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WEB BASED GIS OPTIMIZATION FOR COVERAGE IN WIRELESS SENSOR NETWORKS

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Master’s Thesis

Supervisor

Asst. Prof. Dr. Oğuz KARAN

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The thesis titled WEB BASED GIS OPTIMIZATION FOR COVERAGE IN WIRELESS SENSOR NETWORKS prepared by MUSTAFA SHAKIR MAHDI AL-SALIH and submitted on 12/12/2022 has been **accepted unanimously** for the degree of Master of Science in Information Technologies.

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ABSTRACT

WEB BASED GIS OPTIMIZATION FOR COVERAGE IN WIRELESS SENSOR NETWORKS

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In order to give flood forecasts and warnings, it is important to do research into the creation of a real-time GIS model that can be utilized for the visualization, modeling, and analysis of watershed management. This paradigm must be fully integrated with the Internet. To create an original prototype for a geographic information system (GIS), it is necessary to examine a diverse array of cutting-edge technologies. Due to these brand-new technologies, Internet-based computer modeling may now be carried out in a variety of distinct ways. Hydrology is researched in relation to the many technologies now available and their prospective uses. Using this framework, a number of geographical data structures may be included into a single conceptual framework that can accommodate a wide range of data models. To be useful for field monitoring data, it must have a rapid turnaround time and connect in real time with the geographic information system. As a result, it must be able to swiftly validate environmental simulation models and improve the accuracy of forecasts by analyzing hydrological flows and events in real time. As a last step, it should evaluate whether or not the explored concepts and skills are actual and interact with people

Keywords: GIS, WSN, AI, ML, DL.

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ABBREVIATIONS

AI	:	Artificial Intelligence
FSK	:	Frequency Shift Keying
IoT	:	Internet of Things
PAN	:	Personal Area Network
OFDM	:	Orthogonal Frequency Division Multiplexing
TDMA	:	Time Division Multiple Access

1. INTRODUCTION

1.1 BACKGROUND

A GIS based sensor network is a collection of sensors in a geographic area that are able to communicate with one another. In several applications, an emphasis has been put on collecting location-specific data on various dynamic phenomena. The monitoring of continuous phenomena (for instance, to evaluate plant health and growth conditions or to observe and quantify geophysical activity), the detection of real-time occurrences, and the tracking of mobile objects are a few of the possible uses of sensor networks (e.g., animal monitoring). In order to promote the development of smart environments, buildings, utilities, industries, households, and marine and transportation systems, sensor networks are often used for the collecting of data. Monitoring and managing automobile traffic may be an additional use for sensor networks. For operating the lights and recognizing cars, the vast majority of crossroads use either overhead or subsurface sensors. The use of video cameras, which transmit images to human operators stationed at strategic spots along busy highways, is another common method of monitoring these sorts of roads. Critical buildings and facilities, such as power plants and communication centers, may be protected by sensor networks. Multiple sensors, including video, audio, and others, identify potential dangers before they occur. Sensing technology has long been of interest to business companies due to its potential to save costs, increase equipment performance and maintainability, and maybe boost user performance. Using sensors to monitor the health of machinery is another example of an industrial use for sensors.

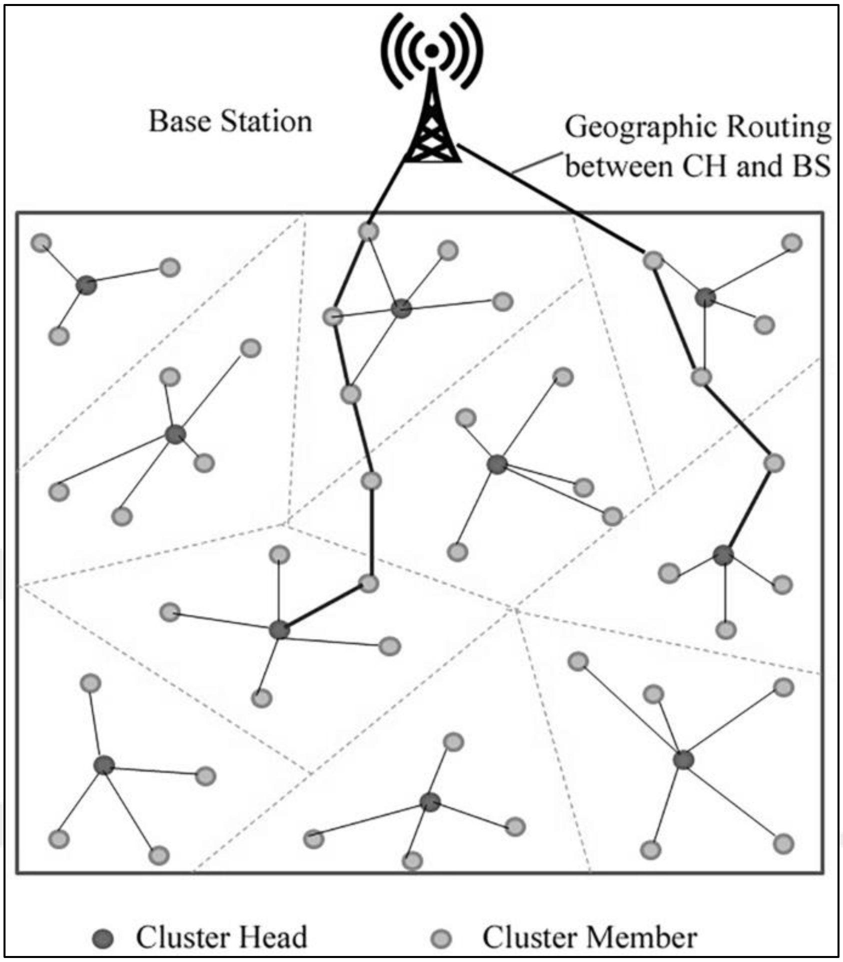

Figure 1.1: Data collection in GIS based WSN

This may include evaluating a piece of machinery's vibration, wear, or lubrication. In this kind of sensor network, the sensors often have limited computing power, storage capacity, and short-range radio communication connections, and are relatively affordable. In the past, sensor networks consisted of a small number of sensor nodes connected to a central processing unit. In contrast, wireless, scattered, and sensing nodes are becoming an increasingly important component of modern networks. In addition to its ability to detect, a sensor node's utility is defined by its computational and communication capabilities, as well as its memory and battery capacity. A sensor can only monitor a certain quantity of space. On the other hand, many sensors working together might provide a far greater field of view, so enabling the effective completion of significantly more complex tasks. Each sensor in a group is capable of detecting and collecting data from its surrounding environment, doing local processing, transmitting data to other sensors, and performing operations that aggregate the observed data. It is standard practice to use them as part of a wireless network to reach remote and difficult-to-reach sites without using a cable connection or power lines. Using sensor networks as opposed to individual sensors makes it feasible to cover a larger area, including previously inaccessible regions. As the size of computers and storage systems has shrunk, so has their energy usage. This has enabled these devices to operate for extended periods of time on battery power. Due to recent advancements in the input and generation of real-time data, sensor network data may now be used in real time on the Internet. Recent advancements in onboard computing, including local data processing, filtering, and sampling, have reduced data transfer and battery use. Geosensor networks are sensor networks that are used expressly for the purpose of gathering geographical information. In the future, sensors and geosensors will be utilized interchangeably. Geosensors may be used on the ground, in the air, under the surface of the sea, on people, in vehicles, and even inside structures.

