ISSN 2278 – 3091

International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE), Vol. 4 , No.4 Pages : 10 - 15 (2015)
Special Issue of ICEEC 2015 - Held on August 24, 2015 in The Dunes, Cochin, India
http://warse.org/IJATCSE/static/pdf/Issue/iceec2015sp03.pdf

Energy Aware Healing in Sensors with Clutter Adaptability

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Abstract: Wireless sensor network encompasses wide variety of applications. But it is most likely to have failure in communication due to the destruction of sensor nodes by sudden deployment from the aero plane or battery exhaustion. This of data forwarding by the ineffective nodes creates holes in the network. For maintaining effectiveness of the network these holes must be detected and healed. An effective solution called energy heal for hole detection and hole healing based on virtual forces is therefore proposed. Here we have chosen mobile wireless sensors to form the network due to its ability to self-organize the network. This algorithm emerged as a modified version of an existing algorithm called HEAL and has two phases first one is hole detection which is similar to heal and second one is advanced hole healing based on energy of nodes. We have further peeped into a special case with clutters and tried judiciously to solve the above problem using the concept of virtual forces.

Key words : clutter, mobile sensor nodes, hole healing, virtual force

INTRODUCTION

Mobile Wireless Sensor networks composed of number of mobile sensor nodes are used to monitor a specific region of interest. They are often used in the high risk applications such as battle field surveillance, forest fire detection, gas leakage detection etc. where manual deployment of sensors are not at all entertained. Therefore some of the nodes in these networks were highly prone to destructions due to sudden dropping from air planes, shocks, battery depletions etc. This leads to the curtailment of the network coverage creating coverage holes. So we claim to ensure the network connectivity by exploiting the concepts of virtual forces as well as nodes locomotion facilities.

Here we are only concerned about coverage holes, which are formed either by the node destruction, or by battery depletion. These holes remain as barriers for communication and deny any potential applications where maintaining the network coverage is at most essential. So these holes must be properly detected and healed. A virtual force based novel algorithm ENERGY HEAL is therefore proposed. This algorithm works on two phases, hole detection and advanced hole healing based on energy. The first phase hole detection is almost similar to its predecessor algorithm heal [1].Here we are giving a brief description about the algorithm's first phase which works on three parts. They are 1) Hole identification -Here each node in the network executes the TENT rule to check whether it is a stuck node. The existence of a hole is assessed by identifying stuck nodes. 2) Hole discovery-here the stuck nodes trigger the discovery of holes and its characteristics like center and radius by the computation of the hole's boundary. 3) Border Detection- it is done to prevent the hole discovery and the healing processes in the network boundary.

Here we have proposed a significant improvement in the second phase of heal incorporating energy awareness in nodes in the network. This results in a much delayed destruction of nodes in the network by battery depletion improving the network life time. We are also incorporating a special situation considering clutters in the area of coverage by exploring the concept of virtual forces to adapt the clutters in the network.

RELATED WORKS

The main works carried out so far in hole detection and healing in sensors were subjected to a detailed study. Here we consider the two phases hole detection and hole healing separately.

Hole Detection

In [2] B. Kun, T. Kun, G. Naijie, L.D. Wan and L. Xiaohu presented a distributed scheme based on communication topology graph. Here the problem arises in the detection of topological holes in sensor networks, where no localization information is available for any node in the network. Holes are detected by exchanging information in a node with 1-hop and 2-hop neighbors. Here the node decides whether it is on the boundary of a hole. This is done by comparing its degree with the average degree of its 2-hop neighbor. The main drawback of this method is that not all the nodes in the network can identify its boundary. In [3] Funk et al proposed a heuristic based technique for detecting holes based on communication topology graph. The hole detection algorithm is based on the topology of the communication graph, that is the only information available is about which nodes can communicate with each other. This approach is not localized as it requires the computation of distance fields over the whole network. In [4] a unit disk graph model is modeled by Funke and Klein to propose a linear-time algorithm for hole detection. This method requires communication graph that follows the unit disk graph model. The authors had proved that by using a very simple linear-time algorithm that helps to find the boundary of the holes in the sensor network. This technique works for only high node density. If the density of the node in the network decreases the algorithm breaks. While in Co-ordinate free boundary method Feke et al [5] described the co-ordinate free technique to detect the boundary of the hole in WSNs. The assumption made here is that the nodes are uniformly distributed in non-hole areas. The methods used in this method rely on a number of natural assumptions that are present in densely distributed sets of nodes, and make use of a combination of stochastic, topology, and geometry. The drawback of this technique is that it requires a high node density. Fang et al. presented bound hole algorithm using right-hand rule to identify nodes on the boundary of geometric holes. But this method is that it has high message complexity. In hole boundary detection algorithm Shirsat and Bhargava [6] assumed the relative geographic information of 2-hop neighbors. The hole boundary detection algorithm takes best approach in detection process. The flaw in this paper is that the algorithm requires synchronization among nodes. Wang et al. proposed boundary algorithm [7] to find the information of the connectives. For the hole detection process the author had used special structure of the shortest path tree The author did not make an analysis on its complexity. This algorithm relies on repetitive network flooding.

