ORTHOGONAL TEACHING LEARNING BASED OPTIMIZATION-"OTLBO"

NODE DEPLOYMENT PROCEDURE OF WSN

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CANDIDATE'S DECLARATION

I, Vikas Kumar Sinha, Roll No. 2K17/CSE/501 student of M.Tech Computer Science & Engineering, hereby declare that the project Dissertation titled "Orthogonal Teaching Learning Based Optimization-"OTLBO" node deployment procedure of WSN" which is submitted by me to the Department of Computer Science & Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any degree, Diploma, Associateship, Fellowship or other similar title or recognition.

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Place: Delhi

Date: 03/11/20

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CHAPTER 1

INTRODUCTION

Continuous monitoring of the physical environment cause advancement in sensing, communication and computing techniques which led the development of Wireless Sensor Networks (WSNs). WSN is defined as a collection of autonomous nodes distributed spatially that can communicate wirelessly. Each node consists of four main components: sensor, processor, radio, and battery. Such nodes are commonly referred to as "Sensor Nodes." A sensor is a device that interprets some of its environmental characteristics. It detects events or changes in quantity and, usually as an electrical or optical signal, provides the corresponding output. A processor is used for computing, base station receives data through radio waves for wireless communication, and sensors uses battery as the main power source. Deployment of the sensor nodes is done based on the environmental conditions of the area, solar panels harvests energy from the nature and can be used as the secondary power supply for the node.

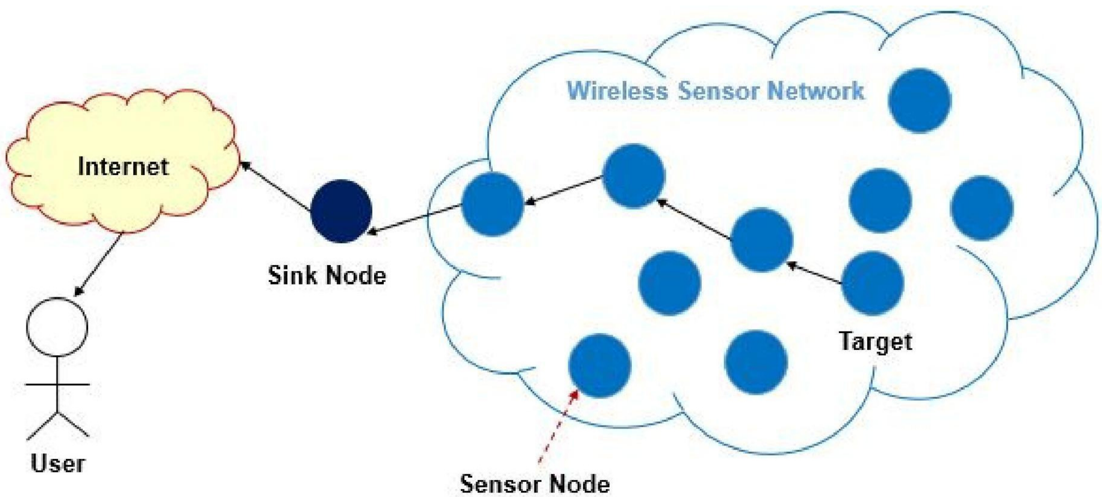


Figure 1.1: Wireless Sensor Network

The basic structure of a WSN is shown in Figure 1.1. The dense deployment of sensor nodes is done in the desired environment. Depending upon the routing protocol of the WSN the sensor senses the environment continuously or after every fixed quantum. Then the sensor node transmits the sensed information either periodically or on the occurrence of some event to the Sink Node. The sensor nodes transmit the information to the Sink Node can be one in a variety of ways as proposed by many routing protocols to increase the efficiency of the network. Traditional sensor nodes transmit the information directly to the Sink Node is very energy consuming and inefficient.

Thus many protocols are proposed which decreases the transmission from the sensor nodes as one depicted in Figure 1.1. It uses multi-hop transmissions so that sink node receives the information which distributes the energy expended amongst many nodes and hence prolongs the lifetime of the whole of the network. Use of such mechanisms and generating the routing protocol which consumes less energy is a need for the proficient use of WSNs.

Two types of WSNs are available: structured and unstructured. One that contains a dense collection of sensor nodes is an unstructured WSN. It is possible to deploy sensor nodes ad hoc in the field. The network is left unattended to carry out monitoring and reporting functions once deployed. Network maintenance, such as managing connectivity and detecting failures, is difficult in an unstructured WSN since there are so many nodes.All or some of the sensor nodes are deployed in a preplanned manner in a structured WSN. The benefit of a structured network is that, with lower network maintenance and management costs, fewer nodes can be deployed. As nodes are placed at specific locations to provide coverage, fewer nodes can now be deployed while ad hoc deployment may have uncovered regions. In order to collaboratively carry out a specific task, sensor nodes have self-organizing capabilities to form an appropriate structure. Wireless Sensor Networks are found suitable for applications such as surveillance, precision agriculture, smart homes, automation, vehicular traffic management, habitat monitoring, and disaster detection.

1.1. Overview of key issues in WSN

The current state-of-the-art sensor technology proposes a solution for the design and development of many types of applications for wireless sensors. Generic (multi-purpose) nodes and gate-way (bridge) nodes are available sensors on the market. The task of a generic sensor node (multi-purpose) is to gather information from the monitored environment. It can be equipped with a range of devices that can measure different physical characteristics, such as light, temperature, humidity, barometric pressure, acceleration, acoustics, magnetic field, etc. Data is collected at the Gateway (bridge) nodes and relay it to the base station from generic sensors. Greater capacity for processing, battery power, and range of (radio) transmission is given to the Gateway nodes. In order to form a WSN, typically deployment includes both generic and gateway nodes.

Figure 1.2 shows the broadly classification of the task into 3 categories, in order to use wireless sensors to enable wireless sensor applications. The first group is the scheme. An individual system is each node of the sensor. Development of new platforms, operating systems, and storage systems is required to support various application software on a sensor system. Communication protocols are the second group, allowing sensors and application to communicate as well as it allows communication between the nodes of the sensor, too. Network efficiency, applications and performance is improved in the last group of services. Network management and application requirements demand the self-organizing capabilities of the node. That is, the sensor nodes are able to place itself and form a network and can then effectively control and manage themselves. As the power, processing capacity, and storage of sensor nodes are limited, new services for management and communication protocols are needed to meet these requirements. Five standard packet switching protocol layers are included in communication protocol: the application layer, the transport layer, the network layer, the data-link layer, and the physical layer. In this survey, we examine how network dynamics and energy efficiency are addressed by protocols at different levels. As sensor network services, functions such as localization, coverage, storage, synchronization, safety, and data aggregation and compression are explored. Implementation of protocols at various layers of the protocol stack can have a significant impact on energy consumption, end-to - end delay and efficiency of the system. Optimizing communication and minimizing energy use are important. In a WSN, traditional networking protocols do not function well as they are not intended to meet these requirements. Hence, for all layers in the protocol stack new energy-efficient. Cross-layer optimization is employed by protocols by supporting interactions among different layers of protocol . In particular, protocol state data on a specific layer is shared across all layers to meet the WSN's specific requirements. Limited battery power is used by the sensor to operate, the use of energy in a WSN is a very crucial issue, and there has been a major research focus on minimizing and harvesting energy. When a sensor node depletes energy, it dies and disconnects from the network, which can have a significant impact on the application 's performance. Based on the count of active nodes and the connectivity is used to major the lifetime of the network and thus to maximize lifetime energy consumption must be done effectively. See **[1]** for more details.

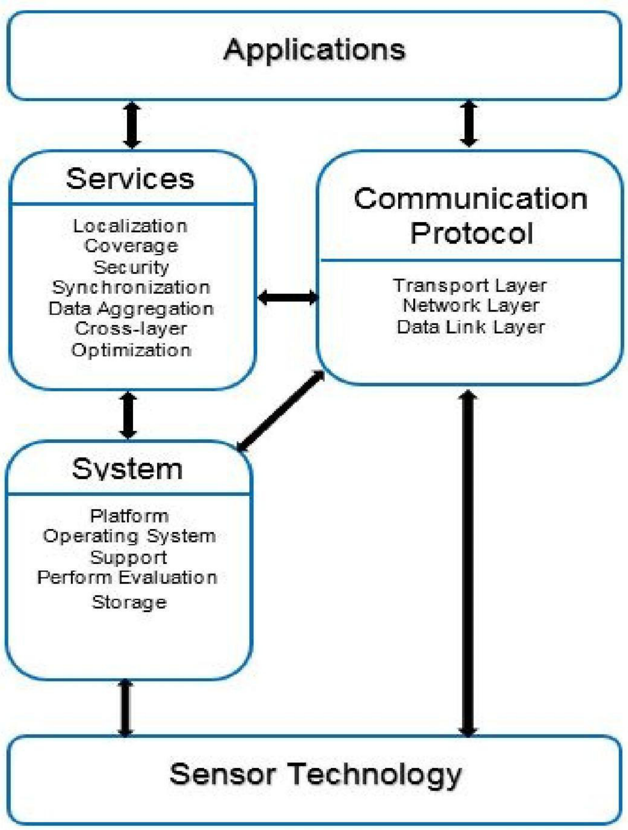


Figure 1.2 various issues in a WSN

WSN energy conservation maximizes the life of the network and is addressed through efficient, security and efficient storage management, reliable wireless communication, to achieve adequate coverage place sensors intelligently, data aggregation and data compression. The above approaches are aimed at meeting both the energy constraints and the application's quality of service (QoS). In order to ensure reliable packet delivery, services such as congestion control, active buffer monitoring, acknowledgement, and packet loss recovery are necessary for reliable communication. The strength of communication depends on the placement of sensor nodes. Long-range transmission and higher energy use may result from sparse sensor placement, while placement of sensors is done in a dense manner in order to reduce consumption of energy and perform short-range transmission. Coverage is correlated to the placement of sensors. The degree of network coverage determines the placement and the count the sensors in the network. To increase the sensed data accuracy network my requires the higher degree of coverage based on the application. We are reviewing new protocols and algorithms developed in these areas in this survey. The various applications are shown in figure 1.3.

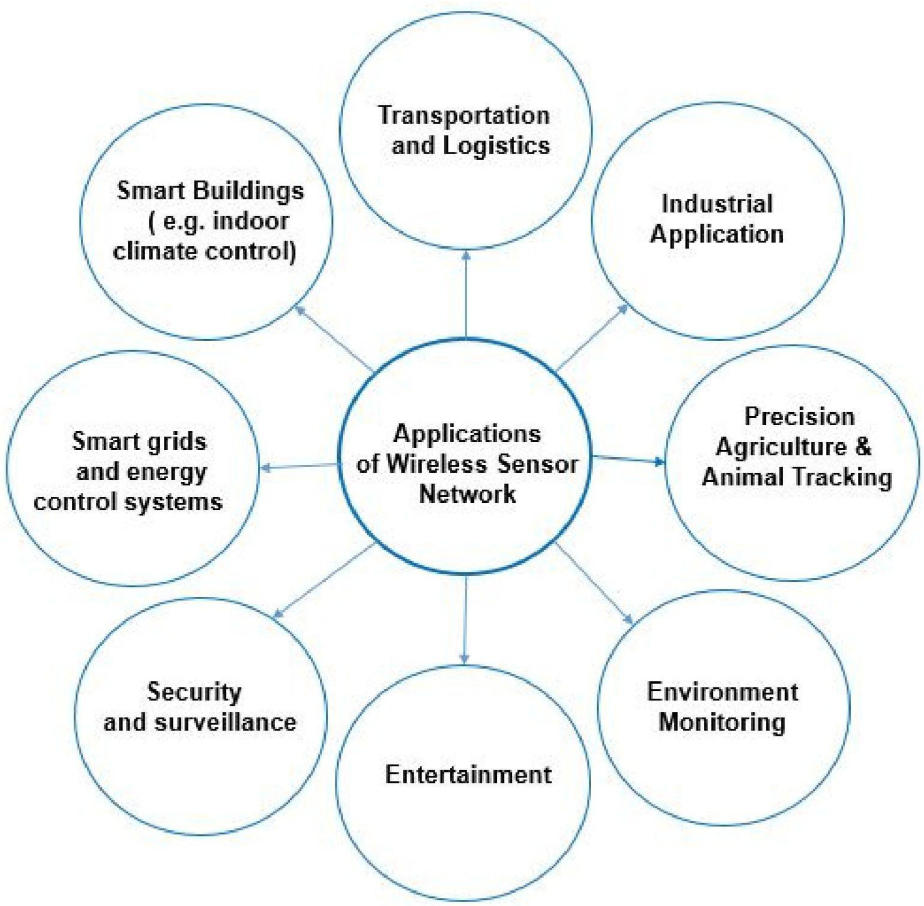


Figure 1.3: Applications of WSNs

1.1. Sensor Node Architecture

A Advances in sensor technology based on the Micro-Electro Mechanical

System (MEMS) have led to the development of miniaturized and low cost sensor nodes that are capable of wireless communication, sensing, and computing. The sensing circuitry is able to measure the ambient conditions associated with the sensor's environment, which is then converted into an electrical signal.

