CHAPTER - 1
INTRODUCTION

1.1 WIRELESS SENSOR NETWORK

Wireless sensor network is an emerging technology of the twenty first century, which promises a wide range of potential applications in both civilian and military areas [1]. A wireless sensor network (WSN) consists of a hundred or thousands of multi function tiny sensor nodes, which are deployed densely inside or very close to a phenomenon (Figure 1.1). Sensor nodes are equipped with a sensor, embedded microprocessor and radio transceiver. They have not only sensing but also data processing and communication capabilities. In most of wireless sensor network applications nodes are deployed in an ad hoc manner without any pre planning. As a result sensor nodes can be deployed randomly at disaster sites. After deployment sensor nodes can build a wireless communication network itself without taking any assistance from the external world. Sensor network is generally operated for a long period of time without any attention from the external world and nodes get their power from a battery. Sensor nodes battery cannot be recharged or changed because nodes are densely deployed in a harsh
environment [2], [3], [4], [5]. WSNs have received tremendous attention from the researchers all over the world in recent years. A voluminous amount of research has been done for exploring the various design and application issues of WSNs. It is envisioned that WSNs will change the way we live, work, and interact with the physical world in near future [4]. The WINS [6] and SmartDust [7] projects for instance, aim to integrate sensing, computing, and wireless communication capabilities to produce low cost tiny nodes in large numbers.

![Wireless Sensor Network](image)

**Figure 1.1 Wireless Sensor Network**

1.2 SENSOR NODE ARCHITECTURE

The basic block diagram of a wireless sensor node is given in Figure 1.2. Sensor node basically consists of four components: sensing unit, processing unit, communication unit and power unit. Besides these component sensor node may have additional components like position finding system and mobilizer [2], [3],[4], [9], [10]. Mica2 [8] mote picture is shown in Figure 1.3.
**Sensing Unit:** Sensing unit is the main component of wireless sensor node and it is responsible for sensing the information from the sensing field. For this purpose, it contains one or more sensors to sense a wide variety of physical parameters including light, sound, temperature, pressure, humidity and air or water quality. Sensing unit also has an analog to digital converter which converts the observed physical parameters analog signal into digital signal and then fed into the processing unit for further processing.

![Figure 1.2 Architecture of a Wireless Sensor Node [4]](image-url)
**Processing Unit:** Processing unit is the main controller of the sensor node which manages the various procedures that enable the sensor to perform various sensing operations, run associated algorithms and enables the node to collaborate with other nodes through wireless communication. It uses the on-board chip memory or an additional storage unit may be integrated with the embedded board. Various types of embedded processors that can be used in a sensor node include Microcontroller, Digital Signal Processor (DSP), Field Programmable Gate Array (FPGA) & Application Specific Integrated Circuit (ASIC). Among all these alternatives, the microcontroller has been the most used embedded processor for sensor nodes because of its flexibility to connect to other devices and its cheap price. Sensor node may vary significantly in their processing capability according to the application. For example, the Mica2 mote model MPR400CB is based on the Atmel low-power ATmega128L microcontroller. It has only 128 Kbytes of program flash memory, 512 Kbytes of measurement (serial) flash memory and 4 Kbytes of programmable read-only memory. In contrast, the Stargate is a 400-MHz Intel PXA255 X Scale processor with 64 Mbytes of synchronous dynamic random access memory and 32 Mbytes of flash memory [13].

**Communication Unit:** Communication unit is responsible for all the communication in the sensor network. It sends the data from one node to another and to the base station. The various choices of wireless transmission media include radio Frequency (RF), laser and infrared. Among all these radio frequency based communication is most suitable for WSN applications. It consists of a short range radio, which usually has a single channel at a low data rate and operates in
unlicensed bands of 868-870 MHz (Europe), 902-928 MHz (USA) or near 2.4 GHz (global ISM band) [5]. Power consumption of a radio is affected by several factors like modulation scheme, data rate; transmit power and the operating duty cycle. When the transmitted power level is -10dBm or below, then mostly transmit mode, power is dissipated in the circuitry and at high transmit levels (over 0 dBm).

![Mica 2 Motes](image)

**Figure 1.3 Mica 2 Motes [8]**

The transmit power levels for sensor node applications are roughly in the range of -10 to +3 dBm [11]. Transceivers can operate in four modes: Transmit, Receive, Idle and Sleep mode. One of the important features of most radios is that idle mode significantly consumes high power and it is almost equal to the power consumed in the receiving mode. Thus, when a radio is not transmitting or receiving then to save the energy, it should be completely shut down rather than
setting it in the idle mode. Another vital factor is that, when radio’s operating mode changes, the transient activity in the radio electronics causes a significant amount of power dissipation. Sleeping mode is an important energy saving feature in WSNs.

**Power Unit:** Each component of the sensor node gets its power from the power unit. Battery technologies that are commonly used in wireless sensor networks are: Alkaline, Lithium, and Nickel Metal Hydride. Alkaline battery provides a cheap, high capacity, energy source. The major drawbacks of alkaline battery are their wide voltage range and large physical size. Additionally lifetime of beyond 5 years cannot be achieved with alkaline battery because of battery self-discharge nature.

