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Performance Evaluation of Hole Repair Algorithm in Wireless Sensor Network

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Abstract: Network causes most of the problems of coverage due to random deployment of sensor nodes in Wireless sensor network. Severe coverage problems occur because of death nodes and serious coverage overlapping which degrade the network performance. In the proposed work, we have developed algorithm taking limited mobility of nodes, area of coverage overlapping and calculating high dense region in the area of network. For repairing the hole area of death node we have developed algorithm to select node in higher overlapped area who knows the its neighbor nodes as death node among other neighbor node which will be ready to move in the hole area without losing its connectivity and coverage with the existing nodes in that area. This cause moderate consumption of energy and increase the coverage of network despite of losing significant amount of energy. We have observe that proposed work has shown the increase of coverage area of network, significant decrement in overlapping area which causes because of random deployment, most effective ratio of recovered hole area in the scenarios.

Keywords: Wireless sensor networks, density control, coverage, mobility, hole repair.

1 INTRODUCTION

IN wireless sensor networks (WSNs), sensor networks consist of a large number of small, light-weight, highly power-constrained, and inexpensive wireless nodes called sensors. These sensor nodes are capable of sensing essential parameters such as temperature, pressure, humidity in the environment, soil quality, luminosity and various other essential data. Along with sensing the parameters, these sensor nodes can also communicate with other sensor nodes thus forming a network. Deployment of sensor nodes in the area of concern. The behavior of deployment varies based on the perception of a network.There is the random and precise way of deployment. Precise is stuck to the static environment where coordinates are known, and random is the unconditional behavior of deployment. Usually, sensors are deployed randomly, possibly showered down from an airplane onto the area of interest, and they typically operate in very hostile terrain, such as forests, nuclear or chemically polluted region, mountains or volcanic regions, which may be inaccessible to direct human intervention. Some sensors are connected to each other in the deployment playground. Such sensors are called highly overlapped where some are far from each other. The sensors which are highly overlapped that area is called as high-density area, and the other area is called sparse area. In this way, we have to control density in the network for better coverage.

Every Node has coverage which is sensing area of that node, two nodes can communicate due to communication range on the part of the area in a network. If the node is able to communicate with another node in the network i.e they are sharing their coverage with each other. Nodes may fail due to exhaustion of the battery power, some software bugs, failure of the electronic component. Also, it is not possible to recharge and replace the battery every time in the network. So the data gathered by the sensor node is highly critical. Now the coverage overlapping [1] of such death nodes is coverage hole which needs to repair for the betterment of coverage in the network. Maintaining coverage of such sensor nodes and its effectiveness is critical to forming robust network.

Mobility is the property of sensor node in the network which allows them to move from one position to other position. Mobility is required by the node which will have the ability to move in the hole area of death node.Every such node in the network has sensing ability. A node having the property of mobility can be called as a mobile node in the Wireless sensor network. For scenario demonstration, we are considering limited mobility. After deployment, monitoring area may have death node due to many reasons whose coverage hole is the challenge to get repaired from the highly overlapped area. Some node could be present in sparse region where repairing coverage hole could be less energy consumption. The developed algorithm is created based on minimizing the overlapping area to get better coverage from the highly dense area to sparse area.

The rest of the paper is organized as follows. We discuss related work is done on this topic and brief several coverage deployments and maintainers algorithm in sensor networks in Section 2. We have analyzed our work in detail in Section

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3. We also explained the implementation of the same algorithm in a distributed manner in Section 4. We explain experimental setup required to form a network using simulation Omnet++. We present the results obtained from our simulations in Section 5 and summarize our work in Section 6.

2 RELATED WORK

A. F. Dai and J. Wu[2006]
Has focused on selecting a small virtual backbone for high efficiency in the monitoring area of wireless ad hoc and sensor networks. They proposed to construct a k-connected k-dominating set (k-CDS) as backbones to balance efficiency and fault tolerance which results show that these protocols can select a small k-CDS with relatively low overhead[2].

B. Y. C. Tseng, P. Y. Chen, and W. T. Chen[2012]
Has identified coverage problem and worked in defining a new k-angle object coverage problem in a wireless sensor network. Each sensor can only cover a limited angle and range. A set of sensors and a set of objects at known locations, the goal is to use the least number of sensors to k-angle-cover the largest number of objects such that each object is monitored by at least k sensors satisfying some angle constraint by centralized and distributed polynomial time algorithms. Work has built a fundamental basis for the angle-coverage-related research [3].

C. S. Megerian, F. Koushanfar, M. Potkonjak, and M. B. Srivastava [2005]
The definition of the coverage problem from several points of view and formally defines the worst and best-case coverage in a sensor network. By combining computational geometry and graph theoretic techniques, specifically the Verona diagram and graph search algorithms. Has defined an optimal polynomial time worst and average case algorithm for coverage calculation for homogeneous isotropic sensors[4].