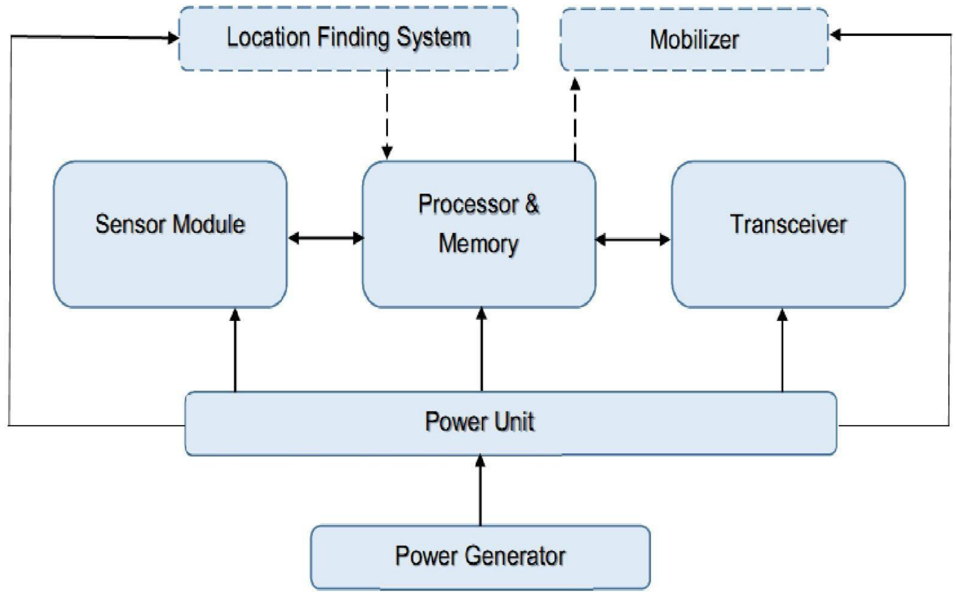


Figure 1.4: sensor node Components

The basic structure of a sensor node, which consists of several components, is represented in Figure 1.3. In general, sensors consist of four fundamental components: a sensing unit, a processing unit, a transceiver unit and a power unit. The mobilizer, location finding system and power generator are some of the additional components that can be found in the sensor depending on the applications. The sensing unit forms the sensors and the ADCs (Analog to Digital Convertors). Based on the desired phenomenon, sensors generate analogue signals and then these sensed analogue signals are converted by ADC into digital signals. The core of the wireless sensor node is the processing unit which includes a constrained memory microprocessor. The converted digital signals are delivered to the processing unit as an input that is linked to a storage with limited space and handles the collaboration between the sensor nodes and other nodes in order to perform the desired sensing tasks.The transceiver is used to connect the network node and is generally able to communicate bidirectionally. The most important unit of a sensor node is the power unit, as all other units are derived to perform their respective tasks. For more details on the sensor nodes, refer to **[2]**.

Although in WSNs nodes have limited power and are not rechargeable there are some application dependent sources which can assist the power unit like solar cells. Specific nodes may incorporate a system for location finding that allows the node, relative to its neighbors or globally, to discover its position. Location finding system is another optional but essential unit in sensor nodes as location of the respective node is generally required from time to time to accomplish the routing efficiently. Thus because of limited transmission and power capabilities major research is done to reduce the number of transmissions without sacrificing the essential information and efficient use of power unit to prolong the lifetime of the nodes and hence the network. To attain high quality and fault tolerance in WSNs, the deployment of sensors needs to be dense and processing need to be distributed via multi-hop communication between sensor nodes is required.

1.2. Sensor Network Protocol Stack

For several reasons, the algorithms developed for ad-hoc wireless networks can not be used for sensor networks. One is that, unlike ad hoc nodes, the number of sensor nodes is typically much higher than in a typical ad hoc network, and sensor nodes are prone to permanent failure. Moreover, sensor nodes, with their limited power and memory, typically use broadcast instead of point-to-point communication. global ID is not present with Sensor nodes, unlike computer networks, so it is difficult to handle typical packet overhead.

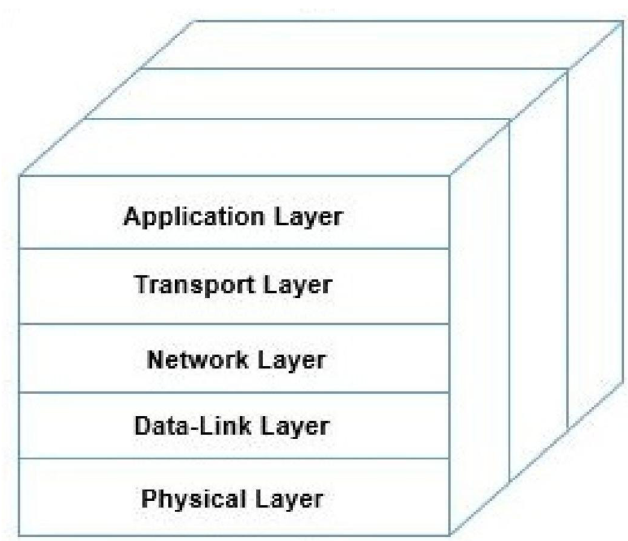


Figure 1.5: Sensor Network Protocol Stack

It is different from the standard TCP/IP and along with the layers used in traditional protocols it has additional planes to handle the issues in the sensor nodes. A protocol architecture for sensor networks appears in Figure 1.4. The protocol stack finds the least-cost-path by combining power efficiency with routing. This protocol architecture integrates networking protocols and power via the wireless medium and promotes collaborative sensor node efforts. The protocol stack consists of a power-management plane, mobility-management plane, and task-management plane backed by the physical layer, data-link layer, network layer, transport layer , and application layer. The power manag
transmit the information and when not to. Mobility m 23 agreement plane (MMP) is responsible to know the route back to the BS in case of movement of the sensor nodes from their initial positions and inform neighbors about the newly moved sensor node. With the updated knowledge of neighbors now they can contribute and use the power of the nodes efficiently. Task management plane (TMP) performs the balancing of

sensing tasks amongst the sensor nodes. It is not necessary that all the sensor nodes in the vicinity should sense and transmit the information. Thus TMP takes such decisions as per the application used in WSNs. So the additional planes are very essential for the objective of WSNs as without them a node will have no capability and will act as an individual transmitting the unwanted information and wasting the constrained power of the sensor node. Robust modulation, receiving signals and transmission is the responsibility of physical layer. As nodes are having limited battery power, the data-link layer MAC (Media access control) must minimize the collision of packets with neighboring nodes. The transport layer provide packets to the network layer which routed by it. Software's are used by application layer for data preparation when an event occurs. the sensor's power level is managed and monitored by the power-management plane to keep track on the power level of sensors. Generally routing techniques requires accurate knowledge of the location of sensor nodes for sensing and routing task. Hence, location-finding system is commonly used by sensor nodes. Sometimes it is needed to move nodes to carry out the specified task. self- organizing capabilities must be there for Sensor network routing. energy-aware MAC, routing, and clustering protocols is used to achieve this purpose in wireless sensor networks. transmission power adjustment and switching the sleep and awake mode is used by most of the energy- aware MAC protocols.

1.3. WSN Characteristics

In a WSN, sensor nodes are randomly scattered or with a static strategy in the network field varying from hundreds to thousands in number. There are many operational characteristics of WSNs, few can be listed as:

- Fault tolerant

  If there is any failure occurs due to lack of energy, H/W issues, destruction or S/W issues, then system should have the capability to handle it and show its robustness against node failure. To indicate the improper functionality of node WSN also incorporate the mechanism of beep signal.

- Scalable

  This is the important characteristic as it provide the capability to enhance the area of coverage by connecting larger number of sensor nodes
- Long life

The node's life-time altogether characterizes the network's lifetime and it ought to be sufficiently high. The sensor nodes should be power productive against the restricted power resource that it has since it is hard to supplant or revive a large number of nodes. The node's communication, computing, sensing, and impelling operations ought to be energy effective as well.

- **Programmable:**

  To improve adaptability, it is important to reprogram the sensor.
- **Secure:** the following properties should hold for every node
  - **Access Control:** Prevents unauthorized attempts to access the node.

- **Message Integrity:** Identifies and forestalls all unauthorized changes to the message.
- **Confidentiality:** to make sure only the authentic node read the message it is encrypted with secret key.
- **Replay Protection:** Assures that reusing of packets will not occur to gain authentic information and get network access. Time stamp is used to prevent the man in middle attack.
- **Affordable:** There are various apparatus, tags and large range of sensors in the wireless network which need to be of low cost to make system affordable.
- For realistic deployment maintenance and installation of elements should be low.

- **Self-Configuration**

  The topology of WSNs is not static and is supposedly changed with no traceable patterns. So the sensor nodes of the network have to be adaptable to such changes while keeping the power efficiency intact. Self-configuration also has to handle the situations like node failures and node additions to the network or any other obstacles.

- Single-Hop Communication

  Traditional WSN protocol used single hop mechanism to send the information to the BS. In this mode of communication all the sensor senses the information and then transmits all the information it has sensed to the BS directly without the involvement of other sensor nodes on its own. This mode of communication is very inefficient and power consuming with lots of redundant information to the BS. Thus modern protocols rely on the multi hop mode of communication for better efficiency.

- Multi-Hop Communication

  In case of larger networks where the distance of the BS from the node is greater than the transmission range of the sensor node. The single hop communication fails. Multi hop communication uses packet forwarding to enhance the network efficiency. The nodes send the information to the sink with the help of other intermediate sensor nodes which receives the information from the node and transfers the information to other node along the path of the BS or to BS itself. Multi hop communication saves transmission energy and is proved to be useful for energy efficiency and network lifetime.

- Automatic Load Balancing

  Nodes in the network must decide who will be the parent node to transmit the information based on the hop count to the respective node, signal strength, link quality and present load quantity of the parent node. Automatic load balancing is dynamic in nature as the number of nodes in the network can run out of power anytime in between the network lifetime.

Efficient Energy Usage

Power is very critical issue in increasing the performance of the network. So energy in a WSN should be expended in optimal manner like sensor nodes can switch off their sensors for a particular period of time and can switch on their transmitters only when any event occurs or after every frame time.

The architecture of single hop and multi-hop wireless sensor network is shown in Figure 1.5. when all nodes are directly connected to sink then it is classified as single hop communication while in multi-hop communication some nodes are not directly connected to the sink node ratherthey are connected to some intermediate nodes.

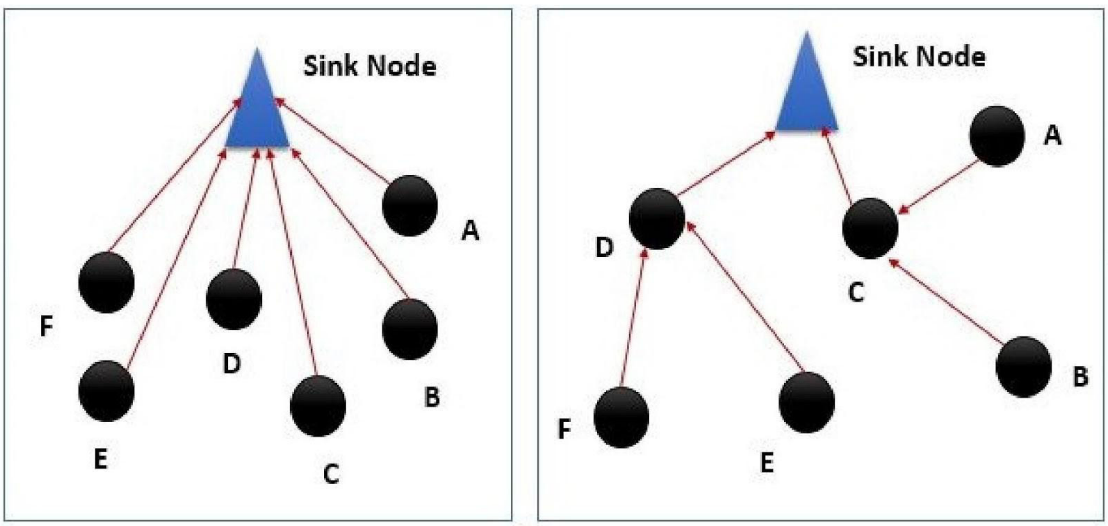


Figure 1.6: Single and multi-hop networks

1.3. Motivation

Wireless sensor network (WSN) is an uncommon kind of ad-hoc network, where nodes structure the network progressively without the assistance of any infrastructure. Typically the nodes are sent haphazardly and should detect a phenomenon, process the gathered sensing information in a collaborative way, and route the outcomes to an end client. For this, both network connectivity and coverage have to be maintained by the active nodes. The network can't ensure the nature of surveillance without sufficient coverage. Plus, data-routing can't be

accomplished without appropriate network connectivity. In wireless sensor networks, sensors are frequently expected to work in far off or hostile conditions, for example, a battlefield or desert to finish the mission. Nodes can be categorized into static and mobile nodes, in WSNs.

Recent research in WSNs has focused primarily on networks where the nodes are static (fixed sensor networks). After the deployment of static sensors nodes positions can’t be altered without anyone else. Then again, mobile sensors can change their position by themselves, contingent upon the tasks prerequisites, and can dynamically change network topology to increase sensor networks' performance. Ongoing research advancements in wireless technology with requests for better user mobility have given a critical driving force to mobile network architecture. Not at all like the current plans wherein sensors are fixed, in the event that we deploy mobile sensors in the network, for example, a battlefield or environmental monitoring area and let some of the nodes move, it can enhance coverage and connectivity. Also, it has a reasonable-cost and is flexible than the current static sensor networks and redeployment. Because of sensor nodes' mobility, mobile sensors' position can be altered based on the prerequisite of the task.

Dynamic change of the sensor node's position would alter the topology and thus enhance sensor networks' efficiency. At the point when sensors are deployed in a neighbouring disaster, where interaction with humans is impossible, we need mobile sensors to achieve coverage and connectivity compensation, area assignment, and node substitution. After a deployment situation, a few nodes over specific areas might be decimated because of interruption, blast, or natural variables like warmth, vibration, and failure of electronic segments or programming errors in the network. Whereas in an alternative situation, the nodes' power sources may prompt the destruction of the nodes, accordingly influencing the coverage and connectivity of the main system. Subsequently, it is fundamental to reconfigure the network by mobile sensors to keep up the connectivity and coverage, and consequently staying away from the network segments.

1.4. Research Objective

Keeping in mind the motivation defined in the last section the intent of this research is explained as follows:

To develop a hybrid scheme to deploy sensor nodes in a specified target field while considering the moving nodes.

To compare the developed approach with standard available approaches in the literature.

To understand the various issues in WSN and formulating the exact problem under consideration

To modify the proposed hybrid approach to handle the connectivity problem in the WSN effectively.

