A Study of Wireless Mobile Sensor Network Deployment

Mr. Mayur C. Akewar
Computer Science and Engineering Department
ShriRamdeobaba College of Engg.and Management
Nagpur, India

Dr. Nileshsingh V. Thakur
Computer Science and Engineering Department
ShriRamdeobaba College of Engg. and Management
Nagpur, India

Abstract— **Wireless mobile sensor network is the collection of autonomous and distributed sensor with additional capacity of mobility. Mobility of sensor nodes adds additional functionality to the wireless sensor network of self deployment and relocation of sensors. Sensors find their own position and placed themselves over the target area after initial sensor distribution. Different approaches have been proposed for the deployment of mobile sensor by considering different issues. Coverage and Connectivity is the main issue of deployment. Some additional issues have to be considered while deploying mobile sensors like sensor relocation, energy efficient movements of sensors, obstacle adaptability, lifetime of network, fault tolerance etc. This paper basically presents the study of different mobile sensor network deployment approaches with their features and drawbacks. The issues of mobile sensor network deployment are investigated in detail. It further discusses the distinct types of algorithms and different ways of deployment such as deterministic, random and incremental deployment along with the self deployment.**

Keywords-Mobility, Self Deployment, Pattern Based Approach, Computational Geometry, Virtual Force.

I. INTRODUCTION

Wireless Sensor Network (WSN) has emerged as an efficient technology for wide variety of applications such as home automation, military application, environmental monitoring, habitat monitoring etc. Use of mobile sensors adds more applications to above list. The wireless mobile sensor network is the collection of autonomous and distributed sensor with additional capacity of mobility that can sense or monitor physical or environmental conditions cooperatively. WSNs consist of a large number of small, inexpensive, disposable and distributed autonomous sensor nodes that are generally deployed in vast geographical areas. Sensor nodes are severely constrained in terms of storage, resources, computational capabilities, communication bandwidth and power supply. WSN face many challenges due to these many constraints such as lifespan of network, efficiency and the performance of network. An efficient deployment technique handles can these challenges. Deployment of the sensors over the target field to form the wireless network is an important criterion to be considered in most of the applications. It is a critical issue because it affects cost and detection capability of wireless sensor network.

Sensors can be mobile or static. Mobility includes different functionality in wireless sensor network like coverage optimization, better lifetime of network, better use of resources and relocation [4]. Sensor nodes may change their location after initial deployment. Mobility may apply to all nodes or only to subsets of nodes. Taxonomy of mobility is given in [39]. Mobility may be active or passive. In active mobility the sensors are intelligent enough to find their path and move while in passive sensors they may be moved by human or environmental assistance. Another type of mobility is defined in [34], they are U- mobility and C- mobility called as double mobility. C- mobility is controllable while U-mobility is uncontrollable. C- mobility is the property of sensor node and U- mobility is affected by environmental condition like wind. Mobility is essential for self deployment [4], [5], [6], [8], [12], [13],[15], that is to find the position and move to deploy themselves. Two mobile sensor platforms Racemote [9] and Robomote [28] are used for mobile sensor network deployment.

In this paper, following deployment problem has considered: ***Given a target area and number of sensor node, how the given approach should self deploy the sensor into a connected ad-hoc network that has the maximum coverage.*** Different approaches have been proposed for the deployment of mobile sensor in context of different issues. Some proposed approaches used different types of deployment patterns like polygon [1], tillings [7], grid [18], [30], triangle [20] and diamond [21] for achieving both coverage and connectivity. Coverage and Connectivity is the main issue of deployment. Some additional issues have to be considered while deploying mobile sensors like sensor relocation [5], [30], energy efficient movements of sensors, obstacle adaptability [6], lifetime of network [1], [16], fault tolerance [17], [30], [33] etc. Some approaches used virtual force [6], [12], [29], [40] based approach where the sensors are modeled as points subjected to attractive or repulsive force according to the distance between two sensors. Computational Geometry based approach is also proposed which is widely used in the problem of sensor deployment over the target area. Voronoi Diagram [5], [13], [19] and Delaunay Triangulation [12], [13] are the basic data structure in Computational Geometry which are used to modeled the deployment of sensors. Fluid [46] dynamics and network dynamics [25] properties are also used to model the sensor deployment. Different way of deployment like incremental deployment [2], [23] and random deployment is used in some of the approaches. In

[11] comparative study of different deployment algorithms is given. [39] Gives the survey of multi objective deployment approaches. In this survey, more specific and comparative study of deployment approaches is investigated with additional feature of mobility. This paper basically presents the study of different mobile sensor network deployment approaches. Also, the issues of mobile sensor network deployment are investigated in detail. It further discusses the types of algorithm and different ways of deployment like deterministic, random and incremental deployment along with self deployment.

This paper is organized as follows: Section 2 gives brief introduction about the key issues of mobile sensor network deployment. Section 3 gives the ways of deployment and type of deployment algorithms. Section 4 gives the study of different approaches of deployment. Section 5 gives the tabular study and comparisons of related research work. The paper ends with conclusion and future work which is given in section 6.

