CHAPTER 1

INTRODUCTION

1.1 WIRELESS SENSOR NETWORKS

Wireless sensor network is built of randomly distributed autonomous sensor nodes to monitor the environmental conditions such as temperature, sound, pressure, smoke, chemical explosion, vibration, etc. They cooperatively pass the sensed data through the network to the control station located away from the sensing field. Many modern WSNs are bidirectional that enables the control of sensor activity like stopping the fuel supply in nuclear reactors. Wireless Sensor Network is widely used in many emerging fields like military border area monitoring, tsunami early warning systems, forest fire detection, industrial automation, elder people health care systems, smart home applications, etc. The Figure 1.1 shows a generic wireless sensor network, where sensor nodes sense the event and send the report to the control station.

Figure 1.1 Generic wireless sensor network
The WSN vary from few to several thousands of sensor nodes, where each sensor node is connected to several neighbor sensor nodes and connected to the control station via multi hop communication. Akyildiz et al (2002) described the concept of sensor networks with the convergence of the technologies like micro electro mechanical systems, wireless communications, and digital electronics.

Akyildiz & Kasimoglu (2004) explored the sensor to actor and actor to actor coordination, described the research challenges for coordination, communication and the components of the sensor nodes in wireless sensor networks. The topology of the WSN can be a random deployment in many applications like forest fire detection, or a simple star network or an advanced multi-hop wireless mesh network. The data propagation technique between the hops of the sensor nodes may be through routing or flooding. Baronti et al (2007) have reviewed the ZigBee/IEEE802.15.4 standards with their energy efficiency, communication, data management and security solutions adopted on wireless sensor networks. Yick et al (2008) explained the applications of WSN like tracking the objects, animals, humans, and vehicles.

Each sensor node has typically several parts like radio transceiver to communicate with neighbor nodes or control station, microcontroller for computation, analog to digital convertor for interfacing with the sensors, actuators, location finding unit to identify the location of the sensor node, mobilize unit to move the node to different possible locations and battery. Akyildiz & Kasimoglu (2004) showed the typical components of a sensor node. The size of a sensor node might vary from that of a shoebox down to the size of a grain of dust. The Figure 1.2 shows a generic sensor node architecture with its components.
The cost of sensor nodes varies depending on the features and functionalities supported by the individual sensor node. Size and cost constraints of sensor nodes reflect in the corresponding constraints on resources like energy, memory, computational speed and communication bandwidth, etc.

1.2 LOCALIZATION IN WSN

In many wireless sensor network applications like military border area sensing, sensor nodes are distributed in a random manner. During the deployment period, the sensor nodes are not aware of their physical location as explained by Amundson & Koutsoukos (2009). Localization is the process of estimating the physical location of sensor nodes in WSN. In WSN, the sensed event becomes insignificant without the knowledge of the location where the event is sensed.

If the location of each sensor node is known, the routing can be done in such a way that it reduces network load and increases the life time of each sensor node in a wireless sensor network. Each sensor node in the
sensing field has its own physical /geographical location. This physical location is referred as the location or co-ordinates of the sensor node in the context of wireless sensor networks. Each location is represented as latitude, longitude, altitude.

A sensor node can get its own physical location directly from the Global Positioning System (GPS) satellites using GPS receivers. But it is cost effective to fix the GPS devices to the large density of sensor nodes and also this approach consumes energy from sensor node battery to operate the GPS devices thereby reduces the lifetime of the sensor nodes. This research work focuses on anchor node based range free localization algorithm, which requires the presence of special nodes called anchor nodes.

Generally a node with self positioning hardware is referred as an anchor node. The main task of an anchor node is to assist other location unaware sensor nodes to compute their own locations. Also in some indoor applications some sensor nodes cannot receive the GPS signals as the Line of Sight (LOS) is not possible in some locations. An alternative solution is to determine the physical coordinates of the individual sensor nodes by utilizing the localization algorithms, where only a few anchor nodes are aware of their own location information by means of their own GPS receivers or by receiving the location messages from the other location aware units. All the other sensor nodes use the radio communication techniques to receive the location information from the location aware anchor nodes and use the received information to determine their own locations.

