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SENSOR DEPLOYMENT ALGORITHM FOR HOLE DETECTION AND HEALING BY USING ENERGY BASED LOCAL HEALING

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ABSTRACT

A wireless sensor network (WSN) are small sensors with limited computational and communication power. Each of which is small, lightweight and portable.They are very vulnerable to various type of failures.Sensors are deployed with power source like battery,these batteries are limited energy capacity this may leads to formation of hole in WSN, These types of failures causes the formation of holes in a WSN. One of the main service of WSN is the monitoring a special region of interest(RoI). The RoI continuity is very important to cover whole RoI continuity, there by entire network. So the holes inside these RoI cause breaks in communication. The Localized Movement Assisted Sensor Deployment Algorithm For Hole Detection and Healing (HEAL) is an efficient and effective method for this hole detection and healing. The key elements that ensure coverage for WSNs are determining the boundary of ROI, detecting coverage holes and estimating their characteristics, determining the best target locations to relocate mobile nodes to repair holes, and dispatching mobile nodes to the target location while minimizing the moving and messaging cost.

KEYWORDS: Wireless Sensor Network(WSN),Hole,Special Region of Interest(RoI).

INTRODUCTION

A wireless sensor network is a bunch of specialized sen-sors with a communication infrastructure for monitoring and recording conditions at particular[3] locations. A sensor network consists of multiple detection stations called sensor nodes, each of which is small,lightweight and portable. They are very vulnerable to various type of failures. These types of failures causes the formation of holes in a WSN.One of the main service of WSN is the monitoring a special region of interest(RoI).The RoI continuity is very important to cover whole RoI continuity, there by entire network.So the holes inside these RoI cause breaks in communication.The Localized Movement Assisted Sensor Deployment Algorithm For Hole Detection and Healing (HEAL) is an efficient and effective method for this hole detection and healing .The key elements that ensure coverage for WSNs are determining the boundary of ROI, identifying coverage holes and estimating their characteristics, determining the best target locations to relocate mobile nodes to repair holes, and dis-patching mobile nodes to the target location while minimizing the moving and messaging cost. Also at time of node reloca-tion, the energy of the relocating nodes are considered. So it avoid the further formation of holes due to energy depletion.

HEAL is a distributed and localized algorithm that operates in two definite phases. The first phase divided into three sub task, hole identification, hole detection and, border detection. Unlike previous methods, it uses a distributed and localized detection method for this purpose. The second phase treat the hole healing with a concept hole healing area. This method consist of two sub task, hole healing area determination and node relocation. In the existing method,the process of hole detection and healing are only based on the calculation of size of big hole and then relocate a group of sensors to heal the hole. They use centralized methods for this purpose. The disadvantages for this method are, detects holes of fixed sizes only, boundary detection by comparing one hop neighbors, message forwarding overhead can be large, not applicable for large density of nodes, repetitive network flooding. In HEAL, hole detection and healing are based on two definite phases like hole identification, hole discovery and border detection.Distributed and localized hole detection and healing algorithm deals with holes of various forms and sizes against the nodes distribution and density. Second phase consists of hole healing area determination and node relocation. Distribute virtual force based local healing allows a local healing where only the nodes located at appropriate distance from the hole will be involved.

RELATED WORK

Different types of methods are used for detecting holes in WSN and border detection. All of them have its on advantages and shortcomings.

In real world wireless sensor network the node deployment is not uniform. So these networks contain some areas that are not covered by any sensor nodes, called holes. The TENT rule and BOUNDHOLE [11] are one of the method that used for determining and build routes around holes. In this method the hole is considered as a region enclosed by a polygonal cycle which contain all the nodes where local minimum can appear In most of network the communication voids are present due to the local minimum circumstance in geographical greedy forwarding. In geographical greedy forwarding the source node knows the location of the destination node. A packet is forwarded to the 1-hop neighbor which is closer to the destination. This procedure continue until the destination is reached. A node where a packet is stuck is called stuck node in this process. This local minimum occur due to the presence of hole in the net work. The stuck node is the boundary node of the hole. To escape packet from stuck node the BOUNDHOLE technique is used algorithm is used[11]. The Homology[4] is another method of finding holes and coverage detection in wireless sensor networks.The rips complex calculate the connectivity[7] details based on the inter node communication. It is a good solution to the coverage problem in WSN. This method contain two type of communication graphs are used, called rips complex and nerve complex. The nerve communication graph give the information about the coverage intersection about the individual sensor nodes. The nerve complex give the exact information about the coverage but it needs the clear knowledge about the location details of the sensor nodes. This is quite difficult to implement in the real world implementation. The rips complex is an approximation of nerve complex, it is easy to implement and does not need the exact node location. It is a centralized approach so it’s have its own algorithmic and topological complexities

