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"A Comparative Analysis of various deployment scheme in WSN"

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Abstract: The process of installing and configuring wireless sensors in diverse environments to gather data and monitor particular characteristics is known as wireless sensor deployment. Implementing wireless sensor networks requires evaluating their effectiveness, difficulties, and room for development. A thorough analysis of wireless sensor deployment can help pinpoint problem areas, provide solutions to problems, and improve the network's functionality for a certain application or environment. It entails evaluating the state, difficulties, developments, and possible advancements of Wireless Sensor Networks (WSNs). The performance, efficiency, and reliability of wireless sensor networks in a variety of application domains can be improved by doing a thorough analysis of WSNs, which will help to identify difficulties and explore potential improvements. Due to broad range of potential applications in a future of remote monitoring and automation, Wireless sensor Network (WSN) has drawn the attention of researchers in recent years. Since the performance and lifespan of any WSN are largely dependent on the effective positioning of Sensor Nodes, this is a significant area. Researchers have put up a number of models for the deployment of SNs across expansive open areas. The classification, operation, and comparative study of these models are the main goals of this paper.

Contents:

1. **Introduction:**Wireless sensor network's (WSN) general designcovers the positioning of sensor nodes, the configuration of base stations or gateways, and the communication protocols applied. Examine the architecture to see if it supports effective data handling and transmission for the desired application and how the sensors were chosen for

the deployment along with the elements like the necessary sensing skills, battery usage, range, and environmental robustness,Wenliang Du, Jing Deng (2004)[1].If the selected sensors satisfy the application's unique needs and if there are any shortcomings or areas that could be improved, the deployment's selection of a network topology check to see if it has sufficient connectivity and coverage for data transmission.To provide the best communication and data collection, consider where to position sensor nodes and gateways,Akyildiz IF (2002) [24]. Examine whether different topologies would be more useful in the given deployment scenario. The wireless sensor network's power management strategies analyze the power usage of the sensor nodes and any power-saving techniques used, such as duty cycling or sleep scheduling, Yick Jennifer, Mukherjee Biswanath (2008) [25]. Check to see whether the power management techniques are adequate for extending the network's lifespan and if battery life may be improved.the wireless sensor network's data transmission's effectiveness and dependability.Determine whether the communication protocols being utilised, such as Zigbee, Bluetooth, or Wi-Fi, are appropriate for the application's needs by taking into account elements like data routing algorithms, network congestion, packet loss rates, and these considerations, ZainEldin, H. (2019) [15].

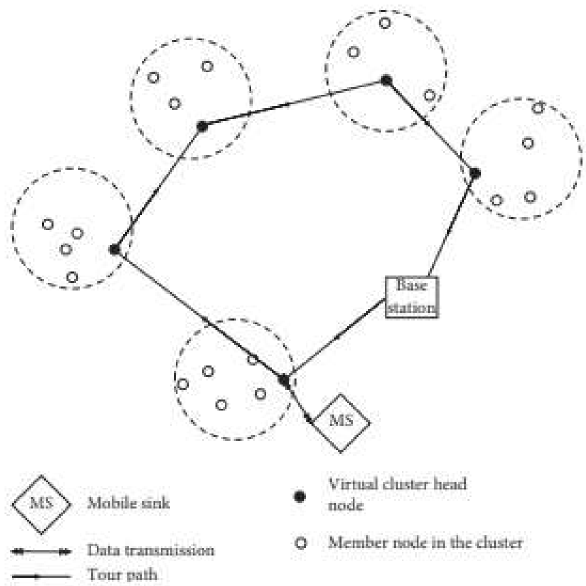

Fig:1 Wireless Sensor Network

By taking into account how sensor data is gathered, compiled, and analysed, the various techniques utilised for data processing and analysis inside the wireless sensor network may be understood, Keming Dong (2020)[7]. if the methods used to process the data are effective and give useful information for the intended purpose. Determine whether the wireless sensor network deployment can be easily expanded or updated to accommodate changes in the environment or more sensor nodes while taking scalability into account.It is decided whether maintenance measures, including node replacement or software updates, are realistic and cost-effective or not, Kumar Ajay, Sharma Vikrant (2013) [9]. The wireless sensor network's security mechanisms are in place to guard against unauthorized access or data breaches. To make this determination, access control policies, authentication methods, and encryption protocols are used, Agrawal D, Zeng QA (2010). The data that the sensors captured and communicated raised privacy issues.

2. Classification of deployment Schemes

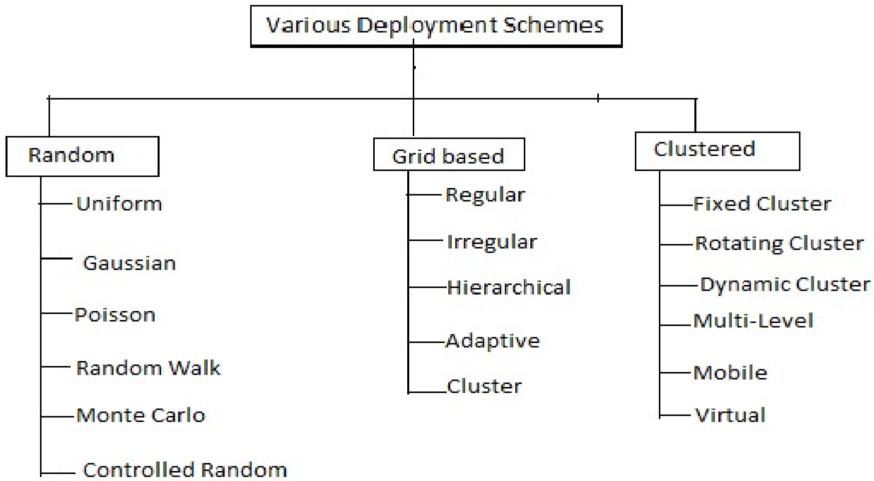

Fig 2: classification of various deployment schemes

3. Random Deployment Scheme: This kind of deployment is not followed the pre-defined path or pattern. Anonymous deployment scheme follows this kind of deployment technique.