D. S. S. Ram, D. Manjunath, S. K. Iyer, and D. Yogeshwaran [2007]
Has worked on randomly deployed sensor networks by using two-dimensional spatial coverage process where the area of interest is the sensing process on paths, rather than in areas. The analysis is done on the coverage process induced on a one-dimensional path by a sensor network that is modeled as a two-dimensional Boolean model[5].

E. G. Xing, X. Wang, Y. Zhang, C. Lu, R. Pless, and C. Gill,[2005]
Has proved a geometric analysis where sensing coverage implies network connectivity when the sensing range is no more than half of the communication range quantifies the relationship between the degree of coverage and connectivity. The Coverage Configuration Protocol (CCP) was achieved by different degrees of coverage requested by applications. Again it was integrated CCP with SPAN to provide both coverage and connectivity guarantees when the sensing range is larger than half of the communication range. In the future, we will extend our solution to handle more sophisticated coverage models and connectivity configuration and develop adaptive coverage reconfiguration for energy-efficient distributed detection and tracking techniques[6].

F. B. C_arbunar, A. Grama, J. Vitek, and O. C_arbunar,[2006]
Has detected and eliminated redundancy problems in a sensor network with a view to improving energy efficiency, related to the coverage-boundary problem, computation of Verona diagrams and in cases of sensor failures and new sensor deployments[7].

G. Z. Yun, X. Bai, D. Xuan, and T. H. Lai,[2010]
Has worked on the deployment patterns to achieve full coverage and k-connectivity under the different ratio of sensing the and communication range where they proposed a polygon-based methodology to achieve 3-connectivity, 4-connectivity, and 5-connectivity for certain ranges of Rc/RS, with respect to 6-connectivity under all ranges of Rc /Rs[8].

H. Zhang and J. C. Hou,[2005]
Has investigated the issues of maintaining coverage and connectivity by keeping a minimal number of sensor nodes to operate in the active mode in wireless sensor networks by considering the relationship between coverage and connectivity, (radio range is at least twice of the sensing range), then complete coverage implies connectivity. Hence, if the condition holds, we only need to consider the coverage problem. Then, we derive, under the ideal case in which node density is sufficiently high, a set of optimality conditions under which a subset of working sensor nodes can be chosen for full coverage.

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I. M. Y. Donmez, R. Kosar, and C. Ersoy, [2010]

Has measured analytical deployment quality in terms of network parameters, including the sensor count, sensing coverage, coverage hole count, coverage hole area size and deployment area size. Also to measure the network quality under the assumption of sensor loss overall suitable metric is implemented. The proposed deployment quality metric (DQM) provide a conservative estimation of the intruder detection performance[9]

J. X. Huang and D. K. Hunter[2008]

Has proposed an innovative coverage hole detection and recovery algorithm for coordinate-free sensor networks. Both the hole detection and hole recovery algorithms are distributed without any central control, which is very convenient for randomly deployed sensor networks with resource-constrained nodes, especially in those scenarios with frequent topology change due to node mobility or unpredictable node failures. Their results were accurate and reliable while detecting the precise boundary of any unrecoverable holes, recovering all recoverable holes using the minimum number of redundant nodes[10].

K. P. K. Sahoo and J. P. Sheu,[2011]

Has proposed limited mobility based connectivity and coverage maintenance protocols for the multi-hop wireless sensor networks. A distinguishing feature in our work is that communication range is equal to the sensing range (Rc = Rs) and mobility of nodes in our algorithms is limited within only one-hop neighbors of a dead node. Besides, our algorithms can also be useful to maintain the connectivity and coverage of the network for Rc < 2Rs.Also designed dynamic maintenance algorithms without disturbing the existing communication and coverage systems of the network taking $1 \leq Rc/Rs < 2$, and our limited mobility of nodes can guarantee the network integrity.

L. H. Mahboubi, J. Habibi, A. G. Aghdam, and K. Sayrafian-Pour,[2013]

Has proposed an efficient sensor deployment algorithms to increase coverage in a mobile sensor network with a priority assignment for different points of sensing field. The multiplicatively weighted Voronoi (MW-Verona) diagram is developed where each sensor moves iteratively in such a way that the prioritized uncovered area in its MW-Verona region is reduced [11].

M. W. Wang, V. Srinivasan, and K. C. Chua, [2007]

Has experimented trade-off between mobility and density in terms of the hybrid structure of the network for the mobile sensor network.They had examined mobility has significant advantages in providing Coverage[12].

