horowitz, University of Virginia, and Dr. Linda Doyle, Trinity College Dublin, Ireland.

An exciting addition to this year's symposium will feature a special panel session on national security. The session, scheduled for Friday morning, is sponsored by the Virginia Tech/Howard University Intelligence Community Center of Academic Excellence (IC CAE) program and is designed to help inform and excite our students and faculty about the mission of the IC. The program will consist of speakers and a round table discussion spanning a broad cross section of national security specialties including Cyber Security, Cryptology, Language and Cultural Analysis, and Science and Technology. Currently, Jim Schatz of Johns Hopkins APL and a former Director of NSA R&D, along with Alan Wade of Wade Associates, retired CIO from the Central Intelligence Agency, are confirmed on the schedule. There will be no cost to attend this session. Updated information on the session can be found here: *http://wp.me/pGWOs-V.*

Back by popular demand will be the Wednesday evening reception, a time for relaxing and socializing with colleagues. As always, we look forward to the symposium party at the German Club on Thursday evening.

We are confident that our discussions of cutting-edge topics will appeal to academic, as well as industry, professionals. Don't miss out – register today!

How to Register

In celebration of our 20th anniversary, we will offer a special fee to all Virginia Tech alumni who graduated in the field of wireless communications. (For validation purposes, VT alumni will be asked to provide their graduation year and their advisor/professor.) A valid student ID will be required to receive the student rate. All fees are listed on the back page of this brochure.

All fees for registration include participation in all activities, including tutorials, CD-ROM proceedings from technical and poster presentations, lunch on Wednesday and Thursday, all refreshment breaks, the reception on Wednesday evening, and the Thursday evening party.

All presenters of technical papers and posters must register by **April 30, 2010**. All other participants should register by **May 19, 2010**, to take advantage of the early bird registration fee. You may register online at *http://www.cpe.vt.edu/reg/wireless/*. You may also register by calling (540) 231-5182.

Location & Lodging

The symposium will be held at The Inn at Virginia Tech and Skelton Conference Center located on the Blacksburg, Va. campus.

For your convenience, a block of discounted lodging rooms, $119 single/$139 double, per night plus tax, are being held at The Inn at Virginia Tech. To make reservations, please call The Inn at (540) 231-8000 or (877) 200-3360. Be sure to mention the name of the symposium when making your reservations. Lodging reservations for The Inn at Virginia Tech must be made by **May 3, 2010**. Lodging accommodations may also be acquired at Hawthorn Suites, (540) 552-5636, Hilton Garden Inn Blacksburg, (540) 552-5005, or at Holiday Inn University, (540) 552-7001.

Transportation

The SmartWay Bus commuter service is an excellent alternative for traveling between the Roanoke Regional Airport and Virginia Tech. The service operates Monday through Saturday with special limited Sunday service, and the fare is only $4.00 each way. For more information, please visit their website at *www.smartwaybus.com*. If you plan to travel on the SmartWay Bus, please notify The Inn at Virginia Tech at 540-231-8000 and their shuttle service will pick you up at the SmartWay Bus stop.

For More Information

If you need additional information regarding the symposium, please contact Jenny Frank, Conference Coordinator, via email at *mprg@vt.edu* or by telephone at (540) 231-2971.

Mailing List Registration

We want to be sure you are registered in our database to receive important mailings about news and events at Wireless @ Virginia Tech. Please visit our web page at *www.wireless.vt.edu*, click on the "mailing list registration" link, and complete the form. For registering, you will receive a copy of a tutorial that has been presented by one of our faculty members.

Program Schedule

Wednesday, June 2, 2010

7:00 AM – 2:00 PM — **Registration**

8:00 – 9:00 AM — **Welcome & Opening Remarks** - Alumni Assembly Hall
Dr. Louis Beex, Technical Program Chair

Keynote Address - "DARPA Demonstrations of Cognitive Radio Capabilities"
Dr. Bruce Fette, DARPA

PLEASE NOTE: Sessions I and II will be parallel sessions

SESSION I – OFDM – Alumni Assembly Hall

Session Chair: Dr. Timothy Newman, Virginia Tech

9:00 – 9:20 AM — **Software Defined Radio Implementation of SMSE Based Overlay Cognitive Radio,** Ruolin Zhoul, Xue Li, Wright State University, Vasu Chakravarthy, Air Force Research Laboratory, Reginald Cooper, Carnegie Mellon University, and Zhiqiang Wu, Wright State University, USA

9:20 – 9:40 AM — **Multicarrier Filter Bank Techniques for Doubly Dispersive Channels,** Pooyan Amini, Chung Him (George) Yuen, Rong-Rong Chen, and Behrouz Farhang-Boroujeny, University of Utah, USA

9:40 – 10:00 AM — **Performance Analysis of QPSK-OFDM in the Presence of Multiple Narrowband Interferers,** Salim Namik, Kevin W. Sowerby, and Michael J. Neve, The University of Auckland, NEW ZEALAND

