

## UC San Diego's Advanced Network Sciences Examines Foundations of Communications Systems

September 15, 2008

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Behind every gadget lies a scientific generalization, a theoretical framework that explains the structure and behavior of your mobile phone or WiFi connection (even when they're misbehaving).

But as important as they are, the underlying theories of communication systems can, at times, be disregarded by engineers eager to convert "theory into practice" and develop the next pocket-sized gizmo or wireless capability. The mission of UC San Diego's Advanced Network Sciences (ANS) is quite the opposite. The collaborative of researchers in UCSD's electrical and computer engineering (ECE), mathematics and computer science and engineering (CSE) departments are more interested in the "hows" and "whys" behind the technology, and seek to expand on the theories behind the complex communication systems that form the infrastructure of modern information society.

"In engineering, there's always this attention put on immediate practical solutions," says Tara Javidi, an assistant professor of ECE and a founding member of ANS. "But thinking about network systems as something much more general and abstract - there's something to that. We tend to think of our work and mission at ANS as bridging the gap between information theory, network theory and more practical distributed systems. There are always advantages in looking at the particulars of a problem to get a specific solution, but there are also advantages to letting go of those specificities to get a general feeling. We are always inspired by the success of information theory in transforming and shaping information and communication industry."

One way the center seeks to create a more holistic understanding of network systems is through its annual Summer Lecture Series, held at the UCSD-division of the California Institute for Telecommunications and Information Technology (Calit2), which provides funding and support for ANS. This year's series took place Aug. 18-22 and was organized by Javidi and assistant ECE Professor Massimo Franceschetti, another founding member of ANS. ECE Professor Rene Cruz - a third founding member of the group - is currently on a leave of absence from UCSD to launch Mushroom Networks Inc., a San Diego technology company that grew out of a project in adaptive systems which earned him accolades from UCSD's Jacobs School of Engineering as an Ericsson Distinguished Scholar. He returns to the university in January.

This summer's lecture series featured a wide variety of world-class researchers in network theory, including Bill Massey of Princeton University, Amy R. Ward of the University of Southern California, Sean Meyn of the University of Illinois at Urbana-Champaign, Nick Bambos of Stanford University and Adam Wierman of the California Institute of Technology. Faculty and students affiliated with UCSD's Jacobs School and Calit2 were able to interact with the researchers and foster future collaborations, despite the fact that many of the researchers came from widely disparate domains.

Says Javidi: "The really fun part of this year's series was that it focused more on the theoretical side of traditional queuing networks as the underlying the theme of the series, as opposed to particular applications of interest. Amy Ward, for example, represented USC's Business School and spoke about network systems as they apply to manufacturing, and Adam Wierman of CalTech works on Web farms, Web servers and computational networks. Nick Bambos talked about wireless networks serving multimedia applications. Each of these networks

are in service of very different applications but can be mapped to a rather common mathematical framework, a framework that has been studied by Massey and Meyn, pioneers in queuing and stochastic network theory. These meetings give us a sense of the underpinnings of our work that are similar, even if the applications might be very different. That's the beauty of it.

"What is really great about the lecture series," she adds, "is that they are each an hour and a half long, and each speaker presents two lectures. That's practically three hours of folks lecturing, so people can go in really deep conversations about the material. That's a real departure from the 20-minute talks at workshops you so often see. Also, the fact that these speakers come for multiple days means the interaction is much deeper and much less rushed."

It turns out that the event is popular not only with the UCSD community, but also among the presenters themselves. Javidi says that several lecturers requested permission for their own students to attend the event next year (which, she adds, will require additional student housing).

Franceschetti notes that students have always been a major focus of ANS. The lecture series gives students a chance to "associate the work they've read with the actual face of a person," he says, adding that professors are more willing to visit UCSD and learn about the student's own research because the university has an organization like ANS.

"One of the main missions of the center is to create an entity for students," says Franceschetti. "We advise them about what classes they should take to make them feel more at home and comfortable in an engineering environment. There's a strong push from the technology community to develop network science, which requires collaboration between mathematics, engineering and physics departments. In creating this organization, we wanted to create an entity for these people to communicate."

Although its focus is on theoretical analysis, ANS also serves as a vehicle for promoting affiliated research projects that also happen to have practical applications. Past studies have included Rene Cruz's work with student Navid Ehsan on "Optimal Rate Allocation and SINR Control in Wireless Networks," and Franceschetti and Javidi collaborated with student Ehsan Ardestani on "Scheduling Policies for Sharing Network Resources." Franceschetti also worked with student Paolo Minero (winner of this year's Claude Shannon Memorial Fellowship) on a project studying "Control Over Communication Channels."

In addition, the researchers affiliated with ANS have several plans for future projects and collaborations. Javidi says the group is thinking about creating a spin-off of its summer lecture series in the form of a Southern California queuing network meeting with Caltech, USC and possibly other universities from the UC system. ANS is also gearing up for its involvement in the 2009 Information Thory and Applications (ITA) Workshop, which will take place in February 2009, and tentative plans are being made for a collaborative lecture series between ANS, ITA and UCSD's Center for Wireless Communications.

Noting that many of ANS's theoretical ideas are reflected in industry - parcticularly in MIMo systems and other means of handling networks - Franceschetti says that ANS also seeks to to strengthen its ties to industry partners like Qualcomm. ANS' first sponsored post-doc scholar, Kashik Chakraborty, was recently hired by Qualcomm's research and development unit, and ANS will sponsor another post-doc scholar this year.

As for how theory will parlay into communication systems five or ten years from now, the future is anyone's guess, says Javidi.

"There are a lot of really hard theoretical problems in networked systems," she explains. "Which one will get solved first? I don't know. A large network of wireless systems is of interest to industry, but we're each working on different things, trying our luck and making our bets. One thing we do know is we would like to have a good emphasis on the theoretical aspects of networking in terms of education for our students. We want them to have

a much broader view of technology, rather than focusing on particular applications. We think of networking as a science with lots of basic and theoretical questions to tackle."

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