N. X. Wang, S. Han, Y. Wu, and X. Wang [2013]

Has proposed asymptotic coverage under uniform deployment model with i.i.d. and 1-D random walk mobility model, respectively. Mobility is demonstrated in terms of sensing energy consumption in comparison with i.d and 1-D random walk mobility model but imposes no impact under the i.d. mobility model. So the -coverage under Poisson deployment scheme with 2-D random walk mobility model has been proposed, which also identifies the coverage improvement brought by mobility[13].

O. B. S. Manoj, A. Sekhar, and C. S. R. Murthy[2007]

Has proposed Dynamic Coverage Maintenance (DCM) schemes that exploit the limited mobility of the sensor nodes. They mentioned the process of moving a node to a new location for maintenance of coverage is termed ‘‘migration’’. The proposed algorithms decide which neighbors to migrate, and to what distance. They also extended algorithm, called Cascaded DCM, which extends the migrations to multiple hops[14].

3. ANALYSIS OF PROBLEMS

Due to the random deployment of sensor nodes and some part of a un-monitored area, there is no guarantee to get uniform distribution of density and maintaining coverage and connectivity in the network. The high essential area if not overlooked can spoil the whole purpose of the network.We have done a survey on literature where they have work more on coverage and connectivity maintenance algorithm so our work proposes on maximizing the recovery of hole area by minimizing coverage overlapping. Based on this analysis algorithm purpose to recover hole area by minimizing coverage overlapping in the network which enhances the quality of service with better energy consumption related to the network. Using mobility in a limited way and keeping track of mobility distance in the case where the number of deployed nodes increases, so the density increases as they are proportional to each other. With approaching different sensing range for mobility distance respectfully with the number of deployed nodes.when the result of one hop mobility comes to the point of not monitoring entire network area so need of two hop mobility with increasing mobile distance is proposed.

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The main contribution of work can be summarized as follows:

The algorithm is proposed where sensors are deployed in a random manner, based on the user input coordinate value of the playground area. After deployment, some part has high coverage degree which is known as the main aspect of our work. In the Autonomous way, the various mobile node is selected among the high-density area of a convex region for maintaining network integrity.The proposed algorithm repairs multiple coverage holes of the network by using few mobile node without distributing the existing coverage and connectivity of the network. For the scenario implementation, we generate death node with its coverage hole based on the number of nodes user say to deploy. Proposed work used mobility in limitation within one hop and two hops to assure the better coverage by minimizing coverage overlapping area.

4.HORA: HOLE REPAIR ALGORITHM

The coverage Hole Algorithm proposed to work on high density area of the network. Throughout the network The coverage Hole Algorithm proposed to work in the high-density area of the network. Throughout the network communication range (Rc) is twice of sensing range(Rs). Nodes are randomly deployed and it is assumed nodes are connected if the distance ≤2 radius. After the random deployment some part of the network where more number of nodes are overlapped with each other whereas in another area few numbers of nodes are overlapped. In such a scenario where node density is high as more nodes are overlapped with each other which is called high dense area, on the other hand, some area is called sparse as few nodes are overlapped with each other. During battery exhaustion scenario there could be the predictable and unpredictable death of node, in our proposed work we have generated coverage hole based on the number of nodes deployed. Each sensor nodes know its own location and location information of its one-hop neighbor.

Our goal is to repair coverage hole by moving some sensor within the large overlapping area to the area of hole region, so the density of the nodes can be maintained in the whole network. Due to our algorithm, a mobile node is selected among the high-density area who has death node as one its neighbor node list. Selected node knew its location and location of its all neighbors based on the distance vector a near distance node is selected from list of neighbor nodes to the death node which will call to move towards hole area without distributing coverage and connectivity with its area nodes.

The terms need to be known for the scenario’s implementation are described below in details

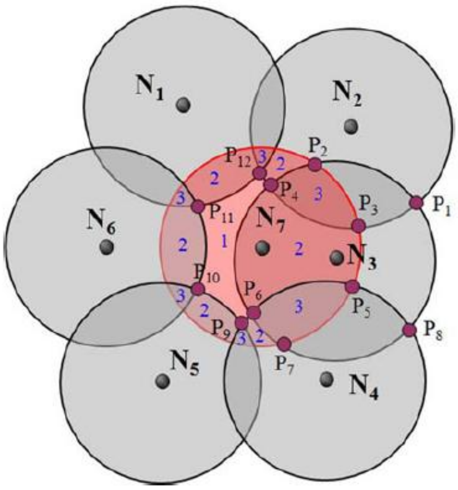

Figure 1:Example of the boundary nodes,covered points, and Kh-value Boundary Nodes

Boundary Nodes

From the Fig. 1, sensors N1 through N6 will be Boundary nodes of sensor N7 as they enclose the hole due to the death of node N7.

