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Research Article

A Comprehensive Review of Different WSN Deployment Schemes

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ABSTRACT

To use wireless sensors, they are installed and configured anywhere data is needed and processes are being monitored. By looking closely at how wireless sensors are used, issues can be found, answers applied and the whole network can work smoothly. The potential to monitor and automate places remotely has made wireless sensor networks (WSNs) more popular. WSNs are developed to manage and transmit data securely for particular uses. Architecture, sensors, how the network is shaped, management of power and communication methods are all major issues. Managing power such as using duty cycling or having a sleep schedule, can both extend the network's usage time and help the battery last longer. Zigbee, Bluetooth and Wi-Fi should be considered as communication protocols. To support SNs across large open areas, researchers have produced models with classification, operation and comparative study in mind.

Keywords: wireless sensor network, nodes, deployment methods.

1. Introduction:

The overall architecture of a wireless sensor network (WSN) includes the use of communication protocols, base station or gateway configuration, and sensor node placement. Analyze the architecture to determine whether it facilitates efficient data handling and transmission for the intended use, as well as how the sensors were selected for deployment, taking into account factors like environmental resilience, battery life, range, and the required sensing abilities.Jing Deng and Wenliang Du (2004)[1].

The deployment's choice of network topology checks to determine if it has enough connectivity and coverage for data transmission, as well as whether the chosen sensors meet the particular requirements of the application and whether there are any flaws or places that might be improved. Think about where to put sensor nodes and gateways for optimal communication and data collecting.[24]. Make sure the settings ensure there is enough power for the way the network is used and that battery use can be maximized.

Discover if Zigbee, Bluetooth or Wi-Fi are suitable for your application by analyzing their performance, taking into account data routing, network congestion and packet loss rates, as explained in Zain Eldin, H. (2019) [15]. It is important to understand how sensor data collection works if the methods for processing and analysing the data inside a wireless sensor network are to be successful Keming Dong (2020)[7]. Understanding how sensor data is collected, processed and analysed helps us understand which techniques are effective for data processing and analysis in a wireless sensor network according to Dong. Assess how easy it would be to enlarge the wireless sensor network to fit changing circumstances and the addition of more sensors.

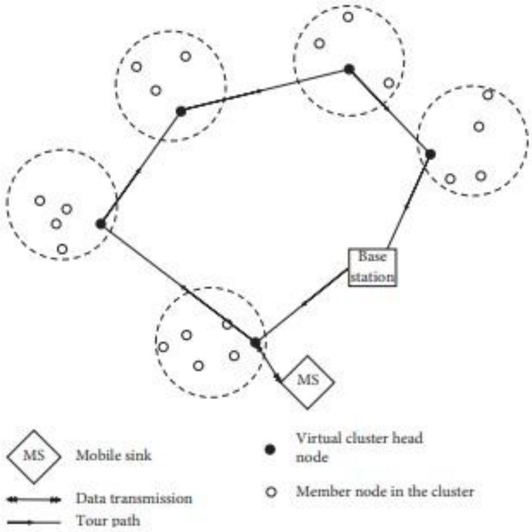

Fig:1 Wireless Sensor Network

His team studied whether it would be realistic and affordable to handle the problem through regular node updates or software fixes, Kumar Ajay, Sharma Vikrant (2013) [9]. The system is designed to prevent unauthorized users from accessing data within the wireless sensor network. This decision is reached with the help of access policy rules, authentication methods and encryption schemes identified by Agrawal D and Zeng QA in 2010. The sensors' ability to gather and deliver information raised concerns about privacy.

