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Research paper

Realistic acoustic sensor network deployment and radio coverage in terrain profile using 3d modeling

Gajendra Sharma *, Manish Kumar, Shekhar Verma

Indian Institute of Information Technology, Allahabad., 211012 Deoghat, India
**Corresponding author E-mail: rs118 @iiita.ac.in*

Abstract

Acoustic sensing can be done by deploying a wireless sensor network in the area of interest. To detect anthrophonic events such as, deforestation along with monitoring the vehicle movement on the muddy road for smuggling intension. In the present time, anthrophonic event classification on the basis of wireless acoustic sensor node remain unanswered. This work explores speedy improvement in wireless acoustic sensor node that classify acoustic event applications. Wireless acoustic sensor node deployment strategy in outside surroundings is proposed. Most of the studies on sensor network in term of deployment consider on flat surfaces. The deployment of wireless sensor network in unequal surface like a forest was rarely reported. The aim is to maximize the quality of coverage of a wireless sensor on a forest surface. A probabilistic sensing model and line of sight algorithm are utilized for this purpose.

Keywords: *AWSN; DTMP; 3D Modelling; Coverage; Terrain.*

1. Introduction

It is known that sensor nodes can perform- simple calculation on the acquired signal, detection of the event and communication of its class with neighboring nodes. The group of such nodes is made up of a wireless sensor network. The deployment of wireless sensor network in outdoor environment helps to detect forest events such as fire, deforestation as well as monitoring of the vehicle movement on the muddy road. The research work on sensor network deployment is considered on flat surfaces. So far in real practice sensor deployment take place in the outdoor environment. In the sensor network for stimuli node location information was required to act according to its placement in the network. A probabilistic sensing model and line of sight algorithm are utilized for this purpose. The purpose is to design a sensor network which provides its location so that a geographic sensor node placement is performed. Proposed sensor network assumes that sensor nodes make a profile of event, extract the feature and then send a message to the fixed relay nodes which assure the connectivity to the base station. To set the priority of event and classify the event to more sparsely covered areas. These relay nodes are selected to ensure a backbone of network connection and cannot be moved throughout the re-deployment process. The sensor node is deployed to monitor specific area and collect information to the base station or respond accordingly. Optimum placement of sensor node is a very important issue to get large coverage area and low power requirement. On the hills tree cutting and trade of woods is taking place in the forest. Radio coverage is the major issue in such location. In the next session (1.1) a Deforestation and Trade Monitoring Paradigm (DTMP) is proposed. The second portion of the paper is organized the radio coverage by using 3D modelling.

2. Deforestation and trading monitoring paradigm

This work proposes a deforestation and trade monitoring paradigm in which a forest location is considered for wireless sensor network deployment. The acoustic events of interest are tree cutting and tractor along with trolley movement on the muddy road. The lumberjack in India commonly used axe and saw for cutting of the tree. The acoustic signal produced during the cutting process and recognize as a tree cutting event. Similarly, vehicle movement on the muddy road produces acoustic signals through the engine of the vehicle and other sources namely exhaust, trolley and so on. An optimal deployment of sensor on the forest environment is the main concern of the proposed research work. The current work is limited to where nodes deploy according to the interest of event (coverage) and connectivity of the sensor network. These assumptions require to investigate where regular deployment is heterogeneous.

The main contributions of this paradigm follow

1) Problem formulation to get connectivity, coverage, less over head in the outdoor profiles.
2) A model for coverage and deployment of sensor nodes.
3) Describing connectivity of sensor network in monitoring area topology.
4) An algorithm can achieve coverage and connectivity in different nature of sensing zones

