ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

COLLEGE OF NATURAL SCEINCES

DEPARTMENT OF COMPUTER SCEINCE

Grid Based Node Deployment Approach using Homogeneous Wireless Sensor Network

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This is to certify that the thesis prepared by *Eyoas Atnafu*, titled: *Grid Based Node Deployment Approach using Homogeneous WSN* and A Thesis Submitted to the Department of Computer Science in Partial Fulfillment for the Degree of Master of Science in Computer Science complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee:

Name Signature Date

Advisor:____

Examiner:____

Examiner:____

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Abstract

Wireless Sensor Network is one of the mechanisms to monitor different Wireless Sensor Network application such as environmental and habitat monitoring. In which cooperatively pass their data through the network to a main location or sink where the data can be observed and analysed.

Sensor placement is an important task in WSN applications. The number of sensors and their location will affect the performance, accuracy, and cost of the deployment. One of the important issues in WSNs application is node deployment which decides where the sensor nodes should be placed in order to satisfy the desired requirements like maximize the efficient coverage area ratio and minimize the size of the network and cost. The effectiveness of these networks is determined to a large extent by the coverage provided by the sensor deployment scheme. Determining the required number of sensors to be deployed is a critical decision for wireless sensor networks

In this thesis we develop a homogenius sensor node deployment scheme using grid based deployment scheme where all of the sensor nodes have similar processing and hardware capabilities by placing node in Hexagonal scheme, which cover with minimum number of sensor node and reduces the cost of sensor node. The number of sensor node used evaluated by comparing with previous system in which the proposed work used minimum number of sensor node for covering the region than from previous one. The proposed system consider the shape of the monitored land and we integrate PEGASSIS, hierarchical clustering routing protocol, where each sensor node transfer data to neighbourhood node. We used MATLAB for implementation of the proposed system and performance evaluation. From the evaluation result, the proposed homogenius node deployment approach has a minimum number of node, cost effective and better coverage than the existing shape based node deployment approach.

Keywords: Node Deployment, Homogenous Wireless Sensor Network, Hexagonal scheme, Sensor Node.

Dedication

To Dr. Karlheinz Böhm father of poor people!

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Abbreviations and Acronyms

ADC	Analog Digital Converter
BS	Base Station
CH	Cluster Head
CSMA	Carrier Sense Multiple Access
DEEC	Distributed Energy Efficient Clustering
GNP	Gambella National Park
GPS	Global Positioning System
HWSN	Homogeneous Wireless Sensor Network
LEACH	Low Energy Adaptive Clustering Hierarchy
MAC	Medium Access Control
PEGASSIS	Power Efficient Gathering in Sensor Information System
QoS	Quality of Service
RC	Communication Range
RF	Radio Frequency
RS	Sensing Range
WSN	Wireless Sensor Network

Chapter One: Introduction

1.1 Background

Wireless sensor network (WSN) can be defined as a self-configured and infrastructureless wireless networks to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location or sink where the data can be observed and analysed[1].

WSNs have been considered in many potential applications, such as surveillance, military, agriculture, medical, robotic, biological detection, and traffic, pollution, habitat, and civil infrastructure monitoring [2].

WSNs are composed for tiny nodes, where the nodes sense data from the environment and pass the data to the central processing unit. The nodes are usually equipped with low power, low energy and very little memory[1,2]. WSNs have been widely adopted for monitoring purpose, e.g., to monitor the environment, habitat, greenhouse, water networks and personal health.

WSN is one of the mechanisms to monitor environmental and habitat monitoring for different wild life [1]. Deploying sensor networks is a substantially more economical method for conducting long-term studies than traditional, personnel-rich methods. It is also more economical than installing many large data loggers. Currently, field studies require substantial maintenance in terms of logistics and infrastructure. Since sensors can be deployed and left, the logistics are reduced to initial placement and occasional servicing. WSN may organize themselves, store data that may be later retrieved, and notify operates that the network needs servicing. Sensor networks may greatly increase access to a wider array of study sites that are often limited by concerns about disturbance or lack easy access for researchers.

One of the important issues in WSNs application is node deployment which decides where the sensor nodes should be placed in order to satisfy the desired requirements like maximize the efficient coverage area ratio and minimize the size of the network and cost. The effectiveness of these networks is determined to a large extent by the coverage provided by the sensor deployment scheme. Determining the required number of sensors to be deployed is a critical decision for WSNs [3]. Therefore, the positions of sensor nodes are determined before deployment and the sensors are manually placed. The number and positions of sensor nodes can determine many basic properties of a WSN, such as coverage, connectivity, cost and lifetime .

Generally, deployment in WSN can be deterministic, namely pre-determined, or non-deterministic [4]. The pre-determined deployment, where the locations of sensor nodes are specified and it usually used in a friendly environment and when nodes are expensive. When the environment is dangerous and inaccessible, deployment using helicopters or automatic vehicles is done which is non-deterministic[4].

Grid based deployment is a deterministic deployment approach which is suitable for moderate to large-scale application, where individual sensors are placed exactly at predetermined points [5]. It is a cost-effective deployment approach because the sensors are deployed according pre-determined plan. However Random deployment applicable for large-scale application and mostly in hostile environment such as military zone. This approach works by throwing the sensor through Airplane or helicopter as result it is not cost effective and it has minimum coverage area cause of the placement of sensor.

In [4], it has state that grid deployment is an attractive approach for moderate to large-scale coverage-oriented deployment due to its simplicity and scalability. For the coverage performance, grid-based deployment schemes are considered as a good deployment schemes in WSNs . Based on these considerations, we focus on popular grid layouts such as rectangular-grid, square-grid, triangular-grid, and hexagonal-grid. From the above grid deployments, Hexagonal deployment has the best deployment scheme, because it covers maximum area of region with minimum sensor node and it has low overlapping issue. As described in [6] hexagonal grid deployment provides better area coverage than other schemes and exhibits higher network coverage than the remaining schemes.

Grid based approach makes it different from other deployment approach as it cover large space of the monitored region and it uses maximum coverage area regarding the above problem. Grid based WSN node deployment is suitable for different WSN application. In this regard, deployment as a result sensor node to provide complete area coverage, enhancing connectivity issue and easy deployment is a basic issue to be addressed.

In this research, we propose Hexagonal Grid based WSN node deployment scheme will be conducted. So, in our scheme we determine number of nodes, position and we deploy nodes based on the shape of the land in hexagonal pattern. Since hexagonal lattice has small overlapping area, we can cover large area with small number of nodes.

1.2 Motivation

Ethiopia is one of the countries that have efficient resources; among them is wild life resource, but these resources lack proper documentation about the status of wild Animals. Wild animals have important for our country in different ways such as to increase our economy in tourism industry, for medical and scientific research, ecological purpose etc. These days in Ethiopia, there are different biodiversity species, which attract many foreigners, but less attention is given for the field of monitoring habitat and environment.

A number of approaches, architecture and models have been proposed on node deployment for WSNs. But there is less work done regarding considering different grid shapes of a given monitored region belong to deterministic node deployment/controlled placement (i.e., when the node is carefully and deliberately positioned to serve its purpose).

Hence, in this research work we are motivated to minimize number of nodes, connectivity of network and coverage of sensor node deployment approach by applying homogenious wireless sensor nodes and hierichical based routing protocol.

Statement of the Problem

Among the challenging issue exist in WSN is how to deploy a sensor nodes in the specified area and having minimum sensor nodes in the network.

Most of node deployment approaches of WSN doesn't properly mitigate the criteria for efficient WSN deployment, and their work mostly concerns about network lifetime or enhancing the battery of each sensor node [3]. However recent researches[3] prove that minimum number of sensor node that have maximum coverage area of deployment has huge value for efficient WSN[3]. Minimizing the number of WSNs are very much useful in real deployments because they are closer to real life situations. This shows that there is a need to have efficient deployment scheme which considers the shape of monitored area and enable us to use minimum sensors in Homogenous WSN[4].

The other issue that doesn't concerns in most of research regarding WSN are the problem of overlapping which must be related with deployment scheme method, the proposed system addresses those problem by using efficient deployment scheme. In addition to the node deployment, a routing protocol for homogenious WSN that has better network lifetime will be selected based on the proposed scheme. The necessity of using technology in different WSN application in a developing country like Ethiopia can be seen as the optimal solution.

1.3 Objectives

General Objective

The general objective of this research is to develop Grid Based Node Deployment model using Homogeneous WSN.

Specific Objectives

To achieve the above general objective, the following specific objectives are identified:

- ✓ Study the works and the current practices that have been done in the area of sensor node deployment in WSNs
- ✓ Design architecture for the proposed node deployment using WSN
- ✓ Develop a simulated prototype for the proposed node deployment model for evaluation..
- ✓ Evaluate the proposed system using simulation experiment.

1.4 Methods

The methods that will be used in order to achieve the objectives are:

Literature Review

We will review different literatures done on sensor node deployment to have an in-depth understanding of the state of the art and to find best approaches that can solve the stated issues.

Software and simulation tools

To implement the proposed system we reviewed different literatures and we select different tools a detailed description of these tools is presented below.

MATLAB 8.1.0 (R2013a): MATLAB allows plotting of functions and data, implementation of algorithms and it has a number of tool boxes uses in algorithm development,

Google Earth: is a popular free Internet application, which offers a library of satellite imagery, aerial photography, and other geographic data of the entire Earth's surface over the internet.

ArcGIS 9.3.1: ArcGIS can be used to store geographic data, make maps and analyze spatial data, discovering geographic information and managing geographic information in a database

Prototype Implementation

The implementation of the proposed approach will be done using MATLAB software.

1.5 Scope and Limitation

The scope of this research is the design and implementation of a deterministic sensor node deployment using WSN system..

However, this work does not focus on energy consumptions, network lifetime, etc., and also, the propose system limited to Hexagonal deployment scheme.

1.6 Application Results

The completion of this research will add value to different WSN application such as the field of habitat monitoring in different regions of Ethiopia which inspired Grid based node deployment approach. WSN can be solution to many complex problems. By monitoring habitat, ecologists can find tremendous hidden aspects of environment that can be beneficial for the growth of society.

In this thesis, we focus on node deployment approach that enables to produce a grid based node deployment scheme for monitored area in diffirent application . The result of this work reduces problems associated with inefficient monitoring of habitat and environment to maximize the overall arrangement on the monitored region and it helps problem encountered in inadequacy of data.

1.7 Organization of the Thesis

The rest of the thesis is organized as follows: Chapter 2 presents the literature review on WSNs, communication architecture of WSN, WSN components, Energy consumption issues in WSN, classification of sensor node, sensor node deployment and routing protocols. Chapter 3 discusses about different research works related to wireless sensor node in habitat monitoring and shape based sensor node deployment in WSNs. In Chapter 4, we present the design of the proposed system. It discusses about the design factors, Requirements for proposed architecture, architecture of the system Chapter 5 presents an implementation and discussion of the result and its evaluation. Finally, in Chapter 6 conclusions, contributions and future work are presented .

Chapter Two: Literature Review

In this Chapter, a review of literatures on WSNs, Architecture of WSN,sensor nodes components and Habitat monitoring. Then, an introduction on one of the important tasks in WSNs called sensor node deployment is described. Furthermore, the different routing protocols for WSN also reviewed and presented

2.1 Wireless Sensor Network

WSN according to [1] defined as it composed of many tiny, low-power nodes that integrate sensing units, transceivers, and actuators that have minimum power processing and sufficient capabilities of communication. They also deployed where there is interest to collect data from the surrounding area, after that it will be sensed to base station. Lack of sufficient on-board properties, procedure and manipulating these devices is difficult, while as the same time providing other interest [7, 8]. Then the data is transferred through different hops, to sink, after that wireless sensor node linked to the main access through gateway. Each node can be dynamic or stationary.

A WSN is a type of wireless network which consists of a collection of wireless devices called sensors which are capable of sensing, processing and communicating[7].

WSN has it own design and resource constrains [8]. Design constrains are related with the purpose and the characteristics of the installation environment. The environment determines the size of the network, the deployment method and the network topology[8]. Each property is arranged minimum energy level, low linkage, minimum capability and computing properties. Research efforts have been done to address the above constrains by introducing new design methodologies and creating or improve existing protocols and applications [7, 9].

A sensor node is a low power which own-directed device that can used a wireless sensor node device that have huge amount of distributed network [9,10]. Each wireless sensor node has embedded machine that convey information to user who access the data and convey data to the users, and it has restricted computing and processing capabilities.

Each sensor node collectively forms a network. As we have shown in the following wireless sensor node, system architecture of Figure 2.1 described. It composed of different sensing device and base station that linked with one with other to collect the surrounding information and to announce general decision about the area of interest.

2.2 Communications Architecture for WSNs

We mentioned above that a WSN is a network made of a numerous number of sensor nodes that have capability of sensing environment, linking and power of computing different things [8].These motes are found in sensor field situated far from the user as shown in Figure 2.1.

The Sensor nodes that form the sensor network. The main goal of each sensor nodes is sensing the environment, communicating with each other through wireless medium, measuring the surrounding environment, gathering data and transferring discrete information through base station to user who access the device.

The base station linked or communicated to user through different communication mechanism. The base station must be put around the sensor field in order to access efficiently. Then the data that are gathered from the sensor node delivered to the base station by multi-hope infrastructure system through the base station.

A Phenomenon is defined as an entity of interest which used to collect some measure about the specific things and sensed, observed and analyzed by the sensor.

The user who is interested in obtaining information about specific phenomenon to measure/monitor its behavior

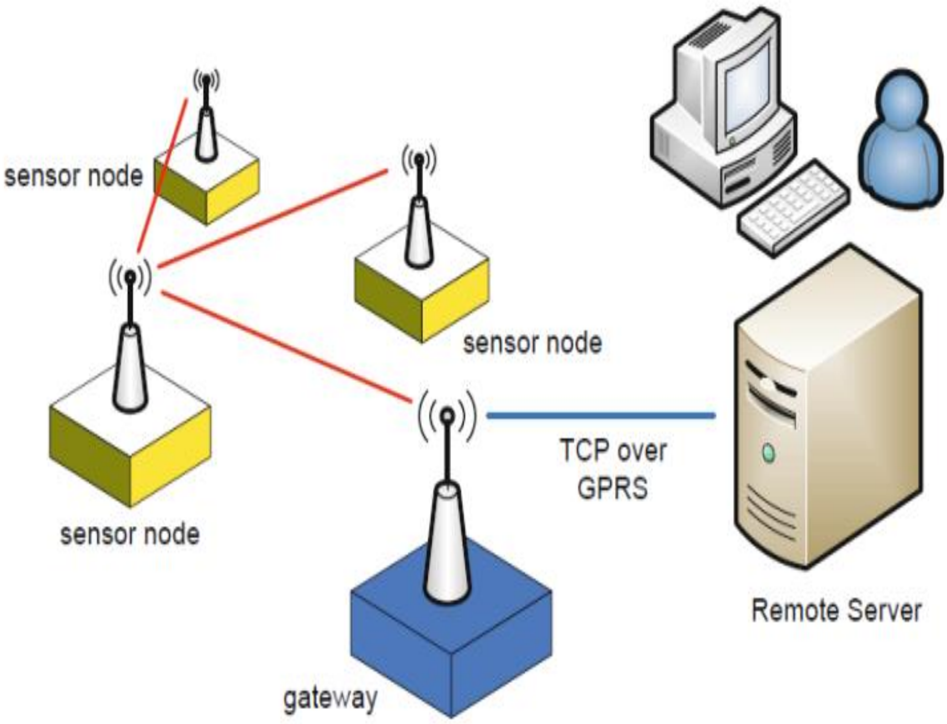


Figure 2.1: *WSN System Architecture*

A multi-functional device that have full energy efficient is Motes [1]. Using Motes in different application areas are widely applied. Each of Motes gather the data from surrounding area of interest in order to apply general application goal. Each Motes communicates with other Motes using a device called transceiver. The Motes are ordered in hundred or even thousands in wireless sensor node. In comparison with sensor networks, Ad Hoc networks will have less number of nodes without any infrastructure

2.3 Components of WSN system

Wireless sensor node has different components among them is sensor node, actor node, cluster node, rely node, base station and gateway [11].

