An Enhanced Node Placement Strategy for Cost Optimization in Wireless Multimedia Sensor Network over Elevated Terrain

A Dissertation Proposal

Submitted

By

Merensongla Aier

To

Department of Electronics and Communication Engineering

In partial fulfilment of the Requirement for the

Award of the Degree of

Master of Technology in

Electronics and Communication

Under the guidance of

Mr. Rajeev Kumar Patial

(Assistant Professor, Lovely Professional University)

(May 2015)

PAC APPROVAL

LOVELY PROFESSIONAL UNIVERSITY

Transforming Education, Transforming India

School of: SECE

DISSERTATION TOPIC APPROVAL PERFORMA

Name of the Student: Merensongla   Registration No: 11307068

Batch: 2013   Roll No. ....

Session: 2014-15   Parent Section: E2308

Details of Supervisor: Designation: AP

Name: Rajeev   Qualification: ME

U.I.D.: 17930   Research Experience: 9yr

SPECIALIZATION AREA: Wireless Com (pick from list of provided specialization areas by DAA)

PROPOSED TOPICS

1. Cost optimization for node placement in multimedia sensor networks (elevated Terrain)
2. Routing protocols in WSN for energy optimization)
3. Image compression in WMSN.

Signature of Supervisor 17930

PAC Remarks:

Approved

APPROVAL OF PAC CHAIRPERSON: Signature: Date: 30/10/14

*Supervisor should finally encircle one topic out of three proposed topics and put up for approval before Project Approval Committee (PAC)

*Original copy of this format after PAC approval will be retained by the student and must be attached in the Project/Dissertation final report.

*One copy to be submitted to Supervisor.

ABSTRACT

Wireless Multimedia Sensor Networks (WMSNs) have widen the horizon of surveillance system. In this work, the multimedia nodes (audio and video) are distributed in the region of interest in a heterogeneous structure. The sensors are deployed in an elevated terrain and are placed in such a way that the placement cost is optimal. An enhanced node placement strategy is proposed based on random deployment and we take into account the target covered by the sensors such that all targets are covered by the sensors with efficient number of nodes. The optimal cost for sensor placement is evaluated by taking the deployment cost, target coverage and elevation in the terrain. We carry out the simulation study for this random placement strategy using our proposed enhanced algorithm for node placement which helps to achieve optimal cost with better coverage and connectivity.

CERTIFICATE

This is to certify that **Merensongla Aier** has completed M. Tech dissertation titled **An Enhanced Node Placement Strategy for Cost optimization in Wireless Multimedia Sensor Network over Elevated Terrain** under my guidance and supervision. To the best of my knowledge, the present work is the result of her original investigation and study. No part of the dissertation has ever been submitted for any other degree or diploma. The dissertation is fit for the submission and the partial fulfilment of the conditions for the award of M. Tech Electronics and Communication Engineering.

Date:

Signature of Guide

Name: Mr. Rajeev Kumar Patial

UID: 12301

ACKNOWLEDGEMENT

It is with deep gratitude and appreciation that I acknowledge the professional guidance, support, advice and understanding of Assistant Professor, Mr. **Rajeev Kumar Patial** of Department of Electronics and Communication Engineering, Lovely Professional University, Jalandhar, Punjab throughout the dissertation session. His knowledge in “Wireless Sensor Network” helped me in finding appropriate details to my study in this field. I would like to thank the **Project Approval Committee members** for their valuable comments and discussions. I would also like to extend my gratitude to **Lovely Professional University** for their aid in academic studies and for allowing me to take parlance in this study. Lastly, I thank God for his blessings and guidance.

(Merensongla Aier)

DECLARATION

I hereby declare that the dissertation proposal entitled **An Enhanced Node Placement Strategy for Cost Optimization in Wireless Multimedia Sensor Network over Elevated Terrain** for the M.Tech degree is entirely my original work and all the ideas and references have been duly acknowledged. It does not contain any work for the award of any other degree or diploma.

Date: __________

Investigator: Merensongla Aier

Registration No: 11307068

TABLE OF CONTENTS

CONTENTS PAGE NO

LIST OF FIGURES vi
LIST OF TABLES vii

1. INTRODUCTION 1
1.1 Wireless Sensor Networks 1
1.2 Factors influencing WSN design 2
1.3 Types of WSN 3
1.4 Wireless Multi-media Sensor Network (WMSN) 4
1.4.1 Applications of WMSN 5
1.4.2 WMSN Network Architecture 5
1.4.2.1 Homogenous and Heterogeneous Architecture. 6
1.4.3 Sensor Node Placement in WMSN 7
2. REVIEW OF LITERATURE 9
3. PRESENT WORK 14
3.1 Problem Formulation 14
3.1.1 Assumptions 14
3.1.2 Problem Definition 15
3.2 Objective 16
3.3 Methodology 17
3.4 MATLAB 19
4. RESULT AND DISCUSSIONS 20
5. CONCLUSION AND FUTURE WORK 36
6. REFERENCES 37
7. APPENDIX 40

LIST OF FIGURES

1.1 Sensor nodes scattered in a sensor field 2
1.2 General hardware architecture of a sensor node 3
1.3 Applications of WMSN 4
1.4 WMSN layout 4
1.5 WMSN Architecture. 6
1.6 Multimedia connectivity in elevated terrain 15
1.7 Multimedia target coverage in elevated terrain 15
1.8 Flow chart of Enhanced node placement algorithm 18
1.9 GUI 20
1.10 (a) Initial deployment with 25 targets 21
1.10 (b) Deployment using our enhanced algorithm 22
1.10 (c) Deployment using existing approach 22
1.10 (d) Comparison with nodes 23
1.11 (a) Initial deployment with 38 targets 24
1.11 (b) Using enhanced algorithm 25
1.11 (c) Using existing algorithm 25
1.11 (d) Comparison graph with 38 targets 26
1.12 (a) Initial deployment with 48 targets 27
1.12 (b) Using enhanced algorithm 28
1.12 (c) Using existing algorithm 28
1.12 (d) Comparison graph with 48 targets 29
1.13 (a) Graphical analysis 30
1.14 (a) Coverage graph with 25 targets 31
1.14 (b) Coverage graph with 38 targets 32
1.14 (c) Coverage graph with 48 targets 33
1.15 (a) Cost comparison with 25 targets. 35
1.15 (b) Reduced costs with 25 targets 36
1.15 (c) Cost comparison with 38 targets. 37
1.15 (d) Reduced costs with 38 targets 37
1.15 (e) Cost comparison with 48 targets. 38
1.16 Graphical analysis of cost. 40

LIST OF TABLES

1. Comparison table of targets and nodes. 28
2. Comparison table of coverage and nodes. 34
3. Comparison table of targets and deployment cost. 39

CHAPTER 1
INTRODUCTION

Wireless sensor networks (WSNs) in recent years have gained high popularity. It is with the advancement in Micro-Electro-Mechanical Systems (MEMS) technology that leads to design and development of small and smart sensors [1]. These small nodes with the ability to sense, process data and communicate makes wireless sensor networks possible. These small and smart sensors are low power devices and consist of a processor, memory, power supply-where the main power source of power being battery, a radio and an actuator. The sensor nodes thus sense and collect data from the physical environment and transfer back the sensed data to the end user.

1.1 Wireless Sensor Networks

WSNs enable the sensors which are small devices to gather information in a large-scale network. The capabilities of these devices have contributed to many new applications and thus attract many researchers to explore the challenges. A sensor node has dual functions, both as data originators and data routers which give two reasons for communication:

a) Source function: when the sensor has event information, it performs communication to transmit their packets to sink/gateway.
b) Router function: it forwards the packets received from other nodes to next destination in the multi-hop path to the sink.

Figure 1.1 shows a sensor node scattered in a sensor field. The scattered sensors will gather the data and route it back to the sink or gateway and finally to the end user through multi-hop. The sink and end-users could also be directly connected. The sink communicates with the task manager or end users via internet or satellite or any other wireless system.

The applications of WSNs are numerous such as in military for tracking of target and surveillance, environmental monitoring, health monitoring, home security and industrial applications. As compared to traditional networks, WSN has design and resource constraints. The resource constraints are: limitation in energy, less bandwidth, short communication range, limited processing capability and storage in each node. Design constraints such as network size, deployment schemes and topology of the network hugely depend on the type of monitoring environment. Therefore, careful management of WSNs are required to meet its applications.

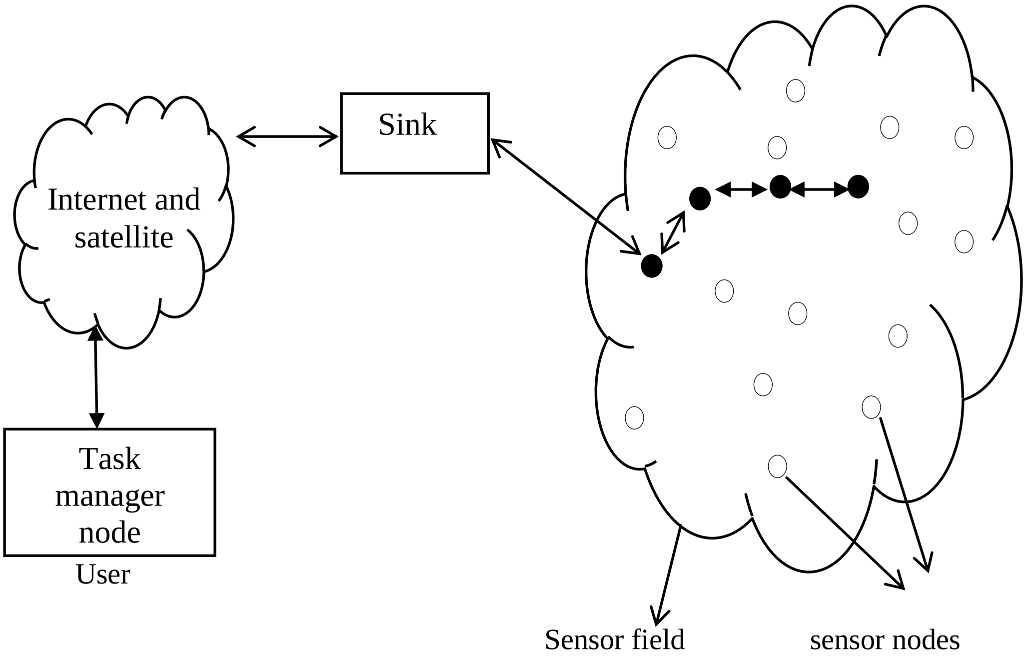


Fig 1.1: Sensor nodes scattered in a sensor field

1.2 Factors influencing WSN design

There are certain factors that influence any WSN design. They include:

- Hardware constraints
- Fault tolerance
- Scalability
- Production costs
- Sensor network topology
- Transmission media
- Power consumption

Fig 1.2 below shows general hardware architecture of a sensor node: The sensing unit helps in gathering information from the environment. The converted digital output if fed to the processing unit. The processing unit is the central unit which helps in sensing, run algorithms and communicate with other nodes. The role of transceiver unit is to establish communication link between the sensor nodes. Each component is powered by the power unit in the network and it uses battery power. Location finding system provides a GPS module or software implemented localization algorithms to locate the sensor nodes. Mobilizer enables the sensor nodes to move around to carry out necessary tasks. For long range communication, additional power generator is required.

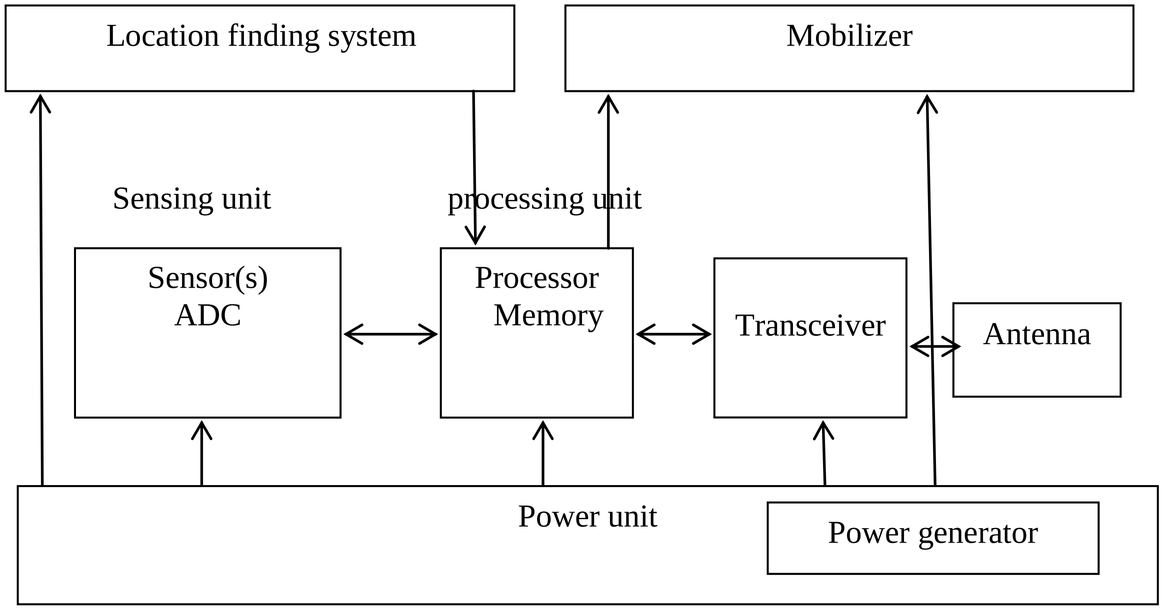


Fig 1.2: General hardware architecture of a sensor node.

1.3 Types of WSN

There are different types of wireless sensor networks deployed depending upon the type of environment [18]. They are:

a) Terrestrial WSNs: These types of sensors are deployed in dense environment randomly or in a uniform manner using grid placement, optimal or efficient placement or using 2D and 3D placement models. Effective communication of the data and transfer reliably back to the base station is important in terrestrial WSN.
b) Underground WSNs: Here, the sensors are buried underground to monitor its environment. Above the ground, additional sink nodes are placed to relay the information from nodes to the base station. These nodes are expensive and require efficient energy. Sensors once deployed are difficult to recharge and replaced.
c) Underwater WSNs: These sensor nodes are expensive compared to terrestrial sensors are so are deployed sparsely underwater. Through the transmission of acoustic waves, the underwater communication is established. The challenges involved in underwater acoustic communication are bandwidth limitation, delay in propagation and signal fading.

d) Multi-media WSNs: It enables to monitor and track any events in multi-media form like video, audio and imaging. These are low cost sensors nodes with camera and microphones attached. To get good coverage, multi-media sensors are deployed in the environment randomly or in a deterministic manner. Multi-media WSN has challenges like high demand of bandwidth, quality of service (QoS), processing and compression techniques of data, cross-layer design and high energy consumption.

e) Mobile WSNs: Mobile sensors have their own movement and can physically interact with the environment for real-time monitoring and tracking in disaster areas or for military purpose. These nodes can move even after the deployment phase and so has better coverage and connectivity as compared to static nodes.

1.4 Wireless Multi-media Sensor Network (WMSN)

Wireless sensor networks consisting of small devices enable large-scale networks and are deployed in the environment to monitor or survey any area of interest. These nodes measure temperature, humidity, pressure or objects location which are scalar physical phenomena [2] and transmit these sensed data to the sink directly or through multi-hops. But WSN has many restrictions in its design as mentioned above. So, to challenge the design and application constraints of traditional wireless sensor networks, multimedia sensors are used and WMSN has become the current trend.

The low cost CMOS cameras and microphones which have become highly available and accessible have helped tremendously in the advancement of Wireless Multimedia Sensor Networks. WMSNs are interconnected wireless network devices used to sense or capture multimedia contents like video, audio, still images and scalar sensor data from the environment.

Compared to the traditional sensor networks, the multimedia systems widen the horizon of surveillance or monitoring systems by enlarging the view, enhancing the view of the interested region and also enable multi-resolution views.

The multimedia sensors monitor and track the events and deliver the retrieved information in real-time. Thus, WMSNs has enhanced the applications of sensor network and several new applications were enabled which were not possible with scalar sensor networks.

1.4.1 Applications of WMSN

Some of the new applications enabled by WMSN are shown in Figure 1.3.