To perform simulation to assess the performance of the developed hybrid approach

1.5. Thesis Organization

The thesis starts with a comprehensive introduction in chapter 1. Chapter 2 is dedicated for literature review, explained in detail in bottom up fashion keeping in mind the problem under consideration. The review is based on current research for the problem under consideration. Chapter 3 is dedicated for the related work in the selected area, this part is application oriented and describes the current available algorithms for the problem. Chapter 4 is dedicated for explaining and formulating the problem and then followed by the proposed work, the problem is explained in different parts for the sake of easiness. Chapter 5 is dedicated for the simulation and analysis of the results obtained. Chapter 6 concludes the thesis work with future work.

CHAPTER 2

LITERATURE REVIEW

A wireless sensor network (WSN) has many important applications in different areas such as security and surveillance, entertainment, remote environmental monitoring etc. The advances in the sensor technologies in recent years have made the availability of smaller, intelligent and cheaper sensors possible. To form a network, sensor node uses the wireless interface which helps node to communicate each other. The design of a WSN is application oriented and may consider the factors such as the environment, system constraints, the application's design objectives cost and hardware.

2.1. Types of WSN

WSN can be classified in five types on the basis of the environment in which they have to operate and face different challenges and constraints.

- **Terrestrial WSNs**

  It typically consists of larger number of low-cost sensor nodes deployed in a given target area, this task is done either in pre-defined or an ad hoc in a fashion. In pre-defined deployment fashion, there are different placement models such as grid placement, optimal placement **[3]**, 2-d and 3-d placement **[4, 5]** models. In ad-hoc deployment fashion, the sensor nodes can be dropped from height and randomly deployed into the target area. The main feature required in a terrestrial WSN is reliable communication while working in dense environment. Sink node must receive the data from terrestrial sensor node effectively. The battery power of the sensors is very limited and recharging the battery is not feasible, however solar cell can be used as a secondary power source. Regardless, it is significant for sensor hubs to ration energy. In a terrestrial WSN the conservation of energy is done with some factors, some of them are eliminating data-redundancy, short-transmission- range, minimizing-delays, low-duty-cycle operations and multi-hop optimal routing.

- **Underground WSNs**

  It comprises various underground sensor hubs or in a cavern or mine which are used to analyze the underground conditions. To hand-off data from the sensors to the base station extra sink node are located over the ground. An underground WSN is more costly than a terrestrial WSN as far as hardware, sending, and support [6, 7]. Underground sensors are costly on the grounds as they needed to be fitting hardware parts which guarantee dependable correspondence through the water, soil, rocks and other mineral substance. In the underground, there is a huge amount of loss of signal and a high rate of attenuation. In this approach, it is required to make a proper approach to deployment while considering cost and energy. sensor nodes are consisting of limited battery power and it is difficult to replace the node in the underground environment. As in the past, a key target is to save energy so as to expand the lifetime of the organization which can be accomplished by actualizing efficient correspondence convention. Underwater WSNs [8, 9] comprise of various sensors and vehicles conveyed submerged. As inverse to terrestrial WSNs, Underwater sensors are more costly, and fewer sensor hubs are conveyed. Self-governing Underwater vehicles are utilized for investigation or social affair information from sensor hubs. Contrasted with a thick sending of sensor hubs in an earthly WSN, a scanty arrangement of sensor hubs is put submerged. Typically acoustic waves are used for the wireless communication in underwater networks. In underwater acoustic communication bandwidth, long propagation delay, and signal fading are considered as major challenges. Self-configure needed to be done by underwater sensor nodes to adapt harsh ocean environment. Sensor nodes in Underwater environment consist of limited powered nodes which can't be recharged or replaced. Efficient Underground networking and communication process is an major issue of energy conservation for underwater WSNs.,

- **Multi-media WSNs**

Multi-media WSNs is proposed to use monitoring and tracking of events in the form of multi-media such as video, audio, and imaging **[10]**. Multi-media WSNs having large number of lower rate sensor nodes which consist cameras and microphones. Wireless connection use to by sensor node to get interconnected for data retrieval, process, correlation, and compression. It guarantees coverage by implementing pre-defined deployment technique into the environment. Challenges in multi-media WSN include high bandwidth demand, high energy consumption, quality of service (QoS) provisioning, data processing and compressing techniques, and cross-layer design. High bandwidth is used for video stream in multimedia communication which results in high data rate leads to high energy consumption.

The development of the approach need which consume less energy and support high bandwidth. Due to delays and channel capacity it is difficult to achieve QoS. For delivering the reliable data it is important to achieve certain level of QoS. To improve the network quality filtering, compression and processing of data is done for removing and merging of redundant data. Similarly, delivery and data processing task can be improved by using cross-layer interaction.

- **Mobile WSNs**

Mobile WSNs sensor nodes have the capability to move and interact implicitly in the coverage area. Mobile nodes can interact with static nodes as well. The major difference between mobile and static node is they have the ability to adjust its position. In mobile WSN network nodes are spread in the area to collect information. Within same range mobile nodes can share information. Another major difference is data distribution. Fixed routing is used in static WSN, whereas mobile WSN uses dynamic routing. Challenges in mobile WSN include deployment, localization, self-organization, navigation and control, coverage, energy, maintenance, and data process. There are various applications of mobile WSN such as environment monitoring, res-cue, target tracking, search and real-time monitoring. Manual deployment is not feasible for disaster monitoring. Nodes in mobile WSNs are capable to provide higher degree of coverage. Based on the target location mobile sensor nodes collaborate for military surveillance and tracking. A compare to static node network Mobile sensor nodes achieves a higher degree of coverage and connectivity. To achieve better target exposure in the presence of obstacles mobile node plan and relocate itself for better coverage.

2.2. WSN Application Areas

Applications of WSN can be classified as tracking and monitoring (as shown in Figure. 2). Tracking applications incorporate following creatures, people, vehicles and objects. Monitoring applications incorporate health monitoring, process automation, environmental monitoring (both indoor and outdoor), location monitoring. There are various different applications some of them which are used in real environment are explained below.

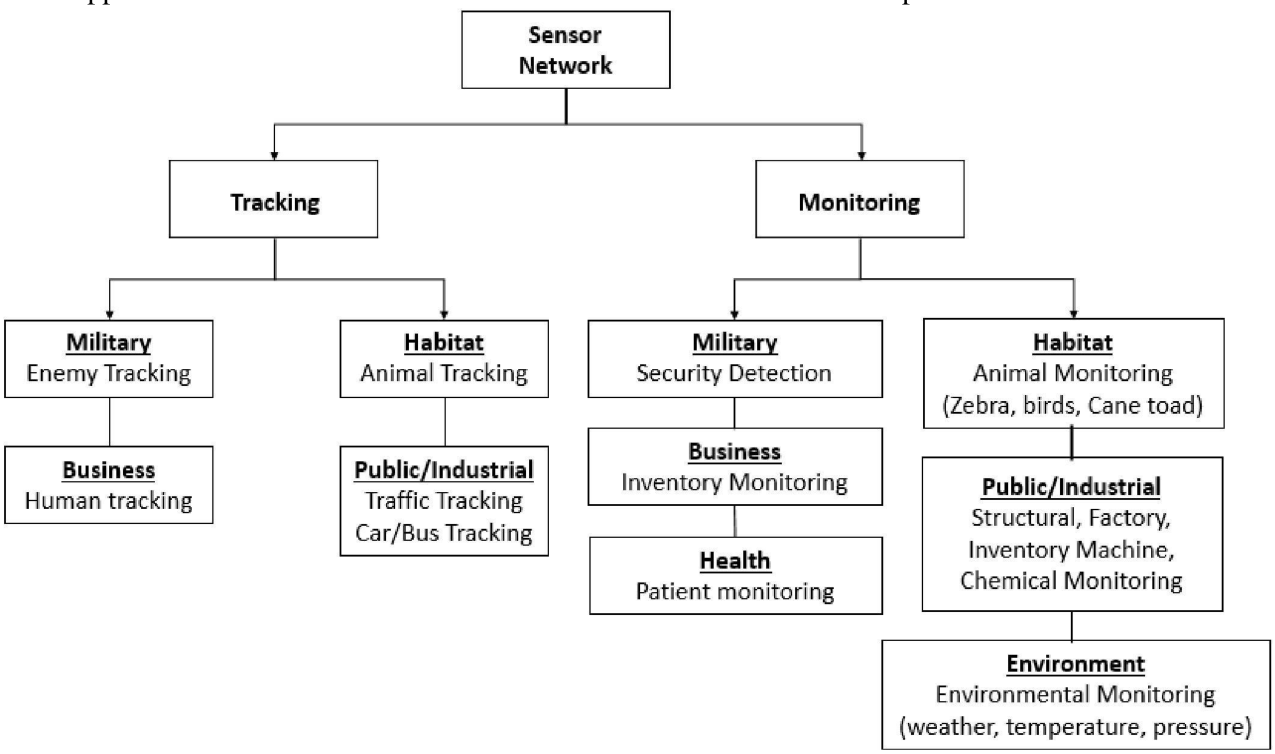


Figure 2.1: Overview of sensor applications

2.3. Application Characteristics

Most of the applications of WSNs share many common characteristics. Some of the similarities based on the interaction(s) between sources and BS are:

- **Periodic Monitoring**

  Sensor can be made to periodically measure the values in the environment and send the measured values to the user.

- **Event Detection**

  Specific events can be detected by the sensor nodes. Such sensor are also applied to addresses the event of natural calamities. Some of the applications with event detection are grass fires, forest fires, volcanic eruptions etc. Classification of events is necessary in case of a sensor network used for more than one event detection.

- **Location Driven**

  Most of the applications work on the changes in the position of the sensors. Applications theft detection, inventory management, detection of behavior of humans are monitored based upon the changes in the position of the sensors.

- **Target Tracking**

  Some applications sense the data even after continuous change in position. In cases of surveillance if any threat is on the move the sensor nodes communicate the source to the BS along with the speed and direction. This helps to estimate the present position of the targets.

2.4. Design Metrics

In the early days of WSNs, majority of its implementation was done for military applications. With the advances in technology and increase in WSNs scope now they are used in a variety of applications. To address these vivid classes of applications some of the essential design issues a sensor network must possess are [18, 20];

- **Scalability**

  As the numbers of nodes in a WSN are dense from hundreds to thousands, scalability is an important issue. Thus the schemes in the sensor nodes should have the ability to expand and scalable to respond to certain events.

- **Fault Tolerance**

  There are many situations which can cause sensor nodes to be failed or blocked from the network. Situations like lack of power, environmental interference and physical damages can often arise of the sensor nodes. Thus the network should be fault tolerant to such scenarios and the working of network should not be affected even after reduction of the sensor nodes. Thus fault tolerance is the ability of the network to work as expected even after node failures.

- **Production Costs**

  The production costs of sensor nodes should be low as the numbers of sensor nodes in the network is very high and most of the network is defined by the sensor nodes only. Thus lesser prices of sensor nodes lead to feasible networks.

- **Power Consumption**

  The transmission of information in WSNs is very energy consuming, proportional to the square of the distance or even four times in some cases when the distance between the source and target nodes is greater than a particular distance. Multi-hoping is used to reduce the energy consumption. But multi-hops introduce complexity for the medium access control and topology management plane. Thus trade-off should be considered about which mode of communication should be used. If the nodes are in close vicinity of BS then direct communication should be preferred over multi-hop communication.

- **Operating Environment**

  Sensor networks can be setup almost anywhere any possible place in the environment like bottom of a ocean, around battle field beyond enemy lines, in a chemically contaminated field, inside large buildings or home, can be attached to humans or animals, can be installed in high speed vehicles, can spread out in forest to prevent disasters etc.

- **Topology of sensor network**

  When density is high even then topology must be maintained.

- **Data Delivery Models**

  These models decide when the node has to transmit the information it has sensed to the BS. Some of the models which are used depending upon the applications are event-driven, continuous, query-driven and hybrid. Event-driven models transmit the information when any desired event has occurred. Transmission is done periodically in case of continuous data delivery model. A query-driven model transmits after receiving a particular query from the BS. Hybrid models are used by some of the applications which combine the approaches of continuous, event-driven and query-driven.

- **Data Fusion**

  As the sensor nodes are deployed with high density in the area of interest it is very likely that a group of these sensors will sense the same information. Such redundant information from the sensors can be aggregated to reduce the transmission. Data aggregation is the technique used for such purposes in which data from more than one sensor is combined with the help of functions like min, max, average or elimination of duplicates. For large networks, data aggregation introduces a little computation capability in the sensor nodes but still saves lot of energy by reducing the amount of transmissions. Thus, varieties of routing protocols use data aggregation for traffic optimization and energy efficiency of the sensor networks.

- **Transmission Media**

  RF, Infrared and Optical.

- **Network Setup**

  Setting up the network is dependent on the application and also plays are role in the performance of the network. Deployment of nodes can be either deterministic or random. In deterministic scenarios the nodes are deployed to the pre-determined locations. Such situations are possible only in the areas with human involvements like inside a building. In random deployment of the sensor nodes distribution of the nodes is not uniform. In such cases when clustering is done position of CH is a critical issue to retain the energy efficiency of the network.

- **Overhead & Data Latency**

  Data latency can be introduced by data aggregation and/or multi-hop communication. Complex algorithms of some routing protocols can sometime create excess overheads which may not be suited for network energy high energy constraints.

- **Quality of Service**

Quality of service is determined by the application. It may be data reliability, energy efficiency, location awareness, synchronized processing etc. These factors decide which routing protocol should be used for particular application. Some applications like military applications are focused on secure and periodic information from the sensor networks and hence the selection of routing protocol for such an application is continuous routing with cryptographic schemes.

2.5. Mobile sensor network deployment key issues:

This section throws light on the key issues for deploying the sensors in a given target areas, that has to be kept in mind while developing the sensor node deployment algorithms in WSN, details can be found in **[11]**.

- **Localization**

For putting the sensors, we ought to get the objective position of the sensors in the target field. To discover sensor node position diverse systems are utilized effectively. We have to do some deployment work on paper when the target field is simple and plane. If the target area is not simple then we may require some technique to get precise location information of the sensors. Global Positioning System (GPS) is used for locating the sensor nodes at each point of time. GPS incorporation is excessively costly, making it impossible to empower in sensor node, therefore many other schemes must be used.

