Technologies and Foundations for Robust and Secure Networked Systems

Fall 2010 Newsletter

Center for Networked Systems

CNS Researchers Break World Record

Using switches donated by member company Cisco Systems, this spring a CNS research team built TritonSort, a data sorting system designed for a single purpose: to break a world record.

Top academic and industry research groups from all over the world annually vie to claim the top position in the competition they entered: the Sort Benchmark, which measures the performance of systems that execute very large data sorts. Former world record holders have hailed from HP Labs, Google, Microsoft Research, and Yahoo, as well as from such universities as Stanford, MIT and Tsinghua University in China. The UCSD team going after the top award consisted of CSE professor Amin Vahdat, assistant research scientist George Porter, postdoctoral researcher Harsha Madhyastha, researcher Alex Pucher, and CSE Ph.D. students Alex Rasmussen, Radhika Niranjan Mysore and Michael Conley. After months of hard work, the group surpassed their original ambitions by claiming the world data-sorting record in one category, while tying the record in another category.

The speed and efficiency of current sorting technology consistently form one of the main limitations to the size, complexity, and efficacy of large Internet sites such as search engines like Google, shopping sites like Amazon, and social networks like Facebook. Because of this, improvements in all aspects of data sorting have been and remain issues of major concern.

Continues on page 3

Improving Video Performance Wins Best Paper Award at CTS 2010

CNS graduate student Cynthia Taylor and professor Joseph Pasquale recently received the Outstanding Paper Award at the International Symposium on Collaborative Technologies and Systems for their paper on “Improving Video Performance in VNC [Virtual Network Computing] Under High Latency Conditions.” Taylor works on distributed systems for mobile devices, focusing on issues of latency, and the paper is part of her ongoing Ph.D. research on proximal resource architectures for thin client computing. The goal: to support next-generation compute and I/O-intensive applications, such as augmented reality using lightweight wearable input/output devices and remote processing.

The paper concludes that adding a Message Accelerator proxy to a VNC system is a very simple but highly effective way of improving video performance ten-fold with VNC under high latency conditions. The researchers showed that even with small amounts of network latency, video performance with the Message Accelerator proxy is as good or better than an unmodified VNC system.

CNS Members

ERICSSON hp invent Google MOTOROLA QUALCOMM NetApp ORACLE CISCO

In This Issue

Huawei Supports CNS Faculty

One of China's leading international telecom solutions providers, Huawei, has provided a substantial gift to CSE professors George Varghese and Dean Tullsen in support of their research on next-generation packet forwarding architecture.

New CNS Hire

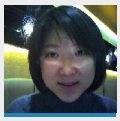
Professors Varghese and Tullsen have welcomed to their group the new CNS postdoctoral researcher, Alberto Dainotti, who joined from the COMICS research group at the Computer Science and Engineering department of the University of Naples "Federico II." He is working with CSE professors on issues related to next-generation packet forwarding architecture. His main research interests are network traffic measurements, analysis, modeling and classification, and network security. Dainotti earned his Ph.D. from the University of Naples in 2008.

Stefan Savage Named CNS Interim Director

Professor Stefan Savage, a member of the CSE faculty, has been appointed as Interim Director of the Center for Networked Systems while current director Amin Vahdat takes a year of sabbatical leave to pursue research at CNS member company Google. Savage has been serving as CNS Associate Director since 2009.

Recent CNS Graduates

ECE Ph.D. student **Raheleh Dilmaghani** submitted her doctoral dissertation, "On Improving Communication in Emergency Response at Network and Organizational Levels," in June 2010. Her advisor was professor Ramesh Rao.



Heasoo Hwang, a CSE student advised by Yannis Papakonstantinou, was awarded a Ph.D. in Computer Science after submitting her dissertation in June 2010 on "Dynamic Link-based Ranking over Large-Scale Graph-Structured Data."