K-cover

The k-cover is a value of the intersection of coverage areas induced by k sensors. For instance, as shown in Fig. 1, the k-cover of node N7 with its neighbor N3 is 2, whereas with both neighbors N2 and N3 are 3 each.

Kh-value
As shown in Fig. 1, we can find all possible k-covers of node N7 with its one-hop neighbors represented by the natural numbers. Now, the highest value of these k-covers, which is Kh-value of sensor N7 = 3.

Common overlapping region
The common overlapping region is defined as the common area of intersection between the coverage area of nodes.

Candidate node
A node that wants to move from redundant region to repair hole is termed as candidate node. It reduces the kh value by moving towards the coverage hole.

The detailed procedure of the proposed Hole Repair Algorithm is described as follows.

4.1 Selection of High Dense Area
Algorithm are proposed in a way where we will calculated distance from distance vector of every sensor node in the network. Distance vector will return kh Value on the basis of nodes having maximum nodes present on the coverage of that node. We obtain highest kh value from the K-cover described earlier. After random deployment, a node who have highest Kh value is the highly dense area. We consider nodes overlapped with more than four nodes are the high dense area so we term kh value as kh≥4. After random deployment , first we look for the high degree of coverage overlapping where kh value will ≥ 4.

The area having high coverage overlapping is called as high dense area. For example follow the figure 1 , where Node N7 is overlapped with more than four nodes so it is high dense area considered in our scenario's.

4.2 Selection of Candidate Node
As the high dense area is selected among another area of the network, selection of candidate node will be done from that area.Every node in the area will know its own location with its one-hop neighbor, node list will be formed at every single node. The node will consider only that node as a neighbor node, whose distance is less than twice radius (d≤ 2r).A node will be selected as candidate node whose has death node as its one of its neighbor and also distance is less than among other nodes towards the death node. Candidate node is also called a mobile node whose has rights to move its location through hora-mobility. Hora-mobility is the proposed algorithm who selects candidate node based on the points elaborated earlier.

To select mobile node exactly we follow some condition:

Condition 1:The common overlapping region of the nodes must be more dense(kh≥4).

Lets assume COR is less dense , then is contradicting us, so the node should be slected from high dense area only.

Condition 2:If a mobile node is not connected i.e distance ≥ 2r with the other nodes, therefore the deployment of node must be sparse.

Nodes deployed randomly, some get placed where connectivity relationship (d≥2r) cannot be obtain therefore deployment of such nodes are considered as sparse region.

Condition 3 : If the candidate node is ready to move , so it reduces the value of kh, and therefore reduces the common overlapping region.

The COR between selected candidate node and inactive node(death node)is reduced when candidate node moves to new places so the value of kh is also reduced. But as to maintain uniform density in the network kh value should be greater than four so it move within the distance ≤ 2 radius and ensures that no more coverage hole should be obtained. Every node in the area gets a change to be selected if its near to death node , all the neighbor nodes done with their turn then that area is considered to be repaired of death node and density is maintained entirely in the case of limited mobility

4.3 Selection of Mobile Region
Moving of the mobile node in the region should be such that its existing coverage and connectivity is not distributed. So very first we should determine mobile region before it moves to repair the hole area Each candidate node that want to move to repair hole ,selects its nearer one hop candidate node. With the help of the one hop candidate it calculated the whether the distance is equal to twice of radius then selection of mobile region is determined correctly. That ensure the new location of the mobile node is not out of the boundary of it mobile region therefore it is obvious that existing coverage and connectivity is not disturbed.

Condition 4: Movement of the mobile region should be determined correctly, so the connectivity is not lost and coverage hole is created again.

The boundary of the mobile region must be less than or equal to the communication range of a node and also mobile node must be connected with at least one node even after its mobility to a new position. Then we can conclude about connectivity is not lost.

4.4 Calculation of New Location

After selecting the high dense area with selected candidate node with its determined mobile region, each node needs to find out its new location of mobility. New location is calculated with the help of HoraMobility algorithm where mobility of the node to that new position must satisfy the following conditions.

Condition 1. Existing connectivity with at least one of the one-hop neighbors of the mobile node is not lost.

In order to achieve this condition, find set of neighbors (No), which are boundary nodes or one-hop neighbors of the mobile node and whose sensing disks enclose the mobile region of that mobile node. Of course, No also includes the assistant node of mobile node. Let, new position of the mobile node be (Xn,Yn) and coordinate of each member of No = (Xj,Yj). In order to achieve Condition I, following in-equation should be satisfied.

$$(Xn - Xj)^2 + (Yn - Yj)^2 \leq R_c^2$$

Condition 2. Existing coverage of the mobile node is not lost.

Let, (Xn,Yn) be the new position of the mobile node and coordinate of each point of Vp be (Xp,Yp). In order to achieve Condition 2, following in-equation should be satisfied.

$$(Xn - Xp)2 + (Yn - Yp)2 \geq R2s$$

Condition 3.Kh-value of one-hop neighbors of the mobile node is not increased.