- **Coverage**

Sensing range is a major factor to decide the coverage of sensor network in the target field. Coverage can be thought as one of the performance metrics of the services in WSN. An efficient node deployment algorithm leads very few coverage holes. In general, the coverage problem is called k-coverage problem. When k =1 the problem is called single-coverage problem and when k>1 the problem is called multi-coverage problem.

- **Connectivity**

To maintain the network topology node connectivity is an important factor to be considered. In WSN nodes can wake up to join or sleep to quite the network at any time which makes the topology dynamic in nature. Many network characteristics such as capacity, robustness, and latency are directly affected by the network topology that also affects the complexity of data routing and processing. In general, a sensor can be connected to k number of sensors which is called as k-connectivity. To maintain the connectivity a sensor has to be connected with at least one sensor in its sensing range. If the connectivity is preserved (possibly over multiple hops in WSN) between any two sensor nodes, the network is said to be connected. Connectivity is a critical issue to be considered while sensor node deployment in the target field area.

- **Communication and Sensing Range**

In a sensor node the sensing unit and the communication unit are independent, therefore the sensing range (R_c) and the communication range (R_c) are not directly related to each other from a hardware point of view. When coverage and connectivity both are considered simultaneously both the units have to be integrated together. The performance of the network depends on R_c and R_c), therefore they have to be decided beforehand which in turn depends upon the type of sensor we use. The R_c/R_c is a critical ratio and thus has to be considered for node deployment. If $R_c<R_c$ then the problem type is coverage and if $R_c>R_c$ then the problem type is connectivity. We can take the assumption that R_c is at least twice R_c, only need to guarantee the coverage and for single coverage problem it will satisfy the connectivity as well.

- **Energy**

Sensors are battery backed up devices and work autonomously so any kind of human intervention is not required for recharging that is they fully dependent on the installed battery life. As the sensors are massively deployed in a hostile target area most of the times, that makes its almost infeasible to recharge all the batteries in the target area, therefore energy is the far most critical parameter in WSN. Energy has to be utilized effectively to maintain the WSN life time. The communication among the sensor noes consumes most of the energy. To consider this problem optimal number of sensors have to be deployed on the field. If nodes are mobile then it consumes extra energy for the mobility in WSN. Energy efficiency and power consumption may be considered while deploying the nodes.

- **Node Density**

Among several design issues scalability is an important one that should be considered during sensor node deployment that may eventually affect the coverage, cost and the performance of WSN. Node density is an important parameter that may increase computational overhead and cost of the network significantly. On the other hand if the density is low then it may lead the problem of network partition or coverage holes. If the density is uniform it will decrease the chances of coverage holes and clustering.

- **Obstacle Adaptability**

If we consider the general case when the target field is not a plane surface then in that case we may have to consider the obstacles during sensor node deployment. In real time scenario it’s very important issue. Sensor nodes may change their path or they can take proper action while encountering any obstacle in their paths.

- **Lifetime**

The lifetime of WSN has a great influence on the required degree of robustness and energy efficiency of the nodes. Network lifetime is an important parameter and is application specific, so lifetime may range from few minutes to several hours or even to several years. Many approaches have been proposed to increase the lifetime, like incremental deployment. When a node is detected non-functional after adding a new node to the network, we have to consider several issues like load balancing, balancing energy consumption and sensor relocation.

- **Sensor Relocation**

  At any time if we detect the coverage hole then we have to relocate the redundant nodes to occupy that region, this process is called as sensor relocation. There may be some other reasons for sensor relocation like to balance energy consumption, message overhead during communication.

- **Movement of Sensors**

  Mobility of sensor nodes add extra overhead as it gives functionalities like relocation, locomotion and coverage optimization property to WSN. Mobility consumes power so resource management is very important in this regard. The idea is if we could anticipate whether a node will move or not we can distribute the energy accordingly but an efficient mobility policy will lead to a better coverage remains an unanswered question or an open problem so far.

- **Fault Tolerance**

  Sensor node loses its energy during its lifetime and fails eventually that may lead to degradation in network performance. The WSN has to be fault tolerant that is the proposed scheme must work even in the case of node failure. We may employ techniques like new node deployment, sensor relocation, load balancing, and incremental deployment. Sensor node mobility is highly considered for handling fault tolerance.

2.6. Deployment Algorithms

The purpose of good node deployment algorithm is to minimize the node redundancy and the network costs, but also can prolong the life time of WSN. All the deployment algorithms can be classified into Centralized or Distributed algorithms. When the node density is low we should prefer centralized deployment algorithm that runs on a single sensor node in WSN that may be a sink node or cluster head node. Periodic communication is done by the sink node to control node functionality in the network. When the node density is large, we should prefer distributed deployment algorithm that runs on each of the sensor node in in WSN, performing their own task. They are more desirable because they are scalable and computationally more efficient. Most of the times central server architecture might not be possible, in those cases distributed algorithms are unavoidable.

2.6.1. Classification based on optimal deployment of sensor nodes in the target field

- **Computational Geometry Based**

  In this approach the target field is considered as a set of grids or polygons, these grids are either fixed or moving. The aim of these grids or polygons is to provide location indication for the moving sensor nodes. The computational geometry method when coverage problem is considered is similar to the deployment problem in WSN.

- **Potential Field Based**

  The sensor nodes of this approach areas considered as the points in the target area and are exposed to appealing or terrible power dependent on the separation between every two sensors, the powers are of type Newton's Law.

To achieve the uniform deployment in the field, they use the threshold value of distance between the sensor nodes so that sensors can move based on the force vector summation. Virtual force can minimize sensing overlap by moving sensors from high to low density areas. Self-deployment of sensors is generally done in this approach, so it is important to ensure the mobility of sensors in the field.

- **Probabilistic Approach**

In this approach, sensors choses its initial positions and dynamic deployment of sensor nodes are done on the target field. The sensor field is assumed to be a two-dimensional grid. Each sensor node is supposed to knows its position. In this approach probabilistic sensing model is used in place of binary detection model.

- **Bio-Inspired Algorithms**

In this approach the initial deployment is done using random deployment and then optimal position of the sensor node is obtained using bio inspired method like particle swarm optimization, ant bee colony, genetic algorithm, teaching learning-based optimization etc.

These algorithms are inspired from nature so they are called as nature inspired or bio inspired optimization techniques. As compare to traditional approach of AI , bio-inspired computing perform more evolutionary approach to learning, whereas programing is done in Artificial intelligence. The programmer creates the something which is improved with its intelligence. More decentralized and bottom up approach is taken by Bio-inspired computing, the methods of bio-inspired techniques consist of simple rules, a and these rules are iteratively applied on the set of simple organisms.

2.6.2. Classification based on the manner of node placement in the target field

- **Random Deployment**

It's the most practical way when the target field is susceptible to frequent changes or when no knowledge is available beforehand about the field. Random deployment is often backed up by robots, they are dropped initially from a height in air. Random deployment is always served as the initial deployment strategy in movement assisted deployment. It's noteworthy that this strategy may not provide a uniform distribution which may be desirable for a longer lifetime of WSN over a particular area in the field. This strategy may cause clustering while leaving the concentration of other part low.

- **Incremental Deployment**

This strategy is a centralized approach, i.e nodes are deployed one at a time. The deployment of a node is based on the information obtained by previously deployed sensor node to determine the deployment position in the field. The calculation of new deployment position is done by the sink node. In this approach we don't require any extra localization method, when the environment model is not available then this approach considers the nodes as landmarks. This approach is a greedy in the sense at each step the location calculated for each node will produce maximum network coverage. This approach is commonly applied to static deployment.

- **Movement-Assisted Deployment**

  The deployment approaches may be inaccurate if the actual node deployment position cannot be controlled due to weather conditions like wind and obstacles. So its desirable to use mobile nodes which may be backed up by robots. The initial deployment is done by random deployment approach and then we use any optimal deployment algorithm to re-deploy these nodes in the field. These algorithms are inspired by multi-robot exploration problems.

2.6.3. Classification based on the mobility of sensor nodes in the target field

- **Static Deployment**

  The static deployment obtains the best location according to some optimization strategy, and the location of the sensor nodes don't change during lifetime of the network. In present scenario, the static deployment includes randomly deployment & deterministic deployment.

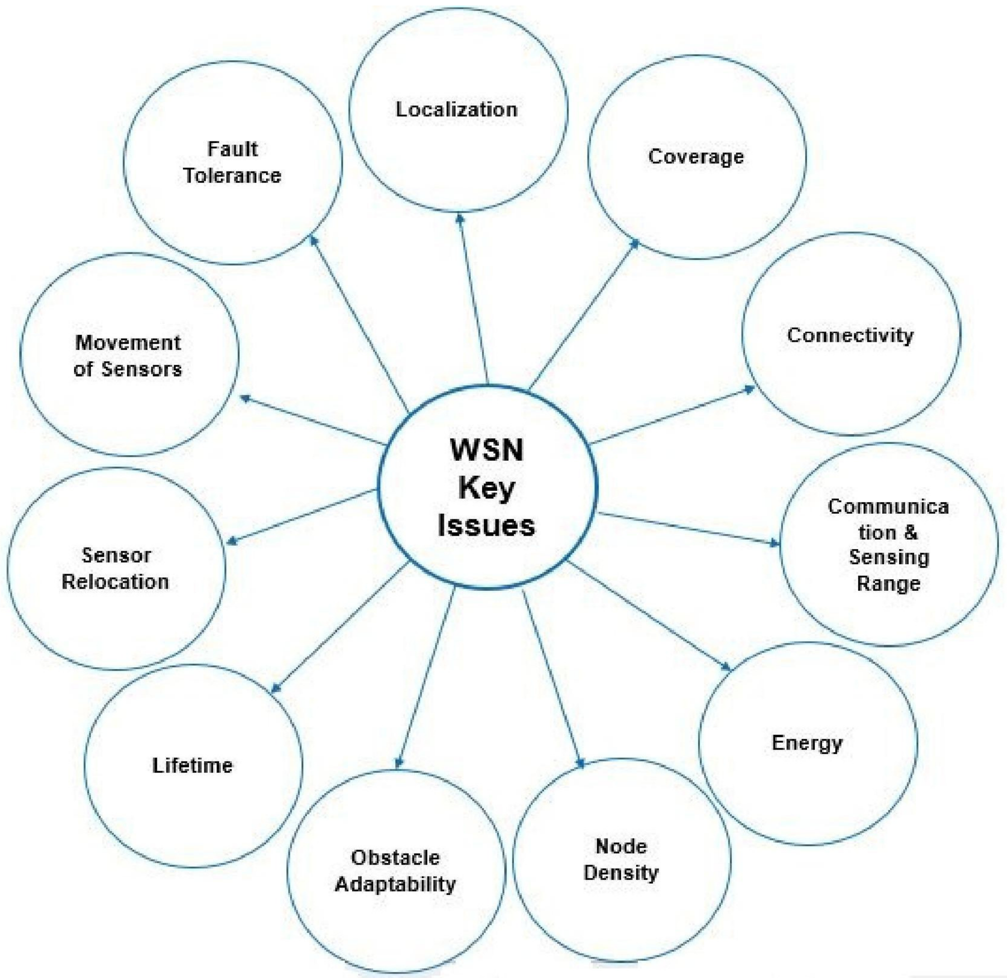
- **Dynamic Deployment**

  The dynamic deployment may be backed up by robots from a height in air. In his approach nodes are first deployed randomly then these nodes are supposed to acquire their best location based on some optimal deployment scheme. This approach considers moving nodes in the field.

CHAPTER 3

RELATED WORKS

Keeping in mind different issues in Wireless Sensor Networks, this section describes few research works in the area of coverage, connectivity, sensor mobility, sensor relocation, obstacle adaptability and WSN lifetime. Below figure depicts the key issues in WSN.



This part centers the issue of finding an optimal coverage of sensor nodes in WSN while ensuring connectivity among sensors. This connectivity preservation is achieved without using centralized control and accurate location information. The optimal node coverage is done in accordance with OTLBO "Orthogonal Teaching Learning Based Optimization" to improve network coverage. OTLBO is an improvement over TLBO "Teaching Learning Based Optimization" that makes TLBO quick to converge and more robust. OTLBO is an ongoing methodology in the optimization field. The connectivity preservation algorithm is localized and is based on a subset of neighbors for taking motion decision. Connected Topology is maintained in the connectivity preserving algorithm; based on the neighbors connectivity of the nodes, the covered distance by the mobile nodes is decided for sub-graph like the relative neighborhood graph. Finally, the node coverage is based on OTLBO optimization technique.

Sensor Node deployment in WSN is fundamentally ordered in two classifications: static and dynamic deployment. Best location is picked by using some optimization technique in the static node deployment and sensor node is unable to change its location in WSN lifetime. The static deployment incorporates the and the randomly deployment and deterministic deployment is incorporated in static deployment tec. Albeit deterministic deployments provide optimal solutions, it is not always plausible since they require exact information of the monitored area.

The feasibility of dynamic deployment or on-demand deployments is when the location of sensors is available, and having the capability of movement. The topology can be obtained in case of on-demand deployment which reduces energy consumption, optimizing routing scheme or flooding, etc.

The coverage schemes associated with on-demand deployment are full coverage (sensors attempt to cover the whole area of interest), barrier coverage (sensors attempt to form a barrier for intrusion detection) or sweep coverage (sensors attempt to cover only some specific points). Based on the connectivity the coverage area is decided for the mobile node so that connectivity can be preserved of the node with its neighbors similar to the relative neighborhood graph.

The chapter focuses on the related works done for the problem of network coverage while ensuring the connectivity among the sensor nodes constantly. The coverage issue is dealt with by “Orthogonal Teaching Learning Based Optimization”, based on TLBO (Teaching Learning Based Optimization). OTLBO makes the convergence rate of the algorithm faster. TLBO is a recent nature propelled global optimization technique. TLBO is a Population-based iterative learning technique that utilizes a populace of initial solutions to obtain the global solution. Based on the simple logic the learners can influenced by teacher is used in this approach. TLBO works in two phases, the first phase is called “Teacher Phase” which means learning from the teacher and the second phase is called “Learner Phase” which means learning through the interaction between learners.