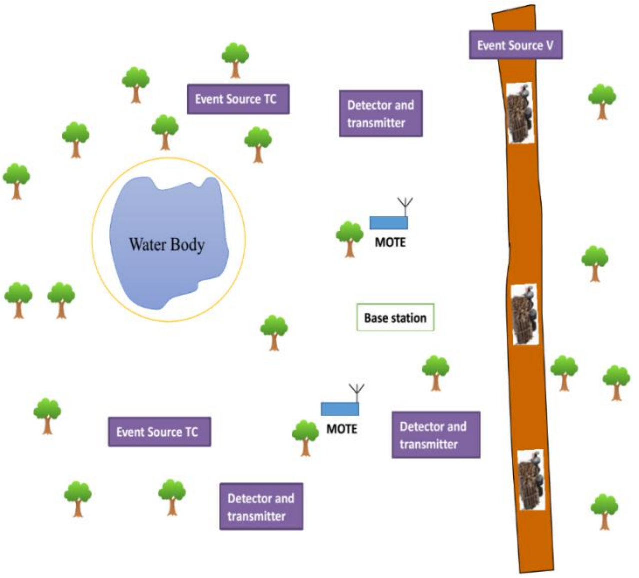

Fig. 1: Deforestation and Trade Monitoring Paradigm.

3. Literature review

A. Köpke et al. [1] proposed environmental model for the wireless sensor network. Attenuated properties of sensor network is described in detail. Attenuation due to an object come in between sensor nodes and without line of sight is considered in simulating results. Mohamed Hefeeda et al. [2] proposed uniformly at random deployment of sensor node and formation of a network in short area in forest monitoring zone. Assumption in this approach was that sensors were self-organized into cluster using distributed protocol. A theoretical background of centralized K-coverage algorithm was proposed. Data routing and sensor clustering problems were not considered in this research work. Chiara Buratti et al. [3] studied issues relevant to environment monitoring using wireless sensors. Less power consumption for sensing and comparing with threshold and transmitting that message in binary format to other communication devices is a challenging task. It concludes short and long-term research challenges. Antonio-Javier Garcia-Sanchez et al. [4] found that in context of protection and conservation of a specimen in outdoor environment including forest and village's deployment of wireless senor network, is a challenging task. Daniel Golovin Caltech et al. [5] worked for the challenging task to find out suitable sensor node for data collection. To accurate prediction of event when the power and bandwidth is limited in sensor network. Three approaches were considered for implementing purpose namely: Multi-Arm Bandit (MAB), Observation Specific Selection (OSS) and Communication Models (CM).
Mathew et al. [6] deploy sensor network that digitally detect environment phenomena, such as moisture level in soil, light pattern and acoustic signature of woodpecker and so on. Distributive, collaborative sensing phenomena was used for collection of data. They concluded wireless sensor network should come in practice for environment monitoring. Moritz Strübe et al. [7] investigation in wireless sensor network in outdoor environment is challenging due to the nature of sensor and software not functioning. Testing of wireless sensor network deployment specific simulation performed in five steps WSN deployment, connectivity check, data acquisition, testing configuration space using Monte Carlo simulation, and sensor node programming. Llkka Kivela et al. [8] proposes the use of wireless sensor network for environment monitoring in outdoor location with variation of both size and background of area. They had deployed 12 sensor nodes to measurement feasibility and reliability in real environment. Distinguishing various noises from each other is a challenging task. They have compared acoustic intensity level by using (three different noise measuring instrument) acoustic sensor node.

4. Problem formulation

Wireless sensor network is a growing field of communication. Sensor nodes are used to sense the data and transmit the data to the head quarter. It is useful for area status monitoring. Wireless sensor networks have various applications in military, health care monitoring surveillance and railway and so on. Sensor nodes are small in size and have small range of communication, and the distance between the sensor nodes to sink node is usually long so that communication is generally multi hop. But the sensor node near the sink node requires more energy than other nodes. So that life of the node is very less when compared to another node. The failure issue of node causes network failure. To avoid network failure, a relay node is used as an intermediate node in a multi-hop communication. Because relay node being the most powerful node having higher communication range, more powerful battery and are costly. Because of the cost issue it is required to design the network in such a way so that it requires minimum number of relay nodes in a network.