II. Key Issues

A. Localization

For placing the sensors we should get the target position of the sensor. For finding the position different techniques are used. Some deployment work is done only on paper when the target area is simple and plane. But for complex area, map of the field is needed to get the position or location information. GPS enabled sensors are used for getting the position of the sensors when the position of sensors is needed at each point of time .In [35], [36], [37] various localization techniques with or without GPS are discussed. GPS inclusion is too expensive to enable in sensor node so different location information gathering scheme must be proposed. Different localization algorithms are discussed in [35]. Sensor can find position of other sensor by local communication [6]. Mobility would appear to make localization more difficult, so for getting neighborhood sensor node information node discovery [36] is needed. Three algorithms for getting neighborhood information are proposed in [37]. Self localization is proposed in [42].

B. Connectivity

Connectivity is important for maintaining network topology. Topology is dynamic in WSN due to the fact that sensor node can wake up joining the network, or go to sleep leaving WSN. The topology affects many network characteristics such as latency, robustness, and capacity. The complexity of data routing and processing also depends on the topology [3]. The sensor should connect with at least one sensor within its sensing range. It should connect with more than one sensor called as k-connectivity [6]. If there is always a network connection (possibly over multiple hops) between any two nodes, the network is said to be connected [3]. Connectivity is an open issue to be considered while deployment.

C. Coverage

Sensing range decides the coverage of sensor network. Network coverage [3] depends upon the sensing quality of the sensors. Coverage is the measure of quality of service of network. The problem of coverage is similar to Art Gallery Problem (AGP) in computational geometry [3], [4] discussed in [14]. An efficient deployment algorithm guarantees very less coverage holes. Coverage is defined as optimization problem in [4], [8], [1]. Coverage can be constrained, as discussed in [44]. Constrained coverage means the sensor should be connected with some k number of sensors called as K- coverage discussed in [12]. Coverage is an open issue to be handled in deployment of sensors. Dynamic coverage is discussed in [38].

D. Communication and Sensing Range

The communication (Rc) and sensing (Rs) range has to be decided which is depends upon the type of sensor. It is very important issue because it could affect the performance of the network. The Rc/Rs ratio has to be considered for deployment. If Rc>Rs then we have the problem of coverage and if Rs>Rc then we have the problem of connectivity, so both coverage and connectivity should be guaranteed. Rs/Rs ratio is considered in most of the pattern based approaches.

E. Energy

Sensors are autonomous device that is it 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 thousand of sensors, so it is essential to manage energy resources to increase the life of network. Most of the energy is used in communication purpose. Balancing energy consumption by optimal placement of sensors is important. If we consider mobile WSN, then mobility itself may consume most of energy available, so managing resources is very essential. [2], [17], [19], [32] and [33] handles the issue of energy efficiency and power consumption during and after deployment of sensors.

F. Node Density

Scalability is an important issue during deployment since it will affect coverage, cost and performance of network. Areas with high density increase network cost, computation overhead, whereas area with low density may has the problem of coverage holes or network partitions. Node distribution would be uniform or non-uniform [16], [32]. The sensor close to sink are more likely used in data transmission so the node density near sink must be more and in other area it would be less called as non uniform density node as discussed in [16] and [32]. Uniform node density decreases the chances of clustering and coverage holes. The number of nodes should be minimum and also able to achieve maximum coverage.

G. Obstacle Adaptability

In most of the applications the target field is not always a plane surface, so we should consider the obstacles [6] during deployment. Obstacle adaptability is very important issue in real time applications. [6], [13] and [10] discussed the issue of obstacle adaptability. Authors proposed different approaches where the sensor node change their path or take action when a obstacle come in their way. Spiral movement policy is discussed in [6] and [13] for obstacle avoidance.

H. Lifetime

Depending on the application, the required lifetime of a sensor network may range from some hours to several years. The necessary lifetime has a high impact on the required degree of energy efficiency and robustness of the nodes [3]. There are different ways of increasing network lifetime, like incremental deployment [2] that is to add new nodes after detecting failed nodes, sensor relocation, load balancing and balancing energy consumption by placing sensors in different densities which varies with the distance of sink. [2], [16], [32] discuss the issue of network lifetime.

I. Sensor Relocation

After detecting the coverage hole the redundant nodes are relocated to the hole region called as sensor relocation. There can be many reasons for sensor relocation like balancing energy consumption, balancing message overhead. [15], [30] proposed a novel approach where sensor relocation is used so as to control event. Wireless array based sensor relocation is proposed in [5].

J. Movement of Sensors

Mobility adds functionality like locomotion, relocation and coverage optimization property to network. Hence, mobility of sensor is important. For better use of resources managing movement of sensors is important since mobility itself requires power. So if one can manage the sensor movement, that is whether a sensor moves or not , so that proper energy allocation could be done and used in other functionalities like sensing and communication. The issue of sensor movement is discussed in [4], [5], [6], [19], [29] and [33]. Efficient management of mobility leading towards a better coverage remains an unanswered question or a open issue.