Sensor node: it has a potential of computing data processing, collecting of efficient data and communicating with other nodes within the network. A sensor nose have the following properties capability of about 4-8 MHz,RAM of 4 KB, 128 KB flash and mostly radio frequency of 916 MHz

Relay node: Appeared at the center of node which used to communicate with the adjacent node across the area. A rely node is a special type of field device that does not have process sensor or control equipment and as such does not interface with the process itself. It has a property of 8 MHz of processor speed, RAM of 8 KB, 128 KB of flash and radio frequency of 916 MHz

Actor node: It is a high end node used to perform and construct a decision depending upon the application requirements. Actor nodes are known by sufficient devices, which has identified by high quality processing potential, high range of transmission and higher battery lifetime. Actor node have the following property: 8 MHz of processor, RAM of 16KB, 128MB of flash and radio frequency of 916 MHz [11].

Cluster head: the main function of cluster node are to perform data fusion and data aggregation. Based on the system requirements and applications, there will be more than one cluster head inside the cluster. Cluster node have the following property: 4-8 MHz of processor, RAM of 512KB, 4MB of flash and radio frequency of 2.4 MHz. The cluster heads differ from other node it has highly reliable, high level security and it can be trusted by all nodes within the network.

Gateway: Sensor network and outside network connected by using a device called Gateway. Compared with the sensor node and cluster head the gateway node is most powerful in terms of program and data memory, the processor used, transceiver range and it can be extended using external memory. Gateway have the following property: 16 MHz of processor speed, RAM of 512 KB, 32MB of flash and mostly radio frequency of 2.4 MHz

Base station: this nodes have computation energy and capabilities of processing different things.

Wireless sensor nodes are equipped with sensing unit, a processing unit, communication unit and power unit [12]. Each and every node is capable to perform data gathering, sensing, processing and communicating with other nodes. The sensing unit senses the environment, the processing unit computes the confined permutations of the sensed data, and the communication unit performs exchange of processed information among neighboring sensor nodes. The basic building block of a sensor node is shown in Figure 2.2 [12].

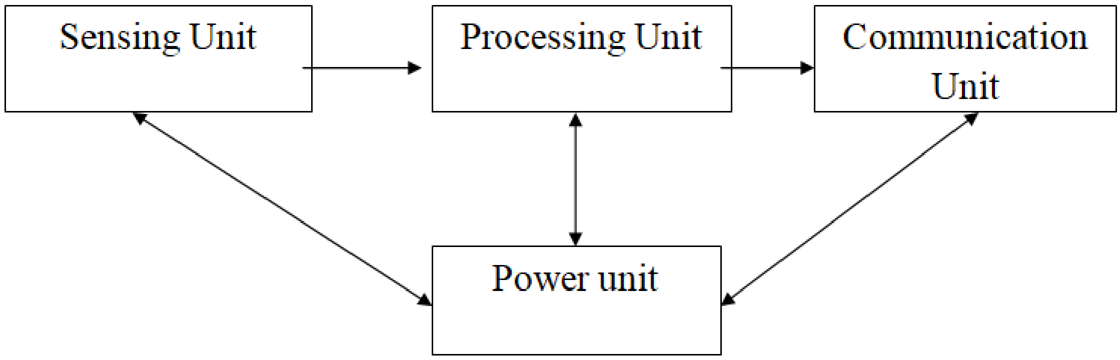


Figure 2.2: *Basic Building Blocks of Sensor Node*

A sensor node is made up of four basic components such as sensing unit, processing unit, transceiver unit and a power unit which is shown in Fig. 2.2. It also has application dependent additional components such as a location finding system, a power generator and a mobilizer. Sensing units are usually composed of two subunits: sensors and analogue to digital converters (ADCs). The analogue signals produced by the sensors are converted to digital signals by the ADC, and then fed into the processing unit.

The processing unit is generally associated with a small storage unit and it can manage the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network. One of the most important components of a sensor node is the power unit. Power units can be supported by a power scavenging unit such as solar cells. The other subunits, of the node are application dependent.

Thermal sensors, Magnetic sensors, Vibration sensors, Chemical sensors and Light sensors are integrated by sensing unit.

The measured parameters from the external environment by sensing unit of sensor node are fed into the processing unit. The analog signal generated by the sensors are digitized by using Analog to Digital converter (ADC) and sent to controller for further processing. The processing unit is the important core unit of the sensor node. The processor executes different tasks and controls the functionality of other components. After that the required services are pre-programmed and loaded into the processor of sensor nodes. The energy utilization rate of the processor varies depending upon the functionality of the nodes. The variation in the performance of the processor is identified by the evaluating factors like processing speed, data rate, memory and peripherals supported by the processors. Mostly in commercial motes the following property of ATMEGA 16, ATMEGA 128L, MSP 430 controllers are used [1].

The computations are performed in the processing unit and the acquired result is transmitted to the base station through the communication unit.

In communication unit, a common transceiver act as a communication unit and it is mainly used to transmit and receive the information among the nodes and base station. Transmit, Receive, Idle and Sleep are state that used in communication unit.

Environmental monitoring has been an important part of WSN applications. It grows widely along with the development of recent technology. In general, environmental monitoring system controls and monitors environment parameters such as temperature, humidity, light and pressure.

Habitat monitoring is a monitoring activity that applied in the area wild life to monitored properly their area from different issue. Its one of the mechanisms to monitor our surrounding environment. Mostly Habitat means area in which an animal or plant naturally properly grows or lives with freedom. Therefore, monitoring habitat important to get different value from our wild life or plants. Pollution can cause negative impact to health and ecological balance. Therefore, removing pollution is important to manage the environment properly.

2.4 Energy Consumption issues in WSN

Energy consumption is the most important factor to determine the life of a sensor network because usually increasing lifetime is essential for the sensor node [13]. However, in scenario it's difficult to optimize energy because its concerns different things. It involves not only reduction of energy consumption but also extending the life network itself as long as possible. Design and operation must be aware of the optimization in any aspect. Because the energy awareness involves groups of communication sensor nodes and the entire network including individual nodes that exist within the network.

The four sub-systems of sensor nodes are the following [14]:

Computing subsystem: the function computing subsystem are for the control of the sensors and implementation communication protocols. Microprocessor (microcontroller unit, MCU) exists in this subsystem. MCUs usually operate under various modes for power management purposes. Consumption of power, the energy consumption level of the various modes and the battery lifetime of each nodes must be considered in these operating modes.

Communication subsystem: in this subsystem it contains short-range radio system, this system communicates with neighboring nodes and the outside world. Radios can operate under the different modes and with different circumstances. In short-range radio system when the transmission and receiving is out of work, before putting in the Idle modes it is important to completely shut down the radio for saving power.

Sensing subsystem: in this subsystem it contains group of sensors and actuators. The nodes are linked to the outside world. Energy consumption can be reduced by using low power components and saving power at the cost of performance which is not required.

Power supply subsystem: the function of this subsystem to supply power to the node using battery. It should be seen that the amount of power drawn from a battery is checked because if high current is drawn from a battery for a long time, the battery will die faster even though it could have gone on for a longer time. Usually the rated current capacity of a battery being used for a sensor node is less than the minimum energy consumption. The lifetime of a battery can be increased by reducing the current drastically or even turning it off often.

There are different protocols and algorithms have been studied around the world in order to reduce overall energy consumption of the sensor network. The lifetime of a sensor network can be increased significantly if the operating system, the application layer and the network protocols are designed to be energy aware. One of the main issues these protocols and algorithms have to be aware of the hardware and able to use special features of the microprocessors and transceivers to properly minimize the sensor node's energy consumption that exist within the network. In these case we can reach a custom solution for different types of sensor node design. Each sensor network exists in different types accordingly the way each sensor nodes are deployed. Because of the issue, it may lead to the different types of collaborative algorithms in WSNs arena.

2.5 Classification of Node Deployment

The most well-known node deployment techniques are static deployment scheme and dynamic deployment scheme for the placement of sensor nodes in the deployment area. The static deployment is a deployment strategy that works based on choosing the best location for SNs, and the position of the SNs is not changed throughout the lifetime of WSNs. After deploying, the sensor node there is no movement from one place to other, which is used to properly maintain the sensor, node if there is any damage or corrupted. Deterministic deployment and random deployment the main well-known static deployment scheme that used in different wireless sensor node application. The deterministic deployment schemes firstly check the environment or the deployment area and then deploy properly accordingly analyzing the area of deployment. Among the studies on deterministic SN deployment based on the target coverage as presented in [3] .In order to make the WSNs get the maximum performance, SNs need automatically move to proper location, and then start to work.

In other case in random deployment, sensor nodes are thrown randomly from air plane or helicopter to the monitored area and then using a different of optimization algorithm. In order to find optimal position of sensor node we have to use different the following optimization algorithm: virtual force algorithm, virtual force-oriented particles algorithm, simulated annealing algorithm, particle swarm optimization algorithm and simulated annealing genetic algorithm [15].

2.6 Sensor Node Deployment

The node deployment strategy decides what type of node is needed and where it should be deployed in order to achieve performance that meets the user's requirements. The goal of node deployment is different in accordance with the role of the node. Coverage of sensor is one of the main objectives of sensor node. The most known coverage categories are three. These are area coverage, point coverage, and barrier coverage. There are different works that deals with area coverage among them are [16]. Biagioni and Sasaki [17] review regular deployment topology such as hexagonal, rings, and stars. They study coverage and connection properties under normal and partial failure conditions. Their work analyzes that regular node placement simplifies the analysis due to its symmetry even if it often leads to suboptimal configurations.

The work of Howard et al. [18] implemented an incremental deployment algorithm that deploys nodes one at-a-time into an unknown environment, and target location determined by information gathered from previously deployed sensor node in the monitored region. With minimum number of sensor node field maximized by Virtual Force Algorithm with concept of attraction and repulsion [7]. In this study there is physical react for change where there is interest within the sensor field, which is main the main of task in distributed algorithms for mobile-sensor where Butler and Rus [19] developed. The concept of relocating sensor within the area of the object can maximize the detection rate. This has the disadvantage of increasing energy consumption by moving whenever an event occurs. By maintaining, the original sensing topology Wang et al. [20] developed a framework for relocating mobile sensors in a timely, efficient, and balanced manner

The other study is based on the environment factors such as climate and terrain [21]. The effect of environmental factors does not properly quantify in their work, which have only limited effect on the deployment area of sensor node.

The goal of relay node deployment is to maximize network connectivity and operation time. The work of Hou et al. [22] proposed a 2-tier sensor network architecture which consisting of sensor nodes that transmit data to AFNs and aggregation-and-forwarding nodes (AFN) relay this data. Tang et al. [23] proposes the deployment problems of relay nodes that connected to all nodes that exist in the network. Lloyed and Xue [24] dealt with model generalization in which relay nodes have longer transmission distances than sensor nodes.

2.7 Objective of Sensor Node Deployment

2.7.1 Area Coverage

Difficult to get maximum coverage 'n' wireless sensor node most of time, so most of the work has based on this problem in the deployment of SNs. Properly covering the area is huge issue which related to energy saving, connectivity, and network reconfiguration. Covering mainly concern with how to deploy the SN to achieve active coverage within the monitored region so that at least one SN monitors every sensor node point in the service-area.

A good coverage is indispensable for the effectiveness of WSNs. According to the work of et al. [8], proposes the coverage area is assumed to be of a disk shape structure and the transmission range of sensor node are equal to the radius of the disk shape deployment area, and the ratio of the area covered by node against whole area of deployment is the index of the monitoring coverage area.

In WSN, the measure of permanence and Quality of Service deals with scenario of properly managed coverage. As previously discusses coverage in a WSN is to ensure that the place of interest (RoI) is monitored with high reliability in order to get the necessary information on the monitored region [10]. Coverage issues can be commonly classified into two types: target coverage problem and area coverage problem. The former ensures the monitoring of only certain specific points which have fixed positions in the area of interest, while the latter is concerned with the supervision of the whole area of deployment. Q-coverage or simple coverage are categorized under Target coverage.

2.7.2 Network Connectivity

The connectivity metric is as important as coverage in WSNs. To say a WSN connected if and only if there exists at least one route between each pair of nodes unless it's not connected [25]. Thus, connectivity depends on the existence of paths and can therefore be directly affected by changes of topology. Maximizing coverage with the connectivity constraint an optimal deployment strategy in wireless sensor node.

Communication between SN and BS, BS and the client, client and server the basic issue in connectivity WSN [7]. In the past the issue of network connectivity is not difficult problem. It considered the complete coverage and connectivity of the SNs, which are located within the identified radius. Due to which only routing between SNs and BS is considered to send the data.

2.7.3 Network Lifetime

Optimizing energy consumption is one of the most important requirements of WSN. Hence, there is a need for energy efficient communication and routing techniques that increase the network lifetime. The major cause of energy waste is collision. Receiving more than one packet simultaneously, these packets are termed collided, whether they coincide completly or incompletely. After that all the containers that are responsible for the collision have to be discarded and the packet must retransmit, which increases energy consumption. The other issue for wasting of energy is over-hearing, which means the destination of packet misused or delivered to nodes that are destined to other nodes. Control-packet overhead is the third energy waste occurs. According to the work of [10] identifies differences of the behaviour of agent-based protocols in real deployment, which ignores the lower layers effects, such as packet collision and overhearing.

2.8 Routing Protocols in WSNs

In general, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network catagory [7]. In flat-based routing, there is no different roles to execute which means all nodes are typically assigned equal roles or functionality. In hierarchical-based routing, nodes will play difierent roles in the network. The role of one node differs from another and each node executes their own task. In location-based routing, position is main issue within the sensor node. sensor nodes' positions are exploited to route data in the network. if certain system parameters can be controlled in order to adapt to the current network conditions and available energy levels we say a routing protocol is considered adaptive [7].

A routing protocol can be categorized in the following: multipath-based, query-based, negotiation-based, QoS-based, or coherent-based routing techniques depending on the protocol operation. In other case, routing protocols can be classifled into the following three groups: proactive, reactive, and hybrid protocols depending on how the source finds a route back to the destination [7].

In proactive protocols, all routes must be computed before they are really needed, while in reactive protocols, routes are computed on demand. Hybrid protocols use a combination proactive protocols and reactive protocols. Choosing the best protocol must consider whether sensor nodes are static deployment strategy or dynamic deployment strategy. Route discovery and setup of reactive protocols uses huge amount of energy.

The other one is cooperative routing, where the nodes send data to a central node where data can be aggregated and may be subject to further processing, hence reducing route cost in terms of energy use. Many other protocols rely on timing and position information. We also shed some light on these types of protocols in this paper. In order to streamline this survey, we use a classiflcation according to the network structure and protocol operation (routing criteria). The classification is show as in Figure 2.3 [26].

