Methods and Techniques of Energy Management Schemes in WSN

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Abstract: *Wireless sensor networks (WSNs) as a result of the potential for their widespread use in many different areas like home automation, security, environmental monitoring, and many more. To prolong the lifetime for these energy hungry sensor nodes, energy management schemes have been proposed to keep the sensor nodes alive making the network more operational and efficient. This network also fails to maintain a long lifespan to manage and maintain network strength in terms of lifespan. By various scholars, several algorithms are proposed with an aim to extend the lifespan of WSN's. The current review presents the state of the art in the energy management schemes, the remaining challenges, and the open issues for future research work.*

Keywords: Wireless Sensor network, LEACH protocol, Energy harvesting, Wireless energy transfer technologies.

1. Introduction

Energy efficiency has become a major theme in wireless sensor network (WSN) research. The interest in energy efficiency may be attributed to limitations imposed by the batteries used to power such devices. These batteries are usually the main source of power for these devices and are characterized by a limited lifespan, after which they are recharged or discarded WSNs form the backbone of ubiquitous computing applications such as military surveillance, disaster, environmental, structural, health and security, and wildlife and habitat monitoring as well as precision agriculture. Deployment of sensor nodes is usually in inaccessible environments, and with limited battery capacity their lifetime is usually an issue of major concern. Several techniques have been proposed in the literature to increase the lifetime of sensor nodes as well as the sensor networks

To help extend the lifetime of sensor nodes and networks, energy conservation methods are usually employed. In this, an effort is made to reduce the energy consumed by the unit. Categorized energy conservation schemes under the three main headings: duty cycling, data driven, and mobility driven techniques. Duty cycling is aimed at reducing idle listening when the node's radio waits in vain for frames and overhearing when nodes stay active listening to uninterested frames. Data driven techniques use some parameters of the data themselves to make decisions to reduce energy consumption during communication while mobility schemes consider the mobility of the sink or relay nodes as a factor affecting the energy consumed in the network.

Typical energy conservation techniques simply seek to prolong the lifespan of the network by reducing the energy used and do not typically require the introduction of new sources of energy. To increase the energy available to the sensor nodes, energy harvesting techniques have been proposed.

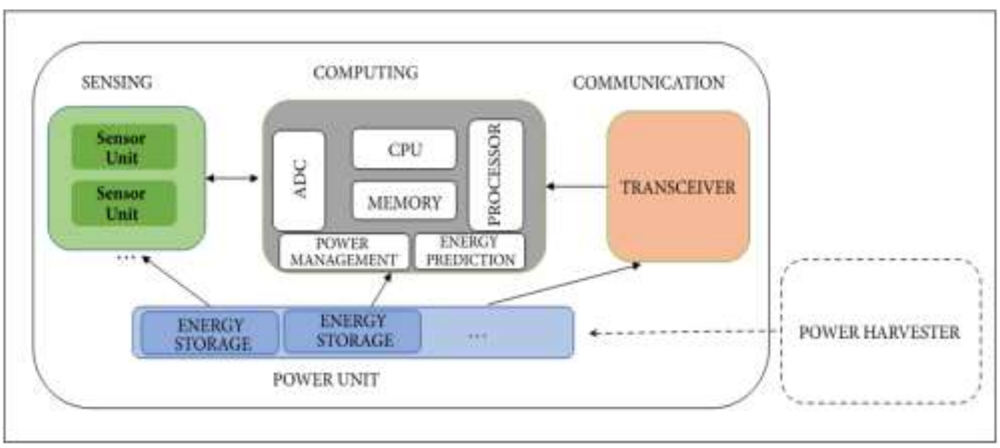

Figure 1: A typical architecture of a wireless sensor node. [1]

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2. Hierarchical Protocols

In hierarchical routing protocols, nodes organize the network into set of clusters. Each cluster is managed by a selected cluster-head [2]. Cluster-head periodically collects data from member nodes of their cluster, compresses it and then removes duplicity among collected data to reduce the number of transmission between cluster-head and base-station.

2.1. LEACH (Low energy adaptive clustering hierarchy) and its variants

LEACH is a routing protocol that collects and sends data to base station with following main objectives [3]:

•Increase network life-time.

•Decrease energy dissipation of sensor nodes.

•Reduce the number of communication messages.

To attain these objectives, nodes organizes themselves into clusters. Member nodes of a cluster sends their respective data to their cluster-head, which is further responsible for sending collected to base station. This results in saving the energy of sensor node because they have to spend lesser energy to send their data to cluster-head instead of base-station. Moreover, cluster-heads aggregates collected data to remove redundancy among similar data and hence reduces the transmitted data to the base station. This results in saving large amount of energy, as aggregated data is sent over a single hop. LEACH operates in two diverse phases including set-up and state-phase. The set-up phase is f further categorized as cluster-head selection and cluster formation. Cluster-head selection ensures that this role rotates among all sensor nodes; to evenly distribute energy consumption among all network nodes. So, selected cluster-head last long only for a round and this role is rotated among other nodes so that selected cluster-head did not die soon. To find out its turn to act as cluster-head, node 'n' generates a random number between 0 and 1 and compare with the cluster-head selection threshold T(n).

