REVIEW ON ENERGY HARVESTING FOR WIRELESS SENSOR NETWORKS

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ABSTRACT:

Sustainable wireless sensor networks (WSNs) are being widely used nowadays due to two key driving technologies behind them i.e. energy harvesting and energy management.

Energy harvesting from environmental energy sources such as solar, wind, thermal, mechanical and so forth are introduced from the perspective of energy supply to the WSN, while energy management of WSN such as the design of MAC protocol, design of routing protocol, and dynamic power management technology are presented from the perspective of energy conservation within the WSN itself. To better understand them in details for optimizing the sustainable WSN performance, in this paper, a review of these two enabling technologies are performed. More depth research into their combined efforts for sustainable WSN is presented and then illustrated with a case study. One of the most commonly referred energy harvesting source, i.e. solar energy, and its energy management which includes a new energy forecast model of wireless sensor nodes and a new model of energy distribution in WSNs using data collection protocol is investigated and demonstrated.

I. INTRODUCTION

In recent years, wireless sensor networks are widely used in many areas such as disaster management, infrastructure monitoring, security and surveillance, etc [1]. For these applications, the research works are mostly paying attention to the realization of functions in the designing of wireless sensor networks rather than the sustainability issue of the network. The wireless sensor node always uses power-limited battery as its energy supply. However, there are a number of nodes in the wireless sensor networks and they are always distributed in extensively wide and complex environment, it becomes very difficult to change the battery of wireless sensor nodes on deployment [2]. In order to make wireless sensor networks more practical, researchers began to study the sustainability of the wireless sensor networks, namely, try to extend the life cycle of wireless sensor networks effectively [3]. Energy harvesting and energy management are two key technologies that enable a self- sustainable wireless sensor network.

There are many forms of renewable energy readily available in the environment at which the wireless sensor networks are deployed, such as solar energy, mechanical energy, thermal energy, sound energy, wind power and so on. In this paper, we conduct a review of wide varieties of energy harvesting technologies for wireless sensor networks. We mainly focus on how to transform various forms of energy existing in the environment into electrical energy that can be used to sustain the operations of the wireless sensors. Energy management technology is mainly to solve the problem of energy conservation in wireless sensor networks (WSNs) [4] [5]. Energy management usually includes optimization of medium access and routing protocols, dynamic power management etc. However, if solely relying on reducing

ISSN (PRINT): 2393-8374, (ONLINE): 2394-0697, VOLUME-4, ISSUE-12, 2017
DOI: 10.21276/ijcesr.2017.4.12.50

energy consumption without energy supplement, it is very difficult to maintain long-term operation of a wireless sensor network.

The objective of this paper is to explore on two key enabling technologies of a self-sustainable and self-autonomous wireless sensor network. Firstly, energy harvesting technologies for wireless sensor network, including solar, wind, sound, vibration, thermal, and electromagnetic are introduced. Secondly, energy management technology used in wireless sensor networks are summarized, which include the design of various MAC protocols, routing protocols, cross layer protocols and dynamic power management technology.

Once the individual energy enhancement technology has been explored and researched, the correlation between both of these key technologies is addressed. To be able to fully optimize the WSN to be self-sustainable, rather than just energy harvesting or improved WSN energy management, it is important to further the research discussion into the combination of both energy harvesting and energy management technologies. A case study on the sustainable wireless sensor network that harvests energy from solar power, the energy model of such wireless sensor networks in green building, and the design of its data collection protocol.

II. ENERGY HARVESTINGTECHNOLOGY

As we all know, there are many potential uses of stray energies in our living space, such as solar, wind, heat, mechanical vibration, acoustic, electromagnetic energy. These energy sources are free and pollution free. Much research work on large-scale application of environment energy including solar, wind, geothermal, etc. have already been done and the related technologies are very mature [6]. However, when the problem changes into how to harvest and storage these natural energies in small-scale form to power miniaturized wireless sensor nodes, previous large-scale energy harvesting technologies are no longer applicable. Hence, many research works have been discussed in the literature on this energy harvestingtechnology for self-sustainable wireless sensor network. Some of the key progresses are described as follows.

A. Solar Energy

For earth, solar energy or light energy is a kind of inexhaustible and clean energy. The basic principle of optical collection is to absorb a large number of photons by the use of photovoltaic materials. If there is enough number of photons to activate the electronic optical pool, electricity can be obtained through appropriate structural design. Because power that can be harvested is greatly depending on the light intensity, optical components are usually placed inan environment with good lighting condition in order toobtain more power.

Opticalcomponents can be connected in serials to generate the required voltage. As manufacturing cost of optoelectronic components is declining, the selection of solar energy as energy source for wireless sensor networks has become a reasonable technical solution.