In order to satisfy this condition, find the set of nodes (W), which are one-hop neighbors of boundary nodes and are two-hops away from the mobile node. Let, (Xn,Yn) be the new position of the mobile node and the coordinate of each member of W be (Xd,Yd). In order to achieve condition 3, following in-equation should be satisfied.

$$(Xn - Xd)2+ (Yn - Yd)2 > R2c$$

Algorithm: Hole Repair Algorithm for inactive sensor nodes in WSN

1. Run the code for simulation
2. Place active and Inactive node randomly in the scenario
3. Apply HoraMobility to all nodes

(for Active node HoraMobility is normal and for Inactive Node, HoraMobility doesn't work because of mobility is disable for nodes)

4. Deploy Runtime Scenario for simulation.
   a) Find out the Location of each node scenario
   b) Calculate Distance Vector Matrix of deploy nodes for initial calculation
   c) Calculate Kh value matrix for neighbor node calculation
   d) Calculate the Overlapping Area Matrix for further operation
   e) Select Candidate node based on the Distance Vector Matrix, Kh Value matrix, Overlapping Area Matrix and Availability of Inactive area in the neighborhood area.
   f) If the candidate node is selected then carry out calculation regarding the limited mobility of candidates node w.r.t Inactive node location, current location and neighbor node.
   g) Using HoraMobility move the Candidate node in the Appropriate location
   h) Carry out Step a to g till simulation stop time or user halt signal
5. Based on required Variable of Simulated Scenario in excel File and Generate the graph from the different scenario for comparison.

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4.5 Contribution

Random Sequence Generation
Generated Number of nodes and ratio of inactive node from User as Inputs in to screen of simulation through omnet++ inet framework, created omnet.ini initialization file for generating random sequence of nodes and variable for getting user value from screen. Value from .ini file is fetched in .ned file which is used as presentation layer of network.

Implementation of Two-hop addon to one hop
Obtain Two Hop Scenario with the implementation of one hop mobility, and evaluated their performance. As number of deployed nodes increases, overlapping area increases for the same average kh value. Overlapping area increases and linearly density of node increases i.e Kh value increases. Therefore our algorithm is suitable for high dense area where we have simulated the variation of Kh value with the increasingly no of deployed nodes.

Overlapping area and density is measured before and after mobility. Our Algorithm does the mobility of node till the user wants to monitor hole coverage area is repaired till the distance < 2r , through either one hop or till two hop, and more on.All the active node are mobile node which keep on moving to repair area of death node under the condition that no more coverage hole gets created.

5.PERFORMANCE EVALUATION

5.1Simulation Using Omnet++ Simulator
OMNET++ is an open source component based simulation tool coded in C++ language in OMNET++, an open source communication framework known as INET is used. It consists of the following components that make up OMNET++ simulation.

_ **Network:** It defines the object and contains module, sub-modules and compound modules. These modules communicate with each other using channel.

_ **NED language**: It is a network description language (NED) used to create network topology. A user can create network topology either graphically or by NED.

_ **Configuration file:** It defines how the simulation will run. In every model, it is called omnetpp.ini. The code in omnetpp.ini can be divided into two parts. One specifies the parameters and other defines the module
that run the complex model functionality.

5.2 Experimental Setup
Table 1 shows the parameter setting for simulation. Deployment of numbers of nodes varies as 100, 120, 140, 160 with different sensing ranges 10, 15, 20m.

Parametrs	Values
Mobility Type	Mass Mobility/Hora Mobility
Travel Area	2000*2000m
Travel Speed	5mps
Simulation Time	90 seconds
No of Host	100, 120, 140, 160
Radius	10,15,20
Active Host	Hosts*(1-(Ratio/100))
Inactive Host	Hosts*(Ratio/100)
Seed-set	Random Sequence {2,5,7,9,3,11}

Table 1 Simulation Parameter Setting

Proposed protocol is simulated using omnet++ 5.2 with integrated INET Framework 3.6.INET Framework has its own predefined dynamic library created, we have edited its Source folder added as Hora Mobility similar to Mobility