A node becomes cluster-head if its generated number is less than a threshold T (n) [4,2]. Cluster-head threshold ensures two things: First, only predetermined fractions of nodes, P, become cluster-head. Second, node which acts as cluster-heading last 1/P rounds are not selected as cluster-head. To meet these requirements threshold is set as:

$$T(n) = \begin{cases} {}^{p}/_{1-p^{*}(r \bmod 1/p)} & if\ n \in G \\ 0 & otherwise \end{cases}$$

Where, r is the current round, and G is the set of nodes that have not been cluster-heads in the last 1/p rounds. At the end of cluster-head selection process, every node selected as cluster-head advertise (ADV) its new role to rest of the network. After receiving the cluster-head advertisement, remaining nodes selects a cluster to join on basis of received signal strength and inform their selected cluster-head of their wish to become a member to this cluster. After cluster formation, each cluster head creates and distributes TDMA schedule among each member of their cluster. This ends the set-up phase and starts the set-up state phase. During steady phase each node transmits sensed data to cluster-head during its allocated time slots.

3. LEACH Model

3.1 *EB-LEACH (Energy Bank LEACH)*

In LEACH, due to random selection of cluster-heads it is quite possible that selected cluster-head has not had enough energy to transmit data to base station and dies. So, all the data that lies with cluster head lost. Due to additional energy bank nodes in clusters, there is no need of rotations for cluster head election like LEACH protocol.

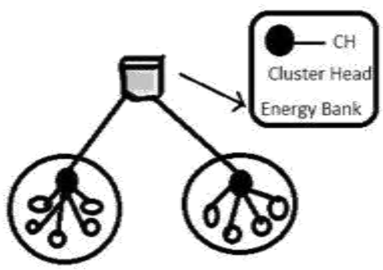

Fig 4: Energy Bank LEACH

3.2. Flow of EB LEACH

The Function of Energy Bank LEACH (EB LEACH) is act according to these steps:

Step 1: Start

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Step 2: Form Cluster and Select Cluster Head (CH) according to LEACH process

Step 3: Compare Cluster Head with Threshold

CH Energy < Th Energy
If (True)
The CH remain same.
Else
CH Borrow Energy -> Energy Bank Node

Step 4: Cluster Head (CH) will remain constant

Step 5: End

4. Energy Harvesting

Energy harvesting approaches scavenge for energy from the external environment such as wind, vibrations, solar, acoustic, and thermal. The techniques used in energy harvesting convert energy from the environment into electrical energy that can be used in wireless sensing nodes/devices. In wireless sensor networks, energy harvesting can be used to overcome the challenge of energy depletion that causes shorter lifetime of the nodes in the network and in other cases of the black hole problem [5]. To realize the promised benefits of energy harvesting, concerted effort is required on the part of researchers to address some outstanding issues. Energy harvesting does not guarantee immortal nodes and continuous operation due to the uncontrollable energy sources, making them unpredictable and difficult to model.

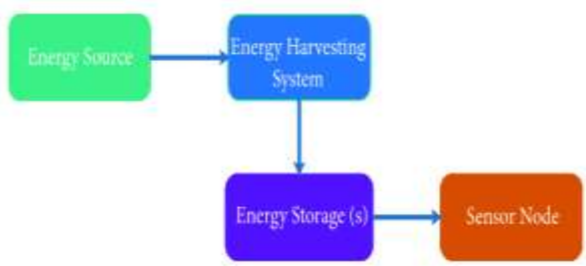

Fig 2: Ambient energy harvesting to store and use.

An example is solar energy which is not available for harvesting at night due to the absence of the sun.

In energy harvesting, nodes in the network may be attached with special devices for scavenging energy from the ambient environment for conversion into electric energy. In the case of solar energy, the size of the panel is directly proportional to the amount of energy converted through the photovoltaic technique. The source from which energy is harvested in a sensor network is a valuable resource since it determines the amount of energy available to the network and the rate of conversion from the source to electrical energy. Energy harvested may be classified under ambient sources, which are sources available in the surrounding environment and human sources [6]. Ambient sources of energy discussed include solar, vibration, thermal, and radio frequency.

The use of batteries in wireless sensor nodes is to act as sources of energy, but with their limited capacity, energy management has become an important research area. Replacing batteries when their capacity is depleted is inconvenient in most applications of WSN. Energy harvesting gives opportunity for nodes to receive energy either from the ambient environment or from intentional sources [7]. This energy can be stored in batteries and hence the batteries must have the ability to be recharged. The amount of harvested energy is usually less than needed to charge a battery and hence must be stored to accumulate for intermittent use.

Table1: Specifications of solar energy harvesting sensor nodes.

