Coverage Maintenance using Mobile Nodes in Clustered Wireless Sensor Networks

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ABSTRACT
Wireless sensor networks constitute the platform of a broad range of applications related to national security, surveillance, military, health care, and environmental monitoring. The coverage problem for Wireless Sensor Network (WSN) has been studied extensively in recent years, especially when combined with connectivity and energy efficiency. This paper focuses on the sensor replacement problem in wireless sensor networks consists of mobile sensors. Mobility equipped sensors are utilized to recover and maintain the overall coverage using the dynamic cluster concept. The proposed fault repair solution does not assume the localization information is available. Mobile sensor nodes make use of simple geometric operation to locate and replace dying nodes to recover or increase the existing coverage and connectivity.

Keywords
Wireless Senor Networks (WSN), Coverage, Connectivity, Deployment, Dynamic Cluster.

1. INTRODUCTION
In wireless sensors networks, sensors are small size and equipped with sophisticated sensing, communication, and computation capabilities. The number of sensors deployed varies from hundreds to hundreds of thousands .These nodes are communicating by radio waves. The power of each sensor is provided by a battery, for which individual consumption for sensing and communications. Sensor nodes exchange environmental information in order to obtain an overview of controlled region corresponding to the primary objective of a sensor network. In fact, in most of the applications, sensors are deployed randomly in risky areas which prohibit any human intervention. This leads to the fact that the sensors are scattered or remote, which ensures neither the required degree of coverage, nor network connectivity. Coverage and connectivity are the fundamental requirements in WSN and can be considered the metrics of interest when targeting quality of service for applications. Coverage is the area or the number of the targets that can be monitored by a sensor. An area can be monitored by several sensors in which case it has a higher coverage degree. The coverage degree is determined by the applications and the number of faults that has to be tolerated. Sensor replacement problem in wireless sensor networks are consists of mobile sensors. Mobility equipped sensors are utilized to recover or to improve the overall coverage and connectivity. Mobile sensor nodes [22], [23] make use of simple geometric operation to locate and replace dying nodes to recover or increase the existing coverage and connectivity. The sensing scheme for mobile sensor networks for locating mobile sensors relative to target field. Proposed sensor replacement protocol successfully manages fault repair in absence of location information and is energy efficient. The rest of the paper is organized as follows. In section 2 briefly introduces the related work, section 3 describes about proposed work, 4 describes the experimental results and section 5 is conclusion of proposed work.

2. RELATED WORK
Apala proposed [5] Planning and Diagnostic or Analysis tools for large scale deployments. Planning tools are used in pre-deployment phase and Analysis tools are used in post-deployment phases. Mo Li and Baijian [15], [9] proposed network topology in WSN. They divide the topology issues into two categories, Topology Awareness Problems and Topology Control Problems. Topology Awareness Problems include geographic routing problems and sensor holes problems. Topology Control Problems can be further divided into two categories: Sensor Coverage Topology and Sensor Connectivity Topology. The coverage topology describes the topology of sensor coverage and is concerned about how to maximize a reliable sensing area while consuming less power. Sensor networks are self-sustaining systems of nodes that co-ordinate amongst themselves autonomously but, their development is slowed down by the constraints of the devices used. Sensors power constraints are battery or solar cells but we are not able to provide the power permanently Good lifetime of the network topology is depends on the energy level of the nodes. Energy level is varied based on the nodes are mobile and static nodes. Monitoring Connectivity is another important concept in topology Control problems. Khelifa [25] presented the method for monitoring, maintaining and repairing the communication network of a dynamic mobile WSN. So that network connectivity is continuously available and provides fault tolerance. In [10] Gandhiya suggested the hybrid mobile nodes needed an extra energy then other nodes for its sufficient activities. In coverage maintenance concept lifetime of the network is another one issue. It may overcome with self scheduling and surplus nodes by means of the setting the different types of modes for sensors. Former one proposed by Yuanyuan and Naixue [2], [7]. Connectivity and Coverage maintenance in WSN [2], [7], [13] each sensor makes self-scheduling to separately control the states of RF and sensing unit based on dynamic coordinated reconstruction mechanism. The connectivity maintenance will decide on the node on/off state of its RF units and the coverage maintenance will decide on the on/off state of sensing units. The state of the RF unit is independent from the sensing unit. Then, there will be four possible sensor states. Sleeping state describes both sensing and RF units are off-duty. Active state describes both sensing and RF units are on-duty. Sensing state describes sensing units in