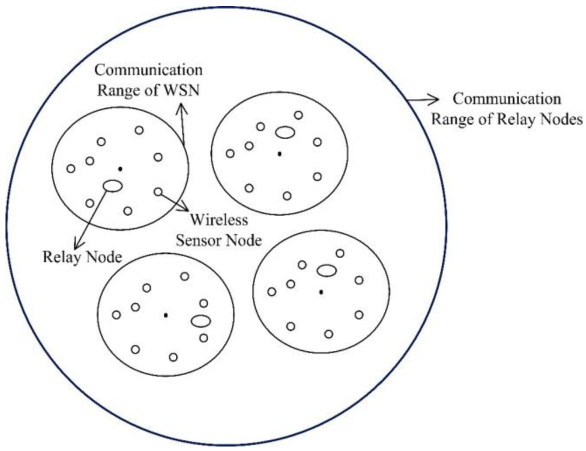

Fig. 2: Two Way Structure of Relay Node Based WSN.

Now the problem is to place these relay nodes to cover monitored area this relay nodes placement is called N-P hard problem. An approximation algorithm is widespread algorithm for this problem. A relay node problem is generally a kind of geometric cover problem, in which a greedy approximation algorithm for relay node is used to fix the placement problem. In first step, we place relay node in form of array at specific geographical position. This type of placement is called cellular placement. In second step, the sensor nodes that are still uncovered is located and placed relay nodes at critical position such that all sensor nodes are covered.
Relay node placement algorithm: -
Let us assume X is designate a set of n sensor nodes $[x_1, x_2, x_3 \ldots\ldots\ldots\ldots x_n]$. In (X, r), r is a communication range of each sensor node $(r > 0)$. Y is a set of m relay nodes $[y_1, y_2, y_3 \ldots\ldots\ldots\ldots y_m]$. x_i & y_i denotes the position of the sensor nodes and relay node at i^{th} positions. For direct communication of sensor node x_i with relay node y_i the Euclidian distance between x_i and y_i $\| x_i y_i \| \leq r$. Now consider a general method for relay node placement. At every stage determine a relay node y to cover some sensor node in X. Let us assume P be a point in the plane. Then $C(p)$ and $D(p)$ denotes circular and disk with radius r centered at p respectively. Relay node x will communicate with sensor node y if and only if $x \in D(y)$ so the problem is defined as to find out minimum number of disk require to cover the whole range such that all the set of X are occupied or covered by $\left[D(y_m)\right]_{m=1,2,3 \ldots m_n}$. If all the point of X is concentrated such that X can be fully covered by some point in the plane; then X is said co-circle set.

In a general method of relay node placement at every stage. A relay node Y to cover some sensor node in X and remove sensor nodes in X that are covered in each iteration only critical nodes are needs to cover by relay nodes. The next problem is to determine the optimum position of these relay nodes.

For a wireless sensor network that is defined by (X, r) suppose there is a point in X such that $\|\Delta(X, x)\|=1$; now we determine the position of relay node y such that it covers the point x, change the relay node position such that for minimal change of relay node, it covers maximum number of uncovered sensor nodes. In this way it can cover maximum number of nodes is called optimal position of relay node. In each and every step, place all the relay nodes in whole range so that it covers overall range of sensor nodes (R). There are two stages of placement of relay nodes.

1) To select the critical point x* from other point
2) To select maximum co-circle subset Z* from Δ (X, x*) and take θ (Z*) as a location of relay node.
3) In this way the requirement of relay nodes is reduced, now select the critical point x* from point set X and to select maximal co-circle Z* from Δ (X, x*) take θ (Z*) as a location of relay node we have two important policies.

- Set cover feature
- Geometry cover feature

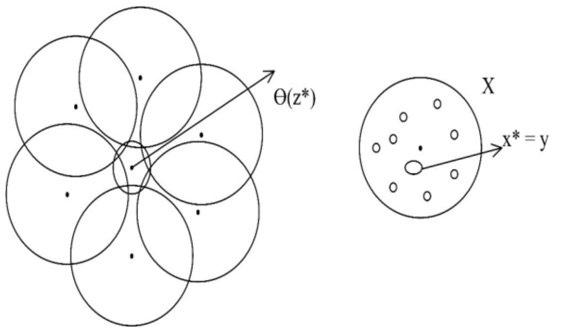

Fig. 3: Critical Placement of Relay Node.