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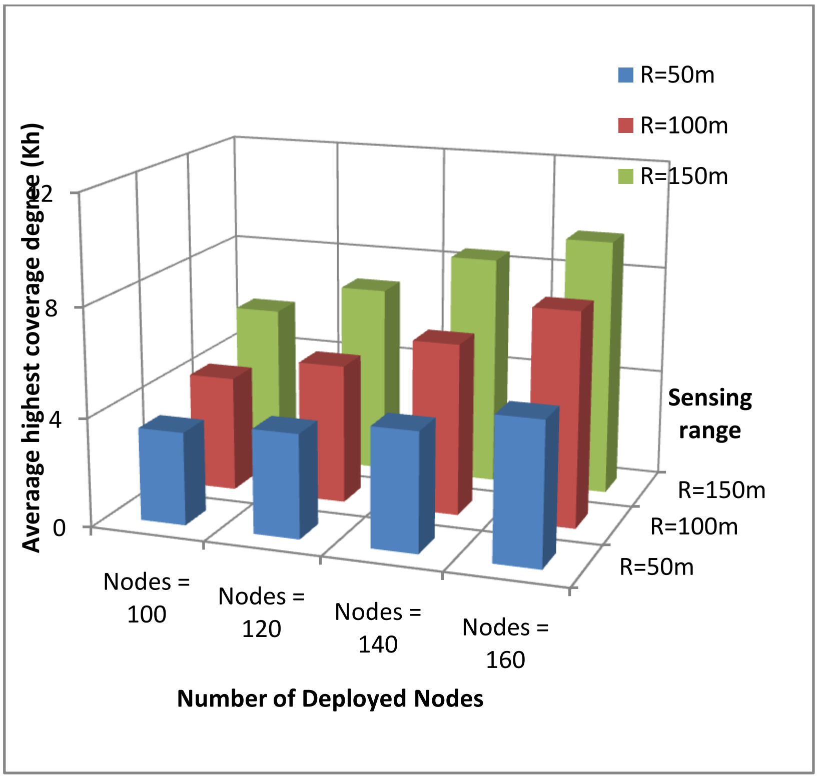
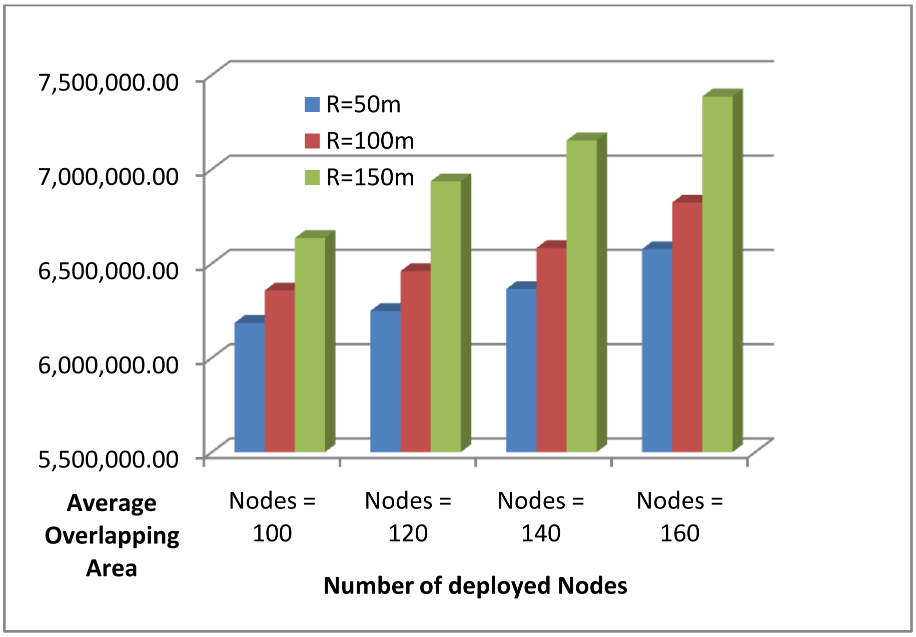
function of INET Framework. New Created Files area HoraMobility.cc, HoraMobility.h, with corresponding ned , ini files.We have created scenario in which we have deployed 100 nodes with user input for the X, Y Co-ordinate for the playground area. Death Nodes are generated based on the percentage evaluation on the basis of number of nodes. Simulation is deployed by increasing number of nodes randomly with different sensing ranges of 50 , 100, and150 m.

