



Review Article

Literature Review on Hole Detection and Healing in Wireless Sensor Network

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Accepted 15 Nov 2014, Available online 25 Dec 2014, Vol.4, No.6 (Dec 2014)

Abstract

The emerging technology of wireless sensor network (WSN) is expected to provide a broad range of applications, such as battlefield surveillance, environmental monitoring, and smart spaces and so on. The coverage problem is a fundamental issue in WSN. There has been lot of work done in the field of Hole detection and healing in WSN. This paper aims to address the work of hole detection and healing in mobile WSNs by various Authors. A detailed literature review of networks boundary, hole identification and various issues related to each of them are also provided. The algorithms are categorized into proper categories for better understanding and have identified various issues in each category. By considering this issues. A modified hole detection and healing method is proposed, that could remove the drawbacks of existing algorithms. Proposed method, HEAL is a distributed and localized algorithm that operates in two distinct phases. First, is Distributed Hole Detection (DHD) proposed to identify the boundary nodes and discover holes. Second, is hole healing which uses a virtual forces based hole healing algorithm. Unlike existing algorithms, proposed algorithm uses QURD based node detection method and could be cost efficient as node selection depends upon the lowest residual energy node. Thus providing energy efficient and cost efficient Hole detection and Healing method.

Keywords: Wireless Sensor Network, Coverage Holes, Boundary Detection, Hole Healing.

1. Introduction

Wireless Sensor Network (WSN) is formed from the tiny sensors. Today Wireless sensor network is used in every field of applications like battle field, traffic control, in colleges, entry gates, etc. The wireless sensor network has reduced the installation cost. The sensor network can be installed in any region such as mountains, forests, battle fields etc. If the area is such that the person cannot approach the area then the sensor networks are installed through planes. A sensor network helps to detect the enemy in the battle field, fire in the forests, measurement of the water level of the dams and many more. In today's daily life the sensor networks are used in the electronic gates to detect the metals, in wash rooms-on water taps etc. In this paper different algorithms proposed by the different researchers for finding the hole and healing the hole in the network is reviewed (G. Wang, 2003).

An area where a group of sensor nodes stops working and does not take part in data sensing and communication is termed as a hole in the network. Holes are the barriers for communication. Holes have a huge impact on the performance of the network. Hole detection identifies damaged, attacked or inaccessible nodes. If there is a hole in the network then data will be routed along the hole boundary nodes again and again which will lead to premature exhaustion of energy present at these nodes.

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. This section gives introduction to WSN and coverage hole problem in WSN

1.1 Categories of Coverage Hole Detection Algorithm

Coverage Hole detection algorithms have been classified into different categories based on type of information used, Computational model and network dynamics which is described as below.

1.1.1 Based on Type of Information used: Type of information can be divided into three approaches topological, statistical and geometrical approach.

1) Geographical Approach

This approach assumes that exact location of sensor nodes is known beforehand. Each node knows its location either with the help of special location hardware such as or by using scanning devices, thereby increasing size and structure of sensor nodes. It is also known as location based approach.

2) Topological Approach

This approach uses only the available connectivity information of network to detect holes. This approach.

