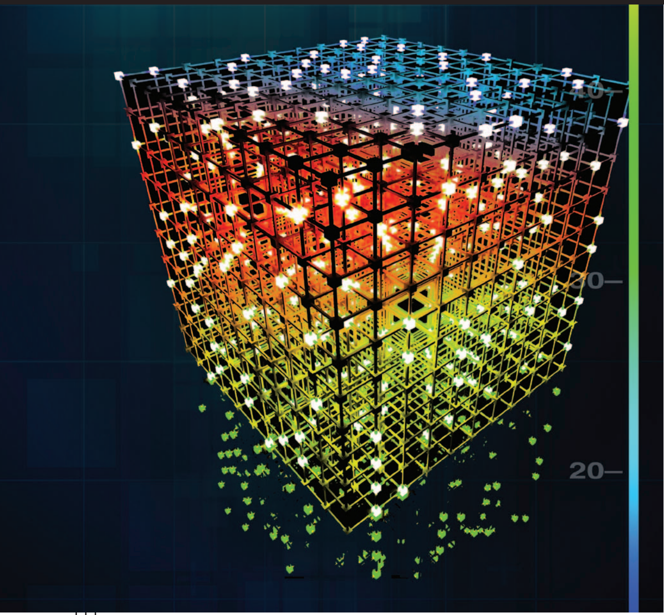


# Modeling and Simulation of Smart and Green Computing Systems

**Kaushik R. Chowdhury,** *Northeastern University, Boston*
**Dave Cavalcanti,** *Philips Research North America, New York*
**Mostafa El-Said,** *Grand Valley State University, Michigan*
**Tommaso Mazza,** *IRCCS Casa Sollievo della Sofferenza, Italy*
**Chittabrata Ghosh,** *Nokia Research Center, Berkeley*

**Advanced modeling and simulation methodologies are an essential aspect of the comprehensive performance evaluation that precedes the costly prototyping activities required for complex, large-scale computing, control, and communication systems.**

Sustainable and efficient utilization of available energy resources is perhaps the fundamental challenge of the 21st century. Academic and industrial communities have invested significant efforts in developing new solutions to address energy-efficiency challenges in several areas, including telecommunications, green buildings and cities, and the smart grid.

Advanced modeling and simulation methodologies are an essential aspect of the comprehensive performance evaluation that precedes the costly prototyping activities required for complex, large-scale computing, control, and communication systems.

Currently, there is increased interest in using a multipronged approach to find solutions to the energy problem, including alternative and renewable energy sources, communication and control systems to enable new green and net-zero energy concepts for buildings and cities, energy-efficient processing datacenters, green communications and energy-harvesting devices, and new smart grid architectures and applications, among others.

## IN THIS ISSUE

The cover features in this special issue describe the latest advances in modeling and simulation of smart and green computing systems, which are critical to sustainable economic growth and environmental conservation in several application domains.

In "Toward Uninterrupted Operation of Wireless Sensor Networks," Swades De from the Indian Institute of Technology and Riya Singhal from Oracle address the challenge of wirelessly transferring radio frequency energy to nearby devices, thereby reducing the need for an operational battery. To increase energy efficiency, the RF energy transfer occurs over multiple hops, while the immediate neighbors always exchange the sensing data. The authors describe the analytical modeling of the conditions under which multihop energy transfer is viable and efficient. Such a network has a significant impact because it eliminates the need to periodically retrieve sensors for maintenance and battery replacement.

In "Bond Graph Modeling for Energy-Harvesting Wireless Sensor Networks," Prabhakar T. Venkata and his


Published by the IEEE Computer Society

colleagues from the Indian Institute of Science and Delft University of Technology, the Netherlands, discuss novel approaches using bond graphs to accurately predict both sensor and network lifetimes. In this context, a bond graph is formed by using energy bonds to link several subsystems together, which in turn represent the dynamic system's connections. Although each subsystem can be independent, including the energy source, storage buffer, microcontroller, radio, and wireless channel, each still requires a finite amount of energy for correct and error-free operation.