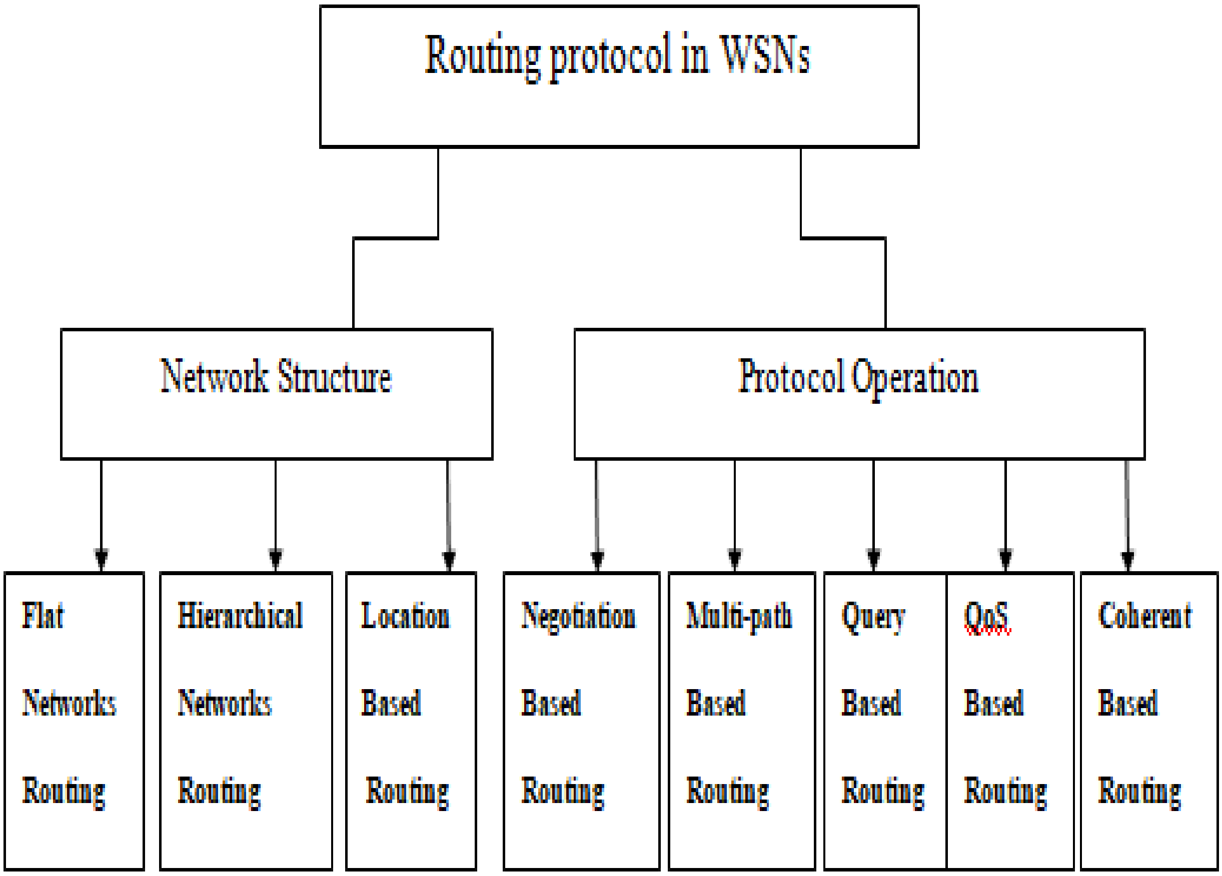


Figure 2.3: *Routing protocols in WSNs*

Some of well-known routing protocol used in WSN [27]:

Low-Energy Adaptive Clustering Hierarchy (LEACH)

Collecting and delivering data to the base station is task that can be designed by Low-energy adaptive clustering hierarchy (LEACH) [27].

The main objectives of these protocol are:

- network lifetiem extention
- minimizing the energy consumption by each network sensor node within the network.
- Applying data aggregation to reduce the number of communication messages across the network.

Hierarchical approach used to achieve the above objective of LEACH to organize the network into a set of clusters. Each cluster is managed by a selected cluster head. The cluster head assumes the responsibility to carry out multiple tasks. The first task consists of periodic collection of data from the members of the cluster. After collecting the data, the cluster head aggregates to remove redundancy among correlated values. The other task is to transmit the aggregated data directly to the base station over single hop. The final task of the cluster head is to create a TDMA-based schedule where each node of the cluster is assigned a time slot that it can use for transmission. After that, the cluster head announces the schedule to all cluster members through broadcasting in order to start the next task within the cluster. To reduce the likelihood of collisions among sensors within and outside the cluster, LEACH nodes use a code-division multiple access–based scheme for communication[27].

The two distinct phases of LEACH operation are: The setup phase, consists of two steps, cluster-head selection and cluster formation. The other one is, the steady-state phase, focuses on data gathering, aggregation, and delivery to the base station. The duration of the setup is assumed to be relatively shorter than the steady state phase to minimize the protocol overhead.

At the beginning of the setup phase, a round of cluster-head selection starts. To decide whether a node to become cluster head or not a threshold T(s) is addressed as follows:

Where r is the current round number and G is the set of nodes that have not become cluster head within the last 1/popt rounds. At the beginning of each round, each node which belongs to the set G selects a random number 0 or 1. If the random number is less than the threshold T(s) then the node becomes a cluster head in the current round.

Threshold-sensitive Energy Efficient Protocols (TEEN and APTEEN):

These are the combination of Two hierarchical routing protocols called TEEN (Threshold-sensitive Energy Efficient sensor Network protocol), and APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol) [27].

Mostly these protocols used for time-critical applications. The problem In TEEN is, the data transmission is done less frequently even sensor nodes sense the medium continuously [27]. The hard threshold takes member value of sensed attribute from each cluster head. The small change in the value of sensed attributes, which have switch on its transmitter and transmit. Reduced number of transmissions by interest of hard threshold allows the nodes to transmit. In order to exist change in the sensed attribute each soft threshold must be reduce the number of transmissions. Therefore, when energy consumption increases the soft threshold should get more accurate picture of the network. Energy efficiency and data accuracy trade-off must be controlled. Because the new values the parameters broadcast when the cluster-head are changed. The problem of theses protocols are the nodes will never communicate, and the user will not get any data from the network at all when the thresholds are not received.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS):

As shown Figure 2.3, Power-efficient gathering in sensor information systems (PEGASIS) and its extension, hierarchical PEGASIS, which is hierarchical routing protocol and a family of routing and information-gathering protocols for WSNs [27]. The main objectives of PEGASIS are two fold. The protocol aims at extending the lifetime of a network by achieving a high level of energy efficiency and uniform energy consumption across all network nodes.

The PEGASIS uses homogeneous network model where all sensor node of have the same ability of sensing range and computing power, and a set of nodes deployed across a geographical area. Each Nodes are assumed to have global knowledge about other sensors' positions and ability to control their power to cover arbitrary ranges. CDMA-capable radio transceivers equipped with each nodes.

The nodes' responsibility is to gather and deliver data to a sink, typically a wireless base station. Reducing energy consumption and delivering the aggregated data to base station with minimal delay is the goal each node in this protocol while balancing energy consumption among the sensor nodes. The other difference from other routing protocol is PEGASIS uses a chain structure.

Directed Diffusion:

This routing protocol is data-centric which used for collecting or gathering information and dissemination in WSNs [27]. The main function of this protocol is it extend the network lifetime each sensor node that exist in the sensing field. This must be done using message exchange and interaction of between nodes within the network. The function of this routing protocol is realized robust multi-path delivery and adapting minimal subset of network. Energy saving combined with the ability of the nodes to aggregate response to queries advantage of this protocol.

We have to consider different things when using this protocol such as data messages, gradients, interests and reinforcements. Using subscribe information and publish the main method for inquirer expresses their interest. From person to person, each inquiry differs based on query and interrogation.

Geographic Adaptive Fidelity (GAF):

This routing protocol works based on energy aware location-based and it mainly designed for mobile ad hoc networks, sometimes it applicable to sensor networks as well [27]. The network area is first divided into fixed zones and forms a virtual grid. As previously discuss each node collaborate with other node in which they play different tasks within their zone.one mechanism to consider this is, nodes will elect one sensor node to stay awake for a certain period of time and then they go to sleep.

This node is responsible for monitoring and reporting data to the BS on behalf of the nodes in the zone. By the above mechanism, GAF conserves their energy in their network without affecting the level of routing fidelity.

Distributed Energy-Efficient Clustering

This protocol works for heterogeneous WSN. In DEEC, each cluster-head chosen by ratio of between energy of each node and average energy of WSN [27].

In this protocol, node containing more energy has more probability to be a cluster head. DEEC does not need full energy information at every time though the choice of cluster head.

It provides good performance in the networks containing normal and advanced nodes. In DEEC, the CHs (Cluster Head) chosen by a possibility based on the ratio between the remaining energy of every node and the average energy of the WSNs. The dissemination of initial and remaining energy of every node must be considered for rotating round number of each sensor. As a result, in order to become a cluster head, the sensor node must have maximum initial energy and they also must have remaining energy.

2.8.1 Performance Metrics of Routing in WSNs

The quantifiable parameters of routing performance are measured by performance metric [27].

Network Lifetime: Network lifetime described by number of aggregated data round until x% of sensor die, where x is calculated by the system analyzer. For example, in different WSN application when all nodes operate at the same time is vital, when the first sensor is drained of its energy from the given round, we call it lifetime.

Data accuracy: The definition of data accuracy depends on the specific application for which the sensor network is designed.

Latency: is defined as the delay involved in data transmission, routing and data aggregation. It can be measured as the time delay between the data packets received at the sink and the data generated at the source nodes.

Average Energy Dissipated: This metric shows the average dissipation of energy per node over time in the network.

Total Number of Nodes Alive: This metric is also related to the network lifetime. It gives an idea of the area coverage of the network over time.

Bandwidth, Capacity and Throughput: These indicate the capacity of data which can be sent over a link within a given time, however since the data size is very small bandwidth rarely matters.

Hop Count: as the name indicate it used to determine the cost of path and energy consumed within the communication process.

As we know the design of routing protocol is very difficult task to do, there are many different issues that affect. So, we have to consider the following issue such as node deployment, scalability, network dynamics, Quality of Service, data aggregation, data delivery models, node capabilities, node/link heterogeneity, data reporting model, energy consumption without losing accuracy, transmission Media, coverage, fault tolerance [24, 27,28].

2.9 WSN Simulation Software

In this part we introduced the main simulation software that used in WSN and We basically focus on free, open-source, simulation tools [29,30].

NS-2 - NS-2 is a wireless simulation software that supports a wide range of protocols and grouped in non-specific network simulator. For configuration and script purpose NS-2 uses OTcl and it supports paradigm of reusability. One of the main known function of NS-2 is support of communication protocol models, among non-commercial packages. It includes both ad-hoc and WSN protocol. NS-2 has been an essential testing tool for network research and, so, one could expect that the new conventional protocols will be added to future releases [29].

OMNET++ . Modular discrete event simulator implemented in C++. Getting started with it is quite simple, due to its clean design. It provides a powerful GUI library for animation and tracing [29,30].

The problem in OMNET++ is lack of available protocols in its library, when we compared to other wireless simulators. However, OMNET++ is becoming a popular tool and its lack of models is being cut down by recent contributions.

J-Sim- A component-based simulation environment developed entirely in Java. It provides real-time processbased simulation. The main benefit of J-sim is its considerable list of supported protocols, including a WSN simulation framework with a very detailed model of WSNs, and a implementation of localization, routing and data diffusion WSN algorithms . J-sim models are easily reusable and interchangeable offering the maximum flexibility. Additionally, it provides a GUI library for animation, tracing and debugging support and a script interface, named Jacl [29] .

NCTUns2.0- Discrete event simulator whose engine is embedded in the kernel of a UNIX machine [29,30]. The actual network layer packets are tunnelled through virtual interfaces that simulate lower layers and physical devices. This notable feature allows simulations to be fed with real program data sources. A useful GUI is available in addition to a high number of protocols and network devices, including wireless LAN. Unfortunately, no specific designs for WSN are included.

JiST/SWANS - Discrete event simulation framework that embeds the simulation engine in the Java bytecode. Models are implemented in Java and compiled. Then, bytecodes are rewritten to introduce simulation semantics. Afterwards, they are executed on a standard JVM. This implementation allows the use of unmodified existing Java software in the simulation, as occurs with NCTUns2.0 and UNIX programs. The main drawback of JiST tool, is the lack of enough protocol models. SWANS simulator provided by this simulator.

MATLAB 8.1.0 (R2013a): a simulator tools that have high performance programming language for numerical computing. MATLAB allows plotting of functions and data, implementation of algorithms and it has a number of tool boxes uses in algorithm development, data acquisition, modeling, simulation, data analysis, exploration, visualization, application development, including graphical user interface building [29,30].

GloMoSim - Simulation environment for wireless networks built with Parsec. Parsec [18] is one of a C language that used semantics for creating simulation entities and communication among variety of architecture.

SSFNet - Set of Java network models built over the Scalable Simulation Framework (SSF). This simulation used for assuring portability between complaint simulators. There are multiple Java and C++ implementations of SSF. DartmouthSSF (DaSSF) , it used simulation of huge scale communication networks using C++ implementation of SSF.

2.9 Summary

In this Chapter, different terms of WSN strategy are discussed, beginning with the concept of WSN technology, indicating different circumstances regarding WSN. Then about component of WSN, where it discusses different class of WSN with their proper tasks. After that the chapter presents sensor node deployment mechanism and different literature about sensor node deployment. The chapter also addresses the concept of routing protocol, by discussing different class of routing protocol in WSN with their clear description each routing protocol. Finally, not least, the chapter discussed WSN simulation software by listing different simulation software with their specification and drawback.

Chapter Three: Related Work

In this Chapter, different research works related to sensor node deployment in wireless sensor networks are reviewed. Those works follow different approaches to ensure coverage in WSNs. These works are categorized based on the node deployment approaches they used.

3.1 Biologically Inspired Techniques

Zack et al [31] describes A WSN is being used to implement virtual fences, with an acoustic stimulus being given to animals that cross a virtual fence line. Each animal is given a smart collar consisting of a GPS unit, a Zaurus PDA, wireless networking and a sound amplifier. The animal is given the boundary of a virtual fence in the form of a polygon specified by its coordinates. The location of the animal is tracked against this polygon using the collar GPS. When in the neighborhood of a fence, the animal is given a sound stimulus whose volume is proportionate to the distance from the boundary, designed to keep the animal within boundaries. They use two approaches to controlling animal position: a physical agent such as a sheepdog or robot, and a stimulation device worn by the animal. In the first approach they use mobile robot that was able to herd a flock of ducks to a desired location within a circular pen. In the second category there are a number of commercial products used to control domestic pets such as dogs. These typically employ a simple collar which provides an electric shock when it is in close proximity to a buried perimeter wire. This allows for a simple collar but requires an installed infrastructure which is prohibitively expensive (to install and maintain) for large scale agriculture.

Movement data from the cows controls the virtual fence algorithm that dynamically shifts fence lines. For the first experiment, each sensor node consists of a PDA with a GPS receiver, a WLAN card, and a loudspeaker for providing acoustic stimuli to the cattle as they approach a fence. The nodes form a multi-hop ad hoc network, forwarding movement data to a base station The base station transmits fence coordinates to the nodes.

To test the various virtual fence techniques, the authors developed a Matlab simulator that models the behavior of a herd of cows both with and without the virtual fence stimulus. We were inspired by Vaughan's duck simulator, but extended the animal model to account for the differences between the species as well as their environments.

The drawback of this works is interception from the observer because they use manually deploying sensor network.

3.2 Grid Based Deployment

The work in [3] focuses on the different deterministic deployment patterns for Wireless Sensor Networks namely a regular hexagon based, an octagon-square based and a tri-beehive pattern for sensor nodes deployment and analyzed all the three sensor node deployment strategies on the basis of their average coverage provided in the application field. The K-coverage map has been studied to resolve the coverage issue which is the usual way of specifying conditions on coverage. The K coverage map is used to check all possible coverage areas and to analyze the relative frequency of exactly K-covered points. The quality of coverage performance was measured using the idea of the K-coverage map for all the three considered node deployment strategies. Finally, it concluded that the Tri-Beehive node deployment pattern is a better option for WSNs in terms of coverage than the other two strategies.

Beza D. [32], developed an approach to address the challenges associated to node deployment in WSNs. The proposed approach enables to handle different shapes of a monitored region for achieving an optimal deployment scheme. The nodes will be deployed over a network in a deterministic fashion in which the position of sensor nodes is known before deployment. These nodes are arranged regularly using triangular grid node deployment strategy over the given shape of monitored region either regular or irregular. This approach computes the minimum number of nodes needed to construct a sensor network and determine the position of sensor nodes using spatial coordinates with corresponding node deployment scheme and network topology.

This approach uses real world deployment scenarios (i.e., taking the real shape of the monitored region of farmland) and determines the position of sensor nodes using spatial coordinates and this makes it more practical than others. And also they compared hierarchical routing algorithms called PEGASIS and LEACH to evaluate the network lifetime of the proposed scheme.

They used 1027 nodes to cover the farm land with area of 0.08864Km2 in which all the sensor nodes were deployed in a deterministic manner but there is still a huge gap to fill as a research. The drawback of their system is they used too much number of sensor nodes than required to cover the area. They also used Triangular pattern for the deployment of sensor, which is possible for overlapping problem.

