Architectural Foundations and Operational Paradigms of Wireless Sensor Networks

Surabhi Mounika[1], G Mahendra[2]
[1]PG Student, QUBA College of engineering and technology
[2]Assistant Professor, QUBA College of engineering and technology

Abstract: Wireless Sensor Networks (WSNs) have emerged as a significant research domain due to their vast applications in environmental monitoring, military surveillance, healthcare, industrial automation, and smart infrastructure. A WSN typically consists of a large number of sensor nodes deployed in a distributed manner to sense physical or environmental parameters such as temperature, pressure, light, and humidity. These nodes cooperatively transmit the collected data to a base station through wireless communication. However, the constrained energy resources of sensor nodes, their limited computational capacity, and the dynamic nature of deployment environments pose critical challenges in the design and implementation of WSNs. The fundamental objective is to achieve reliable communication while minimizing energy consumption to extend the network lifetime. Various strategies, including clustering mechanisms, energy-efficient routing protocols, and power-aware communication models, have been proposed to address these issues. This section provides an in-depth discussion on the architecture, functionality, challenges, and energy optimization techniques in WSNs, highlighting their importance in modern research and real-world applications.

***Index Terms*— Wireless Sensor Networks, WSN, sensor nodes, energy efficiency, clustering, routing protocols, base station, environmental monitoring, power consumption, network lifetime, wireless communication, data aggregation, proactive sensing, reactive sensing, optimization models**

I. INTRODUCTION

1.1 Wireless Sensor Networks

At the end of productive the outline of a wireless sensor network has become the main area of research. A sensor is a gadget (device) that reacts and recognizes any kind of contribution, both physical and ecological conditions, for example, pressure, heat, light, and so on. The performance of the sensor is largely an electrical signal that is transmitted to a controller in addition to prepare. A system of wireless detectors can be characterized as a system of gadgets that you can transmit the data accumulated from the observation of a sphere through remote connections. The information is sent through several cubes, and with a gateway.

WSN is a remote system that comprises of base stations and quantities of hubs (remote sensors). These systems are utilized to screen physical or natural conditions like sound, Pressure, temperature and co-operatively go information through the system to a fundamental area Remote sensor systems are accustomed to detect the earth in responsive and proactive way. Considering the receptive way it detects nature at whatever point the occasion is happened or in an irregular way. While proactive way detects the earth at every single interim of time. The sensor hub detects the earth in two ways principally, one is responsive and the other is proactive [1]. Receptive betokens detecting nature in a standard substructure. Proactive signifies detecting the earth in a discretionary way. A sensor organize has diverse difficulties to look in the present patterns and the hubs are getting sent in various zones to detect distinctive parameters in the earth. The hubs conveyed in undergrounds, and furthermore for climate checking [2] detecting applications military applications.

The deployed WSN have numerous issues in the wake of sending. WSN comprises of various segments a portion of the segments may drain sooner and some may exhaust late depends up on their life time and nature of the system parts. Our principle proverb is to control the power devoured by the system parts amid their transmission of the information and one all the more thing one should remember that the lifetime of the batteries utilized as a part of the system. The batteries which are in the hubs are non replaceable so we have to expand the lifetime of the batteries keeping

in mind the end goal to get additional time working of the hubs without dead.

The central unit of WSN is a Node, in like manner called as bit by UC Berkley. Each sensor hub is required to be fit for recognizing, preparing and imparting took care of data to the neighbouring hubs to outline a framework. Sensor hub is from this time forward made out of sensors to identify the physical ponder, easy to modernized converter, microcontroller for controlling and data dealing with, memory for calculations and data storing, radio unit for short range remote correspondence and battery unit to control each one of the units. For a few applications, if conceivable, sun based fuelled chargeable battery units are used to restrain the mistake of sensors and support cost.

The targets of WSN are:

1. The force and immovable nature of the entire correspondence system ought to be upgraded without extending the imperativeness usage.
2. Original thoughts in tradition setup will be analyzed to also extend the wake-up structure to moreover confer parameter changes (a few byte) to the convenient center points. For achieving this goal, the learning on the case of the arriving development into a framework is required.
3. The course of action of the power saving parts and their privilege pre setup.
4. Convention decisions between the convenient hubs and to improve the resolute nature of the entire correspondence structure while keeping up the formally tight imperativeness spending design.
5. To make novel and correct precise models to separate the execution of the proposed traditions and transmission designs. The precision of the made models should in like manner be checked.