As a teacher is viewed as the most proficient individual in the general public, the top learner is considered as an instructor, in every transformer step.The educator endeavors to scatter information among students, which thus will enlarge the information on the whole class and will assist students with getting quality marks. Therefore the presence of an instructor can upgrade the exhibition of all learners. Thus the teacher increases the mean performance of the class as per his or her capacity i.e. the teacher T1 will attempt to move mean M1 towards her own level as per her ability, thereby expanding the learners’ level to a new mean M2. Learners can increase their knowledge by two different approaches: First, with the assistance from the teacher and Second, through interaction among themselves. A learner interacts randomly with other learners through group discussions, presentations, formal communications, and so on. A learner adds something new to her knowledge as long as the other learner she is interacting with has more knowledge than her. “Orthogonal Teaching

Learning Based Optimization" (OTLBO) is an advancement over TLBO which is based on orthogonal design concept that can be proficiently applied on multi-factor and multi-level problems. OTLBO makes TLBO quicker orthogonal design method.

Wireless sensor networks (WSNs) have been utilized effectively in numerous significant regions, for example, surveillance, target tracking and classification. Two most important factors to judge the performance of WSNs are coverage and target detection probability. Sensor nodes can be deployed according to some effective scheme to get optimized coverage in the field being monitored. Thus the performance of WSN is nothing but a function of sensor nodes deployment.

We can characterize the node deployment in two classifications: static deployment and dynamic deployment. The static node deployment selects the best location in accordance with some optimization technique, and the location of the sensor nodes will remain fixed during the entire lifetime of WSN. As of now, the static deployment is classified in two categories namely deterministic deployment and random deployment. Sensor nodes deployment approach is proposed in X. He et al. **[12] i**n target points overlapping and genetic algorithm is used, this results in the reduction of network cost and can realize the optimal allocation of space resources in wireless sensor networks. X. M. Guo, C. J. Zhao, X. T. Yang et al.**[13]** have proposed how to do target coverage based on grid scan. Moreover, Y. Z. Zhang, C. D. Wu, L. Cheng et al.**[14]** have proposed the deployment of WSN in deterministic space with obstructions.

Robots can be used for dynamic deployment of sensors to utilize sensor networks to the greatest extent possible, sensor before starting the work, sensor nodes move to its proper location automatically. Sensors can be haphazardly tossed, and then a variety of optimization algorithms for deployment optimization can be deployed; like virtual force algorithm **[15]**, virtual force-oriented particles algorithm **[16]**, simulated annealing algorithm **[17]**, particle swarm optimization algorithm **[18]** and simulated annealing genetic algorithm **[19]** more details can be found in Haitao Zhang &Cuiping Liu **[20]**. In mobile sensor networks it has been demonstrated that mobility can make the framework of higher layer algorithms complicated, however it can also enhance the network performance. There is one recent approach given by Valeria Loscrí, Enrico Natalizio& Francesca Guerriero **[21]** "Particle Swarm Optimization Schemes Based on Consensus for Wireless Sensor Networks" that successfully handles this issue but the algorithm does not take into account whether the problem is multi-factor, multi-level search space or not. Literature surveys helped in the construction of WSNs issues like optimization problems for multidimensions and through soft-computing techniques is very promising research field.

3.1. PSO Scheme Based on Consensus for Wireless Sensor Networks

PSO is a very versatile population-based swarm intelligence technique **[21]**. The particles of PSO are placed inside a research space and a fitness function based on their position is evaluated. They can move around the research space by combining their history with the information received by one or more neighbors in the swarm. In the event that we accept that the particles move in a 2-D space, in PSO the new velocity of *ith* particle will be determined by:

$$v_i(t+1) = m \, . \, v_i(t) + \emptyset_p \, .r_p \circ (e_i - \mathbf{x}_i(t)) + \emptyset_g . \, r_g \circ (e_g - \mathbf{x}_i(t)) \quad \textbf{(3.1)}$$

Where xi(t), vi(t), e_i, e_g ,r_p and r_g are all R^2 vectors. x_i , $v_i$are the current position and velocity of the particle I individually; ei is the particle's most popular position, eg is the swarm's best position; rp , rg are two arbitrary vectors in U(0,1)(the e and g in the addendum represent individual and worldwide separately); m, Øp , Øg are boundaries chosen so as to control the viability of the PSO method, and o is the Hadamard lattice, duplication administrator. Thusly, the situation of the particle at whenever moment is resolved as

$$x_i(t + 1) = x_i(t) + v_i(t + 1) \quad \textbf{(3.2)}$$

The three terms of the equation 3.1 characterize the particles' behavior: the first term is called inertia because previous velocity of particles iskept tracked, the second term is the cognitive component and because best known position tracking done by particles, the third term is used for achieving best position of swam due to which it termed as the social component.

3.1.1. Consensus Algorithm

A crucial role in grasping the coordinated movements of various agents in a group is played by analyzing interaction between various agents in a group and studying flow of information among these agents. Along these lines, a basic issue for composed control is to plan proper algorithms and protocols in a manner that information can be shared with limited exchange of data through unreliable channel with dynamic interaction topologies and consensus can be reached by agent groups.

The expression "consensus" in multi-agent systems connotes the way toward agreeing on a specific amount of interest that relies upon the condition of all agents included. An agreement calculation expresses the information trade between an agent and every one of its neighbors in the network. A fundamental variation of the PSO algorithm works by having a population of candidate solutions called particles. In our situation, the particles are the sensor devices that trade data and move to arrive at a mutual target. Vicsek proposes an agreement algorithm dependent on a time discrete model of n independent agents that move in research space. The condition of every agent is refreshed by a standard dependent on its state and the condition of its neighbors, where its neighbors are for the most part the agents found in a limited transmitting/receiving range. Following equation describes the evolution of the system:

$$x_i(t + 1) = x_i(t) + u_i(t) \quad \textbf{(3.3)}$$

$$\text{Where, } u_i = (m_{ii} - 1) \,.\, x_i(t) + \sum j \in N_t(t)\, m_{ij}(t) \,.x_j(t) \quad \textbf{(3.4)}$$

In (3.3) and (3.4), x_i is the status of agent i ,u_i is the control law on agent i , N_i is the set of neighbors of node i and m_{ij} is the weight associated to the contribution of the j^{th} agent on the i^{th} . A neighbor i s a 1 hop distance node. To cover the same state consensus strategy is needed such that right weights get selected. It is worth noting "that a global consensus is reached thanks to the nodes at the boundaries that make consensus regions physically connected."

3.1.2. Modified PSO

It has been considered that for coverage in network is done better by the PSO scheme, or all the applications in which the cost is not too high for the movement of. Usually, in the PSO scheme, the achieved position is best which is globally selected in the research space by swams is best advantage for PSO. It is not useful to consider a global best position, since it infers an incorporated plan of control or, at least, the limit of the nodes to communicate with each other node in the sensor field. So as to consider, the restricted correspondence limits of sensors, it's communicated that the social term incorporates the position that acknowledges the best understanding inside each node's area, where an area is made" just of the sensors inside its transmitting/receiving range. Thus, it's assumed information exchange is done at every iteration in modified PSO algorithm, and identify the maximum consensus among its neighborhood. The velocity update equation is modified as follows:

$$v_i(t+1) = m \, . \, v_i(t) + \O_p \, .r_p \circ (e_i - \mathbf{x}_i(t)) + \O_g . \, r_g \circ (l_i) \quad \textbf{(3.5)}$$

$$l_i = \frac{Xk - Xi \, . \, \|Xk - Xi\|}{\|Xk - Xi\|} \quad \textbf{(3.6)}$$

In Eq. (3.6), x_k is the position of the particles in the arrangement of neighbors of i that got the best estimation of the target function, and drep is a coefficient of repulsion that is intended to keep away from sensors' coverage areas as well. The calculation of the objective function depends on the quantity of events per unit of time that happened in the sensor field, by accepting that the nodes can have global or local information on the sensor field. Velocity update equation just considers the most noteworthy value of the target function henceforth it has to make reference to that we utilized the most consensus.

3.2. Dynamic Deployment of Wireless Sensor Networks by Artificial Bee Colony Algorithm

The ABC algorithm, is also inspired by honey bees intelligent foraging behavior comes under the category of swarm intelligence method. The dynamic deployment problem of WSNs uses this method. Coverage maximization of the network is the aim of optimization technique, as shown in Eq. (3.1). Tt is assumed for the network's scenario:

- The detection radii of the nodes are all the same(r).
- All of the sensors are capable of communicating with the other sensor nodes.
- All nodes are mobile in nature.

In the "ABC algorithm, the solution of the optimization" problem is the position of a food source and the quality of this solution is indicated by the nectar food source amount. Therefore, the sensor deployment in the area considered as the food source in the algorithm. Area coverage is majored or quality check done by nectar fitness value) of the solution. To finding the best solution is the goal of the artificial bee colonies model, to achieve it there are 3 groups of bees: employed bees, onlookers, and scouts. For the choice of the food sources bee waits in the dance area is "an onlooker, and when a bee goes to a previously visited food source, it is an employed bee". Scouts are the random searches which is used by the bees.

Following are the steps of algorithm:

1. Parameter Initialization: detection radius r, size of area of interest A, number of mobile sensors N, colony size cs , maximum number of iterations Max Cycle, and limit for scout l
2. Deploy N sensors randomly for each food source x_i of employed bees using Eq. (3.7)

$$x_{ij} = NIN_j + rand(0,1)(NAX_j - NIN_j) \quad \textbf{(3.7)}$$

3. Population evaluation.

4. c = 0.

5. Repeat steps 6 to 14

6. Produce new solutions u_i in the neighborhood of x_i for the employed bees using Eq. (3.8).

$$u_{ij} = x_{ij} + \O_{ij}(x_{ij} - x_{kj}) \quad \textbf{(3.8)}$$

Here, k is a solution in the neighborhood of i, Ø is a random number in the range [-1, 1], and j is the randomly selected mobile sensor position.

7. Check u_{ij} for staying in the bounds of the area.

8. Between x_i and u_i greedy selection process is applied.

9. values p_i probability is calculated for solutions x_i by means of their fitness values using Eq. (3.9).

$$e_i = \frac{0.9 \times fiti}{fitbec + 0.1} \quad \textbf{(3.9)}$$

10. Produce the new solutions, u_i , for the onlooker bees from solutions x_i , selected depending on Pi , and evaluate them.

11. Between x_i and u_i greedy selection process is applied for the onlookers.

12. Best solution is memorized.

13. abandoned solution need to be determine and replace them with new randomly produced solution using Eq. (3.7).

14. c = c + 1.

15. Until c = MaxCycle.

Each solution represents an array that has m items. Figure 3.1 shows the solution array. Items of the solution array are (x, y) positions of the mobile sensors in the network.

1	2	3	…	2 m
$(x_1 - y_1)$	$(x_2 - y_2)$	$(x_3 - y_3)$		$(x_m - y_m)$

Figure 3.2: Solution Array

CHAPTER 4

PROPOSED WORK

4.1. Problem Definition

The problem under consideration is to develop an approach to find out optimal number of sensor nodes that can be deployed in a specified target field to get the maximum coverage area while ensuring the node connectivity during the lifetime of WSN.

4.1.1. Coverage Problem

The problem requires to obtain a minimum number of nodes to be deployed in the target field, such that every point in the target field is covered optimally. In general, given a set of sensor nodes to be deployed in a specified target field, the problem requires to determine if all points in the field is sufficiently k-covered, i.e. every point in the target field is covered by at least k sensor nodes, where k is defined as a given parameter.

In the proposed work area-coverage is taken into consideration whereby the sensor networks major objective is to monitor a specified region (the collection of all points in the target field), and each point of the field has to be monitored.

4.1.2. Connectivity Problem

By connectivity we mean that the underlying graph of the network is connected in the sense that between any two nodes there is a path in the graph. The path in the graph represents single-hop or multi-hop communication between the nodes. In general, the problem is considered as k-connectivity problem if removal of any (k-1) nodes does not leave the underlying graph disconnected. More formally for homogeneous network, the problem which are faced by it can be stated as: given a set of sensor nodes to be deployed in a specified target field, the problem requires to determine minimum value of communication range (R_c) that can be assigned to all the sensor nodes to ensure global connectivity. In the proposed work k is taken as 1.

In figure 4.1 the problem of coverage and connectivity has been shown, here sensor nodes are deployed in a specified target field. The purpose of sensor nodes are to gather the information about a phenomenon in the target field and disseminate this information to the data fusion center or the sink node ultimately. Here, nodes 1 and 2 are not covered and connected.

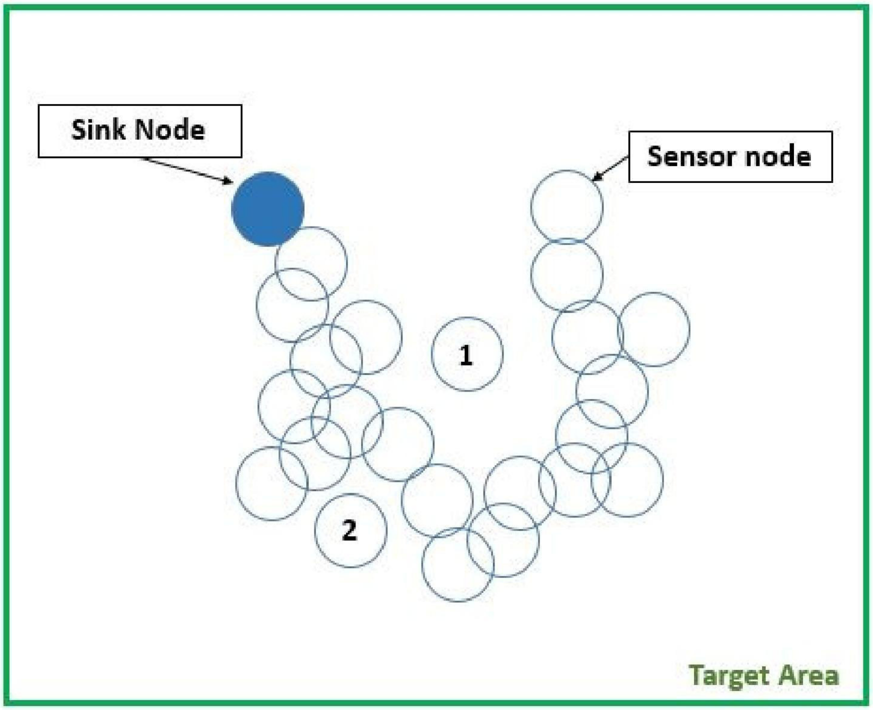


Figure 4.1: An illustration of coverage with connectivity. Sensor node 1 and 2 are not covered and connected in the target area

4.2. Proposed approach for coverage problem

This section, covers the explains the TLBO and OTLBO. It also includes the explanation about the use of the particular scheme for our proposal. In **[23]** author explain in detail about TLBO and OTLBO. In **[24]** Connectivity Preservation and Coverage Schemes are well explained for Wireless Sensor Networks.

