Energy Harvesting for Sensor Networks

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Abstract — By harvesting energy from their local environment, sensor networks can achieve much greater run-times, years not months, with potentially lower cost and weight. At Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), we are developing tools to help sensor network designers power sensor networks for prolonged periods of time.

BACKGROUND

Reduction in size and energy consumption of CMOS circuitry has opened up many new opportunities for low power wireless sensor networks (as shown in Fig. 1). Such networks have significant potential in a variety of applications, including monitoring of animal health and behaviour, structural monitoring for mining equipment, and measuring water salinity levels of oceans and rivers.

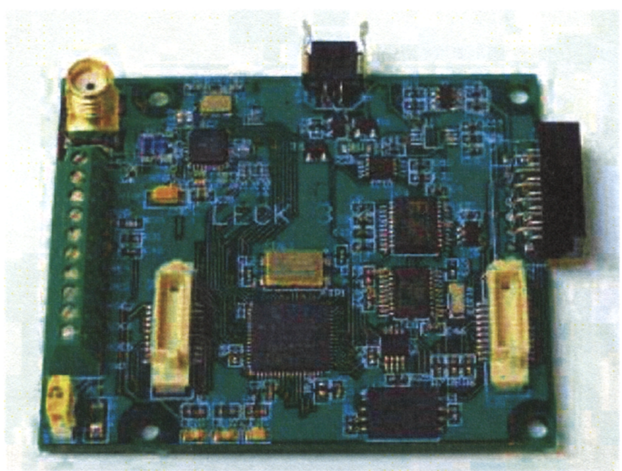

Figure 1: Typical sensor node - Fleck™ [1].

With these opportunites come a number of new challenges. Sensor networks are usually battery powered, so as sensor networks increase in number and size, replacement of depleted batteries becomes time consuming and wasteful. Additionally, a battery that is large enough to last the life, say 5 years, of a sensor node would dominate the overall size of the node, and thus would not be very attractive or practical. As a result, there is a clear need to explore novel alternatives to power sensor networks/nodes, as existing battery technology hinders the widespread deployment of these networks.

EMERGING TECHNOLOGIES

Emerging technologies with the potential to provide sensor node power and hence overcome some of these scientific challenges include vibration [2], solar [2], fluid turbines [3], thermoelectric [4], beta generators [5,6], hydrocarbon nano-turbines [7], and fuel cells [8].

Despite there potential, all these emerging technquies have inherent problems - they may be dependent upon the time of day, weather, or environmental temperature gradients. In the case of hydrocarbon nano-turbines and fuel cells, these, like batteries, require a fuel that needs to be stored.

KEY SCIENCE CHALLENGES

CSIRO has identified 4 key scientific challenges for powering sensor networks:

1. Power sensor nodes reliably, cost effectively and for long periods of time (i.e. greater than 5 years), within constrained physical size limitations.
2. Accurately forecast the energy available to be harvested at the site of the sensor nodes.
3. Determine appropriate energy harvesting and/or storage technology mix to reliably power sensor nodes/networks.
4. Manage and control sensor nodes energy generation and consumption.

STRATEGY

Sensor networks have analogous science challenges to that of distibuted power systems, however, on a much smaller scale i.e. mW's not kW's. With the research team working closely with CSIRO's renewable energy, energy storage, distributed energy management and control groups and other experts in this field, CSIRO is developing the "smart" software tools needed for the planning and energy management of sensor networks.

This is building upon existing distributed generation software which sucessfully simulates and optimizes stand-alone and grid-connected power systems comprising combinations of wind turbines, photovoltaic arrays, hydro power, bio power, internal combustion engine generators, microturbines, fuel cells, batteries, and hydrogen storage, serving both electric and thermal loads.

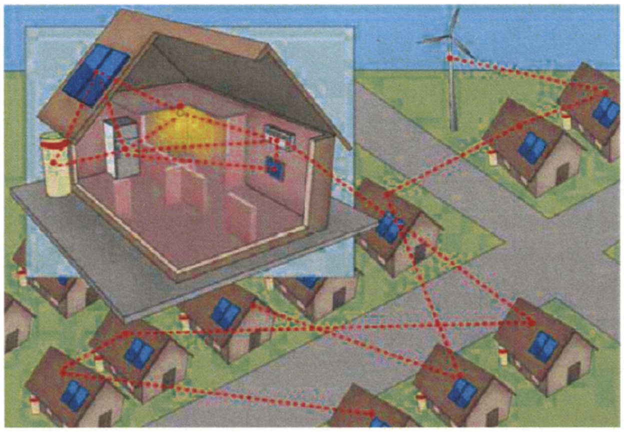

Figure 2: CSIRO's planned zero-emission network.

Figure 3: CSIRO Energy Centre, Newcastle.

The sensor network software is being developed to model energy harvesting, storage and loads scenarios for sensor nodes/networks. Once complete, the software will use algorithms to do a sensitivity analysis to evaluate the economic and technical feasibility of a large number of energy technology options, and to account for variation in technology costs and energy resource availability. Assessments will be able to be carried out across a wide range of technologies, with models of both conventional and renewable energy technologies as shown in Table 1.

Table 1: Sensor network energy scenarios.

Energy Harvesting	Energy Storage	Sensor Node Loads/Modes
• Photovoltaic	• Batteries	• Sleep
• Fluid turbines	• Supercaps	• Active
• Thermoelectric	• Hybrid batteries	• Transmit
• Kinetic motion	• Nano-turbines	• Read to memory
• Vibration	• Fuel cells	• Write to memory
• Induction	• Beta cells	• Ad-hoc
• Pressure		

In addition to software development, there is a significant hardware development component of this project – we are developing a "Hardware Emulation Node" (HEN) that encorporates a single sensor node (i.e. the load) and a mix of energy harvesting (e.g. solar, kinetic motion, etc.) and storage (e.g. batteries, etc.) technologies. The HEN has a smart energy management control system built-in, with the aim to prolong the energy life of the sensor node(s).

The majority of software and hardware development is taking place at CSIRO's Energy Centre Newcastle site and James Cook University.

CONCLUSION

This abstract discussed CSIRO's research work for its Energy Harvesting for Sesnor Networks project. The project is in the process of developing software and hardware tools to help designers make informed choices on the relative merits of new and alternate technologies for powering sensor networks for prolonged periods of time.

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