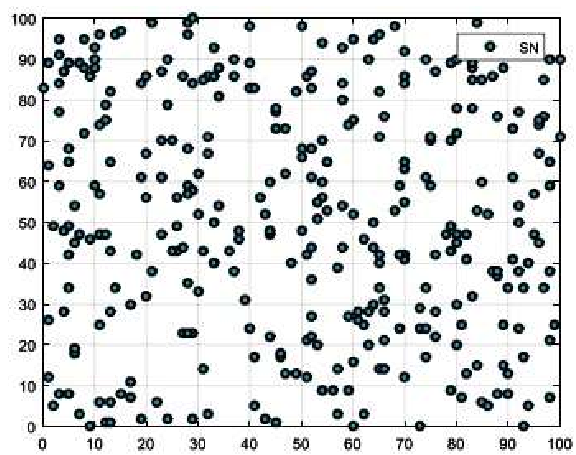

Fig 3: Random Deployment of sensor nodes

3.1Uniform Random Deployment Scheme(URD): By following the uniform probability distribution of nodes this method distributes the node in the targeted area. This kind of probability distribution gives equal chance of selection to each node but this approach will lead insufficient utilization of resources and non-uniform coverage, Ghosh Amitabha, Das Sajal K (2008) [27].The URD deployment method is a popular one in Wireless Sensor Networks (WSNs). The deployment area is filled with sensor nodes randomly dispersed throughout it, with no particular pattern or planned placement. The URD technique deploys sensor nodes in the target area at random, Wang Guiling, Cao Guohong, La Porta om (2006). Either manual placement of the nodes or automated deployment methods can be used to complete the deployment. Reaching a sufficient level of connectivity and coverage is one of the objectives of WSN deployment. Random node placement in URD might lead to unpredictable connectivity and coverage patterns. While some regions might have sparser coverage, others might have a higher density of nodes, Kumar Ajay, Sharma Vikrant, Prasad D (2013) [28]. Network performance and durability are greatly influenced by the density of sensor nodes.The node density in URD often varies based on chance from uniform to random. In addition to improving coverage, connectivity, and data dependability, higher node density also consumes more energy and could hasten battery depletion. URD can be put into practice quite easily and doesn't require in-depth planning or familiarity with the deployment region. It may be appropriate in situations requiring quick deployment or in which systematic placement is impossible due to the size and form of the region. URD does not provide ideal energy efficiency. Nodes may be positioned widely from one another, allowing long-range communication and needing more energy. However, this problem can be reduced by using energy-saving strategies like duty cycling or sleep scheduling.

A simple and efficient strategy for placing sensor nodes in WSNs is uniform random deployment. To ensure the effectiveness of the installed network, considerable thought should be given to the desired coverage, connection, energy efficiency, and scalability needs of the particular application, even though it offers simplicity and convenience of implementation.

3.2 Gaussian Random Deployment Scheme(GRD): In this scheme nodes are placed as per the Gaussian Distribution algorithm. In this kind of distribution nodes are deployed in higher density near the targeted area gradually nodes shift towards the border line. This tendency Gaussian deployment help to achieve balanced coverage of a targeted region and also remove the redundancy of node in a particular targeted area.Gaussian distribution in a process known as Gaussian Random Deployment (GRD)Demin Wang, Bin Xie (2008)[2]. By generating random coordinates for each node based on the Gaussian distribution, the placement can be accomplished. The Gaussian distribution makes sure that the sensor nodes are gathered in close reach to one another, often the deployment area's center. As the distance from the center point grows, the node density gradually decreases. With this distribution, the network should have balanced coverage and connection. GRD offers a network with relatively consistent connectivity and coverage, Halder, S., & Ghosal, A. (2016)[3]. While the steadily declining density enables a wider coverage area, the higher node density around the center point assures good coverage and connectivity there.Based on the Gaussian distribution's parameters, the node density in GRD can be changed. Higher node density can improve coverage and connection, but because of the more frequent communication and data transmission, they may also result in higher energy costs and shorter network lifetimes. The creation of random coordinates using the Gaussian distribution is necessary for GRD. Using the right random number generators and algorithms, the desired deployment pattern can be efficiently accomplished. The GRD plan can be scaled up to a point. As the network grows, extra nodes can be placed in accordance with a new central point's Gaussian distribution. However, it could be difficult to maintain consistent coverage and connectivity across a broad deployment area.Gaussian Random Deployment should take environmental considerations like obstructions, topography, and signal interference into account. These elements may have an impact on the deployed network's coverage, connectivity, and general performance.

By adhering to a Gaussian distribution, Gaussian Random Deployment provides a balanced coverage and connection pattern in WSNs. It allows for the adjustment of node density and can be used for applications that call for a more concentrated deployment around a core location while retaining coverage in the periphery. To optimize the network's performance, energy efficiency, scalability, localization, and environmental concerns must be carefully taken into account.

