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A Survey on Energy Management in Energy Harvesting Wireless Sensor Network

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***Abstract*— In previous year batteries have been the source of energy for wireless sensor network. These batteries are limited source of energy. So for wireless sensor network to work for a life time, we need a self-powered energy sources. These self-powered devices extract energy from their surrounding environment, and the process of extracting energy from surrounding environment is called energy harvesting. It is originated from wind-mill and water-wheel. It is also have low-maintains cast and used for variety of application. The various form of energy harvesting sources is thermal, mechanical, solar, wind and wave. This paper present a survey on various energy harvesting sources for wireless sensor network and their role in minimizing the energy. This paper also presents a detailed survey on most common form of energy harvesting i.e. solar energy and its usefulness in wireless sensor network. This paper also presents the method for energy management within the wireless sensor network.**

***Index Terms*— Energy harvesting, resource allocation, energy management, wireless sensor network**

I. INTRODUCTION

With the recent advancement in wireless sensor network, need arises for a longer battery-life and self-sustainable power devices. Conventional batteries require human interventation and do not have sufficient battery life to support sensor networks. Hence power requirement for operation of sensor network is a major area of concern. So another type of energy source is required which can replace conventional source of power. The electrical energy required to run these wireless sensor network can be out source from thermal energy, mechanical energy and solar energy present in the environment. This help wireless sensor networks to provide them energy for their lifespan. And therefore this process of extracting energy from environment and convert them into useful electrical energy for wireless sensor network is called energy harvesting. The source of these energies present into environment is solar energy, thermal energy, RF energy and mechanical vibration etc.

Wireless sensor networks have wide application in areas such as infrastructure monitoring, security, disaster management and surveillance, etc [1]. The key factor in these networks is realization of function rather than sustainability of the network. These networks use limited power batteries as its energy source. However, it's very difficult to change the batteries on deployment[2].So sustainability becomes the major issue and researcher are now trying to extend the lifetime of network[3]. In this paper we present the wide variety of energies present for energy harvesting to enhance the lifetime of wireless sensor networks. Sensor network, a network of collaborating embedded devices (sensor nodes) with capabilities of sensing, computation and communication, is used to sense and collect data for application specific analysis. A sensor network application has several design dimensions, sensing modality, sensor node computation, communication and storage capabilities, cost and size of each node, type of power source, architecture for deployment, protocols for data dissemination and communication, applications and management tools, to name a few.

The energy harvesting sources used for increase in the lifetime and capability of the devices by replacing the battery usage . These devices placed in inaccessible location provide vital information on operational and structural circumstances is powered by energy harvesters. This paper present the survey on energy harvesting, the research work done so far in this area and various energy harvesting sources.

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II. TYPES OF ENERGY HARVESTING

The classification of energy harvesting is based on the fact that sources they are using for obtaining the electrical energy. As For example solar harvesting devices scavenge solar energy from sun and convert it into usable electrical energy for wireless sensor networks. The different form of energy sources for energy harvesting are solar energy from sun, thermoelectric generators, wind turbines, mechanical vibration devices such as piezoelectric devices, electromagnetic devices and photovoltaic cells[4] . There are various properties which can characterize a portable energy supplier are described by Fry, et al. [5]. These are characterizing into electrical properties, physical properties, environmental properties, operational properties and maintenance properties. Physical properties involve size, shape and weight. Environmental properties involve water resistance and operating temperature range and electrical properties include power density, maximum voltage and current.

As a result, energy harvesting techniques have the potential to address the tradeoff between performance parameters and lifetime of sensor nodes. The challenge lies in estimating the periodicity and magnitude of the harvestable source and deciding which parameters to tune and simultaneously avoid premature energy depletion before the next recharge cycle.As part of this study, we present details of energy harvesting techniques—architectures, energy sources, storage technologies and examples of applications and network deployments. Further, as mentioned above, sensor nodes can exploit energy harvesting opportunities to dynamically tune system param- eters. These adaptations have interesting implications on the design of sensor network applications and solutions, which we discuss.

There are various other uses' of these energies in other domain of our living. As these sources of energy comes natural in the environment and have no cast. The use of this energy for large scale application such as agriculture, high voltage electrical plants etc. have already been done and technologies are very advance. But these advance technologies are no longer applicable for small scale application such as providing power back up to wireless sensor networks. So in this paper i present the review on work done for energy harvesting for wireless sensor network. They are such as.