on-duty and RF units are in off-duty. In Relaying state sensing units are off-duty and RF units are on-duty. It is economically suitable for all applications but monitoring cost is high. Next issue is described by Ryo using Surplus Nodes. It is a high pricey issue but it provides the best coverage result. [1] Surplus nodes in large area for extending the coverage lifetime by scattering the surplus sensor nodes in the target field randomly. In this method, they assumed that each sensor node has three operation modes sensing, relaying, and sleeping. Each sensing node senses environmental data and sends/relays the data to the sink node via multi-hop wireless communication. Each relaying node just forwards the data received from its uplink node to its downlink nodes. Each sleeping node does nothing and keeps its battery. Different approaches are followed to replace the failed nodes or uncovered areas in the large networks. Various approaches used to achieve maximum coverage. It may vary based on the different types of deployments [24] and network structure. Ridha and Riheng [3], [11] introduced the mobile robot or mobile nodes to eliminate the coverage holes by means of collecting the redundant sensors from the field. [3], [16] Mobile robot collect the redundant sensor from the grid field based on combinatory optimizations using Knapsack algorithm with energy residual and distance factors. They concluded as the problem of redeploying sensors in a target field to maximize the sensing coverage. Cluster and Non-Cluster based approaches are recommended for efficient coverage maintenance.

Cluster based approaches are just related to centralized coordination algorithms. The coordination algorithms address three categories of algorithms: [6], [2] Centralized, Distributed and Dynamic algorithms. After coordination performance the coverage barrier information is identified then applies the relocation or replacement algorithm [20], [14] for replacing the holes in barrier area. G.Wang explored [17] the motion capability to relocate sensors to deal with sensor failure or respond to new events, two-phase are used for sensor relocation redundant sensors are first identified and then relocated to the target location. This centralized approach is very suitable for the mobile robot concept. It may act as a coordinator other nodes are act as a maintainers of the algorithm. In the distributed algorithm the sensory field is as partitioned into sub regions and the centralized algorithm is run in each sub-region. The dynamic approach constructed the voronoi diagram it is dynamically constructed using robots based on the hop count. Nodes report detected sensor failure to the robots of their home voroni cells. The robots then move to replace the failed node with spare sensors that they carrying. The replacement concept differ based on different applications, [4] sometimes it may replace based up on the Least Frequently Visited, it may support single or multiple robots ,Snake like Deployment SLD or 'S' shape or Spiral shape replacement algorithms are support single robot concept for replacement. But Greg proposed [4] the Back-Tracking deployment. Back-Tracking concept may support three varieties of movements they are Zigzag, Straight Line or Shortcut. Nayak proposed [4], [6] the back tracking process for moving robot front and back for deploy and replace the nodes. The Cluster formation differs depends up on the energy level of the nodes. Peng Li proposed an energy-efficient cluster-based data gathering algorithm for Mobile WSN [8], [12], this algorithm achieves a good performance in the network lifetime and reliability of data transmission for mobile WSN. Cluster formation algorithms are varied they are LEACH [18], LEACH-M and ECDGA. [21] DoScong forward the LEACH-M which support node mobility through the improvement of the LEACH.LEACH algorithm formed the cluster based on the energy level of the Cluster Head. But ECDGA concept form the cluster based on the energy level of the all members nodes in the cluster. Based on his analysis ECDGA is better one Compared to LEACH-M.

3. PROPOSED WORK

The coverage maintenance concept is carried out using following steps.

