CPS:Small:
Dynamically Managing the Real-time Fabric of a Wireless Sensor-Actuator Network

Project Number: CNS-09-31195
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Start Date: 9/1/2009 – 8/31/2012

Wireless sensor-actuator networks (WSAN) consist of numerous sensing and actuation devices that share information over an ad hoc wireless communication network. WSANs may be used to manage networked systems that distribute goods and services over large spatially distributed domains. Examples of such systems include the national power grid, ground/air traffic networks, and water/gas distribution networks.

This project studies the implementation of feedback control algorithms over WSANs, particularly with regard to the management of large-scale networked systems such as the electric power grid or water distribution networks. Controlling such physical processes usually requires some form of hard real-time support, so that each packet of feedback data must be serviced within a specified deadline. It has, in practice, been difficult to provide such guarantees in real-life wireless networks. This project addresses that issue by developing algorithms that allow control applications and wireless network nodes to work together in maximizing application performance subject to hard real-time service constraints. Given that energy is a precious resource in WSANs, additional effort is devoted to investigate how to effectively trade off energy with control performance, again subject to hard real-time service constraints.

The algorithms being developed by this project are based on a three-prong approach. First, one must control network interference to provide a stable platform upon which real-time guarantees become possible. Second, network flows must be scheduled in a manner that achieves the real-time capacity of the stabilized network. Third, if the network's quality of service falls below application requirements, then the application must modify the controllers that maintain minimum levels of performance under reduced network capacity. Furthermore, to include energy into consideration, transmission rate must be treated as an additional "knob" in all the approaches under study. These approaches are being developed through a novel extension of distributed power control algorithms to real-time flows, recent advances in elastic scheduling of real-time tasks, and recent advances in our understanding of sporadic sampled-data control systems. Energy-aware real-time scheduling theory is also being extended to handle unique challenges present in WSNs. This project's algorithms will be implemented on a wireless test bed consisting of software-defined radios and/or sensor network modules (Mica).

The impact of this project is being broadened through interactions with local industry and graduate curriculum development. A first year graduate course (EE67036) on cyber-physical systems focusing on modeling, verification, and control synthesis has been developed. The project is also working with two small businesses to develop real-time WSAN applications for environmental monitoring (EmNet LLC) and microgrid control (Odyssian LLC).