The work in [33] investigates random and deterministic node deployments for large-scale WSNs. It uses coverage, energy consumption, and message transfer delay as performance metrics and Triangle-Hexagon Tiling (THT) was also proposed in a comparison with random and square grid patterns in case of coverage, energy consumption and worst-case delay. They also presented a novel strategy for calculating the relative frequency of exactly k-covered points which apply kcoverage maps using basic geometry. The k-coverage map was modeled for square grid and THT deployments. For a uniform random deployment, it can be achieved by applying systematic sampling over a given field. Finally, the tradeoffs between these performance metrics were analyzed for each deployment strategy to show which strategy is preferable under the primary factors: the number of nodes, the number of sinks, and the sensing range. The result obtained from the experiments shows that THT is a well performing node deployment strategy for energy consumption and worst-case delay for WSN applications.

3.3 Force Based Deployment

Yi Zou and Krishnendu Chakrabarty [34] have presented the virtual force algorithm (VFA) as a practical approach for sensor deployment. The VFA algorithm uses a force-directed approach to improve the coverage provided by an initial random placement. The VFA algorithm offers a number of important advantages. These include negligible computation time and a one-time repositioning of the sensors. Moreover, the desired sensor field coverage and model parameters can be provided as inputs to the VFA algorithm, thereby ensuring flexibility.

For a given number of sensors, VFA attempts to maximize the sensor field coverage using a combination of attractive and repulsive forces. During the execution of the force-directed VFA algorithm, sensors do not physically move but a sequence of virtual motion paths is determined for the randomly-placed sensors. Once the effective sensor positions are identified, a one-time movement is carried out to redeploy the sensors at these positions. Energy constraints are also included in the sensor repositioning algorithm. The VFA algorithm can be made more efficient if it is provided with the theoretical bounds on the number of sensors needed to achieve a given coverage threshold. A novel target localization approach is also proposed based on the information received from the sensor and the knowledge of the sensor deployment within the cluster. In this case the Author uses two-step communication protocol, when a sensor detects a target, it sends an event notification to the cluster head. In order to conserve power and bandwidth, the message from the sensor to the cluster head is kept very small; in fact, the presence or absence of a target can be encoded in just one bit. Detailed information such as detection strength level, imagery and time series data are stored in the local memory and provided to the cluster head upon subsequent queries. Based on the information received from the sensors within the cluster, the cluster head executes a probabilistic localization algorithm to determine candidate target locations, and the cluster head executes a probabilistic scoring-based localization algorithm to determine likely position of the target.

The main drawback of the proposed work is there is no route plan for repositioning the sensor in the VFA algorithm, where sensor collision can happen in the repositioning. In addition, the current target localization algorithm considers only one target in the sensor field. The deployment only considers random deployment, which is not preferable and the deployment cost is high.

3.4 Boundary Based Deployment

Adyasha Panda [35] presented Habitat Monitoring Using WSNs. The authors use detection method, in which the positions of the cattle are detected and if detections at successive time intervals indicate that the position of the cattle is hardly changing, there is a chance that the cattle is sick or injured and a warning message is issued to the owner of the farm. The positions have been estimated using the Direction of Arrival estimation by maximum likelihood and MUSIC (MUltiple SIgnal Classification) algorithms. The performance of the system has been evaluated in terms of minimum root mean square error and probability of resolution. The results of direction of arrival have been improvised using the averaging process and the multimodal problem has been optimized using differential evolution. They also use phase detection of the signals to differentiate different positions having the same direction of arrival. Finally analysis is done regarding the movement of cattle. If it is found that they do not move and occupy the same position for a considerably large period of time, warning message is issued to the owner of the farmland.

The work has no Hardware architecture to implement. The sensor has minimum network lifetime because the sensor has no any communication between them this can lead to much battery use. The system has no base station to communicate with the sensor and also its not online system to track daily data from the farmland.

The aim of the work Wang et al[24] proposed an approach which partitions the sensing field into smaller sub-regions based on the shape of the field, and then to deploy sensors in these subregions. The sensing field is modeled as an arbitrary polygon possibly with obstacles. An obstacle can have any shape too. So the results may model an indoor environment. In addition, an arbitrary relationship between the communication range and sensing range is allowed, thus eliminating the constraints of existing deployment schemes. Even if the boundaries and obstacles are considered, the algorithm was applicable in indoor environment and has the assumption that all sensors have the same Rc and Rs. This would increase the overlapping coverage between sensors. However, the result can be used in an indoor environment. Therefore the work is limited in indoor environment and fewer nodes are sufficient to form a network.

3.5 Particle Swarm Optimization Based Deployment

Juang et al [17] presented WSN is being used to observe the behavior of wild animals within a spacious habitat (e.g., wild horses, zebras, and lions at the Mpala Research Center in Kenya) Of particular interest is the behavior of individual animals. Animals are equipped with sensor nodes.

The goal in the Zebra Net is to gather data collected at each collar back to the base station. Since not every collar within the range of base station, data cannot be sent directly. Instead it has to hop towards the base station, using collar as intermediate hops. In Zebra Net, all nodes except the base station are data sources, while the base station alone is a data sink. This "data gathering" trait contrasts with the general end-to-end communication prevalent in many wired and wireless networks, where every node can be a source or sink. In addition, Zebra Net nodes are mobile, the nodes move around constantly. The base station also mobile, depending the route taken by the researcher in their vehicles. Furthermore, the base station is the only active some of the time, when researchers are driving around gathering data. In the duration that a base station is inactive, the network essentially has no known destination where the data should be sent.

An integrated GPS receiver is used to obtain estimates of their position and speed of movement. Whenever a node enters the communication range of another node, the sensor readings and the identities of the sensor nodes are exchanged. At regular intervals, a mobile base station (e.g., a car or a plane) moves through the observation area and collects the recorded data from the animals it passes. The drawback of this method is firstly the work of Zebra net is manually deployed which is every time there is an interaction from the observer for collecting the recorded data, it result disturbing the animals and also the work has no gateway.

A.Mainwaring et al [36] proposes WSN for habitat monitoring, in which for monitoring seabird (Leach's Storm Petrel) nesting environment and behavior is presented which deployed at Great Duck Island (GDI). In their work, they deploy network consists of 32 nodes on a small island off the coast of Maine streaming useful live data onto the web. The application driven design exercise serves to identify important areas of further work in data sampling, communications, network retasking, and health monitoring. The paper discusses three issues: firstly it discusses the overall usage pattern of nesting burrows over the 24-72 hour cycle when one or both members of a breeding pair may alternate incubation duties with feeding at sea. The other point discussed is which change can be observed in the burrow and surface environmental parameters during the course of the approximately 7-month breeding season. Finally, they discussed the difference in the micro-environments with and without large numbers of nesting petrels. They use UC Berkeley Mica motes as the sensor nodes, which uses a single channel, 916MHz radio from RF Monolithics to provide bidirectional communication at 40kbps, an Atmel Atmega 103 microcontroller running at 4MHz, and considerable amount of nonvolatile storage (512 KB). Sufficient solar power to run many elements of the application 24x7 with low probabilities of service interruptions due to power loss.

The limitation of the proposed work is the deployment exhibited very high node failure rates and failed to produce meaningful data for the disciplinary sciences.

3.6 Other works

The work in [37] is using a WSN to observe the temperature, salinity, and current profile of the upper ocean. The goal is a quantitative description of the state of the upper ocean and the patterns of ocean climate variability. The nodes are dropped from ships or planes. The nodes cycle to a depth of 2000m every ten days. Data collected during these cycles is transmitted to a satellite while nodes are at the surface. The work uses randomly deploying sensor network.

Teng Ma et al [38] , proposes forest fire monitoring paradigm (FFMP). The purpose of the FFMP is for forest fire early detection and locating based on mixed WSNs (WSNs). Different from pure static and mobile WSNs, mixed WSNs are composed of both mobile sensor nodes and static sensor nodes. Mixed WSNs are a tradeoff between cost and coverage. In the FFMP, the mobile sensor nodes perform as cluster heads and they will construct a backbone network in which the mobile sensor nodes can connect with their neighbors and be capable of transmitting data to the base station. Each static sensor node chooses one neighboring mobile sensor node as its cluster head and uploads the generated messages to the cluster head. The mobile sensor nodes then fuses the information and transfers the fusion results to the base station, where the data were further processed to obtain the temperature distribution graph and locate the fires.

The static sensor nodes are densely deployed in the forest in order to obtain a high sensing coverage rate. They are strictly limited by energy, computation, communication band and storage. Even though it is not necessary to densely deploy the mobile sensor nodes, their quality must be god enough that they can cover the interest area by their communication capability. The energy of a mobile sensor node is much more than that of a static node. We also assume that the mobile sensor nodes are capable of moving and avoiding obstacles which can guarantee that the mobile sensor nodes can move to a proper location.

All the sensor nodes can obtain its geographic information by equipment such as GPS or some other form of localization techniques . This is essential, because when monitoring forest fires, we not only want to know whether there is fire, but also where is the fire. Therefore, the sensors should capable of locating themselves.

The proposed paradigm is composed of three phases: firstly, the mobile sensor nodes deployment, which means after being randomly scattered in the forest, the sensor nodes need to automatically organize themselves into a network. The propose work organize their network in a hierarchical way. Their network is divided into two layers: the static sensor nodes compose the lower layer and the mobile sensor nodes compose the higher layer. The responsibility of the lower layer is monitoring the environment and uploading the information to the higher layer. The sensor nodes in the higher layer need to process the data and upload the processed data to the base station. Initially, the static sensor nodes turn into an energy-saving sleep mode and keep receiving message modules, but only when they are live, The second phase of the proposed paradigm is the information fusion which is Recognizing that in-network computations would generate less energy consumption than that of communication; in their work they can save the energy by fusing the data and transmitting the data fusion. Finally locating the fire, which means after receiving all of the temperature data from the interest area, the base station needs to locate the fire and predict the developing trend

The proposed work uses ns-3 simulator (version 3.21) to evaluate the performance of the FFMP approach. To simulate the readings of the sensor nodes, they extract 100 similar sub-traces from the temperature traces For each experiment, they employ one or several sub-traces to simulate the readings of the sensor nodes

3.7 Summary

In this chapter, discusses different related works regarding WSN. In which it discusses the technology they used, application area they used, different scenario during the deployment and the drawback of each works by analyzing for future works.

Some of the works has done using manually configuring the whole system, which is every time there is an interaction from the observer for collecting the recorded data, it results disturbing the animals.

Other issue with their work is the problem of overlapping coverage between sensors, which result from their deployment pattern they used to deploy. Their work also limited in indoor environment and fewer nodes are sufficient to form a network.

Adyasha Panda [35] developed system that has no hardware architecture to implement. The sensor has minimum network lifetime because the sensor has no any communication between them this can lead to much battery use. The system has no base station to communicate with the sensor and difficult to track daily data from the farmland.

In general, this chapter discusses different WSN works and their method, which means what they use, place of deployment strategy and others. The paper also discusses some of the drawback their work.

Chapter Four: Design of the Proposed Node Deployment Approach

This Chapter presents the design of the proposed Deterministic Node Deployment Scheme using WSN. First we will discuss the design considerations that we are taking into account while building the proposed system will be presented. Then, the proposed model and architecture including the phases along with the components with the designed pseudo codes will be presented.

4.1 Overview

Node deployment or placement of nodes in the network area is one of the main issue in WSN which affects the performance of the network. Using the appropriate deployment increase our correct and efficient data. The placement of sensor can affect with the final product of the data, so each sensor must be put properly. The well-known deployment strategies are Random and Deterministic deployment. In case of Random deployment, the sensor dropped from somewhere from the top to the ground or sky to ground by using Helicopter and other mechanism, mostly used danger or Environmentally difficult areas. Where as in Deterministic deployment the sensor must be placed prior to deployment.

In our proposed system we use Deterministic deployment strategies which is more efficient to get exact data, because we know the placement of each sensor, if there is any maintenance issue, we can handle the situation by the finding the sensor. Another usage of these criteria of deployment is optimization, which means we can handle each sensor without placement of the sensor, and it solve the problem of overlapping sensed data.

Shape based node deployment scheme which considers the shape of monitored area is the best deployment approach because it helps us to deploy sensors according to the given area deterministically. So, it minimizes number of nodes to cover the area rather than deploying randomly.

The main design challenge in WSNs deployment is to prolong network lifetime while achieving best coverage and connectivity between nodes with small number of sensors. There aremany factors related to the inherent characteristics of WSNs that have to be considered in order to design an efficient WSN deployment scheme. Since the nodes in a WSN are constrained in energy supply, processing capability and available bandwidth.

Hence, this work aims to present an approach which will enable to construct a sensor network with the minimum number of sensor nodes which are deterministically deployed with corresponding node deployment scheme. This scheme is intended for habitat monitoring for a given shape of land with a network topology in a way that achieves the desired design considerations such as coverage, lifetime, cost of deployment, etc.

4.2 Design Consideration

Many design factors have been addressed by many researchers in this field. These design factors are surveyed below. These factors serve as hints or guidelines to design a protocol or algorithm for WSNs. Among these the most well-known design factors are:

- Coverage
- Number of nodes
- Ease of access
- Adaptability

4.3 System Architecture

In this section, we have proposed a generalized architecture to provide an optimized sensor node deployment scheme for a given farmland area that considers the aforementioned design requirements. The general architecture of the proposed approach is shown in Figure 4.1 adopted [27]

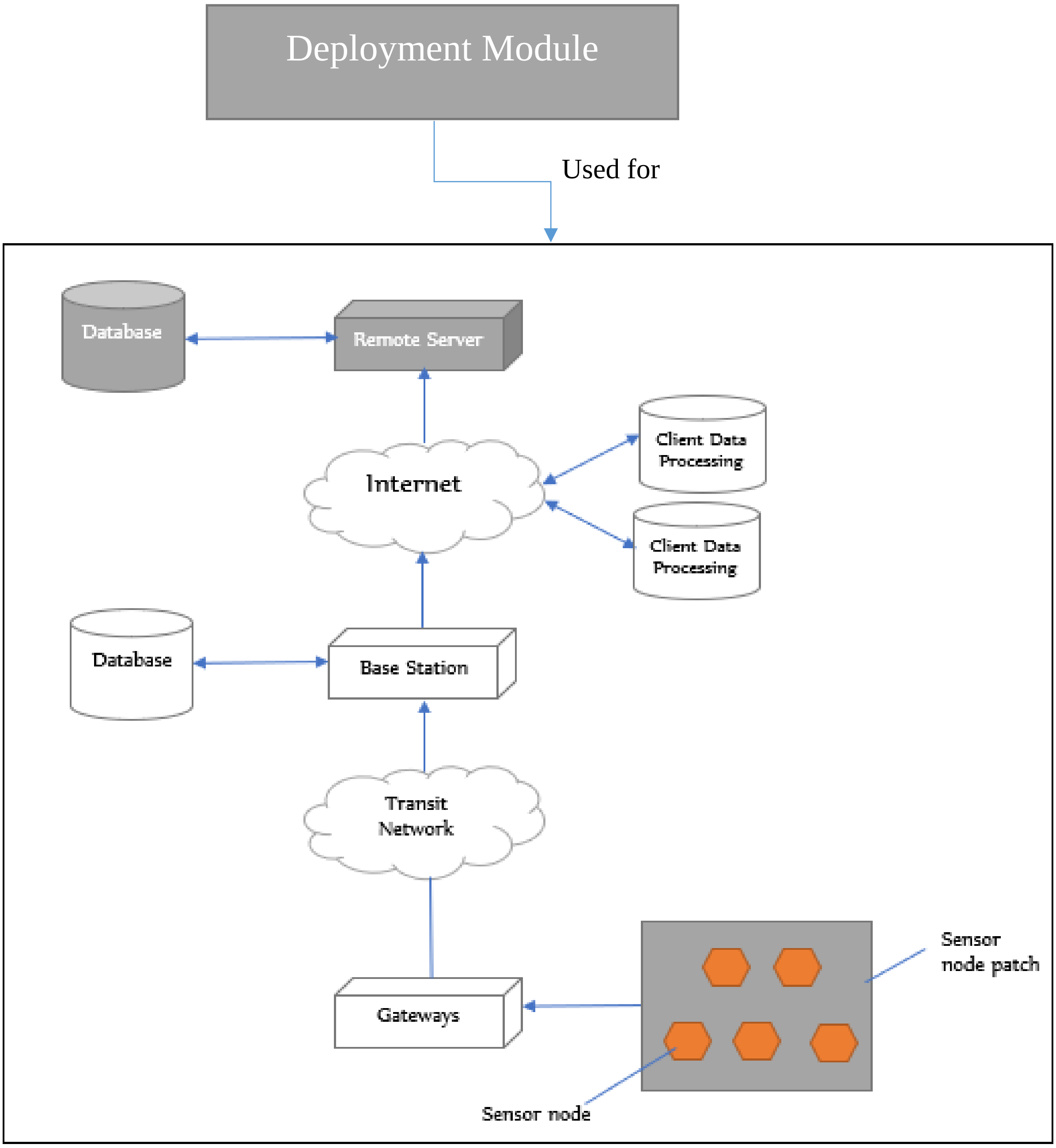


Figure 4.1: Architecture of the Proposed System adopted from [27]

Description of Architecture

(The components that are marked as a Grey color are the researchers work)

Remote Server: users access the replica of the base station database and Provides remote control of the network

DB: store data retrievable.