SESSION II – CDMA – Location TBA

Session Chair: Dr. Michael Buehrer, Virginia Tech

9:00 – 9:20 AM — **Chaos-based DS-CDMA Acquisition Performance in Presence of Fast Fading,** Ramin Vali, Stevan Berber, and Sing Kiong Nguang, The University of Auckland, NEW ZEALAND

9:20 – 9:40 AM — **An Experimental Study on Improving the Accuracy of Indoor User Positioning in CDMA,** Gokul Rameshkrishnaa and Kenneth R. Baker, University of Colorado, Boulder, USA

9:40 – 10:00 AM — **Partial Band Jamming Excision in WCDMA Using Raised Cosine Empirical Mode Decomposition,** A. Roy and J. F. Doherty, Penn State University, USA

10:00 – 10:10 AM — **Refreshment Break**

10:10 – 11:00 AM — **Poster Spotlight Presentations**

P1 **Spectrum Sensing for Analog Signals,** William May, Applied Signal Technology, USA

P2 **Model Based Implementation of SDR Waveforms,** Stefan Nagel and Friedrich Jondral, Karlsruhe Institute of Technology, GERMANY

P3 **Optimizing Base Station Placement in Multi-Floored Buildings,** Liza K. Pujji, Kevin W. Sowerby, and Michael J. Neve, The University of Auckland, NEW ZEALAND

P4 **Wireless Sensor Network Capacity Enhancement Using Spatial Concurrency,** Bharat B. Madan and Shashi Phoha, Penn State University, USA

P5 **Joint Specific Emitter Identification and Location Tracking for OFDM Systems,** Ming-Wei Liu and John F. Doherty, Penn State University, USA

P6 **Making Peace With the Dimensions of the Ambiguity Function,** Daniel J. Rogers, Ben Henty, and Ilya Chukhman, Johns Hopkins Applied Physics Laboratory, USA

P7 **Next Generation Antennas,** Neil Fox, DARPA, USA

P8 **Decode and Forward Technique in Cooperative Spectrum Sensing for Cognitive Radio,** Bikash Nakarmi, Korea Advance Institute of Science and Technology, KOREA, and Ukash Nakarmi, Oklahoma State University, USA

P9 **A Comparison of Fusion Rules for Cooperative Spectrum Sensing in Fading Channels,** Spyros Kyperountas, Neiyer Correal, and Qicai Shi, Motorola, USA

P10 **Direct Digital Synthesizer Based Integrated SDR Transceiver Chip With Spurious Performance Improvement Technology,** Sumit Talwalkar, Gio Cafaro, Tom Gradishar, and Bob Stengel, Motorola, USA

P11 **Low-Complexity MIMO Multicarrier Modulation,** Andrew Marcum and Todor Cooklev, Indiana University, Purdue University Fort Wayne, USA

P12 **Frequency Domain Processing Based Chaos Communication for Cognitive Radio,** Dan Sundersingh, Wright State University, Vasu Chakarvarthy, Air Force Research Laboratory, and Zhiqiang Wu, Wright State University, USA

P13 **Overhead Created by Reactive Reputation-Based Defense Systems on a MANET,** Eyosias Yoseph Imana, Virginia Tech, and Po-Wei Wang, Florida Institute of Technology, USA

P14 **Research Oriented Small Scale Reconfigurable Wireless Networking Fast Prototyping Test-bed,** Zhongren Cao, Joshua Ng, Bhaskar Rao, University of California, San Diego, and Mikael Prytz, Vicknesan Ayadurai, Magnus Almgren, Ericsson, USA

P15 **PaSiVe: Tool for Matlab/Simulink Design Flow for Fast Prototyping Signal Processing Systems on FPGA,** Zhongren Cao, Joshua Ng, Magnus Almgren, and Bhaskar Rao, University of California, San Diego, USA

P16 **On Spatial and Temporal Selectivity of a Class of Vehicular Near Field Propagation Channels,** Haris Kremo, Ivan Seskar, and Predrag Spasojevic, WINLAB, Rutgers University, USA

P17 **Embedding a Software GPS Application within a JTRS Software Defined Radio Architecture,** Alison Brown and Rollin Cogburn, NAVSYS Corporation, USA

P18 **Advanced Model-Based Software Engineering Technologies for Software Defined Radio Configuration,** William C. Liu, Kevin M. McNeill, Mike Cook, and Basil Krikeles, BAE Systems, USA

P19 **Optimizing Topology in Free-Space Optical (FSO) Networks,** Kyle Guan and Reza Ghanadan, BAE Systems, USA

P20 **Policy Management Frameworks for DSA Systems,** Matthew Sherman, Andrew Comba, and Donya He, BAE Systems, and Serey Thai, DISA, USA

P21 **Passive Wireless Surveillance Network,** William Smith, Timothy Uchida, and Christopher R. Anderson, US Naval Academy, USA

P22 **Dynamic Spectrum Access Testbed,** Kaylee Grove and Christopher R. Anderson, US Naval Academy, USA