1. Formation of network structure
2. Deployment of sensor networks in that network its may be a dense deployment or sparse type of deployment.
3. Sensors are placed in the network either manually or automatically to sense the target location. Sensed in formations are transformed to the base station.
4. If any one of the sensor get fail or make a hole in that networking area it may affect the coverage of the network. So the hole is replaced by redundant node either automatically or mobile robots.

Consider a WSN randomly deployed in the target area. A continuous uncovered area is called sensing Hole. Human intervention to keep the network up and running, but some situations it is a tedious job and mostly infeasible .It is envisioned that in near future, very large scale sensor network consisting of mobile nodes will be deployed for applications ranging from environment monitoring to emergency search and rescue operation. This paper has been made the following assumptions:

i. Sensors are randomly distributed into a 2-dimensional field. This can be enabled in the initial deployment process.
ii. The Mobile Nodes travel at a constant speed and can localize themselves.
iii. All the sensors and the mobile nodes communicate via wireless links.
iv. Replacements nodes are at the same locations as the corresponding failed nodes.

A random deployment for mobile sensor network is proposed. A mobile sensor network can be considered as a collection of distributed sensor nodes, which are capable of sensing, moving, communicating within its allowable range. Sensor networks inherently differ from standard communication networks as their aim is to monitor phenomena over space and time. This paper consider wireless sensor networks composed of mobile sensors. Mobility equipped sensors are utilized to replace the failure nodes from that target area to improve the overall coverage. Faulty sensors are described as low energy sensors. This Proposed work has four steps. First an architectural design is described and redundant nodes are deployed randomly. Second, form the dynamic clusters using mobile nodes. Third the Problem is identified (failure node or hole) using path coverage and fourth step is Failure Handling using Sensor Movement Algorithm.

3.1 Architectural Design and Deployment of nodes

Sensor deployment strategies can be classified into two classes which are deterministic and autonomous (random) deployment described in figure 1.In the deterministic deployment, the deployment field is assumed accessible as well as the number of sensors is small to be manually deployed in specific locations, it is only applicable for the structured network or human accessible fields. On the other hand, with large number of sensors and in inaccessible fields, the random deployment to the sensors turns out to be the solution. It may deploy by large vehicles like aircrafts, military helicopters etc. Compare to deterministic deployment random deployment is easy. This stochastic deployment is used when the information of sensing area is not known. Deployment quality and cost are two conflicting aspects in wireless sensor networks. In Random deployment, the monitoring field is covered randomly, it is an appropriate approach for large-scale network applications. However, random deployment requires sensors to be automatically located for coverage and connectivity purposes. In addition, after a period of time, the sensors topology might change due to some sensor hardware failure or deplaned energy. Therefore, redeployment and/or sensors relocation process is essential. Nevertheless, mobility consumed energy as well as sensor load balancing are essential factors to be considered during the initial deployment and relocation processes. Intuitively, sensor nodes in a dense region need to move to a sparse region to improve coverage and connectivity of a sensor network. In this proposed work choose the unstructured random deployment. This sensing field has a lot of special nodes called as Mobile Nodes.

Initial arrangement 10% of node only in moving state for providing the best coverage, rest of the nodes are in static condition. In this field some nodes are in sleeping mode for preserving the energy level of network. Total numbers of redundant nodes are equal to sum of the required nodes and extra nodes. This architectural design is very suitable in thick forest and marine monitoring area.

3.2 Cluster Formation

Wireless sensor networks are widely used in security monitoring applications to sense and report specific activities in a field. After deployment of the sensor field automatically form the dynamic clusters according to its mobile nodes position. Group selection algorithm is used to form the dynamic group and check the connectivity level of nodes in the networks. If any problem occurred in the connectivity area again it may form the cluster dynamically based on good connectivity of nodes. Every sensor node is formed together and arranged in one group called cluster. The main purpose of cluster formation reduces the transfer rate and allocates a group in to sub groups and finally one mobile node form one cluster, this process is called as Dynamic Cluster Formation. Cluster Head and group of member nodes are form the cluster. In this proposed work dynamic cluster is formed based on the movement of mobile nodes. Mobile nodes are act as a Cluster Head. Mobile Nodes are forming the cluster with in its communication range. Use path coverage concepts to find out the hole in the cluster. Path coverage Analysis [19] is do a important role to find the uncovered area through by sending the test messages by cluster head to other nodes in the network, for example, the network is in charge of monitoring a path and discovering any intruder trying to cross it. Proposed work used this path coverage concept for finding holes in the network area. Mainly it has 3 steps in this module. They are,