Gateway: transmit sensor data from the sensor patch through a local transit network to the remote base station that provides WAN connectivity.

Transit Network: to provide network between the gateway and base station.

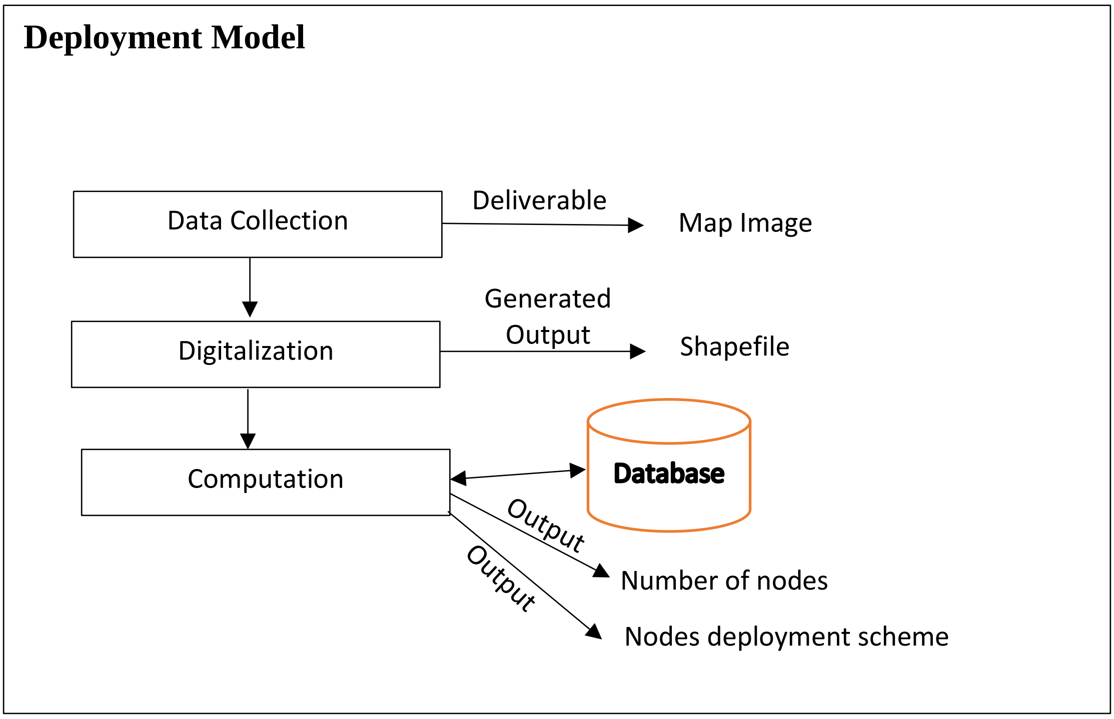
Base station: connects to database replicas across the internet

Sensor nodes: general purpose computing and networking, application-specific sensing

As shown Figure 4.1, the lowest level consists of the sensor nodes that perform general purpose computing and networking in addition to application-specific sensing. The sensor nodes deployed in dense patches that are widely separated. The sensor nodes transmit their data through the sensor network to the sensor network gateway. The function of gateway is transmitting sensor data from the sensor patch through a local transit network to the remote base station. Then the base station connects to database replicas across the internet in order to for user access the data remotely from the replicas of the database.

As we mentioned above the sensor nodes should be placed properly to effectively monitor the environment. Thus, we intend to present a deterministic sensor node deployment for habitat monitoring that is able to achieve full coverage and other desired requirements of a sensor network by using a minimum number of sensors. The positions of sensor nodes are also determined before deployment with the given boundary of habitat. The nodes are deployed according to a regular pattern in which all the sensors in the network are assumed to be homogeneous with identical transmission range and sensing range and the distances between neighboring nodes are equal. Therefore, all sensor nodes transmit their messages to similar distances. This balances the energy consumption throughout the network even if it is dependent more on routing protocol.

The proposed deployment patterns belong to deterministic deployment, static coverage and area coverage as discussed in previous chapter. In deterministic deployment, the sensors are manually placed and data is routed through pre determined paths. The proposed deployment approach goes from data collection up to generation of node deployment scheme. The detailed description of them is presented below:



4.2:Deployment Model

Data Collection

To capture our data, we use Google Earth which is i.e., a popular free Internet application which offers a library of satellite imagery and aerial photography of the Earth's surface. In this case we will add four controlling points using place in order to capture their Latitude/Longitude coordinated and extract the image from the Google map.

pseudo codes

```
Input- Take the location of given habitat land
Task:
START
    Tag four control points using place mark associated to the
       habitat on Google Earth.
    Record and Extract their Latitude/Longitude coordinates of
       control points
     Take the satellite image from Google Earth.
END
Output- Map or extracted image
```

Algorithm 4.1: Capturing Habitat Map

Digitization

After collecting our data by using the above method, the next task is geo-referencing the extracted image or image map based on the four control points using ArcGIS by assigning a coordinate system. Coordinate systems can provide a framework for defining real-world locations. In ArcGIS, the coordinate system is used as the method to automatically integrate the geographic locations from different datasets into a common coordinate framework for display and analysis for mapping, visualization, analysis, and so forth.

Then, we create an ArcGIS ready shape file that contains our GPS points or geographic data (coordinates) in the form of an XY table (long, lat). With this geo-referenced image, we can now digitize new features from the map (i.e., polygon). In other words, we got a polygon feature layer in ArcGIS. Moreover, ArcGIS has a tool called calculate geometry which allows accessing the geometry of the features in a layer. The tool can calculate coordinate values, perimeter and area of our polygon. So we can easily calculate the area of the polygon or a given geometry of habitat land using this tool. Finally all the geographic information can be taken out in the form of shape files.

```
Input: Map Image
Task:
START
Use the coordinates of the control points to georeference the
image in the form XY table or Long, lat.
Digitize new features from the map in the form of polygon.
Access the geometry of the feature or calculate the area of the
polygon.
Get or extract the shape file of the digitized habitat land in
the form of grid pattern.
END
Output: shape file of the habitat land
```

Algorithm 4.2: Digitalizing the Feature

Computation

Now after getting the shape file of the habitat, our next task should be computing. So, we have to concentrate on finding the optimal deployment scheme for sensor nodes using WSNs.

The sensor node deployment scheme can affect the design and performance of all aspects of the system. While generating the node deployment scheme, there are different and important tasks to be done and decisions to be made like:

- determine the number of sensor nodes required to effectively cover and monitor a habitat land.
- determine the positions of sensor nodes in a given land.
- select the deployment pattern or distribution of the sensor nodes .

Here, the network architecture and topology design will be delivered with the node deployment scheme. The process of computation is shown in Pseudo code 4.3.

```
Input: Shape file
Process:
BEGIN
     Read polygon information from shape file
     Put latitude on LAT array and longitude on LON
     Set the first deployment point (x, y) to (MIN (LON), MAX
     (LAT))
     Set sensing range Rs
     Set distance between nodes d, as sqrt (3)*Rs
     Set row to 1 and x_iterator to 1
     Set polygon boundary between point (MIN (LON), MAX (LAT))
     and point (MAX (LON), MIN (LAT))
     While point(x, y) is in boundary
          IF point(x,y) is in polygon, THEN
                        Keep the point in NODES array
          END IF
          Increase the x_iterator by 1
          IF x_iterator mod 2 is 0, THEN
               Increase x by d
          ELSE
               Increase x by 2 times d
          END IF
          IF x > MAX(LON), THEN
               Increase the row by 1
               IF row mod 2 is 0, THEN
                    Set x ← MIN(LON)+(d/2)
                    Set x_iterator ← 1
               ELSE
                    Set x ←MIN(LON)
                    Set x_iterator ← 0
               END IF
               Set y ← y-d
          END IF
     END WHILE
Output: Number of Nodes, the position of nodes, hexagon grids,
Node deployment scheme and Network topology
```

Algorithm 4.3: Sensor Node Deployment Using Hexagonal Pattern

4.4 Deterministic WSN Module

This work is intended to present the Habitat monitoring system using wireless sensor nodes and base station to record the habitat land information. The sensor nodes have several capabilities like sensing, computation and communication. It allows gathering the habitat parameter like habitat monitoring, object tracking , fire detection, traffic monitoring etc. They are capable to communicate with each other or with the base station in order to exchange and process the information collected by their sensing units using routing technology. Therefore, these sensor nodes send all captured data to a Base Station (BS) for processing and further analysis. This base station is responsible for collection of the data from all the sensor nodes and critically evaluates the data. The information is transmitted to the customer terminal through the Internet. Then, the user utilizes the received information to control the habitat parameters. Generally, this WSN system and all the control mechanisms improve the effectiveness and efficiency of resources used and they have the ability to maximize production.

4.5 Summary

This chapter discusses node deployment approach or strategies with their specification of method. It also presents design factors of sensor node deployment by identifying the basic issue in case of deploying WSN. Then the chapter presents the proposed approach of the system with clear specification regarding the step to be taken from data collection up to computation process with their tools used during each step. Finally, it discusses the pseudo code for deploying our Hexagonal grid-based pattern for our proposed system.

Chapter Five: Implementation and Evaluation

In this chapter the assumptions that we consider when we implement the system and the tools that we uses during the implementation of the system will be presented. And then, the implementation and the results will be discussed. The proposed Grid based deterministic sensor node deployment scheme will be measured using Performance evaluation in comparison with existing shape based node deployment scheme and the result of this evaluation is presented.

5.1 Overview

Utilizing WSNs in applications like Habitat monitoring is essential to gather the necessary information and control the technology. Our approach determines the required number of sensors to be deployed so that these sensor nodes cover every point of the monitored region. These nodes are deployed over a network in deterministic fashion. In deterministic node deployment, the position of sensor nodes are known prior to deployment and it is often desirable to determine the required number of nodes.

The proposed deterministic sensor node deployment approach enables to improve the existing shape based node deployment schemes for a homogeneous sensor nodes. This scheme considers the following parameters such as the coverage, network lifetime, network reliability and adaptability.The implementation done on MATLAB environment.

In our work, we consider the practical shape of habitat land and the position of sensor network specified by using spatial coordinates. These nodes are arranged regularly using Hexagonal grid node deployment strategy over the given shape of land regularly.

A proper node deployment scheme is one of the effective optimization means for achieving the desired design goals such as coverage, communication cost, routing, etc. It can serve as reference to guide real-world deployment. Thus, the network topology can be established at setup time. By using above method, we can ensure the coverage of the given area. In addition to coverage,the other issue we have to consider is the position of sensor node. Because the position of sensor nodes can affect various network performance metrics like energy consumption, delay and other, so have to properly manage each sensor node position.

5.2 Assumptions

Our work is based on the following assumptions:

Assumption 1**:** We assume a discbased sensing model where each active sensor has a sensing radius of rs; any object within the disc of radius rs centered at an active sensor is reliably detected by it.

Assumption 2: We assume a disc-based radio model where each active sensor has a communication range of rc; two active sensors at a distance of rc or less can communicate reliably.

Assumption 3**:** We assume that the sensing range of all sensors are the same, as are their communication range

Assumption 4: Sensor nodes can communicate with other sensor nodes and base stations within their radio transmission range and in which the transmission is omni-directional.

Assumption 5: All sensor nodes and BS are stationary after deployment (i.e., no mobility of sensor nodes).

Assumption 6: The sensors are deployed in a two-dimensional area.

Assumption 7: The communication range Rc of sensor nodes is larger than sensor range Rs of nodes.

5.3 Deployment Tools

In this work, we have used different tools in order to implement the proposed system. So that in that part we present tools that are useful for our proposed system. As we indicate in the Chapter 4, we use Google Earth to get the map of the proposed area (Gambella National park), Arc GIS to digitize the shape of park. Another tool we use for this work is Mat lab to implement and simulate the proposed work.

Google Earth - This is a powerful yet simple tool for viewing information geographically—whether it is viewing climate information, analysing change over time, seeing the world the same way you're used to seeing, or remembering routes taken while on vacation. Displays satellite images of varying resolution of the Earth'ssurface, allowing users to see things like cities and houses looking perpendicularly down or at an oblique angle, with perspective It combines the power of Google Search with satellite imagery, maps, terrain and 3D buildings to put the world's geographic information at your finger tips.

Arc GIS 10.5 – Geographic Information System (GIS) used for working with maps and geographic information. we can compile and sort data with spatial reference to its location, which in turn can be used to create maps and Geographic based data tables and maps that can be analyzed and shared with others through which you can make conclusions from thr compiled and analyzed data that you would not be able to sort in any other way if you did not have an X,Y location to ascertain where the data falls for analytical purposes. Used as platform for organizations to create, manage, share, and analyze spatial data. It consists of server components, mobile and desktop applications, and developer tools.

MATLAB - is a tool for numerical computation and visualization. It integrates computation, visualization and programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notations Used for an interactive program for doing matrix calculations and has now grown to a high level mathematical language that can solve integrals and differential equations numerically and plot a wide variety of two and three dimensional graphs.

5.4 Simulation Parameter

Table 5-1:Simulation Parameters of Habitat Land

Parameter	**Values**
Monitored Habitat park area (i.e., Irregular)	0.08864 km2 (88640 m2)
Sensing Range (Rs)	10m (0.01 km)
Nodes Distribution	Nodes are Hexagonally distributed

5.5 Experimental Scenario

The study area lies in Gambella National Park , which located 850 km *west* of *Addis Ababa.* The climate of Gambella is hot and humid with maximum temperatures just before the rainy season in May. Annual mean temperature is with a minimum and maximum of 20.4 and 34.8 0 C, respectively. Annual rainfall is about 1400 mm. The wet season is from May to October when large parts of the park are totally inaccessible.

5.6 Implementation and Results

In this part, we design deterministic sensor node deployment for habitat monitoring using Grid based deployment approach.

Our approach determines the required number of sensors to be deployed deterministically over the network. We used a disc-based sensing model to represent sensor nodes. This model assumes that the effective communication and sensing ranges of a sensor node is a circle with fixed radius. The sensing and communication ranges of sensor nodes are represented by Rs and Rc, respectively. So a circular field with sensing radius Rs is considered in our approach.We used the Hexagonal grid deployment, which helps to determine the position of sensor nodes.

To design a Deterministic sensor node deployment scheme which considers the shape of a monitored area, first we have to get the image of the Habitat land then, shape file of the land. To get the shape of a monitored habitat land we took the image of GNP from Google Earth, we used place marks to add the corner of the image. Then, we record their latitude/longitude value, and save the image in jpg file format depicted in *Figure 5.1*.