One approach can be habituated to control the sum control expended in WSN is to make the group arrangement of the sensor hubs and each bunch has a head. Initially the information is detected by the sensors and after that the sensors transmit the information to its bit then bit is the capable thing to transmit the information parcel to the goal. Interiorly the information is detected by the sensors and these sensors transmit the information to their neighbouring sensors until the point when it achieves the goal. This entire procedure expends more power. Later all the sensor hubs formed distinctive gatherings called bunches. Each group has a few sensors and a solitary head called bunch head. Presently the information is detected by the sensors in the group and the detected information is transmitted to their heads. These heads transmits the information to the base station and from base station to the goal point.

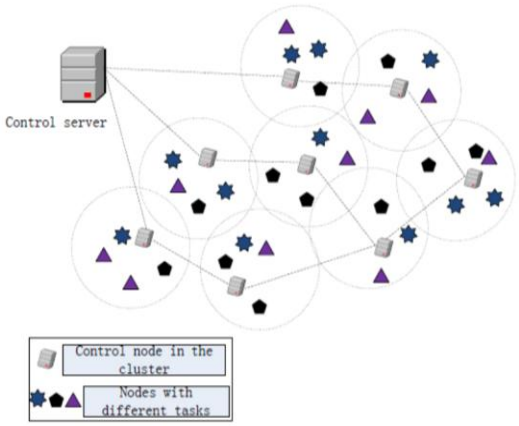


Fig. 1.1 : Wireless sensor networks

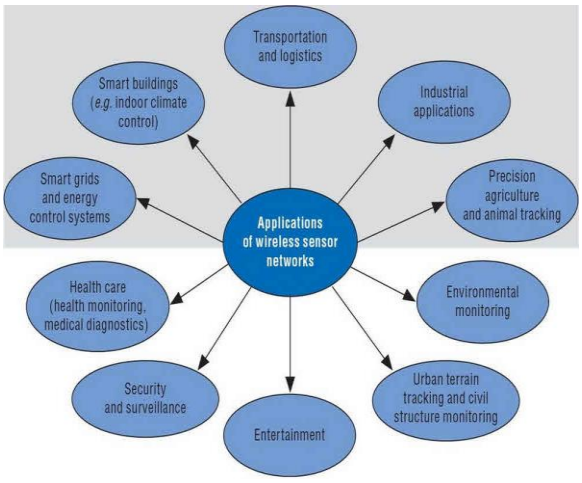
1.2 Wireless Sensor Network Architecture

The most common WSN architecture follows the OSI architecture model. The architecture of the WSN includes five layers and three cross layers. Mainly in the n / w sensor we need five layers, namely application, transport, n / w, data link and physical layer. The three crossed planes are, specifically, energy management, mobility management and task management. These layers of the WSN are used to achieve the n / w and make the sensors work together to increase the overall efficiency of the network.

1.3 Applications of Wireless Sensor Networks

Wireless sensor networks can comprise many different types of sensors, such as low sampling frequency, seismic, magnetic, thermal, visual, infrared, radar and acoustic, which are intelligent to monitor a wide range of environmental situations. The sensor nodes are used for constant detection, event identification, event detection and local control of actuators. The applications of the wireless sensor network include mainly commercial areas of health, military, environmental, home and other.

- Military Applications
- Health Applications
- Environmental Applications
- Home Applications
- Commercial Applications



II SYSTEM ANALYSIS

2.1 LITERATURE SURVEY

M.Sasikala [6] proposed some algorithms for grouping wireless sensor networks. In this document, the author incarnated that wireless sensor networks are the emerging technology nowadays and that aggregation of data through wireless sensor networks has quality and nodes in the network, and adding data requires energy. Power is the biggest limitation in wireless sensor networks. By grouping the sensor nodes, the power required for the nodes to transmit the data can be reduced. By multiple jump we can reduce the energy consumption. The overview of the routing protocols is given in this document.

Mukul pratap singh and Kunal Gupta wrote the optimization techniques for the reduction of energy consumption in [7]. The batteries are not rechargeable and the power is the biggest limitation in wireless sensor networks and for that, the energy consumption optimization techniques involved in this document are like the Colony Optimization of Ants (ACO) and some other techniques like LEACH, HEED also explained in this paper. ACO is the best technique among those that gives us the shortest path from the origin to the destination.

III CLUSTERING

3.1 Introduction

WSN is a collection of very small nodes that has gained great attention from researchers because of its diverse applications in different sectors. Small devices, called sensor nodes, are deployed in a difficult area and left unattended to continuously informs the parameters of the environment, depending on the application. The small nodes are restricted by energy and therefore, it is necessary to consume less energy using the grouping means so that the lifetime of the entire network can be prolonged.