Hole Healing

The several movement strategies for improving network coverage by adopting various healing techniques are discussed in this section.

In movement-assisted sensor deployment by Wang, G. Cao and T.F.L. La [8] Porta described three different types of deployment protocols .These protocols use voronoi diagrams to relocate the nodes at once the holes are being detected. The main drawback of this method is that, this technique cannot be used for large holes. And also this method requires global computation. In decentralized and energy balanced algorithm C.Y. Chang and co-authors [9] proposed three algorithms for maintaining temporary coverage in WSNs. Authors proposed strategies for hole movement for the large hole. This is done in such a way that either the power consumption of the sensor or the energy consumption of the node is balanced or reduced respectively. The drawback of this proposed algorithm is that there is a requirement of synchronization among the nodes in the network. As a solution C.Y. Lin and coauthors proposed tracking mechanism and robot repair algorithm [10]. By using this technique the coverage problem is solved using a moving robot. The robot's footmark is left behind on the sensors during the tracking mechanisms. This helps the sensors to find better routes for sending repairing requests to the robot. The healing algorithm helps to develop an efficient path for communication. The main drawback of this technique is that the authors make an assumption that the WSN has been deployed using robot deployment mechanisms. A. Nadeem, S.K. Salil and J. Sanjay came forward with a pragmatic approach [11] to area coverage in hybrid wireless sensor networks. This paper proposed MAPC- Mobile-Assisted Probabilistic coverage. The MAPC maintained the coverage by moving the sensor nodes to strategic positions in the uncovered area. Using this technique only the sink can involve in the triggering of the hole detection and healing and the source cannot involve in triggering process.

In randomized carrier-based sensor relocation X. Li et al. proposed a randomized carrier based sensor relocation [12] where the robots picks up passive sensors and replaces them in the holes. This is done in a random manner and hence called as randomized relocation. This relocation technique assumes that the boundary of the wireless sensor network is known in earlier that is the main drawback of this paper. In sensor deployment algorithm [13] Z. Yong et al. proposed a virtual force algorithm (VFA) as a sensor deployment strategy to improve the coverage after an initial random placement of sensors. The VFA attempts to improve the coverage area of the sensors. The disadvantage of this proposed algorithm is that it is a centralized approach.

A scan-based sensor deployment method is proposed by S. Yangy et al [14], which is a scan-based movement-assisted sensor deployment technique for wireless sensor networks. In this paper the region of interest is divided into many small grid cells. And the number of nodes in the grid cell is the load of the grid cell. This technique generates enormous message overhead in a denser network since the number of rounds of scan is being increased. And at the final stage of clustering process, if two nearby clusters are empty the scanning process will be incorrect. This is the major drawback of the scan-based method .In Bidding protocol for sensor deployment G. Wang, G. Cao, P. Berman and T. La Portal had proposed two bidding protocol for sensor deployment [15] in wireless sensor network. Here, static sensors detect coverage holes locally by using Voronoi diagrams and bid mobile sensors to move. And these mobile sensors accept highest bids and help to heal the bigger holes.