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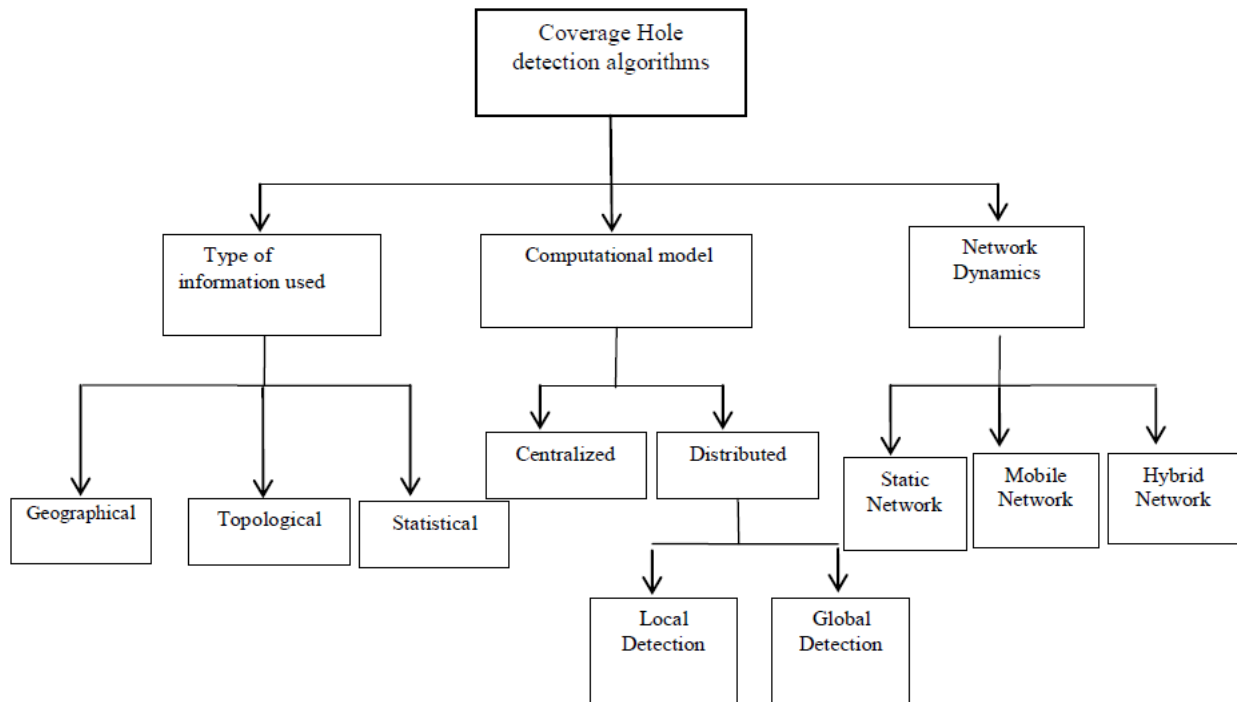


Fig.1 Categories of Coverage Hole Detection Algorithm in WSN

Requires no location information and works even for dense networks. There is no assumption about node distribution.

3) Statistical Approach

It is based on the assumption that distribution of nodes follows some statistical function. There is no need of GPS but it requires high node density i.e. average degree must be 100 or higher. In practice, such dense uniform deployment is not practical.

Based on Computational Model

1.2.2 Based on computational model used: coverage hole detection algorithms can be classified in two categories, viz. Centralized and Distributed.

1) Centralized algorithms

This algorithm runs on one or more nodes at centralized location.

2) Decentralized algorithms

Multiple nodes work together to efficiently detect hole in the network resulting in uniform division of workload. On the basis of nodes that invoke hole detection algorithm, we can further classify distributed algorithms in two categories, namely local detection and global detection. A hole occurs when several adjacent nodes in sensor network fail, and is defined as the convex hull of the region containing failed sensors.

1.2.3 Based on Network Dynamics: This can be further divided as static sensors, mobile sensors and hybrid sensors.

1) Static Sensors

Static sensor nodes cannot move around initial deployment. Once nodes are deployed they cannot move unless they are manually deployed again.

2) Mobile Sensors

Mobile sensor nodes can move around after initial deployment. The main objective in mobile WSN is to maximize coverage. Topology of sensor network is affected by mobile nodes as they form new connections and break old ones. If the coverage area of a node can be covered by its neighbouring node then only a node can move to another area.

3) Hybrid Sensors

Hybrid WSNs consist of both stationary and mobile nodes. Mobile nodes help in healing the coverage holes created by stationary nodes. The probability of the formation of hole in a high density network is less. This categorization is shown in Figure 1

2. Literature Survey

Wireless sensor networks have become a large area of research, with many universities and institutes contributing. There has been a large body of research on detection of coverage holes in WSNs over the last few years.