Homology Problem formulation

We assume as little as possible about the nodes and their geometry. Consider a group of stationary nodes Rd. In most practical settings, d = 2 or d = 3. Our tools are not adapted to any particular d; therefore, we leave d as an open variable throughout the paper. We adopt the following assumptions on our system. A1 Nodes have radially symmetric cover domains of radius rc. A2 Nodes broadcast their unique ID numbers. Each robot can detect the identity of anyone within radius rs via a strong signal, and via a weak signal within a larger radius rw. A3 The radii of communication rs; rw and the coverage radius rc satisfy, mentioned in equation 1

$$2rc = rwrsp(\sqrt{d}) \qquad (1)$$

where d is the dimension of the domain in which the nodes lie. It is important to note what we do not assume. The coordinates of the nodes are unknown.Nodes are completely devoid of any information apart from the identities of very close and somewhat close to neighbors. This capability to differentiate between strong and weak signals provides a coarse form of amplitude measurement. For example, if a particular node scans its communications, it can determine whether a certain node is within amplitude rs or rw or neither.

Topological hole and border detection mechanisms are sim-ple distributed approach to discover nodes near the boundary of the sensor field and the hole boundaries. This mechanism purely relay on the topology of the communication graph. Here the only details available is, whether the nodes can communicate with each other or not. The topological methods never use the any location details about the sensor nodes. The communication graph has node and edges if corresponding wireless station can communicate with each other. If two nodes ca this topological hole and border detection methods a dense communication graph is need.[6,8,10].

AVAILABLE METHODS

In Coverage and Hole-Detection in Sensor Networks via Homology[4] the author introduce a hole detection procedure based on homology theory. Homology gives two type of communication graph called nerve complex and rip complex. Its computation is very difficult because the exact location of sensor nodes are needed.The homology is an algebraic method for counting holes of various standards. There are different types of homologies are present. In this work simple homology with actual coefficients. This method studied the problem of detecting topological holes in wireless sensor networks [12]. It uses a distributed schema that is based on communication topology. A boundary node is detected by examine its degree with average degree of its 2-hop neighbors. Nodes only give some area measure of neighbors from strong and weak signal.

Nerve and Rips

The problem of computing the topological type of a union of sets is classical,it is easily handled using the concept of a nerve.

Definition V: Given a collection of sets (U = U), the nerve complex of U, N(U), is the abstract complex whose k-simplices correspond to nonempty intersections of k+1 ele-ments of U.Hence, the vertices of N according to the elements of U themselves. An edge in N exists between two vertices if and only if the corresponding elements of U intersect. Unfortunately, nerves are very difficult to operate without precise locations of the nodes and a global coordinate system. We therefore turn to a different approach for obtaining a simplicial complex from a sensor network, using only pairwise communication data[2].

The following type of difficulty goes back to the 1927 paper of Vietoris on the foundations of homology theory [15]: similar objects were reinvented by Rips in the 1980 in the context of geometric group theory and have been used extensively since. Definition VI: Given a set of pointsX = fgCR^n in Euclidean n-space and a fixed radius , the Vietoris-Rips complex of X, R(X), is the ideal simplicial complex whose k-simplices correspond to unordered (k + 1)-tuples of points in X which are pairwise within Euclidean length of each other. We will abbreviate this to the term Rips complex. Since Rips complexes are determined by pairwise distances, they are completely determined by the communication graph of the system: whenever you see a triangle in the communication graph, you fill in an abstract 2-simplex. Any time you see a complete subgraph on k + 1 vertices, you fill it in with an abstract k-simplex.