5. Required mechanisms to meet requirements

1) Selecting critical point: As we have already discussed regarding set cover policy. In which first is selecting the critical point. For a critical point selection in which each point of x in the point set of X, we compare the value of $\|\Delta(X, x)\|$ and then we select a point x* as a critical point such that $\|\Delta(X, x)\|$ is minimum, it may be equal to or greater than 1, but remains minimum. This is the position for relay node placement minimizing the value of $\|\Delta(X, x)\|$ also enhances performance for optimum co-circle subset.

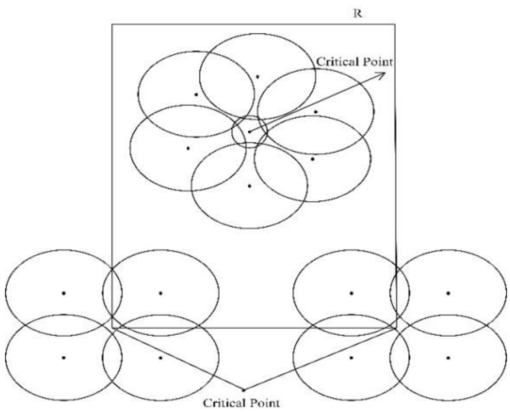

Fig. 4: Corner Placement of Relay Node.

2) et n is the number of Sensor nodes, ρ is distribution density of sensor node, m is number of relay nodes generated by algorithm with m iterations. Whole time is needed for single co-circle generation is O (r2 ρ). Complete maximal co-circle subset takes O (r4 ρ^2 n). The worst-case time complexity of Algorithm is O (r4 ρ 2n +r6) ρ 3m where r is the radius of sensor node range.

6. Proposed WSN structure

To develop a mathematical model that provides development of low power consumption, without pre-assumption to the proper functioning of the network while maintaining connectivity and coverage. For this purpose, two-layer structure is used. In the first layer, cluster sensor nodes are connected to relay node in that manner all the sensor nodes of cluster are in communicating range of relay node. Whereas relay node of each cluster forms a second layer of communication and all relay nodes remain in communicating range of each other. If it does not occur an extra relay node can be used as a communicating node. So, with the help of two-layer structure and wireless sensor nodes with the relay nodes are a good idea and also cost effective.

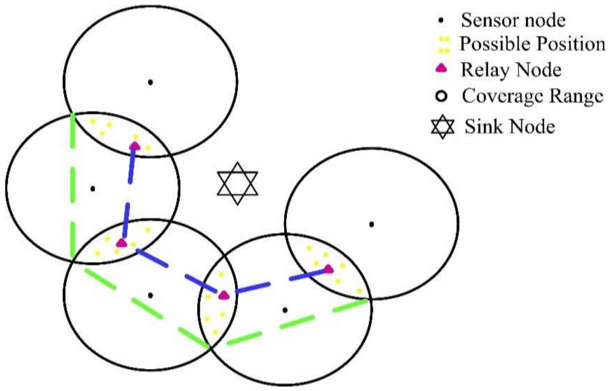

Fig. 5: Hybrid Structure of WSN.

A unit graph is proposed to model a sensor network as shown in fig. 6. Sensing zones S was making priority to monitor (sense) unit graph according to the prior information of threads. All the sensor nodes Sn deployed in the sensing zone are making a communicating link with each neighboring node in bidirectional manner. This routing strategy categorizes as: -

- Geographic routing structure.
- Void and without void routing structure.

6.2. Heterogeneous network

Black color point in fig.6, represent senor node and outer green color circle represents its sensing range is considered 30 meters. Sensor nodes are working on threshold-based data collection technique which collect acoustic signal. Subsequently features are extract in form of a packet and it forward to the managing nodes. Blue color point represents managing nodes. The managing nodes received message from the sensor nodes. These managing nodes work as cluster heads which receive message signals from the sensor nodes placed nearby to recognize event. These packet message of event can send to sink node directly its location and type. A star in the fig. 6, represents a sink node which receives event message and send to base station.

Sensor network deploy once after that we assume an intruder activity zone (IAZ). An intruder activity zone is 300*300 meter in which sensor nodes are activated and rest of the sensor nodes are in sleeping mode as shown in figure (6).

