Wireless Sensor Network Energy Management: A Survey

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***Abstract*— A wireless sensor network (WSN) is made up of many sensor nodes deployed over a geographical area and powered by batteries with a limited lifetime. Implementing the applications of WSN in real world, minimizing energy consumption is one of the major issues. Hence efficient energy management is a key requirement. In this paper, a study on three different methods on energy management is discussed.**

***Keywords*-WSN, Applications, energy management, GAF algorithm, duty cycling, flow based routing algorithm**.

I. INTRODUCTION

A wireless sensor network (WSN) consists of a large number of tiny sensor nodes randomly scattered over a geographical area also referred as sensing field. Each node is having the capability to compute, communicate and sense. Nodes organize themselves in clusters and networks and cooperate to perform an assigned monitoring (and/or control) task without any human intervention. Sensor nodes are thus able to sense physical environmental information such as temperature, humidity, vibration, acceleration and so on. It will collect the data from individual node or from cluster ,process it and send the outcome to the cluster and one or more collection points (sink node or base stations).

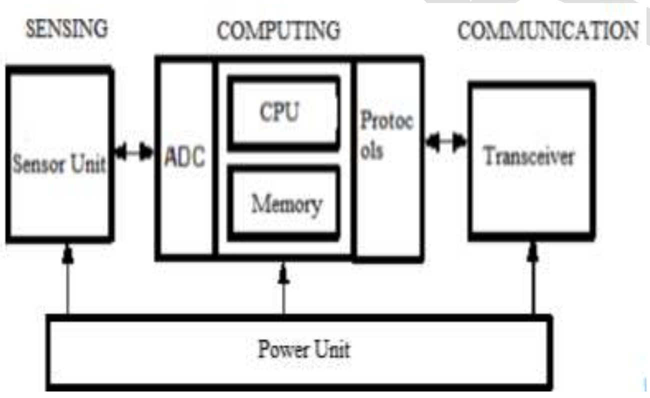

Fig 1: Generalized architecture of WSN

Fig 1 shows the generalized architecture of wireless sensor node. A sensor node consist of a sensing unit, a processing unit, a communication unit, and a power source or energy source. Sensing section consists of a sensor and Analog to Digital Convertor (ADC), where the analog signals produced by the sensors are converted to digital signals by the ADC. It is then given to the processing unit (comprising the processor and storage) [1]. The communication unit acts as the link between the sensor node and the network. The power scavenging source generally derives energy from solar and battery power.

II. SENSOR NETWORKS APPLICATIONS

Sensor networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar, which are able to monitor a wide variety of ambient conditions that include the following:

- vehicular movement,
- lightning condition,
- pressure,
- soil makeup,
- noise levels,
- the presence or absence of certain kinds of objects,
- mechanical stress levels on attached objects, and
- the current characteristics such as speed, direction, and size of an object.

Sensor nodes can be used for continuous sensing, event detection, event ID, location sensing, and local control of actuators. The concept of micro-sensing and wireless connection of these nodes promise many new application areas. Some of the other applications include military, environment, health, home and other commercial areas. It is possible to expand this classification with more categories such as space exploration, chemical processing and disaster relief.

Military applications:

Wireless sensor networks can be an integral part of • military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting systems monitoring friendly forces

- equipment and ammunition
- battlefield surveillance
- targeting
- reconnaissance of opposing forces and terrain.
- biological and chemical (NBC) attack detection and reconnaissance
- battle damage assessment.

Environmental Applications

Some environmental applications of sensor networks include

- tracking the movements of birds
- small animals, and insects
- monitoring environmental conditions that affect crops and
- livestock
- irrigation
- macroinstruments for large-scale Earth monitoring and
- planetary exploration
- chemical/ biological detection
- flood detection

Health applications

Some of the health applications for sensor networks are

- providing interfaces for the disabled
- integrated patient monitoring
- drug administration in hospitals
- telemonitoring of human physiological data
- tracking and monitoring doctors and patients inside a hospital.
- Home applications
- Home automation
- Smart environment

Other commercial applications

Some of the commercial applications are monitoring material fatigue; building virtual keyboards; managing inventory; monitoring product quality; constructing smart office spaces; environmental control in office buildings; robot control and guidance in automatic manufacturing environments; interactive toys; interactive museums[2].