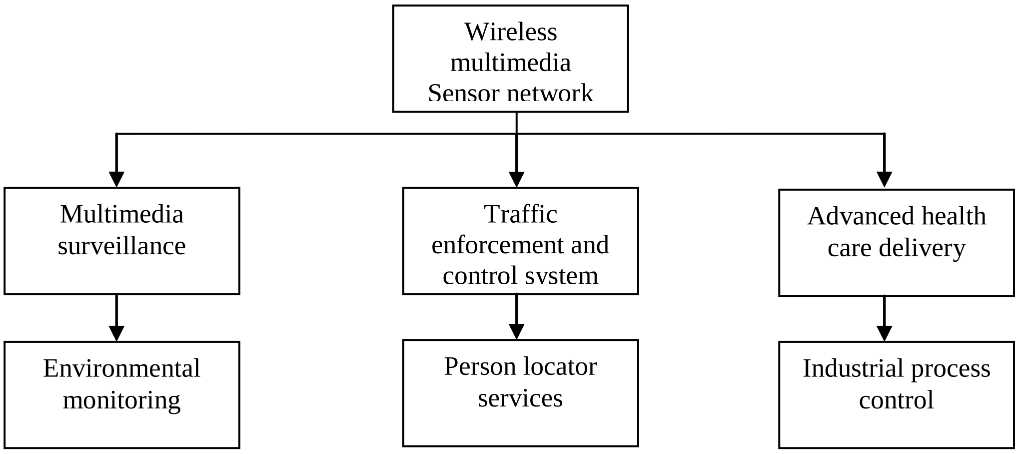


Fig 1.3: Applications of WMSN

1.4.2 WMSN Network Architecture

A typical WMSN is shown in figure 1.4 [3]:

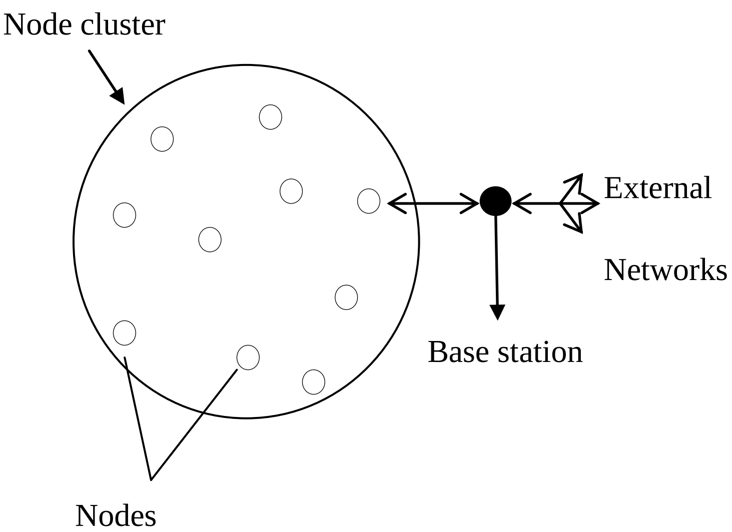


Figure 1.4: WMSN layout

Here, large number of nodes is deployed in the interested region and base station gathers the information from the nodes and store it or process further and acts as a gateway to external networks. The base station should lie close to the sensing nodes as large energy is consumed with increase in transmission distance which determines the lifetime of the sensor network.

1.4.2.1 Homogeneous and Heterogeneous Architectures

In terms of composition, the WMSN network architecture is classified as homogeneous and heterogeneous structures. In Homogeneous structure, nodes having same capabilities like energy, consumption and storage are present. Whereas, Heterogeneous structure consists of sensor nodes which has better sensing, processing and communication capabilities. They are classified into: single tier architecture and multi-tier architecture.

i) Single tier architecture: It is composition of homogeneous or heterogeneous components and is based on flat topology network. In this architecture, the content of the multimedia which is to be recorded or processed using the sensors is communicated via a multi-hop path to the wireless gateway. Figure 1.5 below shows WMSN architecture.

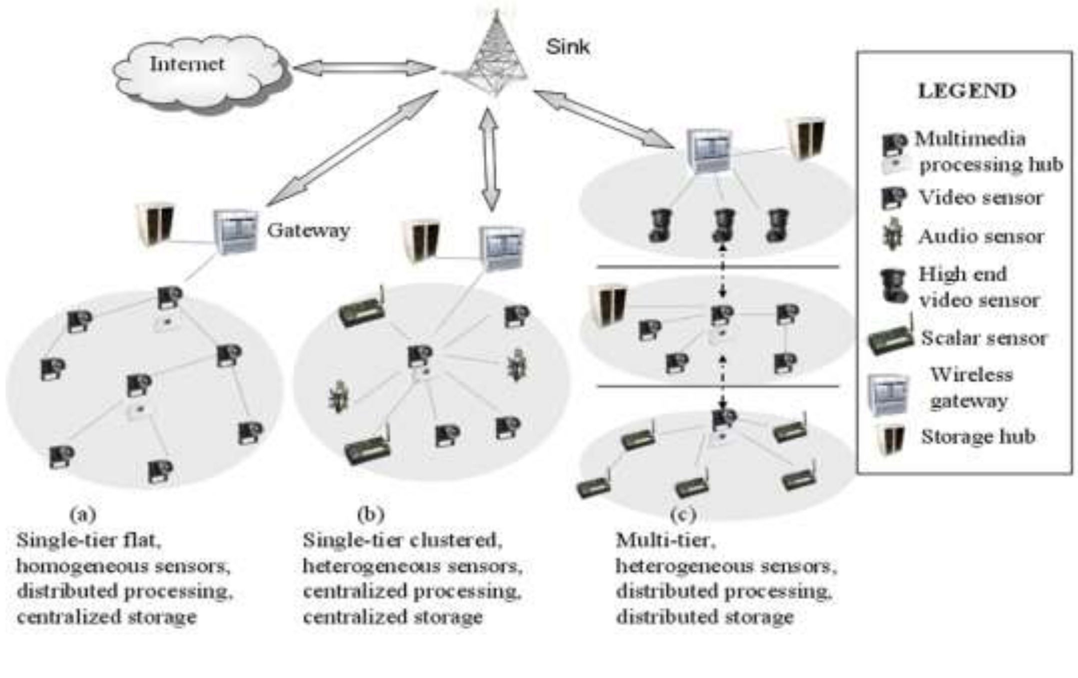


Figure 1.5: WMSN Architecture

Shown in Figure 1.5 part (a) is a single-tier flat, homogeneous video sensor with multiple processing hubs called distributed processing. The storage hub stores the multimedia content relayed through a multi-hop path for further retrieval. The network in part (b) of figure is shown consisting of single-tier clustered heterogeneous sensors. Here the nodes are organized as clusters where the video, audio and other sensors are controlled by a central cluster head. They perform intensive processing and aggregation. The cluster head will gather the information and is transmitted to the wireless gateway or storage hub for further processing and then store.

ii) Multi-tier Architecture: Part (c) of Figure 1.5 shows heterogeneous sensors in a multi-tier architecture. To perform simple task, low-end scalar sensors are placed at lower hierarchy. The sensors gather the information and initiate complex tasks like real-time event monitoring. These high activities are further achieved using high-end sensors with cameras attached at high hierarchy level. Clusters may be present in this architecture where independent operation is performed by each cluster leading to low energy consumption and traffic is minimized due to data aggregation.

In comparison to single-tier architecture, multi-tier architecture offers more advantages for sensor deployment which give better coverage, higher performance, scalability and low cost.

1.4.3 Sensor node placement in WMSN

Placement of sensors in the environment is application specific. To get the optimal sensor placement so that desired coverage of the target and other quality of service requirement is achieved is a challenging task. The placement strategies are classified as [19]:

i) Deterministic

ii) Random

Deterministic placement strategy is used when the target locations are known, the area to monitor is friendly and the node position has severe effect on the network operation. This type of deployment is usually preferred for indoor applications. Whereas, random placement is preferred for harsh environment like in critical area surveillance, forest fire detection or in risky terrains.

The sensors are deployed in such a way that the required design goals are achieved. Some of the primary objectives are:

a) To increase the coverage
b) Strong network connectivity
c) Network longevity
d) To boost data fidelity
e) Tolerance of node failure
f) Low cost

To achieve the design objectives of sensor deployment with the least available resources such as number of sensors by any network designer is challenging. Of the two different placement strategies – random and deterministic, random placement is the most challenging strategy where sensors are to be deployed in hostile environment which may lead to imprecise deployment. Also, earlier the video sensors were not used by many for random deployment due to higher cost and power consumption is more. However, due to the recent developments in low cost, low power video sensors, random deployment has become possible for various risky applications and terrains which is the focus of this work.

In WSN, the scalar sensors are also called Omni-directional sensors [8] as these sensors have Omni-angle sensing coverage. But multimedia sensors are called directional sensors which have limited sensing angle. The coverage problem of directional sensors highly depend on angle of view of the sensor which are limited and so more sensors are required to attain coverage ratio. It also depends on communication radius between the nodes and field of view (FoV) where coverage is obtained only if there is a line of sight between the event to be monitored and the sensor used. The interested event should lie within the sensing radius or range of the sensor. Only then the coverage is achieved.

The coverage is related to the sensor placement strategies where in case of random deployment more number of sensors needs to be deployed in excess in the region of interest. This may cause overlapping and desired coverage area may get reduced. Many algorithms and different deployment strategies are studied in the literature to get the optimal sensor placement. In this work, an enhanced algorithm for sensor placement is studied such that the targets in the region are covered efficiently and that there is strong connectivity among the sensors which helps in achieving optimal cost.

CHAPTER 2

REVIEW OF LITERATURE

Interesting researches on sensor placement is studied using different deployment strategies for surveillance system. Chakrabarty et al (2002) [6] present a work on surveillance and target location using grid coverage strategy. The sensor field is a grid system. Different types of sensors having different ranges and costs are placed using integer linear programming (ILP). This formulates the cost minimization problem and to achieve the complete coverage of the area under surveillance. To place the sensors at the grid points, the authors address this problem by using the concept of identifying codes. This concept helps to detect the target in grid positions from the set of sensors which are also in the grid points. In this work, the vertices of a graph represent the grid points and the sensors are placed at the centre of the balls of the grid points. The unique location of target is identified by unique vertex in the graph. If a sensor and a target are adjacent to each other at the grid points, then the target is detected by the sensor. This strategy helps in tracking multiple targets.

The analysis on target-based coverage with maximum coverage using directional sensors is shown by Cai et al (2007) [5]. It is named directional cover set problem (DCS) where the directions of a subset of sensors cover all the targets. The directional sensors have limited sensing range compared to omnidirectional sensors. So, two algorithms: a Greedy centralized algorithm and a distributed algorithm are proposed and compared to get the maximum coverage of target. The distributed algorithm works on the principle that sensor node reposition itself based on its neighbouring node information. A deployment stage is considered where priority label is given to a target to indicate number of directions of sensor node covered. Low priorities are given to targets with more coverage directions and high priorities are given to uncovered targets at the decision stage. In Greedy approach, each target is covered by at least one directional sensor and that no two directions overlap. This Greedy algorithm provides greater coverage.

A study in heterogeneous multi-tier architecture by Lopes et al (2007) [13] present an environment for wild life monitoring using passive infrared sensor (PIR) and visual sensor. The sensors are arranged in three tiers and there is interaction between first and second and then second and third tiers. The sensors track during any event occurrence in the environment but they remain idle if no event occurs. Such architecture present three applications: detecting, identifying and tracking. The first tier consists of PIR for target detecting whereas the video sensors present in second tier are used for object identification. Finally, the third tier equipped with high performance video sensors performs the tracking of any interested event. This study indicates that the heterogeneous structure has better advantage over single-tier architecture in terms of lower energy consumption and better management of available network resources.

The authors Chellappan et al (2007) [7] work on flip-based mobile sensor deployment which have mobility limitations. All the sensors have a fixed flipping distance and they can flip or hop to a new location only once. The goal is to get the optimal number of flips so that network coverage is at maximum and total number of sensor flips is minimized. Initially some sensors are deployed but holes may occur due to non-coverage by the sensors. To ensure that at least one sensor is present to cover the interested region, the sensors at first determine its location and position in the region. This information is forwarded to the base station (BS) through the sensors located near the BS using shortest paths. The network structure is modelled as virtual graph consisting of two regions: source and hole. If a region has no sensor, it is considered a hole and so a sensor will flow from source region to cover a hole in the region. This solution satisfies the coverage plan and number of flips used.

Wang and Zhong (2008) [17], study on coverage of targets by the chosen sensors with minimum-cost to get the desired coverage lifetime. The authors assume a set of sensors which are fixed having different cost (also defined by size or weight of sensor), different sensing capability but targets are stationary. The problem is formulated using integer linear programming to place the sensors at selected sites such that a minimum of one sensor watches every target at any time and there is minimization of total cost of sensors taken. This work presents scheduling of sensors between sleep mode and active mode using time-slot method. If more number of sensors covers a certain target, then it is scheduled to cover another target but if no sensor is present to watch a target, the time slot of unused sensor is sliced to cover the gap. This scheduling uses greedy approximation algorithm. But their study does not take into consideration the sensor nodes in case of failure and connectivity issues.

Osais et al (2008) [14] also present a directional sensor placement problem but to get minimum cost. As directional sensors have limited angle of view, the authors show that sensors are placed in different directions in the field to minimize the total cost. ILP model with a set of control points and placement sites for sensors were presented. The sensing range, field of view (FoV) and orientation affects the overall costs of directional sensor network where different sensors have different sensing ranges and angle of views. The main design goal is to reduce the cost with constraints such as minimum number of sensors should cover the target and connectivity is established and two sensors can communicate with each other if they are at placement site only. Also, only those nodes at placement sites are able to communicate with the sink node. The cost of the sensor placement is calculated by taking a threshold value of the placement site and varying the number of control points. The observations show that sensor cost increases with increase in control points.

The authors Lin et al (2008) [12] work on cost efficient random deployment of camera sensors for both homogeneous and heterogeneous in environment monitoring. Two types of cost: deployment cost and sensor cost are considered. The expected coverage using single sensor and joint coverage by number of camera sensors is analysed where the environment is obstacle free. Three different ranges define the sensing radius of the camera sensor and coverage is analysed. The study uses adaptive deployment strategy where at first iteration more sensors are deployed and decreases the number of the sensors in the next iterations depending on the area covered. This strategy avoids unnecessary deployment of more number of sensors which helps in achieving efficient cost and also the deployment cost.

Leoncini et al (2009) [10] investigate on deployment strategies where the best strategy for node placement depends on the environmental conditions and should meet the QoS requirements such as degree of coverage (DoC). The sensors are deployed at any arbitrary points in the region to monitor. Here, the authors use a partially controlled deployment strategy where the drop points are chosen by the network designer but after dropping the sensors, the exact location of sensors are uncontrollable which is also a kind of random placement. They find the best deployment strategy by fulfilling the degree of coverage (DoC) and with minimum number of nodes. Their study show that for practical scenarios, the deployment strategy depends on environmental conditions only and not on particular coverage degree.

Pandey et al (2009) [16] consider a clustering approach using a two-tier hierarchical heterogeneous sensor network. It uses regular sensor nodes called LiteNodes (LN) and high-end sophisticated nodes (SN). The LN has limited resources like battery energy, storage and computational aspects whereas the SNs are high performance powered. According to the architecture, LN forward the collected data through multi-hops to SN which acts as cluster head and finally to the base station. The LNs are placed randomly to sense the scalar parameters which create a traffic and minimum number of SN should be placed and form connectivity among the nodes. The traffic constraints and connectivity are solved using binary ILP, Greedy placement approach and GA. The BILP algorithm ensures a grid type placement assuming that SNs are placed at grid intersections in the interested region. As LNs are placed randomly and has a fixed sensing range defined by a circular area, the traffic constraint is achieved but not connectivity. Greedy approach locates the cluster head SN and using its heuristic approach more clusters are formed to locate the neighbouring SN. Thus, connectivity is obtained. The GA technique places the sensors based on fitness value. This concept gives the best solution but is expensive so it is not preferred when cost efficiency is a factor.

Omari and Shi (2010) [15] study on a pro-active deployment scheme and compare it with on-demand and at-front strategies. At-front deployment takes into account the environmental conditions and sensor lifetime and only the required sensors are deployed only once and no further deployment occurs. But in on-demand, further deployment occurs with respect to the demand if in case the available sensors drop below a certain threshold value. In pro-active, node failures and different cost ratios are considered. This strategy adapts to cost ratio variations and is best in performance among the three whereas, the at-front strategy has worse performance.

