Demo Abstract: Multi-Source Power Manager for Super-Capacitor based Energy Harvesting WSN

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ABSTRACT

In this paper, a multi-source power manager (PM) is applied using different types of energy harvesting WSN. Specifically, this PM is embedded in both thermal and solar-powered WSN in order to adapt the consumed energy of the node by changing its wake-up period according to the harvested energy. Experimental results performed on real WSN platforms show that our PM is able to make harvesting nodes converge to Energy Neutral Operation (ENO) with a theoretically infinite system lifetime.

Categories and Subject Descriptors

C2.1 [**Network Architecture and Design**]: Wireless communication

General Terms

Design, Experimentation, Measurement, Algorithms

Keywords

Energy neutrality, Power management, Energy harvesting

1. INTRODUCTION

Energy consumption is a critical issue for the deployment of battery-powered WSN monitoring applications which usually require long-term operations. Therefore, energy harvesting (EH) WSNs, which are the combination of low power wireless nodes, harvesting devices and super-capacitors, provide a solution to extend the system lifetime [3]. Moreover, for ensuring perpetual operations, a power manager (PM) is included to balance the power consumption and the harvested energy over a long period. This leads to Energy Neutral Operation (ENO) [2] with an infinite system lifetime.

The duty-cycle power manager (DC-PM) presented in [3] is an independent harvested source and specifically designed for super-capacitor based EH-WSN. Based on simulations and experimentations, this PM has proved its capability to satisfy ENO condition by changing the wake-up period of a wireless node according to the current voltage of the super-capacitor. The main contribution of this paper is to extend the implementation of DC-PM to two different harvesters, including solar and wind energy. Our test-beds are performed on PowWow platforms [1], which are based on the MSP430 microcontroller and the CC2420 RF transceiver.

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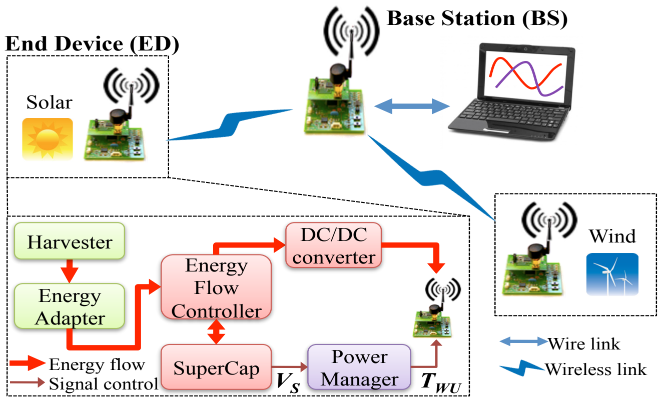

Figure 1: Single-hop EH-WSN following our work.

The rest of this paper is organized as follows. In section II, the generic system architecture with a multi-source power manager (MS-PM) is presented. Experimental results with both solar and wind energy are presented in section III. Finally, the paper ends with conclusions.

2. GENERIC SYSTEM ARCHITECTURE

The proposed monitoring application using EH-WSN is depicted in Fig. 1. A receiver acting as a base station (BS) is connected to a host PC for data visualization. Meanwhile, many transmitters are randomly deployed, equipped by a harvester (e.g. photovoltaic, wind generator) and a super-capacitor (SuperCap) for energy storage. These transmitters, referred as end devices (ED) in this paper, send their data to the BS by using the RICER protocol depicted in [3].

For a generic approach, an energy adapter is added to normalize the output energy from different harvesters. Then, the harvested energy is distributed by an energy flow controller to satisfy two scenarios. When the harvested energy is greater than the consumed energy, the surplus energy will charge the SuperCap, which is used for energy storage. Otherwise, when the environmental energy is not sufficient to supply load devices, the remaining energy is served by SuperCap. Finally, a DC/DC converter provides a stable voltage to the wireless node.

The power manager (PM) is in charge to satisfy the ENO condition by changing the wake-up period of the node (T_{WU}). The time domain is discreted into slots and PM is carried out at the end of each slot. By using the DC-PM presented in [3], the next wake-up period is determined by:

$$T_{WU}(n+1) = \frac{\left[\hat{e}_{Active}(n+1) - \eta\tilde{e}_{Bud}(n)\right] T_{WU}(n)}{\eta\left[\tilde{e}_S(n) - \tilde{e}_S(n-1)\right] + \tilde{e}_{Active}(n)} \quad (1)$$

where $\hat{e}_{Active}(n+1)$ is the predicted consumed energy in the time slot $(n+1)$, η is the efficiency of the DC/DC converter, $\tilde{e}_{Bud}(n)$ is the different energy between the current state and desired state (when $V_S = V_{Ref}$), $\tilde{e}_S(n)$ is the energy in the SuperCap at the end of slot n, $\tilde{e}_{Active}(n)$ is the consumed energy during slot n. This equation shows the interest of DC-PM as it is independent of harvesters. At the beginning of next slot, the PM only needs to estimate $\tilde{e}_S(n)$ from the voltage of the SuperCap ($V_S(n)$) and based on the consumed energy in previous slot ($\tilde{e}_{Active}(n)$), the next wake-up period is computed. This PM has been already applied with thermal harvesters in [3] and is extended to solar and wind energy in this paper.

