# Nodes Deployment Strategies for Sensor Networks: An Investigation

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**Abstract -** *The progresses in modern technology have directed the improvement in sensors forming a wireless network/system, which over the years is used in many fields like military, industry, medical firm, buildings, etc. Generally, the deployment pattern of sensors in Sensor systems is random and uniform for different kinds of applications. Sometimes, this pattern leads to the ineffectual utilization of the network resources; e.g. a smaller quantity of sensors are distributed in remote areas while more number of sensors are located in some areas and some part of the zone is not under the observation of any sensor node. It is possible that some part of the network consumes extra power as compared to other part of the network area. Due to lack of node availability some part may not transfer the information. The proposed investigation is intended to review and compared the existing work with respect to the effective deployment of nodes in sensor systems. The deployment strategies have different effect on different requirements, like energy balanced utilization, life improvement, connectivity and the coverage. Here we analyzed the effectiveness of the existing deployment strategies over different critical issues of sensor systems*

***Key Words***: *Deployment strategies, Lifetime, coverage, connectivity, Sensor networks.*

## 1. INTRODUCTION

Revolution in MEMS-based sensor methodology and wireless communications have promoted the advancement of low-price, low-power, and multipurpose sensor nodes that are tiny in size with low communication range and processing ability.The tiny sensors can sense, save and process some phenomenon in the environment. Moreover, these sensors establishes an ad-hoc infrastructure in the network by communicating with each other through small control packets [1]. Owing to the features of power constraint and non rechargeable power provisions, the power resource of sensor systems should be carefully used as to enhance the lifetime of the system. There are various strategies to use energy efficiently like clustering [2], swarm intelligence [3], data aggregation [4], mobility [5], use of gateways [6], scheduling [7], existing Ad-Hoc protocols [8-9] and Node deployment strategies [10-11]. In this work, we have analyzed the effect of existing node deployment strategies on the lifetime, energy consumption pattern and the coverage of the sensor systems.

## 2. RELATED WORK

Zhang et al. have [12] presented the formal classification of node deployment strategies. They have prepared a performance index of the existing node deployment strategies on the basis of coverage, net connectivity and the lifetime. Poe et al. [13] have considered the node deployment in the large dimensional sensor systems. They have also analyzed the sensor system for worst case delay. They have used three basic node deployment models; uniform random, square grid and the Tri-Hexagon Tiling (THT). To analyze the affect of these models on the coverage, they have used k-coverage and coverage map performance metrics. To analyze the worst case delay, they have used basic and advanced calculus for sensor networks. They concluded that the THT deployment strategy outperforms other two strategies. The authors in [14] have established an optimized sensor system by comparing the network efficiency for circular and grid patterns with the random node deployment.

## 3. INVESTIGATION OF NODE DEPLOYMENT STRATEGIES

### 3.1 Types of Nodes deployment

#### 3.1.1 Static deployment:

Nodes are static after deployment and there is no change in their location. There are various static deployments based technologies are available as follows:

a) Uniform random deployment:
This is the widely used deployment strategy that is used in the sensory systems [15]. But this may lead to the problem of energy holes in the network [16]. Figure 1 shows the random distribution of 100 sensors (red color circles) in a 100 × 100 $m^2$ area. In this pattern, nodes' density is not uniform all over the field. As the sensors transmit data, their power reduce gradually, however, some nodes have more power consumption, which depends on the position of the sensors.

There are some issues in the random distribution of nodes. E.g., in a random distribution, some area may have higher density of nodes as compared to other parts, the part with lower density can remain uncovered. The second issue is related to routing that uses additional hops in dense areas, causing over utilization of the energy. Moreover, nodes in the shallow area have their next hop at very far distance. It also leads to the over utilization. The uniform pattern (Figure 2) solves the problems associated with the random distribution. There will be a balanced power depletion all over the zone and all the nodes will take equal part in the routing process.

b) Non-uniform node deployment:

The main drawback of the uniform strategy is the problem of energy holes [8]. Many non-uniform strategies have been projected in the literature [17-18] to solve this hole problem. In this strategy, more number of sensors are deployed near the center zone as compared to other zones of the area as shown in the Figure 3. Although, this strategy can't completely provide balanced power depletion, however, it mollifies the energy holes issue up to some extent.