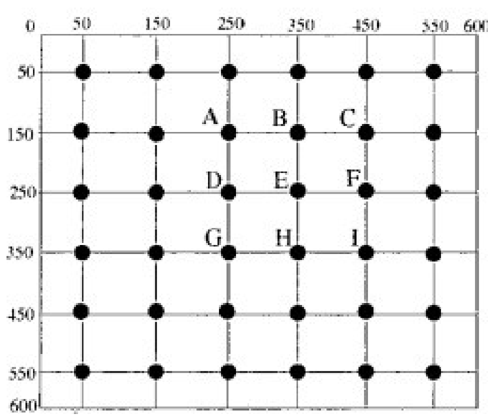

Fig :4 Diagram depicting Gaussian distribution, Gaussian Random Deployment

3.3 Poisson Random Deployment Scheme (PRD): By following the average density, the distribution of sensor nodes on the basis of area, size or position Poisson scheme deploys the nodes into a targeted area. In Wireless Sensor Networks (WSNs), Poisson Random Deployment is a widely used deployment method in which nodes are distributed at random using the Poisson point process, Almagrabi, A. O., Ali (2021)[4]. In this diagram, the positioning of nodes is independent of one another, and the number of nodes inside a given region follows a Poisson distribution. In a Poisson point process-based PRD, sensor nodes are distributed at random throughout the deployment area. To put the nodes, random coordinates based on the Poisson distribution can be generated for each node. The Poisson distribution permits the placement of nodes at random and independently. The density of nodes might vary throughout the deployment area since the number of nodes in a given area follows the Poisson distribution. By adjusting the Poisson distribution's parameters, one can change the node density in a PRD. The node density is normally constant across the deployment region, although it can be changed by adjusting the Poisson process's mean or intensity. Due to the independent and random deployment of nodes, PRDmay present difficulties in data collection and routing. When taking into account the unique deployment features, advanced routing protocols and data aggregation techniques can be used to optimize data collecting and routing efficiency, Pandey, K., & Gupta, A. (2020)[5]. PRDshould take environmental considerations like obstructions, topography, and signal interference into account. These elements may have an impact on the deployed network's coverage, connectivity, and general performance.By using a Poisson point process, PRDprovides a random yet balanced pattern of coverage and connectivity in WSNs. It allows for node density adjustment flexibility and is scalable for network growth. To optimize network performance, localization strategies and sophisticated routing protocols are however required, and environmental considerations must be made for successful implementation.

3.4 Random Walk Deployment Scheme: in this scheme the node drops at random location and it follows the random path by selecting randomly to reach at a certain destination. This process repeats in loop till the deployment of desired nodes. It is helpful in mobility of the node.A random walk deployment scheme is a strategy for positioning sensor nodes in wireless sensor networks (WSNs). Imagine you need to monitor and gather data across a region using a number of tiny sensors that need to be dispersed, Matsuzawa, T. (2006) [6].

A sensor node is first positioned at a random spot in the area using a random walk deployment scheme. Then you move a predetermined distance in a random direction of your choice. You set up yet another sensor node at this new site. This procedure is repeated several times, with each time a new sensor node is placed by randomly moving a specified distance and choosing a direction.This deployment strategy aims to establish a comparatively even distribution of sensor nodes over the region. You can cover a bigger area and prevent clustering or leaving gaps between the sensor nodes by moving at random and in various directions, Zhou, L., & Shan, Y. (2019)[8].

The wireless sensor network benefits from improved coverage and connection thanks to its random walk deployment strategy. It makes sure the sensors are distributed uniformly so they can successfully monitor and gather data from various areas of the region.

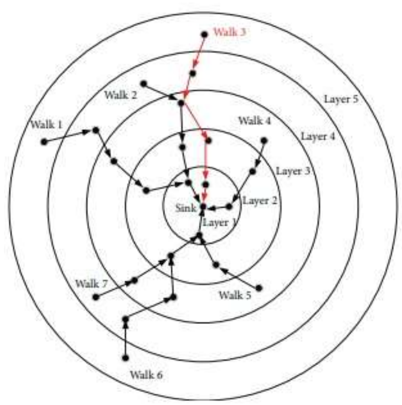

Fig:5 Diagram depicting Random walk Deployment Scheme

3.5 Monte Carlo Deployment Scheme: on the basis of random sampling Monte Carlo method generate the location for sensor nodes. It randomly selects the location on the basis of statistical sampling. It is the most flexible and adaptive approach that uses a randomization technique while achieving certain requirements. To randomly distribute sensor nodes across a space, wireless sensor networks (WSNs) use the Monte Carlo deployment strategy. The term "Monte Carlo" refers to a mathematical idea where issues are solved by creating random numbers. The Monte Carlo deployment scheme functions as follows in the context of WSNs: You begin by choosing a place or area where you wish to place the sensor nodes. A grid or a collection of points are used to partition the space. The sensor nodes are then placed at the randomly generated coordinates in the area.Based on the needs of the network and the region being covered, the number of sensor nodes and the density of their deployment can be managed.

The Monte Carlo deployment strategy makes sure that the sensor nodes are dispersed in a fair and surprising way by selecting the coordinates at random.

When you wish to achieve randomness and avoid any systematic patterns in the placement of sensor nodes, this deployment technique is quite helpful. When you wish to guarantee more consistent coverage or when the precise location of the nodes is not crucial, it can be useful.The Monte Carlo deployment technique is a flexible method that can be used in a variety of WSN applications, such as data collecting, surveillance, and environmental monitoring. It permits a varied and erratic deployment of sensor nodes, which improves coverage effectiveness and dependable network performance.