III. PARAMETERS OF SENSOR NETWORK DESIGN

A sensor network design is influenced by many parameters, which include

- fault tolerance
- scalability
- production costs
- operating environment
- sensor network topology,
- •hardware constraints
- •transmission media
- power consumption.

These factors are important because they serve as a guideline to design a protocol or an algorithm for sensor networks.

IV. METHODS FOR ENERGY MANAGEMENT

Energy management is important to the reliability of the network. Usually, the sensors are located in remote areas making it impossible to access them. In agricultural applications, it is unrealistic to think maintenance could be done on sensors. Sensors spread in a building damaged by an earthquake are also not reachable. Smart dust nodes are designed to be disposable, making it more cost effective to deploy additional new nodes rather than replace batteries in existing nodes[3]. Many wireless sensor applications require the sensors to be operational for many years. It is thus essential that the sensors are reliable and work on their own for the duration of the application. If the sensor loses power, it is gone and so is the reliability of the network.

Few of the methods to manage energy in WSN are discussed below.

1. GAF Algorithm.

To manage energy one method is to use GAF algorithm that effectively reduces energy consumption of the nodes keeping a constant level of routing fidelity. The GAF is an energy conserving algorithm where the nodes in a network form a virtual grid where all the nodes in that virtual grid square are equivalent with respect to forwarding packets. In GAF [4], nodes are either in these three states: discovery state, active state or sleeping state. Initially, nodes start out in discovery state. In this state nodes turn on its radio and exchanges discovery messages to find out other nodes within the same grid. The discovery messages consist of a tuple of node_id, node_energy, and the threshold energy specified by the administrator. When the nodes that take part in the data forwarding process are decided, the responsible node in each grid turns their state from discovery state to active state. The active node sets a timeout value to determine how long the node will stay in active state. After this timeout value, the node goes back to discovery state and recharges its battery.

A node when in discovery state or active state can change back to sleeping when it can determine some other equivalent node will handle routing. When transitioning to sleeping state node cancels all pending timers and powers down its radio.

2. Duty cycling and Adaptive sensing.

Monitoring applications based on sensor networks rely on a synchronous philosophy where readings are carried out with a given sampling frequency. In such a case two main approaches can be considered to reduce the energy consumed by a sensor, i.e., duty cycling and adaptive sensing. Duty cycling and adaptive sensing are complementary approaches that can be used in combination as shown in Fig 2.

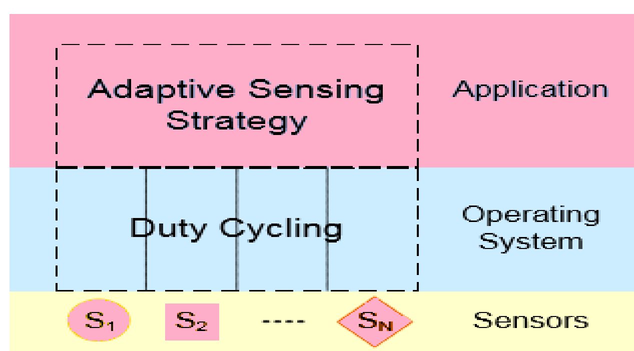

Fig 2: A general structure for sensor energy management.

Duty cycling consists in waking up the system only for the time needed to acquire a new set of samples and powering it off immediately afterwards [5]. This strategy allows for optimal management of energy provided that the dynamics of the phenomenon to be monitored are time-invariant and known well in advance. Since such hypotheses only partly hold in many applications, periodic sensing is typically considered. Here, the (fixed) sampling rate is computed a priori, based on partial available information about the process to be monitored and assuming that the process dynamics are stationary. As a consequence, the sampling rate is larger than necessary (oversampling), e.g., 3 to 5 times, inducing, in turn, energy wasting. A better approach would require an adaptive sensing strategy able to dynamically adapt the sensor activity to the real dynamics of the process.