K. Fault Tolerence

Due to energy constraint sensor node lose their energy and fail, resulting in degradation of performance of the network. For this reason the WSN should be fault tolerance means though any node in the network fails the proposed approach would stabilize the network with no loss. Different techniques are used for fault tolerance like new node deployment, load balancing, sensor relocation and incremental deployment. Mobility of sensor is highly used for handling the issue of fault tolerance. The issue of fault tolerance is discussed in [17], [30], [33].

III. Deployment Algorithm And Performance Matrix

Different deployment algorithms are used for placing sensor over the target field. They are self deployment, deterministic deployment, random deployment and incremental deployment. Random deployments are typically used when the mission deployment area is physically inaccessible (e.g., volcanoes, seismic zones, etc.). On the other hand, deterministic deployments are more likely (and even preferable) used in missions when the deployment area is physically accessible [11]. Deterministic deployment is preplanned deployment where the position of the sensors is calculated before deployment and then the sensors are placed on their respective position. Random deployment does not always lead to effective coverage and also there is a problem of clustering. To overcome such problems mobile sensors would be used. To increase the lifetime of the network, new nodes can be deployed called as incremental deployment [2], [23]. The nodes are iteratively deployed depending on the application requirement in case of incremental deployment. Sensors are static or mobile. Mobility can significantly increase the capability of a sensor network by making it resilient to failures, react to events, and ability to support disparate missions with a common set of sensors [4]. Mobility ensures self deployment of the wireless sensor network. The actual type of deployment affects important properties such as the expected node density, node locations, regular patterns in node locations, and the expected degree of network dynamics [3]. Different deployment algorithms are discussed in [11].

Deployment algorithm can be Centralized [2], [4], [8], [10], [12], [13], [16], [17], [29], [32] or Distributed [4], [5], [6], [15], [19], [23], [25], [30], [33], [35-37], [41], [43], [42], [45]. Centralized algorithm runs on a single node in the system, it may be a sink node or cluster head node. The sink node controls the functioning of the nodes in the network by communicating them over a period of time. Distributed algorithm runs on each of the sensor node in the network, performing their task at their own. The sensor node sometimes called as intelligent node [19] means they take their own decisions. For more details see [3], [11].

Simulation of WSN is needed to evaluate the performance of the network. Different simulation tools are available like Network Simulator 2 (NS-2), OMNET, TOSSIM and MATLAB. The performance is evaluated on the basis of different performance matrix like number of nodes, coverage, energy efficiency, power consumption, Rc/Rs ratio, computation and execution time, mobility cost etc. More specific a certain target area is assumed like $100\times100m^2$ and the performance is evaluated by plotting a graph by assuming number of nodes and coverage as matrix.

IV. Study Of Existing Approaches

The deployment of sensors in the target field directly determines the performance and functioning of the network and further influence the coverage and efficiency of wireless sensor network. A good deployment approach will augment the degree of resource allocation in the network and enable a better performance on information gathering and communication. Different approaches are used for the deployment of sensors over the target field. The approaches are Computational Geometry based, Potential field based, Probabilistic approach, Computational Intelligence based and Bio inspired approachs. Existing approaches dealing with sensor deployment can be generally classified into two types: Physics-based and Geometric based [5]. In physics based approach the sensor nodes are assumed as points subject to attractive or repulsive forces like Newton's Law of forces while in Computational geometry based approach the sensor nodes are assumed as points on 2D or 3D plane. Other approaches use different algorithms which are discussed in this section.

A. Virtual Force Based Approach

In Virtual force based approach the sensor nodes are modeled as points subjected to attractive or repulsive force according to the distance between each two sensors. By setting a threshold of desired distances between sensors, each sensor moves in accordance with the summation of the force vectors and eventually a uniform deployment is achieved. Virtual force method helps move sensors from high density area to low density areas, thereby minimizing sensing overlap. This approach is useful in self deployment of sensor ensuring mobility of sensors. The forces are of type Newton's Law. The advantage of virtual force based method is discussed in [11].

Related Work:

Enhanced form of Virtual force method is proposed called as connectivity preserved virtual force method (CPVF) in [6]. The authors consider the obstacles during deployment. The given approach is used for mobile sensor network for the self deployment. The authors overcome the limitations of previous approaches where large communication range, dense network and obstacle free field or full knowledge of the field layout have been assumed. Virtual force method is used for sensor relocation proposed in [15]. Upon occurrence of physical phenomenon the nodes relocate themselves so as to control the event, while maintaining network connectivity. After the end of the event all the nodes return to the monitoring configuration. An algorithm to manage mobility using network dynamics is proposed in [25]. Each node periodically calculates the virtual force it receives from its neighbors based on the distance with all its neighbors. According to the resulting virtual force a node determines the movement speed and direction in the next interval. Different algorithms using virtual forces are proposed in [29]. In [44] two issues handled, coverage and connectivity. For coverage repulsive force is used and for connectivity attractive force is used. A potential field based approach is proposed in [4]. After initial deployment, group of mobile sensor "clusters" are formed using potential field method and then cluster heads are used to establish hexagonal structure or achieve coverage.