1. Cluster Head send the HELLO messages to its other nodes.
2. Member nodes are send the REPLY messages to its Cluster Head.
3. Cluster Head forward the beacon messages to its Base station.

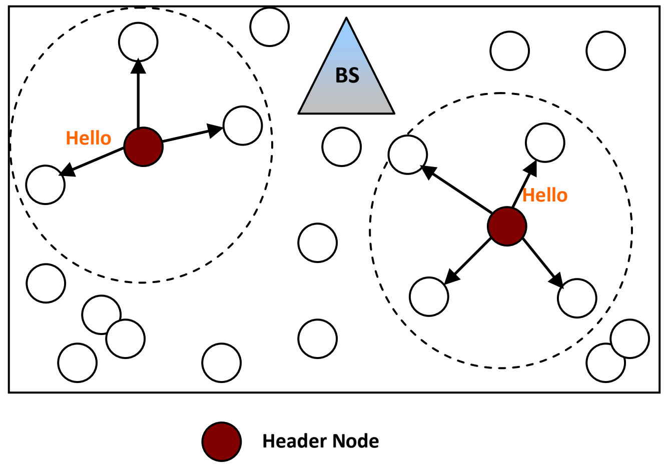

Fig 1: Cluster Head send HELLO messages

Initially Cluster Head Send HELLO messages to its other nodes it is described in figure 1 .With in its communication range all other nodes are joining and form the cluster. Cluster head is waiting sometime for the reply from the other nodes. After some time it may ready to collect reply from the member nodes. If any one of the nodes does not send any REPLY messages with in the range it may consider as failure node.

Second process the Member nodes send the REPLY messages to its Header Node after receiving the HELLO messages using path coverage analysis concept. With in the range other member nodes are sending the reply messages to its header node it is illustrated in figure 2. Reply message has information of location identification and energy level of the each node. All reply messages are received by the header node with in the assigned schedule. Third process Cluster Heads forward the Beacon messages to its base station.

With in the assigned schedule the Cluster Head received the all beacon messages from member nodes. All collected messages are transferred to the Base station. Now base station integrates the one cluster messages and calculates the coverage range of each cluster. This result may provide the low energy level node, barrier coverage and dead node information.

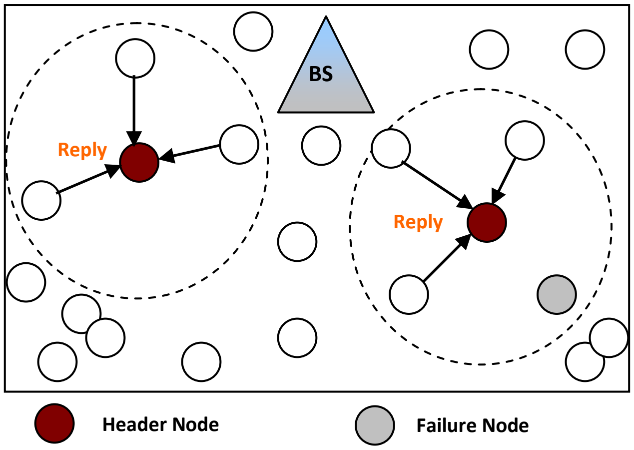

Fig 2: Member Node sends Reply messages

3.3 Hole Identification

Hole is defined in the WSN as uncovered area or barrier coverage. Holes makes an idea is poor coverage, it may create poor signal information to Base station. It may create a bad result in large applications. Coverage barrier is crop up by 3 main reasons.