The authors in [18] have used a circular sensor system that uses multi-hop routing. The number sensors have been increased from the outermost part of the circular zone to the inner most. Although this pattern is more power proficient than the uniform pattern but the cost of the system increases exponentially.

The authors in [19] have used the exponential distribution with the concept of the hybrid routing. In it, multi-hoping is not a constraint, a sensor can directly communicate with the sink instead of its immediate neighbor. Nodes' communication depends upon its residual power.

The authors in [17] had tried to alleviate the cost associated with non-uniform pattern by minimizing the inter and intra cluster power utilization. They have used unequal sized clusters according to the power requirement in the system.

c) Square Grid Based deployment:

Figure 4 shows the deployment of sensors at the center position of the square cell of the zone. Here sensors are positioned at the center of the cell, however, these can be positioned at the corner and edges of the square grids. All the sensors are at a uniform distance from each other. The existing research suggests that the square grid provides an optimized position to the nodes.

Any protocol, which uses the square grid pattern, first fix the location of nodes and the nodes work until complete energy exhaustion. An optimized position of the nodes leads to proper resource utilization, routing and enhanced lifetime.

In the square grid, quantity of of nodes does not affect the analysis process, a single cell is appropriate for the complete network coverage because it has symmetric cell structure.
A square grid pattern also practices sensing and communication ranges like a random pattern. But it is more sufficient than random pattern in terms of the coverage. If, in order to cover a complete area, a random pattern needs 10 nodes, only 3 nodes are enough for a square grid pattern. A square grid pattern can provide 2,3, 4- cell regions coverage.

d) Hexagon Cell Deployment:

Figure 5 shows the division of network field into Hexagon cells. The authors in [19] have divided the hexagon cell area into primary and secondary cells and places the sensors accordingly. This method provides good coverage and lifetime. Contrary to the square grid, the exact k-coverages by the single hexagon cells is not possible.

e) Circular Deployment:

Figure 6 shows the deployment of sensors in a circular pattern. This type of deployment of nodes mainly provides two objectives.
First one is, a vigilant node deployment can be a very optimized way to achieve the desired design objectives, and is classified as the static methodology.
The second one is the cost effectiveness and the reliability of the system.
The authors in [2] have used a circular deployment of nodes. The entire area has been divided into many circular regions. Every circle is further divided into another co-centric circle. The nodes are deployed in such a manner that, inner circle contains more number of nodes as compared to the outer circle. Initially, only the inner nodes are being used for the clustering and communication process, while the outer part nodes are used only when the enduring power of the inner nodes becomes less than the total power of the outer nodes. This method meets many design objectives.

### 3.1.2 Dynamic Node Deployment:

In this scheme, sensors keep on changing their position within the network. This kind of deployment may be supported by the support of a robot. As to make the sensor systems get the maximum enactment, sensors should be automatically transfer to the correct location, then begin to work.
The authors in [5] have used the mobility of the sinks to improve the lifetime of the network.

### 3.1.3 Hierarchical Deployment:

This is also known as clustering deployment. It is a logical deployment in which, some nodes select a cluster head and becomes members of the cluster. Here all the communication tasks are performed by the cluster heads of the system.

There is a lot of work has been done on the basis of hierarchical node deployment pattern [20]. Figure 7 shows the formation of clusters in a 100 × 100m² area.

### 3.1.4 Chain Based Model:

The authors in [21] have formed a static chain based model that uses chain leaders for the communication.

### 3.1.5 Gateway Based Deployment:

The authors in [6] have deployed multiple gateways to minimize energy holes and balanced energy consumption. They have divided the entire area into multiple regions and one gateway node has been installed between two regions. This gateway and all the other nodes are static.

There are two types of gateway model, one are those that uses the normal sensor nodes as the gateway/relay nodes, while others are those models that uses a special (equipped with extra resource) node as an gateway node.