In this section, some of the typical hole detection algorithms of each category is analyzed and summarized. (J. Yang *et.al*, 2010) proposed a Hole Detection and Adaptive geographical Routing (HDAR) algorithm, which focuses on defining and detecting holes in ad hoc network, representing holes and building routes around the holes. It is based on the geographical approach. The contributions

of this paper are threefold. First, a heuristic algorithm is proposed to detect a hole quickly and easily. And the hole can be identified only by one time calculation. Second, a concise representation of the hole is proposed. A hole is recorded as a segment. Third, an approach to let a subset of the nodes located on the hole's boundary announce the hole information to the nodes in the vicinity was developed. The tradeoff between the cost of hole information announcement and the benefit for future routing was discussed. Simulations show that compared with GPSR, HDAR reduces the length of routing path by 12.4% and the number of forwarding hops by 13.2% for all the paths in tested areas. And the length of long detour paths around the hole can be reduced by 61.2%. The number of hops can be reduced by 64.6% compared with GPSR. The simulation also indicates that the overheads of HDAR are only 16.6% those of HAGR.

(F. Yan *et al*, 2011) used the concepts of Rips complex and Čech complex to discover coverage holes and classify coverage holes to be triangular and non-triangular. This is based on topological approach. A distributed algorithm with only connectivity information was proposed for non-triangular holes detection. Some hole boundary nodes are found first and some of them initiate the process to detect coverage holes. Simulation results show that the area percentage of triangular holes is always below 0.1% when the ratio between communication radius and sensing radius of a sensor is two. It was also shown that proposed algorithm can discover most non-triangular coverage holes.

(S. Fekete *et al*, 2004) proposed a boundary detection algorithm for sensors (uniformly) randomly deployed inside a geometric region. Proposed work is based on Statistical approach. The main idea is that nodes on the boundaries have much lower average degrees than nodes in the interior of the network. Statistical arguments yield an appropriate degree threshold to differentiate boundary nodes. They consider a crucial aspect of self-organization of a sensor network consisting of a large set of simple sensor nodes with no location hardware and only very limited communication range. After having been distributed randomly in a given two-dimensional region, the nodes are required to develop a sense for the environment, based on a limited amount of local communication. They describe algorithmic approaches for determining the structure of boundary nodes of the region, and the topology of the region. Methods for determining the outside boundary, the distance to the closest boundary for each point, the Voronoi diagram of the different boundaries, and the geometric thickness of the network were also developed.

(R. Ghrist *et al*, 2005) proposed an algorithm that detects holes via homology with no knowledge of sensor locations; however, the algorithm is centralized, with assumptions that both the sensing range and communication range are disks with radii carefully tuned. This algorithm is based on Centralised approach based on Computational model. It uses only available connectivity information to detect single level coverage holes. Time complexity is $O(n^5)$, with n being the no of

nodes. Approach gives no guarantee to detect hole boundary accurately. The methods presented are novel and of potentially great use in sensor networks. The use of topological methods allows one to dispense with assumptions about coordinates, distances, and orientations: this is a boon.

(P. Corke *et al*, 2007) proposed an energy efficient self healing mechanism for Wireless Sensor Networks. This mechanism is based on Distributed Computational Model. The proposed solution is based on our probabilistic sentinel scheme. To reduce energy consumption while maintaining good connectivity between sentinel nodes, solution was composed on two main concepts, node adaptation and link adaptation. The first algorithm uses node adaptation technique and permits to distributively schedule nodes activities and select a minimum subset of active nodes (sentry) to monitor the interest region. And secondly, a link control algorithm was introduced to ensure better connectivity between sentinel nodes while avoiding outliers appearance. Without increasing control messages overhead, performances evaluations show that solution is scalable with a steady energy consumption. Simulations carried out also show that the proposed mechanism ensures good connectivity between sentry nodes while considerably reducing the total energy spent. (Y. Wang, 2006), (M. Senouci, 2013) are also based on Distributed Computational model.

(Y. Wang *et al*, 2006) propose a simple, distributed algorithm that correctly detects nodes on the boundaries and connects them into meaningful boundary cycles. A byproduct was obtained on the medial axis of the sensor field, which has applications in creating virtual coordinates for routing. Simulation result show that the algorithm gives good results even for networks with low density. The correctness of the algorithm for continuous geometric domains was proved.