2. Classification of deployment Schemes

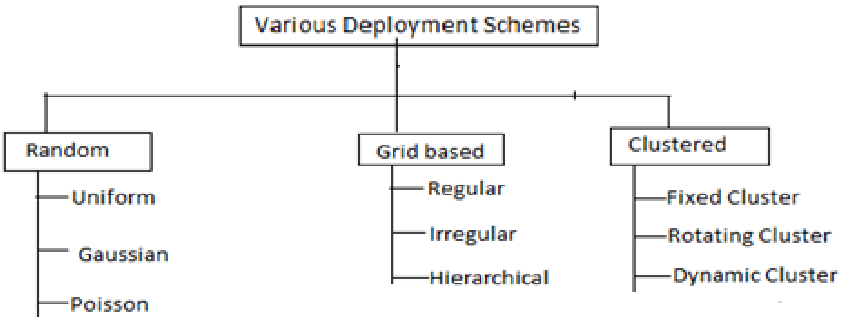

Fig 2: classification of various deployment schemes

3. Random Scheme:

Such deployment does not rely on a scheduled or determined system. Anonymous deployment scheme uses this way of deployment.

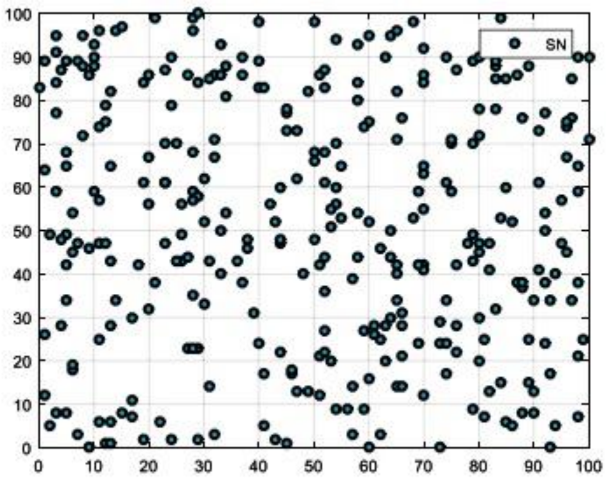

Fig 3: Random Deployment of sensor nodes

3.1 Uniform Random Scheme (URD): This scheme deploy the nodes in the targeted region using the uniform probability distribution. This form of probability equally assigns the possibility of node selection, but it often means that resources will be misused and some areas will not receive equal coverage, according to Ghosh Amitabha, Das Sajal K (2008) [27]. In the deployment area, the sensor nodes are put down randomly, with no organized or scheduled system for their placement. Sensor nodes in the URD approach are placed randomly in the target region, according to Wang Guiling, Cao Guohong, La Porta (2006). Both hand-setting the nodes and programmatic deployment are possible ways to complete the deployment. Getting to a suitable level of both connection and coverage is a major goal of setting up a WSN. Placing nodes randomly in URD can cause unpredictable ways in which they are connected and where they cover. Although some places have less WiFi access, other places may have more nodes, according to Kumar Ajay, Sharma Vikrant and Prasad D (2013) [28]. The level of sensor node density has a large impact on a network's performance and durability. The number of nodes in a URD network changes commonly, from well-organized to random. URD is simple to do and doesn't force users to know much about the place where they are deployed. When things need to be laid out quickly or when the area is too complicated for a precise layout, uniform telecommunication coverage would be the best solution. URD systems are not very energy efficient. Nodes that are spread out from one another allow far-away communication which in turn requires more energy. Still, we can minimize the problem by using duty cycling or sleep scheduling.

3.2 Gaussian Distribution: The nodes in this scheme are positioned according to the Gaussian Distribution algorithm. In this design, the amount of nodes increases where the signal is needed, moving towards the boundaries gradually as the area expands. The method of Gaussian deployment supports fair coverage in a targeted region and eliminates repeating nodes in specific regions. To place each node, we use Gaussian-distributed random coordinates. The Gaussian distribution helps each sensor be positioned nearly at the same location, often right where deployment occurs. Further from the center, there are fewer telecommunication nodes. As a result, the network should ensure even coverage and connectivity everywhere. The network provided by GRD gives good connectivity and coverage most of the time, according to Halder, S., & Ghosal, A. (2016)[3]. As the network density near the center remains high, there's no loss of service at that point, even though overall density is falling. GRD's node density is determined by the input parameters from the Gaussian distribution. GRD requires formulating random coordinates by using the Gaussian distribution. The correct way to generate random numbers and algorithms allows you to set your desired deployment pattern. It is possible to increase the GRD plan to a specific extent. When the network becomes larger, additional nodes should be positioned following the new central point's Gaussian distribution. But, keeping wireless coverage and reception from changing over a wide deployment area can be quite tough.