## 3.2 Comparative Analysis of the effect of Deployment Strategies on the sensor systems

The main factors of the research on node deployment Strategies based algorithm are to escalate the coverage area, boost network connectivity, lengthen the network lifetime, make the load balance, increase the accurateness of the data transmission and fortify the tolerance of nodes. Evidently, It is not possible with the random node deployment to entirely achieve these performance goals.
Simultaneously, a high cost sensor system is undesirable and this issue should be solved. There should be a accurate node deployment strategy which can fulfill the all type of node deployment goals. Commonly, the optimization of the sensors deployment mainly comprises the following performance indicators.

(a) Coverage

In Sensor networks , the straightforward reason for maintaing the coverage is to deliver the high quality of information in the area of interest throughout the network operaion duration.

For most of the applications, a complete coverage is required while for some application a partial coverage is sufficient. This type of applications do not need constant monitoring.

To mollify the full coverage of a given zone of interest, every Point of it should be covered by at least one sensor.

Sometimes, the partial coverage can be supposed as the full coverage. E.g., humidity or pressure measurement in ecological monitoring appliances, where measurement at one place is acceptable for the entire region since it may have the similar measurements in its neighboring area.

However, the overall coverage is highly desirable feature of the sensor systems and it depends on various points like the sensing range, available resources, application and the deployment strategies of the nodes.

In order to provide the required coverage of a zone, we can not only depend on regulating the sensing range as it has its own restrictions owing to the costly power consumption and restricted node capabilities.
Therefore, node deployment strategy becomes a very important method to provide appropriate coverage.

(b) Energy Consumption

A balanced energy consumption is highly desirable in the sensor networks. Power consumption of a node depends on the following functions, sensing, transmitting and the receiving of some bits of information. However, the main reason of the power consumption is transmission. Therefore, the position of a node highly effects the power resource of a node. If a model uses the direct communication, nodes' power will exhaust soon, however, if a model uses the multi-hop communication, power depletes gradually.

The following equation summarized the energy consumption pattern of the famous First order radio energy model [3].

$$E_{tx}(k,d) = \begin{cases} k * E_{elec} + k * \varepsilon_{friss-amp} * d^2, d < d_0 \\ k * E_{elec} + k * \varepsilon_{two-ray-amp} * d^4, d \geq d_0 \end{cases} \quad (1)$$

Equation 1, describes the power disbursed in transmission by a node. Where $E_{elec}$, is the energy consumed in operating an electronic device.
Where, k is the size of a bit to be transferred.
Where, εfriss-amp and the εtwo-ray-amp are the energies consumed according to the distance and position of a node.

$$E_{rx}(k) = E_{elec} \times k \quad (2)$$

Equation 2, defines the power consumed in receiving of data. Nodes' positions and the type of energy models [9] highly effects the energy consumption behavior and the lifetime of the sensor network.

(c) Comparative Analysis of deployment patterns

It is shown in Table 1. According to the table, the square grid pattern outperforms other patterns in terms of the coverage. Uniform pattern has a good energy efficiency while non-unifrom pattern have a high lifetime.

**Table -1:** Comparative Analysis of deployment patterns

| **Deployment Strategies** | **Energy Efficiency** | **Coverage** | **Network Lifetime** | **Simulator** | **Basic Technique** | **Energy Hole** |
|---|---|---|---|---|---|---|
| Region Based [2] | High | High | High | NS-2 | Hierarchical and circular Based | Yes |
| DTP-ACO [3] | High | Very High | High | MATLAB | Hierarchical and Square Grid Based | No |
| Mobile Sink [5] | Very High | High | High | Java Application | Hexagon Cell | No |
| Gateway-Based [6] | Very High | High | High | MATLAB | Uniform | Yes |
| Non-Uniform Node Distribution [10] | High | Moderate | High | Custom | Non-uniform | Yes |
| Data-capacity [11] | Low | Weak | High | MATLAB | Non-uniform | No |
| Exponential [18] | Low | Weak | Low | Ns-2 | Non-Uniform and Circular | Yes |
| Lifetime Enhancing | Very High | Very High | High | MATLAB | Hexagon Cells | No |