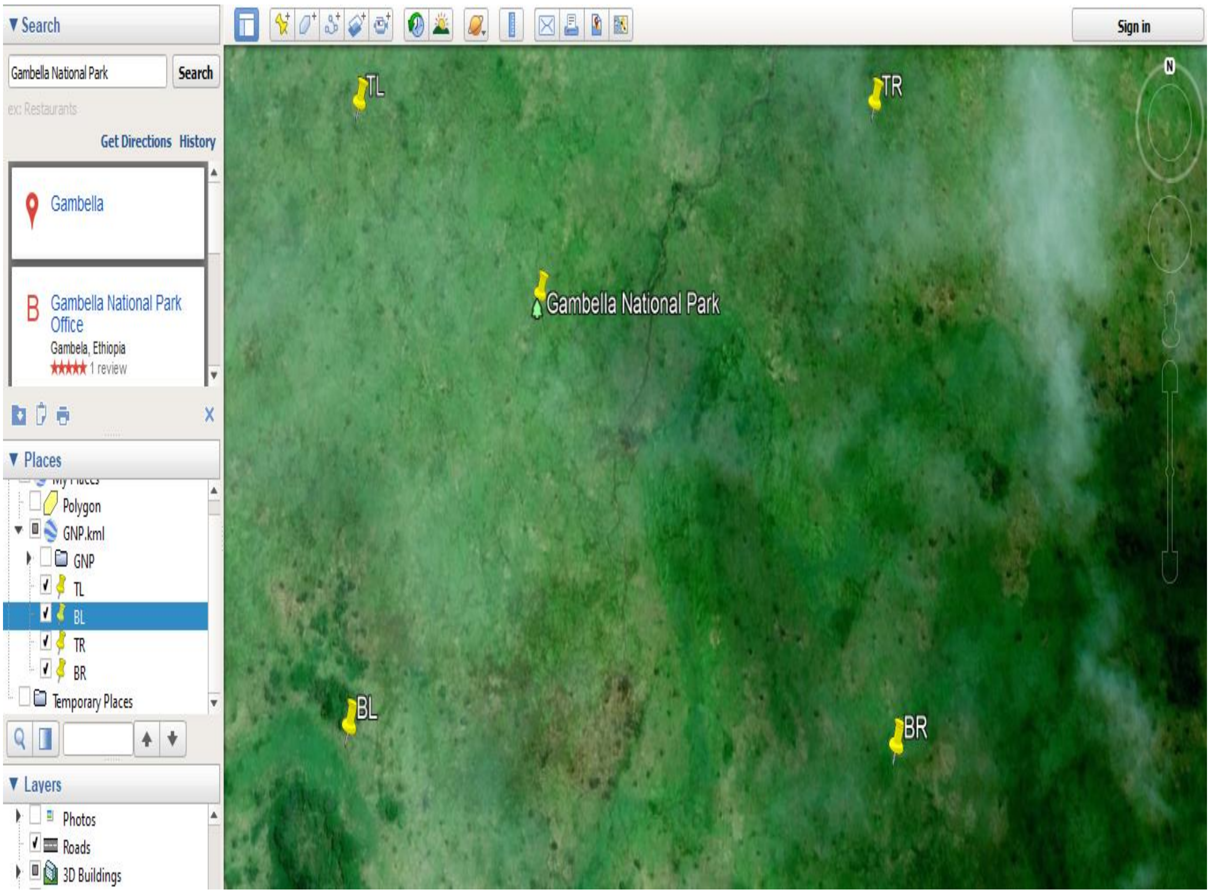


Figure 5.1: *Screenshot of Sample GNP*

After getting the image of GNP from Google Earth, Then the next task is Geo referencing the image we take from Google Earth using ArcGIS tool. In ArcGIS, the coordinate system is used as the method to automatically integrate the geographic locations from different datasets into a common coordinate framework for display and analysis for mapping, visualization, analysis, and so forth. With the geo-referenced image, we can now digitize new features from the map

.On ArcGIS, we import the image and geo-reference it based on the control points. With the geo-referenced image, we got a polygon feature layer in ArcGIS as illustrated in *Figure 5.2*.

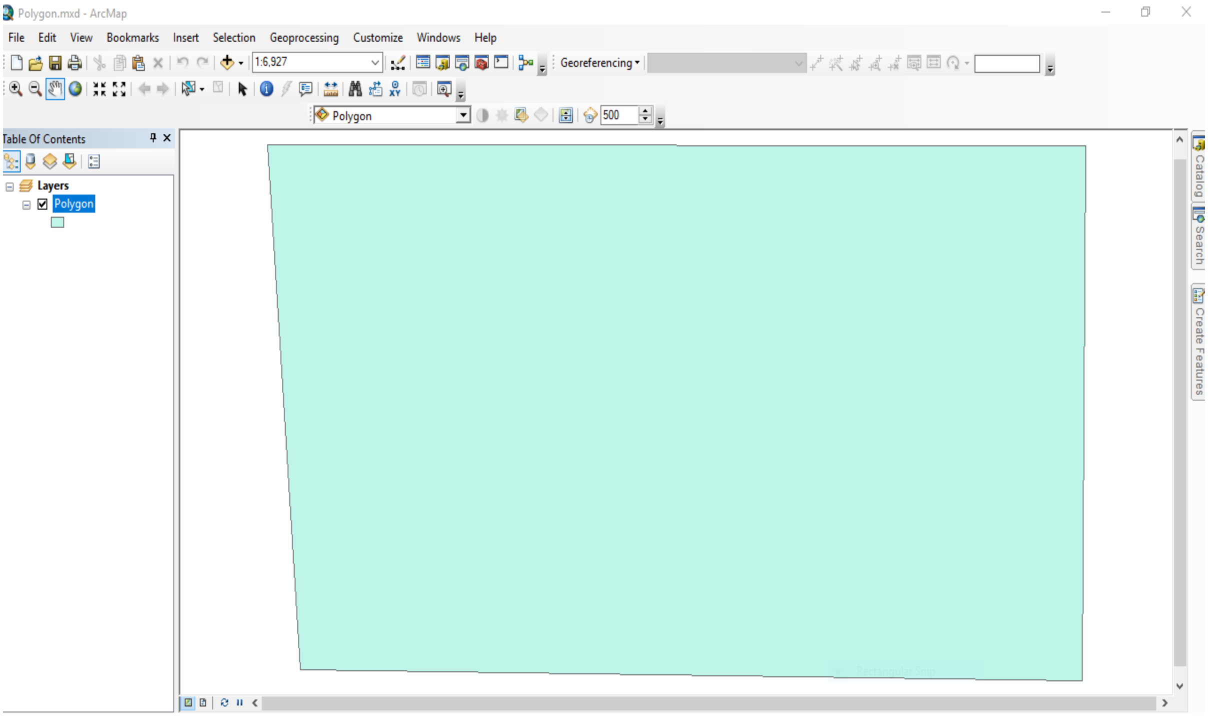


***Figure 5.2**: Screen Shoot of Digitized Habitat Land from Satellite Image*

Our work in MATLAB will start from importing the shape file into our work space in which we are going to read the spatial Information and use to deploy sensors on it. It can directly read the shape file format using Mapping Toolbox capabilities and we can display geographic information in it.

After we get the shape file, we use it in MATLAB for our proposed scheme. First read the coordinate points of the shape file, then put the latitudes and longitudes in array. The distance between nodes d is equal to √3 times Sensing Range of Sensors Rs. We start generating points (i.e. sensors position) with their assigned energy level in Hexagonal pattern starting from top-left border of the polygon until we reach bottom-right, which is the end of the habitat land. We keep points which are only in the polygon in an array of sensors. Not alike the previous work, we can determine exactly the number of nodes we need to deploy on our habitat land without taking maximum number of nodes assumed.

Now we have the geometry/the shape of the region with boundary that is represented by shape files. This shape files contain some geographic information in the form attribute about the given polygon like the coordinate system and attribute of the data, number of spatial features, etc.

The nodes are distributed in Hexagonal pattern within the habitat park region as shown in *Figure 5.3*.

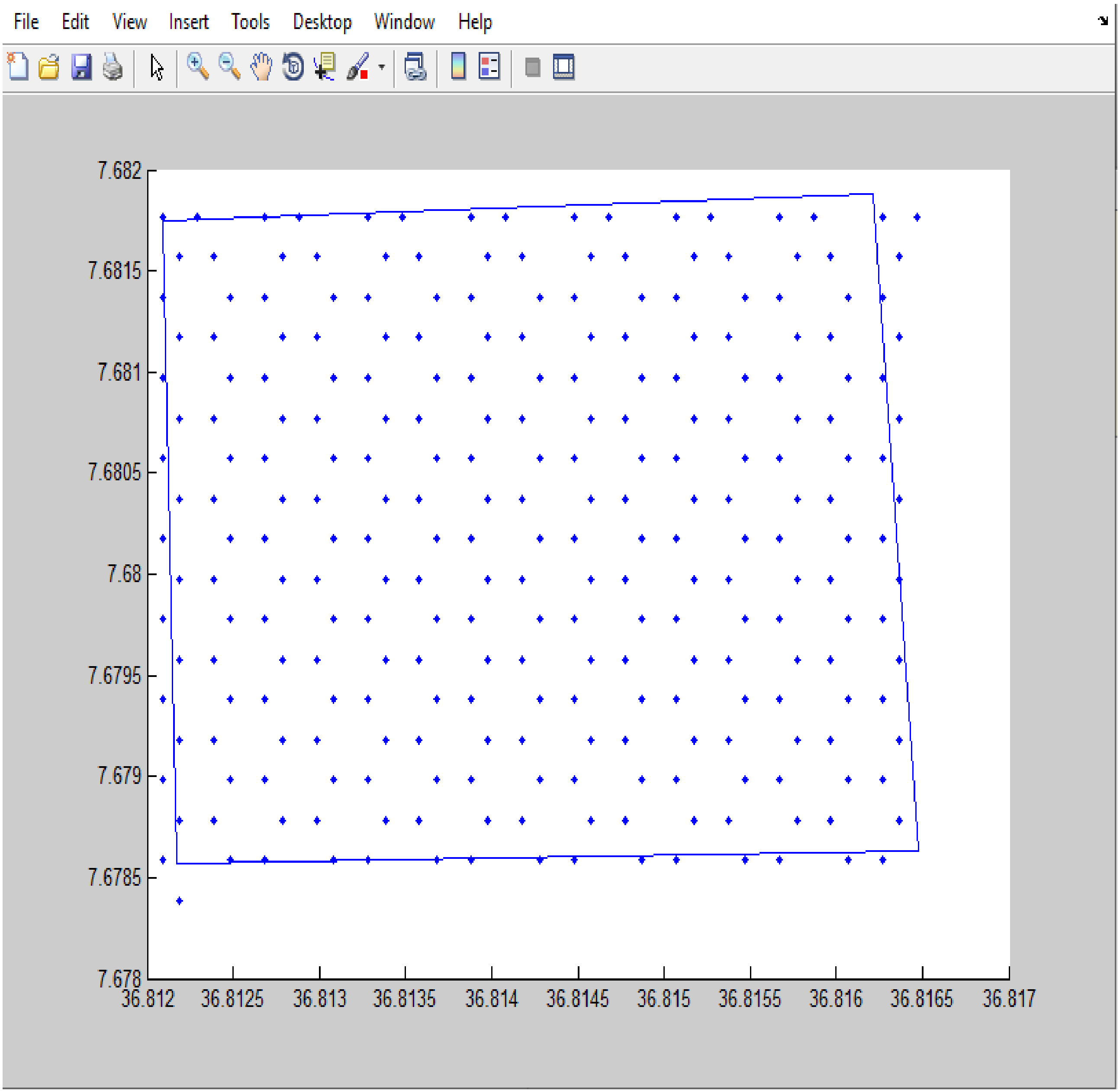


Figure 5.3*: Screenshot of All Distributed Sensor Node Points in Hexagonal Grid*

Then we can determine that a sensor node *n* lies inside or outside the region of land using MATLAB's in polygon function which identifies the points (sensor nodes) are inside or outside the polygon as shown in Figure 5.3. Then, we can project points to the closest boundary by using the gradient limiting equation (i.e., non-linear partial differential equation). Because, the spatial coordinates of the land boundary are used to specify the polygon and permanent points.

As we have seen in the design in Chapter 4, we need a database to record and store information like the position of sensor nodes, the node number, number of grids, maps, etc. which are important for the user. In our case, we are just recording some information in the form of csv, xls and text files. Figure 5.4 shows the position of sensor nodes which are produced during the computation and we are going to keep this information in the form of a csv file

Some sensor nodes position with their respective energy generated by the proposed approach are:

	A	B	C
1	36.815	7.6818	
2	36.815	7.6818	
3	36.815	7.6818	
4	36.815	7.6818	
5	36.815	7.6818	
6	36.815	7.6818	
7	36.815	7.6818	
8	36.816	7.6818	
9	36.816	7.6818	
10	36.816	7.6818	
11	36.816	7.6818	
12	36.816	7.6818	
13	36.812	7.6817	
14	36.812	7.6817	
15	36.812	7.6817	
16	36.812	7.6817	
17	36.813	7.6817	
18	36.813	7.6817	
19	36.813	7.6817	
20	36.813	7.6817	
21	36.813	7.6817	
22	36.813	7.6817	
23	36.813	7.6817	

my-node-points

***Figure 5.4**: Screenshot of Sensor Node Position Stored in CSV Format*

Hence, we can determine the next position from these points. After that, we have to remove the points outside the region using this probability $\frac{1}{s} \times (x, y) \times 2$. Next, we evaluated s(x, y) at each node and reject points with a probability to $\frac{1}{s} \times (x, y) \times 2$ After the rejection method is applied, we can count the number of nodes. The figure shows the distributed nodes within the bounding box of the given polygon.

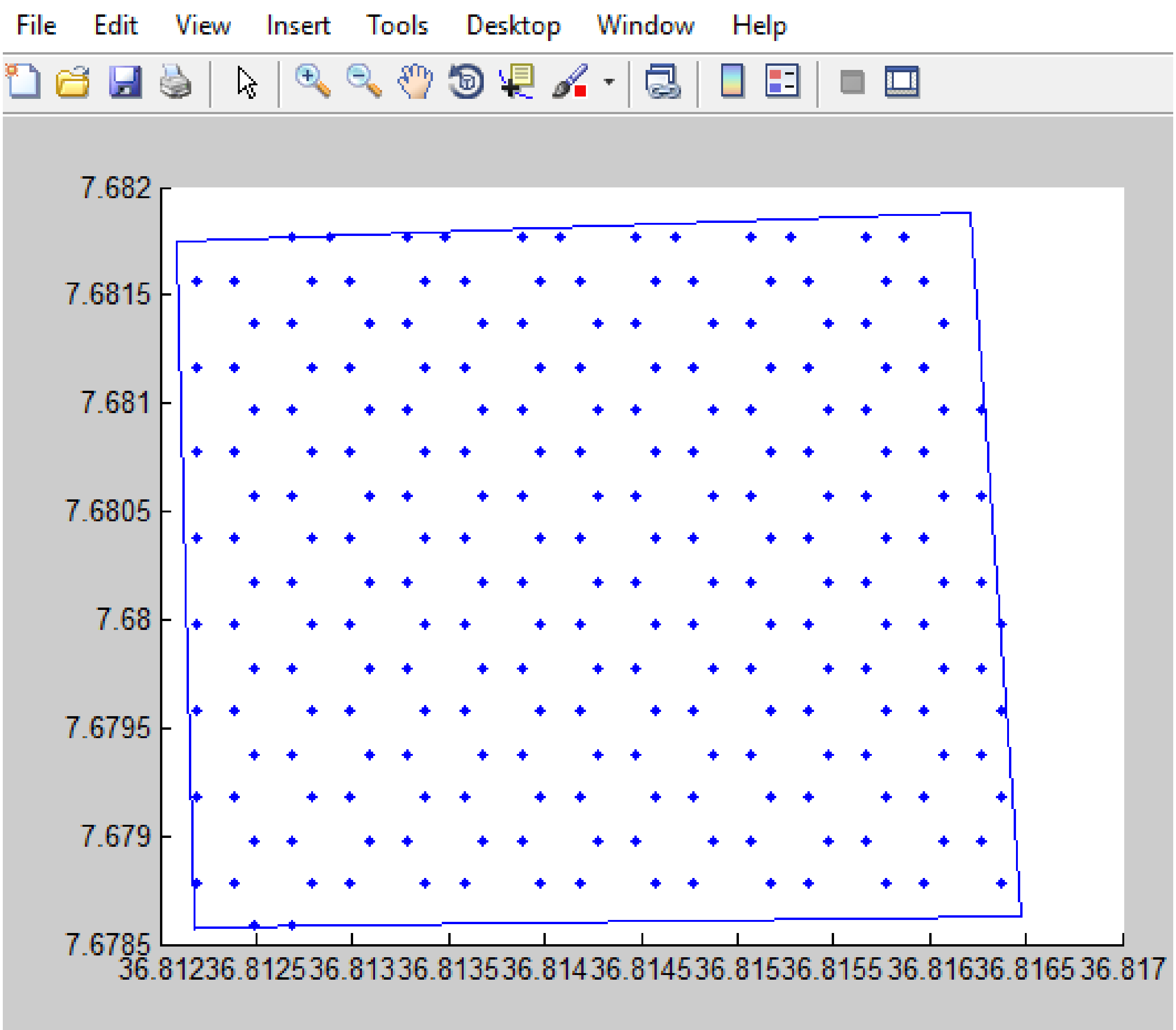


***Figure 5.5**: Screenshot of Deployed Node Inside the Given Geometry of Habitat Park*

Energy consumption is one of the main issues to be considered in the deployment of sensor networks. It has a great impact on extending the lifetime in WSNs. Moreover, the coverage of a sensor network is related to energy conservation. So, in our work we PEGASIS (Power-Efficient Gathering in Sensor Information Systems) is used as routing protocol.

