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BROADBAND OPTICAL WIRELESS LOCAL AREA NETWORKS AND REMOTE SENSING SENSORS

With the increasing popularity of multimedia services supplied over the fixed network (such as Web browsing, video conferencing, and video on demand), it is certainly only a matter of time before users will demand higher bandwidth mobile access. Advances in displays, battery technology, and processing power have made it possible for users to afford and carry laptops and palmtops. The prospects for the delivery of multimedia services to these users is, however, crucially dependent on the development of low-cost physical layer delivery mechanisms. The market needs to consolidate the data into one single handset.

To address the bit rate limitation problems of current wireless systems, **Mohsen Kavehrad**, W. L. Weiss Professor of Electrical Engineering, and his research team are examining the concept of adaptive rate delivery of future mobile/portable multimedia services with high bit rates (>100 Mbits/s) for localized areas. Examples of physical layer technologies are GSM, ultra-wideband, and optical wireless (OW) for the high-bandwidth islands, e.g., classrooms, hotels, homes, shopping malls, airports, train stations, planes, spacecrafts, etc. Consider the area of home networking when every home will be illuminated with bright white LED light which can also be a broadband communications carrier. We are entering a new era of always-on connectivity. The expectation from consumers for not only ubiquitous but also seamless data, voice, and video services presents a significant challenge for today's telecommunications systems.

It is commonly agreed that the next generation of wireless communication systems will not be based on a single access technique but will encompass a number of different complementary access technologies. The ultimate goal is to provide ubiquitous connectivity, integrating operations seamlessly in most common scenarios, ranging from fixed and low-mobility indoor environments to high-mobility cellular systems. Surprisingly, perhaps the largest installed base of short-range wireless communications links are optical, rather than radio frequency (RF). 'Point and shoot' links corresponding to the Infra-Red Data Association standard are installed in 100 million devices a year—mainly in digital cameras and telephones. It is argued that OW has a part to play in the wider 4G vision.

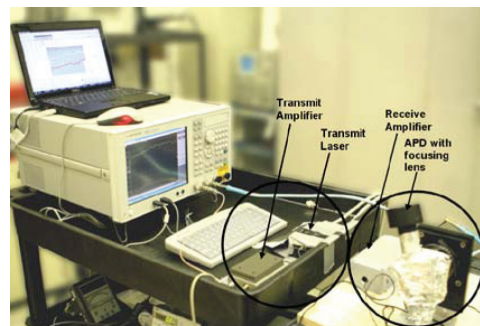
In large open environments where individual users require 100 Mbps or more, OW is a more sensible solution because of its limited cell size. Today's RF local area networks realistically cannot support more than one or perhaps two high capacity users per cell. With cell sizes of approximately 100 meters, which could accommodate tens of users, this is highly wasteful. Multiple high capacity users could only be serviced by deploying a similar number of systems, all within the same locale. This would create a situation where the cells almost completely overlap, which then raises concerns with regards to interference, carrier reuse, etc. In contrast, OW could deliver the necessary capacity to each user through multiple user-sized cells and, because of the intrinsi-

cally abrupt boundary of these cells, interference would be negligible and carrier reuse would not be an issue. Indeed, OW is a future-proofed solution since additional capacity far beyond the capabilities of radio could be delivered to users as their needs increase with time. It is also a "green" technology as power consumption of optical components is smaller than RF ones.

Sensor networks are also increasingly being used for monitoring and controlling vital operations in industries, hospitals, and military installations and vehicles. Current research trends concentrate on RF technology for sensor communications. However, OW communications or visible light communications can offer a much higher data rate or higher reuse factor.

Wireless communications by infrared (IR) or visible light is inherently secure, since it is usually confined within an enclosure. It offers no interference to existing RF sensing or communication infrastructure. It is unregulated worldwide unlike RF spectrum, and small devices can be manufactured that are suitable for miniaturized sensors.

Kavehrad and his former students and postdoctoral fellows have investigated the potential of OW for indoor local area networking. With advancements in solid state optical device manufacturing and increase in availability of off-the-shelf components, OW needs to be reviewed. In a project funded by the National Science Foundation, the Kavehrad research team is designing a wireless optical communication techniques for integration into sensor networks. In the Center for Information and Communications Technology Research Laboratory, Kavehrad and doctoral student, **Jarir Fadlullah**, have built a test-bed comprised of a laser transmitter and an Avalanche Photodiode receiver, and measured the OW channel characteristics in the IR range (See figure below). The laser transmitter has an attached collimating lens, which allows one to focus a spot on the ceiling, where the IR light gets diffused. The reflected light is captured with



a focusing lens at the receiver. This set-up is termed non-directed line-of-sight, as opposed to line-of-sight and diffuse configurations. To obtain frequency responses, a network analyzer is used to modulate the constant laser drive current with RF frequencies swept in the range from 10 KHz to 1GHz.