These reviews brought us some insight to perform this work. By considering the cases of hole detection and healing separately we have learnt quite easily about their worths and flaws. It is obvious that we are using an algorithm which cares for both detection and healing like its predecessor heal.

IMPROVEMENT TECHNIQUES

To improve the performance of existing system we had focused on the energy of the system as well as the presence of clutters in the network. The following constraints were considered individually to analyze the network performance.

- Energy Based Healing
- Clutter Adaptability

Energy Of Sensors

Sensors are autonomous device, which will work without any human assistance, so sensor needs a battery for energy. It is almost infeasible to recharge all battery since WSN consists of thousands of sensors, so it is essential to manage energy resources to increase the life of network. Most of the energy is used for communication purpose. Here we are considering mobile WSN, then mobility itself may consume most of energy available, so managing resources is very essential [16].Our aim is to reduce the creation of coverage holes due to the depletion of energy. Here we have adopted a relatively easy strategy which could cope with the existing algorithm and at the same time useful for increasing the network life time.

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Healing Based On Energy Of Nodes

The relocation of mobile nodes will lead to the depletion of battery power and consequently leads to node's death. This could be prevented if we for saw the energy levels of nodes that take part in healing, and only allowing nodes which are above a particular energy threshold to take part in healing. This would help in improved network coverage and lifetime. We can call this modified hole healing algorithm as energy heal and fig.1 shows the flow chart of energy based hole healing.

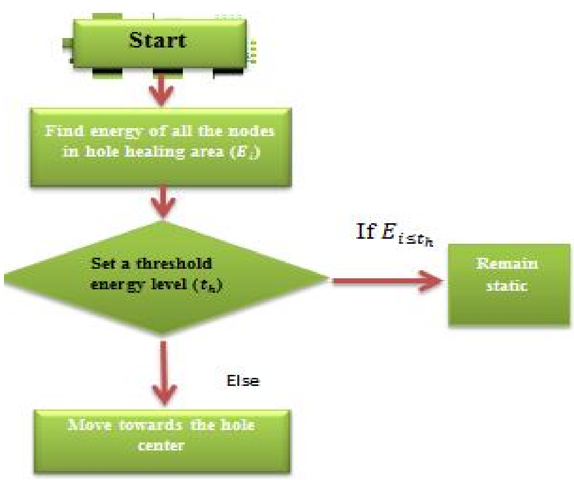

Fig 1: Flow chart of energy based hole healing

Energy Heal Algorithm

We have extended our studies to second phase of heal algorithm. Energy levels of nodes as well as its locomotion facilities are exploited here to heal the detected holes. Our relocation algorithm is based on the concept of virtual forces. Fig.2 shows the simulation of energy heal before the relocation of nodes to the hole area. The circle drawn with black chords connecting the stuck nodes (denoted by green circles) forms the hole with radius equal to the greatest distance between the hole center and any of the stuck node or otherwise hole boundary node. To heal the discovered hole we defined an attractive force (shown by red arrow) that acts from the hole center 'V' and attracts the nodes towards this center. To avoid overlapping between nodes a repulsive force is defined. In this figure we had shown only an area called the hole healing area (HHA) in which the forces will be effective. A local healing is defined here where the nodes located at an appropriate distance from the hole and having an energy level above a particular threshold to get involved in the healing process. The determination of the HHA along with informing nodes on their movement is done by the hole manager node. The HM node possesses information about the characteristics of the hole and neighboring nodes [1].

Determining Nodes With Sufficent Energy

Our prime motive is to establish the network coverage by healing the detected hole, for that it is at most important to find out number of nodes that has to be relocated. Since our relocation algorithm is based on a local healing it necessitates our need to determine a hole healing area from where we have chosen the nodes for relocation. After the identification of the hole, the hole manager (HM) node calculates the center and the size of the hole. The hole defined here is considered as a circle. The HHA, is determined by finding the radius of the circle which defines the hole.