(M. Senouci *et al*, 2013) proposed a Hole detection and Healing (HEAL) algorithm. This allows a local healing where only the few nodes located at an appropriate distance from the hole will be involved in the healing process. The main contribution of this work is the design and evaluation of Holes. This can estimate and effectively overcome the coverage problem in mobile WSNs. This work makes the following specific contributions. First, a collaborative mechanism, called Hole Detection Algorithm (HDA) and Boundary Detection Algorithm (BDA) is proposed to identify the holes inscribed and boundary holes within the RoI. Second, they used a virtual forces-based Hole Healing Algorithm. This algorithm relocates only the adequate nodes within the shortest range. Experimental results for this approach provides a cost-effective and an accurate solution for hole healing in mobile WSNs.

(X. Li *et al*, 2008) proposed the 3MeSH (Triangle Mesh Self-Healing) algorithm. The algorithm utilises a simple connectivity model named the 3MeSH ring, employing computational geometry and graph theory to define both appropriate conditions for the existence of holes and also algorithms to detect and recover them. This method is based on Static approach of network dynamics. The algorithm can recover large holes produced by

accidental node failure, or topology changes in mobile ad-hoc networks. Recovery of trivial holes, having three edges, is also possible, but requires accurate information about the distances between nodes. Because the algorithm is distributed, no central control is required for hole detection and recovery, which promises faster response than a centralized algorithm. Figure 2 shows the Mesh ring structure. Furthermore, communication is limited to those nodes neighboring the hole boundary and flooding, with its associated high level of traffic, is not required. Unlike existing proposals, the algorithmic complexity does not depend on the overall size of the network

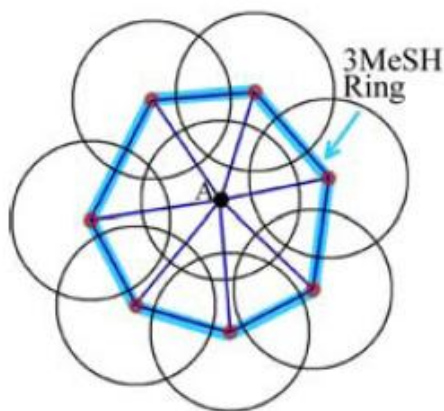


Fig.2 MeSH ring

(G. Wang et al, 2004) proposes a localized construction algorithm to construct a local Voronoi diagram sensor nodes, assuming that each node knows its own and its neighbors' coordinates Voronoi diagram: Each node constructs its own Voronoi cell by only considering its 1-hop neighbors.

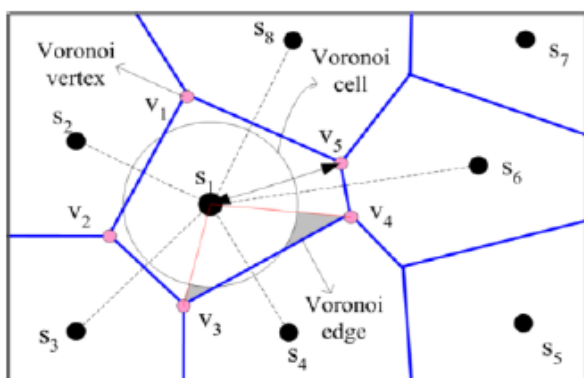


Fig.3 Voronoi diagram

After the local Voronoi diagram construction, the sensor field is divided into sub regions of Voronoi cells and each stationary node is within a Voronoi cell. A node is a Voronoi neighbor of another one if they share a Voronoi edge. This method is based on Mobile Sensors of network dynamics. Fig. 3 illustrates a Voronoi diagram in a bounded sensor field, where the boundaries of the sensor field also contribute to a Voronoi cell. According to the property of a Voronoi diagram, all the points within a

Voronoi cell are closest to only one node that lies within this cell. Therefore, if some points of a Voronoi cell are not covered by its generating node, these points will not be covered by any other sensor and contribute to coverage holes. If a sensor covers all of its Voronoi cell's vertices, then there are no uncovered points within its Voronoi cell; otherwise, uncovered points exist within its Voronoi cell.

(S. Babaie et al. 2012) proposed a triangular oriented diagram (HSTT) that detect of hole and calculate its size. Also for maximum coverage they determined the target localization for mobile sensor for healing of coverage hole. This method is based on Hybrid Sensors. All of them cause to along wireless network life time and optimization. To aim this goal they used circumcircle and incircle to. Compare with Voronoi this have some advantages such as simple for construction, lower calculation than Voronoi diagram for construction and can get exact area of hole no estimation of it.