In many localization schemes like range free methods, the communication between the anchor nodes and the sensor nodes is very much important as the sensor nodes can determine their own location from the beacon messages broadcasted by the anchor nodes. This communication is referred as the ‘anchor-sensor communication’. The main objective of the
sensor network is to collect the valuable information from the sensing area and send it to the control station for the further actions using multi-hop communication or inter-sensor communication.

1.3 ENERGY CONSUMPTION IN WSN

WSN needs long lifetime to fulfill their indented purposes using the limited energy storage capability sensor nodes. The sensor node circuits and protocols have to be energy efficient to reduce the power consumption thereby the lifetime of the WSN can be increased. Advanced computing and networking technologies have enabled the WSNs with intelligence, smart, friendly, context-aware and responsive to human needs. The sensor nodes use their battery energy for all tasks like sensing, computing and communicating with neighbor nodes or control station. High energy consuming tasks reduce the lifetime of sensor node battery. Energy conservation at sensor nodes can be achieved in many approaches like low energy routing, energy efficient security, etc. The energy consuming activities can be generalized as active mode, sleep mode and idle mode energy consumption. Sensor node’s battery energy is consumed even in the idle mode and sleep mode because of the device characteristics. The most commonly used energy storage component is a battery, where in many applications the battery can be neither recharged nor replaced. Hence the battery backup of the sensor nodes are highly energy constrained.

To identify power consumption at each sensor node, it is necessary to identify the factors influencing power consumption. Few factors that affect transceiver power consumption includes the type of modulation scheme used, data rate, reception power, transmit power determined by transmission distance, operational duty cycle, header size, packet payload size, symbol rate
for a modulation scheme, amplifier power, startup power, and startup time. The Figure 1.3 shows the various energy consuming modes of a sensor node.

Figure 1.3 Energy consuming modes of a sensor node

1.3.1 Sensing Cost

A sensor network may be deployed to monitor the enemies, detecting forest fire, observing the movement of earth plates, watching tsunami waves, etc. Various types of sensors may be attached with the sensor nodes depending on the application. Considerable amount of battery energy may be consumed to trigger the cameras, vibrators, pressure sensors to sense the environment. Energy consumed in sensing depends upon the type of the sensing unit used in a sensor node. Factors affecting the power consumed by the sensing unit include signal sampling, conversion of physical signals to
electrical, signal conditioning, and Analog-to-Digital Converter (ADC). Hence efficient sensing techniques must care about the energy consumption issues to keep the sensor nodes alive as maximum as possible.

1.3.2 Computation Cost

The cost of a particular computation can be assessed by knowing the per-cycle mean energy consumption and the total number of cycles of the computation. Generally the total computation power in each sensor mote includes the analog to digital conversions, routing operations like shortest path calculations, routing table updates, routing table exchange, some general computations like data aggregation, packet processing, local decision making tasks, signal strength measurements and executing complex localization algorithms.

1.3.3 Communication Cost

The communication cost is measured by the effective data rate transmitted, listened and received by the sensor nodes. Most of the battery energy is consumed in the transmission and reception of localization related data with anchor nodes or with neighbor sensor nodes, receiving the control messages from control stations, sharing the sensed information with neighbor sensor nodes, exchanging routing information with neighbor sensor nodes, etc.