Justin Ma, a CSE Ph.D. student co-advised by professors Stefan Savage and Geoffrey M. Voelker, submitted his dissertation on "Learning to Detect Malicious URLs" in June 2010. He has accepted a postdoctoral position at UC Berkeley.

Thomas Ristenpart has accepted a position as an assistant professor beginning in January 2011 at the University of Wisconsin-Madison. He submitted his doctoral dissertation, "New Approaches for the Design and Analysis of Cryptographic Hash Functions," in the summer of 2010. His advisor was CSE professor Mihir Bellare.

Vikram Subramanya graduated in June 2010 with a M.S. in Computer Science after submitting a thesis entitled, "Simulation to Scale of the HELIOS System." He now works at Google as a Software Engineer in the Platforms Networking Group.

Hakon Verespej, working with CSE professor Joseph Pasquale, completed his M.S. degree with the submission of his thesis on "A Characterization of Node Lifetime Distributions in the PlanetLab Test Bed." Verespej is now a Software Engineer in the storage systems group at Microsoft Research.

CNS Researchers Identify Potential Network Security Risks of Modern Automobiles

Arbitrary message and false speedometer reading visible on the driver information center; note that the speed is at 140mph even though the car is in Park.

Automobiles that have systems controlled or managed by internally and externally networked computer systems are reaching near ubiquity in the United States. Computers in the form of self-contained embedded systems have been integrated into virtually every aspect of a car's functioning and diagnostics, including the throttle, transmission, brakes, speedometer, climate and lighting controls, external lights and entertainment systems. But are these systems secure?

Looking for an answer to that question, a research team embarked on a comprehensive evaluation of security risks in today's cars and trucks. Led by CNS Interim Director Stefan Savage and recent UCSD Ph.D. alumnus Tadayoshi Kohno, who is now a professor of computer science at the University of Washington, the team performed an in-depth assessment of the security risks of modern automotive computer systems.

In a peer-reviewed paper presented in May at the IEEE Symposium on Security and Privacy in Oakland, Calif., professor Savage and his team presented an "Experimental Security Analysis of a Modern Automobile." In the paper, the authors -- including CNS faculty member Hovav Shacham,– drew attention to potential security issues that can only become more serious with the increase in computerized control of and wireless connectivity with automotive systems. According to the report, the researchers demonstrated "the fragility of the underlying system structure. We demonstrate that an attacker who is able to infiltrate virtually any Electronic Control Unit (ECU) can leverage this ability to completely circumvent a broad array of safety-critical systems."

In addition to presenting their work in the academic forum, their work was also highlighted in a May 14, 2010 New York Times article, "Cars' Computer Systems Called at Risk to Hackers." The research is described at *http://www.autosec.org/*. The paper itself is available online at *http://www.autosec.org/pubs/cars-oakland2010.pdf*.

CNS Researchers Break World Record

Continues from page 1...

The goal of the main competition, GraySort, is to achieve the highest sort rate of TB per minute per 100TB of data. In another category, the "Minute Sort," the goal is to sort the highest volume of data in 60 seconds or less. Additionally, within each competition, there are "Indy" and "Daytona" categories. "Indy" competitors (like Indy race cars) can be designed solely for the purpose of operating within the parameters of the Sort Benchmark. "Daytona" competitors are required to possess the capability to sort other record and key types besides those set by the parameters of the benchmark competition.