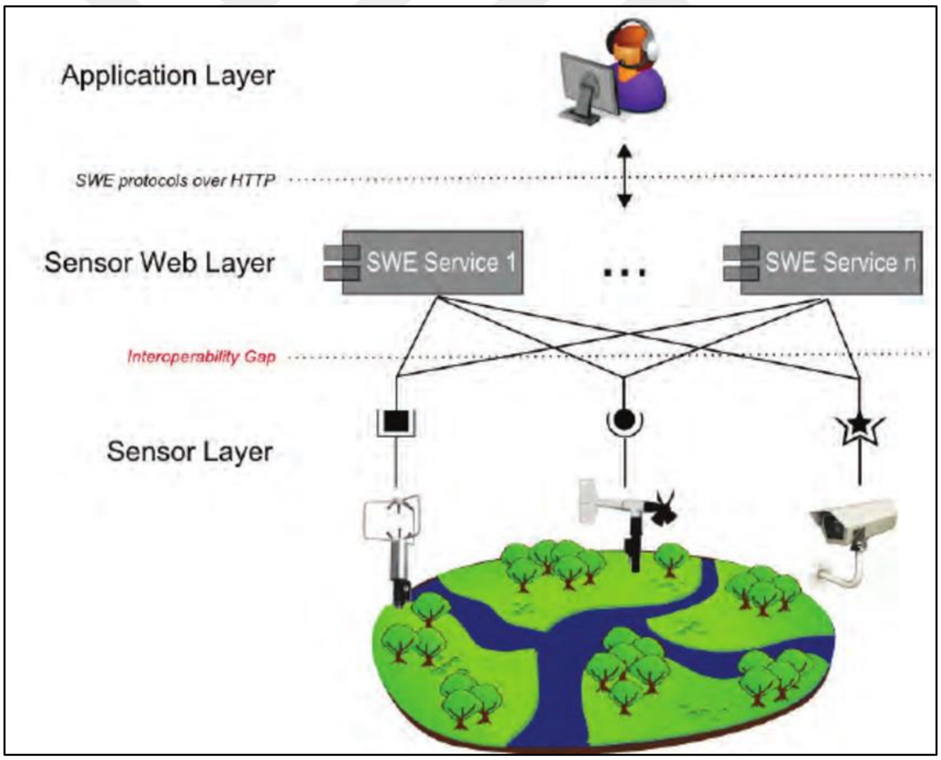

Figure 1.2: Web based geosensors networks

Even while developments in sensor network technology have made it easier to gather and send data, sensors positioned in network nodes may impede sensor networks from reaching their full potential. These limitations present themselves in a variety of ways, including but not limited to sensor range, battery capacity, connectivity, memory, and restricted calculation abilities. As a direct consequence of these limits, sensor network users confront tough obstacles, which has encouraged a large number of researchers from varied sectors to focus their efforts in recent years on the design and implementation of more efficient sensor networks. Using sensor networks for modeling, monitoring, and detection of environmental processes has a number of significant drawbacks. Realistic sensor networks need the incorporation of both static and dynamic environmental elements, such as obstructions. The context of the sensors' environment and the actual events that occur inside the network are two other examples of these traits. It is essential to have a thorough grasp of sensor networks in order to identify and assess these events with precision and efficiency. To achieve this purpose, it is necessary to incorporate adequate models of the phenomenon type, the accessibility or inaccessibility of the observation region, environmental factors, and geographical connections between places. The following are instances; however, they are not exhaustive: The location of sensors and the quality of the initial datasets used to set up sensors are two components that add to the complexity of wireless sensor networks. Because there are a variety of deployment algorithms to choose from and a trustworthy, durable, and resilient network must be constructed, determining the most efficient method for deploying sensors may be challenging. Therefore, the research of wireless sensor networks is a challenging endeavor that requires a wide range of specialized knowledge in addition to a great deal of practical experience. The installation of sensor networks has two key challenges, the first of which is ensuring enough coverage, and the second of which is sustaining effective communication between sensors. Utilizing node sensors enables continuous monitoring of the surrounding environment. Each device is expected to have a range, the details of which will vary depending on what is being detected and the limits of the surrounding environment. It is possible for obstructions to reduce network coverage and produce blind spots in the field of view. The information that has been gathered in the area must be delivered immediately to a processing center or, at the very least, to a sensor positioned near to the processing center through communication between the nodes. The second circumstance necessitates that each sensor be informed of the positions of other sensors in its near vicinity. Due to the near closeness of the sensors, this is the case. It is possible to increase the coverage of sensor networks by strategically installing additional sensors, which may be done in a variety of ways. In a broader sense, the recommended techniques may be categorized into two distinct groups: global and local. Some of the suggested approaches in both categories use computational geometry in the form of Delaunay diagrams and Voronoi triangulations, respectively. Using these frameworks, an evaluation of the sensor locations may be conducted. The geographical dispersion of sensors that are implanted in the surrounding environment has a substantial impact on the ability of sensor networks to cover a particular area. The deployment optimization algorithms attempt to position the sensors in the field such that they give sufficient coverage for the activities that are presently being carried out. Although these approaches are applicable to basic sensor networks, further research is required before they can be used to sensor networks that are subject to environmental constraints, such as sensor networks that are influenced by environmental obstacles. Innovative techniques that take into consideration the geographical aspects of the environment (such as the heterogeneity of the field, the terrain model, and natural and man-made barriers) are advantageous from a practical standpoint. Incorporating geographical data, such as topography, into sensor network models would result in more realistic simulations and make it feasible to deploy sensor networks more efficiently in the real world. By providing the essential data (such as digital terrain models) and geographical analyses, geographic information systems (GIS) might aid in the assessment and optimization of geosensor networks (e.g., visibility analysis).

1.2 PROBLEM STATEMENT

GIR, or the field of Geographic Information Retrieval, was established. GIR is the study of Geographic Information Systems (GIS) and the Internet. The purpose of the Geospatial Content Repository (GIR) is to offer targeted audiences with access to geo-referenced information. To increase public access to geographic information systems (GIS), "distributed geographic information" (abbreviated DGI) refers to the technique of making geographic data accessible to a larger audience than would have been feasible with standard GIS technology. The use of geographic information systems, often known as GISs, enables the provision of access to simulation models and GIS databases to those who, in the absence of such systems, would be unable to use the relevant information.

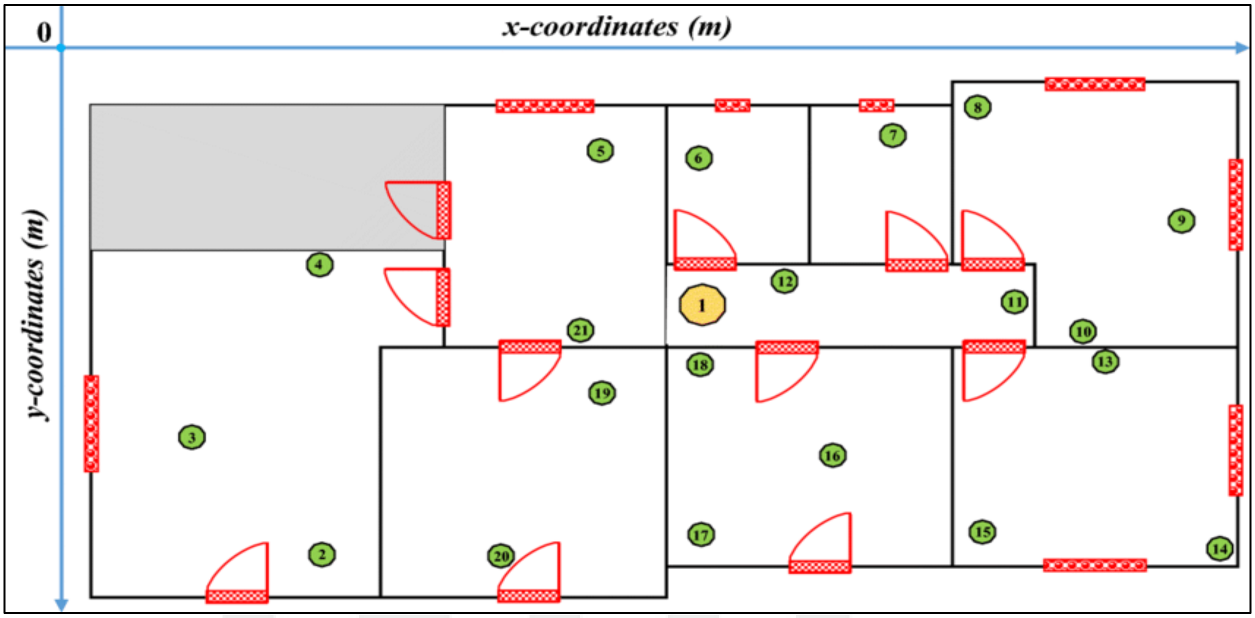

Figure 1.3: geographic information systems (GIS) with distributed geographic information

Individuals were previously unable to develop their own GIS due to the prohibitive cost of gear and software. In addition, GISs were difficult to learn and use, which limited their accessibility. When it comes to implementing web-based GISs, high costs and steep learning curves are no longer a barrier to entrance. In recent years, commercial GIS developers have produced web-based geographic information systems; however, these web-based GISs may be costly, may not be suitable for novice users, and need extensive programming skills. Due to the fact that they are general-purpose GIS tools, they may not be applicable in all situations. In lieu of buying GIS software, it is possible to create Web-based GISs and simulation models from scratch. This provides a solution that is better personalized to the business's demands and decreases the entire project cost. Web-based spatiotemporal models are essential for expanding hydrological modeling on the Internet because they offer improved data retrieval and online analysis. Because they can be accessed with a web browser. As a result, integrating GIS with the Web to offer the public with access to integrated environmental information and spatio-temporal models may reduce threats to people's lives and property by enabling authorities to foresee events. The extensive availability of the Internet facilitates the accessibility of real-time information and resources that are helpful to a wide range of people. The Internet is the most efficient channel for watershed model communication. almost everyone may get dependable hydrological predictions over the Internet. HTML and Java, two of the most popular Internet programming languages, are intended to operate successfully on any computer, regardless of the operating system. If users employ GISs on the Internet, they will be able to reap the advantages of GISs without being dependent on a single platform. Through the deployment of an internet-based approach, the general public and those responsible for making decisions about space may be brought together. There are more opportunities for public input and involvement in the decision-making process, which is one of the advantages. Moreover, government directives promote the use of GIS on the Internet. Certain kinds of information must be made accessible to the general public by law, and the United States government is subject to this duty. The United States Constitution requires that any material produced by the federal government be available to the general public. The only exceptions to this rule are violations of a person's right to privacy or threats to national security. There are several methods to use the Internet, each of which contributes to a more democratic and inclusive form of local environmental decision-making. the Internet will "create a new public space" that will enable "new types of democracy" through promoting communication and dialogue.

1.3 OBJECTIVES

a. The major purpose of this study is to explore how open-source software and industry standards are being incorporated into the development of web-based GIS information systems. As a consequence of GIS's rapid proliferation, a number of educated persons are starting to question both the technology's basic nature and its potential social influence.
b. Our aims are to generate a map of the current and projected infrastructure with varying levels of precision. A web-based information system will provide users with access to data, including academic buildings, dormitories, and administrative blocks, as well as residential and commercial areas. There are residential and business portions inside these facilities.

1.4 CONTRIBUTION

In order to give flood forecasts and warnings, it is important to do research into the creation of a real-time GIS model that can be utilized for the visualization, modeling, and analysis of watershed management. This paradigm must be fully integrated with the Internet. To create an original prototype for a geographic information system (GIS), it is necessary to examine a diverse array of cutting-edge technologies. Due to these brand-new technologies, Internet-based computer modeling may now be carried out in a variety of distinct ways. Hydrology is researched in relation to the many technologies now available and their prospective uses. Using this framework, a number of geographical data structures may be included into a single conceptual framework that can accommodate a wide range of data models. To be useful for field monitoring data, it must have a rapid turnaround time and connect in real time with the geographic information system. As a result, it must be able to swiftly validate environmental simulation models and improve the accuracy of forecasts by analyzing hydrological flows and events in real time. As a last step, it should evaluate whether or not the explored concepts and skills are actual and interact with people.

1.5 THESIS STRUCTURE

The framework of the thesis can be dissected into the following outline to reveal its components: In the second part of this discussion, we are going to investigate both the implementation and some of the earlier work that was done. We are going to give some background information on each of the components in the following part, which is going to be referred to as "Section 3." In the following section, we will not only provide a detailed description of our model, but also a detailed implementation of that model. Both of these will be presented in detail. In the following part of this chapter, we are going to simulate our model and make a record of any observations that come about as a result of running the simulation. Section 6 contains the findings and conclusions of our inquiry. This section is also where we discuss the scope of additional work that may be done in the future.

2. LITERATURE REVIEW

Abdel-Basset et al. [1] created a wireless sensor network (WSN) for Internet of Things (IoT)-enabled smart agriculture by applying an algorithm known as a multi-verse optimizer in their work. As a result of this, we were able to cover the greatest geographical area that was feasible for us.

WSN was deployed by Zheng et al. [2] in order to monitor the ground temperature in order to both improve the architecture of the network and reduce the amount of energy that was consumed.

The notion that patients' physiological parameters may be monitored by means of a network that was constructed utilizing WSNs was conceived by Sudha and the other members of her team [3]. It was decided to make the network more energy efficient so that it may have a longer lifespan and a wider range of communication capabilities. This decision was made in order to accomplish both of these goals.

An energy-conscious WSN architecture for ubiquitous healthcare systems was proposed by Fariborzi et al. [4] as a possible answer to the problem of extending the network's lifespan and covering the rest of the hospital. This might be accomplished through the use of wireless sensor networks. [Further citation is required] [You are required to add references to bibliographical sources] Varshney [5] recognized coverage and scalability as necessary requirements for the provision of healthcare to a larger population with WSN as necessary criteria. These needs are required in order to fulfill the requirements for necessary requirements. Despite the fact that its primary focus is on the deployment of sensor networks, this study makes use of artificial optimization approaches to improve coverage and longevity for wireless sensor network deployments in the context of applications related to environmental and health concerns. Despite the fact that the primary focus of the study is on the establishment of sensor networks, this is nonetheless carried out. In order to achieve this goal, a number of research have been conducted with the goals of increasing the coverage of wireless sensor networks (WSNs) and lengthening the lifespan of these networks. They have not, however, investigated two different evolutionary optimization approaches for WSN deployment in terms of coverage, durability, and connection objectives. The Bees Algorithm (BA) and the Particle Swarm Optimization (PSO) algorithms are the names of these mathematical procedures. The researchers have come to the conclusion that it is in everyone's best interest to skip using the Minimum Spanning Tree (MST) method in the process of deploying the WSN in order to get the most out of the available routes and consume the least amount of energy possible.

