Significance of Energy Harvesting for Wireless Sensor Networks

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Keywords

ABSTRACT
Wireless Sensor Networks consist of a large number of small in size, low-power but smart sensor nodes are interfacing with one another and deployed over a certain inaccessible geographical area with portable sources like betters having limited power and storage space[1][2]. However, the battery presents several disadvantages required to be replaced or recharge them frequently. One possibility to overcome this power limitations problem is to harvest energy from the ambient limitless available energy sources in the environment surrounding to the sensor nodes are either to recharge batteries or directly use to power the sensor nodes of wireless sensor network. Most of the time, energy harvest from one source is not sufficient to meet the power requirement of sensor nodes. Therefore the hybrid energy harvesting techniques would be a solution to solve the low power problem of wireless sensor nodes. However the energy harvesting process may be irregular, thought there may be a limit on the rate at which it can be used, a power management schemes are require to maximize the lifetime of wireless sensor nodes that integrates sensing abilities, computing, wireless communication and The efficient energy management schemes are require for wireless sensor network such as to design energy efficient MAC protocol, routing protocol, data collection protocol and so on that integrates long network lifetime and high quality of service.

In this paper, a review of Energy Harvesting techniques from the ambient energy sources such as solar, wind, thermal, mechanical and so forth are introduced the perspective of energy sources for the wireless sensor nodes.
1. INTRODUCTION

Today’s application on wireless sensor networks (WSN) are more complicated and challenging, most of these application require very less power and Sensor nodes lifetime is limited by the energy capacity of the batteries used and the gradual degradation of the battery, when the battery of a node is exhausted, it is difficult and expensive to replace and the node dies. When sufficient numbers of nodes die, the network may not be able to perform its designated task. Thus, the life time of a network is an important issue of a wireless sensor network. For applications where the system is expected to operate for long durations, energy becomes a severe bottleneck issue. The most important ways to improve the system lifetime is to harvest energy from ambient energy sources surrounding with the nodes in the environment. Depending on the service provided by the wireless sensor networks and its network topology, different definitions of lifetime have been used [4]. In many papers, e.g., [3], the death of the first node in the WSN is defined as lifetime. This is pessimistic because the other nodes in the network may still carry out sensing and communication tasks. In [5], lifetime is defined as the death of a pre-specified fraction of nodes. However, these definitions are based purely on the battery energies of the nodes. The failure to communicate the sensed data to a failure node due to channel fading is not accounted for. In [6], Energy harvesting sensor (EHS) nodes, which refill the energy they consume by harvesting it from the environment and storing it in their batteries, offer a promising and green alternative to tackle the problem of lifetime[7]. While EHS nodes are attracting considerable interest, several new challenges need to be overcome before they can be widely deployed. First, the energy harvesting process can be sporadic. Second, an EHS node needs additional circuitry to harvest, store, and provide a regulated supply of the harnessed energy to its battery or supercapacitor[8]. Hence, energy harvesting nodes are likely to be more expensive than conventional nodes, which come equipped with pre-charged, non-rechargeable batteries. Given the above challenges, hybrid WSNs, which comprise of a mixture of EHS nodes and conventional nodes, are likely. Upgradation of the legacy WSNs, in which conventional nodes are gradually replaced by EHS nodes, also naturally leads to hybrid WSNs. However, relatively less research has been done on hybrid WSNs. In the hybrid WSN considered in [9], the energy harvesting functionality is used only to relay information from a cluster head to the failure nodes.

2. OVERVIEW OF WIRELESS SENSOR NETWORKS

A. WIRELESS SENSOR NODE

Wireless Sensor Node was embedded of sensing unit, computation unit, and a radio unit for communication and powered by ambient energy source surrounding with the nodes in the environment. The power consumed by a wireless sensor node can be divided between the various function it has to perform. The power requirement of each element depends on the particular application and so it is difficult to generalise about which part of sensor node consume the more power[8]. Sensing unit power varies with the nature of a application, irregular sensing might consume less power than constant event monitoring, Sensing unit gathered, filter and synchronized the data and process to the processing unit. The processing unit is responsible for managing data acquisition, handling communication protocols, scheduling and preparing data packets for transmission. The power consumption of computation unit and performance of the processor depend on the architecture, technology, and clock speed utilized. In [9] Communication unit consumes major part of the energy and there is a wide range of wireless communication standards available by factors such as inter-node distance, data rate, and power requirements for networks. The most widely considered standard are grouped within the IEEE802.11 standard for wireless local area networks (WLANs) and the IEEE802.15 standard for wireless personal area networks(WPANs). The architecture of Wireless sensor node with energy harvesting as shown in Figure 1[11].

Figure 1. Wireless sensor node with energy harvesting unit
B. ENERGY HARVESTING UNIT OF SENSOR NODE

The energy harvesting device consists of three main components namely energy harvester, power management/conditioning and energy storage. Figure.2 shows the general block diagram representation of a typical energy harvesting unit.

C. OVERVIEW WIRELESS SENSOR NETWORK

Wireless sensor network consist of a large number of small in size, low-power but smart sensor nodes are interfacing with one another to coordinate specific tasks and deployed over a certain inaccessible geographical area and it is designed to gather real-world information as well as to monitor the condition using network topologies include star, mesh and cluster tree or hybrid networks in the various application areas such as building, utilities, industrial, home, marine, animal habitat, traffic, etc. Information are collected at base station in a wireless manner, pre-processed and then distributed to the end users via different communicating devices. it can be seen that the entire data network is a very large and complex system that is made up of many different subsystems i.e. sensor nodes, base station, management centre, wireland and wireless communication systems. The sensor nodes and the base station are part of the data acquisition network and the wireland and wireless communication systems belong to the data distribution network. Once the sensor nodes are deployed in the application areas, the nodes would sense and collect data from the environment and the collected data are then sent to the base station in a wireless manner. The base station consolidates the collected data and preprocesses the data so that it can be delivered quickly and safely over the data distribution network to the end users. Most importantly, the end users must be able to access the information at anywhere and at any time. In between the data acquisition network and the data distribution network, a management centre is incorporated so as to better coordinate, monitor and control the data flow between the two networks. When data is transferred within the entire network, there are two important factors that need to be well considered data integrity and data security. Figure.3. Show a general architecture of the data acquisition and distribution network[11].
3. ENERGY HARVESTING SOURCES AND TECHNIQUES

Energy harvesting techniques are used to collect energy from ambient sources. Figure 4 shows various types of ambient energy forms suitable for energy harvesting along with examples of the energy sources. The energy types are thermal energy, radiant energy and mechanical energy[10].