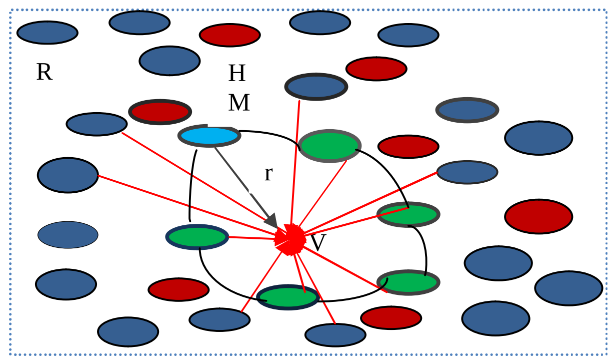

Fig 2: Simulation result before the relocation of nodes

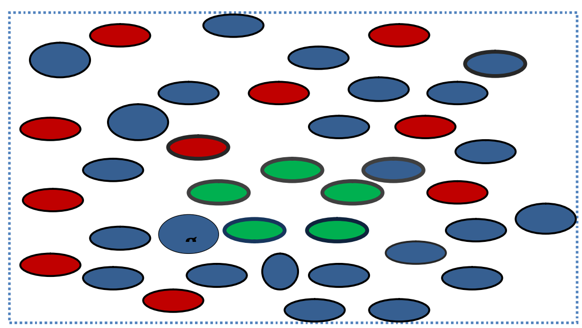

Fig 3: Simulation result of energy heal algorithm

The radius of the hole healing area is given by

$$R = r*(1+ ¶)\ ¶ € R^{+} \qquad (1)$$

¶ is a constant that depends on the nodes density and the sensing range Rs, and r is the hole radius. R^+ denotes that the radius can be incremented iteratively until it could find out appropriate no of nodes to heal the hole.The number of nodes that are above the threshold may be some times insufficient to heal the holes than its energy unaware counterpart in HHA and finally this will leads to the increment of positive constant, that is by increasing the radius of hole healing area to find out sufficient nodes to heal the hole. The rest of the activities remain same as in the algorithm Heal.Fig.3 shows the simulation result. The blue circle denotes energy nodes that can be used for relocation, while the red circles are non-energy node and those remain static irrespective of their position in the (HHA). Here hole healing was done using the blue circles.

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Relocation Of Mobile Nodes

The HM informs the nodes above the threshold energy to involve in the healing process after the determination of HHA. Nodes that receive forces from the hole center, move towards it.

Attractive Force: The hole center v applies an attractive force on every node with energy greater than threshold, which are within the HHA and located at a distance greater than $d_{ath}$from 'V'. A node p within the HHA receives an attractive force $\vec{F_a}$ form the hole center. We have defined a two by two matrix where E_i, E_{th} are first and second elements corresponding to node's energy in the HHA and the threshold needed for healing.

$$A=\begin{bmatrix} Ei & Eth \\ 1 & 1 \end{bmatrix}$$

Consider only det$|A| > 0$

$$\frac{det|A|}{\alpha_i} = \gamma = 1$$

To avoid computational complexities, that is to make the determinant value equal to one, we have taken

$$\alpha_i = 1/det|A|$$

$$\vec{F_a}(b,v) = \begin{cases} \dfrac{-K_a \gamma}{d(b,v) d_a} * \dfrac{r}{e^{d(b,v) * \vec{u_a}}}, & d(b,v) > d_{th}^{a} \\ 0 & , d(b,v) \le d_{th}^{a} \end{cases}$$

$\vec{u}_a$ is a unit vector from the point b, to the hole center v; $d(b,v)$ is the Euclidean distance between the node b and the hole center and located at $d(b,v)$, a distance coefficient d_a is introduced to balance the node movements and its distance from the hole. Each node in the network has unique physical states, such as its distance from the hole center, energy level etc. therefore a constant k_a is defined to determine the intensity at which each node is attracted towards the hole center. Since movements requires energy it must be reduced that is the nodes with greater threshold and nearest to the hole must move towards the hole center than those lying at a greater distance in the network. So an exponential factor is defined to cope with the node movements in the hole healing area.

A Repulsive Force is defined to counteract the overlapping of nodes which comes under the same sensing range.

$0 < \vec{F_r} < d_{rth}$,

$$\vec{F_r}(b,c) = \begin{cases} \frac{k_r}{d(b,c) d_r} \vec{u}_r, & 0 < d(b,c) < d_r^{th} \\ 0 & d(b,c) \ge d_r^{th} \end{cases} \quad (3)$$

$\vec{F_r}$ denotes repulsive force.