Kouakou et al (2010) [9] study a 3D model for indoor applications to get the efficient cost deployment. The authors present first of a kind to get the optimal sensor placement in 3D considering both deployment cost and in presence of obstacles. A heuristic algorithm is proposed and according to this algorithm, the sensors are deployed on the grid like points of the deployable region only one by one. The uncovered region due to presence of obstacles forms a shadow region. So, more sensors are deployed to cover this region. The variable costs of sensors are considered by maintaining connectivity where the unconnected nodes are moved near the connected nodes. The near optimal cost is obtained by taking the number of space that is under the coverage area of deployable points with respect to a unit deployment cost. This algorithm ensures full coverage and connectivity with minimal cost.

The authors Lin et al (2011) [11] work on cost efficient random deployment strategy using only homogeneous wireless camera sensors. But in this case, sensing field with and without obstacles are assumed to obtain coverage and analyse cost efficiency with respect to the number of sensors. The authors assume that the camera sensors know its orientation and location which are deployed using iterative method. All obstacles are taken as having same size (square blocks) and the sensors know their presence in advance. But this assumption is not practical as obstacles could be of different sizes in the environment. In presence of obstacles, the coverage percentage decreases. More sensors are deployed to the uncovered region but the overall cost efficiency also depend on the unit cost of one sensor. When only one sensor is deployed iteratively, this will lead to an increase in deployment cost. This study presents a stable cost effective adaptive deployment strategy.

Bhatt and Datta (2014) [4], study three different strategies: deterministic, random and hybrid in a multi-tier heterogeneous architecture over flat and elevated terrains using multimedia sensors (audio and video). To minimize the cost of deployment, two cost models for coverage and connectivity were proposed. They formulate a minimum deployment cost (MDC) problem and use integer linear program (ILP) and greedy approximation algorithm to solve the sensor placement problem in 3D space. The cost models use ILP and Greedy for deterministic placement whereas the sensors are randomly distributed using a flip model. The effects of node density, slope, weights and number of targets are considered and this study shows that deployment cost depends on the deployment strategy used.

CHAPTER 3

PRESENT WORK

In this chapter, we present the problem of our work, its formulation, objectives and methodology used to solve the problem and an introduction of the tool used. In section 3.1, we explain how the problem is formulated and the exact problem definition. Section 3.2 presents the objectives of our work and in section 3.3 we discuss the solution to our problem using the proposed methodology with the help of a flow chart.

3.1 Problem formulation

This work present a problem to minimize the WMSN node placement cost for surveillance application.

3.1.1 Assumptions

We make the following assumptions to formulate our problem.

1) Wireless multimedia sensor network is taken as a region **A** which is elevated.
2) The region **A** has a set of sensors **S**, where α consists of audio sensors and β is a set of video sensors.
3) Number of targets represented by **T** is covered by the sensors if the target lies within the sensing range R_s**.** The targets that are not covered are also considered in our work.
4) All the sensors in the network are strongly connected to each other and in case of sensor failure, the neighbouring sensor is able to connect with the other available sensor node. The base station lies near the connected sensors.

The network architecture is a heterogeneous structure where multimedia sensors- audio and video sensors are deployed. The region under surveillance such as in risky terrains, the sensors is deployed randomly. These deployed sensors ensure strong connectivity and coverage. Figure 1.6 and figure 1.7 shows the connectivity among the nodes and target coverage by the deployed multimedia sensors respectively.

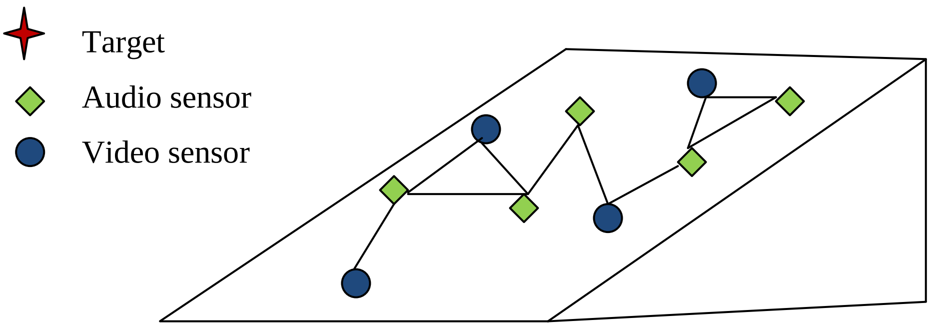


Fig. 1.6: Multimedia sensors connectivity in elevated terrain.

The figure in 1.7 shows the coverage of targets by the multimedia nodes.

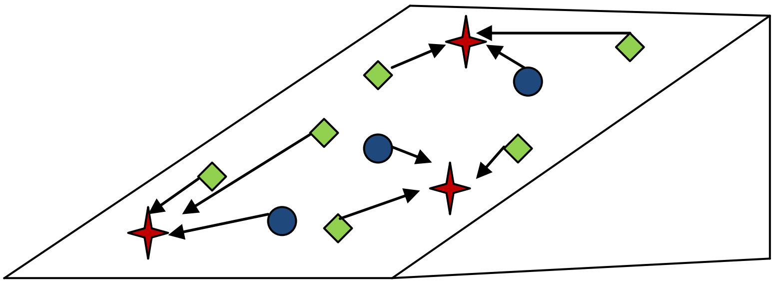


Figure 1.7: Multimedia target coverage in elevated terrain.

3.1.2 Problem definition

Sensor placement strategy such that optimal cost is achieved is a challenging task to any network designer. In this study, it is known as Optimal Cost Sensor Placement (OCSP) problem. The OCSP problem is defined as: If $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are the set of available set of audio and video sensors respectively and **T** is a set of target, then the multimedia sensors are deployed over the surveillance area or region of interest (RoI) with successful target coverage and optimal cost.

Another critical issue in any sensor network is connectivity which is fundamental in obtaining optimal sensor placement. So, the network is modelled as a graph and the vertices of the graph represent the sensor nodes and connectivity is established only if there is a path between the nodes. This connected network helps each sensor nodes to communicate within its sensing range. The audio and video sensors have the sensing ranges defined by the Euclidean distance and is given as if x_{i1} and x_{i2} are the positions of audio /video sensors and y_{j1} and y_{j2} are the positions of targets, then the sensors are said to cover a target if its Euclidean distance between the sensors and targets is less than or equal to sensing range.

$$\sqrt{(x_{i1} - y_{j1})^2 + (x_{i2} - y_{j2})^2} \leq R_s$$

The terrain under study is an elevated terrain and the sensors are placed based on random strategy in 3-D plane and the goal of this work is to achieve the OCSP. There are factors associated with the terrain such as slope or elevation angle and roughness. In our analysis, the terrain has a slope of 45^0 where, θ = tan 45. The roughness factor is denoted by *'k'*. The cost functions of sensors are both fixed and variable [16] and there are weights *w1* and *w2* associated with it respectively. For the deployment cost, fixed cost function is for fixed cost of audio and video sensors but does not depend on deployment point whereas the variable cost depends on roughness factor and slope.

If *f (c)* = cost of one sensor

f (max) = total available cost of maximum sensors

S (d) = is the total sensors in the field

T (c) = number of targets

Then, the deployment cost is given as:

$$C = w1 \times \frac{f(c)}{f(max)} + w2 \times \frac{S(d)}{T(c)} \times \tan\theta \times k$$

Where, k = √2

3.2 Objectives

The objectives of this study are:

- To place the sensors in an elevated terrain based on random strategy for surveillance in 3D space model.
- The number of sensors deployed is to be considered to get optimal target coverage.
- Cost optimization model to achieve network coverage and connectivity.
- Compare and analyse between the existing algorithm integer linear program (ILP) and our Enhanced node placement algorithm.
- To implement the problem in MATLAB for better simulation results.

3.3 Methodology

In this study, the solution to the optimal cost sensor placement (OCSP) problem is an enhanced node placement strategy based on random deployment.

Here, the initial deployment of sensors is done randomly with respect to the number of targets. After this, the sensors check for the target coverage and are able to cover the uncovered targets with optimal sensors. In earlier work, the uncovered targets are not considered but using our enhanced algorithm, all the targets in the field or region of interest are covered. This algorithm helps store the list of fields covered by the sensors so that the covered fields are not revisited by the sensors. This strategy helps in achieving better coverage and connectivity performance. The working of this algorithm is given as:

Step 1:

Plot the sensors in the field randomly

Step 2:

Check for every sensor if the target points are covered

Step 3:

If the point is not covered previously, then there exists a field that is not covered. Now if a field for this previously uncovered point does not exist, then

Step 4:

Go to step 2; otherwise, add new field which will cover previously uncovered target points and then add the target point to the field that covers previously uncovered points

Step 5:

From step 3, if the target points are already covered previously, then the points are already in the field. But if the points are not in the field, then repeat step 2. Otherwise

Step 6:

There is no new field similar to old field that contains the target point. If the condition is not satisfied, repeat step 2. But if the condition is satisfied, then new field is added to the old field and also add the target point to this new field which is similar to the old field that contains the target

Step 7:

Now all the new fields that are covered by new sensors are added to the list of the fields

Step 8:

And for every new field, add to all sensors covering the old field and the list of sensors covering that field similar to that new field

Add new sensor to the list of sensors covering that field.

The flow chart is shown below in figure 1.8

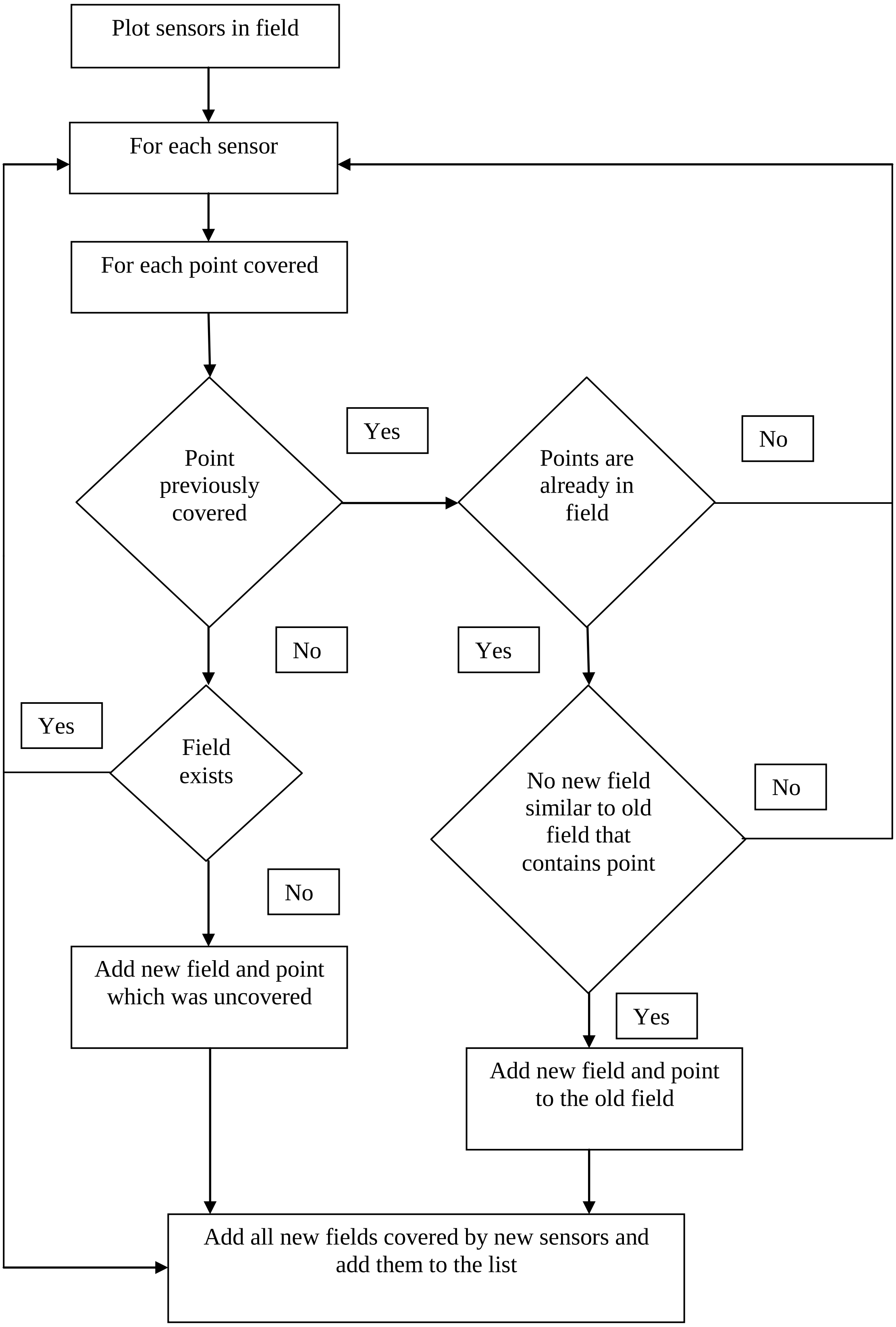


Figure 1.8: Flow chart of Enhanced node placement algorithm

3.4 MATLAB (R2011a)

MATLAB stands for Matrix Laboratory. It is a high level program language used for numerical computation, data analysis, modelling and simulation and in various developments of algorithms. MATLAB helps to solve problems faster than other languages and are used in various applications both for research and academic purpose. The system has the following parts:

- Desktop tools and development environment
- Mathematical function library
- The language
- Graphics
- External interfaces

3.4.1 Features of MATLAB:

- Environment to manage the files and data.
- 2-D and 3-D graphics functions for data analysis.
- Provide tools for solving problems.
- High level language
- It has Application Program Interface (API) to write the language.

3.4.2 Standard windows in MATLAB:

- **Command Window**: To type and execute commands.
- **Workspace Window**: This stores the variables created during a session and one can modify or view again by selecting the variables.
- **Current Directory window**: This shows current path or folder where the files are located.
- **History window**: It displays previously executed commands with date and time of the previous sessions.

3.4.3 MATLAB help

- Help option is present on the top of the window on the right side.
- MATLAB help provides powerful and easy way to learn the MATLAB.
- It explains the commands with examples and proper demonstrations.

CHAPTER 4

RESULTS AND DISCUSSIONS

This simulation of this work is done using MATLAB (R2011a) based on a random deployment strategy in an elevated terrain. Using our proposed approach, various results are obtained and we then compare with the existing work.

5.1 Simulation using our Enhanced node placement algorithm and comparison with existing work.

In this set of experiment we use the proposed algorithm for optimal cost deployment and we study the effects of targets, number of sensors deployed, weights (w1 and w2) and cost. Keeping f (c) = 15 and f (max) = 150, k = √2 and values of w1 = 0.2 and w2 = 0.1.

5.1.1 Number of targets vs. number of sensors deployed:

The GUI is shown in figure 1.9 from where the inputs are taken and output is displayed.

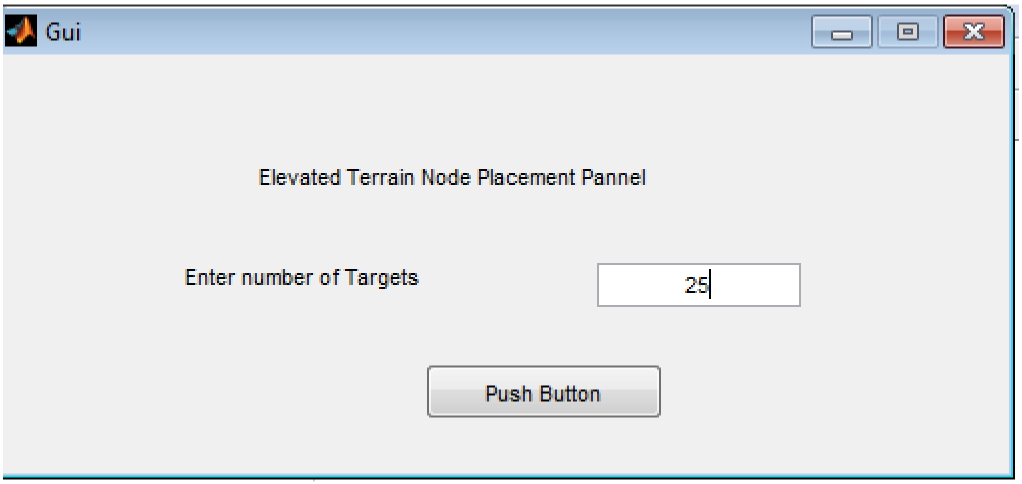
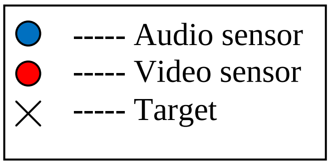


Fig: 1.9 GUI

The network area is 100 × 100 square and we vary the number of targets as 25, 38 and 48 respectively for all sets of performance study.