➢ **SOLAR ENERGY**

Solar energy is principal sources of light and energy for the earth. This is never ending and inexhaustible energy we are getting from sun. The photo-voltaic effect is the phenomenon to convert the solar energy into electrical energy. The basic principle is to absorb a large number of photons by the use of photovoltaic materials. With proper photo-voltaic material and suitable structural design, electricity can be obtained. Good whether condition plays a major role in obtaining the harvested power from environment as harvested power highly dependent on light intensity. The required voltage can be obtained by using these optical devices. These devices are usually connected in series. Nowadays as the prices these solar components are declining, the solar energy becomes the primary resource for this wire-less sensor network.

Problem with solar energy is that it's availability as sun light is only available only during day time or office-hours.so battery back-up is required to ensure the sensors to be operated continuously even in those cloudy days when sun exposure is very low. Various solar energy harvesting system for wireless sensor networks are presented [6-8] in following figure [1]. Since solar energy is easily available and is a convenient harvesting source, several implementations of solar energy harvesting sensor nodes exist. These solar energy harvesting implementations are different along the axes of characteristics of solar panels, battery type and capacity, and complexity of recharge circuit. Further, all these nodes use the Harvest-Store-Use architecture and use different options for storage battery, super-capacitors or both.

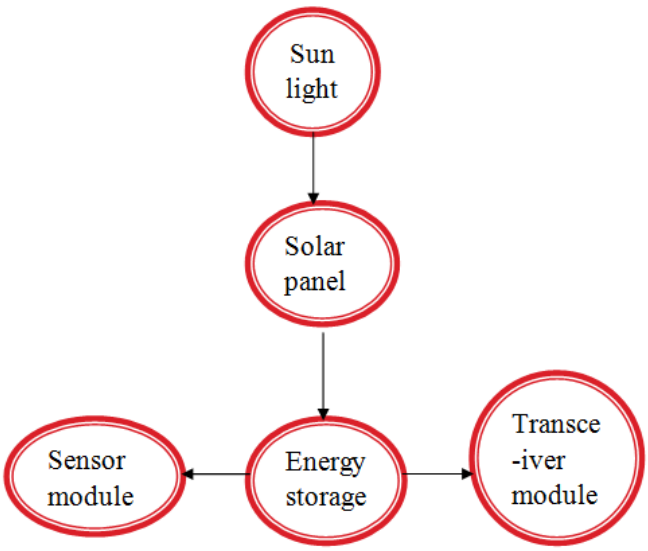

Fig.1.The energy flow of sensor network

➢ **WIND ENERGY**

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. Very few research work are reported in wind energy harvesting but there are efforts have been made to produce power from small-scale wind energy[9-11].wind energy is highly unreliable due to it's unpredictable nature and as wind is not always constant hence it does not produce a constant electrical energy which is required. The noise factor produce by mechanical vibration is another issue. Hence wind energy is not a suitable choice as power source in wireless sensor network.

➢ **THERMAL ENERGY**

Thermoelectric energy Research has began on early 1940 and in 1960 most of the important work has been established such as use of this technology in space air craft. By creating the temperature difference we can produce electrical energy which works for long hours under difficult conditions with characteristics such as small, light weight, no vibration, no noise and less maintenance. It act as low power less than 5W and mounted in a variety of unmanned surveillance sensors, tiny short-range communication devices, and medical instrumentation. Thermal energy product has been widely used nowadays.

➢ **OTHER ENERGY**

When sound waves encounter barriers, the sound energy can be converted into electrical energy. And according to this principle, scientists design and manufacture a kind of membrane-type receiver and connected it with the resonance. When noise comes into this acoustic energy converter, the electrical power will be produced. For instance, noises of jet plane which is equal to 160dB can produce power output up to 100kW. Obviously, there is magnetic energy everywhere on the earth. Therefore, the magnetic energy is a good energy for us to utilize. New engine using magnetic energy was developed by combining generator and electric motor. It can effectively use the electromagnetic energy and pure energy to drive the machine. This engine does not require external energy and is an independent recycling system. Hence magnetic energy is also an alternative source of green energy.

Wireless sensor node that depends on only a single energy source is not reliable, as it does not work well when the energy source does not exist or disappear. In order to obtain energy as much as possible, each wireless sensor node must be designed with an energy collection system which can collect various kinds of energy from environment [12]. Of course, the difficulties in designation of harvesting system are mainly in the following areas: (1) many kinds of energy harvesting technologies and methods are not yet mature, there are still much innovative works which should be done by the researchers; (2) energy harvesting system must meet the requirements of the size of the node; (3) energy harvested by nodes should be stored efficiently.