4.2.1. Teaching Learning Based Optimization (TLBO)

There are two phases of TLBO approach. *Teacher Phase and Learner Phase are first and second phase respectively.*

4.2.2. Teacher Phase

In the society teacher is treated as the person which is having maximum knowledgeable then others , in this approach the best learner act as a teacher of the class. To increase level of the knowledge. class teacher spread it knowledge among all the learner of the class and help them to enhance their grades. According to the capacity mean of the class get increased by teacher i.e. mean M_i move to its own level by the teacher T_i based on its capability, new mean $M_j$indicates the new level of learners. To teach students Teacher T_i will put its maximum effort, but based on the delivered quality of knowledge by a teacher, student will gain knowledge and the students quality present in the class. The populations mean value is used to judge the quality of the students. The quality of the students can be increased from M_i to M_j by putting efforts by Teacher T_i. the new teacher of superior quality required by the student and i.e. $T_j$is new teacher in this case.

Let q be the any iteration where mean value is M_k and teacher is T_q. Mean M_q is moved by T_q towards its own level, now M_{new} considered as new mean. The difference between and the new mean and the existing mean is used to updated the solution:

$$X_{new,q} = X_{oSd,q} + r_q (M_{new} - T_{F}M_q) \quad \textbf{(4.1)}$$

Where the factor of teaching which decide the change in the mean value is T_{TF}, new solution is $X_{new,q}$ and existing solution is $X_{oSd,q}$. To calculate the value of T_{TF} , refer the following equation:

$$T_{TF} = round[1 + rand(0,1) \times \{2 - 1\}]$$

4.2.3. Learner Phase

If other learner is having move knowledge as compare to the present learner, it will learn for them. And perform some modifications:

†or i = 1 to N_n do

Randomly Select two learners Xa and X_b, wℎere a ≠ b a†

$f(X_a) < f(X_b)$

$$X_{new,a} = X_{oSd,b} + r_a (X_a - X_b)$$

else

end

if X_{new} gives improved function value then it is considered Accepted.

4.3. Orthogonal Design

To understand Orthogonal Design let us take a problem which have various possible values of factors called levels. Let us consider there are F number of factors and L levels of each factor, then L^F is the total no of combination. To evaluate all combinations of F and L is not practical if the value of F and L is large.

To study multi-level problems and multi- factor, Orthogonal design was developed as a mathematical tool. This design extract an orthogonal array A of R rows, where combination is evaluated for each row. The 3 key properties of array :

- During the experiment, the array represents a subset of R combinations, from all possible L^F combinations. Computation is reduced considerably because R << LF.

- Each column represents a factor. If some columns are deleted from the array, it means a smaller number of factors are considered.
- The columns of the array are orthogonal to each other. The selected subset is scattered uniformly over the search space to ensure its diversity.

$$new,a = X_{oSd,b} + r_b(X_b - X_a)_n$$

[22] author proposed efficient and simple method for the generation of orthogonal array A where, R = L × L and F = L + 1. The algorithm is written step by step:

Algorithm-1: Orthogonal array A generation procedure.

I/P: Th enuNBERof levels L

O/P: Anorth ogonal array A Calculate

R = L × L and F = L + 1

Initialize a zero NATRix A with R rows and F colUNNs.

for i = 1 to R do

$A_{i,1} = NOD(\lfloor(i - 1)/L\rfloor, L)$

$A_{i,2} = NOD(i - 1, L)$

for j = 1 to F − 2 do

$A_{i,2+j} = NOD(A_{i,1} \times j + A_{i,2}, L)$

end

End

4.3.1. Optimizer (OTLBO)

Optimizer divide the class of learners into various partial vectors and each of the vector is treated a factor for orthogonal design. Among various combination best scale get searched by employing Orthogonal design.

4.3.2. OD-based operator and updating strategy

If there are m learners, we can execute the multi-parent problem efficiently using orthogonal design. Since n factors are associate with each learner, m^ncombinations will be there. Hence orthogonal design is employed to select m (here $A_m(L^F)$ is the orthogonal array, where F = n and L = m) representative sets of combinations to reduce the time in computational. The procedure of OD-based multi-parent is given in Algorithm 2.

Algoritm-2: OD-based operator for m learners.

input: N articles $X_{i,j}$, i c [1, N] and j c [1, n] output:

A new set ofN earners $e_{i,j}$

Construct th eorth ogonal array $A_{N\times N}(N^N + 1)$ using Algorithm1 Delete th e

last (N + 1 − n) colUNnsof$A_{N\times N}(N^N + 1)$ to get B = $A_{N\times N}(N^n)$

Generate N new learners:

†or i = 1 to N do

†or j = 1 to n do index = $B_{i,j}$ $e_{i,j} = X_{indes,j}$

end

end

4.3.3. Steps of OD-based TLBO

As compare the standard TLBO, OD-based operator is used to get more precise solution. To enhance the current population, elitism preservation strategy is proposed, if the fitness is improved then only learner get updated. Algorithm 3 shows the OD-based TLBO procedure. To terminate the algorithm maximum run or the convergence criterion can be used.

Algorithm-3: OD-based TLBO

I/P: Population Size S, MaxiMUM iterations K output: Best

Learner

Construct a ranDON initial eoeulationo$f$ learners X_i, i c [1, s]

for t = 1 to K do

†or i = 1 to S

do Uedate learners t□roug□teac□ere□ase as in original TLBO

aeelyingelitiSNereservation strategy:

Select Nearticlesrandonly and execute algorIT□N 2.

Set $e_i = X_i^{t+1}$ if $f(X_i^{t+1}) < f(e_i)$

Set g = argNIN $f(e_i)$

end

C□eckt□eterNINation condition end

4.4. Connectivity Preservation Algorithm

Based on potential field theory and location deployment is done in deployment algorithm. Each node is treated as a particle and neighboring nodes interaction is used for monitoring the movements. Based on the kind of coverage required the direction is to be chosen depending upon the neighbor's subset which are interaction to each other while the in Relative Neighborhood Graph (RNG) shows the connection of the nodes which specify the distance to be covered. As local information is only required for computation by RNG makes it suitable solution for the problem. Moreover, graphs mean degree can be reduced for computation of RNG by the Euclidean distance usage. The RNG mean degree is three. RNG is capable to be in the connectivity with all the nodes in the graph even after modify the initial graph by removing some edges.

Algorithm-4: Mobile Sensor Deployment (MSD) protocol

Part 1:- Node u direction computation:

1: $\vec{\Delta}$ (x(Δ), (y Δ)) Is the direction vector of u

2: $\vec{\Delta} = \sum_{v \in RNG(u), d(u,v) \in R} (R - d(u, v)) \times \|\vec{vu}\|$

3: $x(\Delta) = \sum_{v \in RNG(u), d(u,v) \in R} (x(u) - x(v)) \times (R - d(u, v))/R$

4: $y(\Delta) = \sum_{v \in RNG(u), d(u,v) \in R} (y(u) - y(v)) \times (R - d(u, v))/R$

5: P(x(u) + x(Δ), y(u) + y(Δ))

6: $\vec{\Delta} = \vec{\Delta} / \|\vec{\Delta}\|$

7: return

Part 2.a:- Speed computation on node u:

1: $v = (R - d^{+}(u))/ð \times 2)$;

2: $v = \min(v, v_{NAS})$;

Part 2.b:- Distance computation for node u: 1:

$d_{NAS} = \max(c, R - d^{+}(u))$;

2: $d_{opt} = \{d \text{ c } [d_{NAS}] \mid \forall\, v \text{ c } RNG(u), d(u_{new}, v) + v_{oth} \times ð < R\}$

3: where $v_{oth}(v) = (R - d(u, v))/(ð \times 2)$

4: and u_{new} is the new position of node u based on:

5: Direction $\vec{A}$ from Part 1.

6: Speed v from Part 2.a.

7: Distance d.

Part 2.c:- Node u destination and movement:

1: Move to u_{new} using:

2: Direction $\vec{A}$ from part 1.

3: Speed v from Part 2.a.

4: Distance d_{opt} from Part 2.b.

5: Take field border into account

4.4.1. Analysis of Algorithm 4

The step by step analysis of algorithm 4 is given as follows, this analysis is divided into two parts, and these two parts are independent to each other for choosing any deployment scheme in part 1.

Part 1: Direction Computation

Node u chooses direction based on the requirement of the deployed area. the direction of node u is provided as $\vec{A}$ normalized vector.

Part 2: Preservation of Connectivity

To preserve connectivity we need to follow the several steps: (a) computation of speed, (b) computation of distance and (c) Destination and movement.

Part 2.a: Computation of speed

Movement speeds computed by node u based on the data which is gathered from its neighborhood. While preserving connectivity, speed of deployment need to be as fast as possible. The worst-case movement of $RNG^+(u)$ is calculated by dividing maximum speed by 2. Speed of node u cannot be null so that it allows at least small moments of node. Nodes at distance R can move towards each other is also allowed. v is the movement speed of the node u which is known at the end of Part 2.a.

Part 2.b: Distance computation

Computing distance is the procedure where distance is computed by the node u to major the distance covered by it before again running Algorithm 1. There is the range [c, d_{NAS}] in algorithm where c is a parameter of the algorithm and it is used to choose the distance. The major objective is to remain connected even in the worst case i.e. $RNG^+(u)$ are in opposite direction , the maximal speed of its RNG neighbors V_{oth} is computed while considering the connectivity. Before being disconnected they can cover distance $d = (R - d^+(u))/2$ before in worst case. Indeed, as links are bidirectional $d^+(RNG^+(u)) \geq d^+(u)$, higher distance the u can't be chosen by $RNG^+(u)$. This distance has to be covered between two checking, i.e. in ð. The maximum possible distance d_{opt}it is computed by node u based on the information given to it and to achieve it can travel to new position while remain connected .

Part 2.c: Destination and movement

This part performs the routing and planning of path. For sensor movement any path planning algorithm can be used as distance, speed and direction is given. Obstacle avoidance and path planning algorithm uses the differences between Part 3 and Part 2 from robotics [29] describes it. The trajectories of each mobile sensors is controlled by motion planning algorithm. Algorithm 1 Part 1 is independent from the other parts completely. To fit it in other direction, it can be easily modified which makes it important property. This helps to modify the direction of node easily without impacting other parts of algorithm.

4.5. Proposed Hybrid Approach

Algorithm-5: Sensor node deployment while preserving connectivity

1. CALL Algorithm 3 to find optimal no. of nodes, N in the sensor field, F.
2. for each node u in the sensor field, F
3. CALL Algorithm 4

4.5.1. Analysis of Hybrid Approach

The algorithm is based on two algorithms, the first algorithm is for optimal deployment of sensor nodes based on the Orthogonal Teaching Learning Based Optimization (OTLBO) which has been proved to be an improvement over Teaching Learning Based Optimization (OTLBO) in terms of convergence rate and is based on orthogonal design technique for multi-factored and multi-leveled problems.

The Algorithm 3 returns the number of nodes that can be deployed optimally on the specified field size, this process is again done in two steps, the first step is to deploy these nodes randomly on the field and then these nodes will move to their optimal position according to a bio-inspired optimization technique to get the optimal positions for the deployment. The second step is to use Algorithm 4 to maintain the connectivity of these nodes during the lifetime of WSN. This connectivity preservation algorithm is taken from "Connectivity Preservation and Coverage Schemes for Wireless Sensor Networks" by TahiryRazaafindraxlambo, and David Simplot-Ryzl, Member, IEEE.

This hybrid approach is designed to get the better approach for the coverage problem and the connectivity problem for mobile nodes in WSN. The connectivity graph considered in Algorithm 4 is Unit Disk Graph (UDG) model, this algorithm also valid for realistic graph (graph maintained by real nodes in the network).

CHAPTER 5

SIMULATION RESULTS AND ANALYSIS

Simulation has been defined as computer based statistical sampling experiment on the digital computer, it’s the process of mimicking the system or problem under consideration for the purpose of analysis. Simulation is considered as very efficient and suitable tool to analyze the performance of the system under consideration.