Evaluation Parameters

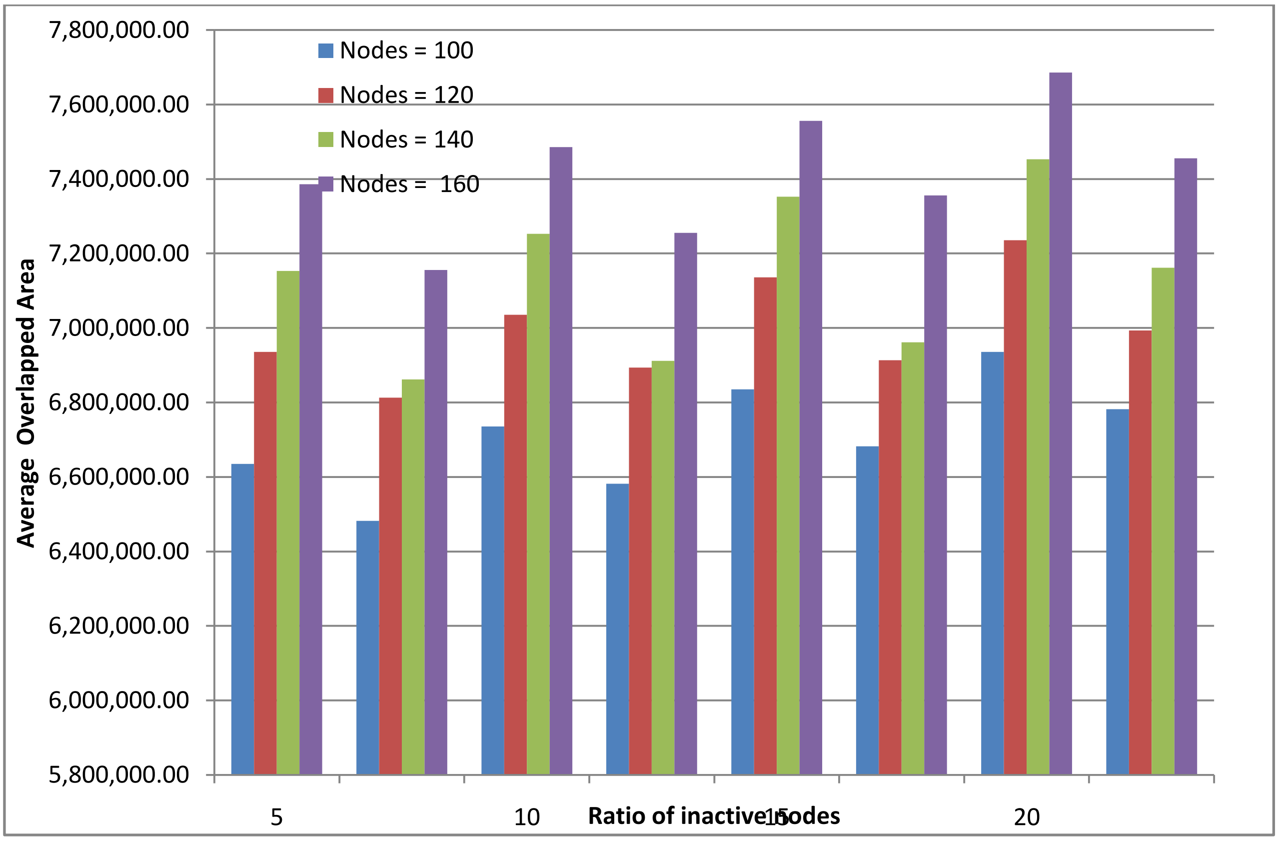
1. Average Highest Coverage degree(kh) with different sensing range .



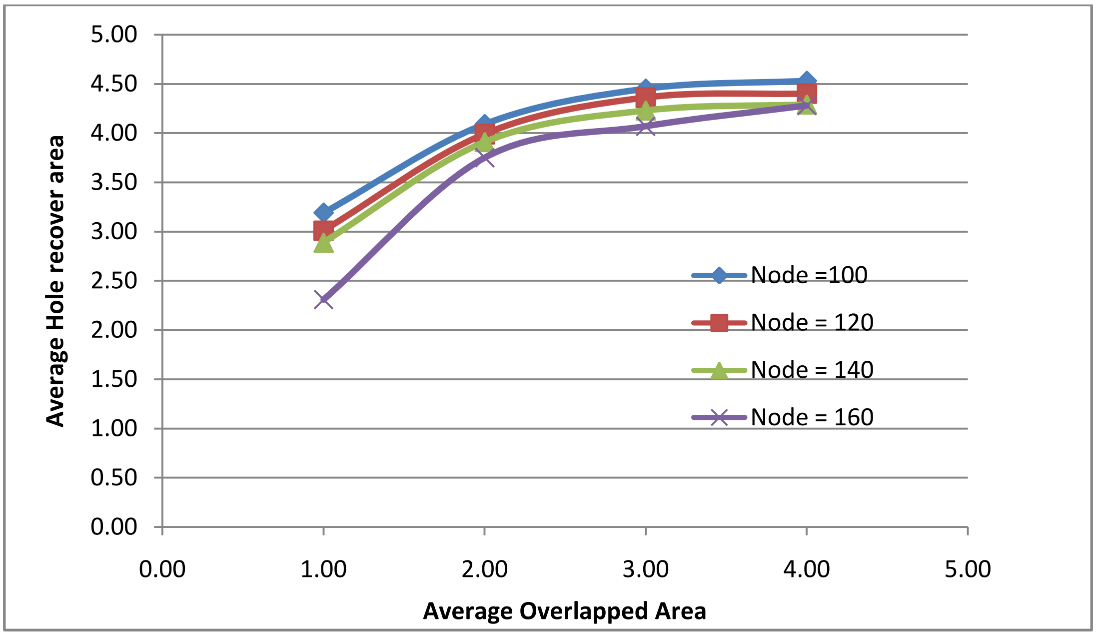
2. Average overlapping Area with Number of increasingly deployed nodes