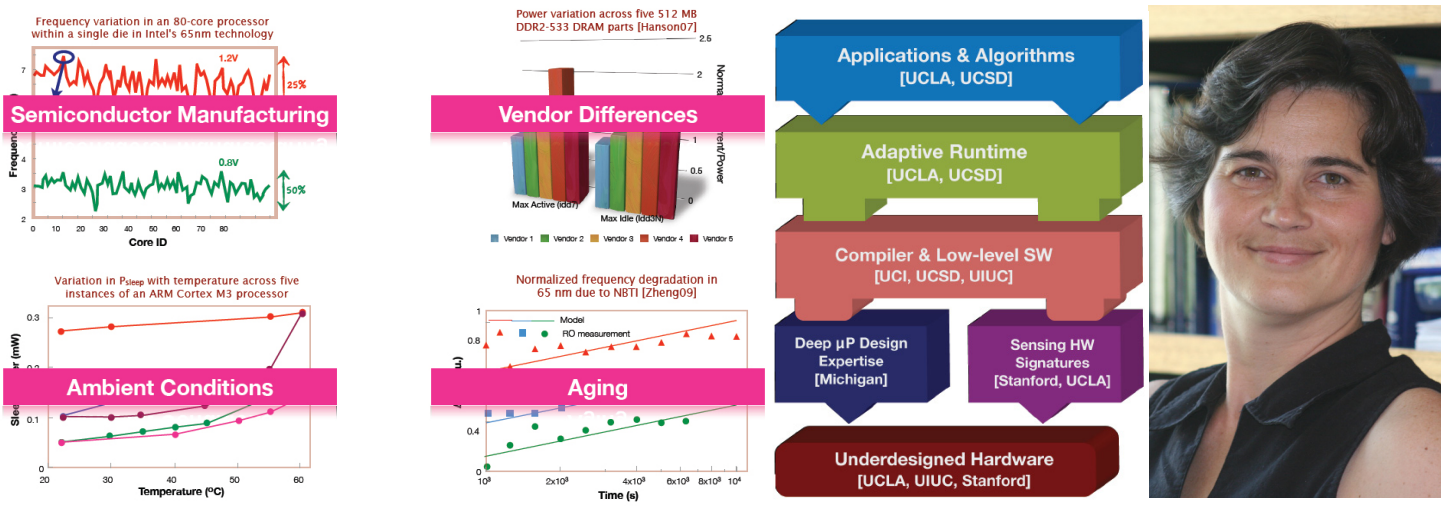
Working in the "Indy" category, the CNS group achieved the benchmark for the GraySort and broke the world record in the MinuteSort, when they sorted one-trillion (1,000,000,000,0000) records in 10,318 seconds at a rate of 0.582 TB per minute.

The improvement in GraySort speed was officially deemed to be a tie because the performance improvement was less than 5 percent better than that of the previous record-holding system. But as research scientist George Porter points out, in using UCSD's TritonSort system, "We achieved the benchmark… [using] one fourth the number of computers as the previous record holder to achieve that same performance." In other words, the UCSD entry used one-fourth the energy and one-fourth the cooling/data center real estate. "This is an important and exciting result," added Porter, who went on to explain why the team chose to take aim at the world record: "[The Sort Benchmark] is a really interesting, exciting, and high-profile motivation for this work… and it whets our appetite here to build those [cutting edge] systems… A lot of our research agenda was driven by our experiences trying to build [Tritonsort, and] it was only through trying to break this record that we uncovered a lot of the fundamental research problems that we're now addressing" to take these accomplishments further."

Although the current systems scale well, large sections of the systems remain unused as they operate. This systemic inefficiency wastes resources – time, energy spent powering and cooling machines, and space – all of which affect the fiscal bottom line. "The inefficiencies involved are multiple," explains Ph.D. student Rasmussen, and "all of the challenges for the future are related to how to solve the problems of efficiency." What is the next goal for the researchers? "We are hoping to beat our current records by 50 percent by the end of 2010," said Rasmussen.

The Sort Benchmark award ceremony took place in June at the 2010 ACM SIGMOD conference in Indianapolis. To view all the current and archived sort competition results and the competition parameters, see the Sort Benchmark website at *http://sortbenchmark.org/*.

CNS Researchers Participate in Major NSF 'Expedition in Computing'



(l-r) Sources of variability; vision of collaboration across six campuses; co-PI and CNS member Tajana Simunic Rosing

As semiconductor manufacturers build ever smaller components, circuits and chips at the nano scale become less reliable and more expensive to produce. The variability in their behavior from device to device and over their lifetimes – due to manufacturing, aging-related wear-out, and varying operating environments – is largely ignored by today's mainstream computer systems.