WSN are useful for monitoring various applications. like it surveillance, security, disaster management, military, health care and environmental studies. The WSN is a collaboration of the large number of nodes with limitations energy, processing and communication capabilities that are implemented to perform an ad hoc operation without have any infrastructure and any central control point. The Sensor node collects data locally from destination domains and then forwards it to the specific sites known as Base Station. The WSN base station always needs to generate an aggregate value for the end users and the aggregation of the data to be forwarded can also help reduce transmission overload and energy consumption. To support the data aggregation in the network the nodes can be accommodated in small groups called Clusters. The grouping can be defined as the division of the nodes into the groups in the base of some mechanism. It has been shown that the grouping improve the useful life of the network, a main metric to evaluate the performance of a sensor network. The grouping is made to achieve energy efficiency and the scalability of net. Cluster formation also implies the assigning the role to the node based on its perimeters. The cluster coordinator that is responsible for the processing, aggregation and transmission of the data to the base station is called Cluster Head (CH) or the leader, while the other nodes that are responsible for detecting and forwarding the collected data to the CHs are called the member nodes.

3.2 Perimeters of the clustering

- Cluster count/Number of clusters
- Cluster size uniformity
- Inter-clustering routing
- Intra-clustering routing

3.2.1 Group count

Based on the group count the network can be divided into two categories: fixed and variable. The fixed cluster count is the one in which number of clusters in the network are fixed, while in variable network sizes the number of clusters is not fixed.

3.2.2 Uniformity of cluster size

Uniformity of cluster size with the size of the cluster It is of two types: pair and Odd. Even in conglomerate size, the number of nodes is the same in all the groups of the network and in odd uniformity the size of the group is different.

IV. POWER OPTIMIZATION

Power Optimization is the process of reducing the power required for a sensor node to sense store and transmit the data from starting point i.e; called source point to the destination point. Previously there are some techniques for reducing the power required the entire process of the sensor networks which includes the calculation of the residual energy. Residual energy is the amount of energy remained after completion of the transmission of data to the destination from source point.

First the sensors present in the environment senses the data and transmit the data to the gateway and then the point starts that the end user requests some data from the gateway then the sensor nodes retrieving the data from the gateway and starts sending the data. First data is transmitted from the first node to the next neighbouring node. After transmission of the data every node starts dissipating some amount of energy called power. Then we need to calculate the remaining power from the total power by that we came to know how much power is utilized and how much power is remained. If the remaining power is more and utilized power is less then we can get clarity over which sensor node utilizes more power and which sensor node utilizes less power by that we can guess which node is good and which is bad.

By calculating the residual energy. The node which is having more residual energy that node can be considered as low power consumed node and the other node is considered as high power consumed nodes.

Clustering is the one of the techniques for power optimization in wireless sensor networks. Clustering means making the individual sensor nodes in to a group and called as a cluster. Each cluster consists of a group of sensor nodes and each cluster has a cluster head which we called as a central node. All the nodes in the cluster will consume power.

There are some bio inspired algorithms of optimization techniques that depend on the substructure of the population. The population inspired by the biological and predicate behaviour optimizes the techniques to reduce the consumption of pustules in the WSN [4]. The different algorithms that are inspired by the lifestyle of the animals are chosen to optimize the energy efficiency in the network nodes.

V EXISTED SYSTEMS

Leach Algorithm

The WSN help in the monitoring of several classes of environment by detecting the Physical Phenomenon. Our main objective is to increase the lifetime of the network so that the battery does not need to be dead soon. The nodes of sensor of clustering are an effective technique to achieve this goal. In this work, we introduce an algorithm of clustering of energy efficient for sensor networks based on the protocol of leaching. Leach, is a routing protocol that conserves the energy for the wireless network of sensors. In leaching, the sensor nodes form clusters and cluster heads act as routers to the sink. This will save energy, as transmissions are only performed using cluster heads. It is estimated that the optimal number of CHS is 5% of the total number of nodes

During the setup phase of each node generates a random number between 0 and 1. If the random number is less than the threshold value then that node becomes CH. The threshold value is calculated on the basis of the following equation as detailed below:

$$T(n) = \begin{cases} \dfrac{p}{1 - p\left(r \bmod \frac{1}{p}\right)}, & if\ n \in G \\ 0 & otherwise \end{cases}$$

Here p is the desired percentage of cluster heads and r is the current round, G is the group of nodes that has not CHs in the last rounds. The sensor the node that is selected as a CH in the previous round is not selected in the coming rounds until all the other nodes of the network becomes cluster heads.

Ants Colony Optimization

Ant colony optimization is a meta-heuristic algorithm for the approximate solution of combinatorial optimization problems that has been inspired by the foraging behaviour of real ant colonies (Colorni et al., 1991). In ant colony optimization, the computational resources are allocated to a set of relatively simple agents that exploit a form of indirect communication

mediated by the environment to construct solutions to the finding the shortest path from ant nest to a considered problem.