Pule et al. [6] conducted research with the objective of determining how useful WSNs are for the purpose of monitoring water quality. They showed, via their research, that it is essential to have appropriate coverage, together with low energy usage and safety.

Saini [7] underlined the low energy consumption of the sensors, the ease with which they may be networked together, and the strategic positioning of the sensors in his review of WSN research on water quality. Saini [7] also pointed out that the sensors can be strategically placed.

Yao and Du [8] came up with a strategy called gradient direction to optimize underwater coverage for the deployment of wireless sensor networks in a three-dimensional environment. This was achieved by deploying the networks in a path that gradually increased in gradient.

In order to reduce the amount of energy that was consumed as well as the number of sensors that were required for the deployment of fixed RFID tags throughout waterways for the identification and localization of contaminated sites, Ellouze et al. [9] developed a solution. This solution was able to cut down on the amount of energy that was used. This action was taken as a means of assisting in the identification and localisation of places that may pose a risk to the safety of those present. Air pollution surveillance According to the findings of Boubrima et al. [10], an effective deployment of WSNs, which must take into account the network's lifespan as well as its coverage, is necessary for two applications of air pollution monitoring: the creation of maps and the determination of highly contaminated zones. This is because an efficient deployment of WSNs must take into account the lifespan of the network as well as its coverage. [You are required to add references to bibliographical sources] They devised a model for the deployment of WSNs that was based on integer linear programming. The model took into account limits on coverage, connection, longevity, and cost. Priyadarshinee and colleagues [11] carried out an examination of the fundamental properties of the WSN as well as its applications. They came to the conclusion based on their findings that the two characteristics of the WSN deployment that were the most essential were the coverage and the energy usage. This conclusion was reached on the basis of their findings. Rajput and Kumaravelu [11] state that scalability, coverage, and a prolonged lifespan are the three most significant criteria for the implementation of WSNs in agricultural environments. [Further citation is required] [Further citation is required] [Further citation is required]

Through the implementation of an innovative metaheuristic algorithm, Abdel-Basset et al. [13] were able to expand the coverage of wireless sensor networks (WSNs) for Internet of Things smart agriculture.

Harvesting of crops, monitoring of soil and plant moisture levels, distribution of pesticides, and management of animals are just a few examples of how Sharma et al. [14] propose to extend the lifetime of WSNs through the use of solar energy harvesting in smart agricultural monitoring. Other examples include the harvesting of crops, monitoring of soil and plant moisture levels, distribution of pesticides, and management of animals. [Citation needed] Other examples include activities such as the harvesting of crops, the management of animals, the watering of plants, and the monitoring of moisture levels in the soil and the plants. [You are required to add references to bibliographical sources]

The researchers Rajput and Kumaravelu [15] discovered a method to decrease the distances over which data is transferred, which, in turn, boosts the network's energy efficiency and coverage in agricultural contexts. It has been suggested by Dutta and colleagues [16] that the rapid deployment of WSNs in the seismic domain is conceivable, provided that progressive changes in the environmental circumstances are taken into mind. [Citation needed] A couple of instances of these characteristics include the magnitude of the earthquake and the distance from its epicenter.

Hung et al. [17] built a WSN-based seismic early warning system while keeping in mind the potential impact it would have on the capacity of the environment to preserve energy. They did this by keeping in mind the potential impact it would have on the environment.

Combining the technologies of routing and node replacement, as described in detail by Mohapatra et al. [18], would reduce the amount of energy that is used while also reducing the expenses that are associated with sensor replacement. This would be beneficial when building an underwater sensor network for real-time monitoring. In order to monitor landslide-prone areas and offer real-time data, Kumar et al. [19] took on the challenge of solving a wireless sensor network deployment problem that was based on the Internet of Things. The researchers evaluated the network connection, coverage, the necessary number of nodes, and the temporal synchronization in order to remotely monitor landslides.

During their time at Torgiovannetto, Giorgetti et al. [20] pushed for the use of WSN deployment for the purposes of online analysis and notifications of landslide monitoring (which is located in Italy). This was done in order to offer critical information as well as conduct an analysis of potential threats. The purpose of both of these was to ensure the safety of all involved.

According to Ramesh [21], the building of the WSN for landslide detection in India's Anthoniar colony, Munnar, Idukki district, and Kerala state took into mind the amount of power that would be consumed by the network. This was done so that the WSN could be used in these locations. The state of Kerala is home to each of these locations. This action was carried out in order to make certain that the network will perform in the manner that is expected of it. It is feasible to monitor the sounds that birds create by using audio sensors that only have a limited amount of energy and memory capacity. This can be done.

The Wireless Sensor Network (WSN) deployment on Skomer Island was carried out with the goals of tracking the geographical behavior of seabirds and providing information on the overall health of the ecosystem, according to the findings that were presented by Naumowicz et al. [22].

The research that Naumowicz and colleagues [23] carried out on the seabirds in the UK National Nature Reserve made use of WSN. In order to keep track of the temperature of the planet, Zheng et al. [24] created a wireless sensor network (WSN) with the assistance of ZigBee technology. During the process of developing WSN, one of the key considerations that was taken into account was how effectively energy was utilized.

Values of the temperature and humidity were collected using a WSN-based temperature and humidity monitoring system that Baghyalakshmi et al. [25] devised and implemented. The readings were taken on both the open terrace and the control room of the SADHANA facility. (Please offer a reference)

Clustering was an important component of Yang et al[26] .'s investigation into the architecture of WSNs for the purpose of doing remote temperature monitoring. This step was taken with the belief that it would result in a decrease in the total quantity of energy that was utilized. Wireless Sensor

Networks, more commonly referred to by their abbreviation WSN, are put to use in the monitoring of fires and the development of fire rescue systems in an effort to reduce monetary losses as well as harm to the environment. This is done in an effort to save the environment.

Al-Turjman et al. [27] highlighted the significance of WSN deployment in forestry as a potential project for the future, highlighting the necessity to consider lifespan, coverage, and energy consumption. They emphasized the significance of WSN deployment in forestry as a potential project for the future. In addition to this, they emphasized the significance of WSN deployment in forestry as an opportunity for a future initiative. In order to identify wildfires and transmit warning messages, TinyOS kernels were integrated into the sensor network built by Li et alwireless. The kernels were put to use for a number of different reasons, including the management of power and the localization of data.

Lei and Lu [28] developed a computational method for the deployment of WSNs in order to construct systems for the near-real-time detection of forest fires, while simultaneously boosting sensor node coverage and network longevity. Their work can be found in the paper "Development of a Computational Method for the Deployment of Wireless Sensor Networks." Their work was published under the title "Wireless Sensor Network Deployment Computational Method" in a journal.

In Abdulsahib and Khalaf's [29] wireless sensor network (WSN), random-spread nodes were introduced in order to increase the network coverage while also lowering the amount of energy that was consumed.

According to the findings of the study that was carried out by Biabani et al. [30], it is possible to improve clustering and routing in WSN deployments by making use of a hybrid PSO and HSA algorithm that takes into account the requirements of the network in terms of energy, proximity, and coverage. [You are required to add references to bibliographical sources]

Suryadevara et al. [31] conducted research on the application of wireless sensor networks (WSN) in the context of the monitoring of domestic products, personnel movements, ambient components, and human physiological indicators in smart homes for the elderly. When they constructed the network of heterogeneous sensors, they employed a tree-based strategy for wireless communication so that they could keep control over the amount of energy that was consumed. This allowed them to conserve as much energy as possible.

In order to expand the range of coverage provided by a wireless sensor network within a three-dimensional (3D) area, Liu et al. [32] made use of both an ant colony (AC) and a genetic algorithm (GA). This was done with the intention of monitoring chronic patients who resided in a nursing home as well as in a smart house. The atmospheres of these two places couldn't be more different from one another from a wide variety of perspectives.

3. MATERIALS AND METHODS

3.1 WIRELESS GIS

The World Wide Web is experiencing a transition from a static information and computation platform to a dynamic one as the Internet continues to evolve. As geo-information consumption has expanded rapidly, the Geographic Information System (GIS) has shifted from being platform-dependent and closed to platform-independent and open. The use of GIS has moved as a result of the proliferation of internet and wireless services technologies as well as mobile computing devices. Typical GIS activities may now be conducted remotely.

As a consequence of advancements in wireless technology, service providers now have more alternatives available to them. Wireless geographic information science (GIS) is a subdiscipline of geographic information science that analyzes and distributes geographic data over the Internet, intranets, and the World Wide Web. It provides access to location data and the accompanying services regardless of whether the user is stationary or mobile. Those who operate in the field and need to identify and resolve difficulties on-site, as well as those who are on route to their destination and want to know the actual traffic situation, will find wireless information access to be quite beneficial. Those who are on route to their destination and want to know the actual traffic status. In addition to knowing one's location, it is crucial to be aware of when, how, and how rapidly one moves, as well as the direction or route along which one travels. This information is vital for humans to comprehend and function in their environment. Utilizing real-time tracking may considerably facilitate the quick delivery of emergency care as well as a range of other services. Because wireless GIS is such an important component of the infrastructure that enables the delivery of services and content, this branch of mobile computing must adhere to its own set of standards in order to fulfill the aforementioned duties. To achieve this objective, Wireless GIS is designed to collect data on the positions of moving people, places, and things, and then transmit this information to receivers that may also be in motion.

URISA is a non-profit organization whose members employ GIS and other information technology to address numerous issues at all levels of government, including state, provincial, and municipal. The Urban and Regional Information Systems Association (URISA) is regarded as the industry's leading organization for increasing the quality of life in urban and regional areas via the use and inclusion of spatial information technology. In addition, wireless GIS services and volunteer GIS services are provided to aid relief operations in developing nations and after natural disasters.

Open Geographic Information System (GIS) is the definition of interoperable systems that "geo-enable" traditional information technology, the Internet, wireless networks, and location-based services. Even the most sophisticated geographical information and services may be made accessible and valuable to users thanks to the standards. Because the standards provide software developers with the necessary tools, this is achievable.

3.1.1 Characteristics of Wireless GIS

a. You will need to incorporate the following technologies into your GIS in order to create a wireless version of it:
b. GPS-based products and services, as well as the World Wide Web, are examples of mobility aids.
c. Wireless communications infrastructure as well as related services
d. processing of information based on geospatial coordinates
e. Internet

The Internet, a worldwide network of linked computer systems, facilitates communication and collaboration between individuals and organizations in a variety of ways. Copper lines, fiber-optic cables, wireless connections, and other technologies, in addition to other techniques, are used to connect millions of private and public, academic, commercial, and government networks with a local to worldwide reach. Internet GIS is web-based software that allows users to view, modify, and retrieve geographic data without the need to install specialized GIS software on their PCs.