Now two CNS faculty members are part of a visionary team of computer scientists and electrical engineers from six universities proposing to deal with the downside of nanoscale computer components by re-thinking and enhancing the role that software can play in a new class of computing machines that are adaptive and highly energy efficient.

CNS faculty Tajana Simunic Rosing (above right) and Yuanyuan Zhou (next page) are among five co-PIs on a $10 million, five-year grant to researchers who will explore "Variability-Aware Software for Efficient Computing with Nanoscale Devices." The grant is part of the funding agency's Expeditions in Computing program, which rewards far-reaching agendas that "promise significant advances in the computing frontier and great benefit to society."

"We envision a world where system components – led by proactive software – routinely monitor, predict and adapt to the variability in manufactured computing systems," said CSE chair Rajesh Gupta, director of the Variability Expedition. "Changing the way software interacts with hardware offers the best hope for perpetuating the fundamental gains in computing performance at lower cost of the past 40 years." The project is based in the UCSD division of the California Institute for Telecommunications and Information Technology (Calit2) and brings together faculty, students and specialized facilities from lead university UC San Diego and four other universities: UCLA, UC Irvine, Stanford, University of Michigan, and the University of Illinois at Urbana-Champaign.

The research team seeks to develop computing systems that will be able to sense the nature and extent of variations in their hardware circuits, and expose these variations to compilers, operating systems, and applications to drive adaptations in the software stack.

According to CNS member YY Zhou (see profile at right), the Variability Expedition represents not only a way to deal with hardware reliability, but a chance to rethink software architecture. "If software is designed in a way where the software can automatically adapt to the changing execution environment including the underlying hardware, the software itself is more reliable, and is robust to errors and variations in not only hardware but also software itself," Zhou explains. "Cell phones, for example, need to adapt to constantly changing environments — not just to the physical environment like extreme heat or cold, but to various applications and devices manufactured by different companies. For this reason, it would be useful for the software stack to be adaptive."

Variability-aware computing systems would benefit the entire spectrum of embedded, mobile, desktop and server-class applications by dramatically reducing hardware design and test costs for computing systems, while enhancing their performance and energy efficiency. Many in-demand applications – from search engines to medical imaging – would also benefit, but the project's initial focus will be on wireless sensing, software radio and mobile platforms.

More details about the project are at *http://variability.org*.

YY Zhou's Quest for More Reliable Computing

She specializes in making computers safer and more reliable. Yet CNS faculty member Yuanyuan (YY) Zhou is also a maven of reliability in another sense: Securing grant funding for the University of California, San Diego.

While only on the UC San Diego faculty for a little over a year, she has won NSF support as principal investigator on four projects, and co-PI on a fifth. And three of the projects kicked off in August or September 2010. Zhou's UCSD grants as solo investigator total more than $1.6 million, and she will be responsible for a portion of the $10 million NSF Variability Expedition project that got underway on September 1 (see article at left).

The recent projects aim to make computer systems more reliable by detecting software bugs more efficiently, creating automated logs to diagnose software issues, and using software and system components to adapt to the variability in manufactured computing systems.

"People always ask why their systems fail, and the computer industry is starting to pay attention to this reliability issue," explains Zhou, who joined CNS and the UCSD Department of Computer Science and Engineering in the summer of 2009. "Fundamentally, my research is about making computer systems less vulnerable to attacks so they crash less. When Windows crashes, it's more of an inconvenience, but when an e-commerce site crashes it can really be a problem."

Zhou is the first holder of the Qualcomm Endowed Chair in Mobile Computing. The chair is one of four established in the Jacobs School of Engineering through Qualcomm's original $15 million commitment to the California Institute for Telecommunications and Information Technology (Calit2).

After earning her Ph.D. from Princeton, Zhou worked for two years as a research scientist at NEC. She then taught at the University of Illinois at Urbana-Champaign from 2002 to 2009.