They have demonstrated potential for transmitting several gigabits per second with this set-up. Kavehrad and Fadlullah presented a paper titled "Wideband Optical Propagation Measurement System for Characterization of Indoor Optical Wireless Channels" based on this system at Photonics West Conference in San Francisco on Jan. 27, 2010 (See news story link here: Penn State Research News). This is the widest directed non-line of sight measurement reported, using practical optical components.

FACULTY SPOTLIGHT



Suman Datta, Monkowski Associate Professor of Electrical Engineering, joined Penn State in 2007 in a joint appointment with Penn State Materials Research Institute. Datta received his bachelor's degree in 1995 from the Indian Institute of Technology and then continued his education on a full scholarship at the University of Cincinnati, receiving his Ph.D. in 1999.

Datta then joined Intel Corporation in Hillsboro, OR, Intel's largest and most complex site in the world. In his eight years at Intel's Advanced Transistor and Nanotechnology Group, Datta rose in the ranks from staff engineer to principal engineer. In 2003, Datta was awarded the Intel Achievement Award for developing the world's first high-K/metal gate complementary metal-oxide-semiconductor (CMOS) transistors with record-setting performance. The high-K/metal gate CMOS transistor innovation marked a new era in high-performance and low-power device technology and forms the building block for every latest-generation Intel microprocessor chip that powers our laptops, desktops, and servers. Datta was the Intel lead device technologist in the joint Intel-QinetiQ research team that demonstrated the world's first enhancement mode and depletion mode indium antimonide based quantum-well transistors operating at room temperature with record energy-performance product. This work, presented by Datta at the 2005 International Electron Device Meeting, sparked world-wide interest in pursuing heterogeneous integration of high-mobility compound semiconductor based materials on silicon platform for low-power, high-speed digital logic applications.

Datta's move to academia in 2007 was sparked by an interest to apply his first-hand knowledge and real-world experience working with high-performance transistors in other research areas, such as self-powered nanoelectronics using scavenged energy. Datta commented, "I was intrigued by the possibility of partnering with researchers from other disciplines and working on ideas much earlier in the research life cycle than is generally feasible in a corporate lab. I was also motivated by the desire to work side by side with young and creative researchers in the early stage of their budding research career."

Upon joining Penn State, Datta was awarded the Joseph R. and Janice M. Monkowski Career Development Professorship in Electrical Engineering. This award, established by Joe Monkowski, an electrical engineering alumnus, was created to support the activities of a faculty member starting an academic career in electrical engineering with financial support and encouragement.

Currently, Datta is exploring new transistor architecture using non-silicon materials to enable energy efficient computing. In December 2009, his research group demonstrated, for the first time, a vertical inter-band tunnel transistor fabricated using indium gallium arsenide material and high-k/metal gate stack. The experimental demonstration, showcased by the 2010 International Electron Devices Meeting program committee for pre-conference publicity, was hailed as a breakthrough in low power device research and demonstration. In addition, Datta's research group is investigating non-classical quantum device structures such as few electron transistors for CMOS "replacement" for future energy efficient and fault-tolerant information processing systems. He is also actively working on direct integration of multifunctional dielectrics with advanced transistors to create a new generation of megafunctional integrated circuits for chip-scale advanced medical imaging applications.

Datta has been awarded 96 patents and has published more than 67 research papers.

A native of India and a naturalized U.S. citizen, Datta, his wife, Anjuli, and two children, Rajeev and Tanya live in Port Matilda.

STUDENT SPOTLIGHT

Johnathan Ross, senior in electrical engineering, enjoys giving back. Ross, originally from Royersford, PA, has been involved in a number of service projects since he came to Penn State. His involvement in the Penn State IFC/Panhellenic Dance Marathon (THON) has provided Ross with a great amount of fulfillment and humility in helping others. THON is the largest student-run philanthropy in the world benefitting the lives of children and families battling pediatric cancer.

The opportunity to work with THON sparked an interest in becoming involved in other projects where he can use his time and abilities to help others. Last year, Ross was part of a team of engineering students, who traveled to the small island of Roatan, one of the Bay Islands of Honduras, over Spring Break. The group, accompanied by **Tim Wheeler**, research assistant in electrical engineering, installed a 2.5kW photovoltaic solar array on the roof of a small school. The use of this renewable energy source will save the school thousands of dollars every year. Ross comments, "It was a once in a lifetime experience and combined my passions of service and education. Building the photovoltaic system helped increase my interest in practical engineering methods and distributed power sources."