The Blind Swarm for Coverage in 2-D[5] analysis problem in robot sensor network. It is a new set of tools for coverage problems in robotic network with minimum information about location and orientation information. This robotic sensor net-work consists a number of robotic sensor nodes with a unique

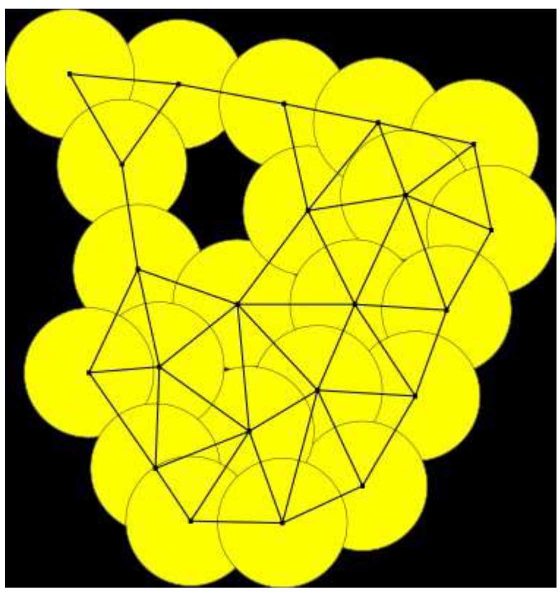

Figure 1. Sensor coverage discs and their union.

id which broadcast. Other robots with in this range of can get this broadcast signal as either a healthy signal or weak signal based on the distance of node.

Topological Hole Detection in Wireless Sensor Networks and its Applications[6] defines a basic method to determine the inner and outer boundary of holes in WSN. It is simple distributed procedure to locate the nodes that come near the boundary of the sensor network as well as near the hole boundaries. This technic is purely based on topology communication graph. This technic does not make use of any location informations of the sensor nodes. So it a simple protocol with only connectivity info required. But its proper working only guaranteed in dense networks.

A New Approach for Boundary Recognition in Geometric Sensor Networks[9] describe a new approach with following problem in the WSN. A large, dense number of sensor nodes are scattered along a polygonal region R. There is no central based control unit, the nodes can locally to neighbor nodes within in the communication radius by

make use of wireless radio. There is no info about their coordinate or distance to other nodes. Here build a simple distributed protocol that allow nodes to identify themselves as being located near the boundary of R and form connected pieces of the boundary[9]. It uses the restricted stress centrality to measure topological boundary informations. The distribution of the sensor nodes follow a suitable random distribution is one of the strong assumption of this technic. An approach based on random distribution may still fail in sometimes. So this technic is more suitable for deterministic methods for boundary recognition[9].
Local Geometric Algorithm for Hole Boundary Detection in sensor networks [13] introduce a boundary detection algorithm for sensor networks which identifies voids in the networks. It uses fuzzy logic and graph theoretic concepts for computations. This hole detection technic is simple and localized. The requirement of synchronization among nodes is one of the drawback of this technic. Once the holes and exact boundary of hole is found, by different methods like Robomote[14], iMouse[15] find path trough these voids and communication make possible.

PROBLEM STATEMENT

During the operation of a wireless sensor network there may be chance for failure of sensor nodes due to many reasons. This failure causes formation of holes in the WSN. These holes make the network into ineffective and functionless. These holes are a threat to communication infrastructure in a WSN. So there is a need for an effective and efficient technic for detecting and recovering these holes problem as soon as early as possible. Our problem is to design a mechanism for detecting the holes in the WSN and heal the detected hole by considering distance and energy of nodes. This technic makes use of node locomotion facilities to heal the hole.

PROPOSED MECHANISMS

In this technic find the best answer to the questions like how to detect a hole?, how to estimate its size?, how to heal the hole without effecting the performance of the WSN?. This distributed and localized hole detection and healing algorithm deals with holes of various forms despite the nodes distribution and density This hole detection and healing are based on hole detection, calculation of energy of sensor nodes and hole healing. Our detection mechanism detects holes with different size and shape. Also this technic ensures that only the nodes with appropriate distance and energy are associate with in the healing process. This technic find the presence of hole in the network and estimate its characteristics. Finally it find the best target location to relocate the mobile node to heal the hole and move the mobile nodes into the target location.