B. Movement Assisted Approach

Mobile sensor network has the capability of movement or locomotion. These movements can be used for placement of sensors and self deployment. Sensor moves in accordance with the direction. The issue of sensor movement is handled in this approach. Obstacle avoidance is the basic need of such type of approach. For further detail see [11].

Related Work:

A scan based movement assisted deployment method is proposed in [29]. By handling the issue of coverage an algorithm named SMART (Scan based movement assisted) is proposed. A unique problem called communication hole is handled here. The algorithm controls the moving distance. Coverage hole detection method is proposed in [40].

C. Computational Geometry Based

The primary goal of computational geometry is to develop efficient algorithm and data structure for solving problem stated in terms of basic geometrical objects: points, lines, segments, polygons, etc. The sensor nodes are assumed as points in 2D or 3D plane. The geometrical structures used are grid and polygons for modeling of sensors. The two common data structure used are Voronoi Diagram and Delaunay Triangulation. The Voronoi diagram has been reinvented, used, and studied in many domains. According to [47], it is believed that the Voronoi diagram is a fundamental construct defined by a discrete set of points. In 2D, the Voronoi diagram of a set of discrete sites (points) partitions the plane into a set of convex polygons such that all points inside a polygon are closest to only one site. This construction effectively produces polygons with edges that are equidistant from neighboring sites. Fig. 1 shows an example of a Voronoi diagram (VD) for a set of randomly placed sites. [47] Presents a detailed survey of Voronoi diagrams and their applications. The advantage of VD over other geometrical structure, like grid, is that its computational complexity is controlled by one parameter that is the number of sensor in the network. Another structure that is directly related to Voronoi diagrams is the Delaunay triangulation [12] [13]. The Delaunay triangulation can be obtained by connecting the sites in the Voronoi diagram whose polygons share a common edge. It has been shown that among all possible triangulations, the Delaunay triangulation maximizes the smallest angle in each triangle. In addition, a Delaunay triangulation must satisfy the empty circle property, which states that there is a circle containing the end points of a Delaunay edge and no other points (edges). Also, neighborhood information can be extracted from the Delaunay triangulation since sites that are close together are connected. In fact, the Delaunay triangulation can be used to find the two closest sites by considering the shortest edge in the triangulation. For more detail and figure see [11].

Related Work:

An efficient incremental deployment algorithm using Largest Empty Circle problem is proposed in [2].

Algorithm indicates position for new nodes to be deployed and number of new nodes. The algorithm is compared with random insertion algorithm. Array based sensor relocation algorithm is proposed in [5] using VD. A local detection diagram (LDD) is introduced as an important tool for local coverage hole detection. Self detection and sensor movement validation schemes are also proposed. Coverage optimization problem is discussed. [6] Used VD for their proposed algorithm. A coverage optimization algorithm based on particle swarm optimization (PSO) and VD is proposed in [8]. Delaunay triangle graph based algorithm (RDTG) is proposed in [12]. RDTG constructs a logical topology graph without intersection of edges, and tries to make node's neighbor equal to 6 by moving the node according the property of maximize the minimum angle of the triangles in DTG. A Delaunay triangle based method is proposed in [13] and [14]. The algorithm eliminates the coverage holes near the boundary of sensing area and obstacles. Delaunay triangle is applied for the uncovered regions.

D. Pattern Based Approach

Deployment patterns are used to model the deployment problem or placing of sensors. Different patterns are used like grid, triangle, diamond and hexagon for placing the sensors. These patterns are modeled as coverage optimization problem. Tilling and tessellations are also used for deployment modeling. Grid [18] is very often used for uniform distribution of sensors. The sensors can be deployed randomly or may follow certain architecture like grid. There are different grids designs defined in literature. Popular grid layouts are a unit square, an equilateral triangle, a hexagon, etc.

Related Work:

Different deployment patterns considering coverage and connectivity is proposed [1]. They considered different communication and sensing range ratios and studied the performance of the network with respect to these ratios. The authors compare the performance of different connectivity (k<=6). The optimal deployment patterns are discussed in [1] for 2, 3, 4, 5 and 6- connectivity. The study of optimal patterns gives rise to tremendous insights into network topology, which will provide guidelines for subsequent extensions thereof in non ideal, practical deployment scenarios. Triangular, rectangular and hexagonal patterns have studied. The patterns which they proposed are very efficient for connectivity. Three deployment strategies are discussed; uniform random, a square grid, and a pattern-based Tri-Hexagon Tiling (THT) node deployment. In uniform random deployment, each of the sensors has equal probability of being placed at any point inside a given field such that the nodes are scattered on the field. In grid based deployment, each node is placed on each of the grid points. The other strategy is based on tiling. A tiling is the covering of the entire plane with figures which neither overlap nor leave any gaps. Tilings are also sometimes called tesselations. Among different tilings author use a semi-regular tiling (which has exactly eight different tilings) where every vertex uses the same set of regular polygons. A regular polygon has the same side lengths and same interior angles [7]. The authors consider a semi-regular tiling that uses triangle and hexagon in the two dimensional plane, the so-called 3-6-3-6 Tri-Hexagon Tiling. The overall coverage pretty much depends on both the sensing ranges and the deployment scheme of the nodes. K-coverage is the usual way of specifying conditions on coverage. A network is said to have k-coverage if every point in it is covered by at least k sensors. Unreliable sensor grids are proposed in [18] by considering issue of coverage and connectivity. Different deployment models are investigated in [20] with their performance evaluation. A diamond pattern is proposed in [21] by considering optimal deployment. Various models of sensor network with the Boolean sensing model is proposed in [38].