"Fundamentals of Green Communications and Computing: Modeling and Simulation," by Murat Kocaoglu, Derya Malak, and Ozgur B. Akan from Koc University, Turkey, describes new metrics such as a holistic carbon-footprint-based method for evaluating energy savings that looks at the larger picture of a device's operation, beginning with the resources spent to create it and including the energy expended in keeping it active. The authors discuss a technique for quantifying minimum energy consumption in networks and explore open issues related to a layered Internet architecture, where energy consumption is calculated as transferred information bits. They also review current strategies for simulation and standardization of green networks and comment on best practices, while highlighting open issues that merit the research community's further attention.

In contrast with articles focusing on tiny sensors, "SimWare: A Holistic Warehouse-Scale Computer Simulator," by Sungkap Yeo and Hsien-Hsin S. Lee from Georgia Institute of Technology, delves into energy-efficient design and simulation of datacenters, which typically exhibit a 20 percent yearly increase in energy needs. To report the power and energy breakdown of a given datacenter, SimWare offers a simulation environment for analyzing power consumption in a system's servers, cooling units, and fans. It also incorporates physical features of heat circulation and the effect of ambient temperature. All this information helps to accurately predict actual energy usage and effectively optimize corrective parameters for the system. The authors demonstrate SimWare's effectiveness by comparing its performance against traces obtained from publicly available warehouse-scale models.

"Using Datacenter Simulation to Evaluate Green Energy Integration," by Baris Aksanli, Jagannathan Venkatesh, and Tajana Šimunić Rosing from the University of California, San Diego, presents an interesting comparison of various datacenter simulation models. Since deploying a new energy-management policy merely for verification purposes is both time-consuming and impractical, a model that provides support for a quick comparison is valuable. Each method can focus on one limited aspect, including the impact of dynamic power management, dynamic voltage and frequency scaling, and quick job response time, but the methods must be comprehensively evaluated using common criteria. The authors also present a case study illustrating how researchers can use the GENSim simulator to design and evaluate green energy integration into datacenters.

We anticipate that the solutions proposed to address the problems described in this issue's cover features will prove to be as interesting and exciting to the readers as they were for the guest editorial team. We optimistically look forward to a technology-assisted greener and smarter world. ■

***Kaushik R. Chowdhury*** *is an assistant professor in the Department of Electrical and Computer Engineering at Northeastern University, Boston. He received a PhD in computer science from the Georgia Institute of Technology. He is a member of the IEEE Computer Society and IEEE. Contact him at krc@ece.neu.edu.*

***Dave Cavalcanti*** *is a senior member of the research staff at Philips Research North America, New York. His research interests include communication protocols for wireless networks, cognitive radio networks, and controls and automation applications for wireless networks. Cavalcanti received a PhD in computer science and engineering from the University of Cincinnati. He is a member of the IEEE Computer Society and IEEE. Contact him at dave.cavalcanti@philips.com.*

***Mostafa El-Said*** *is an associate professor in the School of Computing and Information Systems and chair of the Information System Program at Grand Valley State University, Michigan. His research interests include designing smart autonomic VoIP and Vanet systems. El-Said received a PhD in computer science and engineering from the University of Louisville. He is a member of the IEEE Computer Society and IEEE and is chair of the IEEE CS Technical Committee on Simulation. Contact him at elsaidm@gvsu.edu.*

***Tommaso Mazza*** *is a researcher at IRCCS Casa Sollievo della Sofferenza, Mendel, Italy. He received a PhD in computer science and biomedical engineering from the University of Catanzaro, Italy. He is a member of the IEEE Computer Society and the Italian Bioinformatics Society. Contact him at t.mazza@csc-mendel.it.*

***Chittabrata Ghosh*** *is a senior researcher at Nokia Research Center, Berkeley. His research interests include analysis of coexistence issues among various cooperating wireless networks and MAC layer optimization techniques for wireless sensor networks. Ghosh received a PhD in computer science from the University of Cincinnati. He is a member of the IEEE Computer Society and IEEE. Contact him at chittabrata.ghosh@nokia.com.*