- ✓ Failure Node or Dead Node
- ✓ Low energy level Node
- ✓ Barrier area in the random deployment or Hole.

Path coverage analysis [19] is applicable to any closed path, for example, ellipse, with finite length when the location of the path segment covered by an arbitrary sensor is uniformly distributed over the path. It is used to analyses number of gaps, smaller than a specific size. Based on this discovering concept each header node periodically sends the test messages to its member nodes, and wait for its acknowledgement. If a header node has not received any acknowledgement information from a particular node the cluster head conforms that the particular node has failed. With in the assigned schedule the Cluster Head received the all beacon messages from member nodes.

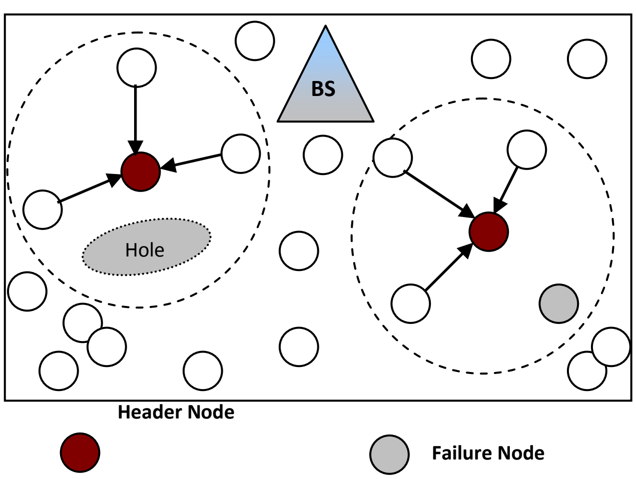

Fig 3: Occurrences of Hole and Failure Node

All collected messages are transferred to the Base station. Now base station integrates the one cluster messages and calculates the coverage range of each cluster. The calculation result is providing the location of each node in the network area and its energy level. The low energy level node is called as failure node. Dead node or failure node is not capable to sensed the information and relay the messages as its energy level is very low. Low energy level nodes are selected depend on the energy threshold value. Required energy level node has greater energy than threshold value. Low energy node has a less energy than threshold. Low energy value is calculated using REPLY of each node. Figure 3 described the hole and failure node details.

3.4 Failure Handling

Cluster head collect all this information from the member nodes of dynamic cluster and send this all working and failure nodes information to the Base station. Base station goes to calculate the coverage and connectivity of the nodes in the network. If it is find any uncovered areas or coverage deficiency in the network it calculate the position of that hole and find nearest high density nodes. The problem can be summarized as following:

There are a redundant sensors Sm, $(a \leq n)$:
SM = {Sm1, Sm2, . . . , Sma};
There are b failure sensors Sd, $(b \leq n)$:
SD = {Sd1, Sd2, . . . , Sdb};

Select the redundant or extra nodes for replacements. After appropriate selection the node is activated to move from original location to target location (uncovered location) using Sensor movement algorithm. Algorithm I explained the Sensor Movement Algorithm.

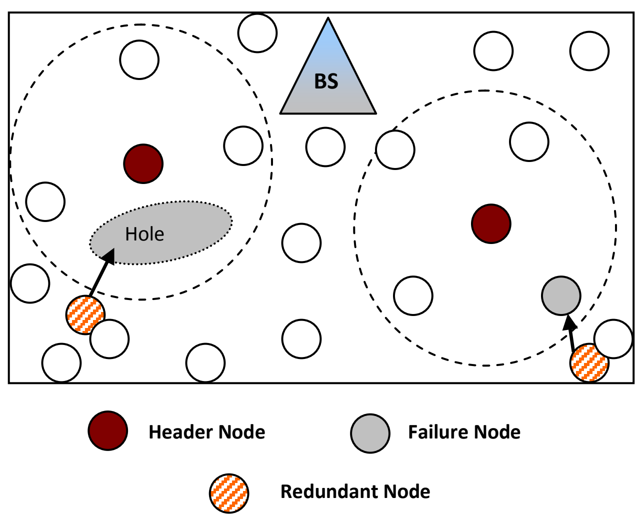

Fig 4: Apply Sensor Movement Algorithm

Base station may select the redundant node using its REPLY messages. The redundant node selection is based on 2 criteria.