The only disadvantage of solar energy is that it is only available during day time (for outdoor environment) or office hour (for indoor environment). A battery is needed to ensure the sensors to be operated all around the clock and the efficiency can be low on cloudy days when sun exposure is very low. A number of recent solar energy harvesting prototypes [7]-[9] for sustainable wireless sensor network are presented in Figure1.

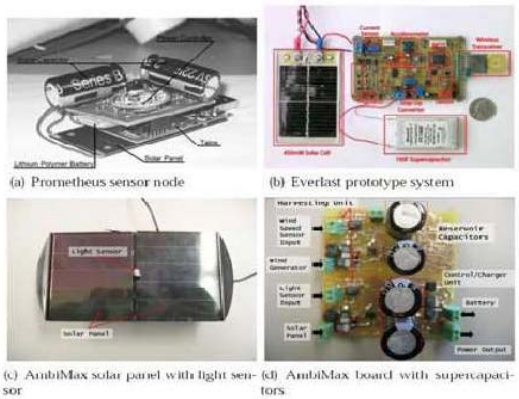

Figure 1: Examples of solar energy harvesting system [7] - [9]

B. WindEnergy

Like any of the commonly available renewable energy sources, wind energy harvesting has been widely researched for high power applications where large wind turbine generators (WTGs) are used for supplying power to remote loads and

grid- connected applications. Although very few research works are reported in the literature on small-scale wind energy harvesting,

some efforts to generate power at a very small-scale have been made recently [10]-[12], and some are presented in Figure2.

The main disadvantage regarding wind power is unreliability factor, as the strength of the wind is not constant and unpredictable, hence it does not produce the same amount of electricity all the time. In addition, since it involves moving mechanical part, it can be noisy.

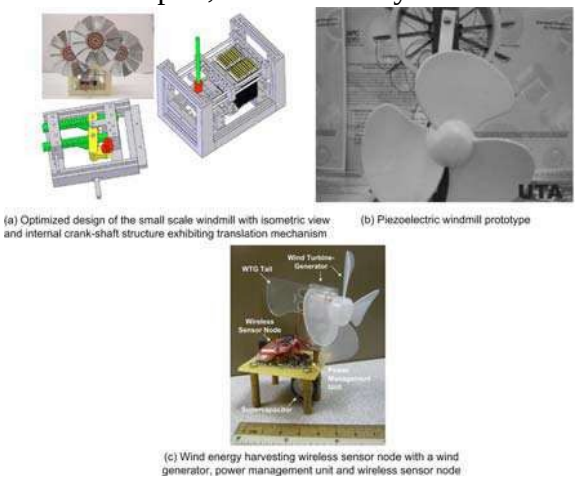

Figure 2: Examples of wind energy harvesting system [10]-[12]

C. ThermalEnergy

Research on thermoelectric technology began in 1940's, reached its peak in 1960's. And this technology was successfully used on the spacecraft. Temperaturedifference generator is featured with characteristics such as small, light weight, no vibration, no noise, less maintenance and can work for long hours under harsh environment. It is suitable to act as low power less than 5W and usually mounted in a variety of unmanned surveillance sensors, tiny short-range communication devices, and medical instrumentation. At present, the relevant products have been widely used. German scientists have invented a new type of battery using the temperature of human body to produce electricity, which can provide long-term "power" for portable miniature electronic devices and eliminates the trouble of charging or replacing batteries. For example, temperature difference which equal to 5 degree C between human skin and clothes can be took advantage of and provide sufficient energy for a common watch. Some examples of the thermal energy harvesting systems are presented in Figure 3.

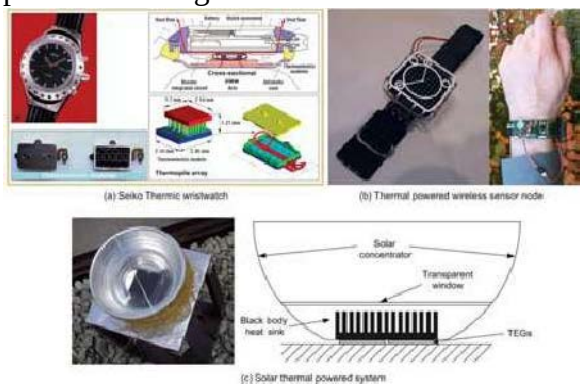

Figure 3: Examples of thermal energy harvesting system [13] -[15]

V. CONCLUSION

In this paper, we provide a comprehensive review on some common energy harvesting technologies of wireless sensor networks, and the introduction of energy management technology. We demonstrate an example of sustainable wireless sensor networks based on solar energy which is for green building. The challenge to harvest environment energy is discussed.

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