Detecting computer bugs is crucial in the fight for system reliability, Zhou says, which is why she was granted $430,000 from NSF to study ways that software and hardware can be used to detect bugs, especially those in parallel and distributed programs.

"Right now," Zhou says, "cell phones, laptops and desktops have multicore processors, but to take advantage of this kind of processing, programs need to be concurrent. Writing these programs is difficult and error-prone, and this has been a major headache for industry. Detecting and preventing these bugs from doing damage has become an increasingly important and urgent issue."

To improve the correctness of parallel and distributed software, Zhou proposes a novel and widely applicable invariance, called data-flow invariance, which can be used to detect various types of software bugs and make software more reliable and secure.

Another strategy Zhou proposes for coping with computer crashes is to diagnose the problem at the source through automatic log inference and informative logging. NSF granted Zhou another $470,000 to research ways to enable developers to quickly troubleshoot production-run failures and shorten system downtime.

"When a crash happens, you don't want to have to send your cell phone or computer back to the manufacturer, because that takes valuable time and might compromise private data," notes Zhou. Not to mention, she adds, the vendor "might not be able to replicate the problem in-house," just as a patient cannot often replicate a health problem to understand the possible root cause.

Instead of costly customer support, Zhou proposes a method for quickly identifying root causes of the system malfunction and releasing patches to fix it, consequently reducing the amount of time the system is down, and ideally sparing the consumer any hassle whatsoever.

As the recipient of the Committee on the Status of Women in Computing Research (CRA-W) Anita Borg Career Award for her contribution to women in computer science, Zhou notes that her projects also incorporate various educational and outreach activities for students, especially for women in computer science programs.

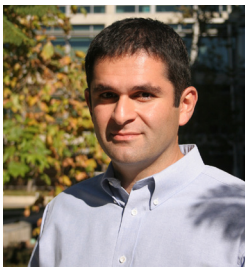
Vahdat Selected for HP Labs Innovation Research Award

For the third year in a row, CNS director Amin Vahdat is the recipient of a grant from HP Labs' Innovation Research Program. The program is designed to provide colleges, universities and research institutes around the world with opportunities to conduct breakthrough collaborative research with HP (a CNS member company).

The award will allow Vahdat to continue a research collaboration with HP Labs that has focused on a scalable, commodity data center network architecture. Most of the award will fund graduate students working with Vahdat on developing interconnecting commodity switches in a fat-tree architecture for clusters consisting of tens of thousands of nodes.

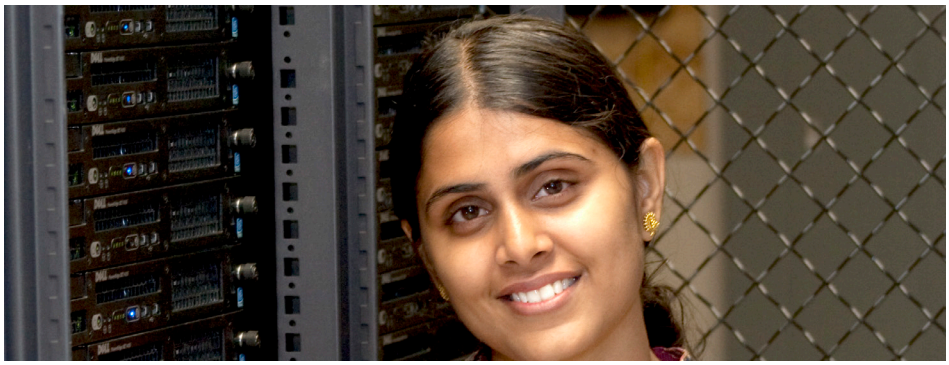
"Our group is targeting a way to deliver full bandwidth for large clusters once 10 GigE [Gigabit Ethernet] switches become commodity at the edge," explained Vahdat. "The goal of our work is to enable scale-out networking, where additional bandwidth and ports can seamlessly be added to a data center on demand."