P23 **End to End QoS Routing for Wireless Ad-Hoc Networks,** S. R. Biradar, Sikkim Manipal Institute of Technology, SIKKIM, Subir Kumar Sarkar, Jadavpur University, WEST BENGAL, and Puttamadappa C, SJB Institute of Technology, Bangalore KARNATAKA

P24 **Personalized Anomaly Detection and its Applications to Wireless Security,** Danfeng (Daphne) Yao, Computer Science, Virginia Tech, USA

PLEASE NOTE: Sessions III and IV will be parallel sessions

SESSION III – SENSING – Alumni Assembly Hall

Session Chair: Dr. Majeid Manteghi, Virginia Tech

11:00 – 11:20 AM **Compressively Sensing Cognitive Radio,** Peter Chin, Steve Jones, Jack Hammonds, Trac Tran, and Phil Chimento, Johns Hopkins University, USA

11:20 – 11:40 AM **Wireless Microphone Signal Detection Using a Compressive Sensing Technique for IEEE 802.22,** Y. Tachwali, F. Basma , W. J. Barnes, and H. H. Refai, University of Oklahoma- Tulsa, USA

11:40 AM – 12:00 PM **Distributed Misbehavior Detection and Mitigation in Cooperative Spectrum Sensing,** Sintayehu Dehnie, Kyle Guan, and Reza Ghanadan, BAE SYSTEMS, USA

12:00 – 12:20 PM **Handshaking Protocols and Jamming Mechanisms for Blind Rendezvous in a DSA Environment,** Aaron Gross and Ryan Thomas, Air Force Institute of Technology, USA

SESSION IV – NETWORKS – Location TBA

Session Chair: Dr. Luiz DaSilva, Trinity College Dublin, IRELAND

11:00 – 11:20 AM **Toward MIMO Performance for Single-Channel Radios,** John E. Kleider, General Dynamics C4 Systems, Derek Morris, U.S. Army CERDEC, Benjamin Hamilton and Xiaoli Ma, Georgia Institute of Technology, Hung-Quac Lai, U.S. Army CERDEC, and Chris Steenhoek, General Dynamics C4 Systems, USA

11:20 – 11:40 AM **A Graph Theoretic Approach to Planning Software Defined Radio Configuration Based on Network QoS Objectives,** Randy Poe, Harris Zebrowitz, Bruce Mackay, and Thad Konicki, Lockheed Martin, USA

11:40 AM – 12:00 PM **Cognitive Radio Migration into Commercial Wireless Networks, J**oe Kennedy and John Carlson, Echo Ridge LLC, USA

12:00 – 12:20 PM **Evaluating WiMAX for Public Safety,** James Martin and Mike Westall, Clemson University, USA

12:20 – 1:00 PM **Lunch**

1:00 – 2:00 PM **Introduction of Keynote Speaker** - Alumni Assembly Hall
Dr. Tamal Bose, Virginia Tech

Keynote Address – "Adaptive Multi-scale Optimization for Enhancing the Performance of Wireless Systems"
Dr. Barry Horowitz, University of Virginia

2:00 – 3:15 PM **Session A1 Tutorial**
"Wireless Without Batteries: Energy-Harvesting Microcontrollers for Radio Communications"
Dr. Gregory D. Durgin, School of Electrical and Computer Engineering, Georgia Institute of Technology

Session A2 Tutorial
"Ensuring Safety, Sustainability and Security in Body Area Network"
Sandeep K.S. Gupta, Tridib Mukherjee and Ayan Banerjee, Arizona State University, and Krishna Kumar Venkatasubramanian, University of Pennsylvania

Session A3 Tutorial
"Cognitive Radio Communications for Enabling Dynamic Spectrum Access"
Dr. Alexander M. Wyglinski, Worcester Polytechnic Institute (WPI)

3:15 – 4:00 PM **Refreshment Break/Poster Session/Research Demos**

4:00 – 5:30 PM **Sessions A1, A2, and A3 conclude**

6:00 PM **Reception**

Thursday, June 3, 2010

7:00 – 9:00 AM **Registration**

8:00 – 9:00 AM **Introduction of Keynote Speaker** - Alumni Assembly Hall
Dr. Allen MacKenzie, Virginia Tech

Keynote Address – "Fluid Networks & Cognitive Radios"
Dr. Linda Doyle, Trinity College, Dublin, IRELAND