The node b, c will experience a repulsive force whenever they are not separated by a distance greater than d_{rth}, k_r is the intensity of repulsive force.

Experimental Result

Simulations were performed using network simulator. We have found the energy of each node and had assigned a threshold energy level for nodes that take part in the healing process. The performance of this algorithm in terms of coverage and network life time, total distance travelled by the nodes, node movements is compared with respect to our predecessor algorithm heal. The experimental set up is as shown in the table 1. Fig.4 shows that the network coverage is good for heal in cases of lesser number of nodes. but the performance of energy heal increases with greater number of nodes as there are more nodes available in the HHA which are above the threshold. As the number of nodes increases the network coverage gets increased.

Fig.5 show that the total distances travelled by the nodes in energy heal is greater than heal in cases with lesser number of nodes but its performance improved with increased node density. The result remains same in the case of node movements.Fig.6.shows that the network life time has increased in the case of energy heal, due to the judicious utilization of battery power of sensors which are prone to depletion.

Table.1: Experimental set up

Max(X,Y)	800,500
Deployment	Uniform
R_s (m), R_c (m)	10, 20
Simulation time (s)	400
Max speed (m/s)	10
Number of nodes	50-300
Routing Protocol	AODV

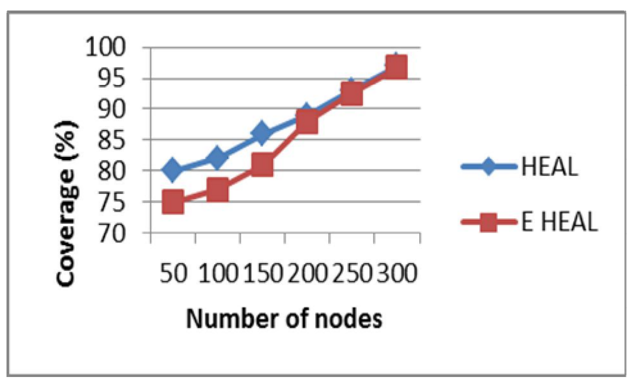

Fig 4: Comparison of network coverage

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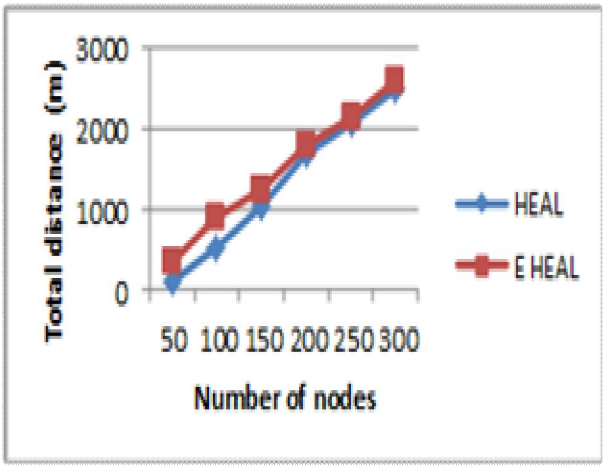