Hole Detection

The first aspect of the proposed technic is hole detection. In this step the stuck nodes are find out from the deployed sensor nodes. The stuck nodes are those nodes where packets can possibly get stuck in packet forwarding. The stuck nodes are traced by using TENT rule (Shown in Fig.1). The TENT rule specifies that a node is not a stuck node when there is no angle spanned by a pair of its adjacent neighbors greater than 2/3. We adapt this technique to find the stuck nodes. The hole detection phase sub divided into three sub task; hole identification, hole discovery and border detection.
The first task is to identify the existence of the hole. Each node p in the network executes the TENT rule to check if it is a stuck node as follow. it orders all its 1-hop neighbours counter clockwise. Let U and V be a pair of angularly adjacent nodes.It draws the perpendicular bisector of up and vp,l 1 , l 2 . l 1 and l 2 intersect at point o and divide the plane into four quadrants (shown Fig.3). Only the points in the quadrant containing p are closer to p than u and v. Finally, if o is outside the communication range of p, the angle vpu is a stuck angle and p considers itself stuck node. Next, using the discovery step find the hole and its charac-teristics. All nodes that are identified as stuck node execute the hole discovery process. This step find the hole boundary and hole characteristics like centre of hole, radius etc. One of the stuck node generate a hole discovery(HD) packet and sent to the neighboring stuck node. This node add its location information to the HD packet and forward to next stuck node. This process continue until the HD packet received by the initiator node. The HD packet initiated node bi extract the node location of the all other boundary node b_1 ,b_2 , bN from the HD packet. From this location information it select two nodes b m and b n so that the distance between them is maximum.

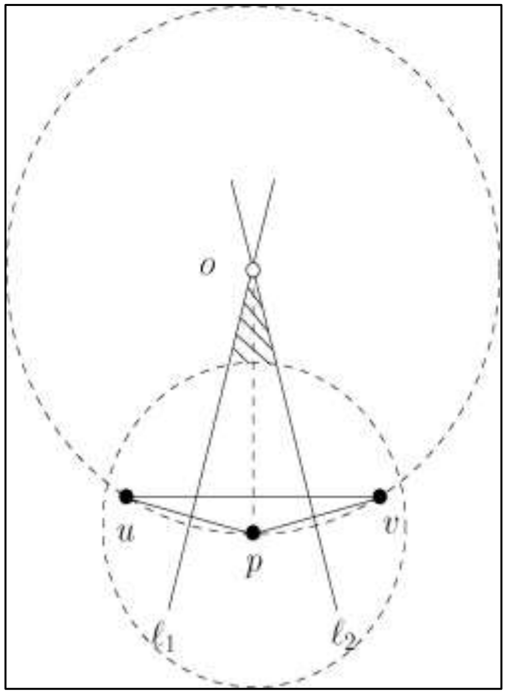

Fig. 2. p is a strongly stuck node.

Distance(bm; bn) = Max{Distance(bj ,bk)/bj ,bk}

Then, it calculates the hole center, which is the mid-point v of segment b_m b_n shown in equation 2,

$$\begin{cases} \mathbf{xv} = (\mathbf{xbm} + \mathbf{xbn})/2 \\ \mathbf{yv} = (\mathbf{ybm} + \mathbf{ybn})/2 \end{cases} \quad (2)$$

Each stuck node dispatch a HD packet without any coor-dination among stuck nodes. Thus, there will be redundancy in the discovery process. It will generate unnecessary traffic and more packet collisions, the situation may become worse especially for large holes. To avoid this problem, use a mechanism to prevent redundancy in the discovery process. The basic concept is to remove redundant HD packets as soon as possible. The technic for deciding whether a HD packet is redundant at each node, if a HD packet arrives and discovers that the packet has a Hole-ID greater than a Hole-ID carried by a packet already sent, the packet will be considered redundant and it will be deleted. At the end of this step node that has the smallest Hole-ID removes the HD packet and names itself as Hole Manager (HM): it will be responsible for the hole-healing announcement.

The next step is called the border detection, found out the network boundary node. There by avoid the initiation of hole discovery process by those nodes. This can be done by using Boolean variable in hole discovery packet and each stuck node compare this values with nodes coordinate values with receiving packet and set the variable. Thus identify the network boundary nodes. To discover the network boundary in a distributed way, will follow the following steps:

1) Each node of the WSN executes the TENT rule
2) Each stuck node launches DHD to identify the nodes that surround the hole
3) In the HD packet, define four Boolean variables to iden-tify the network boundary $X_m$ax; $Y_m$ax; $X_m$in; $Y_m$in . Each stuck node, which receives a HD packet, compares the coordinates $X_m$ax; $Y_m$ax; $X_m$in; $Y_m$in described inside the packet with its coordinates, and if it finds that it has a higher or a lower value than one of these values compared to all its neighbors, it sets the particular Boolean variable to 1
4) At the end of this procedure, the largest hole that defines the WSN boundary will be defined by the coordinates $X_m$ax; $Y_m$ax; $X_m$in; $Y_m$in
5) cancel the healing process that will be launched by the HM node

Thus the boundary of the network is traced and avoid executing the healing process by this boundary nodes.