A) Taking 25 targets:

Initial deployment is shown in figure 1.10 (a)



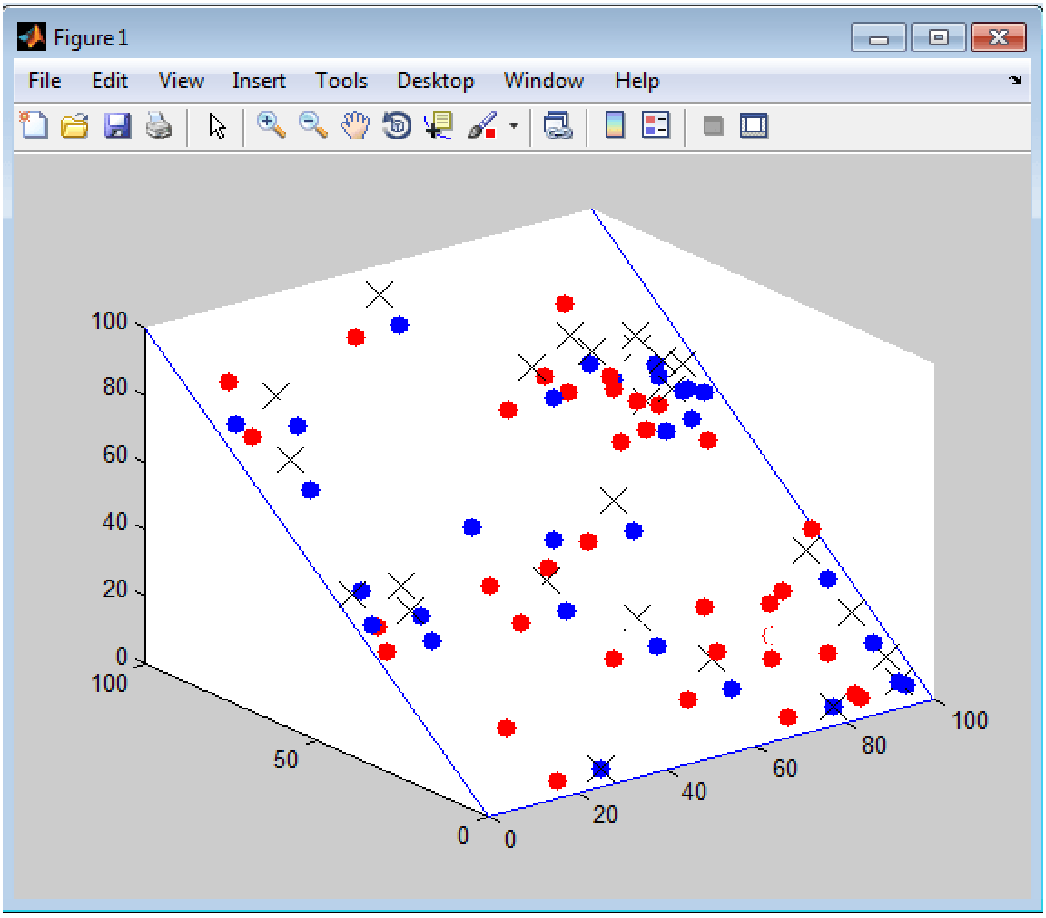


Fig 1.10 (a) Initial deployments with 25 targets

When 25 targets are taken in the field, the sensors are deployed randomly initially as shown in figure above. But this kind of random deployment may leave some targets uncovered even when large numbers of sensors are deployed. So, an enhanced node placement strategy is used which will improve the target point coverage and with efficient nodes.

Figure 1.10 (b) below shows the improved placement using our enhanced placement strategy.

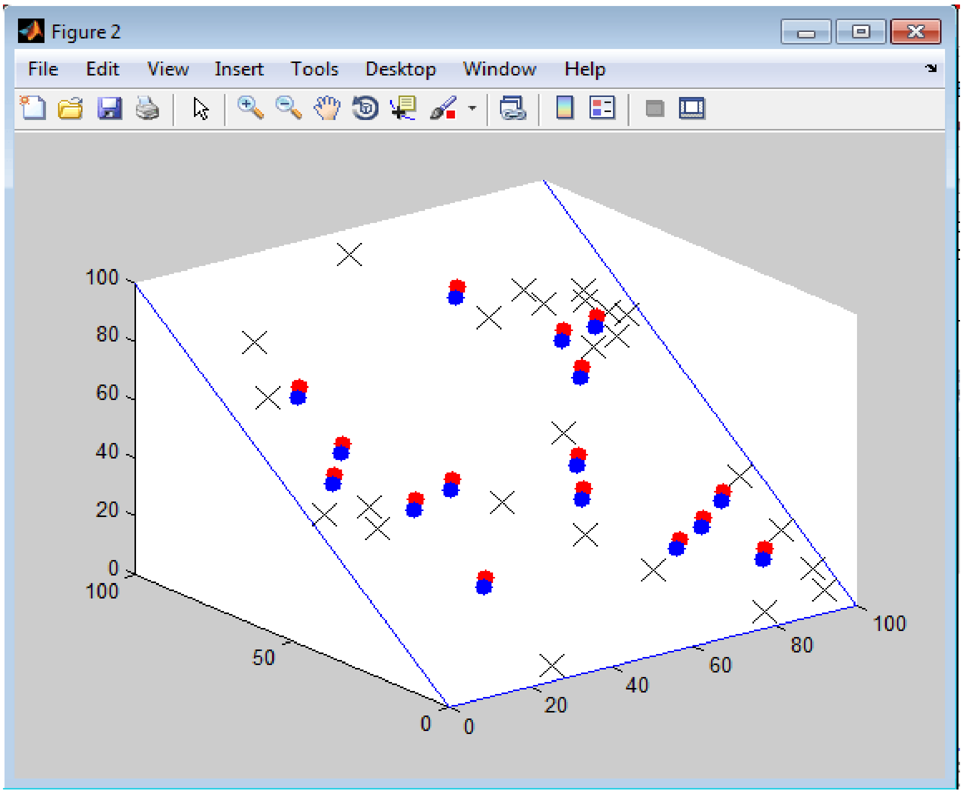


Fig 1.10 (b): Using our enhanced algorithm

Figure 1.10 (c) shows the deployment using existing approach.

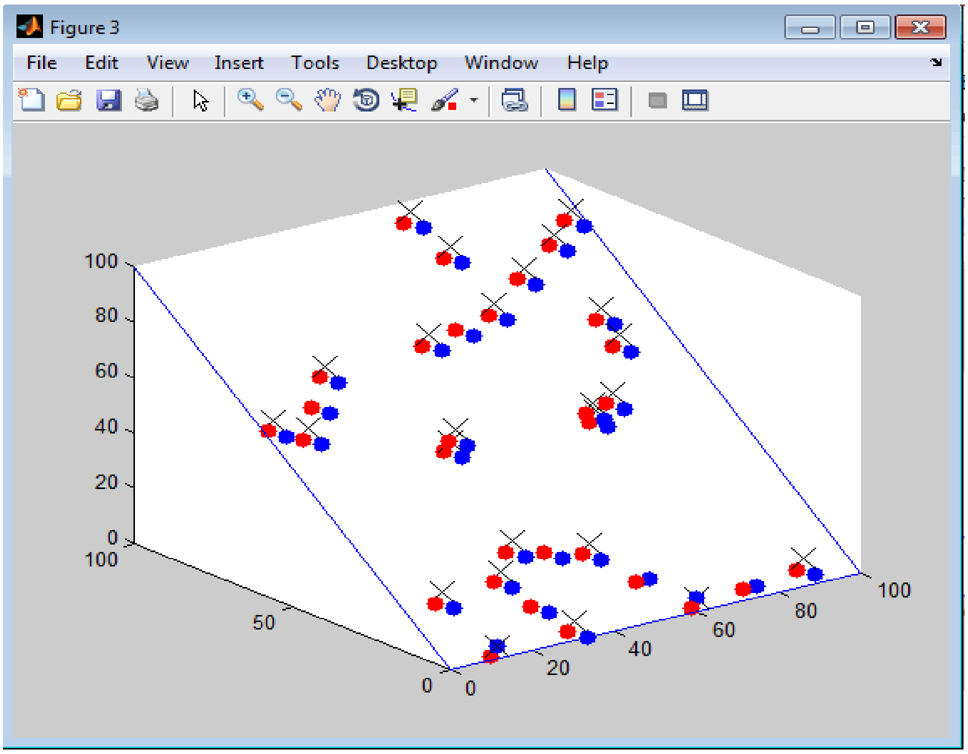


Fig 1.10 (c): Deployment using existing approach.

From the above figures shown, it is clear that our strategy covers the target points using minimum sensors as compared to the existing approach placement which follows a deterministic strategy. Their placement deploys more sensors to cover the same number of targets.

Comparison graph for targets vs. nodes is plotted and we can infer that our method (1) covers the targets with less number of nodes as compared to the existing work-method (2) is shown in figure 1.10 (d).

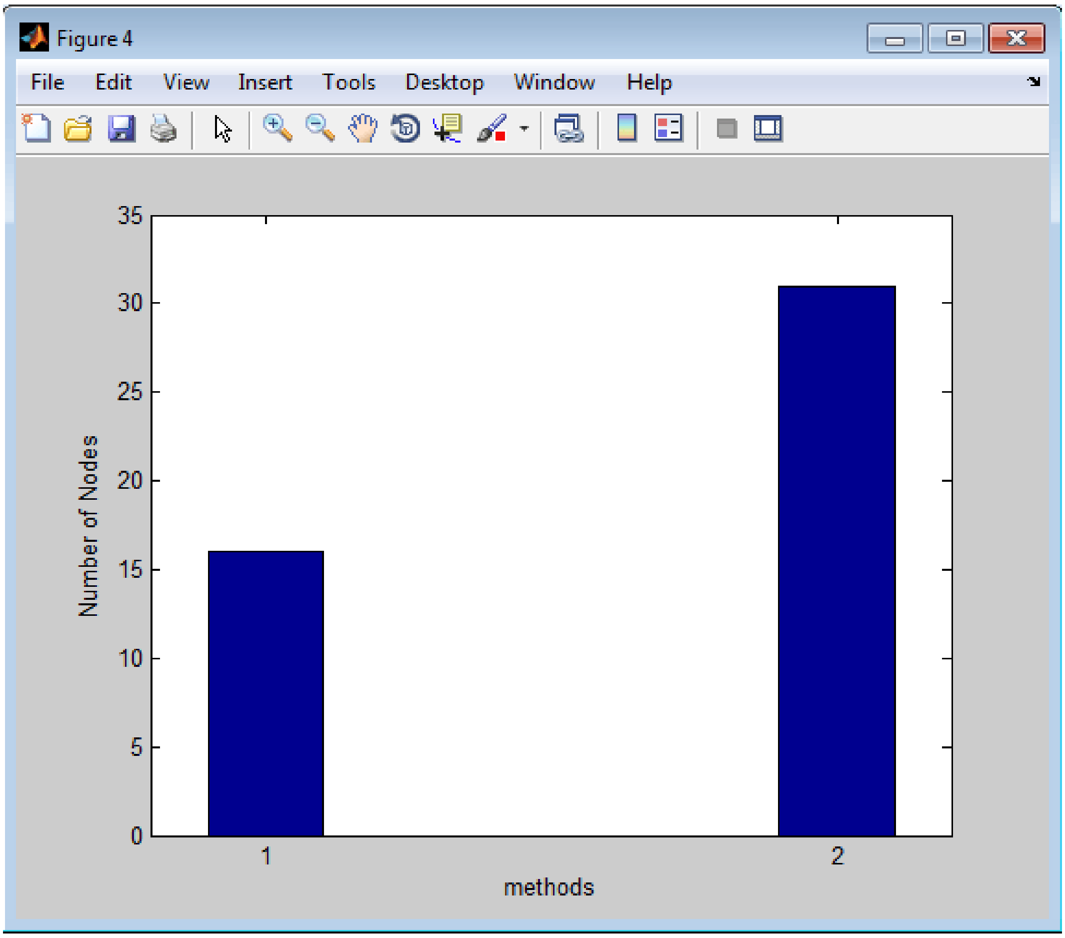


Fig. 1.10 (d): Comparison with 25 targets vs. nodes

Our approach deploys 16 sensor nodes (same for both audio and video) whereas the existing approach deploys 31 sensor nodes (same for both audio and video) to cover 25 targets in the field.

B) Taking 38 targets

Initial deployment is shown as:

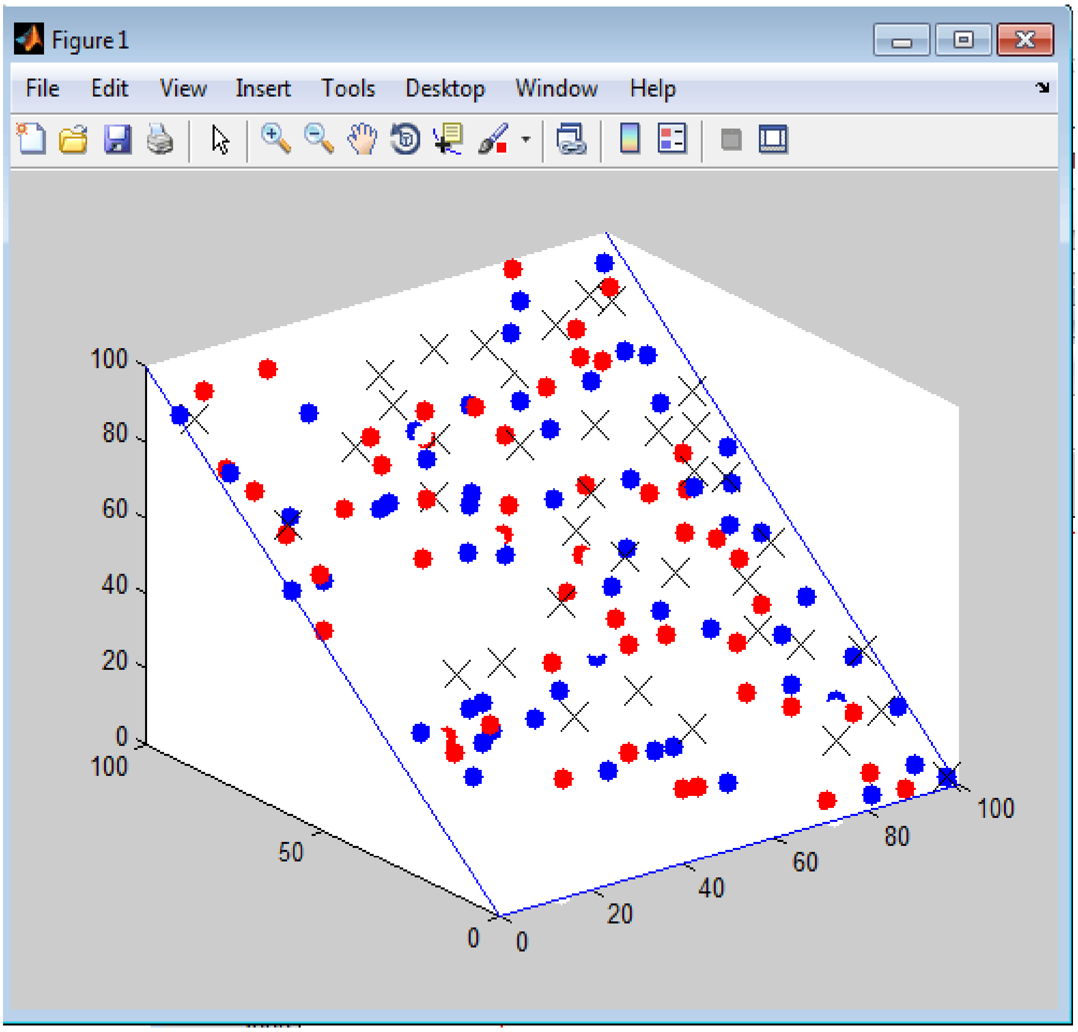


Fig. 1.11 (a) Initial deployment

When the targets are increased to 38, more sensors are deployed randomly initially. Now, using our strategy the nodes are placed as shown in figure 1.11 (b) and node placement using the existing approach in figure 1.11 (c) below:

