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Energy replenishment using renewable and traditional energy resources for sustainable wireless sensor networks: A review

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ABSTRACT

In recent years there has been several technological advances in Wireless Sensor Networks (WSN), but energy still remains a paramount resource. The amount of available energy has a direct effect on the performance, functionality and lifetime of WSN. Being bound by cost and size, sensor nodes are usually equipped with limited amount of energy and therefore requires a replacement of batteries occasionally. But replacement might not always be feasible option and in some scenarios might even be prohibitive. This indicates the need for more viable solutions, these involve generating energy at the sensor nodes or have it delivered to them i.e., energy harvesting or wireless energy transfer. The objective of this paper is threefold: first we present a survey on potential renewable energy resources along with their characteristics and applications in WSN. Second, this study also describes various battery recharging techniques and their applications with respect to WSN. Finally, we discuss formidable issues, challenges and future research directions.

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1. Introduction

A Wireless Sensor Network (WSN) consists of small, low cost, low power sensor nodes deployed in a region for monitoring different aspects of environment. Generally, a sensor node is made of four basic components [1] with additional units being added depending on application requirements. The basic components of sensor node consists of a sensing unit used for acquiring data from the environment and converting it to digital data, a processing unit for processing raw data to store the results, and a transceiver unit for sharing data with other nodes or the end-user. Finally, there is a power unit that consists of a energy sink (battery, capacitor or both) and power management that monitors and routes power to the entire node. Fig. 1 depicts the interconnection of these four units. All the units can be further divided into different parts. Fig. 2 shows the division of power unit into a battery module and a power management module. Lifetime of a sensor node depends on the capacity of the power resources it is equipped with. One way of prolonging lifetime of sensor network would be to periodically replace the batteries of all or some of the deployed sensor nodes. Since WSNs can be deployed in scenarios where nodes are left unchecked for weeks, months and may be years so frequently replacing batteries will be a tiresome task and might even not be possible like in Amazon environment [2], where it is needed to recharge in order to get as much autonomy as possible. In such a case, photovoltaic panels and a combination of efficient communications protocols can allow saving energy, thus extending operating life. WSN deployed in deep sea [3], behind enemy lines [4], data dissemination based applications in disaster environments [5,6] monitoring under extreme conditions like volcano [7], avalanche rescue [8], and underground monitoring [9] are few more examples where battery replacement is not possible. Moreover, failure of a sensor node can have a significant impact on the performance of entire WSN.

Being a low cost and a small device, sensor nodes can only be equipped with limited energy source which can only provide limited functioning time. In other words, power is a critical asset and must be utilized efficiently. Power efficient techniques have been proposed from all aspects starting from conserving power in WSN such as [10]. In [10], authors propose a trade-off of functionality with battery life by gradually reducing the use of additional functions with respect to battery life of MicaZ mote. This is achieved by reducing the runtime of additional functions in which a mote can switch-off and conserve energy during idle periods. The authors in [11] examined the increase in lifetime of a node by exploiting battery recovery effect (a phenomena by which a battery self recharges while left idle). A similar approach has been presented in [12] in which the proposed protocol exploits chemical properties of the battery minimizing the latency of packets while increasing the lifetime. A number of other power-aware protocols for medium access control are also evaluated in [13].

Similarly, an extensive review on energy conserving schemes is presented in [14]; the schemes are broadly classified into three segments duty cycling, mobility based and data driven. A comprehensive survey on wake-up scheduling schemes is presented in [15]. Such schemes enhances power conservation and can also contribute in energy scavenging. The design of WSN node also has a impact on battery life [16]. All the work mentioned above certainly contributes towards life extension, however, duration of WSN application is always unpredictable and relying only on conserving schemes and energy efficient protocols is not an essential solution to power constraint.

An auxiliary solution to approaches listed above is energy harvesting and recharging. Different sources of energy exists in different forms (e.g. light, vibration, air, and electromagnetic waves). These sources can be harvested and used to extend battery life of a sensor node. Harvested energy can also be used for battery extensive tasks. Battery life can also be extended by recharging a battery either physically or wirelessly. Reducing or eliminating the problem of limited lifetime will enable node designers to enhance the functionality of a node by adding extra features and components.

There are a number of studies on energy harvesting, recharging and their implications in WSN [17,18]. While our survey is similar to the these studies, however, this paper presents a survey of alternative techniques that can address the issue of limited power in wireless sensor nodes. More specifically, we focus on energy harvesting from renewable as well as traditional energy resources in sustainable Wireless Sensor Networks. We discuss sources available, techniques used for scavenging, storage methods and deployment architecture. These methods will not only prolong the lifetime of a node but can

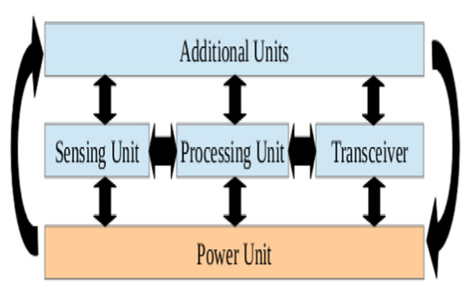

Fig. 1. Interconnection of basic components of a wireless sensor node.

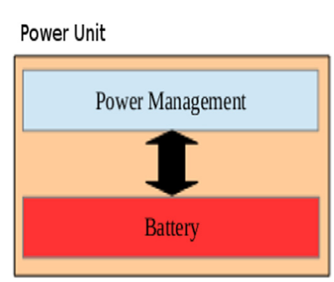

Fig. 2. Sub-module of power unit in a wireless sensor node.