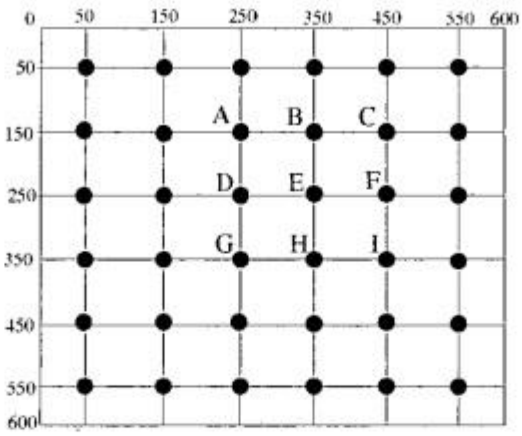

Fig :4 Diagram depicting Gaussian distribution, Gaussian Random Deployment

3.3 Poisson Random Deployment Scheme: also known as PRD, places the sensor nodes in a desired area by mirroring the average density of the nodes. Distributing nodes globally using the Poisson point process is a popular Poisson Random Deployment method in Wireless Sensor Networks, according to Almagrabi, A. O., Ali (2021)[4]. This diagram assumes each node is placed without relation to others and every region has a number of nodes that follows a Poisson distribution. Under a Poisson point process-based PRD, the location of sensor nodes is decided by chance in the deployment area. Each node's random coordinates can be generated, following the Poisson distribution. Nodes in this setting may be randomly and independently placed according to the Poisson distribution. In a deployment area, some regions may have more nodes than others since nodes are positioned according to the Poisson distribution. Nodes are typically given out evenly around the region, but you can increase or decrease their density by altering the Poisson process relied on. Using the specific ways data is delivered, advanced routing methods and data aggregation steps can enhance the efficiency of how data is collected and transmitted according to Pandey, K., & Gupta,

A. (2020)[5]. A PRD must plan for environmental factors such as objects in the way, differences in terrain and possible harm to the wave signal. They could affect how much the network can reach, how well it connects and how well it performs in general. Using a Poisson point process, PRD ensures that both monitoring and connectivity are distributed randomly but fairly among nodes in WSNs. Optimizing the network requires suitable local techniques and efficient routing algorithms and environmental circumstances are crucial for a smooth implementation.

Table 1: Comparative Study of various Random deployment schemes

Scheme	**Fault tolerance**	**Scalability**	**Energy Efficient**	**Load Balancing**
Uniform	No	Typical	No	Typical
Gaussian	Typical	To some extend	Better than uniform	Yes
Poisson	Typical	Inherently Scalable	Better than uniform	Yes

4. Grid Based Deployment Scheme:

Setting wireless sensor nodes up in a grid pattern for a specific area is considered a parametric deployment. Some forms are:

4.1Regular Grid Deployment: In this, the distribution of sensor nodes is in a routine pattern over the planned area. Sensor nodes are installed at each point where two grids meet. As a result, sensors are arranged in a uniform pattern and maintenance and monitoring of each sensor is simple. This solution works best for big areas. Sensors in wireless sensor networks (WSNs) are set up according to grid deployment to make their placement consistent and distributed. A grid of cells with similar sizes is constructed and in each cell, sensor nodes are inserted at chosen points. Deployment in evenly spaced grids in WSNs ensures that all regions of a network receive equal coverage. Because grid sensors go where the grid needs them, you can usually plan ahead and make designing and maintaining the network simpler. Nodes are easy to identify nearby using their position on the regular grid. By working with the repeated grid in the design, data routing is made less complicated. Yet, for locations where the form of the land varies or the climate is regularly changing, using a uniform grid may become problematic. In such settings, plans that consider the local features might be the best option.