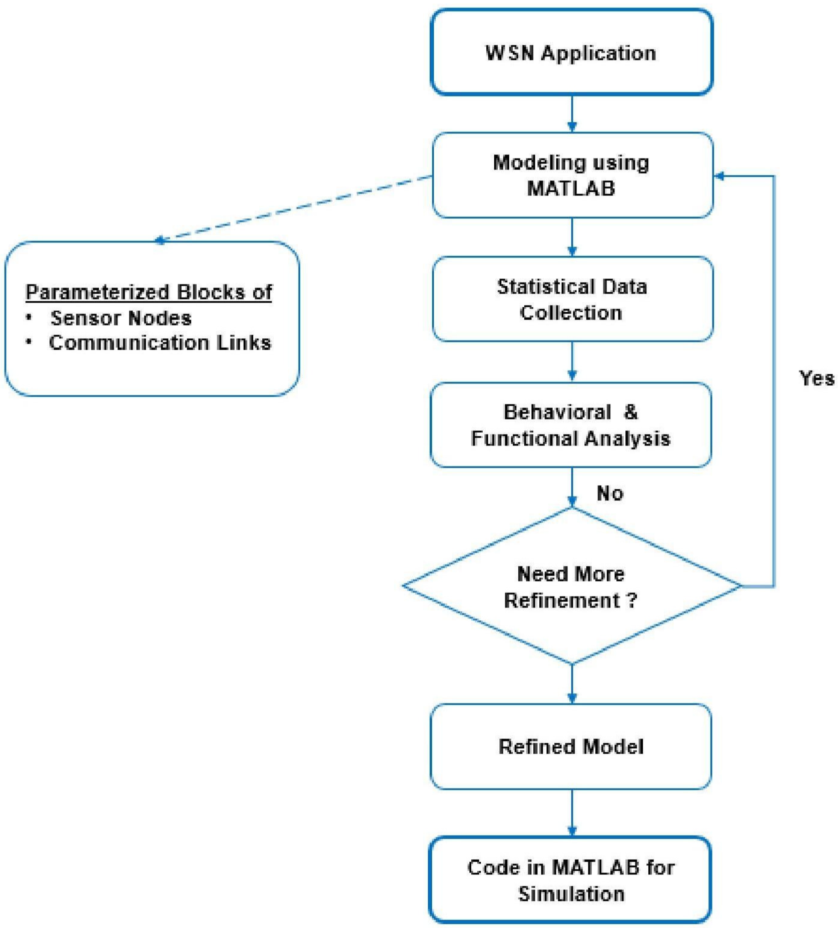


Figure 5.1: Process of simulation

The overall simulation process is described in the figure 5.1, Wireless Sensor Model is represented by a system model with simplified assumptions. Following section describes the system model and the assumptions taken under consideration.

5.1. System Model

In a target field a point is said to be covered if that point can be detected by one or more sensor nodes. Let R_c be taken as the *sensing range* of a sensor node then we say a location is covered if its distance to at least one sensor node is within R_c.

Two sensor nodes are said to be directly connected if the distance between the nodes is less than the *communication range*, R_c. In WSN, coverage and connectivity both are important sometimes, because the ultimate aim of wireless sensor network is to gather and the information is forwarded to the sink node. This is why, the connectivity, which is defined as the ability to deliver all the gathered information to the sink node, is also considered to be critical. In this regard deployment of the sensor nodes are done randomly in the target field first then these nodes are considered to be moving nodes and find out their optimal positions in the field according to*OTLBO* technique which is a *bio-inspired optimization* approach.

Let consider the square sensor field(Z) for monitoring area which contains (N) mobile nodes which are randomly deployed. According to the probability density function F(z) event get occurred. Based on the event probability the sensor nodes get distributed is the idea behind it. Number of nodes n used for the coverage of region R of Z is required is calculated by (5.1). this is the consideration which is used for the OTLBO algorithm analysis.

$$n = \frac{\int_R F(z)\, dz}{\int_Z F(z)\, dz} \quad \textbf{(5.1)}$$

In the sensor field the position of the node where the event occurred is retrieved by the objective. Hence, the global information is needed by objective function. Ideally each area is having (n_i. N) numbers of sensors which is compared with the actual number of sensors located to evaluate the performance at the time of convergence. Cost model is depending on traveled distance d which is considered to be proportional to the energy, as follows:

$$E_N(d) = kd \quad \textbf{(5.2)}$$

Where the constant k can take value between 0.1 and $1\frac{J}{N}$.

by every node in every iteration global and local objective function get calculated for this system model. the position of node in sensor field where the event occurred is considered by GOF. Hence, global information is needed by this version. Whereas location of the event within the sensing are of node is tracked by LOF. Objective function is calculated by every node and it depends only on local information termed as Local Objective Function.

For the purpose of simulation we draw concentric circles of inner radius R_c and outer radius R_c to represent sensor nodes. If two circles overlap, then we say, they are connected nodes and thus can communicate with each other. We assume that the target area to be considered is sufficiently larger than the sensing and communication ranges of the sensor nodes, and thus we assume there is no *boundary effect*.

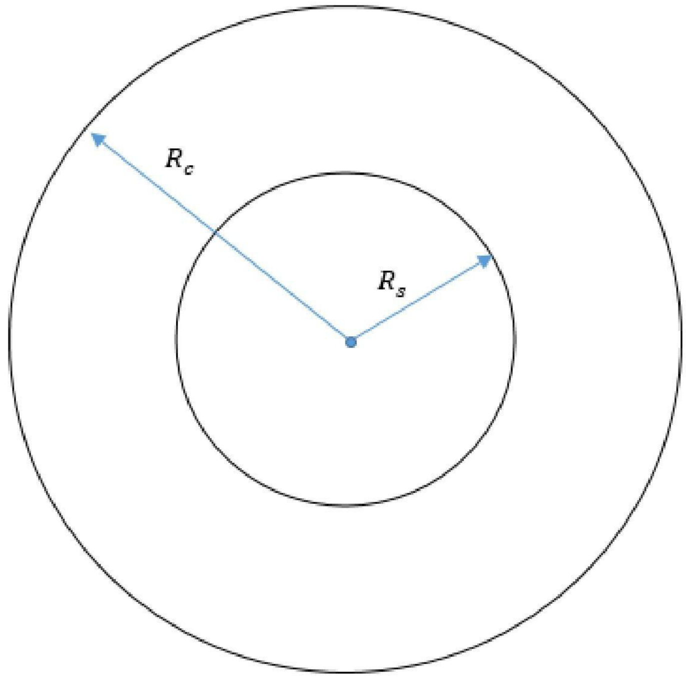


Figure 5.2: A model of a sensor node

We have considered a *homogeneous network* i.e. all the sensors are alike when sensing and communication capabilities are considered in the network, we have considered *individual detection model* in which each node detects an event independently, furthermore a range-based *disk model* is considered for sensing and communication with in R_c distance sensors will detect points for sensing purpose, for communication purpose, no node failure is assumed in the network. sensor nodes initial deployment in the target field is done using *random deployment scheme* with uniform distribution.

For the purpose of connectivity, it is assumed that all the communicational link are bidirectional, and because all the nodes are alike, they have same communication capacities, thus the communication graph can be modeled as Unit Disk Graph (UDG).

Let k is the node density, N nodes are deployed randomly with uniform distribution in the target field of size A, and then the deployment model is in accordance with equation 5.3:

$$N = kA, \text{ where A goes to infinity} \quad \textbf{(5.3)}$$

5.2. Simulation Setup

Simulation is done in MATLAB, the purpose of the simulation is to compare the performance of the proposed algorithm i.e. node deployment using orthogonal teaching learning-based optimization which is a bio inspired optimization method to obtain the best location of nodes for the coverage problem, while ensuring the connectivity of the nodes all the times in the network.

For the purpose of simulation, we have taken isotropic sensors in which sensing area is considered as a circle in 2D or a disc in 3D, binary detection sensing model is taken as a detection model that assumes perfect detection i.e. probability of detection is 1.0 if the point under consideration is within the circle otherwise its treated as 0. The target field is a square field with dimensions 100m X 100m, number of sensor nodes to be deployed is 50, sensing range is 12.5m, communication range is two times of the sensing range, number of maximum runs is 100, maximum velocity of nodes is 10 m/s,

Table 5.1: Simulation Parameters

Number of sensors	50
Sensing range (R_s)	12.5 m
Movement step (c)	0.1
Sensor field size (L x L)	100m x 100m
Number of runs	100
V_{max}	10 m/s
Communication range (R_c)	2 R_c m
Time interval (ð)	5s
Simulation time	5000s
Confidence Interval	95%

5.3. Performance Evaluation

For the purpose of result evaluation, we need to consider the difference between the ideal number of sensors in the specified target field that is equal to (n. N) and the performance parameter is checked by the convergence condition of the Algorithm 3 which satisfies when the count of sensor nodes located is same in the specified area. Here noteworthy point is sensor nodes can have overlapping coverage areas, moreover we are using the mobile sensor nodes so it is important to keep track on the usage of energy at the time of movement. Movement energy is considered to proportional to the energy cost model described in equation 5.2.

The objective function is used for the performance evaluation defined in equation 5.1 that gives the optimal number of fractional of deployed nodes in the specified target field. The result is based on the initial random deployment in the target field then OTLBO is used to get optimal deployment in the field and finally the connectivity preservation algorithm is run to ensure the connectivity during the lifetime of the sensor nodes in WSN. The connectivity preserving algorithm uses different regular node patterns to compare the reachability of nodes to the sink node. The performance is checked assuming that the nodes in the initial phase are disconnected entirely and when the simulation is carried on for different time duration, produces a connected graph. During simulation presence of obstacles in the field is not considered for the connectivity point of view.

5.3.1 Performance Metrics

Two performance metrics, total area coverage and reachability evaluation are taken under consideration for analysis of the protocols are as follows:

- **Area Coverage:** Area covered by sensor nodes divided by total area of the target field.
- **Reachability Evaluation:** Connectivity graph is connected or not during

lifetime of WSN.

5.3.2 Simulation Results

The simulation comparison is done with PSO (Particle Swarm Optimization) which is standard swarm based optimization technique, the simulation is written in MATLAB, the program runs for 1500 iterations.

Equation (5.4) and Equation (5.5) is used to update velocity and position of the particles in PSO algorithm as described in chapter 3.

$$v_{ij}(c + 1) = m (c) \times v_{ij}(c) + c_1 r_{1i}(c) (y_{ij}(c) - x_{ij}(c)) + c_2 r_{2i}(c) (\hat{y}(c) - x_{ij}(c)) \quad \textbf{5.4}$$

$$x_{ij}(c + 1) = x_{ij}(c) + v_{ij}(c + 1) \quad \textbf{(5.5)}$$

Where c_1 and c_2 are acceleration constants, $r_{1i}(c)$ and $r_{2i}(c)$ are random numbers in range [0, 1]. $x_{ij}(c)$ and $v_{ij}(c)$ represents the position and velocity of i_{th} particle in j_{th} dimensions at time c, $y_i(c)$ is the local best position of i_{th} particle and $\hat{y}(c)$ is the global best position. The inertia weight m (c) at time c is set by using equation (11):

$$m (c) = 0.9 - c/MaxNUNber \times 0.5 \quad \textbf{(5.6)}$$

where MaxNuNBer is the maximum number of cycles. PSO algorithms' swarm size is 20 and the acceleration constants are set c1 = c2 = 1.

The results are stored in table 5.2, for the performance measures mean, standard deviation (std) Best and the worst cases are listed for direct comparison. The results show the performance of OTLBO is better than PSO for all 30 independent runs each having 1500 iterations. Initial deployment is taken same for the fair comparison and to avoid the biasness in the results.

Table 5.2: Results of Node Deployment

	stationary sensors initial coverage area	**PSO**	**OTLBO**
Mean	.74	0.93	0.96
Std	0.03	0.013	0.01
Best	0.78	0.95	0.97
Worst	0.69	0.91	0.94

5.3.3. Analysis

The deployment of the sensor nodes which is shown in figure 5.2 is final, each node is given a unique identity to locate on the graph. The network topology is decided by the communication range. The communication graph is connected to ensure the connectivity of the nodes duration the lifetime of WSN.

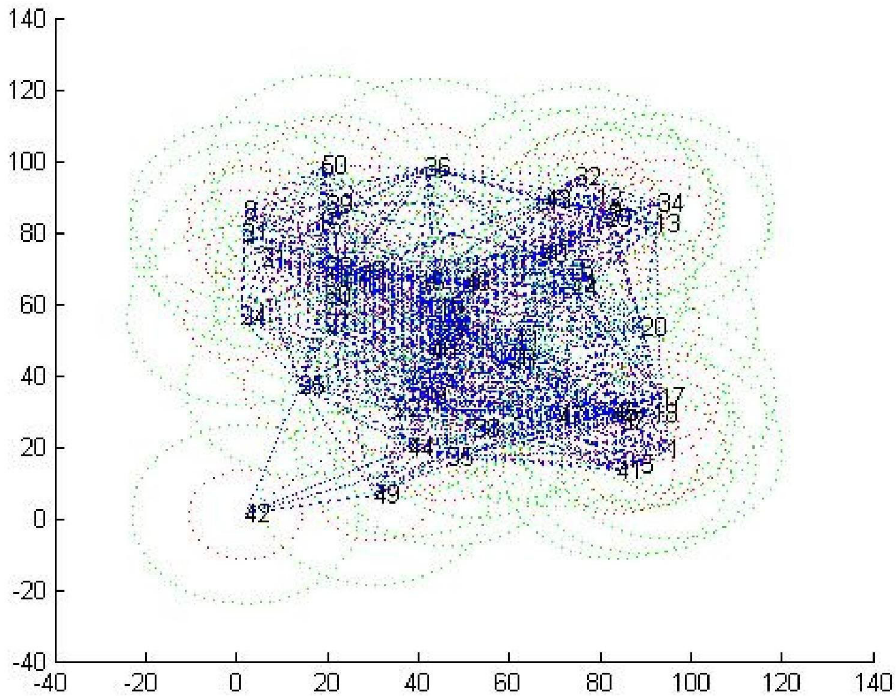


Figure 5.3: Final deployment of sensors

the performance of the proposed approach is compared using two graphs which are plotted to demonstrate the best and worst case scenario. Mean of sample run is taken for 30 runs each one of them consists of 1500 rounds.

In figure 5.4 the graph shows that in the case where sensor nodes are dynamic deployed in a specified field Orthogonal Teaching Learning Based Optimization (OTLBO) outperforms PSO approach, the figure shows the best case where the deployment of the node gives the maximum coverage on the field, given the initial deployment is done randomly and then the nodes they move to obtain their optimal position, then to maintain the connectivity as well the connectivity preservation algorithm is applied on the nodes that causes these nodes to move further at their best location. We have assumed here that no node can be entangled by any of the obstacles that may present in the ground. In figure 5.5, the worst case is shown whereby two above said approaches differ the most possible manner. The graph shows that the performance of the OTLBO still performs better than PSO in the same scenario but for different sets of runs.