Ross can trace his interest in electrical engineering to his years in boy scouts. His interest was piqued during his work on the engineering merit badge when he built several elementary circuits including a "lie detector" and a photovoltaic powered dragonfly that would flap its wings in the sun. Once at Penn State, Ross' interest in electrical engineering was solidified when he took PHYS 212.

Ross, a member of the Schreyer Honor College, has a proven track record as an excellent student having been on the dean's list for seven semesters. In addition, he is the recipient of several scholarships and awards including, the Matthew P. Blickley Memorial Fund and the Lockheed Martin Corporation Scholarship. He is a member of Eta Kappa Nu and Tau Beta Pi engineering honor societies.

Ross has had multiple internships through his college years including GE Energy Infrastructure, GE Transportation and Aberdeen Test Center. Ross stated, "The internships were an integral part of my education that helped shape my work ethic and real world engineering principles." Ross is specializing in the areas of power and energy. This area interests Ross because of the radical changes coming to the energy sector in the coming years.

Upon graduating in the spring, Ross will join Lutron Electronics in Coopersburg, PA as a project electrical engineer. There is no doubt that this ambitious young man will also find a way to fit plenty of service hours into his schedule.

FACULTY UPDATES

Sven Bilén, associate professor of electrical engineering and **Ken Jenkins**, professor of electrical engineering and department head, presented a poster paper regarding the Electrical Engineering Research Experience for Undergraduates program at the National Science Foundation grantees conference held in Reston, VA, on Jan. 30-Feb. 2.

Suman Datta, associate professor of electrical engineering, joined the editorial board of the Association for Computing Machinery's Journal of Emerging Technologies in Computing Systems (JETC) as an associate editor. JETC covers the latest findings in emerging technologies beyond traditional semiconductors for computing applications. In addition,

Datta will be visiting Arizona State University in February to present a seminar on "Energy Efficient Transistors for CMOS and beyond CMOS applications."

Ken Jenkins, professor of electrical engineering and department head, served on the External Review Committee in January at the University of Pittsburgh for their graduate program in electrical engineering.

Mohsen Kavehrad, W. L. Weiss Professor of Electrical Engineering, is an invited speaker at the Optical Society of America Topical Meeting, Optics & Photonics Congress on Feb. 3 in San Diego, CA. His paper titled "Combating Atmospheric Scintillation and Dispersion on a Laser Imaging Link Using Multiple

Parallel Beams" is co-authored with Z. Hajarian and J. Fadlullah.

Raj Mittra, professor of electrical engineering, was an invited speaker at the Asia-Pacific Microwave Conference in Singapore during the week of Dec. 7, 2009. Mittra gave a keynote speech titled "Square Kilometer Array—An Unique Instrument for Exploring the Mysteries of the Universe using the Square Kilometer Array" at the Applied Electromagnetic Conference in Kolkata, India, on Dec. 14–16, 2009.

Victor Pasko, professor of electrical engineering, presented an invited talk on electric coupling between the lower and upper atmosphere at the Annual Meeting of American Meteorological Society's Seventh Symposium on Space Weather on

Jan. 17–21 in Atlanta, Georgia.

Congratulations to **Jerzy Ruzylo**, professor of electrical engineering, who has been selected by Penn State to be awarded the title of Distinguished Professor of Electrical Engineering.

STUDENT RECOGNITION

Tim Gilmour, graduate student in electrical engineering, had his paper titled "Manual Rat Sleep Classification in Principal Component Space" published in Neuroscience Letters, volume 469, Issue 1, 18 Jan. 2010. The paper is co-authored by Jidong Fang, Zhiwei Guan, and Thyagarajan Subramanian.

REPORT FROM THE UNDERGRADUATE LABS COMMITTEE

The Undergraduate Labs Committee is responsible for the core undergraduate labs and the EE computer lab; facilities that are used by EE undergraduate students. The committee is tasked with implementing and maintaining a set of laboratory facilities that are modern and contain state-of-the-art equipment to enhance learning in the core EE courses. Committee responsibilities include strategic planning, budgeting, developing and maintaining vendor relationships, and wise use of available grants.

Each year the committee undertakes a major renovation to a lab. Past projects have included remodeling the core undergraduate labs in rooms 309 and 310 EE West, the Senior Design Lab in 301 EE West, and the EE Computer Lab in 304 Hammond. Planning is done during the spring semester and renovations are done during the summer. During 2009, the budget available to the committee was substantially reduced due to the recession and University-wide budgetary constraints. Instead of undertaking a major renovation project, the committee voted to do incremental improvements to the presentation facilities in the third-floor EE West labs and in the EE East seminar room and conference room.