4.2 Irregular Grid Deployment: The distance between nodes is not the same in this kind of deployment. Grid lines are spread out in different amounts between each node. It can help create a specific area that has the proper amount of population. It achieves a level of coverage and final utilization that is best for wireless sensors in extra busy spots. Instead of putting nodes uniformly on a grid, irregular grid deployment makes it possible to strategically distribute nodes to address all coverage needs inside the deployment environment. Focusing attention on parts of a network that are essential to security or need more protection can be achieved by including more nodes at those spots.

The use of an irregular grid makes it possible to design for local environments. Construction arrangements may be affected by any obstacles, geographical details or environmental characteristics. When the aim is to connect certain communities better or identify places where connectivity might be hazardous, positioning sensors in an uneven pattern across the network can make endless advancements on network infrastructures. Overall, irregular grid deployment offers flexibility and customization when it comes to positioning sensor nodes to optimize coverage, connection, and resource usage based on the particular requirements and characteristics of the deployment region.

4.3 Hierarchical Grid deployment Scheme: There are different levels, each showing information at various sizes. As an example, the highest level shows the whole region and the lowest level focuses on one specific region. As a result, a sensor can efficiently send information to neighboring nodes and proceed to acquire the data at the base station. To optimize network performance and resource usage, Mehta and Saxena (2020) [16] explain that it makes use of both a grid layout and a hierarchical design.

The grid deployment has areas sectioned into several layers, each one representing different rankings in a hierarchy. All sites are placed on the most important grid, with smaller grids separating areas inside each larger grid cell. The deployment area can be divided into several hierarchical levels to improve how resources are allocated and used, according to R. Velmani and B. Kaarthick (2015) [21]. Grids at the lowest level can crowd the nodes close together to gather data within a local area, while higher-level grids have fewer nodes and are designed for larger scale handling or managing things. The grid layout supports both effective data aggregation and routing. Several points within a network can gather, collect and transfer data, cutting down both network usage and the amount of energy consumed.

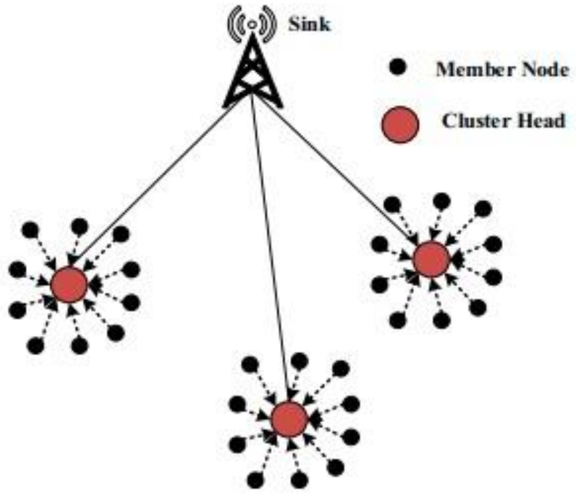

Fig 6: Diagram Depicting Hierarchical Grid Deployment Scheme

Table 2: Comparative Study of various Grid-based deployment schemes				
Scheme	**Coverage**	**Scalability**	**Energy Efficient**	**Connectivity**
Regular	Good	Low	Limited	High
Irregular	Tailored	Low	Limited	High
Hierarchical	Better	High	Typical	Typical

5. Cluster-based Deployment Schemes:

This scheme organizes the nodes in the form of clusters.

5.1 Fixed Cluster-Head Scheme: A cluster head (CH) is set up at a particular place and the remaining stations are ranked close to the head based on which station communicates the strongest with it. CH take the data from the rest nodes and transfer it to the base station. With this approach, the chosen cluster head sensors help reduce the energy needed for data transmission in wireless sensor networks. Strong organization within clusters of nodes ensures effective control over resources, Fang, K., Liu, C., & Teng, J. (2017) [18].