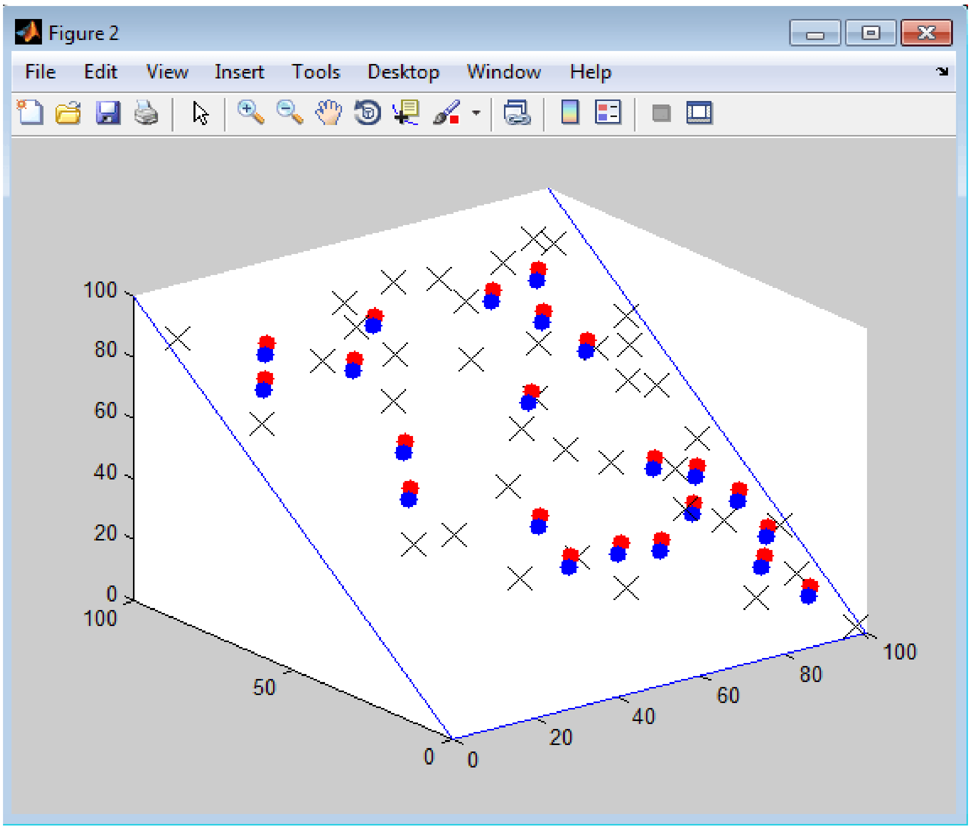


Fig. 1.11 (b): Using our enhanced algorithm

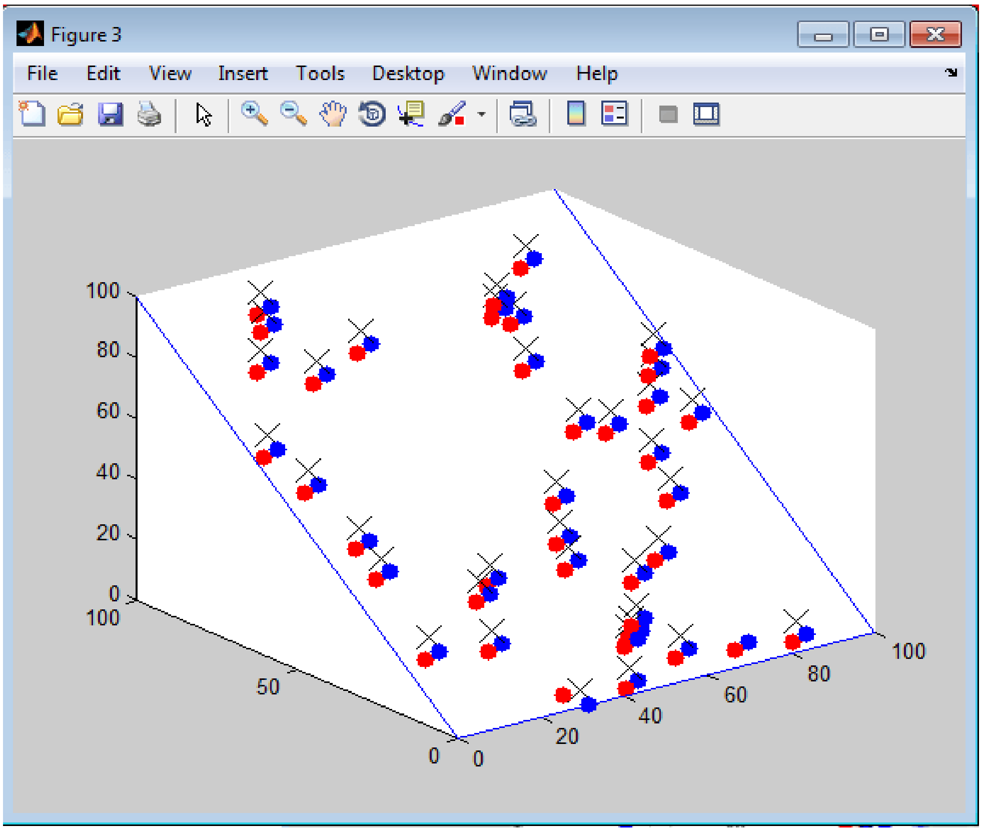


Fig. 1.11 (c): Using existing deployment.

From the above figures we infer that our approach deploys 22 nodes whereas the existing approach deploys 48 nodes when 38 targets are considered. Thus, our approach gives better placement and more efficient strategy with the increase in targets.

Figure 1.11 (d) below shows the comparison graph.

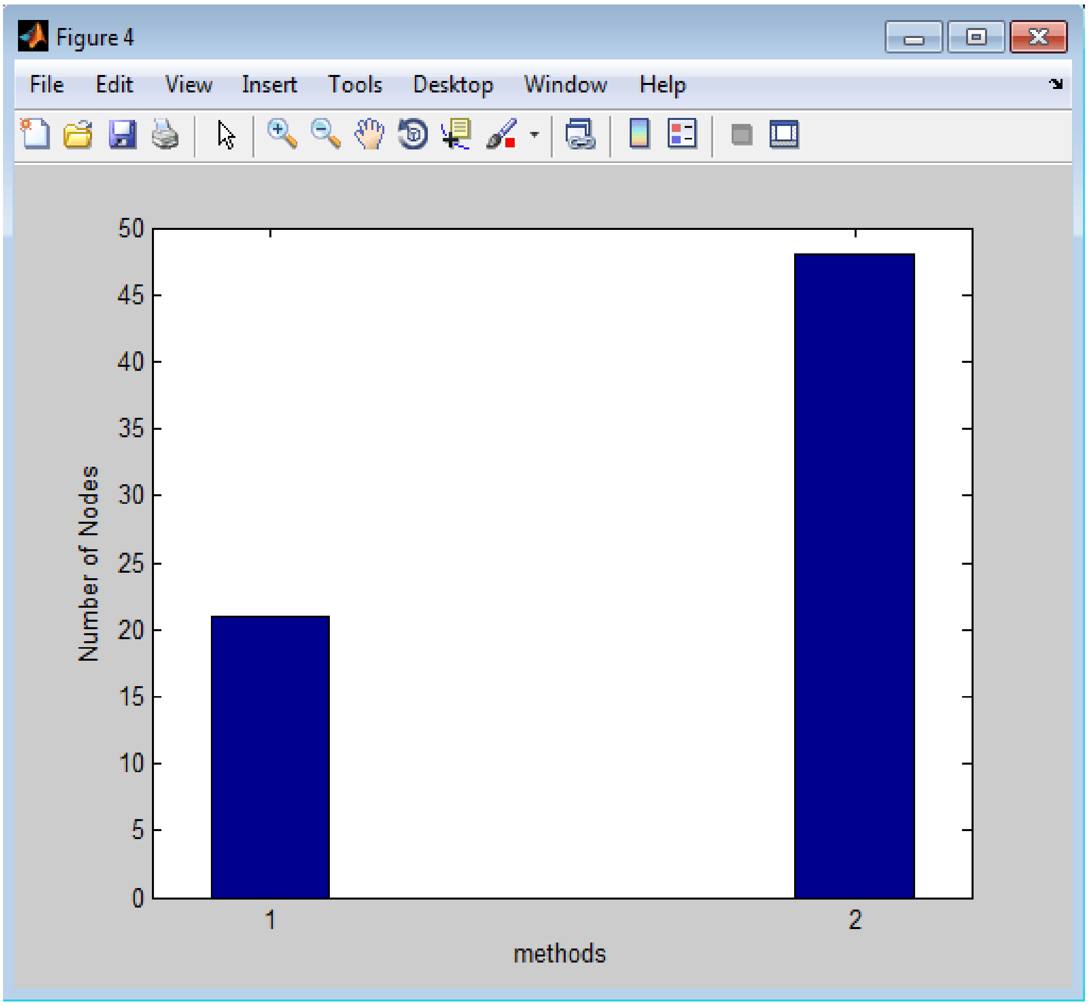


Fig. 1.11 (d): Comparison graph with 38 targets: our method (1) vs. existing method (2)

Comparison graph for targets vs. nodes is plotted and we can infer that our method (1) covers the targets with less number of nodes as compared to method (2).

C) Taking 48 targets

Initial deployment is shown as:

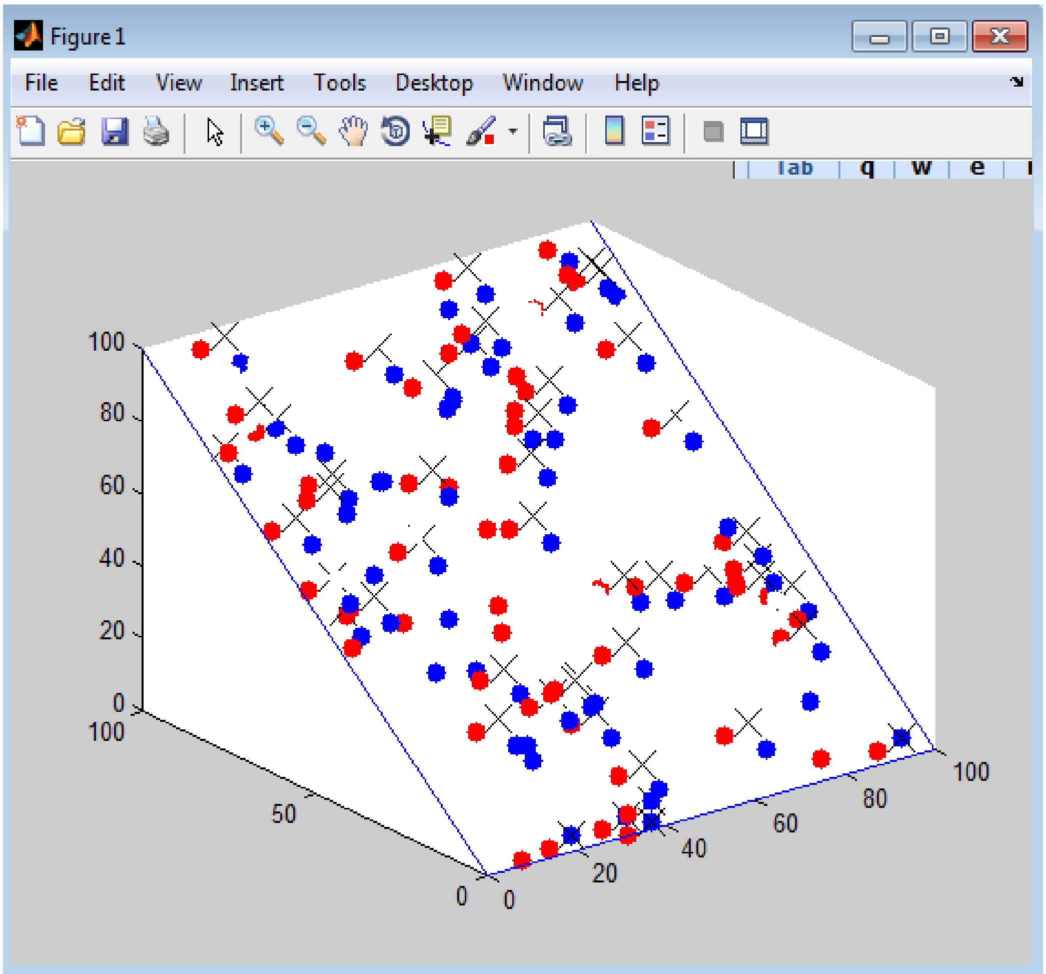


Fig: 1.12 (a): Initial deployment.

In this case we take 48 targets and perform the initial deployment. The sensors are deployed in excess randomly in the region to cover the targets.

Figures 1.12 (b) and 1.12 (c) below shows the deployment using our strategy and existing work respectively as:

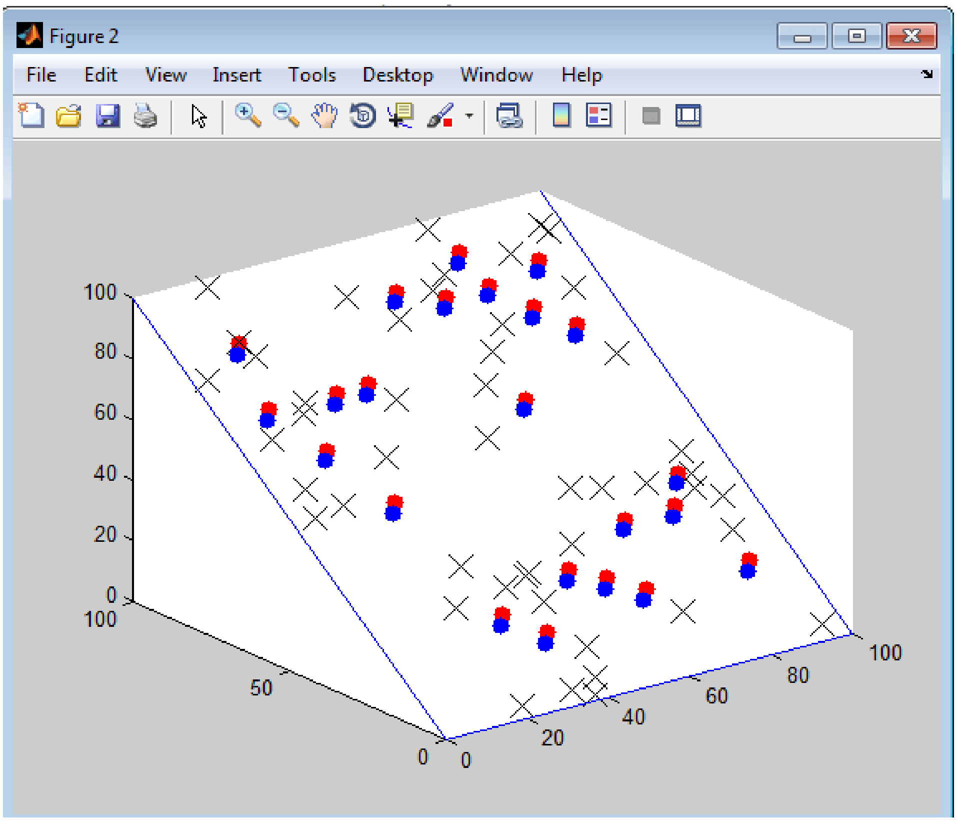


Fig. 1.12 (b): Using our enhanced algorithm

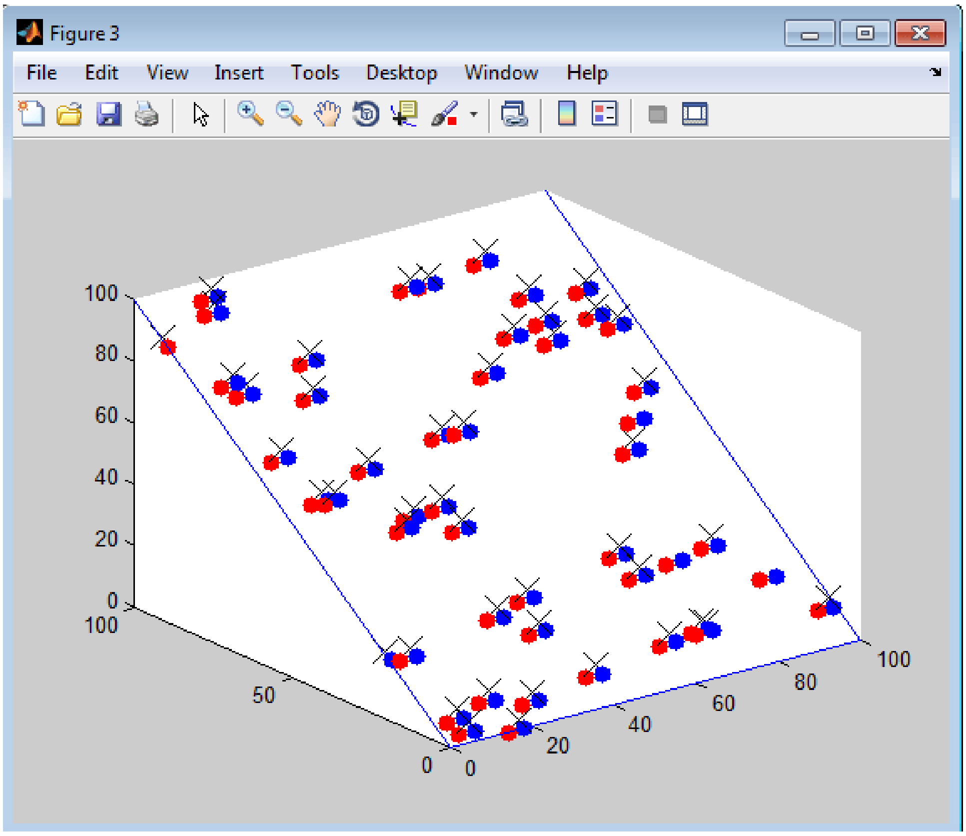


Fig. 1.12 (c): Using existing method.