9:00 – 10:15 AM	**Session B1 Tutorial** "Overview of LTE" Dr. Nishith Tripathi, Award Solutions
	Session B2 Tutorial "Video Over Cognitive Radio Networks" Dr. Shiwen Mao, Auburn University
	Session B3 Tutorial "Filter Bank Multicarrier for Next Generation of Communication Systems" Dr. Behrouz Farhang-Boroujeny, University of Utah
	Session B4 Tutorial "Detection and Classification of RF Signals and, Physical Layer and Network Layer Behavior of a Network of Software Defined/Cognitive Radios" Dr. Shubha Kadambe, Rockwell Collins
10:15 – 11:00 AM	**Refreshment Break/Poster Session/Research Demos**
11:00 AM – 12:30 PM	**Sessions B1, B2, B3, and B4 conclude**
12:30 – 1:30 PM	**Lunch**
1:30 – 2:45 PM	**Session C1 Tutorial** "Efficient Design of Wireless Sensor Networks for Urban Environments" Dr. Brian Woerner, West Virginia University
	Session C2 Tutorial "Wireless Social Networks: It Takes Two to Tango" Drs. Anil Vullikanti and Madhav Marathe, Virginia Tech
	Session C3 Tutorial "Game Theory for Cognitive Radios and Networks" Dr. Luiz DaSilva, Trinity College Dublin, Ireland Dr. Allen Mackenzie, Virginia Tech
	Session C4 Tutorial "Emerging Wireless Standards and the TV White Space" Dr. James (Jody) Neel, Cognitive Radio Technologies, LLC
2:45 – 3:30 PM	**Refreshment Break/Poster Session/Research Demos**
3:30 – 5:00 PM	**Sessions C1, C2, C3, and C4 conclude**
6:00 PM	**Party** – Virginia Tech German Club (Shuttle Service Provided)

Friday, June 4, 2010

8:00 AM – 12:00 PM	**Special Session on National Security** – Alumni Assembly Hall Dr. Jim Schatz, former director of NSA R&D Alan Wade, retired CIO from Central Intelligence Agency
8:30 – 10:00 AM	**Session D1 Tutorial** "Wireless Position Location" James J. Costabile, SRA International
	Session D2 Tutorial "Role of Emulation in Test and Evaluation of Emerging Wireless Networking Technologies" Maneesh Varshney, Vivek Srivastava, Rajive Bagrodia, and Sheetal Doshi, Scalable Network Technologies
	Session D3 Tutorial "Wireless Communication Circuit Design at Millimeter Wave Frequencies" Dr. Theodore S. Rappaport, Felix Gutierrez, and James Murdock, University of Texas, Austin
10:00 – 10:30 AM	**Refreshment Break/Poster Session/Research Demos**
10:30 AM – 12:00 PM	**Sessions D1, D2, and D3 conclude**
12:00 PM	**All events conclude**

Keynote Speakers

"DARPA Demonstrations of Cognitive Radio Capabilities"
Dr. Bruce Fette, DARPA

Wednesday, June 2, 2010, 8:00 – 9:00 AM

DARPA has provided significant leadership to the field of cognitive radio - radios that understand what is going on in the spectrum and adapt as required to maintain communication. Currently DARPA is developing the Wireless Network after Next (WNaN), a handheld radio that integrates highly scalable networking principles and a primary objective of cost effectiveness. This talk will cover the principles that lead to scalability improvements of ad hoc wireless networks. We then consider the cognitive radio principles of adaptivity, and current issues in cognitive radio research.

"Adaptive Multi-scale Optimization for Enhancing the Performance of Wireless Systems"
Dr. Barry Horowitz, University of Virginia

Wednesday June 2, 2010, 1:00 – 2:00 PM

Large mission-specific systems that employ wireless components must be designed to accommodate constraints related to wireless technologies. These include such critical factors as bandwidth availability, energy constraints, processing limitations, and high rate of introduction of new interoperable COTS product configurations into the system with significantly different performance capabilities across product generations. An important trend in wireless components is the ability to make them "smart"; i.e., the smart component can adjust its operation based on its self-generated internal assessment of the current situation, balancing considerations of its own performance and operating constraints. However, smart components will typically only be able to directly measure a limited subset of system states, bounding just how smart they can be regarding the relationship between their own performance and overall system performance; and these measurements come at some cost related to the constraining factors. Through a mixture of enhancing the measurement capability of each component and coordination with other components in the system, a specific wireless component can acquire a richer understanding of the overall operating state of the system. Accordingly, a general design strategy for wireless systems is to recognize this complex situation, involving, on the one hand, improved situational measurements for each involved component so as to more precisely assess its trade-offs regarding its local constraints and overall system performance, but at the same time recognize the implications of improving measurement on the constraining elements related to each component. In short, it would be desirable, on a situational basis, to only measure and coordinate when the value to the overall system warrants it. A dynamic measurement strategy, coupled with components that are designed to operate in a variety of different modes related to the constraining factors, provides the basis for optimizing a system's performance on a situational basis. A system design concept called "Adaptive Multi-scale Optimization" will be introduced that provides an approach to designing systems that dynamically manage wireless components' measurements, coordination, and operation so as to best achieve overall system objectives. Some theoretical results will be presented and several real-world examples will be provided to illuminate the practical implications of such a system design approach.

"Fluid Networks & Cognitive Radios"
Dr. Linda Doyle, Trinity College Dublin, Ireland

Thursday, June 3, 2010, 8:00 – 9:00 AM

Abstract not available at press time.