PEGASIS is a routing protocol in which a chain based approach is followed. This protocol follows agreedy algorithm starting from the farthest node and all the sensor nodes form a chain like structure. It works on the principle that each node will transmit to and receive from its close neighbors. There is a leader in the chain which is responsible for transmission of the combined data to the sink node [40]. Nodes take turns being the leader in the network which evenly distributes the energy load amongst the nodes. This even energy distribution and high energy efficiency leads to the extension of the network lifetime. It attempts to reduce the delay that the data acquires on the way to the base station. *Figure 5.6* shows the connectivity of sensor nodes in PEGASIS protocol [40].

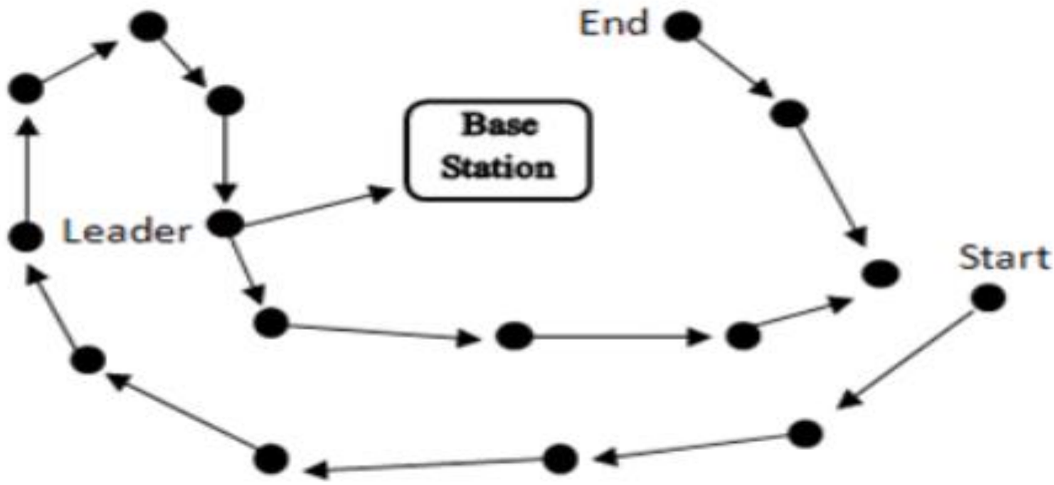


***Figure 5.6**: PEGASIS Chaining Approach*

We used PEGASIS routing protocol algorithm with those parameters. Then, the nodes will be organized to form a chain as shown in Figure 5.6, which is accomplished by the sensor nodes themselves using a greedy algorithm starting from some node. The sensed data moves from node to node, gets aggregated, and finally a designated node transmits it to the BS. The average energy spent by each node per round is reduced while the nodes take turns transmitting to the BS.

As previously described in PEGASIS, there is no data aggregation and it is a chain-based approach. Because of balance in energy distribution PEGASSIS offers extending lifetime of the network. As a result, the number of node deaths in PEGASIS is lesser as when we compared to others routing protocol.

The overheads are very small, almost negligible, in the case of PEGASIS protocol and as a result, it does not affect other network characteristics. Thus, PEGASIS out performs the LEACH protocol in terms of communication overhead for dynamic cluster formation.

Some of the advantage PEGASIS routing protocol are:

- Normal nodes only reach to their neighbour and every nodes will take data fusion in regulation.
- The distance of the connected nodes to each other have been minimized especially

- Each node take turns to become the cluster head, so that it can save energy.

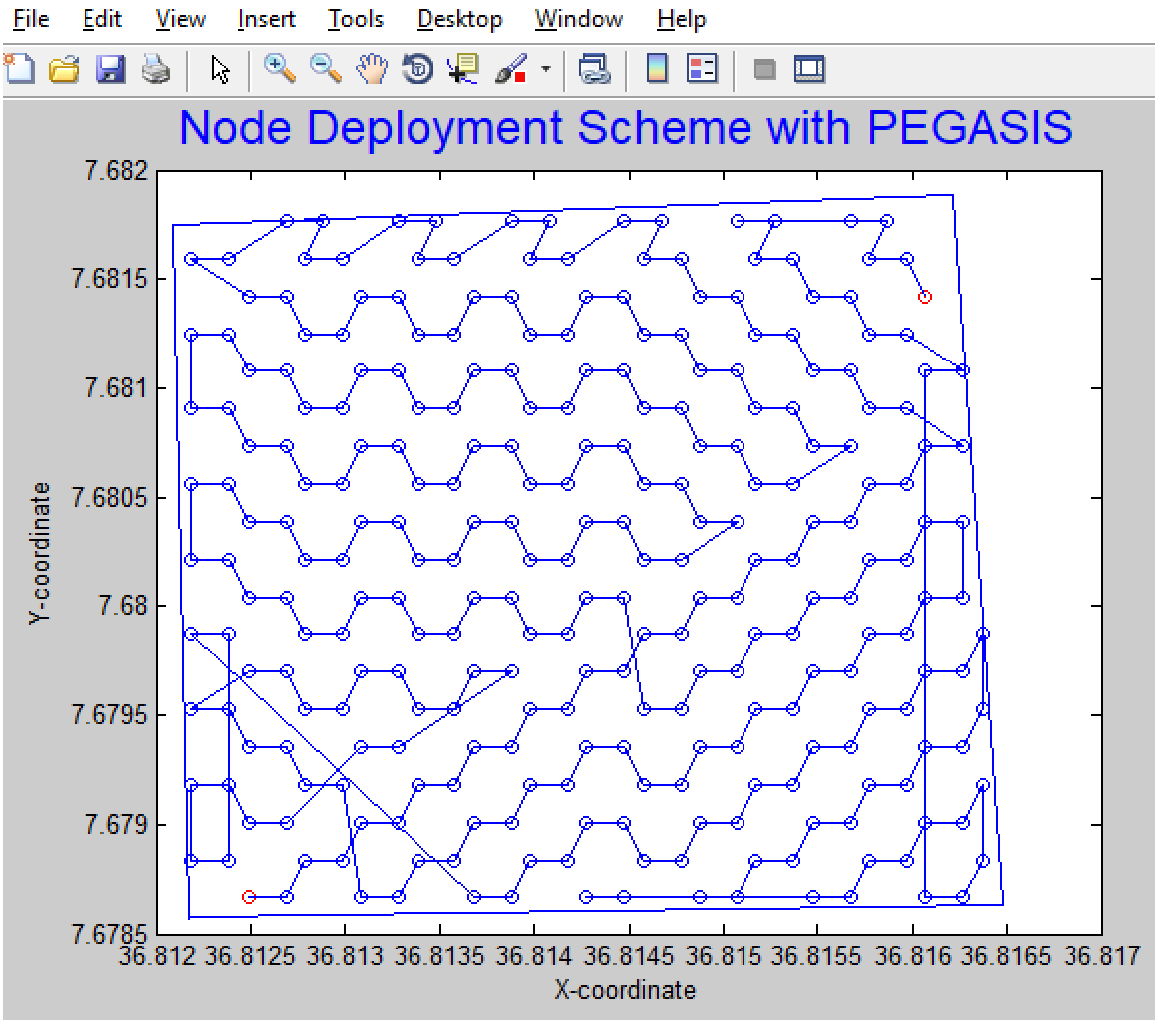


Figure 5.7*: Screenshot of the Proposed Node Deployment Scheme with Routing Path Generated by PEGASIS for the Given Shape of Habitat Land*

5.7 Evaluation

In this part, we evaluate the work we have done in the implementation part using evaluation metrics. The evaluation metrics of proposed systems are number of nodes, network coverage, network connectivity, cost and adaptability.

5.7.1 Number of Nodes

An optimized sensor nodes deployment covers many aspects among them the basic one using minimum number of nodes for covering the land.

The existing shape-based deployment approach using grid-based uses to much sensor node to cover the land of specific region, but in our proposed work we use minimum number of sensor node for covering the land.

Based on the formula derived by [41,42], we can calculate the minimum number of nodes required in the network area using function of area A and sensor nodes must be deployed in distance ***d***. ***d*** is equal to √3***Rs***, where ***Rs*** is the Sensing Range of each Sensor nodes.

Here, its formulas for calculating number of nodes within the area of network.

Table 5-2:formula for calculating number of nodes

Model	Number of Nodes
Triangle	N= $1.15\frac{[\boldsymbol{A}]}{\boldsymbol{a^2}}$
Square	N= $1\ \frac{[\boldsymbol{A}]}{\boldsymbol{a^2}}$
Hexagon	N= $0.77\ \frac{[\boldsymbol{A}]}{\boldsymbol{a^2}}$

Therefore, in our case the length of a side of a tile is d**.**

- To find the number of nodes in hexagon, every vertex is connected is connected to three other nodes, so 6/3 nodes are required for every hexagon in average. After calculating the number of hexagons by dividing the specified area to the area of one hexagon, it should be multiplied in 6/3. We get the above calculation in Table 5.2.

Number of Sensor Nodes = $0.77\ \frac{[A]}{\mathrm{d}^2}$

Where, d means √3 times Rs.

Using the above formula, we can calculate the number of nodes required for our assumed park area. From the assumption mentioned at the beginning of the Chapter, we know the following:

A= 0.08864

Rs= 0.01

$$N = 0.77 \times \frac{[0.08864]}{(\sqrt{3}\ \mathrm{x}\ 0.01)^2} = 227$$

As we can see, our hexagonal deployment scheme requires minimum number of sensor node which is (**N=227**). The existing triangular deployment scheme uses **1027** sensor nodes with the same assumed area. Therefore, we can conclude that our proposed deployment scheme fully covers the park area by using minimum number of sensor nodes. As the paper indicated in [43], Hexagonal pattern deployment uses fewer sensor node to cover the same area when we compare from triangular and square-based patterns.

Table 5-3:comparision with previous works

Different Approach	**Deployment Pattern**	**Routing Protocol**	**Number of Sensor Node**
Existing Approach	Triangular	PEGASSIS	1027
Proposed Approach	Hexagonal	PEGASSIS	227

5.7.2 Coverage Area

The term coverage in the WSN can be considered as the maximum range or area up to which the network is able to send or receive the data and also able to track the objects for monitoring them.

In our proposed work, we used Hexagonal grid sensor network deployment pattern, which provides better area coverage than other schemes. The sensor node has deployment intersection points, which used to intersect of the circular field with radius, say R. As a result, all unit cells within the circular field have equal edge length d which have equal area within each unit hexagon cell.

Accordingly, K-coverage, we can easily know the coverage of all grid-based scheme. For the case of hexagonal deployment scheme, which have six points. We have to put the sensor node at the point of hexagon pattern. A network is said to have k-coverage if every point in the network is covered by at least k sensor nodes. So, in our case the deployed sensor has covered the park area by at least one sensor node within the area of network, which means every point in the area can be sensed by at least one sensor node.

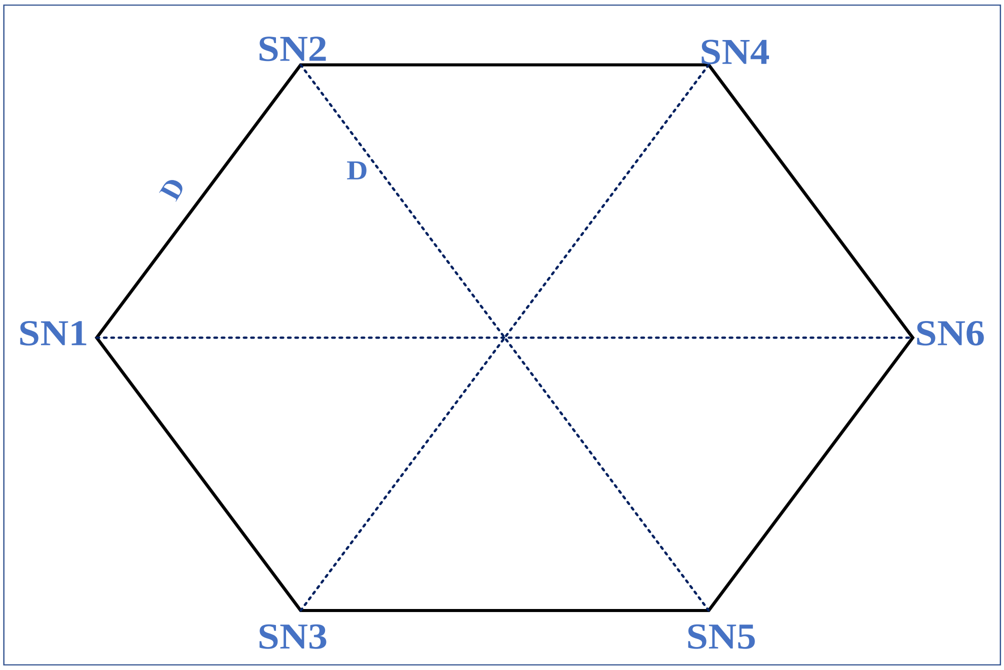


Figure 5.8*: Sensor Node Coverage Scenario Based on Hexagonal Pattern*

Where D is distance between each sensor network.

