Low Power, Application-Driven Communication Hierarchy for Wireless Microsensor Networks

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Low power communication is crucial for maximizing the operational lifetime of energy-constrained microsensor networks. An energy-efficient communication system must trade-off energy gracefully in exchange for some quality metric and incorporate application-specific components that are tuned for specific tasks and operational scenarios. These guiding principles appear in design examples at three levels of the communication hierarchy: the routing protocol, the middleware/API, and digital integrated circuits, as illustrated in the figure below.

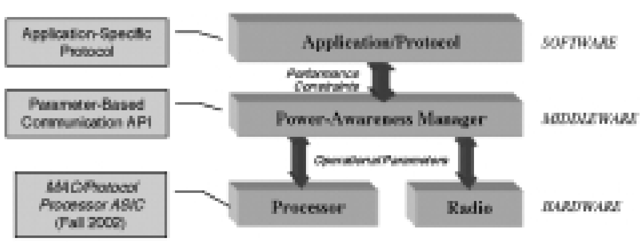

Fig. 5: Power aware design accross the communication hierarchy.

Designing energy-efficient protocols for high-density networks of thousands of nodes can be a daunting task. One productive approach is to borrow the lesson from application-specific circuits that reducing unnecessary functionality consequently reduces energy. Application-specific protocols improve communication efficiency by tailoring their behavior to the expected needs of the application. We have designed an address-free forwarding scheme that offers a simple and elegant solution to the problem of forwarding sensor data to a base station, in an environment where radio receivers may shut down frequently and arbitrarily to conserve network energy. Nodes obtain a metric of their distance to the base station, and packets are forwarded dynamically based upon receiving nodes′ distance to the base station rather than a specific address.

Application and protocol designers that utilize wireless communication typically do not wish to concern themselves with processor voltages, transmit power, or the constraint lengths of convolutional codes. It is therefore imperative that an Application Programming Interface (API) bridge the gap between these low-level “knobs” for energy scalability and those performance parameters more accessible to an application. We have proposed a power-aware communication API that allows the application to bound four properties of the wireless transmission: range, reliability, latency, and energy. Power-aware middleware converts these application-level constraints into the least-energy parameter settings for the energy-scalable hardware. In other words, the energy consumption of hardware—which is typically expressed in terms of physical parameters such as voltage—is evaluated as a function of the application level parameters of latency, reliability, and range.

We are currently designing a communication processor for wireless sensor networks. The processor will feature an instruction set and datapath organization that is conducive to wireless media access and protocol handing. Energy-quality tradeoffs will be enabled through dynamic voltage scaling, possibly into subthreshold operation, and dynamically reconfigurable functional units.

In summary, application-specific, energy-scalable design across the communication subsystem—from protocols to integrated circuits and the glue between them—will be a key enabler for energy-efficient microsensor communication.