Tutorials

Wireless Without Batteries: Energy-Harvesting Microcontrollers for Radio Communications
Dr. Gregory D. Durgin, School of Electrical and Computer Engineering, Georgia Institute of Technology

Wednesday, June 2, 2010, 2:00 – 5:30 PM

Session A1

This tutorial will demonstrate how simple, energy-scavenging microcontrollers can be used to conduct radio communications with small, battery-less devices. By harvesting energy from incident RF waves or other hybrid sources, we demonstrate unique forms and techniques for wireless communications. We will discuss first-principles operation of these low-powered communications links, with case studies that include the Intel WISP platform as well as 5.8 GHz high-voltage sensors for realizing "Smart Grid" applications. The outline includes history of passive RF communications, low-power microcontroller trends, backscatter and energy harvesting, case study: Intel WISP platform, power optimized waveforms, multi-antenna systems, Van Atta phase modulator, 5.8 GHz backscatter software radio, case study: high voltage sensor, and system demonstration.

Ensuring Safety, Sustainability and Security in Body Area Networks
Sandeep K.S. Gupta, Tridib Mukherjee and Ayan Banerjee, Arizona State University, and Krishna Kumar Venkatasubramanian, University of Pennsylvania

Wednesday, June 2, 2010, 2:00 – 5:30 PM

Session A2

Wireless Sensor Networks (WSNs) are increasingly used to monitor, coordinate, control, integrate, and facilitate many physical processes, e.g. vehicle management, crisis response, and health-care. Such systems experience inherently cyber-physical interactions with the physical environment in which they are embedded. WSNs are prominent examples of a new class of systems called Cyber-Physical Systems (CPSs). This tutorial focuses on a specific class of WSN – the Body Area Networks (BANs). BANs are networks of wireless sensors worn on or implanted within the human body, which can potentially revolutionize health-care by enabling anytime and anywhere monitoring and actuation. A major concern however is the potential hazard to the environment (human body) from interruptions in and side-effects of its operations. For example, in a cardiac care BAN consisting of heart function monitors (EKG, PPG sensors) and actuators (pace-makers) the potential hazards of operation include battery exhaustion or initiation of untimely actuations (shocks) by replaying old commands

or unwarranted electromagnetic interference from nearby electronic devices such as mp3 players. We view the challenge of addressing the potential hazards as the satisfaction of three properties: Safety (i.e. ensuring side-effects of operation are within desired limits), Sustainability (i.e. ensuring uninterrupted operations) and Security (i.e. ensuring authorized access to private health data).

This tutorial is intended for researchers interested in safety, security, and sustainability (S3) of CPSs such as BANs. The tutorial will principally provide: 1) an overview on the S3 requirements for BANs and CPSs in general; 2) a discussion on the modeling, design, and analysis approaches taken to address the S3 requirements in BANs; and 3) a discussion on the open issues to motivate future research opportunities mainly focusing on inter-dependencies among the S3 requirements for the BAN systems in particular and CPS in general. Solutions for BAN satisfying the S3 criteria should cover its five principal operations: sensing, communication, storage, processing, and actuation; and take into account the interactions among the sensors and the environment. In this regard, some of the issues covered will be: 1) design and verification of safe and sustainable BANs, taking into account the interactions between the computing entities and the physical environment, and stochastic behavioral models for the crisis response scenarios; and 2) environmental-coupled security solutions with emphasis on sustainable communication security in BANs using physiological signals for the required cryptographic key agreement and proactive actuation in smart-infrastructures relying on emergency (criticality) awareness.

Cognitive Radio Communications for Enabling Dynamic Spectrum Access

Dr. Alexander M. Wyglinski, Worcester Polytechnic Institute (WPI)

Wednesday, June 2, 2010, 2:00 – 5:30 PM

Session A3

Cognitive radio is the next disruptive radio communication and networking technology. It is currently experiencing rapid growth due to its potential to solve many of the problems affecting present-day systems. One of the challenges that cognitive radio is attempting to solve is the issue of wireless spectrum scarcity due to traditional allocation methods. This tutorial will present how cognitive radio systems can enable the dynamic spectrum access paradigm in order to achieve more efficient utilization of the wireless spectrum. Topics to be covered include: wireless spectrum occupancy characterization, non-contiguous transmission techniques, and cognitive radio optimization/adaptation.

Overview of LTE

Dr. Nishith Tripathi, Award Solutions

Thursday, June 3, 2010, 9:00 AM – 12:30 PM

Session B1

This tutorial provides a comprehensive high level view of Long Term Evolution (LTE). LTE is a 4th generation (4G) wireless network technology that provides superior packet data performance. It can provide data rates as high as 300 Mbps in the downlink and 75 Mbps in the uplink while reducing the cost-per-bit for service providers. This tutorial provides a technical overview of LTE. The tutorial lists the key goals and requirements of LTE. An overall LTE network includes E-UTRAN (Evolved Universal Terrestrial Radio Access Network) and EPC (Evolved Packet Core). Roles of various LTE network nodes are mentioned. Technologies such as OFDM and multiple antenna techniques are discussed. These technologies help LTE achieve high spectral efficiency. Overall network acquisition and call setup procedures are illustrated. Handover scenarios are described. Finally, key aspects of deploying LTE network planning and deployment are summarized.