The comparison graph using 48 targets is as given below:

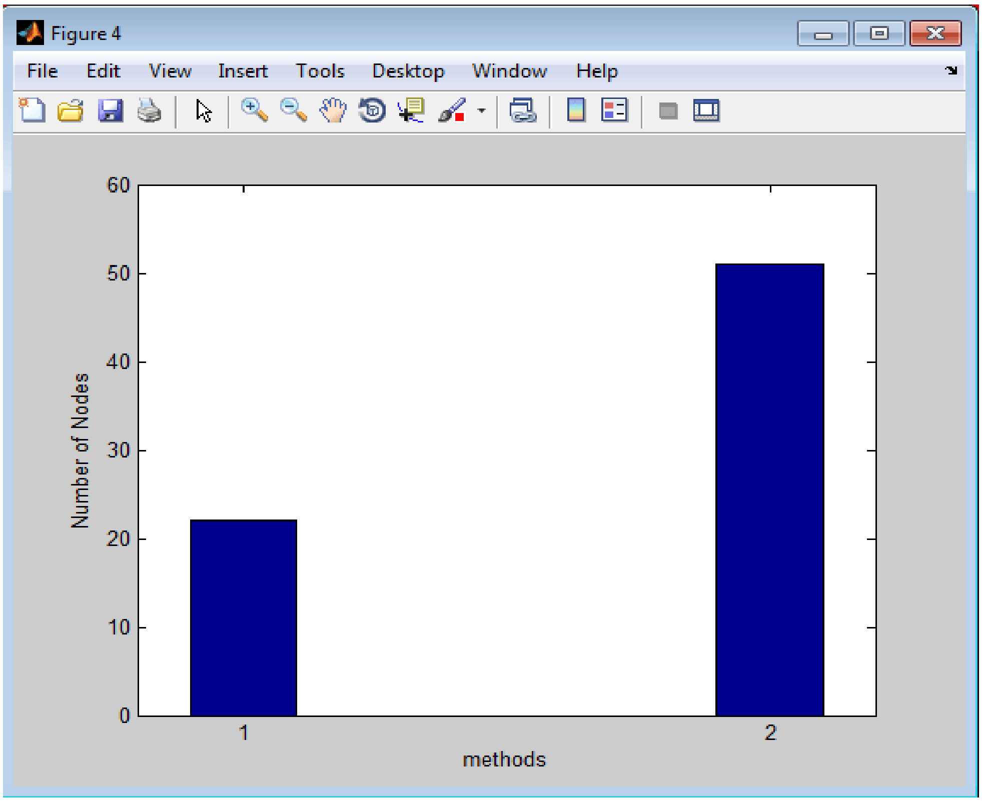


Fig. 1.12 (d): Comparison graph with 48 targets

For 48 targets, our method (1) deploys 24 sensors and the existing method (2) requires 51 sensors to cover the given targets.

From all the above figures using 25, 38 and 48 targets, we observe that our proposed method covers the targets with less number of nodes in all the cases. A detail tabulation of all the above cases is shown in table 1.

S.No	Number of Targets	Number of Nodes Deployed	
		Proposed algorithm	Existing approach
1.	25	16	31
2.	38	20	48
3.	48	24	51

Table 1: Comparison of targets vs. nodes

The comparison with graphical analysis for 25, 38 and 48 targets is plotted and shown in figure 1.13.

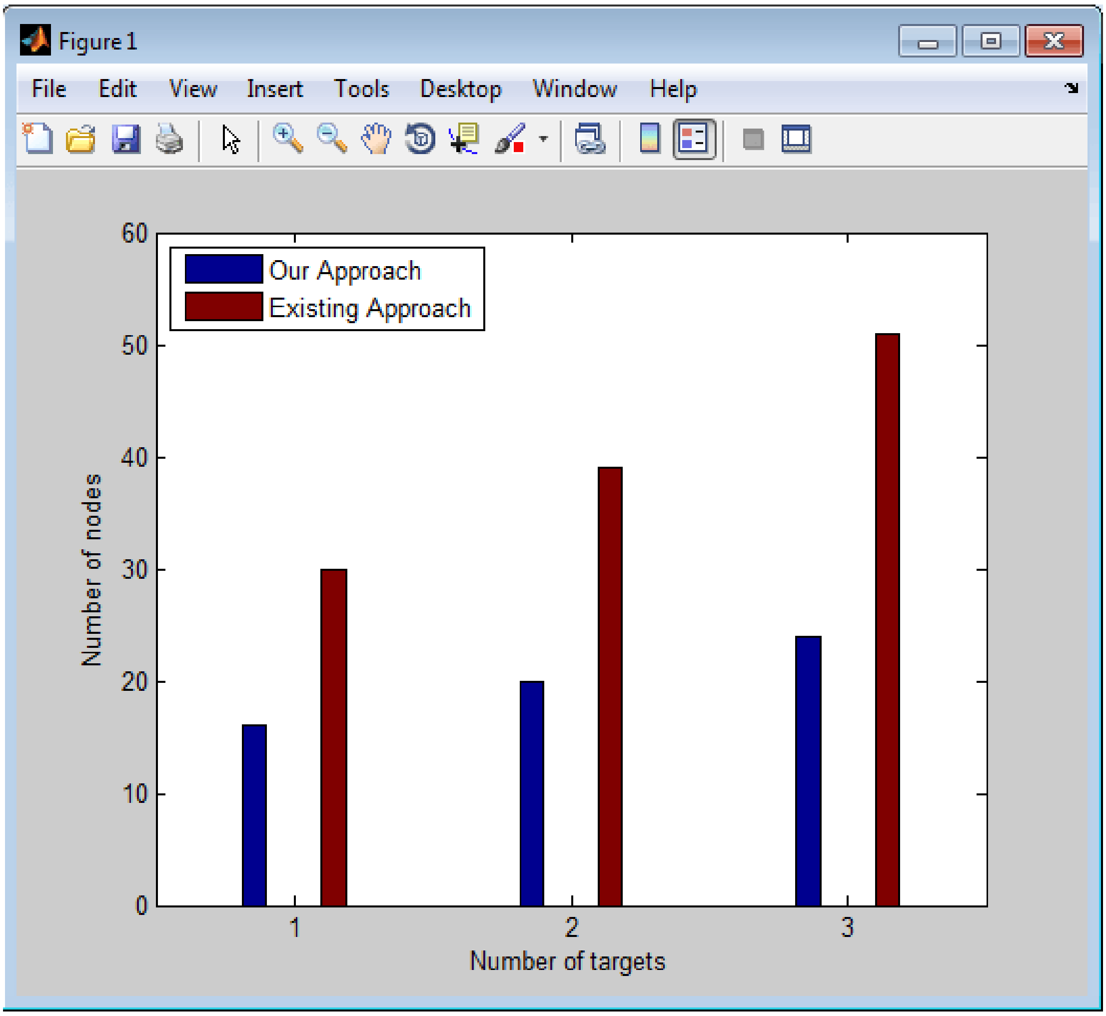


Fig: 1.13: Graphical analysis

In all the above cases, our enhanced node placement strategy deploys minimum sensors for target coverage as compared to the existing deployment strategy.

5.1.2 Number of Targets vs. Coverage:

In this section we analyse the coverage with respect to three different sets of targets – 25, 38 and 48 as above cases respectively and then compare the results with the existing approach.

A) With 25 targets

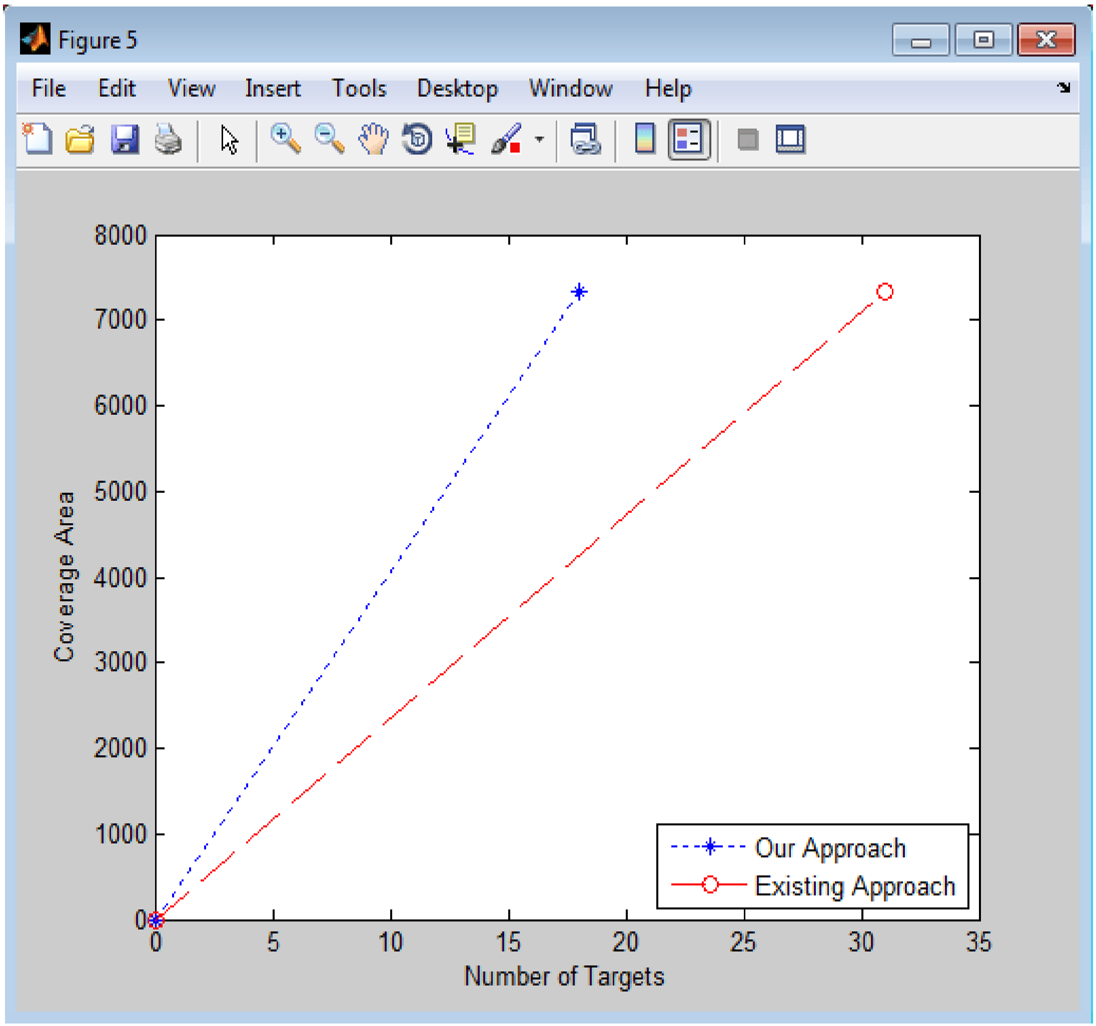


Fig. 1.14 (a): Coverage graph with 25 targets

From figure 1.14 (a) keeping the number of targets 25, the number of nodes varies for both the approaches. The sensors deployed using our approach is 16 whereas in the existing approach 31 nodes are deployed. But the area covered is 7.3319×10^3 units for both the cases. Thus, our approach gives better area coverage with less number of nodes.

B) With 38 targets

From the figure 1.14 (b) below when the number of targets is 38, the number of nodes varies for both the approaches. The sensors deployed using our approach is 20 whereas in the existing approach 48 nodes are deployed.

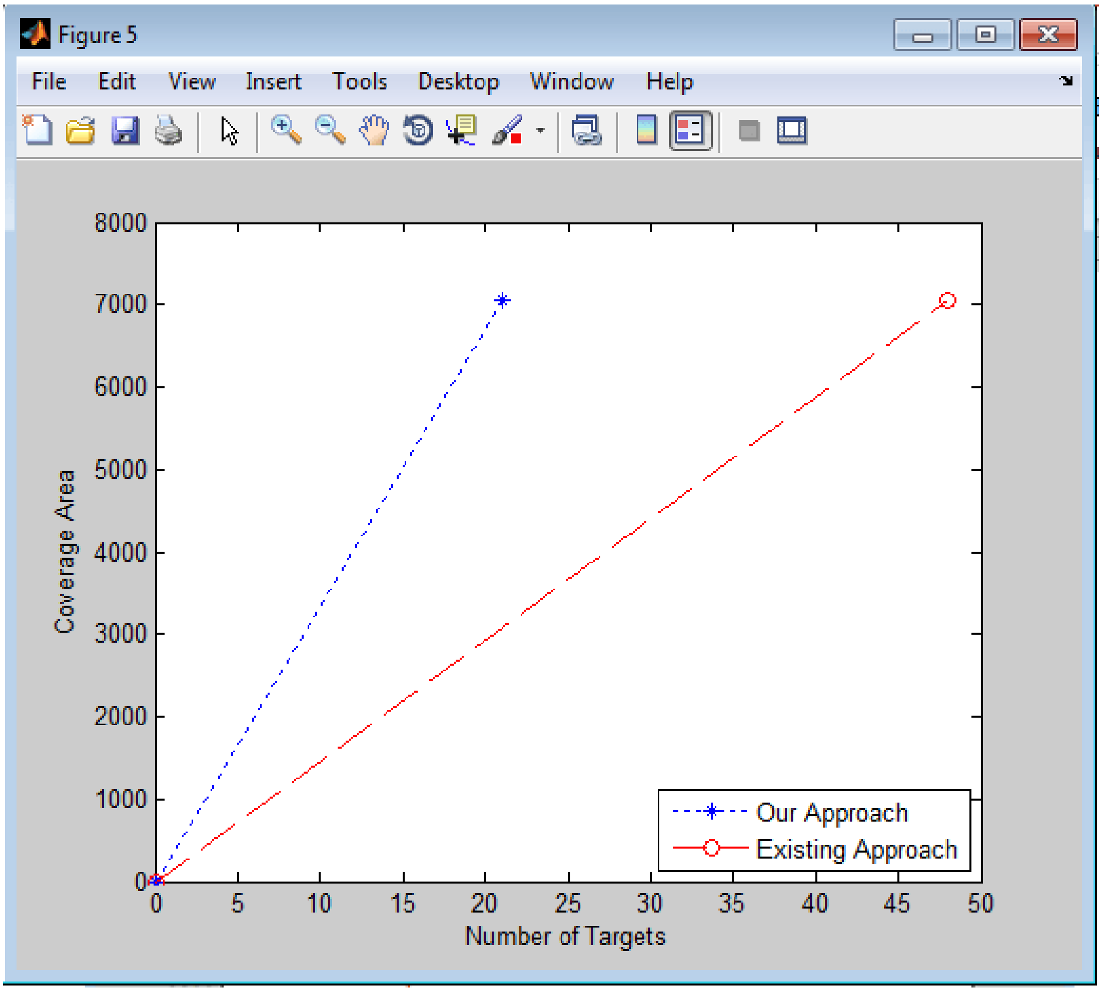


Fig. 1.14 (b) Coverage graph with 38 targets

The area covered is 7.4674×10^3 units for both the cases. Thus, using our placement strategy we yield better coverage result with less number of nodes.