Because of the expansion of the internet, the availability of more products and services has increased substantially. Recent advancements in client-server technology have made it possible to transmit vast quantities of spatial data via a relatively narrow data channel. The term "thin client" refers to a computer or piece of software that relies heavily on another set of computers (its server) to perform the bulk of its routine computing tasks (Thin Client definition). In constructing a network, full-featured personal computers, often known as "thick clients," are used. Thin clients lack features such as hard drives since they cannot operate without being linked to a network. However, thick clients are capable of functioning autonomously. When a thick client is not linked to a network, it is often referred to as a workstation.

f. GPS technology & services

The Global Positioning System (GPS) is a vital component of mobile communication because it can detect the exact position of an object on Earth and follow it in real time if the object is equipped with a GPS receiver. It is a system that calculates your location based on the location of your mobile phone. A second handset-based positioning system, known as Assisted Global Positioning System (A-GPS), may be able to provide positioning services by using supplementary data. Alternative Global Positioning System (GPS) technologies, such as wireless A-GPS, may perform location-related tasks that the standard GPS receiver cannot. On the one hand, it utilizes wireless communication networks, such as GSM networks, to give the A-GPS receiver with the necessary aided information data. This data may comprise, among other things, an almanac, an ephemeris, a time stamp, and a Doppler shift. In contrast, a highly sensitive Assisted-GPS receiver might detect a weak satellite signal. Particularly, the GPS's capacity to locate an individual's internal position has the potential to increase the device's use in a range of scenarios, such as the processing of transactions during emergency situations, the collection of information while traveling, and the monitoring of youngsters. In terms of earthquake rescue, this is undoubtedly a step in the right way.

Due to advancements in electronics and semiconductor technologies, GPS receivers have shrunk to the millimeter range. Smartphones are equipped with a variety of GPS receiver chips to enable them to receive cellular and satellite signals. The great majority of mobile phone service providers, including Deutsche Telekom and O2, give their clients with access to an A-GPS server. However, in order to have access to the aforementioned indoor navigation and location services, A-GPS subscribers must pay extra connection costs.

g. Mobile devices

Mobile devices, also known as portable or handheld computers, are small enough to fit in the palm of your hand and often have a touchscreen and a small keyboard. Mobile gadgets are also known by their alternative names. Numerous current personal digital assistants integrate input and output capabilities on a single touch panel. By adding data collection devices, corporate digital assistants may be able to give business users with access to a more extensive range of features. Numerous applications have been conceived for mobile technology such as mobile computers, personal navigation systems, and other like goods. These mobile devices have also been manufactured.

Mobile devices are the clear frontrunner in the battle to give clients with timely, relevant, and location-independent geospatial data.

The necessity to take advantage of rising network capacity while simultaneously satisfying the needs of a more diverse user base has been the driving factor behind the development of more sophisticated mobile communication devices. Mobile phones enable those who are always on the go to retain touch and carry-on discussions. During the last several years, mobile devices' storage space, processing speed, and usefulness have increased significantly, while their prices have decreased. It is now possible to do tasks that formerly required hefty computers while traveling with nothing more than a mobile phone. Because suitable mobile operating systems and wireless communication protocols are now more commonly accessible, the compatibility between mobile apps and desktop/web applications has also increased. The newest outgrowth of geographic information systems (GIS) is mobile GIS, which refers to geographic information systems optimized for use on mobile devices. This page provides information on the concepts, methodologies, and applications of map-based mobile services. This article illustrates wireless mobile GIS solutions with an example.

h. Wireless communication technology & services

a. Due to the fast evolution of infrastructure, technology, and services around wireless communication, it is now possible to use mobile devices like as cell phones and personal digital assistants (PDAs) to access the Internet and the office back end from any location. Here are some distinguishing characteristics:
b. The International Telecommunications Union (ITU) defines the third generation of mobile communications technology, which is commonly referred to as 3G. (ITU). The maximum bandwidth at rest or walking pace is 384 kilobytes per second (kbps), in a vehicle it is 128 kilobytes per second (kbps), and for embedded applications it is 2 megabits per second (Mbps). It is mobile.
c. This standard's large bandwidth makes it possible to transmit substantial amounts of data, which enables a variety of applications. It has been operational in Europe and other regions with sufficient population densities to justify the additional financial investment required for the necessary infrastructure for some time. The development of fourth-generation wireless networks, or 4G, is under ongoing. General Packet Radio Service (GPRS) is a wireless communications standard that permits data transfer rates of up to 115 kilobits per second.

d. Spread-spectrum Code-division multiple-access, or CDMA, is the abbreviation for the digital mobile phone technology. No user is assigned a specific frequency with CDMA; rather, the entire spectrum is shared among all channels. This enables for a bigger number of channels.
e. When nodes in a WLAN (Wireless Local Area Network) need to communicate with one another, high-frequency radio waves are utilized in place of physical cables.
i. Spatial data processing

There are presently online applications that may be used to view and analyse spatial data, and all of the major database providers provide their clients storage, maintenance, and querying capabilities for geographical data. These same companies have also produced mobile-device-optimized software. ESRI offers a range of GIS applications, including Desktop GIS, Server GIS, Online GIS, Mobile GIS, and their Constant Updates.

Using spatial processing technology, it is possible to manipulate, analyze, and visualize geo-information. Space-related data is often geo-coded, compressed, and sent across a network with exceptionally low bandwidth requirements. With the aid of several standards, such as WML and Mobile Location Protocol, a broad range of processing components may be integrated (MLP). Before they may be deemed completely established, the standards for the error-free and congestion-free transmission of spatial data over wireless networks still need further development.

3.2 ARCHITECTURE AND APPLICATIONS OF WIRELESS GIS

3.2.1 Architecture

As seen in Figure 3.1, the structure of a wireless geographic information system is guided by a client-server approach. The server consists of the following three components in particular:

a. RDBMS (Relational Database Management System).
b. A user interface for geographical data accessible online. The information provided to a routing engine.

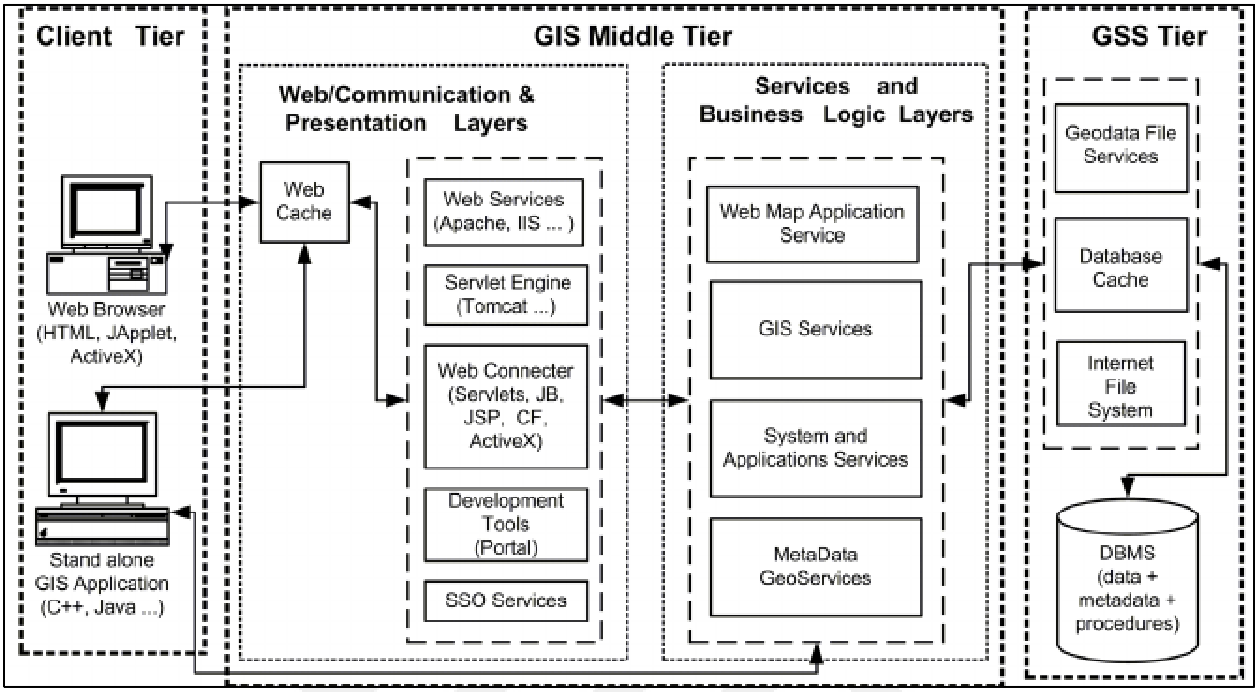

Figure 3.1: The 4-tier architecture of a Wireless GIS

A standard RDBMS is used to administer the database; however, a spatial database may store any form of large GIS data collection. The web-accessible RDBMS acts as a bridge between the geographic and semantic data realms. In addition to merging, deleting, and adding geographical data, as seen in Figure 3.2, it efficiently indexes and searches geographical data. Web-based spatial interfaces provide mobile users with access to the RDBMS's gathered data. It offers the means by which data from several users may be combined, as well as the means by which data can be effectively transmitted and retrieved inside the user's environment. Additionally, it gives the capacity to aggregate data from numerous users. User services need a spatial database engine, such as ODBC or SDE, to facilitate the transmission of data between the GIS database and the wireless server.