Video Over Cognitive Radio Networks

Dr. Shiwen Mao, Auburn University

Thursday, June 3, 2010, 9:00 AM – 12:30 PM

Session B2

A cognitive radio (CR) is a frequency-agile wireless communication device with intelligent control and a monitoring interface that enables dynamic spectrum access. The CR concept represents a paradigm change in spectrum regulation and utilization. Its high potential has stimulated a flurry of exciting activities in engineering, economics, and regulatory communities in searching for better spectrum management policies and techniques. As basic understandings are gained, we need to consider how to fully capitalize on CR's high potential for enabling new applications in emerging CR networks. Historically, CR has evolved from PHY (e.g., reconfiguring radios on the fly) to higher layers (e.g., network-wide situation awareness). Although we are approaching Shannon Limit in the PHY, there is still huge space for improvement in higher layers, especially in Quality of Service (QoS) provisioning for multimedia applications. However, since efficient dynamic spectrum access has driven most of the CR research so far, this rich problem area has not been the primary concern in mainstream CR research.

In this tutorial, we will address the important problem of enabling video service over emerging CR networks. We start with an introduction to software defined radio (SDR), CR and CR networks, along with a brief review of current standardization status and available programmable platforms and test-beds. We then introduce the framework of dynamic spectrum access, which allows secondary users to exploit spectrum whitespaces with bounded interference to primary users. We provide a case study with a sensing error-aware CR MAC protocol as well as an analysis of its interference and throughput performance. Next, we provide an introduction to the key concept and techniques of video coding and a brief review of coding standards. We also discuss the new challenges arising from video communications over wireless networks. Finally, we present three pieces of representative work on video over CR networks, namely, a game-theoretic resource allocation scheme, a scheduling scheme for video over infrastructure-based CR networks, and a distributed scheme for video over multi-hop CR networks. We conclude the tutorial with a discussion of open problems and future directions in this important problem area.

Filter Bank Multicarrier for Next Generation of Communication Systems

Dr. Behrouz Farhang-Boroujeny, University of Utah

Thursday, June 3, 2010, 9:00 AM – 12:30 PM

Session B3

Orthogonal Frequency Division Multiplexing (OFDM) has been the dominant technology for broadband communications in the past. Despite OFDM success, recent studies have shown that OFDM is not the best choice for multiple access applications, including cognitive radios. The major problem with OFDM relates to poor out of band spectra of subcarriers which leads to significant interference among different users (cognitive and non-cognitive). Filter bank multicarrier (FBMC) is an alternative solution that has been explored over the years in parallel with OFDM, however, it has been only recently that FBMC is more recognized as a preferred choice over OFDM for some new and future applications. This tutorial presents FBMC and compares it with OFDM in some future applications.

Detection and Classification of RF Signals and Physical Layer and Network Layer Behavior of a Network of Software Defined/Cognitive Radios

Dr. Shubha Kadambe, Rockwell Collins

Thursday, June 3, 2010, 9:00 AM – 12:30 PM

Session B4

This tutorial provides an overview of some of the recent signal detection and classification algorithms. In particular, algorithms that work well at low SNRs, and for RF signals that are of interest in software defined radios and cognitive radios are covered. In addition, behavior learning and classification techniques that are being developed for a radio's physical layer and network layer are discussed. Some of the applications of these techniques are also provided. Required background is briefly provided while describing the algorithms. Hence, this tutorial can be useful for both the novice and expert who would like to know more about recent techniques.

Efficient Design of Wireless Sensor Networks for Urban Environments

Dr. Brian Woerner, West Virginia University

Thursday, June 3, 2010, 1:30 – 5:00 PM

Session C1

Over the last several years, wireless sensor networks have taken significant steps from research topic towards reality, as supporting device technology has matured. In an urban setting, wireless sensor networks can enhance both convenience and security. Throughout this tutorial, we consider an example of an intelligent wireless network of heterogeneous sensors, deployed to aid in detecting and dispatching aid to emergency situations within an urban setting. Inexpensive and ubiquitous acoustic sensors may identify potential incidents, while more expensive cameras may be used to determine the nature of specific incidents.

We use this example network as an illustration to explore key issues in the design of wireless sensor networks. We will examine four key topics in depth: (1) physical layer wireless technologies for the transport of information including the use of cooperative communication techniques, (2) efficient representation of the information from multiple sensors, including the use of compressive sensing methods, (3) methods for efficient routing and network management, and (4) options for achieving energy efficiency within the network. The tutorial will draw examples from a DEPSCoR-funded research project underway at West Virginia University, as well as drawing from a broad survey of current literature in the field.