Energy Calculation

The nodes are deployed in the sensor field with a specified energy level. The main source of energy is from a battery. The energy of the sensor nodes decreased from time to time from the initial deployment. The main factors affecting this degradation are communication range, sensing range, antenna length etc. So at the time of relocation, we have to consider the remaining energy level of the sensor nodes in the hole healing area. Otherwise the nodes with lower level of energy participated in the healing process. After healing process the energy will depleted soon and the nodes become useless. So it causes formation of additional holes in the network. To avoid this worst case, before the nodes are relocated for healing the remaining energy of nodes are calculated and node with highest energy move more distance than node with lower energy.

Hole Healing

The second aspect of the HEAL consist of two sub phases including Hole Healing Area (HHA) determination and node relocation. Here use the node locomotion facilities to heal de-tected holes. This is completely distributed and uses the virtual force concept. In this phase define the HHA (Hole Healing Area) in which the forces will be effective. It allows a local healing where only the nodes discovered at an appropriate distance from the hole will be involved in the healing process.

HMnode calculates the centre and radius of the hole. To find out the HHA first find out the radius of the hole. For this an iterative approach is used based on the formula R= r *(1+ B) where r is the radius of hole, B is constant depend on node density and sensing range. Start with a value 0 to B and increase up to finding sufficient number of nodes to recover the hole.

In the node relocation stage heal the hole by the help of nodes with sufficient energy in the HHA. For this purpose two type of virtual forces used. An attractive force that attract the node to the hole centre and a repulsive force that reduce the overlapped area between nodes to heal the hole. The nodes that receive forces from the hole centre, move towards it. The attractive and repulsive forces are balanced to minimize the overlapping area between cells. Thus the holes are healed using this method.

COVERAGE ENHANCEMENT AND HOLE HEALING

Monitoring the region of interest is the service provided by the WSN. The main role of this service is sensing the environment condition and sending the sensed info to the destination node. The Region OF Interest must be entirely covered all the time. Holes occur in the region of interest cannot be avoided. The occurrence hole is mainly due to nature of wireless sensor network or attacks on wireless sensor network network. Hence this affects communication between the nodes. Thus, it is important to detect and heal the holes in the network for an effective communication to take place.

Mobile sensor nodes like Robomote, iMouse etc can move around the initial deployment location for maximizing enhanc-ing coverage area. Several movement strategies are make use for this purpose. Because mobile sensors run on batteries, expanding their lifetime is an important issue. iMouse thus propose a dispatch problem that addresses how to schedule mobile sensors to visit emergency sites to maintain their energy as much as possible. Integrated mobile surveillance and WSN system (iMouse) consists of numerous static wireless sensors and several more powerful mobile sensors. The static sensors form a WSN to monitor the environment and notify the server of unusual events. Each static sensor comprises a sensing board and a note for communication. An event occurs when the sensory input is higher or lower than a predefined threshold. Mobile sensors can move to event locations, ex-change messages with other sensors, take snapshots of event scenes, and transmit images to the server.[14][15].

One of the key issues in the wireless sensor network area is the deployment of mobile sensor nodes in the ROI, where interesting events might happen and the corresponding detec-tion mechanism is required. Before a sensor can give useful data to the system, it must be deployed in a location. Optimum deployment of sensors results in the maximum utilization of the available sensors. In Energy-Efficient Deployment of In-telligent Mobile Sensor Networks, distributed energy-efficient deployment algorithms for mobile sensors and intelligent de-vices that integrated Ambient Intelligent network are proposed. These algorithms employ a synergistic combination of cluster structuring and a peer-to-peer placement scheme. In a peer-to-peer mode, each node moves itself to a sparse region so that the coverage of the area may increase and/or an energy-efficient node topology may be achieved. In a clustering mode.