3.6 Controlled random deployment Scheme: In this kind of technique, sensor nodes are deployed randomly but in a controlled way or with a certain boundary. A method used in wireless sensor networks (WSNs) to strategically put sensor nodes throughout an area is known as a controlled random deployment strategy. It is also referred to as controlled random placement or controlled random distribution. Controlled random deployment, as opposed to totally random deployment, gives some level of control or guidance to the process to accomplish particular goals.The placement of sensor nodes is still based on chance in controlled random deployment, but it is governed by predetermined guidelines or restrictions. These guidelines may be created depending on the needs of the network, the goals of the deployment, or particulars of the area being covered. These boundaries depend on a geographical or environmental location of targeted region.

Random Deployment Methods are most suitable where the pattern of deployment is not necessary or it is able to change or determine the sensor node placement strategy. Based on the various factors like node density, coverage requirement and energy efficiency.

le 1: Comparative Study of various Random deployment schemes

eme	**lt tolerance**	**ability**	**rgy Efficient**	**d Balancing**
form	No	Typical	No	Typical
ssian	Typical	To some extend	Better than uniform	Yes
son	Typical	herently Scalabl	Better than uniform	Yes
dom Walk	Typical	Yes	Limited	Yes
ite Carlo	Rule based	Yes	Limited	Yes
trolled Random	Rule based	Yes	Rule based	Yes

4. Grid Based Deployment Scheme: When the deployment strategy of wireless sensor nodes involves the grid pattern to deploy the nodes in a particular area falls under this category. Some variations are:

4.1Regular Grid Deployment: Forming regular pattern of grid the sensor nodes are distributed uniformly across the targeted area. Sensor nodes are placed at the intersection line of grid. In this way it provides an evenly distributed spaced arrangement of sensor nodes and also provides easy maintenance and monitoring of a node. It is best suitable for large area deployment. Regular grid deployment is a technique used in wireless sensor networks (WSNs) to uniformly distribute sensor nodes across a deployment region in a grid-like way. It entails creating a grid of cells with similar sizes in the area and inserting sensor nodes at predefined places inside each cell. In WSNs, regular grid deployment offers a number of benefits, The deployment makes sure that sensor nodes are distributed fairly evenly and uniformly throughout the entire region by inserting sensor nodes at regular intervals within the grid cells. The placement of the sensor nodes may be simply estimated and known in advance because the grid determines the node positions, which makes network design and management easier. Since it is simple to identify neighboring nodes based on their grid placements, the regular grid structure makes it easier to identify neighbors. Data routing techniques can utilize the structured nature of the deployment with the regular grid pattern, making the routing process easier.However, in situations when the deployment region has irregular forms or fluctuating climatic conditions, regular grid deployment may have drawbacks. Other deployment plans that take into account the local features may be more appropriate in such circumstances.

4.2 Irregular Grid Deployment: In this kind of deployment the distance between nodes is not even. Grid lines are also unevenly distributed so varying in space between nodes. It also allows density adjustment within a targeted area. It also provides a balanced coverage and even utilization of resources in denser node placement in less critical area.A technique used in wireless sensor networks (WSNs) to distribute sensor nodes in a non-uniform or irregular fashion throughout a deployment region is known as irregular grid deployment. Contrary to regular grid deployment, which places nodes inside a structured grid at regular intervals, irregular grid deployment allows for more flexibility in node placement to meet particular needs or environmental conditions.The deployment can be adjusted to satisfy the various coverage needs of various places within the deployment area by deploying sensor nodes in an atypical pattern. By adding more nodes there, areas of greater interest or vital relevance can receive more attention. The deployment of an irregular grid enables customisation based on local conditions. To deploy nodes as efficiently as possible, it may consider impediments, geographical characteristics, or environmental factors. It is feasible to enhance network connectivity by concentrating on locations that need better communication linkages or areas with prospective connectivity issues by strategically putting sensor nodes in an asymmetric grid.

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: In this kind of scheme nodes are arranged in multiple levels so form a hierarchical like structure. Each level represents a different granularity. For example, top-most level represents the entire area whereas lowest level represents the sub-set of entire area that is specific region. This quality enables the efficient route of communicationwith neighboring node and transmit the data to the high-level node to base station.In wireless sensor networks (WSNs), a hierarchical grid deployment methodology is a technique used to arrange the sensor nodes in a grid-based deployment region. In order to maximize network performance and resource utilization, it combines the advantages of both grid-based deployment and hierarchical organization, Mehta, D., & Saxena, S. (2020) [16].

The deployment region is separated into several layers of grids, each of which represents a different hierarchical level, in a hierarchical grid deployment. The whole deployment area is covered by the highest-level grid, while following lower-level grids separate smaller geographic areas inside the larger grid cells.Scalability is made possible by the hierarchical structure, which efficiently divides the deployment area into smaller areas. It makes network administration easier and makes it possible to add or remove nodes without having an impact on the entire network. Resource allocation and utilization can be improved by splitting the deployment area into hierarchical levels, R. Velmani and B. Kaarthick (2015) [21]. Lower-level grids can arrange nodes more densely for localized data collecting while higher-level grids may have fewer nodes and focus on global monitoring or control. Effective data aggregation and routing are supported by the hierarchical grid layout. At several hierarchical levels, data can be gathered, compiled, and sent, which reduces network traffic and energy use.