1.4 MOTIVATION OF THE RESEARCH

High energy consumption in a wireless sensor network depletes the battery energy of sensor node quickly, which isolates the sensor nodes from the network. Isolation of sensor nodes affects the efficient data collection, multi-hop communication thereby the bidirectional communication between
sensor nodes and control stations is affected severely. This failure causes severe consequences to the intention of the wireless sensor network application. Hence energy conservation is the mandatory quality for any wireless sensor network application deployed in a geographically isolated location. Maximum localization coverage helps the WSN application to observe the condition of wider area. Control stations need uninterrupted power supply for their continuous working. Conventional standalone power systems like solar power plants, wind power plants, tidal power plants, etc are highly dependent on weather conditions. Continuous energy production is the most difficult and important feature to be guaranteed when designing a standalone power system. For state-of-art, Ribeiro et al (2009) proposed a standalone power system for telecommunications by combining the most mature generators and technologies related to renewable energies and environment friendliness. In this system, when sunlight and wind are available, photovoltaic and wind generators produce energy to feed the telecommunication equipment. When the generated power exceeds the telecommunications equipment needs, the excess power supplies the electrolyzer and produces hydrogen until its storage is full. While wind and photovoltaic power is not enough to supply telecommunications equipment needs, the fuel cell produces the required power using already stored hydrogen. But many of the isolated geographical locations cannot fulfill the requirements of the power plants like hydropower generation, thermal power generation, etc.

Energy of the sensor nodes can be conserved in many ways through energy efficient localization, data aggregation, routing as explored by Heinzelman et al (2000). The necessity of the energy conservation motivated us to design an energy efficient localization technique to reduce both localization-communication cost and localization-computation cost at each sensor node. The need for monitoring larger area motivated us to increase the
localization coverage. The limitations of the existing standalone power systems motivated us to design a novel standalone power system for isolated geographical locations.

1.5 RESEARCH OBJECTIVES

The proposed energy efficient localization approach increases the lifetime of the sensor nodes deployed in the hostile environment. This prolongs the lifetime of the wireless sensor network. To achieve this, following are the objectives of this research.

- To design and analyze the performance of the IUAN assisted LDM construction approach with minimum number of packet transmissions/receptions during localization process in hostile environment.

- To design and analyze the performance of IAS based localization algorithm with minimum number of arc computations in control station.

- To design and analyze the performance of the SP-GA-SP system which utilizes the gravitational force and generates energy to prolong the lifetime of sensor nodes deployed in hostile environment.

1.6 CONTRIBUTIONS

An energy efficient localization approach has been proposed. This approach increases the lifetime of the wireless sensor network deployed in the hostile environment and the contributions are summarized as follows.
In the first proposed work, the IUANs construct the LDMs for the sensor nodes deployed in the hostile environment. These LDMs are further processed in the CS to compute the location of individual sensor nodes. This approach reduces the localization-communication cost at individual sensor nodes which conserves the energy and increases the lifetime of the entire wireless sensor network. This approach also improves the localization coverage.

In the second work, the control station retrieves the LDMs from the IUANs and executes the IAS based localization algorithm to compute the location of the sensor nodes. The proposed IAS algorithm removes the maximum localization computations at each sensor node and minimizes the computational cost at the control station. This approach has proven a better result in terms of localization-computation cost.

In the third work, the SP-GA-SP system converts steam energy extracted from coal into electricity. Here steam energy is used to extract and retract the cylinder arms to trigger the gravitational force. Sensors and microcontroller unit maintain the timing of extraction and retraction of arms for the continuous power generation. This system generates the power for CS and the IUANs located in the isolated environment. Further the IUANs use the LASER transmission method to recharge the sensor nodes. The overall block diagram of the three contributions of the proposed research work is given in the Figure 1.4.
1.7 ORGANIZATION OF THE THESIS

This thesis is organized into six chapters. The chapter 1 provides the background, motivation and objectives of the proposed research work. Literature survey related to the research of the proposed works is highlighted in chapter 2. The IUAN assisted LDM construction approach and its advantages are explained in chapter 3. The IAS based localization approach and its advantages are explained in the chapter 4. The SP-GA-SP system and its efficiency are explained in the chapter 5. The conclusion and further enhancements are provided in chapter 6.

The next chapter reviews the literature survey related to the research of the proposed works.