Guest Editorial: Special Issue on Networked Embedded Systems

For better part of their history, computers and radios had very little to do with each other. Both evolved independently, though along similar evolutionary paths: from stand-alone “infrastructural” devices to personal assets. With the advent of microelectronic computing devices, *microcomputing* found its role in an ever expanding set of applications from consumer appliances, gaming, industrial automation, and robotics to telecommunication systems. Indeed, embedded *computer* systems have become pervasive touching almost all aspects of our daily lives. The embedded computer, or more specifically the embedded software, can be considered a universal component delivering all sorts of functionality from signal processing, intelligent decision making to a whole host of telecommunication functions. Along similar lines, but with a different evolutionary timeline, microelectronic radios matured from one-way broadcast communication devices to bidirectional personal communication devices.

So, it was only a matter of time, when computers and radios found themselves in the same box, or even the same microelectronic substrate. This combination of microelectronic computers and radios has been a powerful driver of growth and revolutionary advances in the telecommunications industry over the last decade. These advances have been made possible by the enormous flexibility in embedded software and on-chip computational capabilities to improve communications (e.g., compensate for channel conditions, device, and environmental characteristics) and networking functions. Further, driven by the microelectronic economic realities of continuously improving functionalities and systems capabilities along with falling prices, the telecommunications industry has quickly diversified and expanded to fill a variety of communication needs from home/office wireless networks to cellular telecommunication networks. A cellular phone is an example of a new breed of *networked embedded systems* (NES), that is, embedded systems with interesting (wireline and/or wireless) communication interfaces. Advances in microelectronic devices and semiconductor manufacturing allow such systems to be built in a single board, package or chip. The NES are often distributed embedded systems where the total design must include not only conventional hardware and software, but also networking ends, protocols, and so on. The new chips, in turn, find role in a rapidly expanding set of application domains from telecommunications, networking, and sensor networks to biomedical devices.

While enormously useful than either the computers or radios of earlier years, the design of such systems is a challenging task. Many of such chips do not just contain radio and computer components, but complete system functionality, such as networking functions across all levels of the protocol stack. And yet, these devices must often operate in very constrained environments related to their size, energy availability, network connectivity and so on. New networking techniques are needed that are energy efficient and utilize robust, high throughput but low-power communication schemes.

The goal of this special issue of the *ACM Transactions on Embedded Computing* is to explore the state-of-the-art and recent advances in networked embedded systems.

As a reflection of the emerging discipline, the current design techniques and tools in networked embedded systems are specific to application domains. Along these lines, one application domain in NES that has captured the imagination of a large number of researchers and galvanized whole new communities into action is of *sensor devices and sensor networks*. These are often ad hoc networks consisting of distributed sensing (and actuator) nodes that are collectively tasked with some application functionality, such as tracking vehicular movements, detecting environmental threats, and so on. Research in sensor networks has drawn active community members from a broad range of areas from distributed control systems, to data mining, programming languages, operating systems, middleware, networking, and embedded systems. Naturally, in response to our call for papers we received diverse submissions addressing different aspects of sensors and sensor networks. After a very thorough review process, we selected three out of eight submissions as candidates for the TECS Special Issue.

In the first paper, Raghunathan et al. present an energy efficient packet scheduling technique that dynamically reduces the output transmission rate of a wireless system by exploiting the slack created by low-link utilization. They also present an extension of their techniques for multiple input streams that is an energy efficient version of weighted fair queuing algorithm for fair packet scheduling.

In the next paper, Bulusu et al. address the problem of localization or estimating spatial relationships among objects in a sensor network. They use beacons (nodes at known positions) for localization and propose two algorithms: HEAP and STROBE. HEAP suggests candidate points for incremental beacon placement to improve localization, and STROBE co-ordinates densely deployed beacons to reduce self-interference and hence, conserve energy.

In the third paper, Zou and Chakrabarty examine the problem of achieving good coverage during sensor deployment. They start with an initial random placement of sensors and then generate movement “force” vectors that direct the movement of sensors so that coverage is maximized. They also propose a power-efficient target localization approach that minimizes the communication between sensors and the cluster head by using a probabilistic scoring technique.

For the evolving area of networked embedded systems, we are certain that this special issue represents merely the beginning of an exciting research domain. We are glad to present this special issue with carefully chosen papers that would provoke discussions and materially contribute to the advances in theory and practice of NES. This issue would not have come about without the hard work and persistence by our authors, and reviewers. We sincerely thank them for their contributions. We hope you enjoy this section of the *ACM Transactions on Embedded Computer Systems*.

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