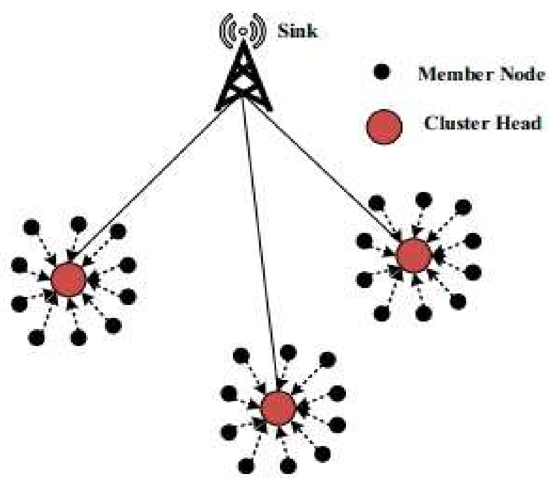

Fig 6: Diagram Depicting Hierarchical Grid Deployment Scheme

4.4 Adaptive Grid Deployment Scheme:In this kind of scheme grid pattern can change dynamically on the basis of requirement. In can be modified in real-time based factors like failure of node, data traffic or level of energy of each node.In wireless sensor networks (WSNs), an adaptive grid deployment scheme is a technique used to dynamically change the grid layout and node placement in response to shifting network conditions or application needs. Adaptive grid deployment enables for on-the-fly adjustments to optimize network performance and resource utilization, in contrast to fixed grid deployment methods where the grid cells and node positions are predetermined. The initial division of the deployment area is a grid structure with predetermined grid cells. Depending on the needs of the application, the grid cells can be all the same size or can have different sizes. The network constantly keeps an eye on a number of variables, including node density, energy usage, data traffic, and environmental conditions. To pinpoint areas that need adjusting or optimizing, this data is analyzed.The grid structure can be dynamically modified based on the analysis. Depending on the evolving needs or network conditions, this may entail resizing the grid cells, adding or removing grid cells, or relocating the grid cells. To provide the best coverage, connection, or energy efficiency, the sensor nodes can be moved to new grid cells when the grid layout changes. Either distributed algorithms or localized control can be used to relocate nodes.

All things considered, the adaptive grid deployment strategy enables WSNs to adjust to changing circumstances and enhance network performance. The grid structure and node location can be dynamically adjusted, resulting in effective resource utilization, energy savings, and increased coverage and connection.

4.5 Clustered Grid Deployment Scheme: In this scheme, sensor nodes form a group into cluster with a structure of grid. Each group of cluster contains a set of neighbor node in which one node acts like a cluster head and this node is responsible for inner communication between nodes. As it reduces the long-distance transmission it works on efficiency of nodes of energy as well. In wireless sensor networks (WSNs), a clustered grid deployment scheme is a technique used to group the sensor nodes inside a grid-based deployment area. In order to ensure effective coverage, communication, and resource utilization in WSNs, it combines the advantages of grid-based deployment and cluster-based organization, Chen, Y.-W. (2015)[17].

Similar to standard grid deployment, clustered grid deployment divides the deployment region into a grid structure. The grid cells are further arranged into clusters in this approach, though. Each cluster is made up of a group of adjacent grid cells, and each cluster normally has a cluster head or central node in charge of overseeing and coordinating the other nodes.Overall, WSNs may achieve effective coverage, communication, and resource utilization thanks to the clustered grid deployment scheme. It combines the advantages of cluster organization and grid-based deployment, offering a scalable framework for various wireless sensor network applications.

These schemes offered organized node deployment in thew targeted region the choice of this scheme depends on a requirement of area, coverage, network, data traffic and resources.

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
Adaptive	Dynamic	High	Yes	Low
Cluster	Improved	High	Yes	Low

5. **Cluster-based Deployment Schemes**: This scheme organizes the nodes in the form of clusters.

5.1 Fixed Cluster Head Deployment Scheme: In this scheme, cluster heads (CH) are fixed and the rest are assigned to the head on the basis of communication strength and proximity. CH are responsible for collecting data from the rest nodes and send it to the base station. It simplifies routing of data allow over all transmission energy-efficient.In wireless sensor networks (WSNs), the fixed cluster head deployment methodology is a technique for pre-designating particular sensor nodes as cluster heads. The administration and coordination of the nodes inside clusters is critical for effective resource management and communication, Fang, K., Liu, C., & Teng, J. (2017) [18].

The deployment area is separated into clusters and the cluster heads are fixed and preset in the fixed cluster head deployment scheme. Based on elements like node capabilities, connection, energy level, or network location, cluster heads may be chosen. As soon as the cluster heads are established, they are fixed for the duration of the network's operation.Fixed cluster heads make network control and management more effective. In their individual clusters, the cluster heads can help with synchronization, data aggregation, routing selections, and distributed algorithms, enhancing network performance and stability.In dynamic or mobile scenarios, the fixed cluster head deployment technique could have constraints. Different deployment strategies would be needed if there were to be any adaptive or dynamic selection of cluster heads due to changes in network conditions, node failures, or shifting traffic patterns.

Overall, the fixed cluster head deployment strategy offers a structured and effective method for building wireless sensor networks by utilizing the roles of designated cluster heads for improved network control, resource utilization, and communication.

5.2 Rotating Cluster Head Deployment Scheme: In this Scheme, the cluster head revolves around sensor nodes over the time. Turn wise each node acting as a cluster head and ensures equal distribution of energy consumption. Rotation is based on the Pre-determined Schedule which decides the turn and adjusted the nodes in case of failure.In a rotating cluster head deployment approach, the sensor nodes take turns acting as the cluster head over time in wireless sensor networks (WSNs). By frequently switching out the cluster heads, this plan intends to spread duties and energy use more evenly across the network.