- High dense area is selected (i.e.) large number of nodes deployed in the small area.
- Energy Level of Redundant Node. Condition for energy level of each node is Low Energy < E_{th} < High Energy

E_{th} is denoting as threshold value of energy, it is assigned as 35J per node. Figure 4 describes the selected redundant nodes and its movements, the nodes are selected for that movement it is selected depends on the density of the nodes and energy level of the nodes. Using Sensor Movement Algorithm Base station replaces the dead node or hole by selected redundant node. Mainly 2 metrics used for that movement algorithm are Distance and Angle. Distance indicates the total distance between the failure node and selected node. Angle specifies which direction particular selected node move and reaches the target. Algorithm1 describe how the sensor moves from current location to target location it is described in figure 5. In Sensor Movement Algorithm Sm represent a mobile redundant sensor from the set SM, Sd represent a low-energy static node from the set SD, and E_{th} is the energy threshold. If a sensor node Sd has its current energy less than E_{th} in the cluster then it may replaced by the redundant node Sm.

Algorithm 1. Sensor Movement Algorithm

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Notations:
d0        : Distance between Sm and Sd
TRsi      : Transmission Range of sensor Si
K1, K2    : accuracy coefficient
dm1, dm2  : the first, the second movement
Begin:
d0 =apply Euclidean distance(Sm, Sd);
a1= TRsi - d0
if d0 >=a1 then
dm1= K1x a1
else
dm1= K1x d0;
end if
angle=rand(360^0);
move(dm1,angle); First Move
d2=Euclidean Distance(Sm,Si)
a2= TRsi - d2;
if d2>= a2 then
dm2= K2xa2
else
dm2= K2xd2
end if
angle=acos((d2* d2+dm1*dm1- d0* d0)/(2* d2*dm1));
move(dm2,angle); Second Move
d3=Euclidean Distance(Sm, Si)
if d3+dm2- d2<Error then
angle= last-angle//Correct direction
else
angle=acos((d3* d3+dm2*dm2- d2* d2)/(2* d3*dm2));
end if;
move(d3,angle) Third move
End;
```

The distance is calculated by base station using Euclidean distance formula and angle calculates using Law of Cosines formula. Calculated values are sending to redundant nodes which one is placed nearest to the failure node. Then the redundant node is ready to move to the target location from the current location. Now the cluster area is fully covered by the selected redundant nodes.

Next the mobile nodes are move to the next location and form the dynamic clusters with other nodes and calculate the coverage ratio of that deployed nodes in the target environment, this operation is continue until the target area should be covered.

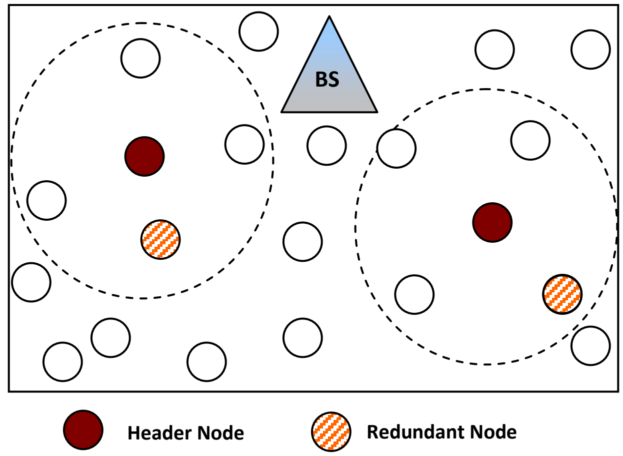

Fig 5: Redundant Nodes covered the hole

4. SIMULATION RESULTS

In this section we evaluate non cluster and cluster through extensive simulation. We use the following performance metrics are Coverage ratio and Energy Usage, the average total energy utilized by mobile nodes during the simulation. We simulated our algorithm with Simulator NS2. The following table 1 summarizes the simulation parameters used.