A 2008 HP Labs Innovation Research award allowed Vahdat's group to build a hardware-software prototype of a 36-PC scalable data center switch architecture. The 2009 award shifted the focus to building better scheduling algorithms for dynamically changing communication patterns in the data center.



UC San Diego is one of only 52 universities in the world to receive a 2010 Innovation Research award. HP reviewed more than 375 proposals from 202 universities across 36 countries. The HP Labs program is designed to encourage open collaboration between HP and the academic community on mutually beneficial, high-impact research. This year's proposals were solicited on a range of topics within the eight broad research themes at HP Labs – analytics, cloud, content transformation, digital commercial print, immersive interaction, information management, intelligent infrastructure and sustainability.

CNS Graduate Student Summer Internships



CSE graduate student Radhika Niranjan Mysore was a CNS summer intern at Microsoft Research

Every summer CNS faculty coordinate with the center's corporate partners and affiliates to place CNS graduate students in internships. The CNS Internship Program matches talented Ph.D. and M.S. students from the departments of Computer Science and Engineering as well as Electrical and Computer Engineering with mentors in industry who supervise their work on research projects of common interest. Over the years these collaborations have resulted in conference papers, journal publications, and dissertation topics.

Participants in the CNS 2010 Summer Internship Program:

- **Mohammed Al-fares** worked with supervisor Khaled Elmeleegy at Yahoo! on "TCP/CDN Analysis and Optimization."
- **Hamid Bazzazz** worked in Google's RAD Business Unit, led by Dr. Rong Pan, on "Adaptive Transport Optimization for Mixed Mobile Environment."
- **Elio Damaggio** collaborated with IBM's Richard Hull on Project ArtiFact.
- **Sambit Das** worked at Ericsson Research with Mallik Tatipamula on "Leveraging Multi-core General Purpose Processors for Fast Switching."
- **Revathi Dukkipati** was mentored by Dr. Tominaga of Sanyo while researching smart energy systems.
- **Nathan Farrington** spent the summer collaborating with Moray McLaren and Nathan Binkert at HP Labs.
- **Rishi Kapoor** worked on a project at Google.
- **Alden King** worked on the ROSE compiler infrastructure project led by Dan Quinlan at Lawrence Livermore National Laboratory.
- **Lonnie Liu** worked on projects related to mobile and wireless issues with Microsoft's Alex Wolman.
- **Keaton Mowery** interned at Google with Guangqi (Grant) Ye. They studied the application of clustering to spamfighting.
- **Radhika Niranjan Mysore** (pictured above) interned over the summer at Microsoft Research.
- **Malveeka Tewari** worked on a project at Amazon.com.
- **Daniel Turner** interned under Jeff Mogul at HP Labs while working on a project that sought to understand failures in enterprise level networks.

For information about how to participate in the CNS 2011 Summer Internship Program, please contact Interim Director Stefan Savage at *ssavage@cs.ucsd.edu* or Kathryn Krane at *kkrane@ucsd.edu*.

UC San Diego Energy Dashboard: A New Perspective on Energy Management

Research Scientist Yuvraj Agarwal (pictured at right) and CNS graduate student Thomas Weng, working with CSE Professor Rajesh Gupta, have developed an Internet portal that allows users to see up-to-the-second information on energy use on a structure-by-structure basis for 60 of the largest buildings on the UCSD campus in La Jolla. The data is provided by UC San Diego Physical Plant Services from over 200 energy meters providing energy usage at the building level, and from roughly 40 individual power meters that measure energy consumption in an office, e.g., a computer and monitor drawing power from a single socket. A denser deployment of meters, which would measure and display individuals' energy use, is currently under way.

Research scientist Yuvraj Agarwal points to real-time graph and comparison of building energy usage on the UC San Diego Energy Dashboard.