3. Average overlapping Area with number of deployed nodes (before and after mobility)



4 Average hole recover area with average Overlapped area for number of deployed nodes.



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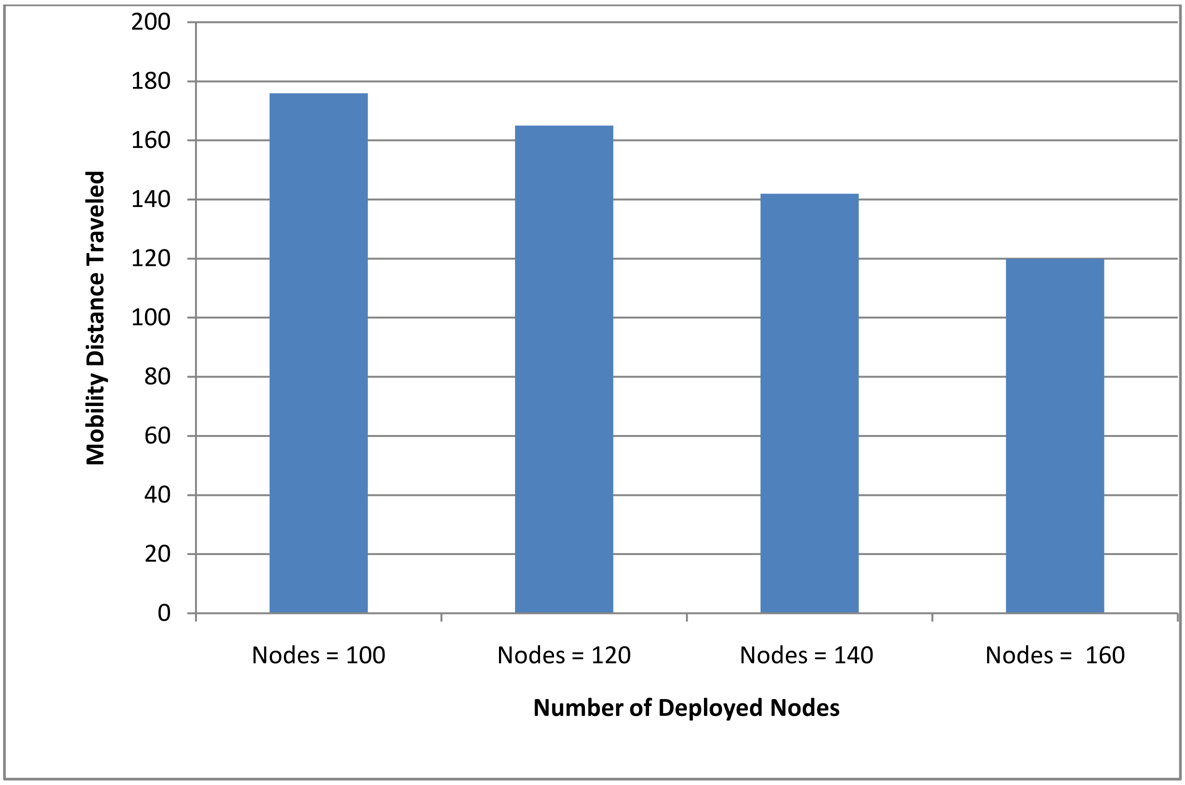
5 Average Mobility Distance with increasing number of deployed nodes.



6. CONCLUSION

Based on the random deployment pattern of sensor nodes in wireless sensor network, concept of minimizing the coverage overlapping area to maximize the coverage area, an efficient hole repairing algorithm is proposed by maintaining the connectivity and coverage of the nodes. For maintaining coverage and connectivity of the network with considering limited mobility of nodes, a coverage hole repair algorithm is proposed. With the help of Distributed algorithms mobile node is selected based on their degree of coverage overlapping (Kh-value) and the calculation of the new positions is made by using nonlinear programming method. Moreover, After mobility of node, density of the network is uniformly maintained by not increasing degree of coverage overlapping with there neighbours. Algorithm are proposed where mobility of a node is limited within one hop, two hop result are contributed and evaluate them in terms of performance of mobility distance. Therefore power consumption due to mobility is least. From the performance evaluation, it is observed that our algorithm outperforms in terms of energy consumption and percentage of coverage.

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