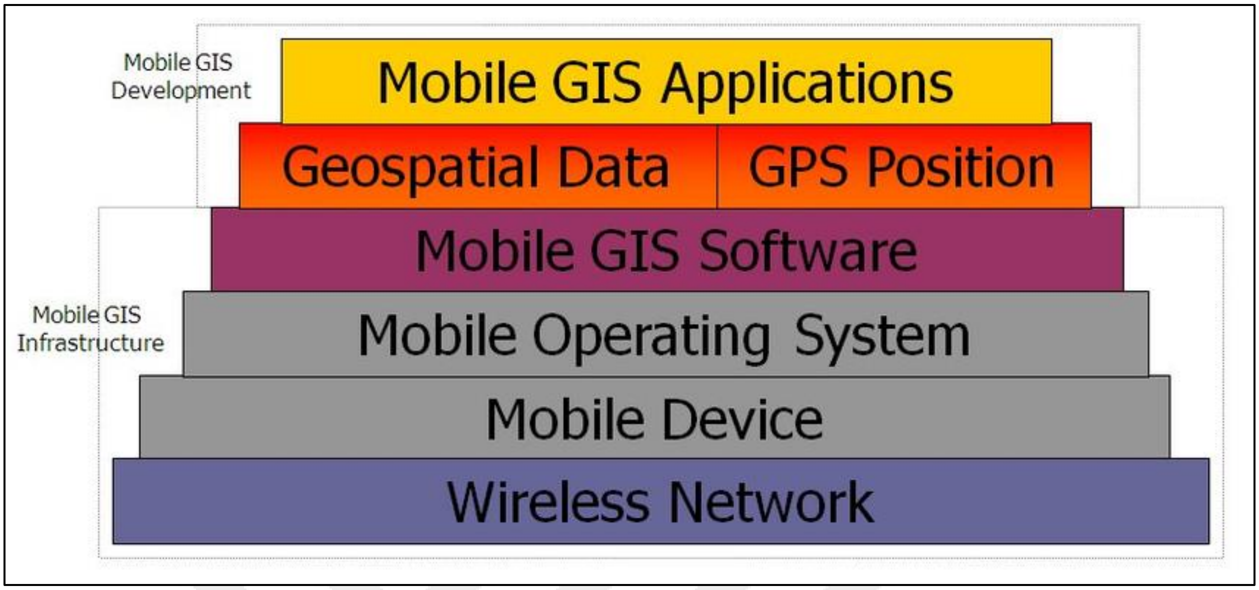

Figure 3.2: Wireless GIS operation

3.2.2 Applications

The conventional method of data collection is laborious and fraught with the danger of making mistakes. Typically, paper maps, drawings, and notes are used to capture geographical information gathered in the field. These analog sources were digitized manually or with the use of automation in the office. It is possible that the database had outdated information by the time it was completed. With the aid of Wireless GIS, location-based applications may be developed using field-collected data in the form of digital maps stored on tiny mobile devices and disseminated through a wireless network. The information may be stored on small mobile devices. Different types of consumers need unique services. The term "emergency response" refers to a service that falls within this classification. This sort of service involves searching a certain region for the mobile device in question; it is one of the services included in this category. When it comes to supporting location-based searches, various service providers use geographical data in various ways. Providing a list of local restaurants, banks, supermarkets, and other businesses are a few examples.

Multiple service providers use wireless GIS to more accurately adapt their service area to each customer based on the consumer's geographical location. The tracking capacity is routinely used and has tremendous potential for use in search and rescue operations; nonetheless, it raises ethical problems about the preservation of persons' right to privacy in non-emergency circumstances. Firefighters, police officers, engineering teams, surveyors, utility staff, members of the military forces, census workers, and even field biologists are among the many users of wireless geographic information systems (GIS) today. Figure 3.3 provides some instances of common wireless GIS applications.

3.2.3 Related Terms to Wireless GIS

As a consequence of the considerable interest in and research into wireless GIS that has followed the development and convergence of GPS, the Internet, and wireless communication technologies, terms such as mobile GIS, tele cartography, and mobile cartography have evolved. These terms are all associated with wireless GIS. Among the key uses for mobile GIS are the collection and validation of data in the field as well as the navigation of rescue vehicles. People who use location-based services in the field and those who are interested in such services comprise the target audience. Because of this, words like "location-based services" and "field GIS" are uncommon (LBS). The mobile Geographic Information System (GIS) was characterized as an integrated software and hardware architecture that allowed users to access geospatial data and services over wireless or wired networks on their portable electronic devices. Field-based GIS refers to a kind of geographic information system used in the field to gather fresh point data or to update the attribute tables of an existing GIS database. Two instances of these occupations are shown below. Numerous types of location-based services exist, including business navigation, street routing, location discovery, and vehicle tracking. Tele cartography, sometimes known as mobile cartography, is the study of the concepts, strategies, and technology behind the interactive, dynamic, and adaptable cartographic presentation of geographical information for use on mobile devices. This representation must take into account several factors, such as location, time, the user, the activity, the data, and the system.

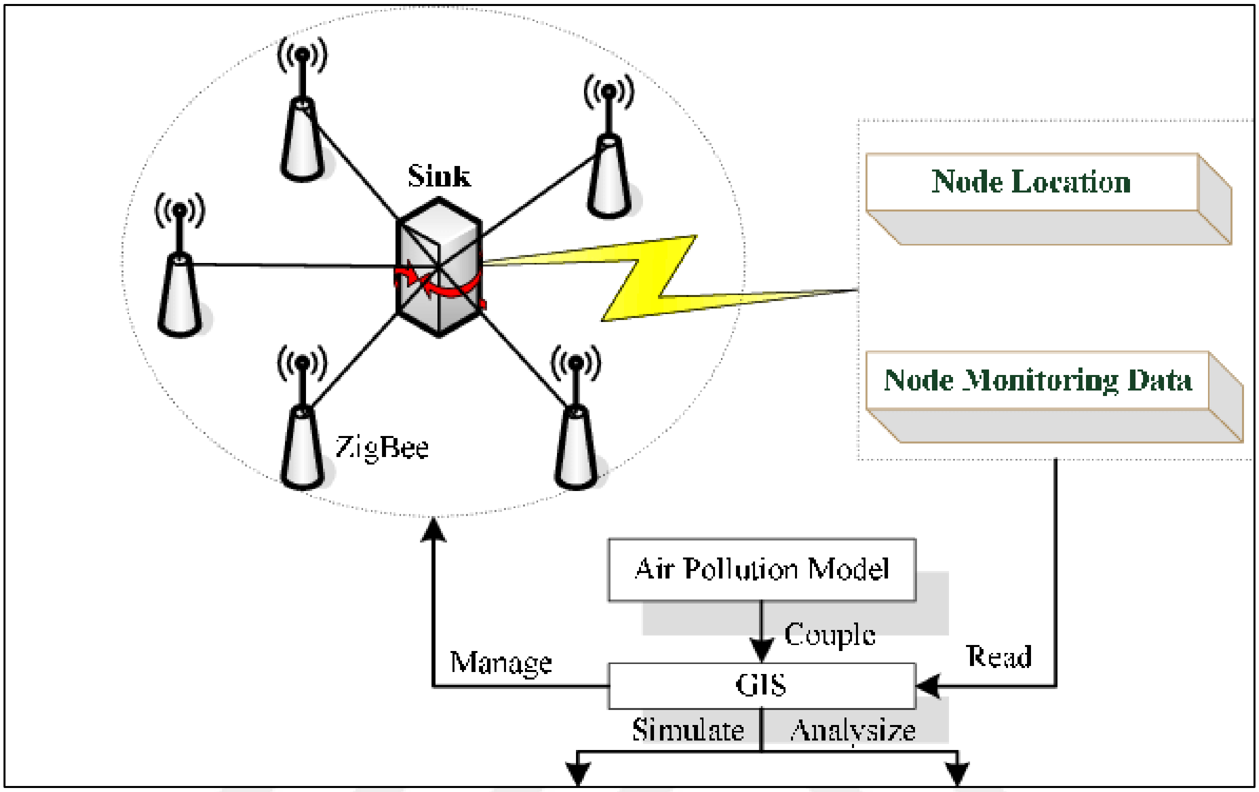

Figure 3.3: Applications of Wireless GIS

3.3 VISUALIZATION TECHNIQUES OF DISTRIBUTED SPATIAL INFORMATION

There has been a tremendous shift not only in the research and perusing of data, but also in the transfer of information since the advent of the Internet. The field of digital mapping has seen considerable hardware and software developments over the course of the last decade. Both traditional desktop GIS and mobile wireless GIS need the capacity to effectively display geographical data. All of these changes have contributed to the actualization of virtual reality. Numerous case examples illustrating the development of visual representations are provided in Figure 3.4.

According to the OGC's explanation of the standard for the Internet map interface, the four key processing processes for Internet-based geo-information visualization are inquiring, producing, expanding, and presenting the data. The objective of the querying process, also known as filtering, is to choose a subset of the source datasets that fulfills the client query's requirements. Generation is responsible for transforming the query result into a graphical user interface component, also known as the generation of display series. During the expansion step, also known as "formation," the final map is created, and it is then delivered to the display service for rendering. For instance, Google Earth's description balloons may include both normal text and rich media such as HTML and JavaScript (Henry 2009). Google Earth's spatial database has been queried using this function. When a WebServer such as Geoserver produces KML documents with data layers and attribute information, it also generates a second document with a query window bubble. This second document is accessible via the KML files. The query window has a JavaScript-enhanced form that may be used to generate queries. Depending on the form of the query provided to GeoServer, the results may be returned as either an HTML table or a KML layer. Using GeoServer's WMS service, Google Earth may show either the produced KML or HTML layer.

3.3.1 Contents and Features of Distributed Geo-Information Visualization Service

On the basis of what has been learnt from web-based geo-information applications, client-side visualization services may be separated into four different categories: raster/image maps, vector maps, 3D maps, and virtual geographic environments. These sorts of maps and settings are available in virtual geographic environments (VGE).

a. Raster or image map is now the most popular method for displaying GIS data on the internet. Image maps can be generated in one of two distinct ways: the first method pre-generates the map by superimposing map symbols on the image background; the second method gives the user control over the appearance of the map by allowing them to select from a variety of display modes and replace individual map symbols as needed. Both approaches require superimposing map symbols onto an image backdrop, but the first method builds the map beforehand. Optionally, you can view an image map in its static, non-interactive version, or you can make it interactive by scrolling, zooming, and using other features. For the pre-generation, it is customary to employ common function interfaces such as NSAPI (Netscape server application programming interface) or ISAPI (Internet server application programming interface), as well as server-side webpage technologies such as ASP (active server pages), JSP (Java server pages), CGI (common gateway interface), PHP (Hypertext processing), SSI (server side includes), Servlet (server applet, or Java applet), etc. Image maps are typically saved as JPEG, GIF, or PNG (Portable Network Graphics) files when the creation process is complete (portable network graphic format). When seen from the user's perspective, the image map should load in all modern web browsers. In this situation, thin clients may be the answer to all of your computing problems.

b. Vector map used often in conventional GIS visualization. Plug-ins, Active x, Java, DXF, Active CGM, SVG, and other forms of software are required to improve the functionality of the majority of web browsers since they lack native support for vector maps. This is because the majority of browsers do not support vector maps. The appearance of the raster map is less refined and less precise than that of the vector map. In addition, a vector map allows zooming in and out, scrolling, and the adding of layers. However, if a substantial quantity of vector data is provided, the initial download time may be prolonged. Creating a multi-scale vector database is the solution to the issue. In addition to this, the vector map browser's server resources are unreliable. In contrast to conventional GIS, it may be challenging to show map symbols in their whole. Commonly, a spatial data engine middleware is used to convert vector datasets on a server-side website into a file stream or object flow that can be read by the client browser. If the vector datasets are kept on the server in a database, a subset of those datasets will be acquired using spatial data query middleware and provided to the client for expansion and display using a client-side spatial engine. In an architecture composed of a thick server and a medium client, data flow transmission allows client growth and display.

c. 3D maps There are rare circumstances in which a website may be instantly seen, searched, and reviewed in every major internet browser. OpenGL, which was created by SGI Company, Java, which was created by SUN, and Chomeffects, which was created by Microsoft are a few of the technologies employed in the construction of 3D maps. Java3D, Viewpoint, Cult3d, pulse3D, shout3D, blaxxun, shockwave3D, and Atmosphere B3D are further technologies. The Open Graphics Library, sometimes known as OpenGL, is a standard that offers a worldwide application programming interface (API) for creating 2D and 3D computer graphics in a number of programming languages and on several computing platforms. The interface consists of more than 250 distinct function calls, which allows the creation of complex 3D scenarios using the smallest building blocks. The Java 3D Application Programming Interface (API) is a 3D API based on a scene graph. It utilizes either OpenGL or Direct3D as its main operating system. The Java Community Process was included into the development of Java 3D beginning with version 1.2. Microsoft introduced Chromeffects as a technique to display 3D pictures and video in a web browser or standalone player software for advertisements incorporating flashing text and other forms of motion. Chromeffects is also developed to improve the user interface of online apps. Chromeffects is necessary to show complex multimedia despite the present bandwidth limitations. Web developers may utilize markup languages such as HTML, XML, C++, VBScript, and JScript to construct 3D environments with audio and video that can be viewed in a web browser. These surroundings may also have interactivity. A future version of Chromeffects was planned to support the three-dimensional representation of databases.

d. A computerized representation of the earth The Virtual Globe Environment contains 3D GIS, remote sensing, geo-visualization, geo-computation, virtual reality, networks and communications, agents, geo-cognition, and further associated technologies. Virtual reality environments consist of intelligent, cooperative simulations of the physical world (VGEs). Important components of a VGE are geo-spatial analysis and geo-visualization. These characteristics make it simpler to work on collaborative projects, aid in planning and decision-making, and can even be used for educational and entertainment purposes.