The deployment region is separated into clusters in the rotating cluster head deployment method, and initially, a set of cluster heads is chosen. Cluster heads may be chosen based on elements like node capability, energy level, or connectivity. The nodes within each of these initial clusters are managed and coordinated by these cluster heads.WSN management is made dynamic and energy-efficient by the rotating cluster head deployment technique. It provides energy balance, load distribution, and fault tolerance by routinely rotating the cluster heads, increasing network performance and lifespan.

5.3 Dynamic Cluster Formation Scheme: In this Scheme, the formation of cluster is based on the specific algorithm. On the basis of communication strength, level of energy and proximity the nodes will organize itself. On the basis of network condition, the clusters can dynamically enable self-healing and adaptability and the formation of new cluster and merge or split of old clusters also occurs. A technique used in wireless sensor networks (WSNs) to construct clusters in a dynamic and adaptive way based on the network conditions or application needs is known as a dynamic cluster creation scheme. Dynamic cluster formation, in contrast to fixed cluster formation approaches, allows for the construction, modification, or dissolution of clusters as needed to improve network performance.

According to the dynamic cluster formation scheme, clusters can form and disband depending on a number of factors, including energy levels, communication range, and network topology. By adjusting the cluster structure to the shifting network conditions, the plan seeks to enhance energy efficiency, load balancing, and communication efficacy in WSNs.

5.4 Multi-Level Cluster Deployment Scheme: In this scheme thesensor nodes represent in multiple level form and in this way, they form a hierarchical structure. It introduces network Scalability as a new feature apart from other inherited features. A technique used in wireless sensor networks (WSNs) to group sensor nodes into various levels of clusters and establish a hierarchical structure is known as the multi-level cluster deployment scheme. By providing various degrees of cluster heads and cluster forms, this strategy seeks to enhance the scalability, energy efficiency, and communication efficiency of large-scale WSNs, Narayan, V., & Daniel, A. K. (2020) [19].

The network is divided into clusters at different levels using the multi-level cluster deployment strategy. often, the highest-level clusters are made up of a single root cluster, while lower-level clusters often contain a number of sub-clusters. Cluster heads at each level are in charge of overseeing and organizing the nodes in their respective clusters. Higher-level coordination and communication are offered by the cluster heads of the sub-clusters.The multi-level cluster deployment strategy offers a hierarchical structure that makes it possible to manage resources and aggregate data efficiently, especially in large-scale deployments. Depending on the chosen structure, it divides the deployment area into a number of tiers. With the base station at the top level, each level denotes a unique layer of clusters.

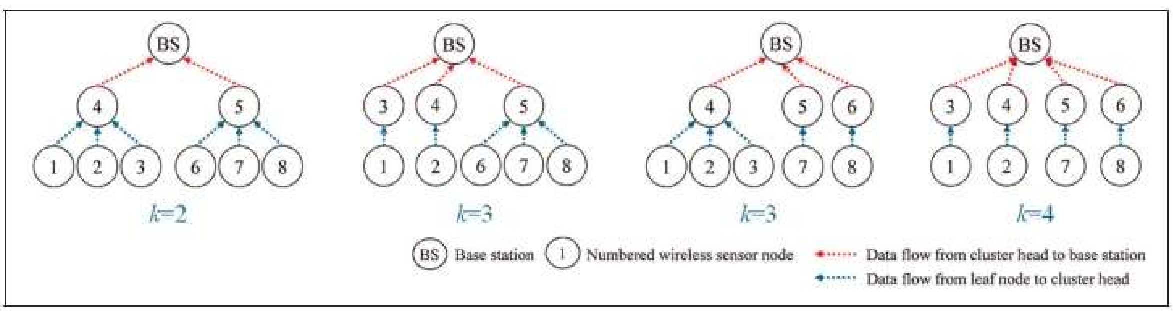

Fig 7: Showing Multi-Level Cluster Deployment Scheme

5.5 Mobile Cluster Deployment Scheme: It involves deployment of sensor nodes in mobile kind of platform like vehicles or robots. These mobile nodes move in the deployment area and collects the data for a specific task. It is most suitable for dynamic environment where nodes need to adapt changes.To improve network performance, wireless sensor networks (WSNs) adopt a mobile cluster deployment methodology in which cluster heads or mobile nodes are dynamically assigned and roam throughout the network. This system allows cluster leaders to move over time based on various criteria or algorithms rather than being fixed in place, Wang, J., Ju, C., Kim (2017) [12]. The movement of the cluster heads is predetermined by a mobility pattern or algorithm. The pattern may be determined by variables including network coverage, energy efficiency, or information gathering needs. It controls the cluster heads' movement patterns and timing inside the network. The cluster heads adjust their placements according to the mobility pattern by either relocating to new locations or trading places with other nodes.

The trade-offs involved with the mobile cluster deployment plan must be taken into account, such as the cost of node movements, communication hiccups during reformation, or synchronization difficulties. For the stability of the network to be maintained and performance to be maximized, effective mobility patterns and control mechanisms are necessary.