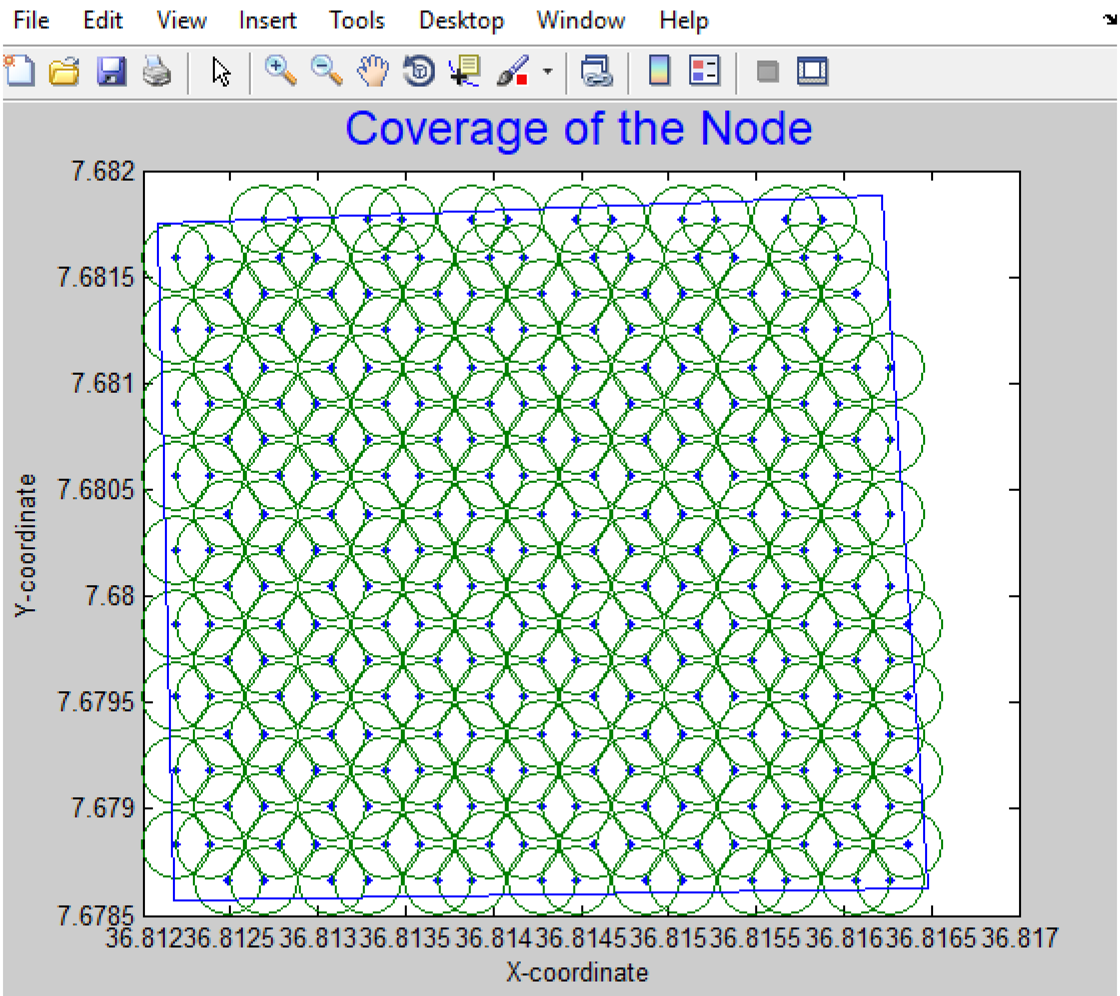


Figure 5.9*:Coverage of Deployed Sensor Node*

5.7.3 Network Connectivity

When we say a network is connected if a node within the network can communicate with another active node by means of single hop or in multiple hop [44]. From our deployment every sensor node has connected within the area of deployment connected with one or more than one sensor to each other. As a result, we can the system achieve network connectivity by using PEGASSIS routing protocol.

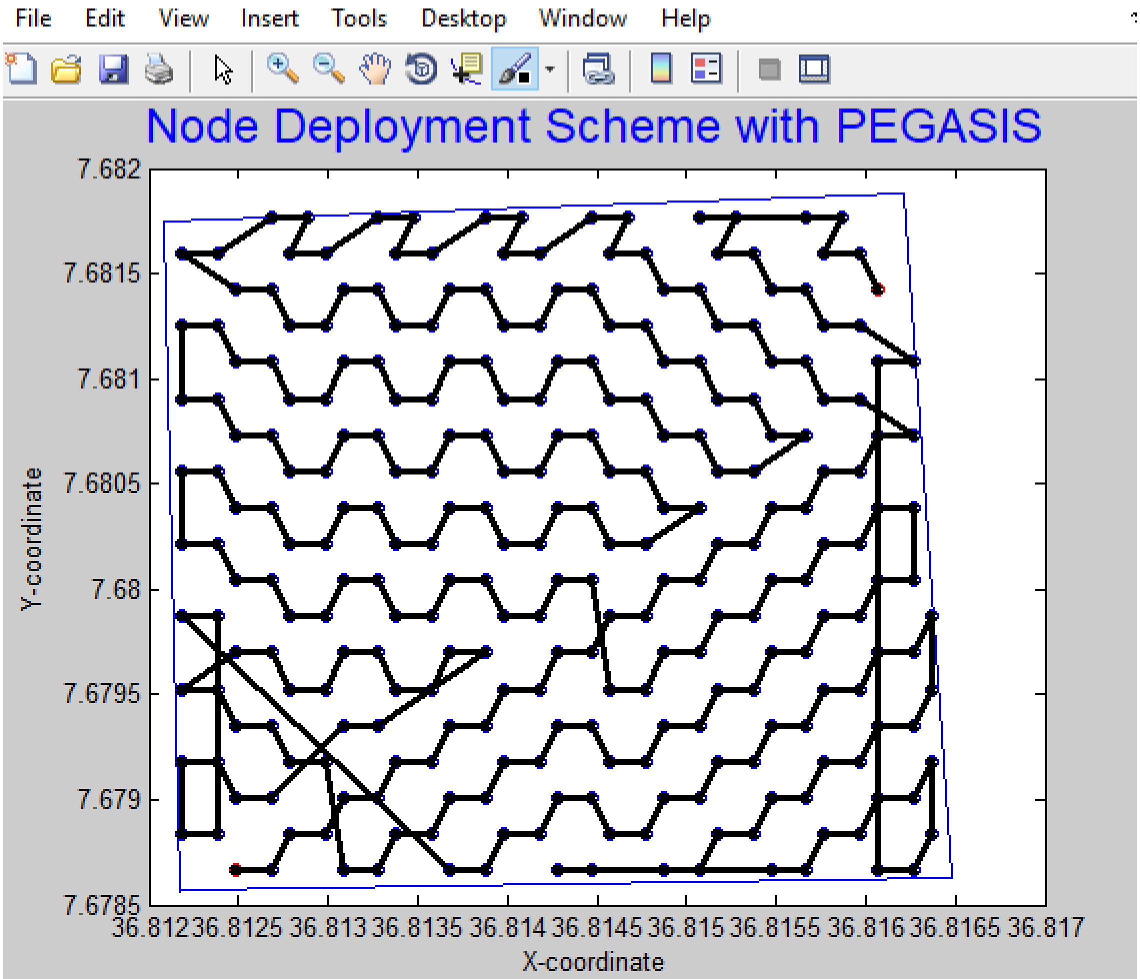


Figure 5.10*: Connectivity of Deployed Sensor Node*

5.7.4 Deployment Cost

In sensor node deployment, optimization takes huge place by many researchers. One of the basic criteria for optimal WSN deployment is reducing the number of sensor node to deploy in the given land. The proposed system uses grid based WSN deployment, which determine the position of sensor and number of sensor node. Unlike random deployment strategy, in grid-based deployment approach we know the position of sensor which assigned by ourselves. So, putting sensor node in exact position without just dropping many sensor nodes in one place reduce our sensor node for deployment purpose.

As we know the minimum cost for one sensor node costs around 1000$, So our approach is it takes minimum number of sensor node to cover the entire region of deployment area, which is much improvement from previous one because the cost of one single sensor node even difficult to buy.

5.7.5 Adaptability

Our proposed deployment scheme is adaptable to any shape of land. We have tasted the scheme in different shapes and the following figure illustrate it.

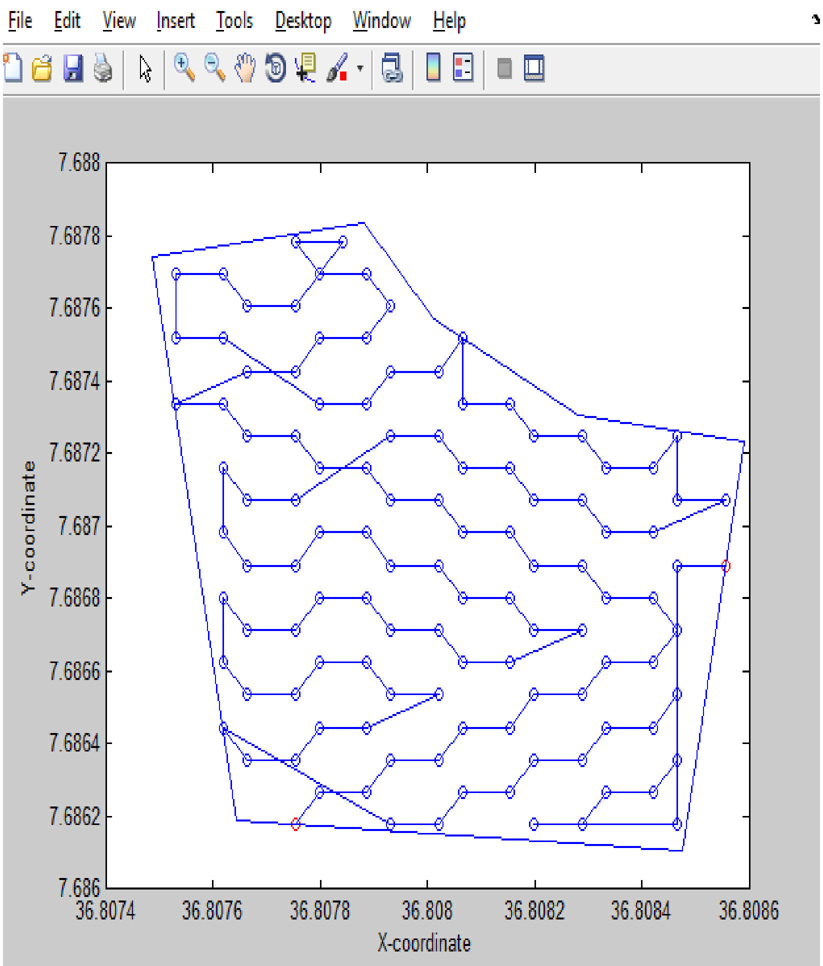


***Figure 5.11**: Proposed Deployment Scheme with different Shape of Monitored Area*

5.8 Summary

In this chapter discusses overall implementation of the proposed node deployment system starting from tools used and parameter used. Then discusses the way we collect data from google earth and how we implement in mat lab software. Finally presented proposed node deployment with evaluation part.

Chapter Six: Conclusion and Future Work

In this thesis, we first describe about Environmental and natural resource from different perspective regarding interaction and impact human societies on the environments. The paper also discusses Tourism industry in Ethiopia, which described as one, which is still in its infancy by many cases.

The proposed work also discusses about wildlife protection, which is essential for tourism industry for our country. The problem regarding wildlife protection is also presented. Then, WSN deployment strategy discussed and how to solve the problem regarding wildlife protection. A deployment scheme is proposed with the minimum number of sensor nodes to form a sensor network.

To conduct this, a number of literatures have been reviewed to provide background information about WSNs, node deployment, habitat monitoring and routing protocol and different research works related to sensor node deployment in WSNs. After discussing different literatures regarding the above issues, the proposed system design presented. Next , we demonstrated the shape based customized sensor node deployment using WSNs in habitat monitoring. Hence, for the given shape of the habitatland, our approach produces the corresponding node deployment scheme.

To achieve this, a deterministic deployment strategy was proposed in which the nodes are arranged in an hexagonal deployment pattern. It is an efficient coverage strategy since the nodes are deployed in hexagonal pattern.

The thesis has also shown the appropriateness of the proposed deployment strategy by means of performing different experimental simulations using different performance metrics in environment, mathematical modeling, theoretical analysis and formula deduction. The performance of the proposed node deployment system was measured in comparison with other previously proposed node deployment strategies.

The proposed scheme was intended to minimize the number of sensor node by satisfying the desired coverage of a given region with a minimum number of sensor nodes.The routing protocol we use in our proposed system is PEGASIS because it has better network lifetime.

Based on the cost of deployment, the number of nodes implies that the WSN deployed with the proposed scheme provided higher coverage with low cost than the previous works.

6.1 Contribution

In general, the contributions made by this thesis can be summarized as follows:

- Developed node deployment approach that can be used for different WSN application.
- The proposed deterministic hexagonal node scheme utilizes resource usage by minimizing sensor node used while fulfilling a node deployment design requirement.
- The proposed deployment scheme covers the gap in existing triangular deployment scheme
- The system provided a node deployment scheme with minimum number of sensor nodes that has a maximum coverage area.

6.2 Future work

As a future work we suggest to extend the existing work to address the following issues:

- The proposed system deployed two-dimension area, but it can be extended to three-dimensional area.
- The proposed system uses hexagonal pattern structure, but it can deploy in different patterns Such as Square.
- We use PEGASIS chain-based routing protocol for our proposed system, but can use other routing protocol which maybe we get better network lifetime such as DEEC cluster-based routing protocol.
- The proposed system uses Homogeneous WSN, but it can be deployed to Heterogeneous WSN which consists of sensor nodes with different ability, such as different computing power and sensing range

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Appendices

Sample Code

The following are sample code used in our proposed system. The codes are written in matlab software using C++ programming language.

Code specification:

```
a=0.08864;
Rs = 0.01;
num=1;
num_plot=1;
En=0.25;
send_to_sink=0;
ctl_pkt_leng=100;
data_pkt_length=2000;
die_node_num=0;
die_node_num_pri=0;
run_round=0;
transmited_packet=0;
En_Cost=0;
En_Cost_pre=0;
inter_cost=0;
begin_to_send=0;
En_cost_per_round=0;
alive=1;
dead=0;
```

Appendix A: Code for displaying node deployment scheme with PEGASSIS routing protocol.

```
hold on;
figure(1);
plot(XLon,YLat,'LineWidth',1); %draw the polygon line
title('Coordinates before deployment','Color', 'blue','fontsize',18);
xlabel('X-coordinate');
ylabel('Y-coordinate');
hold on;
while 1
    plot(xP, yP, '.','markersize',5);
    hold on;
    [in,on] = inpolygon(xP,yP,XLon,YLat);
    if xP(in)
        if yP(in)
        XR(nc) = xP;
        YR(nc) = yP;
        nc = nc+1;  %node iterator
        end
    else if xP(on)
        if yP(on)
        XR(nc) = xP;
        YR(nc) = yP;
        nc = nc+1;  %node iterator
        end
    end
    xIterator = xIterator +1;
    if mod(xIterator,2) ==0
        xP = xP+d;
```

```
    else
        xP = xP+(2*d);
    end

    if (xP>max(XLon) && yP<min(YLat)) || (yP<min(YLat))
        break;
    else if xP>max(XLon)
        row = row+1;
        if mod(row,2)==0
            xP = min(XLon)+(d/2);
            xIterator = 1;
        else
            xP = min(XLon);
            xIterator = 0;
        end
        yP = yP-yd;
    end
end
```

Appendix B: **Code for showing sensor node point before deployment**.

```
hold on;
figure(1);
plot(XLon,YLat,'LineWidth',1); %draw the polygon line
title('Coordinates before deployment','Color', 'blue','fontsize',18);
xlabel('X-coordinate');
ylabel('Y-coordinate');
hold on;
while 1
    plot(xP, yP, '.','markersize',5);
    hold on;
    [in,on] = inpolygon(xP,yP,XLon,YLat);
    if xP(in)
        if yP(in)
        XR(nc) = xP;
        YR(nc) = yP;
        nc = nc+1;  %node iterator
        end
    else if xP(on)
        if yP(on)
        XR(nc) = xP;
        YR(nc) = yP;
        nc = nc+1;  %node iterator
        end
    end
    xIterator = xIterator +1;
    if mod(xIterator,2) ==0
        xP = xP+d;
    else
        xP = xP+(2*d);
    end

    if (xP>max(XLon) && yP<min(YLat)) || (yP<min(YLat))
        break;
    else if xP>max(XLon)
        row = row+1;
        if mod(row,2)==0
            xP = min(XLon)+(d/2);
            xIterator = 1;
```

```
        else
            xP = min(XLon);
            xIterator = 0;
        end
        yP = yP-yd;
    end
end
```

Appendix C: Code that show coverage of the node**.**

```
hold on;
figure(3);
plot(XLon,YLat,'LineWidth',1); %draw the polygon line
title('Coverage of the Node','Color', 'blue','fontsize',18);
xlabel('X-coordinate');
ylabel('Y-coordinate');
hold on;
plot(Node.x,Node.y,'.')
scatter(Node.x,Node.y,720)
plot(XLon,YLat,'LineWidth',1);
hold on;
```

Declaration

I, Undersigned, declare that this thesis is my original work and has not been presented for degree in any other university, and that all sources of material used for the thesis have been acknowledged.

Declared by:

Name: **Eyoas Atnafu Kebede**

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Signature: _______________________

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