Table1. Simulation Parameters

Parameters	Values
Simulation Time	5o Sec
Area Size	500x500
Node Placement	Random
No of nodes	100
Mobile Nodes	5
Sensing Range	15m
Moving Speed of Mobile Node	20m/s
Initial Energy of redundant Node	100J

Mobile Nodes Power=300Joule; It is 3 times greater than other nodes. Sensing radius r_s=15M; Capacity of a node=20Kbps; communication range r_c is described as $r_c=2r_s$. Comparison of the cluster and non cluster based approaches based up on the Energy usage and coverage ratio. Usually in the non clustering concept not provide the good result, because the mobile nodes are randomly move in the region for coverage repair, so it required high energy and time for repairing.

Figure 7 illustrates the relation between clustering and non clustering concept based on the simulation time and energy usage of the mobile nodes. In non clustering concept such as least frequently visit, snake like movement and back tracking movement the energy loses is high because mobile nodes may uses excessive movements for communication, and explore the region.

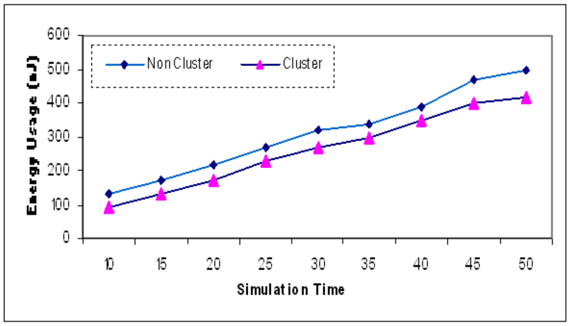

Fig 7: Energy Usage

Figure 8 demonstrates comparative relationship between mobile nodes and its coverage ratio. In clustering concept each mobile node covered the target region. Non clustering concepts are covered only 40 to 85% but in clustering concept provides the satisfactory solution up to 97% coverage ratio.

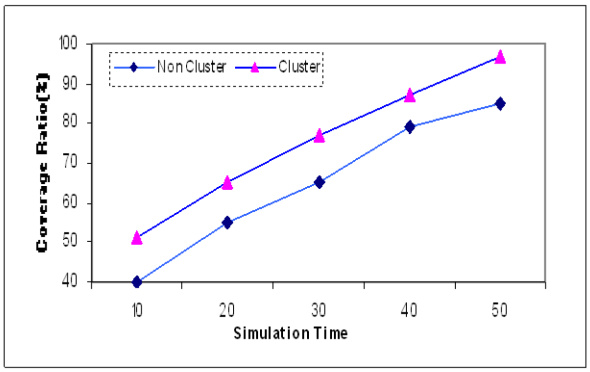

Fig 8: Coverage Ratio

Simulation results verified the effectiveness of our solution. Results have proven that our approach outperforms classical approach like non clustered network. It is also proved to be scalable. Using mobile nodes has tremendous prospects due to their capability to gather information and to take actions in hazardous fields beyond men's reach.

4. CONCLUSION

The coverage problem for WSN has been studied extensively in recent years, especially when combined with connectivity and energy efficiency. Coverage is defined as how well and how long the sensors are sensing, communicating and transmitting the information in the target area. In this paper, Mobile nodes are used to maintain the coverage in the random deployment area. Dynamic clustering concept is used to find out the coverage barrier in the target area by the energy efficient communications with redundant nodes compared to non clustering concept. Sensor movement algorithm is used for maintaining the best coverage by means of activating the redundant node from high density location to uncovered area. This algorithm applied by base station to remove gap and faulty node from the location .Mobility equipped redundant sensors are moved to recover or to improve the overall coverage. This proposed work described the easiest and low cost for deployment process .It is light, high covered and energy efficient. Hence which is applicable for large and human inaccessible area such as chemical leak monitoring, mining detection, and thick forest, where human intervention is prohibited.

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