A compact power source is provided by lithium battery. This type of battery has constant voltage supply, very little decay and few millimeters across. Another important thing of lithium battery is that it can operate at the temperature of - 40⁰ C. Drawback of lithium battery is that it has a very low discharge current. When compared to an alkaline discharge rate of 25mA, a Tadiran battery has discharge current of just 3mA. Nickel Metal Hydride battery is another majorly used battery type. Easy recharge ability is their main benefit. Significant energy density decrease is the disadvantage of these rechargeable batteries. Nickel Metal Hydride battery of AA size has approximately half the energy density as compared to an alkaline battery and the cost is approximately five times more than an alkaline battery. One thing that should be taken into consideration before using Nickel Metal Hydride battery, they provide only 1.2 V and a number of system
components require 2.7 volts or more. Thus many system components cannot be operated directly with these rechargeable batteries [12].

1.3 OBJECTIVE OF THE RESEARCH

One of the most severe constraints of sensor nodes is limited energy supply because they are battery operated devices. Designing energy efficient routing protocol to prolong sensor network life has become one of the hot research topics in recent years. In this research proposal, following aspects have been identified to design cluster based energy efficient protocol for wireless sensor network:

1. Identification of requirements and issues related to routing in a sensor network
2. Development of a framework for sensor network routing simulation
3. Developing cluster based energy efficient routing algorithms for sensor network

1.4. RESEARCH METHODOLOGY

To design new cluster-based energy efficient routing algorithms which prolong the sensor network life, the following methodology has been proposed and implemented.

1.4.1 PROBLEM IDENTIFICATION

A wireless sensor network is usually comprised of a large number of sensor nodes that are physically small, communicate wirelessly and deployed without any prior knowledge of the network topology. Sensor nodes are battery operated devices and due to the limitation of their physical size tend to have limited storage space, energy supply and communication bandwidth. WSNs provide efficient and
costs-effective solutions for several monitoring and tracking applications. However, it is necessary to implement mechanisms or procedures to deal with the sensor resource constraints such as energy supply. WSN lifetime, therefore, shows a strong dependence on battery lifetime.

The hierarchical organization of the sensors into groups and assigning specific tasks to group before transferring the information to higher levels is one the mechanisms used to deal with the sensor limitations and is commonly referred to as clustering. A hierarchical architecture typically comprises two layers of routing where one layer is used to select cluster-heads and the other is for routing. Cluster-based algorithms are particularly useful for applications that require scalability to hundreds or thousands of nodes. The hierarchical structure of these algorithms is a promising method for efficiently organizing the sensor network and with the knowledge of their particular role in hierarchy nodes can control their activities for reducing the energy consumption. Thus clustering helps in solving sensors constraints by reducing the cost of transmitting data to base stations, reducing the power consumption in the devices, facilitating the gathering of sense data, maximizing the routing process execution, and allowing scalability.

1.4.2 DEVELOPMENT OF FRAMEWORK

Power conservation and power management are integral parts of any communication protocol in WSNs. The main task of a sensor node is to detect events, perform local data processing and then transmits the data. One of the important goals to develop efficient routing protocols is minimizing the energy
consumption in a sensor network. The proposed framework of the cluster based wireless sensor networks has the following main aspects:

(i) Developing novel methods for cluster head election in a sensor network on the basis of distance and residual energy of nodes.

(ii) Integrating multihop short distance communication into the system for minimizing the range of data transmissions.

(iii) Maximizing the number of alive nodes over time to prolong the network lifetime.

(iv) Minimizing the total energy spent in the sensor network.

(v) Balancing of energy dissipation among the sensors to avoid early depletion of certain sensors of network.

1.4.3 DEVELOPING CLUSTER-BASED ENERGY EFFICIENT ROUTING ALGORITHMS

The proposed framework has been used to develop three cluster-based energy efficient routing algorithms. The first algorithm is for the homogeneous sensor network. It has proposed two different probabilistic cluster head election schemes for base station nearer and far nodes in a sensor network. Routing algorithms which are energy-efficient in a homogeneous environment will behave sub optimally in a heterogeneous environment because the nodes have different energy consumptions and reserves. Therefore the second algorithm is for two level heterogeneous networks where some of the sensor nodes have high energy than the other. For taking the advantage of heterogeneity, it proposes three-tier architecture and a flexible framework based on residual energy. The idea behind
this contribution is to elect only high residual energy normal nodes as cluster head in a round. For further reducing the transmission load of normal cluster heads, advanced nodes which are not cluster head in a round, act as the relay node for normal cluster heads. The third algorithm is for three level heterogeneous sensor networks. It takes the advantages of multiple levels of fidelity available in a sensor node without making any compromise with the performance of the network. Normal nodes become cluster heads only when they have sufficient residual energy to perform this duty. If a normal node becomes the cluster head, then advance and super nodes further save the energy of it by introducing three-tier architecture for it. They take over the data transmission load of it when they are not itself elected as cluster heads in a round.