Abstract—In wireless sensor network, random deployment of nodes may cause serious coverage overlapping and the death of the nodes may also cause severe coverage problems in original network. There are several hole repair algorithms which take density of the nodes in the post deployment scenario. These algorithms consider limited mobility of the nodes and nodes with higher degree of coverage overlapping is selected. Coverage holes of the network are repaired by moving nodes which has high degree of density. This maintains uniform network density without increasing the coverage degree of the neighbor node. In existing system small holes are not considered. It only concentrates on larger holes. In the proposed work both small and large holes are considered. These holes are identified by beacon signals and are completely replaced. Here the hole detection and replacing are based on two distinct phases 1) hole identification 2) hole discovery and border detection. Distributed and localized hole detection and replacing algorithm deals with the holes of various forms and sizes despite node distribution and density. The proposed algorithm consumes less amount of energy when compared to existing algorithm.

Keywords: WSN, Coverage overlapping, Hole detection, Hole repair algorithm

I. INTRODUCTION

Wireless sensor node is a collection of nodes spread in area of interest. Wireless sensor network provides wider range of applications like monitoring battle field, environmental surveillance. Sensor deployment may be random or deterministic. Sensor nodes are mostly deployed in random manner that is, the coverage of sensor node is not uniform. There may be disconnected areas and some areas may be densely covered while some may be sparsely covered. To monitor these area maintaining the coverage and connectivity is very vital. Every point inside the region must be covered by at least one sensor node. Coverage can be classified into three classes : Area coverage, point coverage and barrier coverage. Area coverage, is on how to cover an area with the sensors, while point coverage deals with coverage for a set of points of interest.

Decreasing the probability of undetected penetration is the main issue in barrier coverage [17]. Coverage overlapping may be caused due to random deployment of sensor nodes. Connectivity is failed when the information passed did not reach the node.

Types of holes: Coverage Holes: The coverage holes are formed when the design of the network fails. They are formed when the sensor nodes are arranged unsystematically in the area. Coverage hole can appear into existence due to poor installment, or nodes whose power are weak. So they are formed by the power depletion, topology failure and by presence of obstacles. Routing Holes: The routing holes are formed when one of the nodes is damaged and it disables that route. Then the new route is reconstructed to outcome from the routing holes. It is caused by the power depletion and environmental disasters. Jamming Holes: The jamming holes are formed when any high frequency signal comes in contact with the wireless network and network breaks the signal and connects with the new signal. They are also formed when the jammers are installed in the nearby areas. They are caused by the presence of obstacles. Black Holes: The black holes are formed when the data sent by one node is not received by the other node and the sender is not aware that the data is received or not by the receiver. The data is discarded in between the traffic only. Out of all the types of holes, coverage holes are the most important to detect as they play a vital role in assuring good QoS. They help to identify whether each point in sensing field has the required degree of coverage or not. They are the indicators of general health of sensor networks and help in identifying geographic characteristics of target region. Hole boundaries can determine areas of interest like fire, flood, or earthquake. They help to find out locations where more nodes need to be deployed and thus assist in patching the holes. Hole detection ensures reliability by preventing data loss as discussed in [18].

To guarantee complete coverage in random deployment, it is often assumed that the number of scattered sensors is more than that required by the critical sensor density. However, this normally requires a great number of sensor nodes to be deployed another way to improve network coverage is to leverage mobile sensor nodes. Mobile sensor nodes are equipped with locomotive platforms and can move around after initial deployment [16]. Voronoi diagram and Delaunay triangulation are commonly used in WSN coverage optimization algorithm.
Nodes also die due to software bugs, loss of energy and destructive agents. Death of the node is considered as hole. Death of the nodes leads to packet loss. Sensory information may be lost due to node failure. To pass the data without any obstacles the node failure has to be repaired without affecting the coverage and connectivity. To recover from failure the coverage area of the node is considered. When a node is failed, the boundary of the node is detected and the neighboring nodes with maximum coverage is identified. Such nodes are moved to the region of failed nodes. By moving such nodes the existing coverage and connectivity is not disturbed.