Allowing for slow connections, providing services for accurate geographical visualization, staying app-agnostic, and being easily scalable and responsive on the server end are some common criteria for web-based vector maps. There are four ways to visualize data: on the server, on the client, via an intermediary data conversion, or through client-server collaboration. Despite the fact that the client-server collaborative work method is well-suited to the task of massive data visualization on a variety of display devices, achieving efficient data transfer and a smart scaling technology remains a difficulty. This is particularly true when designing a communication interface. While the client-server collaborative work technique is well-suited to the challenge of large-scale data visualization on a variety of display devices, it is also well-suited to the task itself.

3.3.2 Visualization in Distributed Web Environment

a. Progressive Transmission of Vector Map

The transmission of data for vector maps in stages is gaining popularity and success. Due to Web GIS, the transmission of enormous quantities of geographic data through the Internet has become commonplace. Despite this, the transmission efficiency of geographical data remains a serious issue. The Internet's bandwidth has significantly increased over the years, but it is still insufficient to fulfill the expanding need for the rapid dissemination of vast quantities of data online.

Both the iterative and step-by-step methodologies for transmitting raster pictures over the Internet have been implemented successfully. Progressive raster transmission reduces picture resolution while maintaining visual quality via the use of different compression algorithms (such as JPEG or wavelets). It is also possible to divide the raster picture into numerous smaller pieces, which may subsequently be stored in a temporary directory on the server. This is an additional option. The browser will then display these elements in the sequence in which they were sent to the user's machine.

Nonetheless, the transmission of a progressive vector map is also possible, but it would need a somewhat different operating principle. A geographic information system's (GIS) principal goal is to depict data via the application of a coordinate system using point, line, and surface symbols. These symbols correspond to their equivalents in the material universe. Even though they are on separate levels of the visual hierarchy, both may still be drawn simultaneously. In a dispersed online context, however, the bandwidth restriction prevents the client from downloading all data simultaneously. A vector map must thus be separated into a file flow or an object flow, which is then provided sequentially. The process of producing a file flow or an object flow is what "data caching" refers to. It is accountable for ensuring that the integrity and completeness of the original data set are preserved in any files or objects that are transferred as part of the procedure. In this thesis, a vector data network is developed using Ajax (Asynchronous JavaScript and XML) technology. We can significantly minimize network bandwidth by delivering an asynchronous Ajax XMLHttpRequest. Consequently, we may achieve the same results as with standard desktop apps while saving bandwidth. It has become evident that using Ajax to enable the transfer of raster images as tiles is a viable strategy. The Ajax engine may handle a portion of the client's request to reduce server-side burden. This is one of the primary ways in which Ajax technology differs from conventional transmission methods.

b. Vector map design for networked applications

The expressiveness that may be achieved on a vector map through the utilization of symbols is significantly more than that which can be produced on a raster picture. The ability to use abstract map symbols is a must for any program that creates maps. Alternately, the design of the map symbols that are utilized in a web-based application needs to take both the resolution of the visual display device and the network transmission rate into consideration. It is possible to interpret the online design as an enlargement of the overall map design. The web design can be built utilizing any Java AWT (Abstract Window Toolkit) that is optimized for high-speed internet connections and is independent of platform. Windowing, graphics, and various user interface widgets are all included in the AWT. It is now included in the Java Foundation Classes (JFC), which is the application programming interface (API) that is considered to be the industry standard for the development of graphical user interfaces (GUIs) in Java. The remote extension of maps is a further strategy that the narrowband network might adopt. [Case in point:] The server will build the client's desired raster map format after it has finished implementing the local extension functions of the map symbols, and it will then deliver this format to the client. After that, the client's view of the map will look like this. There must be a significant number of client devices available in order to finish the display and expansion graphics properly. This functionality is included into Geosurf's picture services (particularly the Geosurf Image Renderer and the Geosurf Servlet), so users will always have access to it).

c. Construction of 3D virtual scene

The surge in popularity of virtual reality may be ascribed to technological and multimedia advancements. VRML permits the creation of virtual worlds with three-dimensional objects, lighting, animation, and music, as well as other environment components. Using the "model/world" MIME type, one or more VRML files, each describing a unique online environment, are uploaded to the Internet. With VRML, it is feasible to produce aesthetically appealing images; nevertheless, it is not simple to include the tiniest of details while keeping the file size in check and ensuring excellent navigation features. Not all operating systems support VRML, which is an additional drawback.

When compared to VRML, Java 3D exposes itself to be a more robust and portable language. OpenGL (Open Graphics Library) and DirectX programming APIs served as the foundation for the creation of Java 3D. The computer language Java3D is an object-oriented (OO) language. As shown in Figure 3.5, it has a variety of graphical display capabilities and is also compatible with pointing devices such as mice. This permits the interactive modification of 3D Web Pages. The Java programming language may be extended with Java 3D. It provides a high-level application programming interface (API) for describing and manipulating 3D scenarios visually. As a result, it is now fundamentally dependent on a powerful programming language. Because Java3D is an application programming interface built on top of Java, it offers a totally object-oriented approach to the creation and maintenance of the virtual agent and its operating environment. With its support, the system is capable of a more seamless integration of 3D content, interface, and events. An attractive feature of Java 3D is its comprehensive event architecture. A unique aspect of this design is that it gives a single interface for timer and scene change events. In addition, Java3D was built from the bottom up to use multi-threaded programming approaches, resulting in a substantial speed boost.

3.4 WIRELESS GEOSENSOR NETWORKS: AN OVERVIEW

Sensor networks are often composed of relatively affordable, intelligent, and small sensors with limited on-board processing capabilities and storage capacity, as well as wireless communication connections with a limited range that are supported by radio technology. In the past, sensor networks were composed of a distributed collection of sensor nodes that were all physically connected to a central data hub. In spite of this, wireless communication is presently a viable alternative for the sensor nodes. A sensor node may be identified based on the size of its sensing area, the amount of storage space it provides, the length of time its battery can last, its processing power, and its networking power. A sensor's field of view is extremely narrow. In contrast, a sensor network that collaborates to monitor a greater territory and accomplish more ambitious objectives is more successful. Every sensor in a network is capable of collecting data from its immediate surroundings, doing analysis on that data locally, relaying the results to other sensors in the network, and aggregating data as necessary.

Geosensor networks offer a wide variety of possible applications, including the real-time detection of phenomena (such as the detection of floods and volcanoes) and the tracking of items (e.g., animal monitoring). Networks have several possible uses, including but not limited to environmental monitoring, change detection, traffic tracking, border security, public safety, etc. They are used for the efficient and trouble-free collection of data required by intelligent environments in a range of contexts, including but not limited to buildings, utilities, industries, homes, ships, and automated transportation systems. Sensor networks provide the monitoring and management of traffic in a number of ways. At the majority of junctions, vehicle detection and light control systems are managed by sensors installed above or below the ground. Additionally, high-traffic sections of roads are often monitored by video cameras, and the information captured by these cameras is analyzed by control room personnel (Chong & Kumar 2003). There is a possibility that sensor networks might enhance the security of vital institutions such as power plants, data centers, and other such facilities. Thanks to sensor networks that use video, audio, and other sensors to detect impending danger, threats may be identified early, allowing for quicker responses. Sensing has attracted the interest of business sectors for some time as a way to save costs, improve equipment efficiency and maintainability, and maybe even enhance user performance.

3.4.1 Wireless Sensor Networks Technology

The contemporary sensor networks use capabilities and technologies that were unavailable even a short time ago. These capabilities and technologies were unavailable. From sensors to processors to communication devices, Silicon Labs, Moog Crossbow, Newtrax, and Microstrain are aiming to minimize the size, complexity, and cost of every component of a sensor network. This comprises the size of the sensors as well as the size of the networks. The development of a network of microscopic, intelligent sensor nodes that are implanted throughout the environment has greatly improved our day-to-day existence. Despite their little size, these sensors offer a great deal of computer power, making it simple to program them to serve as processing nodes in a sensor network. This is feasible because sensors transmit a great deal of data. Numerous modern comforts, such as cameras, gps systems, microphones, and thermometers, incorporate sensory capabilities into their designs. In addition to these benefits, the introduction of high-powered CPUs into MEMS and other devices, as well as the availability of massive databases and communication platforms, ushered in a new era of technologically powerful sensor networks.

The ability of wireless networks based on IEEE 802.11 standards to give equal capabilities to wired networks at a fraction of the cost of conventional networks is one reason wireless networks are gaining popularity. The group is responsible for defining the IEEE 802.15 standard for local area networks with a range of 5 to 10 meters.

A sensor network with a limited range is the kind of technology that functions most effectively when applied in private networks. The manufacture and implementation of low-cost sensor networks will be significantly aided by the development of suitable algorithms and technologies for short-range sensors (Anon n.d.). The amount of energy required for computation and communication has also decreased due to improvements in chip capacity and processor fabrication. It is now conceivable to combine all three functions—sensing, processing, and communications—onto a single chip, which reduces the entrance barrier and opens the way for widespread deployment. In the near future, advances in microelectromechanical technology will provide sensors that are not only more powerful, but also more portable, intelligent, affordably priced, and versatile.

