Wireless Sensor Networks: Application Driver for Low Power Distributed Systems

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ABSTRACT

Wireless sensor networks allow deployment of sensing elements close to the phenomena of interest. Sensing close to the signal generation point should lead to improved SNR in general, and enable detection in otherwise obstructed environments. This fundamental benefit of local sensing, combined with the decreasing cost and increasing availability of low cost microsensors/actuators and processors, suggests that effective systems will exploit densely distributed elements. However, dense sensing capability is only scalable if the elements are networked to support collaborative processing near the sensory inputs. [1] Therefore, in many contexts low-power wireless communication is a critical enabler of these systems because it overcomes the logistical infeasibility of deploying wires in remote, dynamic, and mobile-node, contexts.

The **spatially dense and temporally continuous monitoring** capabilities of wireless sensor networks will transform the way in which we understand and interact with the physical world: e.g., contaminant flow monitoring in soil, air, and water; precision agriculture; transportation and traffic management; and remote-habitat monitoring for biocomplexity studies. However, in order for wireless sensor networks to effectively provide dense and continuous monitoring/data collection, they must be able to operate unattended for long periods of time. Long lifetime obviously requires that the individual components be low-power. However, component-level efficiency is not sufficient; the distributed sensor network as a whole must be designed with energy-efficiency as a primary constraint. For example:

- Due to low-lying antennae and uncontrollable environmental settings, long-range communication consumes significant amounts of energy. Consequently these systems should perform **in-network processing** so that sensory data is processed as near the source as possible and the number of bits communicated over links is reduced significantly. [1, 2]
- In many contexts it may be feasible to deploy many times more elements than are needed to provide coverage at any point in time. To achieve long-lifetime, the network should be designed to **exploit redundancy** by coordinating duty cycles and coverage across these nodes over time; and by taking advantage of energy-aware load balancing across multiple paths. [2, 3]
- Capabilities such as **triggering** are critical to allow lower-power capabilities to activate higher-power capabilities only when they are needed. For example, sensing techniques with low communication overhead (e.g., vibration detection) can activate ones with higher communication overhead when necessary (e.g., distributed signal for localization and tracking).

There are several component-level capabilities that are needed to support such system-level low-power techniques. For example:

- Low-power wakeup circuitry, as in a **paging channel**, is needed so that nodes can be wake up other nodes.
- **Adjustable-power, short-range radios**, and RSSI measurement circuits, so that transmission range and energy expenditure can be adjusted through software and during node operation to support adaptive-density systems and efficient cluster formation.
- **Accurate power measurement** onboard to support self-adjusting, load balancing coordination for which a node should be able to approximate energy reserves.
- Alternate **energy sources** and scavenging techniques

This paper will elaborate on these issues and will also argue for focused collaboration between the low-power design communities and the systems community to enable larger scale experimental efforts.

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