Distributed sensor networks (DSNs) are important for a number of strategic applications such as coordinated target de-tection, and localization. The coverage provided by a random deployment can be improved using a force- directed algorithm. In DSN, present the virtual force algorithm (VFA) as a sensor deployment strategy to enhance the coverage after an initial random deployment of sensors. Sensors do not physically move but a sequence of virtual motion paths is identified for the randomly deployed sensors. Once the effective sensor positions are identified, a one-time movement-asissted sensors is carried out to redeploy the sensors at these positions. One of the draw back of this technic is, it require global computation, ie all the nodes need to run the algorithm.[17]
The movement-assisted sensor deployment deals with mov-ing sensors from an initial instability state to a balanced state. A localized Scan-based Movement-Assisted sensoR de-ploymenT technic (SMART) develop an optimal load bal-ance solution based on the classic Hungarian technic (mesh based) that uses minimum total moving distance. Assume that sensors are deployed randomly into the monitoring area without consideration of any physical obstacles. Then partition the monitoring area into many small regions and use the number of sensors in a region as its load and enhance the coverage of the network by some movement-assisted sensor replacement. It had a drawbacks that, it can cause large message overhead due to the increase of scan. Also it can have global computation and for large number of holes these methods are not sufficient.[18][19]
Self-aware actuation to allow a network to reorganize its available sources and form a new functional topology in the face of run-time dynamics. This approach is called self aware because the actuation is not governed by a user command or application but initiated by the network to improve its own per-formance. In Self Aware Actuation for Fault Repair in Sensor Networks, the performance criterion is coverage. This technic develop an algorithm called COverage Fidelity maintenance algorithm (Co-Fi) that uses mobility as an adaptive actuation facility for automated placement repair of the network.This technic does not consider the node failure that caused by the physical damage.

EXPERMENTS

The Energy based localized sensor deployment method for hole detection and healing in WSN implemented in the NS-2 simulator. The deployment of sensor nodes in the region of interest is carried out using NS-2.

Table.1 Comparison Between Proposed Solutions

Proposed solutions	Main drawbacks	Advantages
[4]	Centralized, not necessary to detect a hole	Do not need coordinate and location informations
[5]	Centralized, not mention node placement and relocatin	Minimum assumptions need minimum Knowledge about environment
[6]	Centralized, high complexity, work in dense network,not necessary to detect	Simple, only connectivity informations are needed
[7]	Require high node density	Running time is linear in its inputs
[8]	Assume a uniform node density,require high node density	Computation is easy,distinguish between outside and interior boundaries
[9]	Only for deterministic methods,chance for failure	Distributed technic
[10]	Centralized approach,repetitive network flooding	Only 3 network flooding Also implement with non uniform distribution of nodes
[11]	High message density	Distributed, asynchronous
[12]	Require relatively complex combinatorial structures	Distributed, no assumption on the distribution of nodes
[13]	Require synchronization among node	Distributed,Simple and localized

The sensor nodes are deployed statically and the holes are found out from the sensing area. The current sensing are consist of 200 mobile sensor nodes with one hole present in it. After the initial sensor deployment the nodes are communicated to each other and find the stuck nodes. From the stuck node information find the hole and finally heal the hole based on our technic. The current technic tested on the basis of nodes and hole characteristic as well as the previous work in the field.

To analysis the performance of the healing process, the nodes are deterministically deployed into the sensor field in different times with varying hole radii. The same way the test was conducted on the basis of changing the number of holes in the current sensor field. The total distance travelled by the sensor nodes to cover the holes, attractive and repulsive force to heal the hole are directly depend on the radius of the circle. The distance covered by the nodes in the HHA is not uniform movement is decided by their position and energy. The holes near the hole boundary as well as the nodes with higher energy levels travel more distance than other nodes. The size of the hole determines the number of movements performed by the nodes to heal the hole. Up on the experimental results, the presence of both large and small holes did not influence the correctness of the technic.

The performance of the implemented energy based localized sensor deployment technic for hole detection and healing was compared with that of DSSA, SMART[16] . also this technic is compared againt the technic in[1]. DSSA is a centralized movement assisted virtual force based algorithm. SMART is a grid quorum based movement assisted localized algorithm. With these two methods compare the performance of the current technic. The discrimination is mainly carried on the basis of number of movements of sensor nodes, rate of improvement in the network coverage and the total distance travelled by the sensor nodes to heal the hole. The result of comparison is given in the following figures. This proposed technic take less number of movements of sensor node to heal the hole after a better node density. The graph in the the fig.3 shows the performance comparison based on number of movements. With the low node density the proposed technic shows some worst result compared to other. When the node density incresaes the performance increases. The same result shown (fig.4) in the comparison of the proposed technic increases. The same result shown in (fig.5) the comparison based on total distance traveled. It shoe better performance than DSSA.