5.6 Virtual Cluster Deployment Scheme: In this scheme only logical cluster of nodes are formed in place of physical cluster. This function follows a particular algorithm. The main highlight of this scheme is that the routing and aggregation of data, forms without the need of explicit cluster heads.In wireless sensor networks (WSNs), a virtual cluster deployment methodology is a technique where sensor nodes are grouped into virtual clusters based on specific criteria without the usage of explicit cluster heads. In this plan, the cluster structure is built virtually, and nodes that are part of the same virtual cluster work together and interact with one another to accomplish particular goals. The network is divided into virtual clusters based on the set parameters. A group of sensor nodes that exhibit similar traits or satisfy the predetermined criteria make up each virtual cluster. Nodes may simultaneously be a part of many virtual clusters.According to shifting network conditions or goals, the virtual cluster deployment strategy can adaptively reconfigure virtual clusters. Nodes can dynamically join or exit virtual clusters, and the structure of the virtual cluster can be changed to improve performance or satisfy particular needs.The technique can reduce energy usage by grouping nodes into virtual clusters based on proximity or communication range. Direct communication between nodes in the same virtual cluster can eliminate the need for long-distance communication and save energy. When planning the deployment of a virtual cluster, it's critical to take the communication and coordination overhead into account. Achieving efficient and successful operation depends heavily on the design, management, and optimization of virtual clusters as well as inter-cluster connectivity.

Table 3: Comparative Study of various Clustered deployment schemes

eme	**lt tolerance**	**ability**	**rgy Efficient**	**d Balancing**
d Cluster	ited	h	ited	
ating Cluster	roved	h	nced	
amic Cluster	anced	amic	er	roved
ti-level	ited	ctive for large scale	roved	
bile	roved	amic	mal	istributed
ual	anced	ctive for large scale	ctive for long distance	er/Yes

6. Discussion: These deployment strategies provide improved monitoring capabilities, situation adaptability, and resource efficiency, Fan Chao (2021) [20]. The individual application requirements, ambient circumstances, deployment area features, and the elements to be tracked or analyzed all play a role in the various deployment scheme selection. Depending on the particular needs of the WSN application, these deployment strategies can be merged or modified. The selection of a deployment strategy is influenced by elements including network scalability, energy efficiency, mobility, and coverage area as well as the level of required data accuracy,Di, C., Li, F., & Li, S. (2020) [13].Data accuracy, latency, and response time are just a few of the variables that affect how reliable and effective a wireless sensor network deployment is overall. If the network satisfies the desired performance requirements, it functions properly. Examining the wireless sensor deployment's cost-effectiveness, Consider the initial investment, ongoing maintenance expenses, potential savings or benefits from the deployment, and the area where the application nodes are installed, Frank et al (2020) [23]. Environmental monitoring, healthcare, industrial automation, smart cities, agriculture, and many more fields are examples of thisSingh, S. K., & Kumar, P. (2019) [14]. the efficiency and influence of WSNs in various applications, taking into account elements like data precision, real-time monitoring capabilities, and the capacity to offer insightful information.

Some other types of deployment schemes are:

(a) **Mobile robot-based sensor deployment:** Robots fitted with sensors are used in mobile robot-based sensor deployment to gather information from varied settings or carry out certain sensing activities. These robots can move autonomously or under remote control, which enables them to access many sites and situations that could be challenging or hazardous for people to access.Vision sensors can record visual data about the surroundings, such as pictures, films, and 3D point clouds. These sensors include RGB cameras and depth cameras (like LiDAR Light Detection and Ranging). Sensors for measuring several environmental factors, such as temperature, humidity, pressure, gas concentration, or air quality, can be carried by mobile robots, . These sensors are frequently employed in tasks like assessing the indoor air quality or monitoring the surroundings. The forces and torques delivered to the robot's end effector or any other particular robot part are measured by these sensors, Soua, R., Saidane, L., &Minet, P. (2010) [31]. They are frequently employed in robotic manipulation jobs requiring deft force control or in situations where a robot must interact with its environment.Robots using cameras and other sensors can patrol a space, keep an eye out for trespassers, spot anomalies, or give human operators real-time video feeds. For duties like inventory management, material handling, or quality control, mobile robots with sensors can move about factory floors, warehouses, or logistical hubs. Robots can be used in outdoor settings to gather information on wildlife behavior, weather conditions, pollution levels, and air quality. Research, conservation initiatives, and disaster management can all benefit from this information.Feng, S., Shi, H., Huang, L., Shen, S., Yu, S., Peng, H., & Wu, C. (2021) [32]. Mobile robot-based sensor deployment makes it possible to gather useful information from a variety of environments, and it may be used in a variety of fields to improve productivity, security, and environmental awareness.Depending on the intended use, mobile robots can be fitted with a variety of sensors.

(b) Barrier perimeter-based sensor deployment: Sensors are strategically positioned around a barrier or perimeter to look for and keep an eye on any unauthorized access or breaches. This technique is known as barrier perimeter-based sensor deployment. Security systems frequently employ this strategy to safeguard critical locations like military sites, commercial buildings, or residential residences. To detect any efforts to breach or tamper with the physical barrier, these sensors are positioned along its perimeter or built into it. Vibration, pressure, break-wire, microwave, infrared, and acoustic sensors are a few examples of common types of intrusion detection sensors, Larbi-Mezeghrane, W., Bouallouche-Medjkoune, L., & Larbi, A. (2017) [33].To offer visual surveillance of the region, closed-circuit television (CCTV) cameras are frequently placed along the barrier perimeter. To find and record any suspicious activity, these cameras can be given motion detection or object tracking capabilities. The access and exit points of the protected area are controlled by these systems, which frequently make use of electronic locks, key cards, or biometric verification. The perimeter sensors and access control systems can work together to offer a complete security solution. The sensors detect a breach, and an alarm is set off to notify security staff or a central monitoring Centre. On-site security officers, security guards, or automated notifications to the proper authorities are just a few examples of the response systems.Barrier perimeter-based sensor deployment improves the security and surveillance of a protected area by deploying a mix of these sensors and security measures. It provides real-time surveillance, allowing early identification of unauthorizedentry attempts, and aids in deterring possible attackers. The sensors' collected data and warnings help in the quick reaction to and mitigation of security threats.