The whole deployment area is organized into clusters and the cluster heads in this scheme are set and cannot change position. Depending on the node's abilities, association with other nodes, durability or where it sits in the network, a cluster head could be chosen. After cluster heads are selected, they remain unchanged throughout the whole lifetime of the network. When the cluster heads are fixed, network control and management become more efficient. Within each cluster, the head nodes can guide synchronization, collect data, help pick routes and run algorithms which improves the network's efficiency and reliability. When the network situation is highly mobile, using a single cluster head deployment might not be practical. If something like adaptive or dynamic cluster head selection happens because of network conditions, failures or traffic shifts, different deployment methods will be necessary.

In general, the fixed cluster head deployment method is a clear approach that lets wireless sensor networks benefit from the organized roles of cluster heads for better network control, managing resources and clear communication.

5.2 Rotating Cluster-Head Scheme: Here, taking over as cluster head is rotated between the sensor nodes over a period. Every node that becomes a cluster head is made to consume energy carefully so that the energy is distributed equally among all the nodes. Each sensor node in a rotating cluster head approach acts as the cluster head at different times on the schedule. Changing the cluster heads regularly is intended to make duties and energy use more even between different parts of the network.
The rotating cluster head deployment method splits the deployment region into clusters and at beginning, a specific set of cluster heads is chosen. Cluster heads often, but not always, are chosen based on a node's ability, energy status or its level of connectivity. Nodes within the initial clusters are organized and directed by the cluster heads.WSN functionality is improved by rotating the role of cluster heads among the nodes. Going through regular cluster head rotation, it helps keep the energy, workload and network steady and longer lasting.

5.3 Dynamic Cluster Scheme: The method for forming clusters in this Scheme is set by a particular algorithm. With as a guide the community as a whole will become organized through communication strength, how much effort is given and closeness. Depending on the network's condition, clusters are able to deal with issues themselves and change according to needs, including the growth or breakup of clusters. The method of building wireless sensor network (WSN) clusters flexibly, depending on the network's situation or application requirements, is called a dynamic cluster creation scheme. Under dynamic cluster arrangements, clusters may form, shift or disappear as required to increase the network's performance.

As described by the dynamic cluster formation scheme, clusters can appear and disappear based on energy, communication range and the network topology. The strategy updates cluster structures because of the network's changing conditions to lower power usage, distribute load equitably and improve how messages are relayed in WSNs.

Table 3: Comparative Study of various Clustered deployment schemes

Scheme	Fault tolerance	Scalability	Energy Efficient	Load Balancing
Fixed Cluster	Limited	High	Limited	Yes
Rotating Cluster	Improved	High	Balanced	Yes
Dynamic Cluster	Enhanced	Dynamic	Better	Improved

6. Discussion:

To sum up, the new deployment strategies bring better risks tracking, flexible adjustment to changing conditions and more use of resources, Fan Chao [20]. Various requirements such as the individual setup, the environment, deployment site characteristics and things to be monitored, all influence which deployment scheme is chosen. For specific reasons, these deployment approaches can be used together or changed. Data accuracy, latency and response time are among the variables that can make a deployment of wireless sensor networks more reliable and effective,Di, C., Li, F., & Li, S. (2020) [13]. A network functions well if the required performance is met. When looking at how cost-effective wireless sensor deployment is, evaluate the money spent to install and maintain them, savings or benefits from their use and the positioning of the application nodes, according to Frank et al (2020) [23]. For example, WSNs are useful in areas like the environment, healthcare, factories, smart cities, agriculture and many other areas eliminated Singh, S. K., & Kumar, P. (2019) [14]. taken into account the effectiveness of WSNs in various applications by focusing on factors including how precise the data is, how quickly monitoring can happen and how informative the outcomes are.

7. Conclusion:

Trends in edge computing, data analysis, 5G and the Internet of Things (IoT) are being examined along with new challenges for WSNs. Their high speed and low latency make data transmission simple and keep communications costs down by enhancing their connectivity, according to Kandris D, Nakas C, Vomvas D and Koulouras G (2020) [22]. Nevertheless, proper deployment of many WSNs within 5G networks is difficult due to the need for compatibility with present technology and for increased energy consumption as data rates increase.

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