It is obvious that an efficient sensing strategy, by reducing the number of samples, also reduces the amount of data to be processed and -possibly- transmitted to clusters and/or the base station.

The operating system has to provide a set of primitives for powering on and off the sensors to support duty cycle mechanisms. Afterwards, the application uses such primitives to acquire data according to the (adaptive) sensing strategy it implements.

3. Multiple Mobile Base Station (BS)

Multiple and mobile base stations can be used to prolong the lifetime of the sensor network. The lifetime of the sensor network is divided into equal periods of time known as rounds. Base stations are relocated at the start of a round. An integer linear program can be used to determine new locations for the base stations and a flow-based routing protocol to ensure energy efficient routing during each round.

Consider two different sensor network deployments as shown in Fig 3 showing a sensor node A is one hop away from its nearest base station when two base stations are deployed. For sensor node B the hop-count from its nearest base station is same in both the cases. Thus, by employing two base stations instead of one we have effectively either reduced or retained the hop count of each sensor node in the network. Since the energy consumed in routing a message from any sensor node to its nearest base station is proportional to number of hops the message has to travel, employing multiple base stations effectively reduces the energy consumption per message delivered.

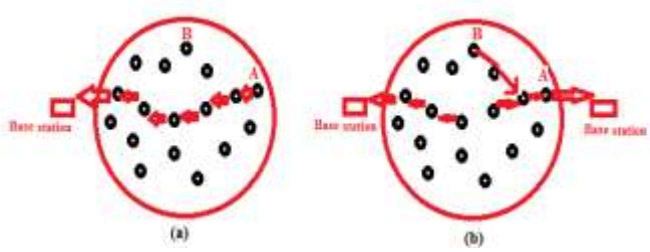

Fig 3: Sensor field with one BS and two BS

Flow based Routing algorithm

Sensor nodes can use the flow information obtained by solving the integer linear program to route messages in an energy efficient manner[6]. Consider sensor node A with its incoming and outgoing number of messages as shown in the Fig 4. Once a sensor node has this information it would perform its routing as described below.

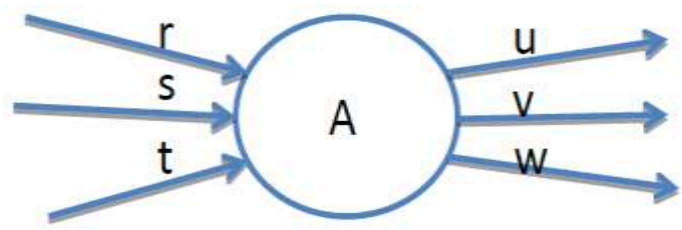

Fig 4: A Scehmatic representing flow based algorithm

1) For every outgoing link a counter is maintained. The value of the counter is set to the floor of the flow going out on that particular link.
2) Whenever a node needs to transmit its packets, it would select one of the outgoing links in a round robin fashion.
3) If the counter value of the selected link is greater than the number of packets that have to be transmitted, then all the packets are transmitted on that link and counter value is decremented by the number of packets transmitted, otherwise the number of packets equal to the counter value of the link are transmitted along the link and its counter values is set to 0. To transmit the remaining messages outgoing links are selected in a round robin fashion.
4) If the counter value of all the outgoing links is zero then a link is selected arbitrarily and all the packets are transmitted on this link.

V. CONCLUSION

In this paper, generalized architecture of wireless sensor network is discussed. The flexibility, fault tolerance, high sensing fidelity, low-cost and rapid deployment characteristics of sensor networks create many new and exciting application areas. Sensor networks needs to satisfy the constraints introduced by factors such as fault tolerance, scalability, cost, hardware, topology change, environment and power consumption. Since these constraints are highly stringent and specific for sensor networks, new wireless ad hoc networking techniques are required. Three different methods for energy management have been discussed. It can be concluded that multiple mobile base stations method is a rigorous approach to optimize energy utilization that leads to a significant increase in network lifetime.

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