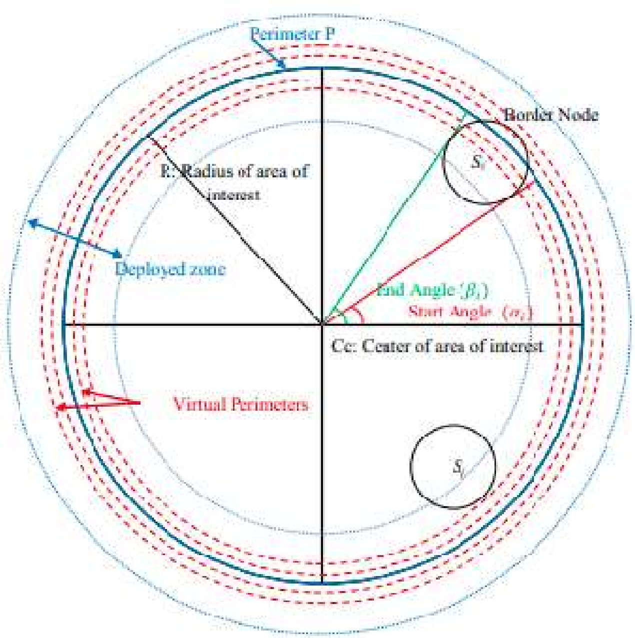

Fig: 8 Representing Barrier perimeter-based sensor deployment Scheme

(c) **Multi-dimensional 3D based sensor deployment:** The use of sensors that can collect data in several dimensions, such as depth, distance, and spatial information, in order to build a complete 3D model of the environment is referred to as multi-dimensional 3D based sensor deployment, Chaurasiya, V. K., Jain, N., & Nandi, G. C. (2014) [35]. These sensors allow for a three-dimensionally accurate and detailed sense of objects, surfaces, and surrounds.ToF(Time-of-Flight) Infrared light is emitted by cameras, which time how long it takes for the light to return from nearby objects. ToF cameras can create a depth map and a three-dimensional representation of the environment by measuring the time delay and calculating the distance to various spots in the surrounding area. Two or more cameras are used in stereoscopic cameras to take pictures from slightly varied angles, Chessa, S., Escolar, S., Pelagatti, S., &Carretero, J. (2015) [34]. To generate a 3D representation of the scene, depth information can be recovered by comparing the differences between the photos. Laser beams are emitted by LiDAR sensors, which track the amount of time it takes for the laser pulses to return after striking nearby objects.

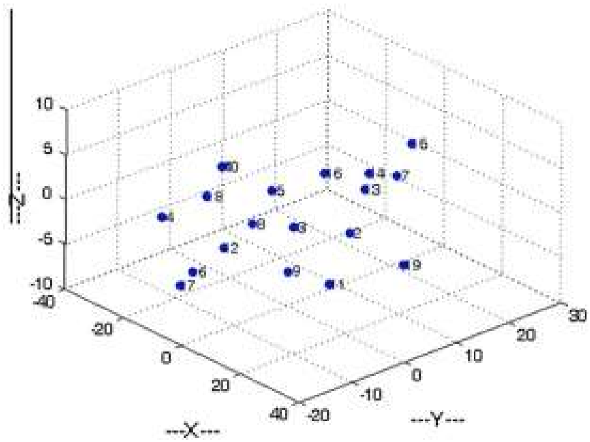

Fig:9 Mapped Arrangement of Sensor Nodes in Multi-dimensional 3D based sensor deployment

Using this information, a dense point cloud describing the environment's three-dimensional structure is created.Structured light sensors project a light pattern into the scene and examine how the pattern is altered by the surfaces of the objects. These sensors can calculate depth information and build a 3D model of the surroundings by capturing the distorted pattern. Ultrasonic sensors produce sound waves and time how long it takes for the waves to return after striking an item. These sensors can calculate the distance to objects and produce a 3D representation by analyzing the return time.Robots and autonomous vehicles can see their surroundings in three dimensions thanks to these sensors, enabling precise navigation, obstacle avoidance, and object manipulation. Real-world settings and objects are captured using 3D sensors, making it easier to integrate virtual aspects into the real world for immersive experiences. In manufacturing operations, 3D sensors can be used for precision measurements in challenging three-dimensional areas, object recognition, and quality control. An in-depth understanding of the environment can be attained by utilising multi-dimensional 3D sensors. This technology makes a wide range of applications across numerous industries possible, improving three-dimensional perception, interaction, and analysis.

7. **Conclusion:** Determining the emerging trends in WSN and Challenges, improvements in edge computing, data analytics, 5G and beyond connection, and IoT integration are required andthink about how these trends will affect the implementation, operation, and management of WSNs in diverse applications, Almagrabi, A. O., Ali (2021)[4].Opportunities and difficulties for WSNs are presented by the implementation of the 5G and forthcoming 6G networks, Priyadarshi, R., Gupta, B., & Anurag, A. (2020)[11]. These networks' increased connectivity enables easier data transmission and reduces communication overhead thanks to their high speed and low latency, Kandris D, Nakas C, Vomvas D, Koulouras G (2020) [22]. However, difficulties include managing the large-scale deployment of WSNs inside the 5G infrastructure and compatibility with current WSN protocols, as well as greater energy consumption due to higher data rates, Ramesh Maneesha Vinodini (2014).Future developments and difficulties in WSNs are a reflection of ongoing attempts to enhance the effectiveness, intelligence, and dependability of sensor networks so they may better serve a variety of applications and progress IoT and associated technologies.

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