ABSTRACT

Energy efficiency is the need of the day in Wireless Sensor Networks (WSN). Only the network that lives long, will prove worthy for the effort and cost spent in establishing it. A network's lifetime is considered as the time till which the first sensor node or a group of sensor nodes run out of energy. Apart from energy efficient strategies, there are few other ways to increase a network's lifetime like using solar paneled sensor nodes, using double storage nodes which could scavenge energy from environment, wireless energy transfer, harvesting energy from natural phenomena etc.

But many of the above technologies are in beta phase or under research. Even with solar powered nodes, uninterrupted power supply is not guaranteed. Hence, energy efficient strategies for various functionalities of a sensor network become inevitable. The aim of this thesis is to propose a few energy efficient strategies to increase the lifetime of a WSN.

On analyzing the power system of a sensor node, it is observed that its radio component is more power hungry than its sensing and processing counterparts. Hence, all the proposed strategies in this thesis are focused on optimization of communication in WSN. Methods have been proposed in the areas of Localization/Positioning of sensor nodes and Sleep Scheduling.

Localization is the process which enables the sensor nodes to know their physical location. Generally, they are categorized based on the method used for positioning. Methods which use absolute range estimations like distance or direction of arrival are called *Range based* and the ones which use message from anchors are called *Range Free*.

Sleep Scheduling is a commonly used mechanism in a WSN to reduce energy consumption by sensor nodes by minimizing the energy spent

on *Idle Listening*. Sleep scheduling methods are broadly classified as *Duty cycling* approaches, *Wake up radio* based approaches and *Asynchronous* approaches.

In Duty Cycling approaches, the sensor nodes are scheduled to be in either Active state or in Sleep state. Wakeup radios use special hardware which use less energy compared to traditional receivers. The receiver circuit comes up only after an alert is received by the wake up radio. In asynchronous approach sensor nodes randomly switch between Active and Sleep states

The proposed strategies in this thesis are based on Duty Cycling. In this research work, two energy efficient localization strategies and two sleep scheduling strategies have been proposed. The nodes at any point in time (apart from initial stages after deployment) invariably vary in their residual energy. The first proposed localization strategy tries to balance this energy variation so that each sensor node could have similar lifetime. This is made possible by shifting the responsibility of localization on high energy nodes. This is briefly highlighted in the following paragraph.

In the first proposed strategy the WSN is clustered. The ClusterHead and a few nodes which have comparatively higher energy form the set called MasterNodes. These MasterNodes could afford to position themselves by spending some energy. Hence, they adapt a high precision localization strategy called Mobile Anchor Positioning with Genetic Simulated Annealing (MAP-GSA) for their positioning. During positioning, with the help of beacons from the mobile anchor they additionally learn the nature of the Radio Frequency (RF) environment in which they are deployed, using fuzzy logic and build the Fuzzy Inference System (FIS).

This FIS can fuzzify an input crisp Received Signal Strength Indicator (RSSI), convert to fuzzy distance estimate and finally give a distance, corresponding to the input RSSI. The low energy nodes called the ListenerNodes broadcast a Help message. The MasterNodes respond back with its location and distance (between ListenerNode and MasterNode). With this, the nodes use Genetic Simulated Annealing (GSA) for positioning themselves. This method reduces the idle listening time and the number of messages needed for localization consequently enhancing the lifetime of the network.

The second method proposed is a path planning strategy when using a mobile anchor for localization. Many mobile anchor based localization strategies are circle-based algorithms. The idea behind this work is that, if the mobile anchor's path is planned and the mobile anchors send beacons from appropriate or strategic positions, the number of beacons needed for such circle-based localization algorithms can be reduced. In this thesis a hexagon based path planning strategy called Hex-path is proposed where three mobile anchors are used. One of the anchor stays in the centre and the other two anchors position themselves at the vertices of a hexagon and broadcast beacons. Then they use the centre as pivot and move around the hexagon sending beacons from the vertices. Since the method uses only 13 beacons for localization of MAP-GSA lifetime of the network is thereby enhanced.

The other two methods proposed in the thesis are Sleep Scheduling approaches. From literature studies, it is understood that many natural phenomena like movement of animals, seismic activities etc., have a pattern of occurrence. For sensing the above category of applications, the proposed strategies in this thesis use a probabilistic model to study the recurrence pattern and predict its future occurrence.