3. EXPERIMENTAL RESULTS

A single-hop EH-WSN illustrated in Fig. 1 has been implemented with three PowWow nodes: one BS and two ED nodes. The first ED node is equipped with two photovoltaic cells of size 4x6cm while the second one is powered by a small wind generator. A SuperCap with capacitance C_S = 1.1mF is used for the energy storage and DC/DC converter efficiency is $\eta = 0.85$. ED nodes are powered on when $V_S > 2.9V$ and powered off when $V_S \leq 1.9V$. The wake-up period (T_{WU}) is set in the range of $[1-10]$ s. The DC-PM is activated each time the ED wakes up to converge the node to ENO with $V_{Ref} = 3V$.

The solar-powered ED node is setup in our office where the light condition is around 800lux and 1m far away from the BS. As it can be observed on Fig. 2, at the beginning (interval 1), the node satisfies the ENO with T_{WU} = 2s and V_S is kept around 3.1V. When the light condition decreases in the interval 2, T_{WU} is increased to 3s to reduce the consumed energy of the node. T_{WU} is reduced to 2s again in interval 3 when the light condition is almost similar as interval 1. This behavior is repeated in the next two intervals (4 and 5). In interval 6, the light condition is really bad and T_{WU} is therefore, increased to 10s, which is the maximum value. Finally, when the light condition is better, the node is converged to ENO with T_{WU} = 2s and V_S = 3.08V, which is closed to V_{Ref}.

Meanwhile, the wind-powered ED node is setup on the roof of our building and around 10m far away from the BS. Fig. 3 shows adaptations of the T_{WU} according to the change of wind energy. Sometimes, the wireless node is powered on from a strong wind which provides a burst of harvested energy (interval 2 and 5). The node has a fully charged

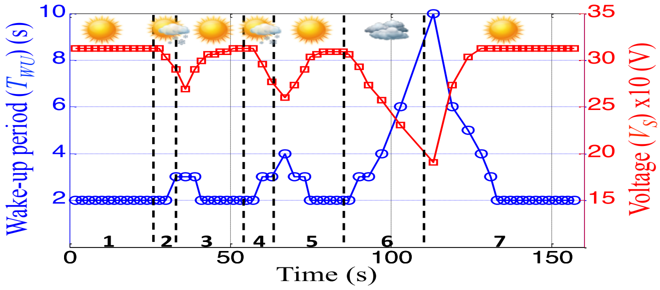

Figure 2: Voltage (V_S) and wake-up period (T_{WU}) of the solar-powered ED node. In good condition, T_{WU} is converged to 2s when the node satisfies ENO (interval 1 and 7).

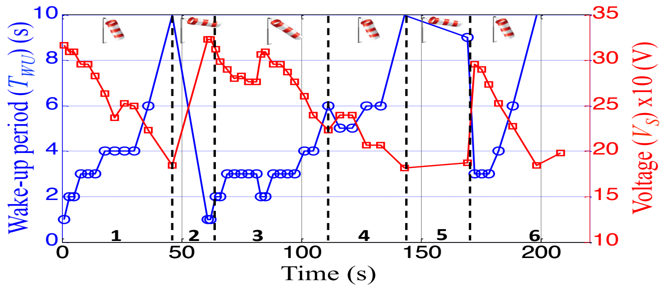

Figure 3: Adaptations of the wind-powered ED node. The node is powered on after a strong wind (interval 2 and 5) with a burst of harvested energy.

energy in first wake-up with T_{WU} = 1s. However, the harvested energy after that is progressively reduced and T_{WU} keeps increasing up to 10s and then, the node is completely powered off (around 50s and 150s, $V_S < 1.9V$). Moreover, we can observe a lot of variations of the wake-up period. As wind is a high variable energy source, the node is either powered off or unabled to converge to ENO. Therefore, wind energy seems rather suitable for detection applications than continuous monitoring as in case of solar energy.

4. CONCLUSIONS

In this paper, a multi-source power manager providing practical adaptations has been validated with two different energy sources. This MS-PM efficiently makes the solar-powered node converge to sustainable operations as solar energy is roughly stable and predictable. Therefore, solar-powered WSN can be used for habitat or smart building monitoring which usually requires regular tracking. Meanwhile, wind-powered WSN seems useful for event detection applications such as tracking a train passing through a tunnel.

5. REFERENCES

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