VI. PROPOSED APPROACH

6.1 Proposed System Explanation

In this project proposing an optimization technique which is based on bird's life style. This technique is predicated on the swarm intelligence Flock of birds or schooling of fish.[12]. Each bird in the swarm is considered as a particle or solution quandary and each particle has a fitness value. Velocity which shows the over-sight of the path to reach the destination. Position of the particle. Each particle has its personal best value called pbest and all the particles in the swarm has an ecumenical best fitness value called gbest. [12]

PSO was introduced and developed by Eberhart and Kennedy in 1995. PSO is multi objective and dynamic optimization. It is one of the algorithms taken from inspiration of animals in which flock of animals. In flock of animals find aliment desultorily which is most proximate to victuals position. Animal's up- date to each other about position of food. It will update again and again until food source is found. Particle swarm optimization con- sists of a group of particles, where particle represent a potential Solution.

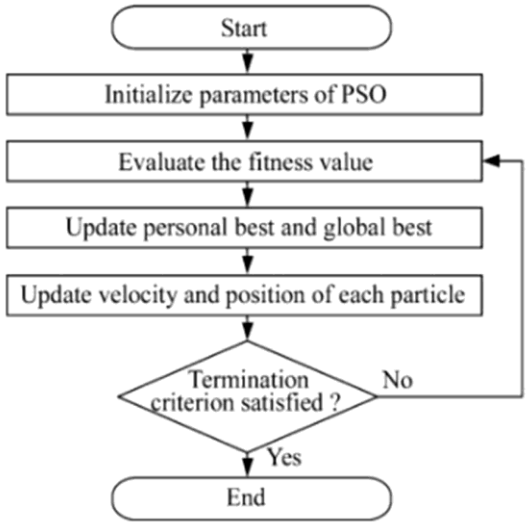
By the way of life of feathered creatures this calculation is produced and is utilized for the enhancement reason in the sensor hubs. The accompanying areas give a concise clarification how the flying creature's way of life is taken as a motivation and how it is connected and contrasted with our systems. What are all the conceivable terms in that calculation are clarified unmistakably in following areas.

Fig 6.1 Bird Flock

6.2 Features of PSO

Some features of PSO that make it so efficient to solve optimization problems are the following:

- In comparison with other heuristics, it has fewer parameters to be tuned by the user.
- Its underlying concepts are very simple. In addition, its coding is very easy.
- It provides a fast convergence.
- It requires less computational load compared to most other heuristics.



VII OPTIMIZATION FUNCTIONS

7.1 Optimization

Optimization is the process of finding an alternative with the performance more profitable or highest attainable under the limitations given. In wireless sensor networks optimization is the main task. Optimizing the cost, optimizing the power, optimizing the area likewise optimization plays an important role in the wireless sensor networks.

Optimization functions are the mathematical equations which are used to calculate the maximum and minimum values of particular terms under the given limitations. The optimization function is called as a cost function where we are going to calculate the values of the particular parameters using the certain mathematical equations.

For power optimization in wireless sensor networks we are going to calculate the fitness function or cost function of the sensor nodes using these optimization functions. In this project we are using 5 optimization functions named Sphere, Ackley, Grewank,

Rosenbrock, Schewfel. These are the five optimization functions used to calculate the fitness values of the sensor nodes.

VIII EXPERIMENTAL RESULTS

Here the results are embodied using Matlab as a platform. The X and Y axis are number of iterations and the fitness Value respectively. Depends up on the fitness value we can say that we reach the optimization solution.

Here proposed method contains different optimization functions and the graphs are given below.

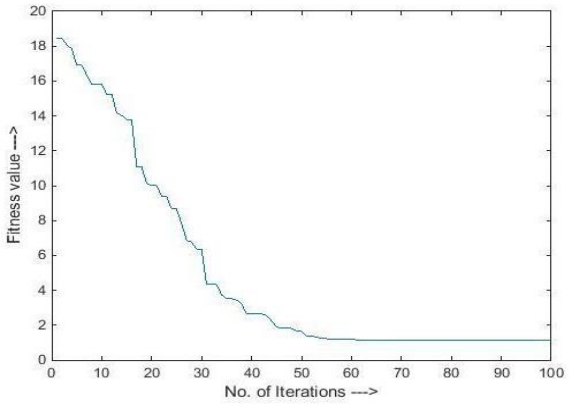


Fig. 6.1: Ackley Function.

8. CONCLUSION

By the proposed approach called particle swarm optimization we can reduce the power consumption of the networks and the lifetime of the batteries can be increased. Since the batteries are non-rechargeable and by using the proposed approach we can choose the best head for the group of nodes called mote and by that we can automatically reduce the energy consumption in WSN. Now days many researches are going on in the power consumption of networks by many researchers.

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