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Issues and Challenges in Energy Harvested based Wireless Sensor Network

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***Abstract*—** Wireless sensor network (WSN) suffers the problem of battery consumption, which cannot be replaced in remote regions. Energy harvesting is a prominent technique for the above problem. Energy can be harvested from the external environment like solar energy, wind energy, thermal energy, RF energy, piezoelectric energy, etc. to recharge the batteries which subsequently increases the life of the network. These conventional sources of energy provide energy on a macro scale, but in relation to WSN they need to be carried out on a smaller scale. Energy harvesters may or may not provide the continuous energy to the networks. This area needs to be explored while keeping in mind issues and challenges to meet the requirements of the network. This paper discusses the limitations of WSN, energy harvesting techniques and the issues and challenges in implementing energy harvesting in WSN. Environment, design, size, reliability, performance, resource sharing, hybrid energy harvesting, battery issues, low power and security are some of the major issues and challenges in energy harvesting based WSN.

***Keywords*—**Wireless Sensor Network, Issues and Challenges, Limitations, Energy Harvesting, Solar harvesting, RF energy harvesting.

I. INTRODUCTION

Wireless Sensor Network (WSN) consists of tiny sensory units called nodes interconnected to form a network for a special task. These sensory units or nodes detect the surrounding environment, accumulate data, process it and pass it onto the sink node. Sensor networks have a number of applications like medical applications, farming, environmental science, weather prediction, tracking and monitoring, military applications, and so on A sensor node performs various tasks like sensing, conversion of data, computation, storage and communication. All its working relies on batteries.

Use of batteries limits the life of the sensor nodes, therefore, approaches must be there to prolong the battery lifetime of the network. The above can be done using energy harvesting techniques to harvest the energy from the external sources to extend the lifetime of the network. Energy harvesting capable node is equipped with energy harvesting circuit which extracts the energy from the external environment, converts it into the usable electrical signal which is then can be used for later use. [1],[2]

This paper is organized as follows, section I introduces the energy harvesting in WSN, section II discusses the limitations of WSN, section III gives a brief description of energy harvesting techniques used in WSN and various issues and challenges in energy harvesting in WSN are listed in section IV and section V concludes the paper.

II. LIMITATIONS OF WSN

WSN has a number of limitations in different fields. Following are some major limitations of WSN [1], [2]:

1. Limited Battery Capacity

Sensor nodes are equipped with relatively small batteries, which is one of the limitations of WSN. The majority of the sensor nodes die due to the loss of power for operation. Low battery powered nodes result in data loss, network failure and degradation.

2. Large Battery Size, Cost and Weight

As WSN suffers from limited battery capacity for its operation, using large batteries incurs high cost and adds weight to the node making it bulky and incompatible with the node.

3. Low Transmission Range

The above two limitations can be overcome by the use of low power processor and communication radio antenna which will lead to lower transmission range among the sensor nodes.

III. ENERGY HARVESTING

Energy Harvesting is the process linked to transformation of external energy into electrical energy. The use of energy from external sources to convert it into electricity is a traditional concept. Different sources of energy include water, solar, thermal, wind, piezoelectric, mechanical, vibration, etc. Energy harvesting in WSN is the promising technique to enhance the lifetime of the network. A number of researches have been done to harvest the energy in WSN to prolong its lifetime.

The various types of energies harvested from different sources are:

1. ***Solar Energy:*** Solar radiations have photons which are responsible for generating electric current when they illuminate the semiconductor. Widely used material for this purpose is crystalline silicon (c-Si) besides, other forms of silicon are also available for the productions of photovoltaic cells like mono-crystal, multi-crystal, micro-crystal and amorphous form. Solar energy has the capacity to generate enough power for the operation of wireless sensors. Solar panels are used for the generation of electricity to be supplied to the sensor node. It is a clean and free energy that does not contaminate the environment by its bypass products as it directly provides DC voltage without any additional rectification circuit [3]. Power generated from solar energy is 10 mW/cm^2 for outdoors and 0.1 mW/cm^2 for indoors.

2. ***RF Energy:*** This radio energy can be extracted from the radiations of some radio frequency signals already present in the environment. Sources may be a WiFi system, GSM, base station radiations, local transmissions, etc. The amount of power received by receiver depends on the gain of the antenna, distance between Tx and Rx and power transmitted by transmit antenna Tx according to the Friis Transmission equation. The amount of power generated by WiFi is 0.001 $\mu W/cm^2$ and for GSM is 0.1 $\mu W/cm^2$.[3]

3. ***Piezoelectricity:*** The word piezoelectricity is derived from Greek word 'piezo' meaning pressure and 'electric' meaning electricity. The amount of voltage generated is proportional to the pressure applied on the special type of material called piezoelectric material. Some of the piezoelectric materials are quartz, polyvinylidene fluride (PVDF), barium titante ($BaTiO_3$) and soft and hard lead ziconate titane piezoceramics (PZT-5H and PZT-5A). These materials require dynamic forces to produce a continuous supply. The power produced from piezoelectric materials is 100 $\mu W/cm^3$. [3]