(d) Figures Analysis

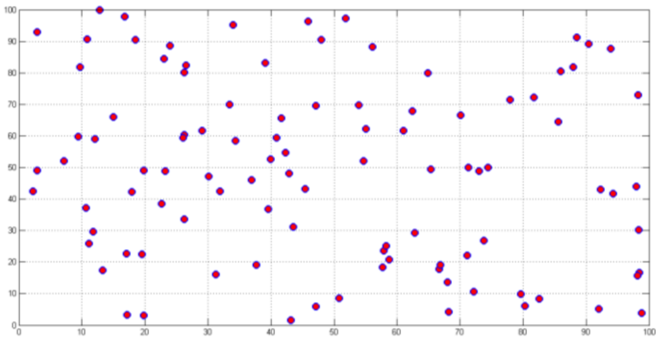

**Fig -1**: Matlab view of random distribution of sensor nodes

The Figure 1 is an illustration of the random deployment of nodes. Here, nodes are concentrated in some part of the area, as a result, complete coverage is not possible here, Over time, lifetime of this network will abrupt badly.

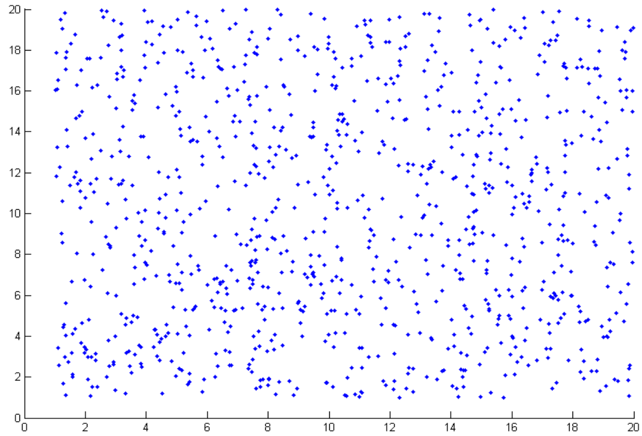

**Fig -2**: Matlab view of uniform distribution of sensors

The Figure 2, provides a complete coverage of the area, due to the uniform deployment pattern. The energy consumption here depends on the position of the sink. If it has a central sink that is located at the middle of the zone, nodes near the sink will suffer from the heavy load and energy holes will from in the system. At the end, a lot of energy will remain unused in the system.

The figure 3 shows the non-uniform pattern. Here the density of nodes is increased in that part of the area which carry a heavier load as compared to the other part of the area. Now tte additional number of nodes can bear the load of the network.

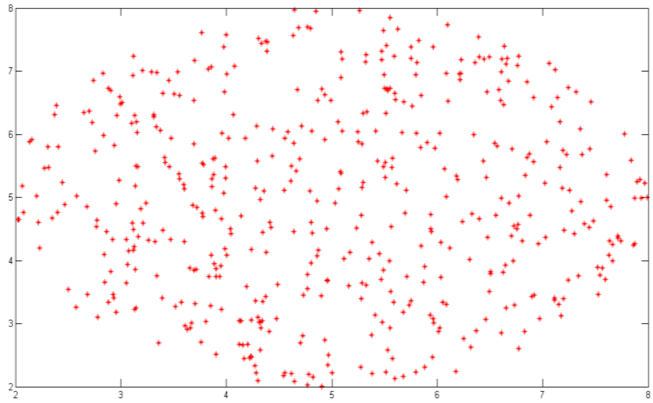

**Fig -3**: Matlab view of Non-uniform distribution of sensor nodes

The Figure 4, shows the square grid pattern, in which one cell is being covered by one sensor node. The authors in [22] have used this pattern along with mobile sensors.