E. Modeling of Deployment Problem

Related Work:

The deployment problem is modeled as electrostatic problem in [24] called as Packetostatics. Deployment of massively dense sensors is discussed with optimal distribution considering issue of network topology. Network dynamics is used for managing mobility in [25]. The dynamics of classical mechanics systems are described via underlying laws of motion and laws of force between objects. Cellular learning automata are used to model deployment problem proposed in [41]. The algorithm first clusters the network then the base station to help the deployment process by controlling the number of nodes in the cluster. The proposed mechanism is based on the irregular cellular learning automata. Learning automata residing in each cell in cooperation with the learning automata residing in its neighboring cells selects for the base station to repel or attracts its members. A fluid dynamics approach is proposed in [46]. Models sensor network as fluid body and each sensor node has fluid element.

F. Other Approaches

Related Work:

A robot deployment algorithm is proposed in [10] and [22]. A robot deployment algorithm that overcomes obstacle and employs full coverage with minimal number of sensor node is discussed in [10]. A mobile Robot is used for placing sensors. The robot explores the environment and deploys a stationary sensor to the target location from time to time. An algorithm for distributed search and rescue with robot ad sensor team is proposed in [22]. The question "Is mobility improves coverage of sensor network?" is discussed in [26]. An algorithm for reducing power consumption using node control method is proposed in [33]. Two algorithms named "moving distance based static topology" and "Shortest route with negotiation" are proposed for node failure detection. Non uniform sensor deployment in mobile sensor network is discussed in [16] and [32]. Balancing energy consumption by placing sensors in different densities which vary with the distance to the sink to increase network lifetime is proposed. Authors give the reason for non uniform distribution of sensors which are used in certain application. The sensor close to sink are more likely used in data transmission so they lose their energy and become passive resulting in coverage hole near sink so non uniform deployment is preferred over uniform distribution in other words more dense near sink and less dense in remaining area. A minimum power self deploymentscheme is proposed in [17] and incremental self-deployment algorithm is proposed in [23]. [31] Proposed a novel architecture for integrating sensor network into mobile pet game. Different localization algorithms are proposed in [35-37] and [42], [43]. A localized algorithm is proposed in [45]. It means that each sensor makes self-deployment decisions independently, using K-hop neighborhood information for constant k.

V. COMPARISON BETWEEN DIFFERENT EXISTING APPROACHES

Ref. No. Pub. Year	Paper Highlight	Algorithm Proposed/Used	Distributed/ Centralized	Main Issues Handled	Main Drawbacks
[2] 2002	Incremental Deployment	Largest Empty Circle	Centralized	Network Lifetime, Energy Consumption	Obstacle Adaptability
[4] 2007	Potential Field Approach	Clustering & Merging	Distributed & Centralized	Coverage, Sensor Movement	Obstacle Adaptability, Connectivity
[5] 2009	Sensor Relocation	Local Detection Diagram(LDD)	Distributed	Coverage, Sensor Movement	Obstacle Adaptability, Connectivity
[6] 2009	Virtual Force	Floor based Scheme	Distributed	Coverage, Sensor Movement, Connectivity	Computational Overhead
[8] 2009	Coverage Optimization	Partical Swarm Opimization(PSO)	Centralized	Coverage	Obstacle Adaptability, Connectivity
[10] 2009	Robot Deployment	Node Placement, Spiral Placement	Centralized	Coverage, Obstacle Adaptability,	Connectivity
[12] 2010	Virtual Force, Graph Theory	Delanuay triangle graph (RDTG)	Centralized	Connectivity, Coverage	Obstacle Adaptability
[13] 2012	Grid based Delanuay Triangulation	DT Score	Centralized	Coverage, Obstacle Adaptability,	n/w lifetime
[15] 2007	Relocation, Virtual Force	------	Distributed	Coverage, Connectivity	NA
[16] 2008	Non Uniform Sensor Deployment	Movement assisted sensor positioning(MSP)	Centralized	n/w Lifetime	Connectivity and coverage
[17] 2009	Optimization Problem	-	Centralized	Power Consumption, Fault Tolerance	Coverage and connectivity
[19] 2005	Intelligent Mobile Sensor	Voronoi Diagram	Distributed	Energy Efficiency, Sensor Movement	Obstacle adaptability
[23] 2002	Incremental Deployment	-	Distributed	Coverage	NA
[24] 2005	Electrostatic Problem	-	NA	Connectivity	NA
[25] 2008	Mobility for Improving Coverage	-	Distributed	Coverage	NA
[26] 2005	Mobility for Improving Coverage	-		Coverage,	NA
[29] 2007	Virtual Force	Hangerian, SMART, Extended SMART	Centralized	Coverage, Sensor Movement	Obstacle adaptability
[30] 2005	Sensor Relocation	Grid Quorum	Distributed	Fault Tolerance	
[32] 2008	Non Uniform Sensor Distribution	MAND	Centralized	Energy Efficiency	Coverage
[33] 2010	Node Failure Detection	MST, SRN	Distributed	Fault Tolerance, Power Consumption, Sensor Movement	coverage
[34] 2009	Double Mobility	Event Driven, Dominating Set Maintenance	Distributed	Coverage, n/w Lifetime	NA
[35] 2004	Localization without GPS enabled Sensor	MontoCorlo	Distributed	Localization	coverage
[36] 2007	Node Discovery	Machine Learning	Distributed	NA	coverage
[37]	GPS less Localization	-	Distributed	Coverage	NA