C) With 48 targets

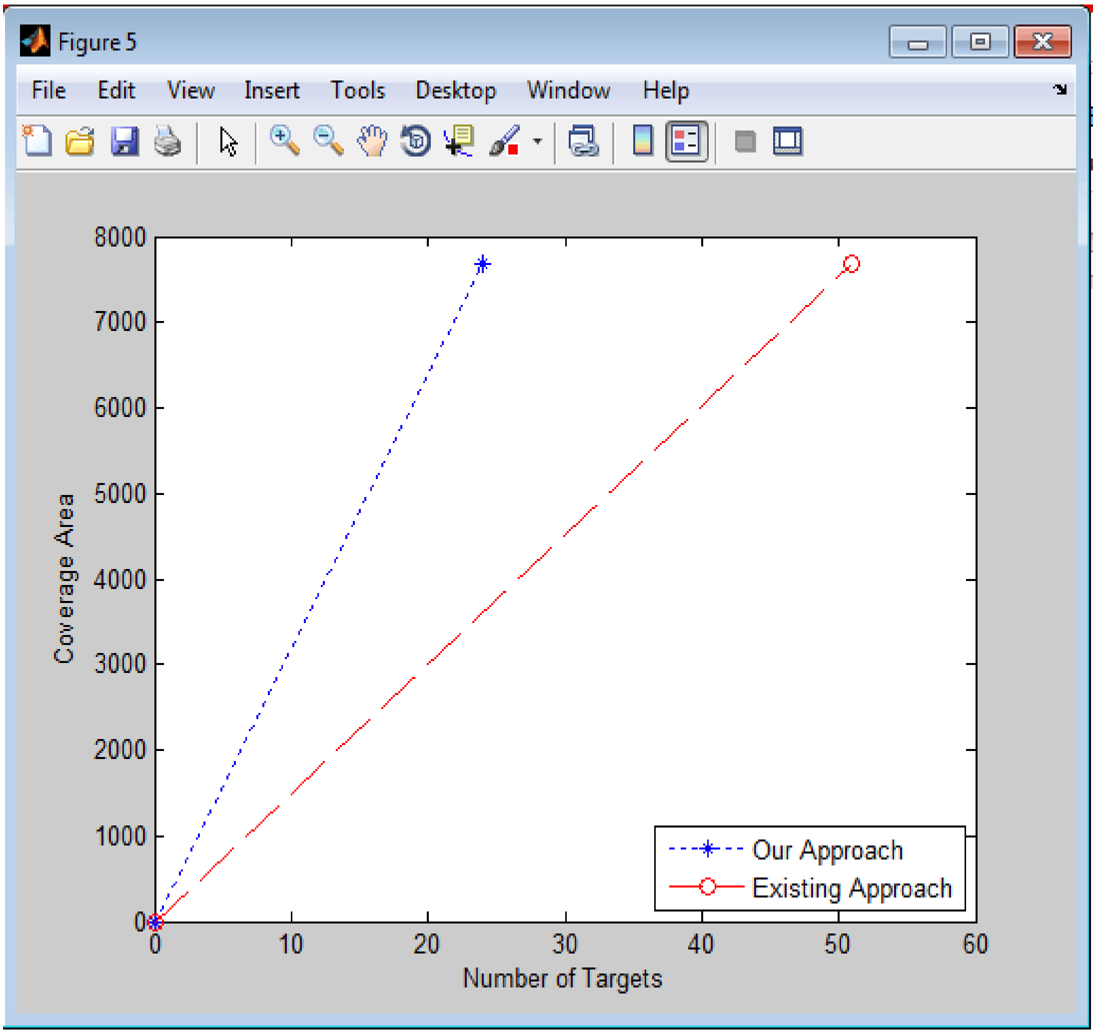


Fig. 1.14 (c): Coverage graph with 48 targets

In figure 1.14 (c), using our approach 24 nodes are deployed for 48 targets and the area covered by these nodes is 7.9635×10^3 units, Whereas in the existing approach, 48 sensors are deployed to cover 48 targets with same area coverage as that of 24 nodes. So, our approach is more efficient compared to the existing one. Figures 1.14 (a), 1.14(b) and 1.14 (c) shows that with the increase in targets, sensor deployment increases and thus coverage is more.

The calculated values of coverage with respect to number of targets and nodes using our proposed method and existing method and its comparison is given in table 2 as.

S.No	Number of Targets	Number of Nodes		Coverage Area	
		Our Approach	Existing Approach	Our Approach	Existing Approach
1.	25	16	30	7.3319×10^3	
2.	38	20	49	7.4674×10^3	
3.	48	24	51	7.9635×10^3	

Table 2: Comparison of coverage vs. nodes and targets

From the table above we see that the coverage obtained using our strategy is better. Our approach ensures that all the targets are covered and in case of non-coverage, the neighbouring sensor covers the target point. This provides strong network connectivity among the nodes and thus better coverage.

5.1.3 Number of targets vs. deployment cost:

In this section we analyse the deployment cost with respect to the number of targets. We take 3 different sets of targets – 25, 38 and 48 respectively and then compare the variations in cost. We compare the results with the existing approach. In our study, the same targets taken are considered for all the cases. The deployment cost is dependent on the weights of the sensors (audio and video) *w1* and *w2*. The factor '*k*' also called the slope in the elevation is considered in obtaining the optimal costs.

We have,

$w1=0.2, w2=0.1, f(c) = 15, f(max) = 150, k = \sqrt{2} = 1.414;$

$$C = w1 \times \frac{f(c)}{f(max)} + w2 \times \frac{S(d)}{T(c)} \times \tan\theta \times k$$

A) With 25 targets

S (d) = 16, T (c) = 25

So, C 1 = 0.2 × 0.1 + 0.1 × 0.64 × 1 × √2 = 0.1105 (Our Approach)

S (d) = 31, T (c) = 25

C 2 = 0.2 × 0.1 + 0.1 × 1.24 × 1 × √2 = 0.1953 (Existing Approach)

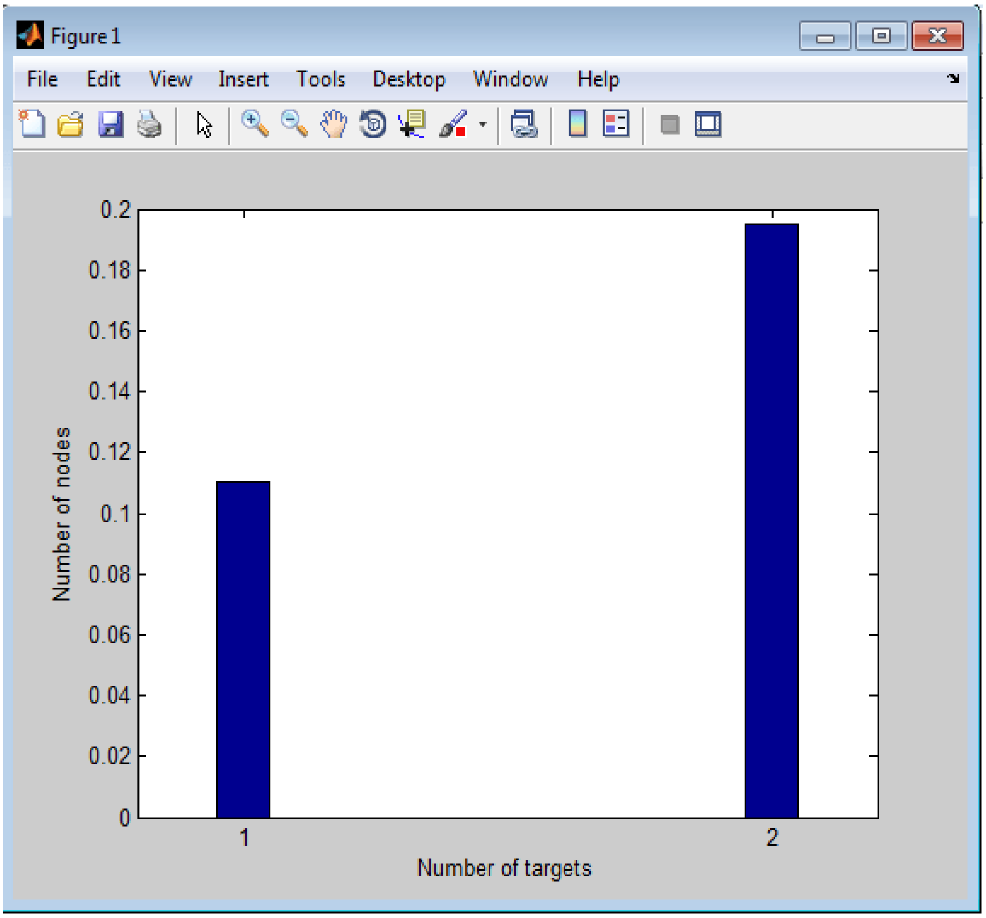


Fig. 1.15 (a) Cost comparisons with 25 targets

From figure 1.15 (a), it is clear that our proposed method (1) has lower deployment cost as compared to the existing method (2). The reduced cost percentage is given as:

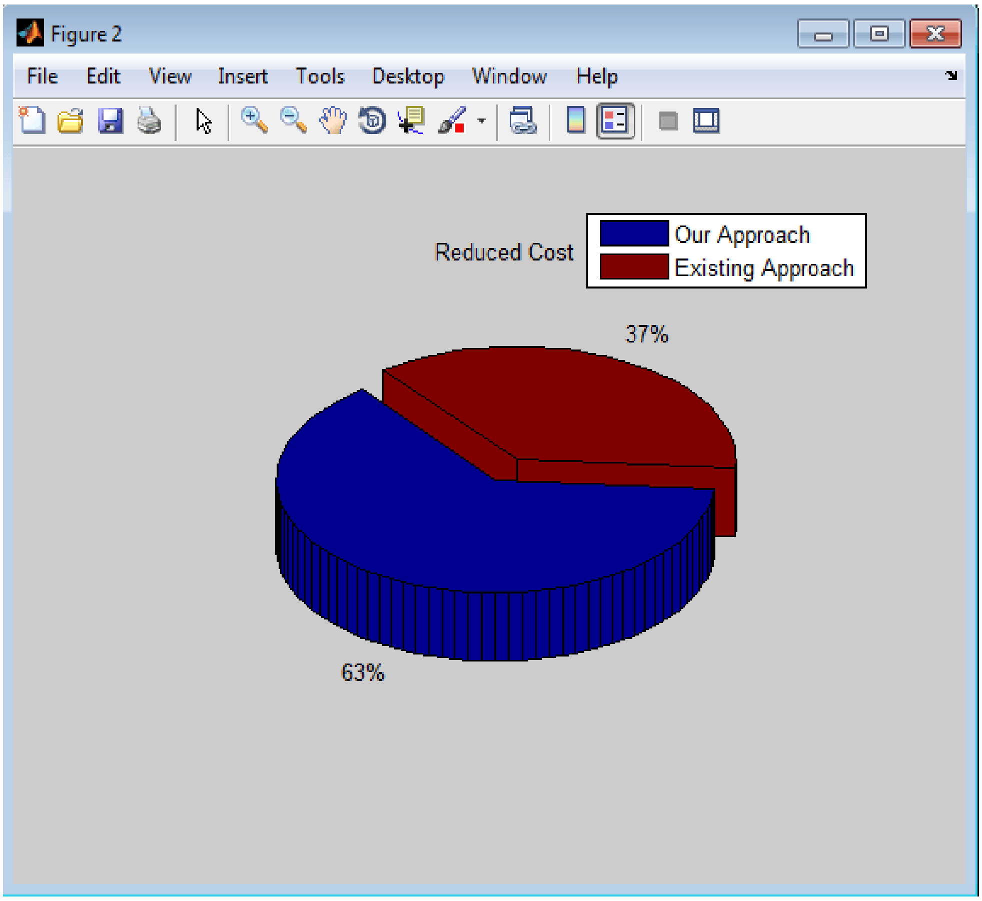


Fig. 1.15 (b) Reduced cost with 25 targets

Figure 1.15 (b) shows the overall reduced cost which is about 63 % by our approach as compared to the 37 % by the existing approach.

B) With 38 targets

S (d) = 20, T (c) = 38

So, C 1 = 0.2 × 0.1 + 0.1 × 0.52× 1 × √2 = 0.0944 (Our Approach)

S (d) = 48, T (c) = 38

C 2 = 0.2 × 0.1 + 0.1 × 1.26× 1 × √2 = 0.1786 (Existing Approach)

Figure 1.15 (c) shows the deployment cost. The overall reduced cost is shown in figure 1.15 (d).

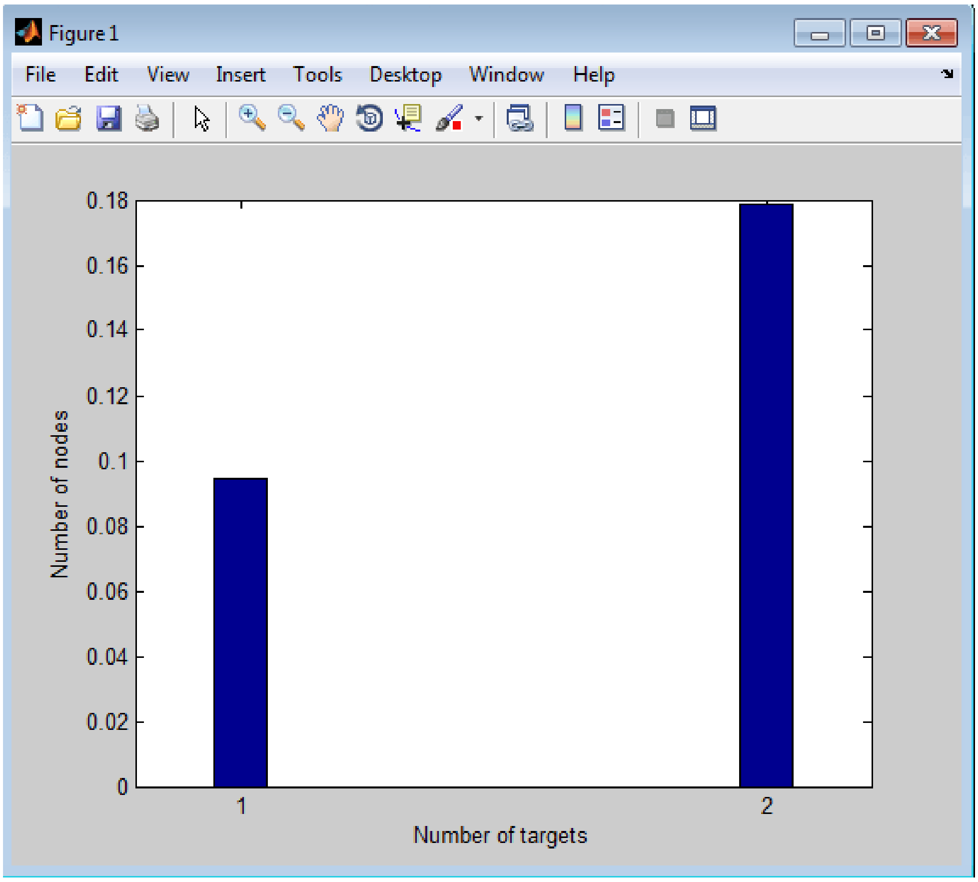


Fig: 1.15 (c) Cost comparisons with 38 targets

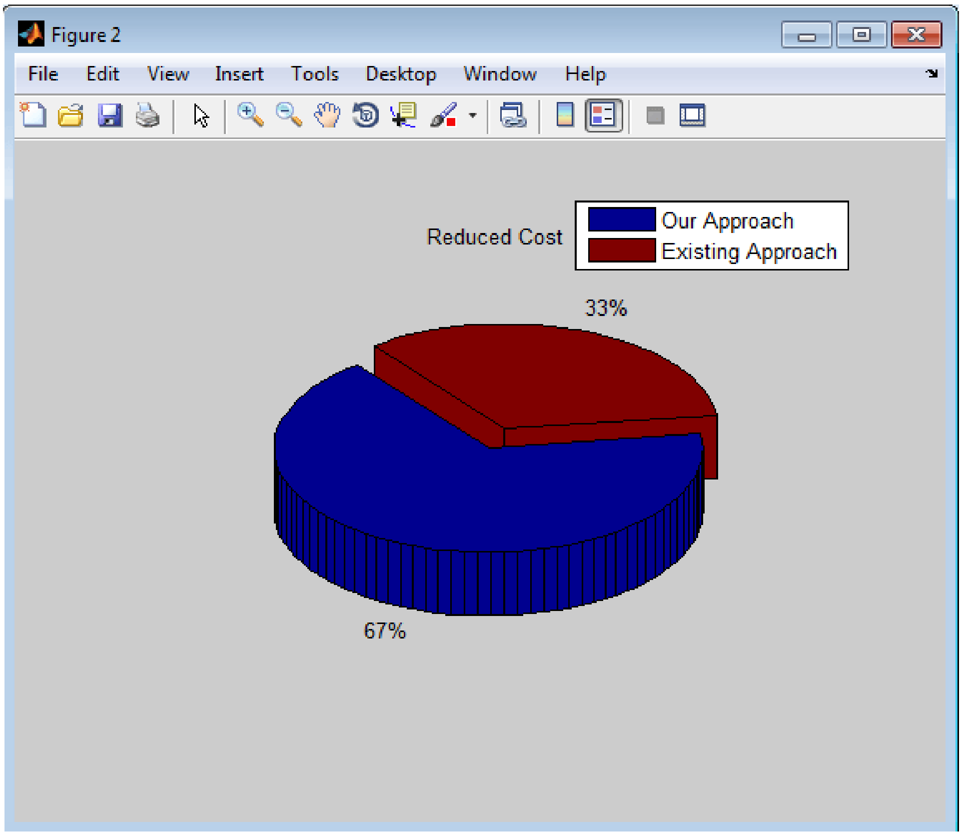


Fig. 1.15 (d) Reduced cost with 38 targets

C) With 48 targets

S (d) = 24, T (c) = 48

So, C1 = 0.2 × 0.1 + 0.1 × 0. 5 × 1 × √2 = 0.0907 (Our Approach)

S (d) = 51, T (c) = 48

C 2 = 0.2 × 0.1 + 0.1 × 1.06 × 1 × √2 = 0.1702 (Existing Approach)

Figure 1.15 (e) shows the deployment cost. The overall reduced cost is shown in figure 1.15 (f).