![Energy sources and respective transducers to power autonomous sensor nodes](image)

**Figure 5.** Energy sources and respective transducers to power autonomous sensor nodes

**A. THERMAL ENERGY HARVESTING TECHNIQUES**

Thermal energy is the other form of energy present in the environment in terms of heat. Thermal energy harvesting devices could use the thermal energy of different sources like temperature of persons and animals, machines or other natural sources. A thermoelectric generator basically consists of a thermocouple, comprising a p-type and n-type semiconductor connected electrically in series and thermally in parallel. The thermogenerator based on the Seebeck effect produces an electrical current proportional to the temperature difference between the hot and cold junctions. An electrical load is connected in series with the thermogenerator creating an electric circuit. The Seebeck coefficient is positive for p-type materials and negative for n-type materials. The heat that enters or leaves a junction of a thermoelectric device has two reasons: the presence of a temperature gradient at the junction and the absorption or liberation of energy due to the Peltier effect. [12]

**B. RADIANT ENERGY HARVESTING TECHNIQUES**

Another source of energy present in the environment is electromagnetic radiation, either in the form of light known as solar energy, or lower frequency RF radiation. Solar energy is a mature technology for large scale energy generation. Photovoltaic systems are found from the Megawatt to the milliWatt range producing electricity for a wide range of applications. RF radiation is employed to power ID cards by directing high power electromagnetic energy to the devices from a nearby source. In addition to energy, it is possible to send information as well. However, the term energy harvesting implies that it is the same device which gets its energy from the environment. In cities and very populated areas there is a large number of potential RF sources: broadcast radio and tv, mobile telephony, wireless networks, etc. The problem is collecting all these disparate sources and converting them in useful energy. The conversion is based on a rectifying antenna (rectenna), constructed with a Schottky diode located between the antenna dipoles. The energy levels actually present are so low that no present electronic device can use them. However, future technologies may allow the fabrication of lower power devices that would “recycle” RF energy generated for other purposes by different elements[12].
C. MECHANICAL ENERGY or KINETIC ENERGY

Kinetic energy is one of the most readily available energy source, both for Human and for Environment energy harvesting devices. The principle behind kinetic energy harvesting is the displacement of a moving part or the mechanical deformation of some structure inside the energy harvesting device. This displacement or deformation can be converted to electrical energy by three methods by a piezoelectric material, by electrostatic energy and by magnetic induction. The piezoelectric effect are when subjected to mechanical strain, suffered an electrical polarization that is proportional to the applied strain. This is the piezoelectric effect used for mechanical to electrical energy conversion. The principle of electrostatic generators is that the moving part of the transducer moves against an electrical field, thus generating energy. The magnetic induction transducer is based on Faraday's law. The variation in magnetic flux, \( \Phi_m \) through aelectrical circuit causes an electric field. This flux variation can be realized with a moving magnet whose flux is linked with a fixed coil or with a fixed magnet whose flux is linked with a moving coil. The first configuration is preferred to the second one because the electrical wires are fixed. As the relevant magnitude here is the magnetic flux through a circuit, the size of the coil is inversely related to the obtained electric field and therefore, to the generated energy. This means that big transducers with large area coils will perform better than smaller transducers, unless a larger time derivative is involved with the small scale generators.[12].

4. BENEFITS OF ENERGY HARVESTING FOR WIRELESS SENSOR NODE

Energy harvesting techniques gives the power solution for low power wireless sensor nodes which is deployed in inaccessible area.

1. It reduce the dependency on power battery, the power consumption of the sensor nodes are very less due to the microelectronics technology and multiple energy sources are available around the sensor nodes, hence hybrid energy harvesting may be sufficient to eliminate the battery of wireless sensor nodes.
2. It reduces the installation cost. it does not require power cables, wiring and very easy to install
3. It reduces the maintenance cost. it does not require to be replaced or recharge the battery frequently. It is self power sensor node
4. It provide sensing and actuation capability in hazardous environments on a continuous basis.
5. It provides long term power solution. wireless sensor node will remain perform the designated function as long as the ambient energy sources is available.

5. CONCLUSION

Wireless Sensor Networks consist of a large number of small in size, low-power but smart sensor nodes are interfacing with one another and deployed over a certain inaccessible geographical area with portable sources like betters having limited power and storage space. In this paper has theoretical study, the architecture of Wireless Sensor Node that integrates sensing unit, computation unit, and communication unit powered by ambient energy source surrounding with the nodes in the environment. Wireless sensor node consists of energy harvesting unit ,it has three main components namely energy harvester, power management/ conditioning and energy storage that performs the function convert ambient energy in to the electrical from and stored in the battery or directly power to the sensor node. Also discussed the General architecture of the data acquisition and distribution of wireless sensor networks. A review the energy harvesting various types of ambient energy sources available in the environment and their techniques of energy harvesting. Also discussed the benefits of energy harvesting for the wireless sensor nodes and requirements of hybrid energy harvesting.

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