There are several hole coverage algorithms. These algorithms consider only multiple node failure as a hole and single node failure is not considered. This results in data loss and energy consumption of energy by the nodes are also high. Proposed hole detection and replacing algorithms detects single node failure and heals it hence data loss is prevented.

Main contribution of the work is as follows:

- Connectivity is preserved by moving the neighboring nodes with high degree of density.
- Single node failure is detected and healed so that the sensory information cannot be lost.
- Coverage holes are repaired using few mobile nodes.
- The boundary range of each node is known.

II. RELATED WORKS

In [1] Ammari H.M. And Das S.K. addressed the problem of k-coverage in WSNs such that in each scheduling round, every location in a monitored field was covered by at least k active sensors while all active sensors are being connected. Sensing coverage was an essential functionality of WSNs. It is also well known that coverage alone in WSNs is not sufficient, and hence network connectivity should also be considered for the correct operation of WSNs. Sensors duty-cycling strategies for generating k-coverage configurations in WSNs is studied. First, the k-coverage problem in WSNs is modeled. Second, a sufficient condition of the sensor spatial density for complete k-coverage of a field was derived. Relationship between the communication and sensing ranges of sensors to maintain both k-coverage of a field and connectivity among all active sensors is provided. Third, four configuration protocols was proposed to solve the problem of k-coverage in WSNs. It selects a minimum number of sensors to achieve full k-coverage of a field while guaranteeing connectivity between them.

In [2] Bai.X, Yun.Z, Xuan.D. and Lai T.H. (2010) discussed about optimal deployment in terms of the number of sensors required to achieve four-connectivity and full coverage under different ratios of sensors' communication range to their sensing range. A new pattern, the Diamond pattern, which can be viewed as a series of evolving patterns was proposed. When the Diamond pattern coincides with the well-known triangle lattice pattern it degenerates to a Square pattern. The proposed pattern was asymptotically optimal when communication range achieves four-connectivity and full coverage. Another new deployment pattern called the Double-strip pattern was discovered. An asymptotically optimal deployment pattern was proposed to achieve four-connectivity and full coverage for WSNs.

In [3] Gupta.H, Zhou.Z, Das S.R. and Gu.Q. (2006) designed and analyzed algorithms for self-organization of a sensor network to reduce energy consumption. Spatial query execution was an essential functionality of a sensor network, where a query gathers sensor data within a specific geographic region. Redundancy within a sensor network can be exploited to reduce the communication cost incurred in execution of such queries. One approach to reduce the communication cost of a query is to self-organize the network, in response to a query, into a topology that involves only a small subset of the sensors sufficient to process the query. The query is then executed using only the sensors in the constructed topology. The self-organization technique is beneficial for queries that run sufficiently long to amortize the communication cost incurred in self-organization. In particular, the notion of a connected sensor cover was developed and designed a centralized approximation algorithm that constructs a topology involving a near-optimal connected sensor cover. A distributed self-organization version of the approximation algorithm is developed.

In [4] Ma.C, He.J, Chen H.H. and Tang.Z. (2013) investigated the problems of hidden devices in coverage overlapped IEEE 802.15.4 WSNs, which was likely to arise when multiple 802.15.4 WSNs are deployed closely and independently. A typical scenario of two 802.15.4 WSNs with partial coverage overlapping is considered and Markov-chain based analytical model to reveal the performance degradation due to the hidden devices from the coverage overlapping is proposed. Impacts of the hidden devices and network sleeping modes on saturated throughput and energy consumption are modeled.

In the post deployment stage, coverage holes are created in the network due to predictable or unpredictable death of the nodes such as battery power exhaustion or explosion. In the existing work a distributed NLP algorithm is proposed to minimize the coverage overlapping of the nodes due to random deployment and thereby to maintain uniform density of the network. The vector-based coverage algorithm cannot guarantee the minimization of overlapping area.