2008					
[40] 2004	Movement Assisted, Virtual Force	-	-	Coverage	Obstacle adaptability
[41] 2010	Cellular Learning Automata	-	Distributed	Coverage	Connectivity
[42] 2007	Landmark Node	-	-	Connectivity	coverage
[43] 2005	Dynamic Coverage	-	Distributed	Coverage	NA
[44] 2004	Constrained Coverage	-	Distributed	Coverage, Connectivity	NA
[45] 2011	Focused Coverage	GA, GRC	Distributed	Coverage	NA
[46] 2006	Fluid Dynamics	-	-	Coverage	NA

VI. CONCLUSION AND FUTURE WORK

In this survey fundamental problem of deployment in mobile sensor network is discussed. Following deployment problem has considered: Given a target area and number of sensor node, how the given approach should self-deploy the sensor into a connected ad-hoc network that has the maximum coverage. The issues of mobile sensor network deployment are investigated in detail. It further discusses the types of algorithm and different ways of deployment like deterministic, random and incremental deployment along with self deployment. Different approaches for mobile sensor network deployment are discussed in detail with their comparisons. The approaches are virtual force based, movement assisted, computational geometry and pattern based approach. Modeling of deployment problem with other real world problem is also discussed.

For future study, more real world problem formulation for deployment could be addressed. Again the soft computing approaches and bio inspired algorithm could be studied in future work.

REFERENCES

[1] Ziqiu Yun, XiaoleBai, Dong Xuan, Ten H. Lai, and WeijiaJia "Optimal Deployment Patterns for Full Coverage and k-Connectivity (k<=6) Wireless Sensor Networks" IEEE/ACM transactions on networking, vol. 18, no. 3, June 2010.

[2] Luiz Filipe M. Vieira, Marcos Augusto M. Vieira, LinnyerBeatrys Ruiz, Antonio A.F. Loureiro, Di´ogenesCec´_lio Silva, Ant.onioOt´avioFernandes "Efficient Incremental Sensor Network Deployment Algorithm" 2002.

[3] Kay Romer and FriedemannMattern "The design Space of Wireless Sensor Networks" IEEE Wireless Communications, Dec. 2004.

[4] Jaeyong Lee, AvinashDharne and SuhadaJayasuria "Potential Field Based Hierarchical Structure for Mobile Sensor Network Deployment" Proceedings of the 2007 American Control Conference, July 2007.

[5] W. Li, Y. I. Kamil and A. Manikas "Wireless Array Based Sensor Relocation in Mobile Sensor Networks" ACM 2009.

[6] Guang Tan, Stephen A. Jarvis, Member, and Anne-Marie Kermarrec "Connectivity-Guaranteed and Obstacle-Adaptive Deployment Schemes for Mobile Sensor Networks" IEEE transactions on mobile computing, vol. 8, no. 6, June 2009.

[7] Wint Yi Poe and Jens Schmitt "Node Deployment in Large Wireless Sensor Networks: Coverage, Energy Consumption, and Worst-Case Delay" ACM November 2009.

[8] Nor Azlina Bt. Ab Aziz ,Ammar W. Mohemmed and Mohammad Yusoff Alias "A Wireless Sensor Network Coverage Optimization Algorithm Based on Particle Swarm Optimization and Voronoi Diagram" Proceedings of the 2009 IEEE International Conference on Networking, Sensing and Control, Okayama, Japan, March 26-29, 2009.

[9] G. Song, W. Zhuang, Z. Wei, and A. Song, "Racemote: A Mobile Node for Wireless Sensor Networks," in Proc. 5th IEEE Conference on Sensors, IEEE, 2006.

