ENERGY-EFFICIENT PERVASIVE COMPUTING

INDO-US PC3 WORKSHOP
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Geoffrey Challen

Currently I am a post-doctoral scholar supervised by Professor Hari Balakrishnan at MIT. In August, 2011, I will begin a junior faculty position at the University at Buffalo.

I am interested in power as a design constraint spanning all classes of computer systems—embedded sensors, mobile phones, personal computers, datacenter servers, and large-scale networks. My research agenda is rooted in the belief that studying power consumption and management at multiple levels of the computing infrastructure will yield insights relevant *at all levels*. Power consumption is a major barrier to the advance of pervasive computing, and at PC3 I will contribute my interest and expertise in this area.

My graduate research completed earlier this year focused on energy management for wireless sensor networks. I built three systems—Lance, IDEA and Peloton—that manage energy at the *network*, rather than node, level. Lance improves the performance of data-intensive sensor network applications by considering both the cost and value of information when collecting data. IDEA provides a network-wide energy coordination layer facilitating energy optimizations impossible for a single node to perform alone. Peloton proposes a distributed operating system for coordinated resource management built on state sharing, a distributed energy ticket abstraction, and local neighborhood ticket management. Along similar lines, I contributed to the development of PowerTOSSIM, which added power modeling and to the TinyOS simulator; the Pixie sensor node operating system, which promoted energy to a first-class system resource; and MoteLab, a public testbed supporting all kinds of sensor network research.

A present I am expanding the interest in power adaptation I developed while working on sensor networks in three directions: wireless networking, operating system design, and mobile computing. All these areas are central to pervasive computing, and my overall goal is to reduce, manage, and understand the energy consumption of pervasive devices.

WIRELESS NETWORKING: At MIT I am working with Prof. Balakrishnan on techniques to save power in Wifi networks. We are experimenting with physical-layer techniques enabling rapid packet source and destination detection that, if accurate, could allow clients to discard packets not addressed to them without enabling power-hungry digital decoding. We are leveraging the power of the AirBlue FPGA-based 802.11 software radio, which unites a stack that is easily to modify and hardware capable of real-time processing. AirBlue is almost capable of interoperating with commodity devices and providing the platform for real wireless protocol experimentation the community currently lacks.

OPERATING SYSTEM DESIGN: With Mark Hempstead at Drexel University I am designing operating systems capable of powering the next generation of heterogeneous power-proportional hardware architectures which incorporate multiple components with different power-performance tradeoffs. We have coined the term *power agility* to describe the

ability of a system to operate these devices balancing performance and power consumption. Given increasingly heterogeneous devices, power agility requires not merely adjusting individual components but activating and deactivating them to react to changes in demand caused by variations in device usage. On power-agile devices scheduling and resource allocation are complicated by the fluid nature of the underlying hardware. We are currently addressing the challenges inherent to the five roles that the operating system plays while operating power-agile hardware: measuring and predicting performance; along with selecting, preparing and executing device state transitions.

MOBILE COMPUTING: Together with SUNY Buffalo faculty Murat Demirbas, Steve Ko and Tevfik Kosar I am building a large-scale participatory smartphone testbed. Having previously built MoteLab, I know first-hand how important testbeds are to advancing research, and no public smartphone testbeds exists today. We envision a testbed called PHONELAB that enables smartphone operating system and mobile application research in a realistic environment at a scale not previously possible. PHONELAB will consist of a large number—1,000 or more—of reprogrammable Android devices used by students and staff at SUNY Buffalo. PHONELAB aims to provide **power**, **scale**, and **realism**. Power, to allow the modification of phone software above and below the OS-application interface while simplifying instrumentation and data collection to facilitate efficient experimentation. Scale, to provide access to an order of magnitude more participants than typically used by smartphone studies. And realism, by minimizing experimental disturbance and allowing participants to use their phones naturally. I see PHONELAB as a platform for improving the battery lifetimes and energy-efficiency of smartphones, as well as using phones to facilitate interaction between users and their environment.

We are eager to collaborate with other institutions to develop similar testbeds that can be federated with PHONELAB. India has phone-savvy citizens and students as well as excellent technical universities that would be an ideal partners in this effort. The capabilities of phones usage of features are likely to vary across cultures, and it would be interesting to see what different usage patterns globally-distributed testbeds would uncover. We also foresee PHONELAB as an experimental environment for developing pervasive applications appropriate for use in newly-industrialized countries like India. Public-health applications are one example, and a group at SUNY Buffalo is already collaborating with public health researchers to use smartphone sensing to estimate exposure to pollutants, a project we will deploy on PHONELAB when ready.

I have previous experience with cross-cultural collaboration obtained during the Harvard volcano-monitoring project, which I helped lead. Working closely with scientists at the Instituto Geofísico at the Escuela Politecnica Nacional (IGEPN) I participated in three field deployments on active Ecuadorean volcanos over four years. I have also benefited from professional and personal relationships with several excellent Indian-American scientists: Kiran Muriswamy-Reddy, a former graduate-school colleague, now at Amazon; Karthik Dantu, currently a post-doc on the Harvard RoboBees project; and Rohan Murty, a graduate-school colleague and close friend. I have found Indian scientists enjoyable to work with, and am eager to initiate contacts with them early in my professional career.