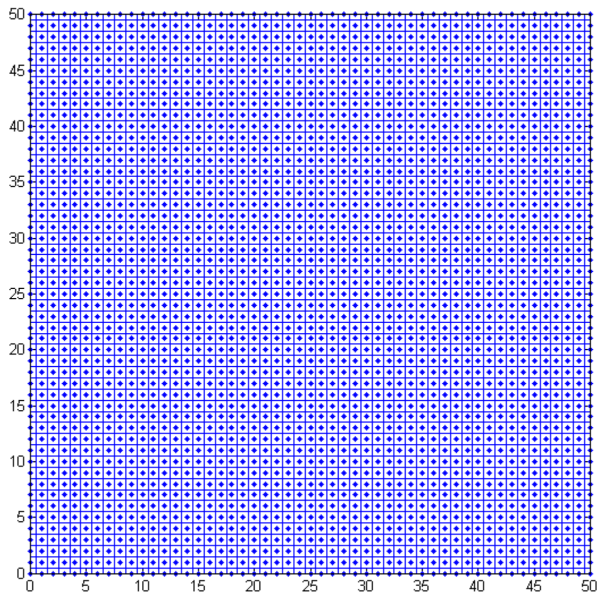


**Fig -4**: Square Grid Based Nodes deployment

The authors have employed a K- connected deployment strategy after the random distribution. They used square deployment arrangement for K=2 (minimum coverage) and K=4 (maximum coverage). The sensor nodes arrange a uniform pattern deployment with the help of mobility. Through the self deployment, nodes are deployed such that each grid cell of the square has exactly one sensor and each sensor should be connected with minimum two sensors. This method provides both coverage and high lifetime.

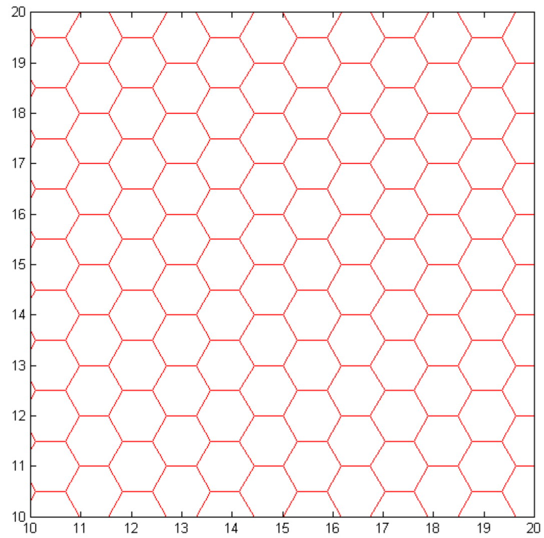


**Fig -5**: Division Of Area into Hexagonal Cells

The figure 5 shows the partitions of the area into a number of hexagon shaped cells. The sensors can be placed either at the center of the cell, corner of the cells or at the boundaries of the cells.

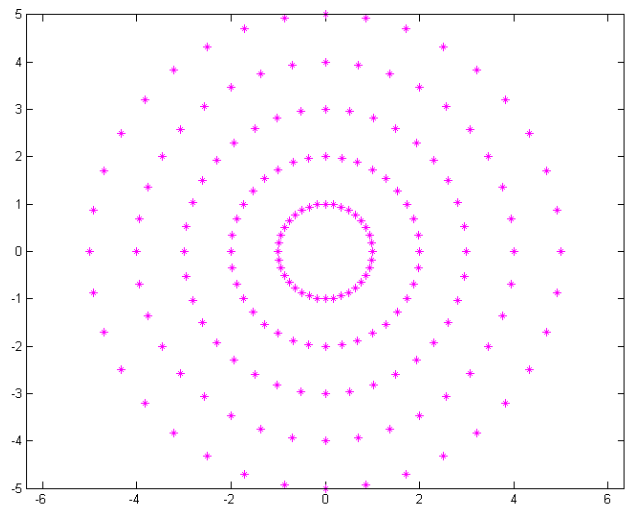


**Fig -6**: Circular Deployment pattern

The Figure 6 shows the circular pattern of the nodes. Nodes are placed at the edges of the co-centric circles at 5º apart. This pattern can be used as static as well as dynamic.
The figure 7 shows the hierarchical pattern of the nodes. It is a kind of logical deployment of nodes in the area. One node communicates with the sink on the behalf of its members.