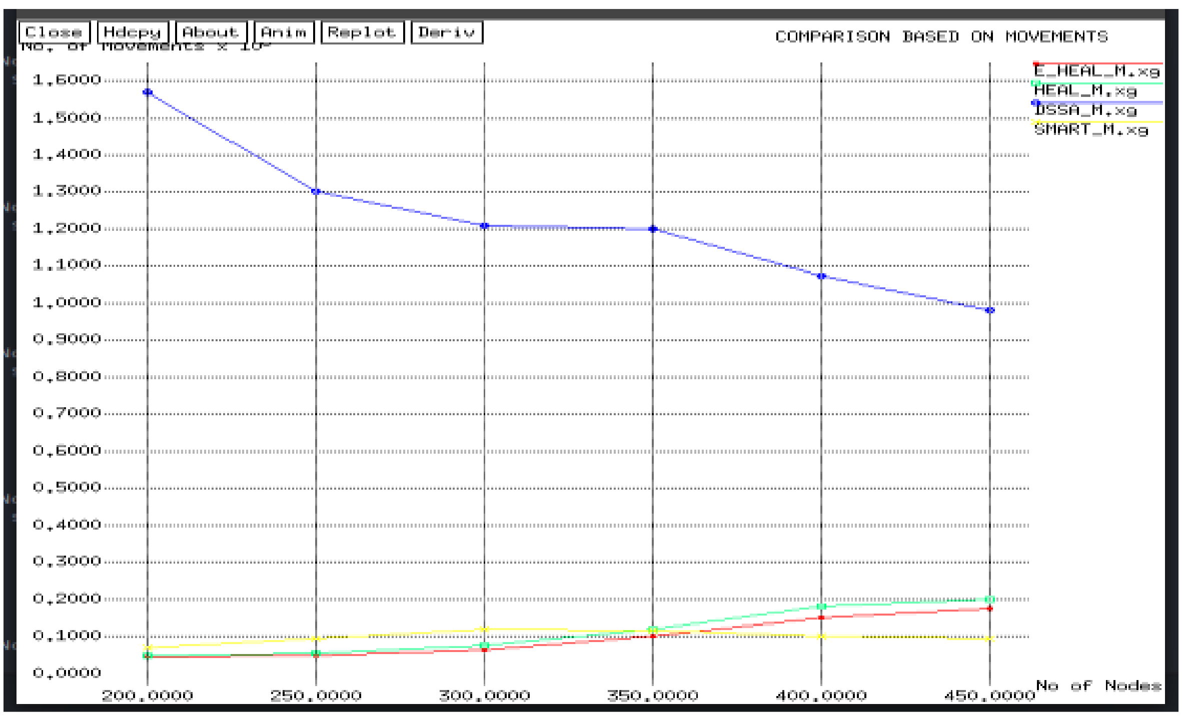

Fig. 3. comparison based on movements.

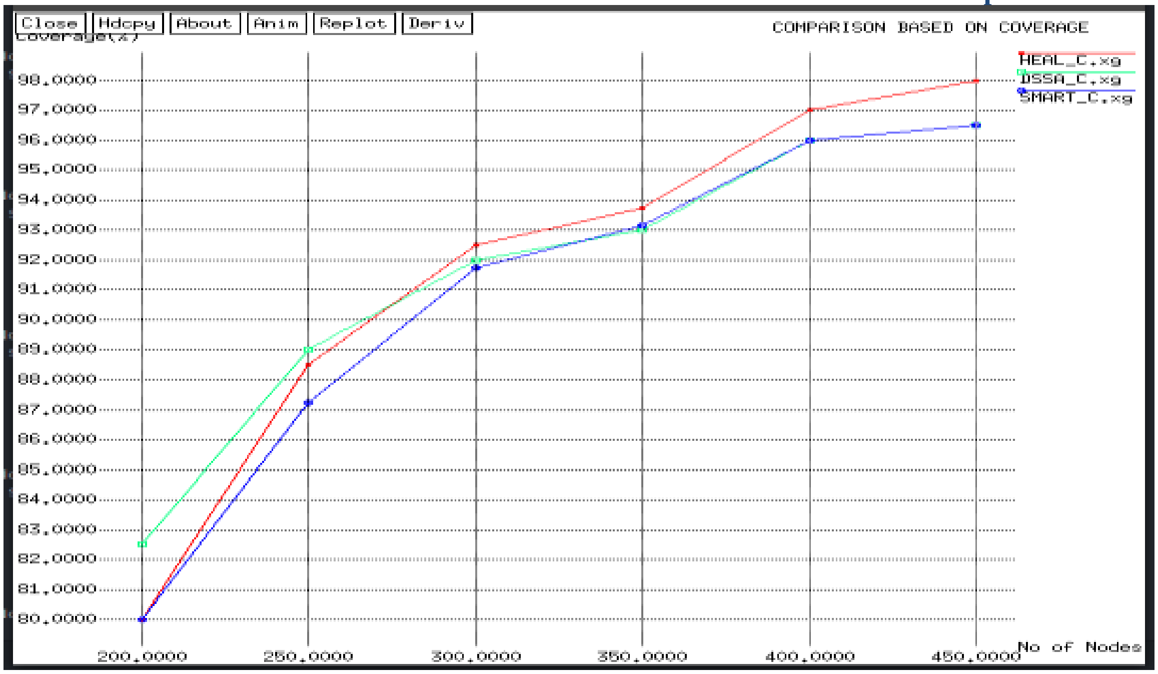

Fig. 4. comparison based on coverage.