Existing recovery schemes focused on reestablishing severed links without considering the effect on the length of pre-failure data paths. The density control is converted into the flow control problem for deciding the
maximum mobile distance. The asymptotic coverage under uniform deployment scheme with random walk mobility model is analyzed. In terms of dynamic k-coverage under the Poisson deployment scheme with random walk mobility model, coverage varies based on the relation between coverage and the sensing range is studied. Main disadvantages are Existing recovery schemes either impose high node relocation overhead or extend some of the inter-actor data paths. Existing recovery schemes focused on reestablishing severed links without considering the effect on the length of pre-failure data paths.

III. HOLE DETECTION AND REPLACING FOR OPTIMAL COVERAGE

A network of sensor nodes can be installed in different areas to monitor the events. The nodes can be equipped with sensors to measure temperature, tactical monitoring, humidity and gases which are produced by fire in the trees or vegetation. Holes are considered as the major problems in wireless senor network, it was created by irregular manner of sensor deployment or battery depletion attacks. In proposed work hole detection and replacing algorithm is developed. Using this algorithm single node failure is also detected as a hole. Based on the concept of minimizing the coverage overlapping area to maximize the coverage area, an efficient hole replacing algorithm is proposed by maintaining the connectivity and coverage of the nodes. The nodes are deployed randomly and the network is fully connected. In such a deployment scenario, the node density of the network can be non-uniform as density of the nodes in the large overlapping area must be higher than the density of the nodes in the sparse region. Besides, it could be possible that coverage hole is generating due to predictable or unpredictable death of the nodes. Hence, the holes are repaired by moving few sensors from the large overlapping area to the hole region so that uniform density of the nodes can be maintained in the whole network.

Advantages of Proposed System includes Very low complexity, Deals with holes of various forms and sizes, Works despite of the nodes distribution and density.

Fig 1 shows system architecture. One of the fundamental services provided by a WSN is the monitoring of a specified RoI. The main duty of RoI is sensing the environment and communicating the information to the sink. However, the occurrence of holes in the RoI is unavoidable due to the inner nature of WSNs, deploying randomly, environmental factors, and external attacks. An event occurring within these occurrences of holes is never detected and reported and therefore, the main task of the network will not be completed. Thus, it is primordial to provide a self-organizing mechanism to detect and recover holes. Nodes send beacon signal from this signal the hole occurrence is identified. Then hole is discovered. The hole is temporarily healed by moving sensor nodes. Nodes are moved to the place where hole is detected and healing process is preceded. By moving nodes the packet loss is avoided.

The Hole detection and replacement is done in following phases: Topology formation, Hole detection & position discovery, Border detection, Hole healing.

A. Topology formation

Topology formation is one of the important issue in a wireless sensor network. Wireless sensor network mainly used for monitoring the events such as disaster tactical in military surveillance. It can be placed in regular manner or irregular manner. Deploying sensors irregularly may create holes in sensor networks. Battery consumes the energy of sensors. It is considered that the sensors are distributed randomly over a large target region. Each and every sensors can sense specified events in its sensing range, and communicate with others in its transmission range.

B. Hole Detection & Discovery Detection

DHD is the algorithm, it detects hole in WSN. Gabriel graph of the network operates over DHD a distributed and localized hole detection algorithm. Coverage holes may exist in WSNs due to presence of obstacles or invalid sensor nodes in the sensing field. The holes make the data routing failure when the nodes transmit their data back to the sink. Suppose a large amount of sensor node are scattered in a geometric region, with the nearby nodes communicating with the each other directly node failure causes great data loss.