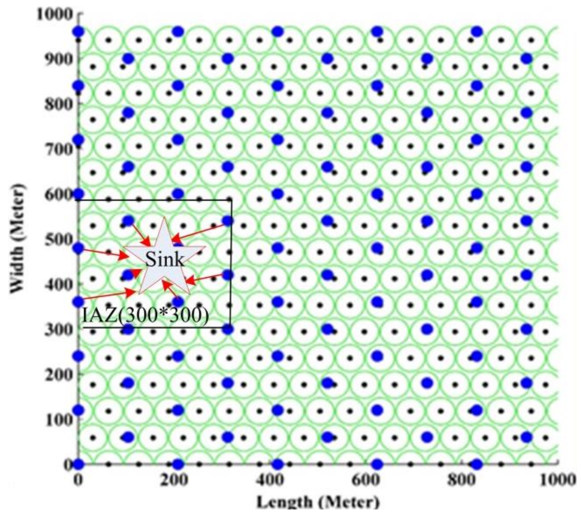

Fig. 6: Proposed Sensor Network in 1000 *1000 Meter.

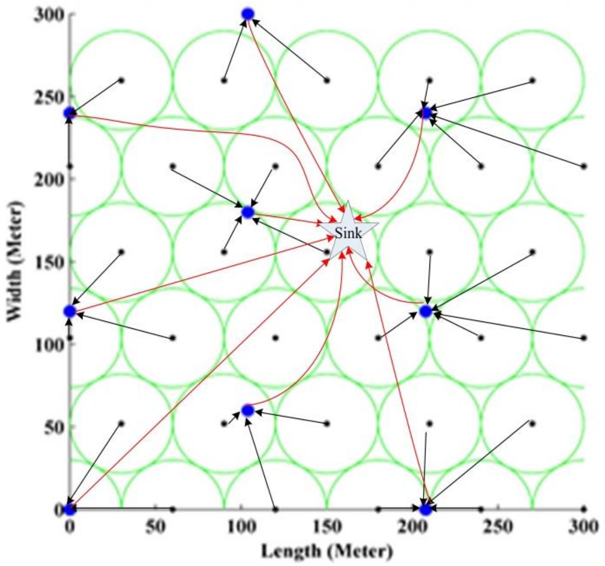

Fig. 7: A 300*300-Meter Area of Sensor Network.

In IAZ sensor nodes follows hierarchical structure, send data to sink node on event occurrences and rest of the time sensor nodes in sleeping mode. Event message received by the cluster heads (manager node) are shown in figure (7). Sensor node is sending the event information to nearest cluster head.

Second section

The deterministically radio where the network is modeled is a significant part of research. A distance between the nodes should be under or equal to the pre-assumed communication range of sensor nodes. The proposed solution is modeled with this assumption. The stable radio environment in real forest environment for event message transmission between the nodes depends on making path probability of radio channels. It is wireless sensor network for data collection from forest having 2D structure. The most of the forest having terrain profile and detection of intruder activity in this area. A 3D structure model with radio coverage map is simulated as shown in figure (8). A rough terrain is taken for experiment purposes in which radio coverage map is simulated.

Classification of terrain: The terrains are basically classified into:

1) Smooth terrain.
2) Undulating terrain.
3) Rough terrain.

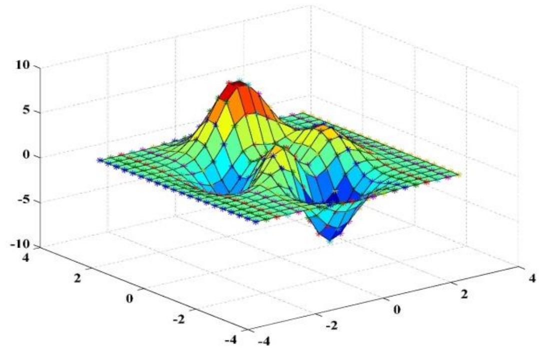

Fig. 8: Sensor Node Deployment on A 3D Terrain.