4. ***Thermal Energy:*** Thermal energy is responsible for producing electricity when there is a temperature difference (Seebeck Effect). Electricity is produced by thermoelectric generators which consist of arrays of n-type and p-type semiconductor materials connected in series. These generators require a temperature difference of 10-200 Celsius. The phenomenon of generation of electricity is based on the fact that heat from hot side is conducted by hot shoe which has high thermal conductivity as well as high electrical conductivity through semiconductors. N-type semiconductor releases electrons and the current produced from p-type semiconductor reaches the electric load through cold shoe. The amount of power produced is 60 $\mu W/cm^2$ at a temperature gradient of 5 degree Celsius. [3]

5. ***Wind Energy:*** Wind energy is one of the existing renewable sources of energy in many countries like Spain, Germany and Denmark on a macro scale. Keeping in view its capability of producing power in high power electronics, its application can also be given consideration in small scale. Wind speed and motor affects the output power. Microturbine based on DC motor can act as a voltage source. It is observed that large propeller provides maximum output at smaller values of load (~60 ohm) and smaller ones provide peak values at higher loads (~250 ohm). So, depending upon the load blade can be chosen. The maximum amount of power generated at 4.5 m/s wind speed is 5.5 mW with 9 cm blades. [3]

IV. ISSUES AND CHALLENGES

The production of electricity from external sources on micro scale counters some issues and challenges:

1. Design issues: Energy reduction is one of the goals in WSN and can be done using hardware design and efficient power management. Hardware can also be designed while keeping in mind the environment issues and workload assigned to a node. Designing energy harvesting capable node is more of an engineering task as it has to take into consideration environment, operational parameters and practical load requirements.

2. Reliability: The harvesting device to be used should produce the same amount of power under different circumstances with minor variations. But in case of solar power harvesting, its performance depends on the day/ night and weather conditions.

3. Performance: Many harvesting devices have high impedance values ranging from hundreds to few thousands of

ohms, which is a function of power, load and temperature. The goal of MPPT (Maximum Power Point Tracking) is to maximize energy transfer for large harvesting devices and minimize MPPT overhead in small harvesting devices.

4. Battery issues: Battery requires regular maintenance cost as it has limited number of recharge and discharge cycles, thus, loses its ability to hold charge and require replacement after one or two years. Supercapacitors have gained a lot of attention because of power density, low equivalent series resistance and low leakage current than electrolytics. Supercapacitors have more than half a million charge/discharge cycles and more than 10 years of operational lifetime. [4]

5. Resource Sharing: A node having abundant energy may share its resource with the neighboring node having minimum or less energy for its operation. This process should be done while considering a threshold energy set for donor node. [5]

6. Environment issues: Energy harvesting suffers several environmental issues. Solar energy is not available all the time and also weather conditions are also unpredictable. Vibrations in case of seismic energy may follow an unknown pattern with different values at different locations like terrain, plains, mountains, rivers, etc. Thus, energy varies with time and space. This variation causes non-uniform energy harvest leading to energy discrepancies. Depending on the pattern of energy availability, the algorithm can be designed for predicting the duration of maximum energy availability.[6]

7. Low Power: Some of the harvesting techniques generate low power which cannot operate a node function. The harvested power should be enough that the network could operate with that minimum energy with losses.

8. Size: Size of the sensor is an important parameter for various applications. Smaller size of the energy harvestor makes the low power operated devices portable. It should be less bulky and comparable to the size of the sensor. There is a tradeoff between the compactness and power efficiency of the harvesting device.

9. Hybrid Harvesting Sources: Harvesting from multiple sources can result in complexity and issues in compatability. It can also increase the size of the node and make it bulky. It has its separate issues in designing the circuits, protocols for harvesting and operation, etc.

10. Security: Security is the main concern as both information and energy are transmitted over the wireless media. A secure protocol is needed to optimize information decoding and energy harvesting. Thus, the concept of simultaneous wireless information and power transfer (SWIPT) [7,8,9] proposed splitting of the received RF signal into two streams through a splitter, one for energy harvesting and other for information decoding.

V. CONCLUSION

Energy harvesting is a promising technique to enhance the lifetime of the sensor network. The motive is to avoid the excessive use of batteries which are limited in capacity and result as non-biodegradable waste. Various harvesting techniques have their own merits and demerits. This paper uncovers and describes opportunities for future research challenges in the area of energy harvesting based wireless sensor networks (EHWSNs), which are typically deployed in remote locations without the possibility of frequent maintenance. Additionally, this paper provides an overview of state-of-the-art harvesting techniques that can be combined into EWSNs so as to improve their lifetime, output performance, reliability and operational efficiency. Research is going on to provide reduced size, light weight energy harvesters. Various issues and challenges in energy harvesting based WSN are discussed which provides new scope of improvement in the performance of the network. There is a vast scope of improvement in this field and research is going keeping in mind various issues and challenges.

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