Wireless Social Networks: It Takes Two to Tango

Drs. Madhav Marathe and Anil Vullikanti, Virginia Tech

Thursday, June 3, 2010, 1:30 – 5:00 PM

Session C2

We are witnessing a silent revolution in the world of technology, where digital devices are touching all aspects of our society. From smart phones that are as powerful as computers just a few years back, to miniature sensors that are as small as a speck of dust that can be used to measure interesting real world and societal phenomenon, we are witnessing a proliferation of digital devices that when networked will collectively provide individuals with a pervasive computing experience. The digital devices will sense, learn, and exploit social and spatial context to provide users with context-based services. Wireless networks will become more connected to the social networks of users to whom they provide services. On one hand, social networks comprised of interacting individuals will provide the necessary context for wireless networks. In turn, wireless networks will provide new ways for social networks to evolve and exchange information. In other words, these networks will be coupled and will co-evolve. Currently, social networks and wireless networks are studied separately. The coupled and coevolving networks present new and unique challenges that cannot be understood by studying these networks in isolation. These challenges range from the design of cross layer protocols that are capable of context-sensitive information diffusion to better coordination amongst individual social agents.

This tutorial will describe an interaction-based computational modeling approach to study large co-evolving wireless and social networks. We will focus on coupled socio-wireless networks spanning large urban areas consisting of 107-109 communication devices and individual users. Synthesis (inference) and analysis of such complex networks poses new computational and mathematical challenges – the tutorial will discuss some of the rigorous techniques developed to address these challenges. We will discuss carefully chosen realistic applications to illustrate the utility of the modeling approach.

Game Theory for Cognitive Radios and Networks
Dr. Luiz DaSilva, Trinity College Dublin, Ireland
Dr. Allen Mackenzie, Virginia Tech
Thursday, June 3, 2010, 1:30 – 5:00 PM
Session C3

Game theory is a field of applied mathematics that describes and analyzes interactive decisions. Its ability to model individual, independent decision makers whose actions potentially affect others makes game theory particularly suitable for studying the environments in which cognitive radios operate. In this tutorial, we will describe some of the main applications of game theory to cognitive networks. These include: models of cooperation and coexistence among cognitive radios and between cognitive radios and legacy users; spectrum auctions and other economic models; and the modeling of partial or incomplete information in decision making.

Game theory is one of the main tools in the rigorous analysis of interactions among cognitive radios. The intended audience for this tutorial includes post-graduate students, academic faculty, and industrial researchers who want to be able to read and understand published research that applies game theory to the analysis and design of cognitive networks, as well as those who are considering using game theory in their own research. The tutorial does not assume knowledge of game theory; basic concepts in cooperative and non-cooperative games will be introduced as they are used.

We will address the following topics in this tutorial: motivation: a case for game theory in cognitive radio research; game theory basics; power control and interference games; distributed channel assignment and topology control games; cooperative models of dynamic spectrum access; real time spectrum markets; and mechanism design: truth telling and incentive compatibility.

The presenters have long research experience in applying game theory to wireless communications problems and first proposed the concept of cognitive networks in 2005. They co-authored the book *Game Theory for Wireless Engineers* in 2006 and numerous papers on game theory modeling of cognitive radios, which have appeared in the *Proceedings of the IEEE, IEEE Transactions on Wireless Communications, IEEE JSAC*, etc. They have presented tutorials on cognitive networks at CROWNCOM, MobiCom, and TridentCom.

Emerging Wireless Standards and the TV White Space
Dr. James (Jody) Neel, Cognitive Radio Technologies, LLC
Thursday, June 3, 2010, 1:30 – 5:00 PM
Session C4

What's the difference between 802.11p, 802.11r, and 802.11s? What's 802.16m and LTE-Advanced and how do they relate to WiMAX and LTE? What networks will be deployed in the TV White Spaces? "Wi" are there separate standards for WiBro, WiMAX, WiBree, and WiFi?

The number of wireless standards continues to explode and just staying abreast of all of them is a full time job. This tutorial is intended to help the audience keep track of the wireless world by briefly touching on critical aspects of emerging wireless standards. With particular emphasis given to the TV White Space standards, planned topics include: cellular standards (3GPP/3GPP2, cdma2000, TD-SCDMA, LTE, WiMAX), TV White Space standards (802.22, 802.11af, CogNeA, 802.16h), wireless LAN standards (802.11 a/b/g/n, fast roaming, mesh, 802.11y, vertical handoffs), wireless PAN standards (Zigbee, WiMedia, Bluetooth, WiBree, Wireless USB), next generation cellular standards (802.16j, 802.16m, LTE-Advanced), satellite deployments (Iridium, GlobalStar, INMARSAT), and underlying communications theory of emerging standards (OFDM, MIMO, Antenna Array Systems).