3.4.2 Wireless Sensor Networks Problems and Technical Challenges

The processing of data, sustaining connectivity, and management of sensors are three of the most challenging technical challenges in sensor networks. There are technical challenges in the areas of wireless ad hoc network discovery, control, routing, collaborative processing, querying, tasking, and deployment as a result of harsh, uncertain, and dynamic environments; the constraints imposed by environmental obstacles; and the energy and bandwidth limitations of sensors. These issues are the result of a mix of causes.

a. Sensor Network Topology

It is difficult for a network sensor to execute its job without first acquiring knowledge about the network's topology. In order to facilitate processing and cooperation, each node must be aware of the status and location of its neighbors. In many instances, it is possible to make reasonable predictions regarding the topology of the planned network. Whenever sensors are lost, moved, or added to a dynamic network, the topology must be generated in real time and often updated. This situation's topology is not static; rather, it is dynamic and constantly changing. After that, it should be possible for various kinds of sensors, both stationary and mobile, to locate one another in the environment. In the context of establishing sensor networks, it is sometimes necessary to define or identify the global topology, even though each sensor node only communicates with its neighbors. This is because the global topology may influence the deployment of the networks. In addition to comprehending the network's structure, each sensor must be aware of its position within the network. The Global Positioning System, sometimes known as GPS, is one answer to the problem of being lost and confused. In circumstances when the usage of a global positioning system (GPS) would be impractical or too expensive, alternatives such as relative positioning algorithms have been developed.

b. Network Control and Connectivity

Due to the variable nature of resources like as electricity, data transit, and processing power, sensor networks may be needed to dynamically change their configuration and function independently. Connectivity in unplanned networks must emerge spontaneously from a combination of algorithms and programs. Therefore, the software and system architecture must provide the necessary control over the network's dependability in the case that communication links are insufficient. To achieve this objective, study must be conducted on a range of pertinent topics, including the ideal network size and number of connections and nodes for redundancy.

Connectivity and environmental adaptability may be ensured by installing a sufficient number of network nodes to manage network routes and by providing algorithms to determine the optimum network pathways. This will increase the network's adaptability. The diffusion routing methodology is one of these techniques. This strategy takes use of data acquired from geographically nearby nodes. The sacrifices that must be made in sensor networks between latency, reliability, and energy consumption represent another significant obstacle. This might be affected by features of the system such as the network's size and the number of nodes per square meter.

c. Data Fusion and Processing in Sensor Networks

Nodes in sensor networks perform essential tasks, including data gathering and processing. Distributed information fusion and collaborative signal and data processing across the network are two fields of research that use sensor networks. The extent of information exchange between nodes and the combination of information from other nodes are two of the most important technical problems in this area. When more data is handled from more sensors, performance may be enhanced, but at the cost of higher connection requirements. Raw signals, for instance, need a greater transmission bandwidth yet lose less information than more polished types of data. In collaborative signal and information processing in sensor networks, it is crucial to consider the different performance vs resource consumption tradeoffs.

The detection, tracking, and classification of targets are essential applications of sensor networks. When several targets are crowded into a small region, data dependency becomes a significant issue. Each node's acquired environmental data must be connected to specified goals. In order to minimize redundancy and enable fusion, it is also necessary to link targets identified by one node with targets detected by other nodes. Optimal data association is computationally expensive and requires a substantial amount of data transport bandwidth. Consequently, for usage in sensor networks, approaches for linking distant data must strike a compromise between performance and resource consumption.

d. Sensor Network Interface and Data Query

A sensor field may be compared to a massive and intricate database. Instead of manually entering data, dynamic data gathering utilizes input from the environment. This is an alternative to data entering by hand. There is data dispersion across a network, some of whose nodes may be situated in disparate locations and linked in unreliable methods. When implemented across these networks, the constraints of low-latency, real-time, and high-reliability add an extra degree of challenge to the database view.

It is essential to offer a user-friendly interface for interactively modifying and querying the sensor network. Users should be able to provide instructions and access data such as operational priority and target type while respecting the privacy of sensor-specific information. Both the process of establishing an easily queryable database and a language that can be used for both activities and queries provide obstacles. The organization of data, the use of caching, and the compilation and placement of queries are more obstacles that must be overcome.

e. Real Time Output in Sensor Networks

Due to technical advances in sensor platforms for data collection, storage, processing, handling, preparation, and analysis, it is now feasible to get real-time data streams from sensor networks. These streams may serve a number of functions. As a direct consequence, sensor systems generate vast quantities of data in a broad range of forms, all of which are available as data streams. Consequently, the difficulty comes in the creation of adequate real-time data management tools for analyzing and processing the sensor network's data stream. Various algorithms may be used to modify real-time data streams, such as those used to monitor financial transactions. Because sensor network data is often georeferenced, the algorithms now in use are incapable of handling sensor networks. The development of new technologies that can swiftly evaluate massive data streams while simultaneously considering their temporal and geographical properties is an additional obstacle.

On the other hand, the widespread availability of Internet connectivity and the rise in the number of real-time data streams from sensors have increased people's interest in the development of online sensor networks. The phrase "sensor web" is used to describe networks that allow users to choose relevant data streams depending on context and other variables (location, application, time, etc.). Users must be able to choose the required sensors and information sources from a drop-down menu. The creation of the software necessary for real-time data analysis, processing, and querying is a complex endeavor, as is determining how to connect sensor networks and the data they produce to the internet.

f. Sensor Network Deployment

The geographical locations where the sensors are intended to be dispersed in the environment may have a major influence on the sensing performance (such as sensing capabilities according to environmental restrictions and installation suitability) and running expenses. This is due to the fact that environmental limitations differ from location to location (e.g. hardware, deployment, maintenance). Outside of the most basic settings, the placement of sensors is seldom a simple operation, necessitating the use of complex decision-making systems.

In sensor networks, the development of novel algorithms for sensor placement is one of the greatest obstacles. This may be achieved using stochastic global optimization approaches or local geometric procedures that integrate information about the terrain (including any man-made facilities) with precise sensor models. Because there are so many various applications for sensor networks, it is vital to create creative optimization techniques for generating and selecting sensor placement candidates. To take full use of the processing power provided by the new technologies, the optimization process must be conducted on high-performance computer facilities.

This dissertation focuses primarily on the subject of sensor placement inside networks. As a result, the remainder of this chapter will be devoted to introducing the concepts of coverage and sensor deployment in networks, as well as optimization and their methodologies in sensor network deployment.

3.4.3 Spatial Modeling Issues in Deployment Of Wireless Geosensor Networks

Geosensor network communication may be conceived as a graph in a two-dimensional (2D) Euclidean space, with nodes representing locations and edges denoting connections. Assuming that the sensors are able to communicate with one another, the purpose is to arrange them such that the combined sensing zones can monitor the whole region. This idea lays special emphasis on sensing and communication, the modeling of which has a direct influence on sensor location. When modeling sensing and communication, these topics will focus on the geometrical challenges that occur. At the conclusion of this part, we will describe two geometric structures that are widely utilized in the geometrical geosensor deployment methods. The Delaunay triangulation and the Voronoi diagram are these structures.

a. Sensing models

The binary disc model is the most fundamental kind of sensing model. It specifies that the region of a sensor's sensitivity is entirely confined inside a certain disk. It takes into account a sensing range, which is effectively a circular disk with a radius of Rs, for each sensor; Points that fall within a sensor's sensing range are completely covered by that sensor, but points that are outside a sensor's sensing range are not covered at all (Figure 3.4.a). This model does not account for the unavoidable signal attenuation as it travels since it assumes that the surrounding environment is completely devoid of impediments. The coverage issue of a sensor network may be readily described by the binary disc model if the union of the sensing disks, which may or may not be similar, is calculated (Figure 3.4.b).

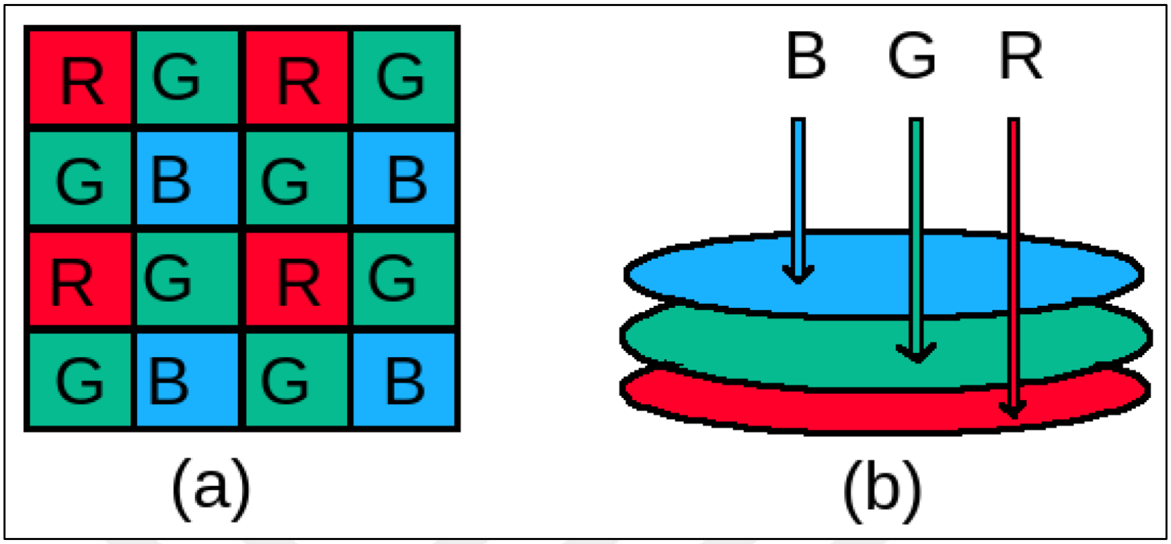

Figure 3.4: Binary disc model of sensing: (a) Only the gray region is covered by the sensor s_i; (b) Modeling

the issue with sensor network coverage that the binary disc model causes. To expand the range of applications for this model, the following improvements are made:

a. Sensitivity, on the other hand, is not a constant; it changes as one moves away from the sensor node.

b. The shape of the sensing area is not entirely round.