Node	Solar Panel (mW)	Solar Panel Size (inXin)	Energy Availability (mWh/day)	Storage Type	Battery Type	Battery Capacity (mAh)	Sensor Node used	MPPT Usage
Heliomote	190	3.75*2.5	1140	Battery	Ni-MH	1800	Mica2	No
HydroWatch	276	2.3*2.3	139	Battery	Ni-MH	2500	TelosB	Yes
Fleckl		4.56*3.35	2100	Battery	Ni-MH	2500	NA	NO
Everlast	450	2.25*3.75	2700	Supercap (100F)	NA	NA	NA	Yes
SolarBiscuit	150	2*2	900	Supercap	NA	NA	NA	NO

				(1F)				
Sunflower	4 PIN Photodiodes 20mW	NA	100	Supercap (0.2F)	NA	NA	NA	NO
AmbiMax	400	3.75*2.5	1200	Supercap (two 22F) & Battery	Li-poly	200	TelosB	NO
Prometheus	130	3.23*1.45	780	Supercap (two 22F) & Battery	Li-poly	200	TelosB	NO

5. Wireless Energy Transfer

Wireless energy transfer also known as wireless power transfer is the ability to transfer electrical energy from source storage to some destination storage without any plugs or wires [8]. In 1900, Nikola Tesla experimented the wireless transfer of power from device to another without contact with large electric fields. These large electric fields diminished the energy transfer efficiency and coupled with the size of large antennas required to make these transfers feasible [9] Tesla's invention was abandoned. Due to the pervasive use of portable devices, wireless power transfer or wireless charging (these terms being used interchangeably in this paper) has reemerged with much acceptance, already having commercial use in applications, for example, the electric toothbrush and mobile phone wireless charging like in Apple IPhone, Samsung Qi, etc. Wireless power transfer has been achieved in applications such as RFID and medical implants using nearfield coupling. In 2007, Witricity was reintroduced by [10] who reported of powering a 60 W bulb from 2 meters with 40% efficiency using strongly coupled magnetic resonance. Application areas include the electric vehicle charging applications medical sensors, implantable devices and consumer electronics, and power transfer in concrete.

In the transfer of RF energy (between 850 and 950 MHz, central frequency of 915 MHz) broadcasts radio waves in the 915 MHz ISM band and a receiver tuning into the same frequency harvest RF power.

The broad categorization of wireless power transfer technologies is inductive coupling, electromagnetic radiation, and magnetic resonant coupling.

5.1 Inductive coupling: Inductive coupling is the near field wireless transmission of electrical energy from a primary coil to a secondary coil. It is generated when an alternating current in a primary coil from a source generates a varying magnetic field that induces a terminal voltage of a secondary coil at a receiver. In inductive coupling, the size of coil is directly proportional to the amount of energy generated. Its charging efficiency is reduced over short distances. Its simplicity and ease of use have led to several commercial applications including electric toothbrushes, charging pads for mobile phones or laptop and medical implants and RFID tags.

5.2 Electromagnetic radiation: Electromagnetic radiation or EM radiation emits energy from the transmitting antenna of a source to the receiving antenna through EM waves. The electromagnetic spectrum can contain regions of ambient energy levels of low and high regions and the efficiency of conversion depends on the part of the spectrum. Classifications of EM radiations are omnidirectional and unidirectional. Omnidirectional radiation transmits broadcast EM waves in an assigned ISM band and a receiver in the same frequency harvests the radio power. Unidirectional radiation on the other hand transmits from one source to a receiving antenna in an assigned band. Omnidirectional EM waves dissipate over distances and in a paper by [9] the power transfer efficiency was 1.5% with a receiver at 30 cm. EM radiations with omnidirectional antennas can be used in low-power sensor nodes with low sensing activities to prevent hazards to humans. To achieve high power transmission in unidirectional antennas, microwave beams transmitted on microwave frequency of 2.45 and 5.8 GHz is used. Laser-beamed systems can be used for unidirectional power transfer under the visible or near infrared frequency spectrum. Unidirectional radiation is not suitable for wireless sensor networks because they require line of sight and has complicated tracking mechanisms. Omnidirectional radiations are used in applications where either the location of nodes is unknown a priori or nodes are mobile.

5.3 Magnetic resonant coupling: Magnetic resonant coupling works on the principle of magnetic resonant coils where coils on the same resonance frequency are strongly coupled through non-radiative magnetic resonance. Energy is transferred from a source coil to a receiver coil on the same resonance frequency with little losses to external off-resonance objects. The coils could be made small enough to fit into portable devices such as sensor nodes without decreasing efficiency. Experimental results from charging a 60-W light bulb at 2 m in [10] reported 40% power transfer efficiency. Challenges in magnetic resonance coupling include orientation and interference, with the maximum charging distance of 2 m achieved only when the transmitting and receiving coils are aligned coaxially. A 45-degree rotation of the coaxial alignment reduces the coupling factor and when charging multiple devices mutual coupling between the receiving coil and other objects may cause interference.

6. Conclusion

This work presented different types of hierarchical routing protocols for wireless sensor networks. In the beginning, LEACH protocol was defined to increase the network life-time by rotating the role of data collection, aggregation and transmission to offer uniform distribution of load among all nodes. We discussed the broad categorization of energy harvesting technologies and techniques and followed the discussion with the current energy transfer techniques and finally the approaches for conserving energy.

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