C. Position Discovery

From this module the hole characteristics such as hole position and radius can be discovered. Once a node identifies itself as a dead node it generates a new HD packet, marked with its ID and forwards it to the next node. This process is repeated until the HD packet has travelled around the region and eventually been received by the forwarded node. The received HD packets extracts the locations of the boundary nodes. Any two longest nodes in the set of boundary nodes is selected to determine hole.
D. Border Detection

Border detection algorithm is distributed algorithm. The boundary nodes are detected, which will launch the hole discovery and the healing process. In order to differentiate the network border and hole border the coordinate value of nodes are compared. The node deployment is not uniform. So these networks contain some regions that are not covered by any sensor nodes. Topological hole and border detection methods are simple distributed approach to locate nodes near the hole boundaries. This method purely relay on the topology of the communication graph. The only information available is, whether the nodes can communicate with each other or not. The topological methods never depend on any location informations about the sensor nodes. The communication graph has node and edges checking wireless communication with each other. If two nodes can communicate with each other then they come under a common communication range.

E. Hole Healing

Nodes locomotion facilities to heal detected holes is exploited. Relocation algorithm is completely distributed. To heal the discovered hole an attractive force that acts from the hole center and attracts the nodes towards this center is defined. Similarly, a repulsive force is defined among nodes to minimize the overlapping in between. The HHA in which the forces will be effective. A local healing is performed only on the nodes located at an appropriate distance from the hole.

In healing process, a method is proposed which works on both energy and distance for giving longer lifetime to the network. If only shortest distance of relocation is considered, nodes nearer to the holes will be selected or if only the nodes having maximum energy are selected, then longer distance may used for relocation. Therefore, a combination of energy and distance is used as a effective solution for hole healing.

First the average energy of all the nodes is calculated, so that the nodes which are having residual energy greater than a threshold value is selected. Then, the hole healing area is calculated so that the nodes could be relocated for effective coverage. Then some movement to hole healing area is given such a way that the nodes gets relocated. The proposed method selects the next node to be relocated by utilizing energy in an efficient manner. By doing this, packet dropping rate decreases.

V. RESULTS

Fig 2 shows deployment of nodes. Environments like forest, battle fields nodes are deployed randomly. Random deployment means setting positions of wireless sensor nodes randomly and independently in the target area. Random deployment of nodes causes coverage overlapping. Random deployment is a feasible and practical method to deploy nodes in hostile environment.
Fig 3 Failure detection

Fig 3 Node failure is detected. Failure of node is detected by beacon signals when the nodes do not send back acknowledgement. 1,11,5 indicates dead node. When the nodes are dead there is no other path for the data transfer to take place. Hence causes data loss.

Fig 4 Hole healing

Fig 4 illustrates Hole healing. To heal the hole, neighbouring nodes are moved. Nodes are moved in such a way that its own coverage and connectivity is not disturbed. The neighbor node 9 is moved to heal the failure. After the node is passed the data transfer will be resumed through 9.

Fig 5 Comparison of number of nodes moved

Fig 5 illustrates comparison of nodes moved in existing and proposed system. Number of nodes are plotted along the x-axis and count is plotted along y-axis. It is clearly shown that the number of nodes moved in proposed system to heal failure is less compared to the existing system. Hence the energy consumption will be low in the proposed system compared to the existing system.

Fig 7 Comparison of packet loss

Fig 7 shows packet loss comparison between existing and proposed system. Time is plotted along x-axis and packet size is plotted along Y-axis. Packet loss is caused because of node failure. By using HHA algorithm the failure is detected and healed quickly. Hence packet loss is minimized compared to the existing system.

V. CONCLUSION AND FUTURE WORK

Detection and healing failure is an important aspect in WSN. Hole detection and healing algorithm used increases network lifetime to make efficient network connectivity for data transmission. Failure is healed by moving neighbouring nodes from higher density area. It involves minimum relocation of nodes. So the energy consumption of the nodes is relatively low. The failure is detected and healed efficiently which reduces the packet loss.

In future work to reduce packet loss actor node is used temporarily in the place of failure. When the nodes fail the neighbouring nodes are moved to heal the failure. During the node relocation there may be packet loss until the network is formed. To reduce packet loss actor node is placed temporarily in the place of failed nodes. When the network is formed perfectly actor node will be removed and data transfer takes place between the nodes.

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ISSN (Print): 2319-2526, Volume 4, Issue 6, 2015

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