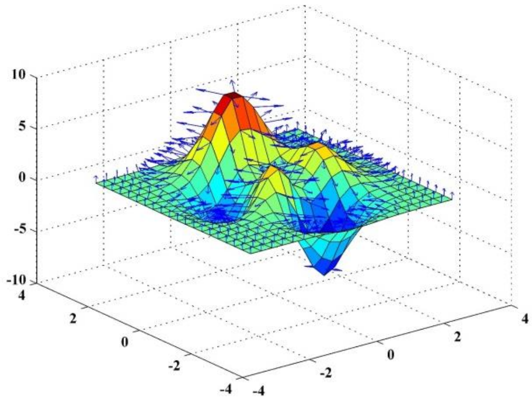

Fig. 9: Sensor Radio Signal Propagation.

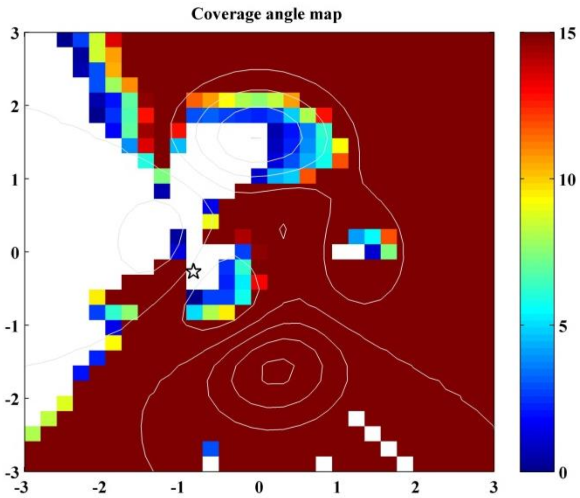

Fig. 10: Cover Angle Map 30 Peaks.

7. Results and performance evaluation

Acoustic sensor (Omani directional) node placement optimally in the WSN at forest (undulating) environment is addressed. The WSN consist sink node, relay nodes and acoustic wireless sensor nodes (AWSN) for allowing high performance in term of distance between sensor node, energy consumption and radio coverage in terrain with foliage environment. An innovative Deforestation and Trade monitoring paradigm (DTMP) with mathematically represent problem is under study. In the first phase floor plan geographic routing is consider which knows sensor position.

In the second phase terrain profile consider for realistic scenario in which sensor nodes deployed in the X, Y, Z coordinates. The maximum height, where sensor node deploys in terrain profile considered is 15 meters. The coordinates taken in the mathematical range of (-3, 3) for X and Y coordinates and the interval selected between sensor nodes is 0.2069, the Z coordinate value is measured according to X, Y coordinates. In the figure 8, ‘*’ symbol shows the sensor position on the terrain. The figure 10 is divided into contour which occupied by different color such as dark red, yellow, blue and no color. This color represents height position of sensor nodes. No color shows line of sight in the network, blue color (0-5meter) yellow color (5-10meter) and dark red (10-15) meters.

Table 1: Parameter Used in Geographic Approach

Sn	Parameters	Quantity / Assessment
1	Monitoring Area (A)	1000m*1000m
2	Intruder Activity Zone (AIAZ)	300m*300m
3	Initial Source Position	(0,0)
4	Final Source Position	(1000,1000)
5	Number of sensor Nodes(N)	84
6	Radio transmission range (R)	60 meters
7	The sensor node density $S_d = N\pi R^2/A$	0.8 nodes/m2
8	Flow length	$l = 1000\sqrt{2}$ m
9	Relay nodes	$R_n = l/r$

8. Conclusion

Deforestation and trading of goods (wood logs, sand, mud, and stones) can be fatal threads of flood near the water body which motivates for event detection in a protected zone of the forest. In this work, a paradigm called the Deforestation and trade monitoring paradigm (DTMP) is proposed. The purpose of the DPMP is for forest acoustic events detection and location based on mixed wireless sensor networks. The anthrophonic acoustic events are tree cutting by axe and saw and vehicle movement on the muddy road. The mobile sensor nodes perform detection of the event and are connected with their sink nodes are capable of transmitting data to the base station. Each of the static sink nodes fuses the information and transfers the fusion results to the base station. The simulation illustrates the proposed approach performs well in early deforestation and trading detection. In future, this approach can significantly improve the lifetime of WSNs.

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