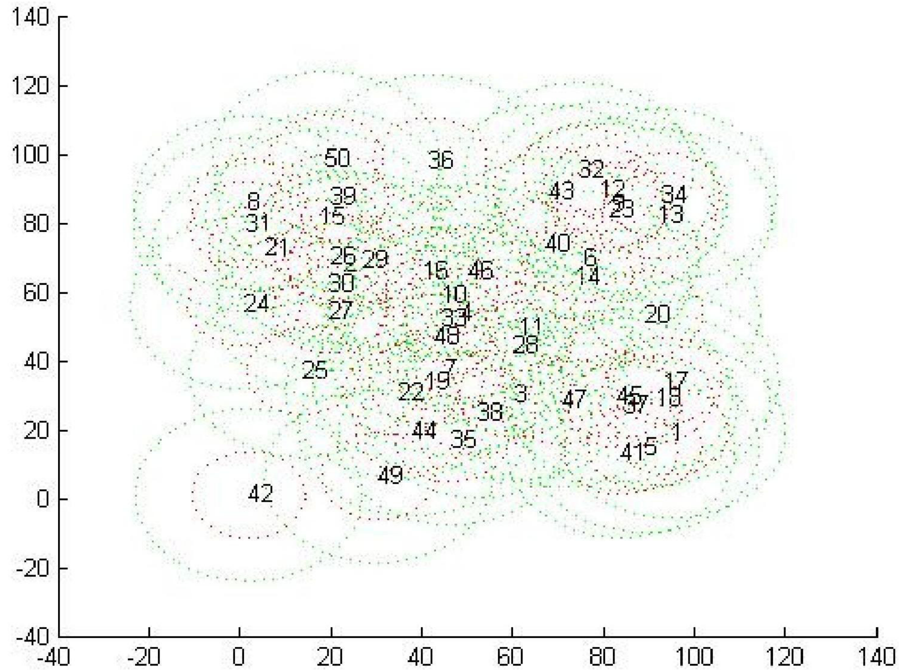


Figure 5.4: Final deployment of sensors without topology

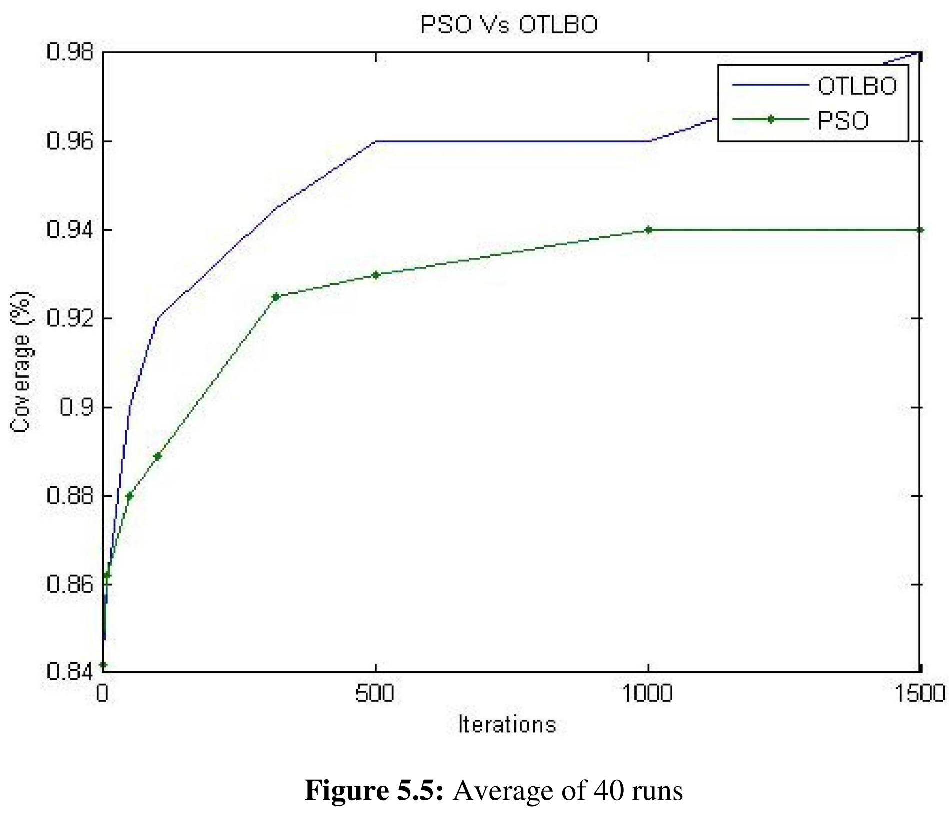


Figure 5.5: Average of 40 runs

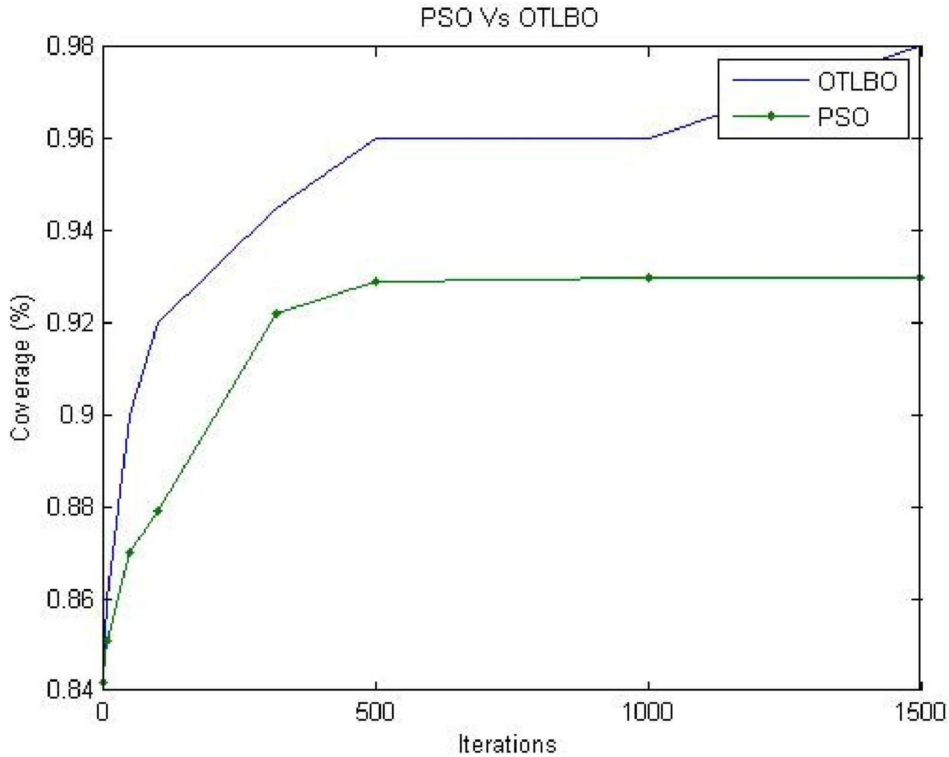


Figure 5.6: The most difference in a run

CHAPTER 6

CONCLUSION AND FUTURE WORK

Coverage is an crucial property in WSN, it's a performance metric of the sensor node deployment scheme. We are concluding that for optimization of different kind of problems like separable, multimodal, unimodal or non-separable OTLBO is a very powerful approach. As compare to like PSO, GA and its variants it results better faster convergence time. In future we can perform it on multi-objective optimization problem and we can also investigate its usage in the field of data mining and other engineering applications. To get better result we apply this approach on the node deployment procedure of WSN.OTLBO improves the convergence rate as compare to TLBO by using orthogonal design on TLBO.

Another important pillar of Wireless Sensor Network is Connectivity. In this work we are proposing connectivity guaranteed deployment technique for mobile sensor deployment. There are two independent parts in Algorithm 4. 1) In Direction computation, based on the application requirement mobile sensors direction is computed. In this regard, we considered area coverage problem only in which the sensor node deployment approach tries to increase the area coverage rate. We proposed the approach which provide the coverage with square almost similar to coverage of regular pattern coverage. In the order to preserve connectivity, we have used a scheme for preserving connectivity, so that at the time of deployment disconnections of nodes can be avoid over a specified time duration in WSN. Nodes maintain their initial connection with neighbors to preserve connectivity. The algorithm chooses the Relative Neighborhood Graph (RNG) since the computation can be locally and it can maintain the required global connectivity also. It's shown by analysis that if we have a efficient physical channel in the network then the always guarantee the connectivity. It's noteworthy that we have considered Unit Disk Graph (UDG) model is used for algorithm description and evaluation but the model can also be replaced by any realistic models. The only thing that is required is that each node must be able to discover its neighborhood node and must be able to compute its neighbor's subset assure to achieve connectivity with higher rate.

The proposed work can be extended for k-coverage and k-connectivity problems whereby we can consider node failure case also. The proposed work can also be extended for taking the energy as a parameter, thus developing an approach for energy efficient approach for node deployment while ensuring the connectivity in the network.

References

[1] Jennifer Yick, Biswanath Mukherjee, Dipak Ghosal, “Wireless sensor network survey”, Elsevier, Computer Networks 52 (2008) 2292–2330.

[2] Jiming Chen, EntongShen and YouxianSun “The deployment algorithm in Wireless Sensor Network: A Survey” Information Technology Journal 2009.

[3] S. Toumpis, T. Tassiulas, Optimal deployment of large wireless sensor networks, IEEE Transactions on Information Theory 52 (2006) 2935–2953.

[4] J. Yick, G. Pasternack, B. Mukherjee, D. Ghosal, Placement of network services in sensor networks, Self-Organization Routing and Information, Integration in Wireless Sensor Networks (Special Issue) in International Journal of Wireless and Mobile Computing (IJWMC) 1 (2006) 101–112.

[5] D. Pompili, T. Melodia, I.F. Akyildiz, Deployment analysis in underwater acoustic wireless sensor networks, in: WUWNet, Los Angeles, CA, 2006.

[6] I.F. Akyildiz, E.P. Stuntebeck, Wireless underground sensor networks: research challenges, Ad-Hoc Networks 4 (2006) 669–686.

[7] M. Li, Y. Liu, Underground structure monitoring with wireless sensor networks, in: Proceedings of the IPSN, Cambridge, MA, 2007

[8] I.F. Akyildiz, D. Pompili, T. Melodia, Challenges for efficient communication in underwater acoustic sensor networks, ACM Sigbed Review 1 (2) (2004) 3–8.

[9] J. Heidemann, Y. Li, A. Syed, J. Wills, W. Ye, Underwater sensor networking: research challenges and potential applications, in: Proceedings of the Technical Report ISI-TR-2005-603, USC/Information Sciences Institute, 2005.

[10] I.F. Akyildiz, T. Melodia, K.R. Chowdhury, A survey on wireless multimedia sensor networks, Computer Networks Elsevier 51 (2007) 921–960.

[11] Mr. Mayur C. Akewar, Dr. Nileshsingh V. Thakur, “A Study of Wireless Mobile Sensor Network Deployment”, IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501 Vol.2, No4, August 2012

[12] X. He, X. L. Gui, and J. An, “A Deterministic Deployment Approach of Nodes in Wireless Sensor Networks for Target Coverage”, Journal of XiAnJiaotong University Vol. 44, No.6, 2010, pp.6-10.

[13] X. M. Guo, C. J. Zhao, X. T. Yang et al, “A Deterministic Sensor Node Deployment Method with Target Coverage Based on Grid Scan”, Chinese Journal of Sensors and Actuators, Vol.25, No.1, 2012, pp.104-109.

[14] Y. Z. Zhang, C. D. Wu, L. Cheng et al, “Research of node deployment strategy for wireless sensor in deterministic space”, Control and Decision, Vol. 25, No. 11, 2010, pp. 1625-1629.

[15] Q. Luo, and Z. M. PAN, “An Algorithm of Deployment in Small-Scale Underwater Wireless Sensor Networks”, Chinese Journal of Sensors and Actuators, Vo. 24, No. 7, 2011, pp. 1043-1047.

[16] X. Wang, S. Wang, and J. J. MA, “Dynamic Sensor Deployment Strategy Based on Virtuai Force-Directed Particle Swarm Optimization in Wireless Sensor Networks”, Acta Electronica Sinica, Vol. 35, No. 11, 2007, pp. 2038-2042.

[17] Y. S. Lin, and P. L. Chiu, “A Near-optimal Sensor Placement Algorithm to Achieve Complete Coverage Discrimination in Sensor Network,” IEEE Communications Letters, Vol. 9, No. 1, 2005, pp43-45.

[18] Y. Liu, “Wireless Sensor Network Deployment Based on Genetic Algorithm and Simulated Annealing Algorithm”, Computer Simulation, Vol. 28, No.5, 2011, pp. 171-174.

[19] W. H. Liao, Y. C. Kao, and Y. S. Li, “A Sensor Deployment Approach Using Glowworm Swarm Optimization Algorithm in Wireless Sensor Networks”, Expert Systems with Applications, Vol. 38, No. 2011, pp. 12180–12188.

[20] A Review on Node Deployment of Wireless Sensor Network Haitao Zhang and Cuiping Liu IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 6, No 3, November 2012 ISSN (Online): 1694-0814

[21] Valeria Loscrí, Enrico Natalizio and Francesca Guerriero, “Particle Swarm Optimization Schemes Based on Consensus for Wireless Sensor Networks”.

[22] Wing-Leung Y, Yuping W. “An orthogonal genetic algorithm with quantization for global numerical Optimizationg” IEEE Trans EvolComput. 2001; 5(1):40–53.

[23] Chandra Satapathy, Anima Naik, and K. Parvathi, “A teaching learning based optimization based on orthogonal design” *SpringerPlus*2013, **2**:130 doi:10.1186/2193-1801-2-130.

[24] TahiryRazafindralambo , Member, IEEE , and David Simplot-Ryl , Member, IEEE “Connectivity Preservation and Coverage Schemes for Wireless Sensor Networks” in IEEE TRANSACTIONS ON AUTOMATIC CONTROL, VOL. 56, NO. 10, OCTOBER 2011.