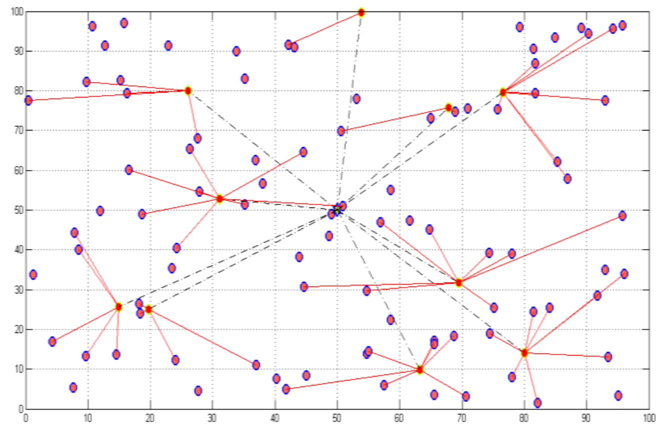


**Fig -7**: Hierarchical pattern

Figure 8a and 8b shows the change in the position of a sensor after the its movement along a path. This is called a dynamic deployment pattern of the nodes.

The movement of the nodes is beneficial in two types of performance indicator; coverage and balanced power consumption.

In order to cover the entire area, a uniform dissemination of sensors over the monitored field is very significant. With mobility, the sensor nodes have the supplementary capability of locomotion. It can move from high condensed area to low condensed area. Initially, nodes are deployed randomly, then the node finds its own location and deploys itself to the required location with the help of mobility and achieve uniform distribution.

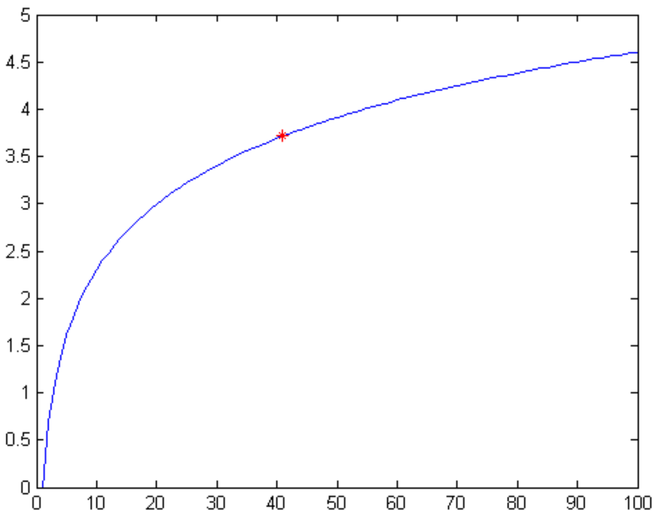


**Fig -8a**: Movement of a sensor

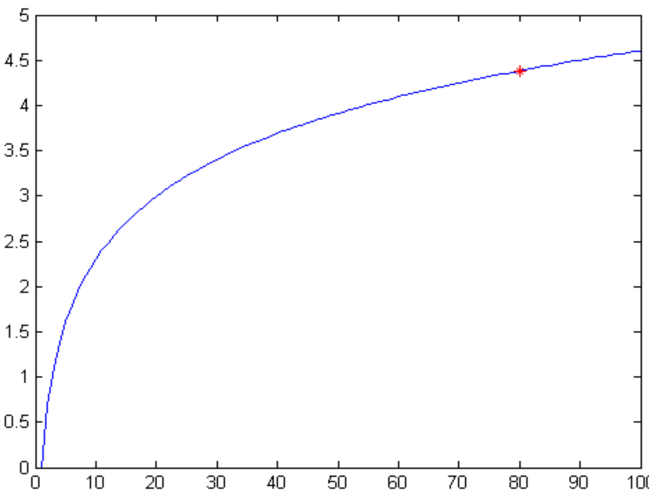


**Fig -8b**: Movement of a sensor to another position

Another main advantage of mobility is in energy consumption. If a sink finds low energy in a zone, it can switch to a zone of the higher energy[16].

## 4. CONCLUSIONS

In this article, the complete process of wireless sensor network systems about the deployment strategies has been investigated and analysed. We have presented various type of deployment models available in the literature. We have also compared the exisiting work on the basis of difference performance indicators. It has been analysed that uniform pattern covers the entire area but it sufferes from the energy holes problem. Non-uniform node distribution eliminated the holes problem up to some extent, but it proved very costly. However, the cost can be reduced by further optimizing the network resources. In the dynamic pattern we, need robot to assit the node movment. In future we will model a sensor system which meets design goals of the sensor systems in an effective way.

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