Energy harvesting technique	Power density	Efficiency

Photovoltaic	Outdoors (direct sun):15mw/cm.	Highest + 32+1.5%
	Outdoors (cloudy day): .15mw/cm.	Typical 25+1.5%
	Indoor < l10 w/cm.	-
Thermoelectric	Human :30 w/cm.	+ 0.1%
	Indastrial : 1 to 10 mw/cm.	+ 3%
pyroelectric	8.64 w/cm. at tmp.rate of 8.5 c/s	-
Pizoelectric	250 w/cm.	-
	330 w/cm.	-
Electromagnetic	Humen motion : 1 to 4 w/cm.	-
	Industrial 360 w/cm.	-
Electrostatic	50 to 100 w/cm.	-
RF	GSM 900/1800 MHZ 0.1 w/cm.	50%
Wind	380 w/cm. at speed of 5m/s	5%

Fig.2. Comparison of various energy harvesting techniques.

III. METHODS OF ENERGY MANAGEMENT

Energy management is definitely an important energy-saving means. And the objective of energy management in wireless networks is not only reducing energy consumption but also balancing energy among all the nodes as sustainable wireless sensor networks always use energy harvesting technology, energy management considering energy harvesting is more complex than WSNs only relying on battery supply. Until now, there are many kinds of methods for energy management. They often involve node energy management, MAC protocols, routing protocols, cross-layer optimization, etc.

i) NODE MANAGEMENT

For a single node in sustainable wireless sensor networks, the main objective is to make itself work permanently. [13] Proposed optimal energy management policies for energy harvesting sensor nodes. Based on its study, the generated energy should be stored in a buffer. The sensor node in wireless sensor networks could sense a random field and generates a packet periodically. These packets are stored in a queue and transmitted using the energy available at that time. The energy management policy is throughout optimal and also minimizes the mean delay. Peering T proposed a new concept named dynamic voltage scaling (DVS) [14], which means it could dynamically adjusts the supply voltage of the microprocessor according to the system load. DVS has a perfect effect on energy conservation, but system must have ability to measure or predict the system load. Sinha A [15] firstly introduced the strategy of dynamic power management (DPM) into wireless sensor networks.

ii) ROUTING PROTOCOL

Main objective of routing protocol of wireless sensor network is to establish best path between source nodes and sink nodes. At the same time, the routing protocol should also have some characteristics such as energy saving, fault tolerance and low latency. And energy saving is definitely the main principle in routing protocol design. Some typical routing protocols in WSNs are mentioned as follows. As for cluster-based routing protocol, the network is usually divided into clusters. Each cluster consists of a cluster head and a number of cluster members. Cluster heads are responsible for coordinating works of all the nodes of the same cluster, data fusion, data forwarding etc. This protocol includes LEACH protocol [16] and TEEN protocol [17]. In the data-based routing protocols, all nodes are treated equally. This protocol is simple and robust. However, it has poor scalability. In addition, data-based routing protocol has to maintain routing tables, which will take up much storage space and increase communication throughput of the network. DD protocol [18], Rumor protocol [19] and SPIN protocol [20] are typical data-based routing protocol. Next, geographic routing protocol like GPSR protocol [21] only depends on adjacent nodes, so it is almost a stateless protocol. The nodes in a wireless networks always use the shortest Euclidean distance to establish or maintain routing table, storage are avoided and it has a short delay of data transfer. Energy routing protocol is one of routing protocols for wireless sensor networks firstly proposed. The global information of the whole network is needed for routing. However, due to energy constraints in wireless sensor networks, the node can only access the topology information of local network. As a result, it is only an ideal case. Based on this theory, Shah etc. put forward the energy aware routing protocol (EAR) .

iii) CROSS LAYER OPTIMIZATION

Generally, most communication protocols of sensor networks are designed with hierarchical structure called layers which are independent of each other, and layers are relatively simple. So networks with different systems are easy to communicate. However, in order to achieve a better efficiency with optimized system performance, cross-layer optimizations is proposed to enhance the information communication among network layers, so layers can avoid being interfered each other. Many cross-layer protocol such as E-AIMRP [22] etc. have been designed creatively.

IV. COMREHANSIVE HARVESTING

Wireless sensor node that depends on only a single energy source is not reliable, as it does not work well when the energy source does not exist or disappear. In order to obtain energy as much as possible, each wireless sensor node must be designed with an energy collection system which can collect various kinds of energy from environment [12]. Of course, the difficulties in designation of harvesting system are mainly in the following areas: (1) many kinds of energy harvesting technologies and methods are not yet mature, there are still much innovative works which should be done by the researchers; (2) energy harvesting system must meet the requirements of the size of the node; (3) energy harvested by nodes should be stored efficiently.

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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