[10] Chih-Yung Chang, Jang-Ping Sheu, Yu-Chieh Chen, and Sheng-Wen Chang " An Obstacle-Free and Power-Efficient Deployment Algorithm for Wireless Sensor Networks" IEEE transactions on systems, man, and cybernetics—part a: systems and humans, vol. 39, no. 4, july 2009.

[11] Jiming Chen, EntongShen and YouxianSun "The deployment algorithm in Wireless Sensor Network: A Survey" Information Technology Journal 2009.

[12] Jun Li, Baihai Zhang and Lingguo Cui "A Restricted Delaunay Tringulation Graph Based Algorithm for Self-Deployment in Mobile Sensor Networks" Journal of Computational Information Systems 2010.

[13] Chun-Hsien Wu, Kuo-Chuan Lee, and Yeh-Ching Chung "A Delaunay Triangulation Based Method for Wireless Sensor Network Deployment".

[14] SeapahnMegerian, FarinazKoushanfar, MiodragPotkonjak, and Mani B. Srivastava "Worst and Best-Case Coverage in Sensor Networks" IEEE transactions on mobile computing, vol. 3, no. 4, october-december 2004.

[15] Garetto M, Gribaudo M, Chiasserini CF, Leonardi E (2007) A distributed sensor relocation scheme for environmental control. In: The ACM/IEEE Proc. of MASS

[16] Cardei M, Yang Y, Wu J (2008) Non-uniform sensor deployment in mobile wireless sensor networks. In: Proc. Of WoWMoM, pp 1–8

[17] W. Li and C. G. Cassandras, "A minimum-power wireless sensor network self-deployment scheme," in *Proc. Annu. IEEE WCNC*, New Orleans, LA, Mar. 2005, vol. 3, pp. 1897–1902.

[18] Shakkottai, S., Srikant, R., and Shroff, N. Unreliable Sensor Grids: Coverage, Connectivity and Diameter. In IEEE Twenty-Second Annual Joint Conference of the IEEE Computer and Communications Societies(INFOCOM 2003) (New York, NY, USA, Mar. 2003), vol. 2, ACM,pp. 1073–1083.

[19] Heo N, Varshney P (2005) Energy-efficient deployment of intelligent mobile sensor networks. IEEE Trans Syst Man Cybern 35:78–92.

[20] X. Bai, S. Kumar, D. Xuan, Z. Yun, and T. H. Lai, "Deploying wireless sensors to achieve both coverage and connectivity," in *Proc. ACMMobiHoc*, 2006, pp. 131–142.

[21] X. Bai, Z. Yun, D. Xuan, T.H. Lai, and W. Jia, "Deploying Four-Connectivity and Full-Coverage Wireless Sensor Networks," Proc. IEEE INFOCOM, 2008.

[22]G. Kantor, S. Singh, R. Peterson, D. Rus, A. Das, V. Kumar, G. Pereira, J. Spletzer, s"Distributed search and rescue with robot and sensor teams," in Proc. of the 4th Int'l Conf. on Field and ServiceRobotics, 2003.

[23] A Howard, M. Mataric, and G. Sukhatme, "An incremental self deployment algorithm for mobile sensor networks," *Autonomous Robots*, vol. 13, no. 2, pp. 113–126, 2002.

[24] S. Toumpis and L. Tassiulas, "Packetostatics: Deployment of massively dense sensor networks as an electrostatics problem," in *Proc. IEEE INFOCOM*, Miami, FL, Mar. 2005.

[25] Ma K, Zhang Y, TrappeW(2008) Managing the mobility of a mobile sensor network using network dynamics. IEEE Trans Parallel DistribSyst 19(1):106–120

[26] B. Liu, P. Brass, and O. Dousse, "Mobility Improves Coverage of Sensor Networks," Proc. ACM MobiHoc, 2005.

[27] J. M. Kahn, R. H. Katz, and K. S. J. Pister. Next century challenges: mobile networking for ¨smart dust¨ . In Proceedings of the 5th annual ACM/IEEE international conferenceon Mobile computing and networking, pages 271.278. ACM Press, 1999.

[28] Dantu, K., Rahimi, M., Shah, H., Babel, S., Dhariwal, A., and Sukhatme, G. Robomote: Enabling Mobility In Sensor Networks IEEE/ACM International Conference Information Processing in Sensor Networks, Apr. 2005.

[29] S. Yang, M. Li, and J. Wu, "Scan-based movement-assisted sensor deployment methods in wireless sensor networks," *IEEE Trans.OnParallel and Distributed Systems*, vol. 18, no. 8, pp. 1108–1121, 2007.

[30] G. L. Wang, G. H. Cao, T. LaPorta, and W. S. Zhang, "Sensor relocation in mobile sensor networks," in *Proc. 24rd Annu. Joint Conf. IEEEComput.Commun. Societies (INFOCOM)*, Miami, FL, Mar. 2005, pp. 2302–2312.

