Exploring energy efficiency in multi-scale computing systems

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MuSyC investigators at UC San Diego, pictured in front of Calit2's GreenLight Instrument modular data center, include (l-r) Rajesh Gupta, Tajana Simunic Rosing and Amin Vadhat.

The University of California, San Diego and nine other universities are members of a new research center charged with finding ways to improve the design of computing systems ranging from large data centers to tiny brain sensors. In its first three years, the Multi-Scale Systems Center (MuSyC) will focus on tackling a critical issue affecting multiple scales: energy efficiency.

"Energy is one of the key issues to be solved in order for systems to work more efficiently," said UC San Diego Jacobs School of Engineering professor Tajana Simunic Rosing, who is leading MuSyC's

Large-Scale Systems effort. "At a very small scale such as a brain-machine interface, without energy you cannot do anything at all. At a very large scale such as a data center, if you are not efficient about how you deal with energy, you go bankrupt."

MuSyC is funded by the Defense Advanced Research Projects Agency (DARPA) and industry members of the Semiconductor Research Corporation (SRC). Its kickoff meeting was held in mid-November.

According to the new research center, its multi-scale approach stems from recognition that "a new generation of applications is emerging that are destined to run in distributed form on a platform that meshes high-performance compute clusters with broad classes of mobiles, surrounded in turn by even larger swarms of sensors. The broad majority of these new applications can be classified as distributed sense and control systems that go substantially beyond the 'compute' or 'communicate' functions traditionally associated with information technology."

By focusing on energy, MuSyC aims to pave the way for "energy smart" distributed systems that are deeply aware of the balance between energy availability and demand, and that can adjust their behavior through dynamic and adaptive optimization through all scales of design hierarchy.

The new center's research agenda is initially structured to explore distributed sense and control systems (led by UC Berkeley's Alberto Sangiovanni-Vincentelli), large-scale systems (led by UC San Diego's Rosing) and small-scale systems (led by Douglas Jones of the University of Illinois at Urbana-Champaign). Another theme — exploring intermediate-scale systems such as mobile and portable devices — is foreseen, pending additional funding after MuSyC's first year of operation.

UC San Diego is taking the lead on large-scale systems because of existing expertise and projects underway within the Jacobs School's Computer Science and Engineering (CSE) department, the Center for Networked Systems (CNS) and the California Institute for Telecommunications and Information Technology (Calit2). The Calit2-based GreenLight project, funded by the National Science Foundation (NSF), will collaborate closely with MuSyC.

"One of the big attractions of having UCSD as a leading institution in this center is the infrastructure we bring to the table," said Rosing. "Part of that infrastructure is the NSF GreenLight project, which focuses on better understanding energy efficiency at the data-center scale. The GreenLight Instrument recently deployed on this campus will allow us to measure efficiency, quantify it, and help people design more efficient systems going forward."

The Large-Scale Systems team led by Rosing aims to develop a multi-scale energy management solution to monitor, model and manage energy across a spectrum of heterogeneous devices and hierarchy levels in large-scale data centers.

In addition to Rosing, three other UC San Diego researchers are involved in MuSyC. All have faculty appointments in the Jacobs School of Engineering's CSE department: CNS Director Amin Vahdat; Calit2 Associate Director Rajesh Gupta; and Allan Snavely, associate director at the San Diego Supercomputer Center.

Gupta's work is focused on active duty-cycling, e.g., when a whole server is not needed, how to replicate some of its functionality in a low-power manner so the server can sleep while it still looks as if it is awake. Vahdat is developing a scalable network infrastructure that can be tested in a real-life data center, to measure and show how much faster and more energy efficient it is. SDSC's Snavely will look at how to

characterize applications and machines, to better understand how much power and what kind of performance can be delivered for running a specific application on a specific machine. Rosing's lab will then figure out the right way to partition jobs and to control power and cooling within a data center such as the modular GreenLight Instrument on the UC San Diego campus.

"So it's a way to put together a bunch of different pieces that until now have been studied disjointly, and to show the benefits of doing this together," explained Rosing. "We're convinced that it is by doing cross-layer optimization that the biggest benefits can be obtained."

Four other universities are part of the Large-Scale Systems research within MuSyC. At Stanford University, John Ousterhout will study novel memory architectures and software interfaces to those architectures, to better understand the energy implications of very high performance required by applications such as Facebook that could be done very, very fast and therefore more energy efficiently. UC Berkeley's Randy Katz will focus on the interface between the data center and the SmartGrid, i.e., scheduling of jobs across distributed data centers. At the University of Southern California, Jeff Draper and Bob Lucas are exploring resilience and reliability in applications such as video streaming where data recovery does not have to be 100 percent perfect. And Vivek Sarkar and Lin Zhong of Rice University are investigating the application layer — how to make managed runtimes more efficient.

Other academic institutions participating in MuSyC include Caltech, North Carolina State University, University of Maryland, University of Michigan, University of Pennsylvania, and the University of Illinois at Urbana-Champaign.

According to UC San Diego's Rosing, MuSyC's Large-Scale Systems team has ambitious goals for its first year. "We want to gain a clear

understanding of what the biggest sources of inefficiency are," she noted. "We also want to understand clearly the metrics for different classes of applications, to identify the workloads that make sense to run that would represent well what is out there in the real world, so we can benchmark and show our success. And finally, we hope to work on some initial deployments within the GreenLight infrastructure."

MuSyC is the sixth center funded by SRC and DARPA under their joint Focus Center Research Program (FCRP). "The FCRP is unique because of its multi-university, multi-disciplinary approach to complex research problems," said Betsy Weitzman, SRC executive vice president and FCRP executive director. "The Multi-Scale Systems Research Center will follow in this tradition as it works to create structured and formal design methodologies to manage the complexity of multi-scale systems design."

"The FCRP works so effectively because of the shared and equal dedication of government, industry and the academic community," added UC Berkeley endowed chair MuSyC director Jan Rabaey. "That common sense of direction is what has led to a broad range of truly innovative solutions to hard problems over the past decade, and I am convinced it will continue to do so in the next."

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