(G. Wang et al, 2003) proposed a bidding protocol to assist the movement of mobile sensors. In the protocol, static sensors detect coverage holes locally by using Voronoi diagrams, and bid for mobile sensors based on the size of the detected hole. Mobile sensors choose coverage holes to heal based on the bid. If hole exist, it estimates its size and determine target position inside the hole. Static nodes then calculate the bid using formula $\pi * (d - \text{sensing-range})^2$, with d being the distance between target location and the node that wants to bid. Static sensors send bidding message to nearest mobile sensor whose base price is less than its bid. Each mobile node compares the received bids and chooses the message with highest bid and moves to the target location specified in message. This bid becomes new base price of mobile node.

3. Contribution

Work done by various Researchers in the field of coverage hole detection and healing is studied in Section 2 .Table I describes the characteristics of various proposed coverage hole detection and healing algorithm. A modified hole detection and healing method is proposed, that could remove the drawbacks of existing algorithms. Proposed method is a distributed and localized algorithm that operates in two distinct phases. First, is Distributed Hole Detection (DHD) proposed to identify the boundary nodes and discover holes. Second, is hole healing which uses a virtual forces based hole healing algorithm. Unlike existing algorithms, proposed algorithm uses QURD based node detection method and could be cost efficient as node selection depends upon the lowest residual energy node. QUAD Rule, ensure that each individual node is capable of communicating in 360^0 with respect to its communication range. The QUAD rule specifies that a node is not a stuck node if where there exists at least one 1-hop neighbour within the range of angle spanned by itself which is less than $\pi/4$.The process of discovering a hole is first initiated by the identification of stuck nodes. Each node executes the QUAD rule to check whether the node itself is a stuck node or not. Thus providing energy efficient and cost efficient Hole detection and Healing method.

Table 1 Characteristics of various coverage hole detection algorithms

Author	Concept Used	Advantages	Disadvantages
S. Fekete et al, 2004	Average density and centrality density	Avoids GPS	Complex computations, Unrealistic assumption on sensor distribution and density
G. Wang et al, 2004	Using computational geometry	Extensible to large deployments because communication and movements are local	Poor performance on initial clustered deployment and lower communication range.
R. Ghrist et al, 2005	Using homology	Works in coordinate free sensor networks	Not scalable, Complex calculations
Y.Wang et al, 2006	Using shortest path tree	No UDG constraint, Works for random distribution	Need high node density, High communication overhead due to flooding, Can't detect multiple adjacent holes
P. Corke et al, 2007	Using convex hulls	Can discover holes based on normal message traffic	Local detection algorithm need initial state information , Global detection algorithm need location information
X. Li et al, 2008	Using homology and connectivity information	Scalable, large holes can be easily detected	Fails for trivial holes
J. Yang et al, 2010	Using TENT rule	Single node can detect hole efficiently	Need localized nodes
F. Yan et al, 2011	Rips and Cech Complex	Can detect non-triangular holes efficiently	Communication overhead
S. Babaie et al, 2012	Using triangular oriented structure	Exact hole area is identified	Need localized nodes
M.Senouci et al, 2013	Using TENT rule and virtual forces concept	Minimize resource consumption	Can't detect holes at the network boundaries, UDG constraint

Conclusions

In this paper, a broad survey of a vital problem in sensor networks that are the detection of holes and healing process in network is focused. Coverage holes are the most important to detect as they play a vital role in assuring good Quality of Service. Identification of various coverage hole detection algorithm is therefore important. The work done by various authors in a sensor network is described in details. A literature review of holes in WSN is provided. To remove the drawbacks of existing method, a modified hole detection and healing method is proposed, that could remove the drawbacks of existing algorithms. HEAL is a distributed and localized algorithm that operates in two distinct phases. First, is Distributed Hole Detection (DHD) proposed to identify the boundary nodes and discover holes. Second, is hole healing which uses a virtual forces based hole healing algorithm. Unlike existing algorithms, proposed algorithm uses QURD based node detection method and could be cost efficient as node selection depends upon the lowest residual energy node. Thus providing energy efficient and cost efficient Hole detection and Healing method.

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