[31] Liang Liu, Huadong Ma, "Wireless Sensor Network Based Mobile Pet Game", *Netgames'06*, October 30–31, 2006, Singapore, ACM 1-59593-589-4.

[32] Cheng-Hung Liu, Kuo-FengSsu "A Moving Algorithm for Non-Uniform Deployment in Mobile Sensor Networks", The International conference on Mobile Technology, Application and System 2008, (Mobile Conference) 10-12 September, 2008, ACM.

[33] Takefumi Ogawa, Tatsuya Shinjo, Shinya kitajima, Takahiro Hara, Shojironishio "Node control methods to reduce power consumption using push-based broadcast for mobile sensor networks", journal of mobile multimedia, vol. 6, no.2 (2010) 114-127.

[34] JiLuo, DanWang, Qian Zhang, "Poster Abstract: Double Mobility: Coverage of the Sea Surface with Mobile Sensor Networks",Mobile Computing and Communications Review, Volume 13, Number 1.

[35] Lingxuan Hu, David Evans "Localization for Mobile Sensor Networks", MobiCom'04, Sept. 26.–Oct. 1, 2004, Philadelphia, Pennsylvania, USA.2004 ACM 1-58113-868-7/04/0009.

[36] Vladimir Dyo, Cecilia Mascolo, "A Node Discovery Service for Partially Mobile Sensor Networks", 2007 ACM 978-1-59593-929-6/07/11.

[37] Chang Wu Yu, Chun-Hsin Wang, Li Chun Hsu, Kai Jen Cheng, "Coverage Algorithms in GPS-less Wireless Mobile Sensor Networks",

[38] PETER BRASS, "Bounds on Coverage and Target Detection Capabilities for Models of Networks of Mobile Sensors", ACM Transactions on Sensor Networks, Vol. 3, No. 2, Article 9, Publication date: June 2007.

[39] Michał Marks "A Survey of Multi-Objective Deployment in Wireless Sensor Networks", Journal of Information, 2010

[40] Wang G, Cao G, Porta TL (2006) Movement-assisted sensor deployment. IEEE Trans Mob Comput 6:640–652

[41] M. Kalantary, M. R. Meybodi, "Mobile Sensor Network Deployment Using Cellular Learning Automata Approach", 2010 International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT)

[42] FaridBenbadis, Katia Obraczka, Jorge Cort´es, AlexandreBrandwajn, "exploring landmark placement strategies for self-localization in wireless sensor networks", The 18th Annual ieee International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'07)

[43] A Sekhar, B. S. Manoj, and C. S. R. Murthy, "Dynamic coverage maintenance algorithms for sensor networks with limited mobility," in *Proc. 3rdIEEE Int. Conf. Pervasive Comput. Commun. (PerCom)*, Kauai Island, HI, Mar. 2005, pp. 51–60.

[44] Poduri S, Sukhatme GS (2004) Constrained coverage for mobile sensor networks. In: Proc. of IEEE ICRA

[45]Xu Li, Hannes Frey, Nicola Santoro, and Ivan Stojmenovic, "Strictly Localized Sensor Self Deployment for Optimal Focused Coverage", ieee transactions on mobile computing, vol. 10, no. 11, november 2011

[46] Muhammed R. Pac, Aydan M. Erkmen, IsmetErkmen "Scalable Self-Deployment of Mobile Sensor Networks:A Fluid Dynamics Approach", Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems, October 9 - 15, 2006, Beijing, China

[47] F. Aurenhammer, "Voronoi Diagrams—A Survey of a Fundamental Geometric Data Structure," ACM Computing Surveys 23, pp. 345-405, 1991.

AUTHORS PROFILE

Mr. Mayur C.Akewarreceived Bachelor of Engineering degree in Computer Technology from KarmvirDadasahebKannamwarCollege of Engineering, Nagpur, India in 2010. Presently he is pursuing his PG (M.Tech) in Computer Science and Engineering from ShriRamdeobaba College of Engineering & Management, Nagpur, India. His research interest includes Wireless Sensor Network.

Dr. Nileshsingh V. Thakur received Bachelor of Engineering degree in Computer Science Engineering from Government College of Engineering, Amravati, India and Master of Engineering degree from College of Engineering, Badnera under Amravati University and SantGadge Baba Amravati University in 1992 and 2005 respectively. He received Ph.D. degree in Computer Science Engineering under Department of computer Science Engineering from Visvesvaraya National Institute of Technology, Nagpur, India on 1st February, 2010. His research interest includes image processing, sensor network, computer vision, pattern recognition, artificial neural network and evolutionary approaches. He is having over 20 years of teaching and research experience. Presently, he is Associate Professor in Department of Computer Science and Engineering at ShriRamdeobaba College of Engineering and Management, Nagpur, India. He is the author or co-author of more than 40 scientific publications in International Journal, International Conferences and National Conferences. Dr. Thakur is a member of editorial board of over eight International journals; also, he is the life member of ISTE, India, IAENG and IAEME. He also worked as the reviewer for international journals and conferences.