The UC San Diego Energy Dashboard grew out of a simple premise. "If you cannot measure energy use, you will not be able to make much headway in reducing your energy footprint," said Agarwal, who was the principal architect of the dashboard. "Energy models of buildings are decades old, and nobody was looking to see if those were still valid… People tend to think that by shutting off the lights in an office, they've done their part for the environment. In fact, our measurements indicate that personal computers can account for almost 25 percent of energy consumption of a building, and most of the time, these PCs are turned on but are not actually in use. If you also include servers and data centers, the contribution of so-called IT equipment can be a staggering 50 percent of total baseline energy use, because a lot of the energy is used during nights and weekends when utilization for these PCs and servers tends to be very low."

Grad student Thomas Weng

The tools available on the Energy Dashboard include real-time power measurement of the entire UCSD campus; energy consumption for each building; and power usage of individual devices such as PCs and servers that are plugged into electrical sockets in some CSE offices. The campus meters are all viewable by the public, but privacy concerns dictate that access to the individual meters be restricted to the owner of that meter.

The Web portal provides statistics updated at least once every minute on total power consumption, power generation, imports from San Diego Gas & Electric, and a comparison between power usage and production. (UC San Diego produces about 82 percent of its annual energy load using 1.2 megawatts of electricity from photovoltaic panels and a 30-megawatt natural gas-fired co-generation plant.) To locate energy-use data on each building, visitors to the Energy Dashboard can select the UC San Diego School of Medicine, Scripps Institution of Oceanography, or any of the university's six undergraduate colleges (e.g., the CSE Building, which houses CNS, is located on the Warren College campus).

According to Agarwal, his group is now working on an Energy Dashboard API that will make it possible for anyone at UC San Diego to integrate their own power meter into the dashboard and take advantage of its visualization and comparison features. In the longer term, the researchers are looking into ways to release the API to the larger community outside of UC San Diego, so that anyone with the appropriate energy meter can post, visualize and compare their energy use data on an externally available Energy Dashboard. For more information, visit *http://energy.ucsd.edu/.*

CNS Lectures On-Demand

The following talks from the CNS Lecture Series were added to the CNS Lecture Archive over spring quarter and summer and are available for on-demand viewing using Adobe Media Player.

"Policy and Mechanism in the Future Internet"
Michael Walfish, Assistant Professor,
Department of Computer Science, University of Texas, Austin

"Architecting Protocols to Improve Connectivity in Diverse Mobile Networks"
Aruna Balasubramanian, Ph.D. Candidate
Department of Computer Science, University of Massachusetts, Amherst

"Web-Scale Data Management"
Raghu Ramakrishnan, Chief Scientist
Audience and Cloud Computing, Yahoo!

"Tor: Anonymous Communications for the Department of Defense... and You."
Roger Dingledine, Project Leader
The Tor Project

CNS Lectures are held on UC San Diego campus where they are free and open to the public.

Get Connected

Stay up-to-date about upcoming CNS events, including lectures and Research Reviews, by signing up for the CNS Events RSS feed. To do so, visit the CNS website at

http://cns.ucsd.edu

and click on the link "CNS Events RSS Feed."

Upcoming Events

CNS Winter Research Review
Wednesday, February 2 and Thursday, August 3, 2010
UC San Diego Faculty Club

The CNS Winter Research Review will feature talks on the current technology challenges facing our member companies, updates on CNS research grants, a student research poster session and reception, and numerous opportunities for informal interaction and networking.

The Research Review is open to invited guests only. If you are interested in attending, please contact Kathryn Krane at *kkrane@ucsd.edu* with your inquiry.

Mission and Objectives of CNS

The mission of CNS is to develop key technologies and frameworks for networked systems. By combining our research talents and strengths in partnership with industrial leaders, CNS achieves critical mass and relevant focus, accelerating research progress and creating key technologies, frameworks and systems understanding for robust, secure networked systems and innovative new applications. CNS also works to educate the next generation of top students with a perspective on industry-relevant research and to train students on how to continue their leadership throughout their careers. This is accomplished by bringing together leading faculty, students, and companies to investigate the most challenging, interesting and important problems in computer networks.

If you are interested in joining the Center, please contact Director Amin Vahdat at vahdat@cs.ucsd.edu.