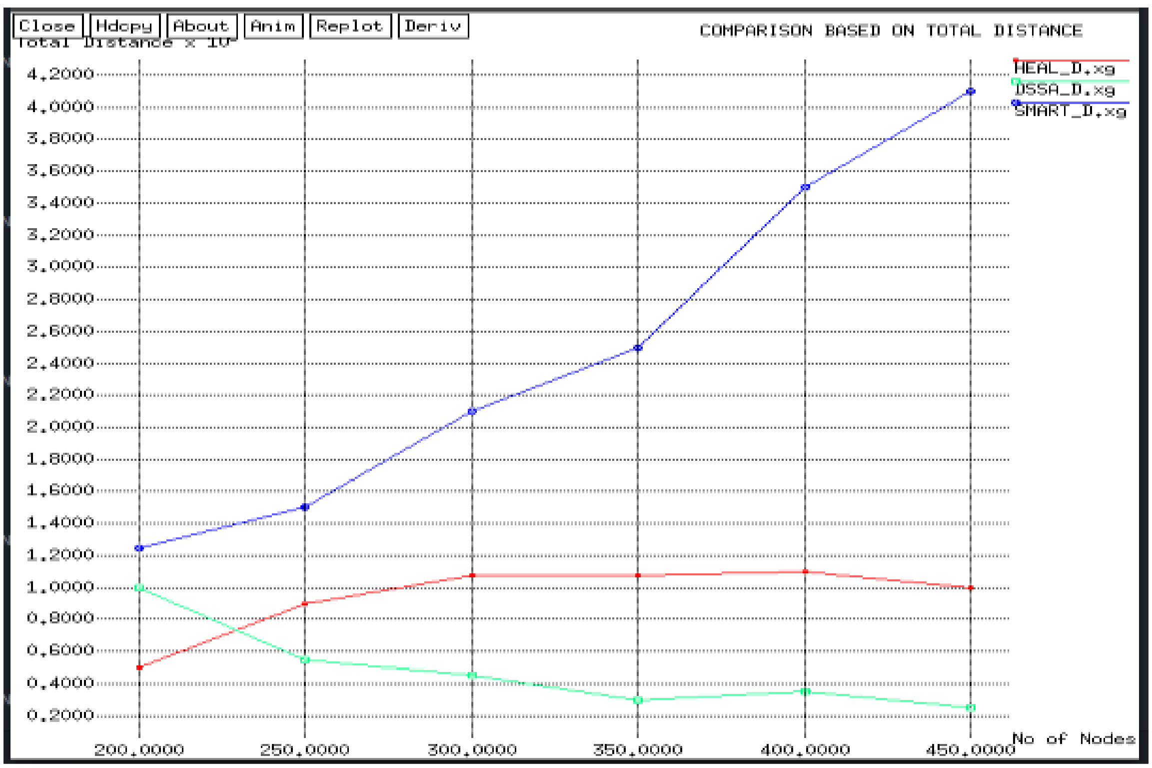

Fig. 5. comparison based on distance.

CONCLUSION

The problem of effective hole detection and healing in Wire-less Sensor Networks is a difficult task. With these proposed technic we can efficiently find and heal the hole in a WSN. This proposed and implemented technic became a lightweight and comprehensive two phase protocol for ensuring coverage enhancement in Wireless Sensor Networks. It can heal holes of various shape and forms with low complexity. It shows performance improvements by considering the energy of nodes for relocation. The current technic is worked in two phase. In first phase it detect the existence of the holes in the WSN and find the characteristics of the hole such as centre, radius etc. then using the second phase of the technic the detected hole healed with minimum effort. The nodes are relocated for healing is on the basis of distance and energy. So the coverage and performance of the network will be maintained. The wireless sensor network found large applications in civil and military field, so this technic have its own importance in these fields. Also it shows some performance improvements than the current methods.

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