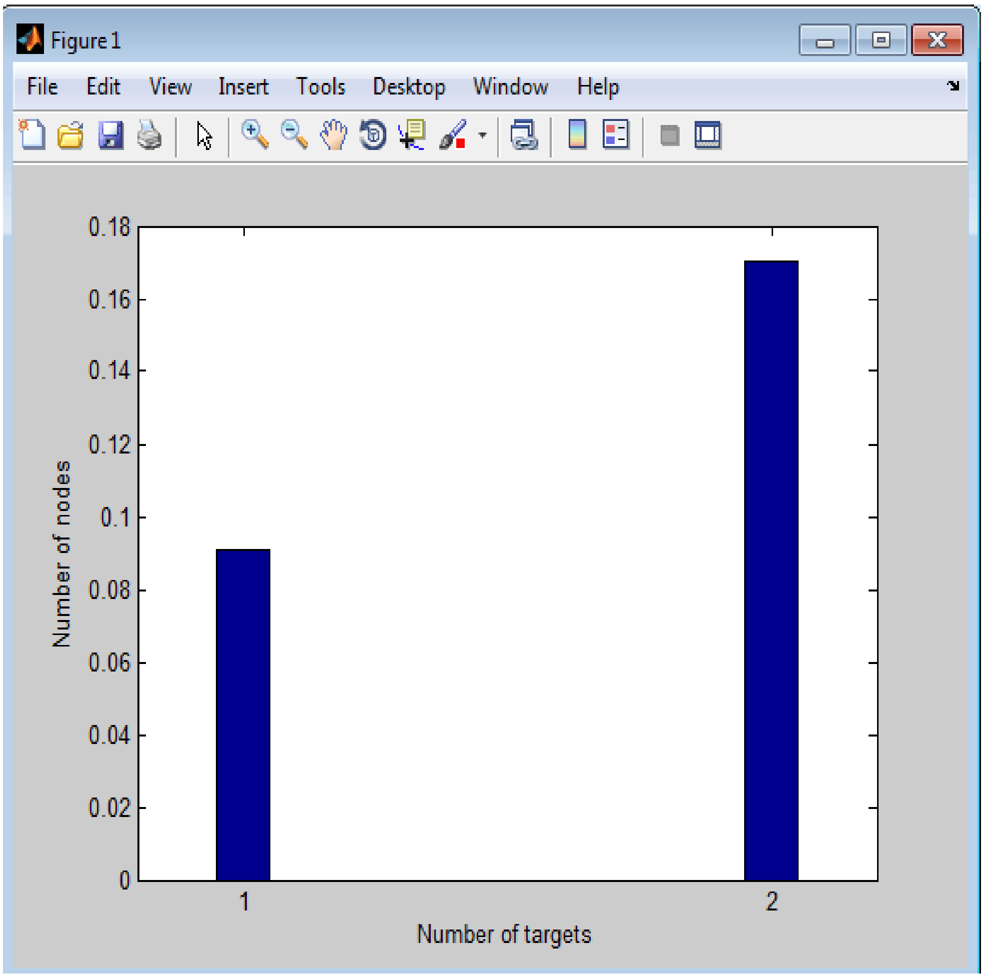


Fig: 1.15 (e) Cost comparisons with 48 targets

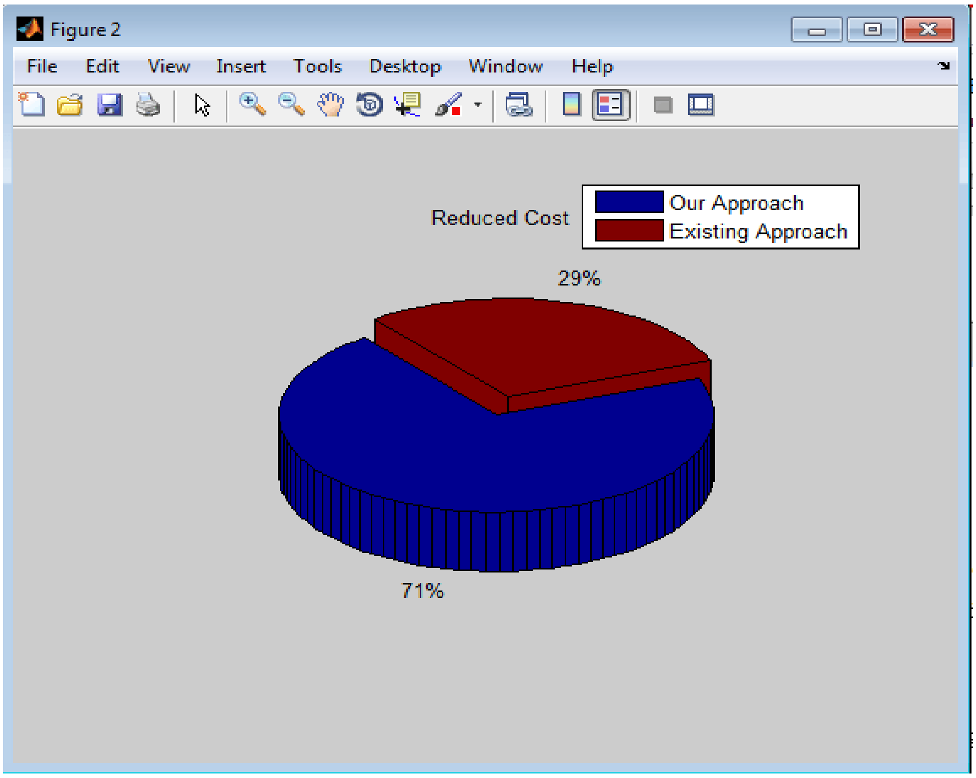


Fig: 1.15 (f) Reduced cost with 48 targets

From all the above figures 1.15 (a), (b), (c), (d), (e) and (f) the deployment cost is reduced largely using our approach than the existing one and thus the overall reduced cost percentage achieved is better using our enhanced placement algorithm.
The calculated values of deployment cost with respect to number of targets for both our proposed method and existing method and its comparison is given in detail in table 3.

S.No	Number of targets	Deployment cost	
		Our approach	Existing approach
1.	25	0.1105	0.1953
2.	38	0.0944	0.1786
3.	48	0.0907	0.1702

Table 3: Comparison of targets vs. deployment cost using our approach and Existing approach

The graphical analysis for comparison with 25, 38 and 48 targets between our approach and the existing approach is shown in figure 1.16.

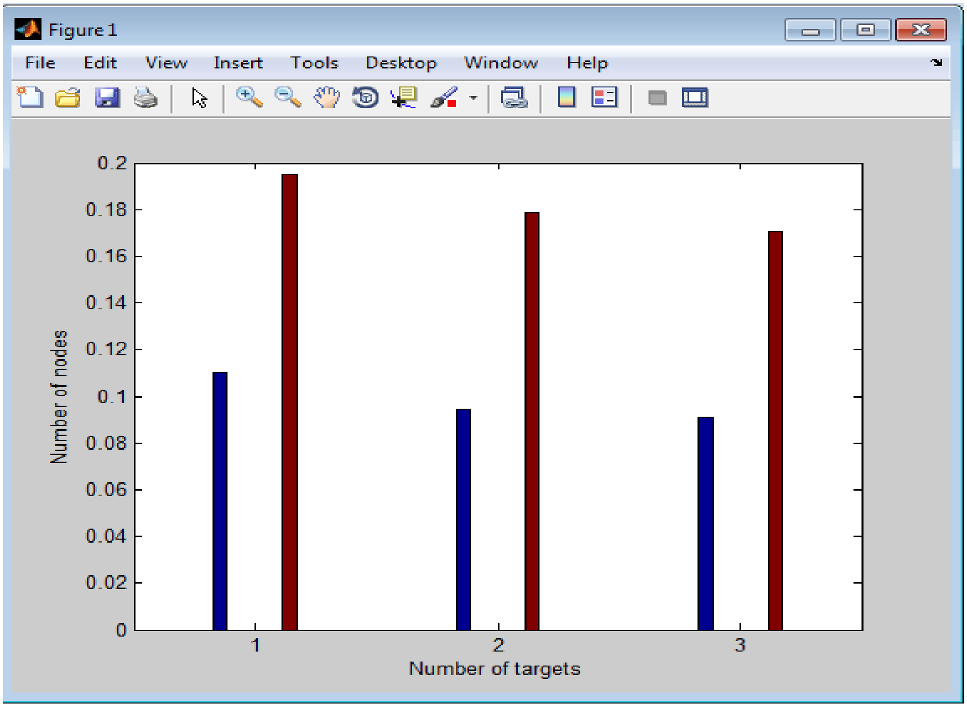


Fig: 1.16 Graphical analyses of results above

Our cost model depends on weights of the nodes, ratio of the nodes deployed to the total number of targets and slope of the terrain. So, with increase in number of targets from 25, 38 and to 48, the sensors for deployment increases which increases the coverage of the target and the deployment cost is reduced and the optimal cost sensor placement (OCSP) is achieved.

From the above set of experiments performed we have analysed the number of nodes deployed in an elevated terrain for a given number of targets. Using our enhanced node placement strategy, our approach help achieve minimum number of sensors compared to the existing work. Also, the coverage area is more with minimum number of sensors using our strategy. Taking the terrain specifications into consideration, we have obtained the optimal cost with our placement strategy in a multimedia sensor network.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

Conclusion

Extensive studies have been done to understand the design and challenges in a wireless multimedia sensor network. Our focus is to design a Multimedia Sensor Network and study a node placement strategy for cost optimization in case of elevated terrain which is a fundamental issue in a sensor network. We have addressed and analysed the OCSP problem with our enhanced node placement algorithm based on random deployment. Based on performance, we studied the sensors deployed with respect to targets, coverage obtained, deployment cost and connectivity issues. The results are discussed in detail and we then compare it with the existing work. The analysis shows that our approach yields better results than the existing approach.

Future Scope

There are many issues related to sensor placement strategies and in future better performance studies can be done under more practical scenario such as in presence of obstacles or in different terrain specifications under a given deployment cost.

CHAPTER 6
REFERENCES

Akyildiz, I.F; Vuran, M.C. (2010) "Wireless Sensor Networks", USA: John Wiley & Sons, 1st edition, 2010.

Akyildiz, I.F; Melodia, T; Chowdhury, K.R, A survey on wireless multimedia sensor networks, *Computer Networks* (Elsevier) 51 (4) , pp.921-960, 2006.

Ang, L.M; Seng, K.P; Chew, L.W; Yeong, L.S; Chia, W.C, "Wireless multimedia sensor networks on reconfigurable hardware: information reduction techniques", Dordrecht: Springer, 2013.

Bhatt, R; Datta, R, Cost modelling and studies with different deployment strategies for wireless multimedia sensor network over flat and elevated terrains, *International Journal of Wireless Information Networks,* Vol. 21, pp.15-31, March 2014.

Cai, Y; Lou, W; Li, M, Cover set problem in directional sensor networks, *Proceedings of IEEE International Conference on Future Generation Communication and Networking*, Washington, DC, USA, 2007, pp.274-278.

Chakrabarty, K; Iyengar, S.S; Qi, H; Cho, E, Grid coverage for surveillance and target location in distributed sensor networks, *IEEE Transactions on Computers,* Vol. 51, No. 12, pp.1448-1453, 2002.

Chellappan, S; Bai, X; Ma, B; Xuan, D; Xu, C, Mobility limited flip-based sensor networks deployment, *IEEE Transactions on Parallel and Distributed systems*, Vol. 18, No. 2, pp. 199-211, 2007.

Guvensan, M.A; Yavuz, A.G, On coverage issues in directional sensor networks: a survey, *Ad Hoc Networks*, Vol. 9, No.7, pp. 1238-1255, 2011.

Kouakou, M.T; Yamamoto, S; Yasumoto, K; Ito, R, Cost efficient deployment for full-coverage and connectivity in indoor 3D WSNs, *Multimedia, Distributed, Cooperative and Mobile Systems, DICOMO Symposium*, Gifu, pp. 1975-1982, July 2010.

Leoncini, M; Resta, G; Santi, P, Partially controlled deployment strategies for wireless sensors, *Ad Hoc Network*, Vol.7, No.1, pp. 1-23, 2009.

Lin, Y.-T; Saluja, K.K; Megerian, S, Adaptive cost efficient deployment strategy for homogeneous wireless camera sensors, *Ad Hoc Networks*, Vol. 9, No. 5, pp.713-726, 2011.

Lin, Y.-T; Saluja, K.K; Megerian, S, Cost Efficient Wireless Camera Sensor Deployment Strategy for Environment Monitoring Applications, *GLOBECOM workshops IEEE*, pp. 1-6, 2008.

Lopes, C.E.R; Linhares, F.-D; Santos, M.M; Ruiz, L.-B, A multi-tier, multimodal wireless sensor network for environmental monitoring, *UIC 2007*, Hong Kong, *Lecture Notes in Computer Science*, Vol. 4611, pp. 589-598, 2007.

Osais, Y; Hilaire, M.-St; Yu, F.R, The minimum cost sensor placement problem for directional sensor networks, *proceedings of the 68th IEEE Vehicular Technology Conference*, Calgary, pp. 1-5, Sept. 2008.

Omari, S.-Al; Shi, W, Incremental sensor node deployment for low cost and highly available WSNs, *Proceedings of the Sixth International Conference on Mobile Ad-hoc and Sensor Networks'*, Hangzhou, pp. 91-96, 2010.

Pandey, S; Dong, S; Agrawal, P; Sivalingam, K.M, On performance of node placement for hierarchical heterogeneous sensor networks, *Mobile Networks and Applications*, Vol. 14, No. 4, pp. 401-414, 2009.

Wang, J; Zhong, N, Minimum-cost sensor arrangement for achieving wanted coverage lifetime, *International Journal of Sensor Networks*, Vol. 3, No. 3, pp. 165-174, 2008.

Yick, J; Mukherjee, B; Ghosal, D, Wireless sensor networks survey, *Computer Networks*, Vol. 52, No. 12, pp.2292-2330, 2008.

Younis, M; Akkaya, K, Strategies and techniques for node placement in wireless sensor networks a survey, *Ad Hoc Networks*, Vol.6, No. 4, pp. 621-655, 2008.

http://www.mathworks.com/products/matlab/

APPENDIX

LIST OF ABBREVIATIONS

WSN: Wireless Sensor Network

MEMS: Micro-Electro-Mechanical-System

WMSN: Wireless Multimedia Sensor Network

CMOS: Complementary Metal-Oxide Semiconductor

FOV: Field Of View

ILP: Integer Linear Program

PIR: Passive Infrared sensor

BS: Base Station

SN: Sophisticated Node

GA: Greedy Approach

MDC: Minimum Deployment Cost

ROI: Region of Interest