Fig 5: Comparison based on total distance

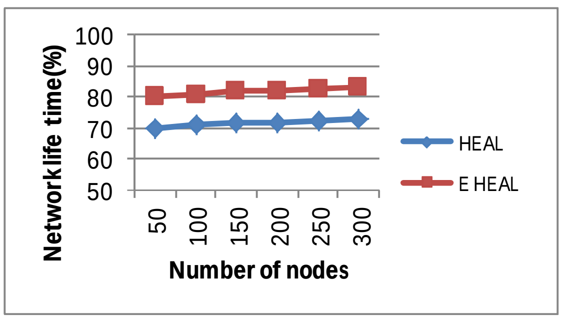


Fig 6: Comparison based on network life time

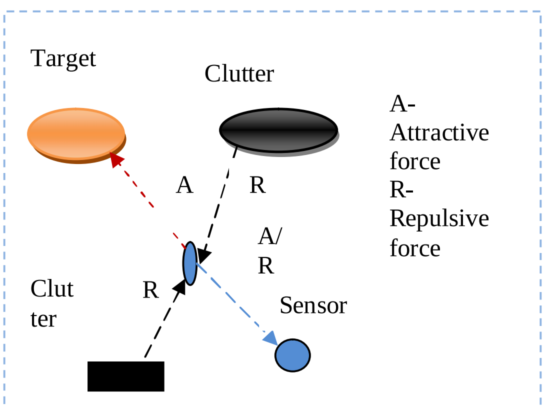


Fig 7: Illustration of forces in the presence of clutters

CASE WITH CLUTTERS

Clutter Adaptability

In most of the applications the target field is not always a plane surface, so we should consider the clutters during deployment. Clutter adaptability is very important issue in real time applications. In addition to the positive and negative forces due to other sensors, a sensor is also subjected to forces exerted by clutters and areas of preferential coverage. This provides us with a convenient method to model clutters and the need for preferential coverage. Sensor deployment must take into account the nature of the terrain, e.g. clutters such as building and trees in the line of sight for infrared sensors, uneven surface and elevations for hilly terrain, etc. [17].Fig.7 shows that clutter is exerting a repulsive force on the sensor, while target and other nodes exert attractive force on the node. Here we have formulated the repulsive force exerted by the clutter as force from the node which is closer than the threshold distance multiplied by a weighing factor. The repulsive force exerted from the clutter to the node whose position goes through or penetrates the clutter is given by

$$\vec{F}_r(b,\upsilon) = \begin{Bmatrix} \frac{O_i}{d(b,v)d_r}\vec{u}_o & 0 < d(b,v) < d_o^{th} \\ 0 & d(b,q) \geq d_o^{th} \end{Bmatrix} \qquad (4)$$

O_i defines a constant which defines intensity of repulsive force from the clutter which varies with respect to the position and physical state of the clutter. Consequently at the end of the deployment no sensor node will be within the clutter, i.e., the nodes will reconfigure themselves without curtailment of communication among them. Fig.8 shows the simulation results with and without considering the clutters.

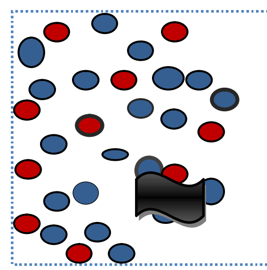
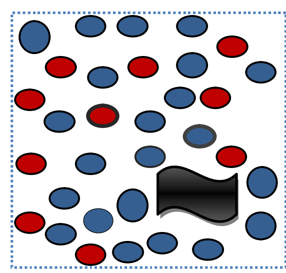


Fig 8: Simulation result (i) without clutters



(ii) With clutters

Experimental Results

Fig.9 shows that the network coverage has improved with obstacle adaptability. The network reconfigures considering the obstacles, preventing communication curtailment by the formation of coverage holes and resulted in improved network coverage.

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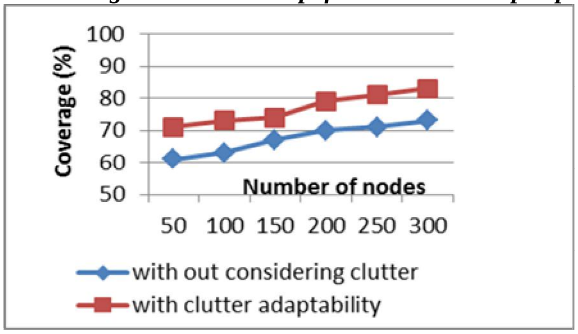

Fig 9: Comparing cases with and without clutter adaptability

V. CONCLUSION

This paper described about two major flaws in an existing hole healing algorithm heal. We have proposed and simulated a modified energy aware algorithm called energy heal for hole healing in the sensors and came forward with an adaptable solution in cases with clutters both mend to ensure network lifetime and coverage. The energy heal algorithm being concerned about the node's energy before the selection of nodes in the hole healing purpose, it reduces further chances for developing coverage holes by sudden battery depletion. We have found that the awareness of energy as well as clutters in the network will lead to a better network performance.

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