We installed technology podiums with a standard complement of equipment – PC, monitor, projector, projection screen, video/audio switcher, sound system, wireless microphone, and DVD/VCR player – in the new seminar room in 101 EE East, in the Control Systems Lab in 302 EE West, and in the two circuits labs in 309 and 310 EE West. Additionally, a video projector was installed in the 127 EE East conference room and the projectors in room 302, 309, and 310 EE West were upgraded to brighter models.

With these changes, all four undergraduate teaching labs on the third floor of EE West have similar capabilities for student presentations and for teaching as technology classrooms. Additionally, we got a jump start on next year's major renovation project by purchasing lab benches for the new Microwave Lab in 329 EE East.

2010 Upgrade Plans

For 2010 the committee will upgrade equipment in the new Microwave Lab in room 329 EE East. Since microwave test equipment is expensive, we must rely on generous donations from our strategic vendors or look for sources of external funding. Decisions on what to upgrade will be made during the spring 2010 semester beginning in January 2010.

Committee members: Sven Bilén, James Breakall, Marsha Church, Jeffrey May-er, Sal Riggio, Bernard Ropchock, David Salvia, and Mark Wharton, chair.

The pictures below show the upgrades:

Control Systems Lab – 302 EEW



Electronics Lab – 309 EEW



Circuits Lab – 310 EEW



Microwave Lab benches – 329 EEE



Seminar Room – 101 EEE



Conference Room – 127 EEE



ATTENTION ALUMNI

The Society of Penn State Electrical Engineers and the Department of Electrical Engineering are announcing several new initiatives.

First, a [mentoring program](#) is in the planning stages. We had hoped to have this program running by spring but the timing is more appropriate if we start this program in the fall for Juniors. We are collecting names of alumni who would like to mentor students. You do not need to be located in State College or Pennsylvania. Please e-mail your name and contact information directly to Cathy McClellan at cls118@psu.edu. Forms will be available to download in March.

Second, an [Early Career Recognition Alumni Award](#) has been created to honor outstanding Penn State electrical engineering alumni at the outset of their career. This is an exciting new way to recognize our alumni. Nominations are due by May 15 and can be made by anyone with knowledge of the career progression and accomplishments of the nominee. Additional information and the nomination form can be downloaded from our department Web site.

Third, we are updating the department Web site which should be "live" in a couple of months. We are exploring the addition of a new section for developing an [alumni network](#). This would include sharing your business/company information, your career progression, and other information. This area would also include information for companies interested in hiring our graduating students or alumni. At this point, I'm looking for feedback from alumni and companies on how useful this would be. Please forward your comments and suggestions to Cathy McClellan at cls118@psu.edu.

Save the Date! May 21 is the Society of Penn State Electrical Engineers [spring meeting](#). More information will be coming.

FALL 2009 GRADUATION

Graduation was held on Dec. 19, 2009 with the following degrees conferred:

Bachelor's degree: 44

Master's degree: 15

Doctoral degree: 7

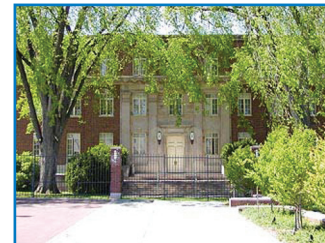


DID YOU KNOW

The famous architect, Charles Klauder, from Philadelphia (1872–1938), designed a number of university buildings on the campuses of Penn State, University of Pittsburgh, University of Pennsylvania, Cornell University, Princeton University and others. His designs on the Penn State campus include the [Electrical Engineering West Building](#) as well as Old Main, Pattee Library, the Nittany Lion Inn, and Rec Hall. One of his more famous buildings is the Cathedral of Learning at the University of Pittsburgh pictured below.



Cathedral of Learning,
University of Pittsburgh



EE West Building, Penn State

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Our monthly electronic newsletter has a distribution of 5,000 alumni, friends, colleagues, and universities. In addition, we print a number of newsletters each month to send to electrical engineering departments in universities across the country. This has been a wonderful means to keep in touch with our alumni, and spread the word about the activities and events of the electrical engineering department.

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For more information, please contact Cathy at 814-863-0253 or cls118@psu.edu.

Contact Information:

Department of Electrical Engineering, 121 Electrical Engineering East, University Park, PA 16802, Phone: 814-865-7667, FAX: 814-865-7065

Web: www.ee.psu.edu

Please submit news items to: Cathy McClellan at cls118@psu.edu

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