Wireless Position Location
James J. Costabile, SRA International
Friday, June 4, 2010, 8:30 AM – 12:00 PM
Session D1

In 1996, the FCC issued the order for enhanced-911 (E-911) to provide the location of wireless callers using 911 emergency services resulting in significant development in wireless location technologies. Interest in locating wireless callers has continued to grow well beyond providing emergency services to include law enforcement scenarios such as criminal tracking and border enforcement, to commercial applications such as targeted location-based marketing.

This tutorial describes the wireless position location technologies in use today including both handset-based and network-based approaches and their performance including accuracy, latency, robustness in both outdoor and indoor environments, and applicability across various wireless communication technologies (e.g. GSM, CDMA). Finally, we will discuss location technologies for 3G wireless systems and how hybrid systems that use more than one technology can be leveraged for improved performance.

Role of Emulation in Test and Evaluation of Emerging Wireless Networking Technologies
Maneesh Varshney, Vivek Srivastava, Rajive Bagrodia, and Sheetal Doshi, Scalable Network Technolgoies
Friday, June 4, 2010, 8:30 AM – 12:00 PM
Session D2

This tutorial enumerates various evaluation methodologies for existing and emerging wireless networking technologies and identifies their pros and cons and suitability for specific analysis requirements. The tutorial is divided in three parts: the first part discusses the familiar simulation and physical testbed approaches of evaluation, the second part explores the recent advances in software emulation based testbeds that overcome some of the shortcomings of the preceding approaches and the final part introduces a novel evaluation methodology based on the concept of Software Virtual Networks (SVNs).

A SVN can be created by taking a high-fidelity, accurate representation of a communications network (be it physical or yet to be realized) and recreate it digitally in a simulation environment to obtain an emulation of the network. Fidelity is maintained in the emulation with respect to the network operation and timing; as a result applications and network management software that run on the live network are unable to differentiate between actual equipment and its emulation. SVNs are interoperable with physical testbeds and live deployments and this enables novel methods of evaluation wherein emerging communication networks are partly represented as SVNs and part live. Thus, SVNs enable the evaluation to scale to the desired numbers without facing the limitations of limited hardware resources that exist on live testbeds.

Wireless Communication Circuit Design at Millimeter Wave Frequencies
Dr. Theodore S. Rappaport, Felix Gutierrez, and James Murdock, University of Texas, Austin
Friday, June 4, 2010, 8:30 AM – 12:00 PM
Session D3

Since the introduction of cellular radiotelephone in the late 1970s and WiFi in the late 1990's, wireless communication systems have traditionally operated in a narrow range of carrier frequencies; namely, the decade of frequencies between 450 MHz to 5.8 GHz, However, in the last several years, new massively broadband wireless networks, such as Ultrawideband communications (UWB) and Wireless Personal Area Networks (WPAN) at 60 GHz (as contemplated by the IEEE 802.15.3.c standard body) have become important for the future of wireless communications, particularly at the edge of the network. For the first time in the history of wireless communications, the carrier frequencies of future networks appear ready to ramp upward in dramatic fashion, and the corresponding bandwidths of these future networks will scale similarly to rates never before imagined. Just as clock speeds and memory sizes of personal computers have scaled exponentially over the past couple of decades due to improvements in semiconductor technologies, and just as the car engine of today leaves little for youngsters to tinker with as compared with those of 30 years ago, wireless communications is poised to begin a rapid change to a new era, requiring wireless researchers interested in experimental research and prototype development to learn new skills and new fabrication techniques for building and testing future wireless systems.

This tutorial provides an overview of the trend towards higher carrier frequencies and massively greater bandwidths, and provides a detailed description of the tools, techniques, and methodologies needed to develop integrated electronics that work at millimeter wave frequencies and above. Unlike lumped circuits and off-the-shelf hardware that are used in today's relatively low frequency wireless transceiver protoypes, we demonstrate how the connector losses, wavelength sizes, data rates, and equipment costs become prohibitively high such that integrated circuits cannot be avoided for the development of future communication devices and prototypes. Thus, future researchers and experimenters will need to be able to design integrated circuits, and will need to test and connect such circuits together to formulate meaningful prototypes. In this tutorial, we present an overview of the various semiconductor technologies that exist today for the fabrication of integrated circuits at millimeter wave frequencies, and demonstrate the types of tools that must be used in order to properly design, simulate, and validate integrated circuits. We discuss the testing hardware, and the verification techniques that must be used to fully characterize the circuit characteristics of millimeter wave devices, and we also cover packaging techniques. We also discuss the requirements of transceiver components, such as antennas, RF front ends, mixers, oscillators, and Analog to Digital convertors (ADCs) that will be required to handle multi-Gigabits/s data rates. We then provide examples of actual circuits that have been designed and tested by researchers throughout the world, and include examples from our work at The University of Texas, including lessons learned along the way. The goal of this tutorial is to help the newcomer to the world of millimeter wave RF and baseband circuit design, so that future wireless engineers may take their knowledge of wireless system and algorithm, and implement them in integrated form factors that are well suited for millimeter wave frequencies and above.

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