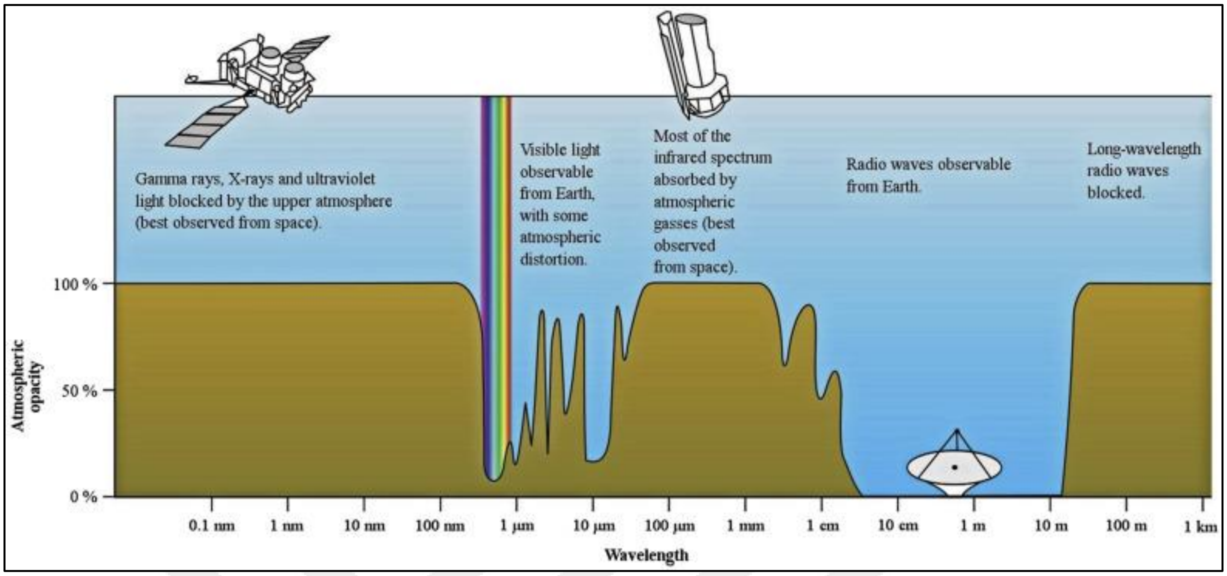

Figure 3.5: Attenuation of the sensing capacity with increasing distance to the sensor s_i

The probabilistic sensing model, which is used to simulate the sensitivity of sensors such as infrared and ultrasonic detectors, is based mostly on this premise. This model allows for the specification of both the initial sensor detection uncertainty (R1) and the maximum sensing range (Rmax). There is a probability function of distance for all positions between the two disks in the diagram (Figure 3.6):

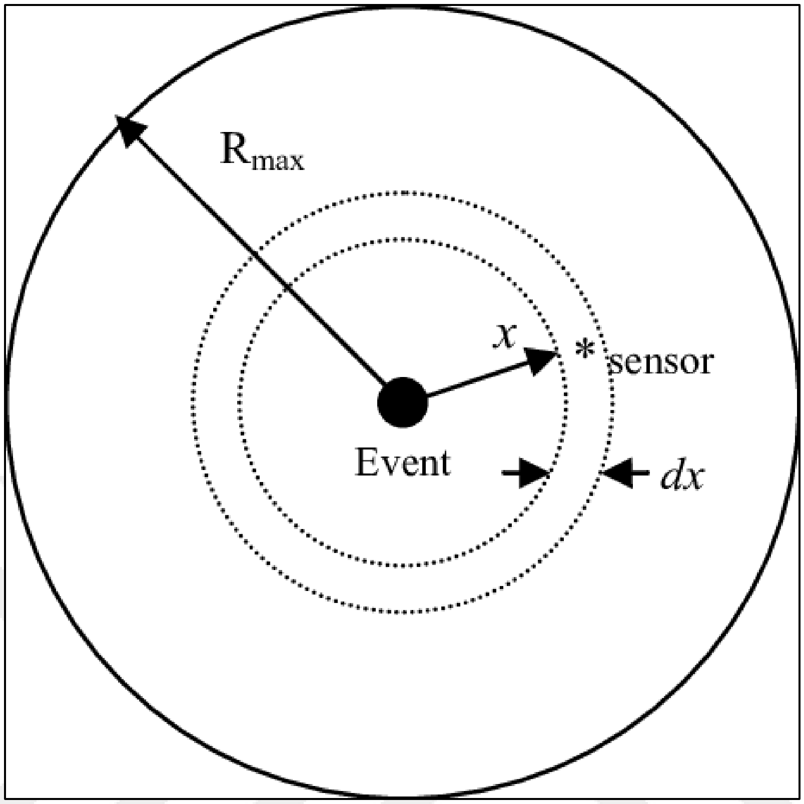

Figure 3.6: Probability sensing model: The dark gray disk is covered; the coverage of the light gray nut is a probability function of distance to s_i; elsewhere is not covered

a. Non-circular sensibility

a. If the sensor sends data in all directions and the environment immediately around it is steady, then the circular sensing zone represents the real world accurately. Conversely, there are situations in which these presumptions are invalid:
b. The phrase "directional sensors" refers to a variety of sensors, such as cameras, whose field of vision is limited to a single direction (Figure 3.4).
c. If there are obstructions in the surrounding area or if the environment is not uniform, the sensor's detecting capabilities will not be uniform in any direction. .

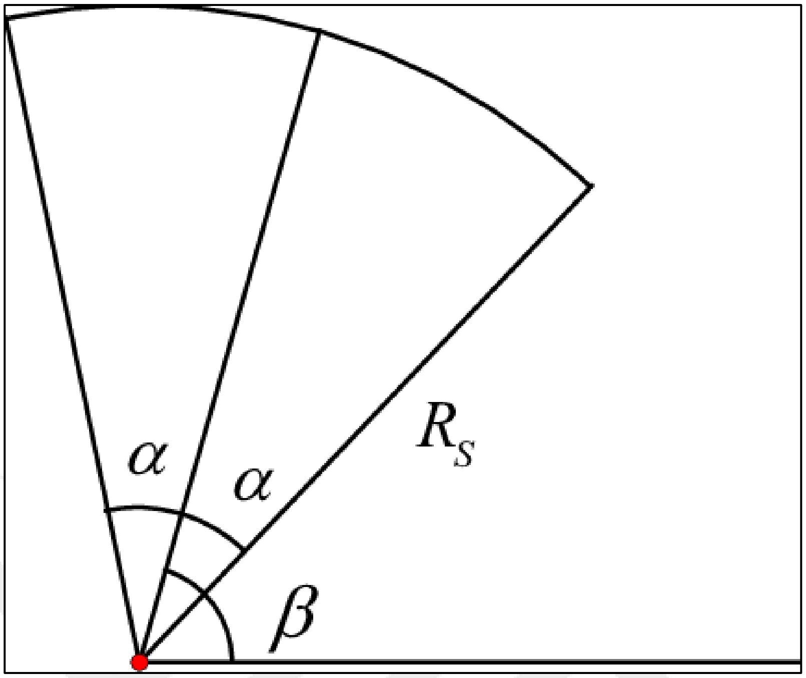

Figure 3.7: directional sensor

b. Communication Models

The phrase "wireless sensors" refers to a category of sensors distinguished by their low power consumption, compact size, and dependence on radio technology for wireless transmission and limited storage. Because communication between sensors requires energy, it is vital to make the process more energy-efficient in order to extend the useful life of wireless sensor networks. The inherent unreliability of radio connections between sensors, on the other hand, makes it very challenging to develop a realistic simulation of radio communications.

Modeling sensor coverage is quite similar to the simplest model of sensor communication, the binary disk model. This model implies that each network node has a communication radius Rci. This indicates that sensors situated within Rc of si may be able to receive data from si (Figure 3.4.a). However, practical data has cast doubt on this communication idea since, in reality, the radio signal intensity provided by the sensors weakens with increasing distance. Numerous physically disruptive phenomena, like as interference, scattering, diffraction, and reflection, are brought about by the existence of other transmissions and obstructions along its route.

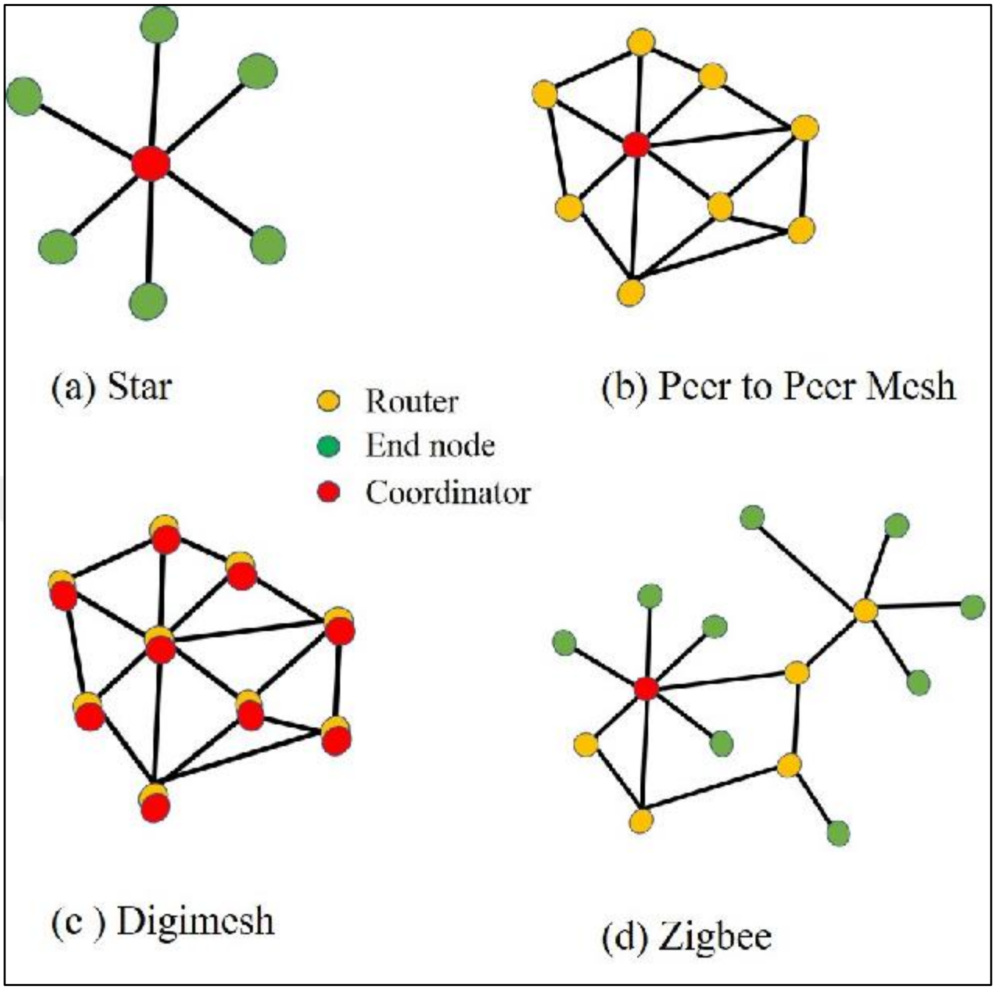

Figure 3.8: Basic sensor network topologies

Due to the manner in which wireless sensor networks interact, they are well suited for modeling using graphs. Each sensor in this network functions as a node, and two nodes are linked by an edge if the Euclidean distance between them is less than the minimum communication radius. Consequently, several parameters were able to be retrieved from the induced communication graph:

a. On the graph, the "degree" of a sensor is determined by the number of sensors directly next to it.
b. To restate, if the induced communication graph is linked, then all of the sensors in the network are able to communicate with one another since they are all connected to the same source of information. This suggests that there is always a means of communication between any two

sensors, regardless of their configuration. In other words, they are either directly connected to one another by an edge, which would make them one-hop neighbors, or they are related to one another through a series of edges (i.e., they are multi-hop neighbors).

c. "k-node connected" refers to the condition where there are at least k-disjoint pathways connecting any two pairs of nodes in a sensor network. This grade indicates the dependability of the network.

c. Preliminary geometric structures

In this part, we will discuss both the Delaunay triangulation and the Voronoi diagram, which are two geometric structures often utilized in geosensor network deployment approaches.

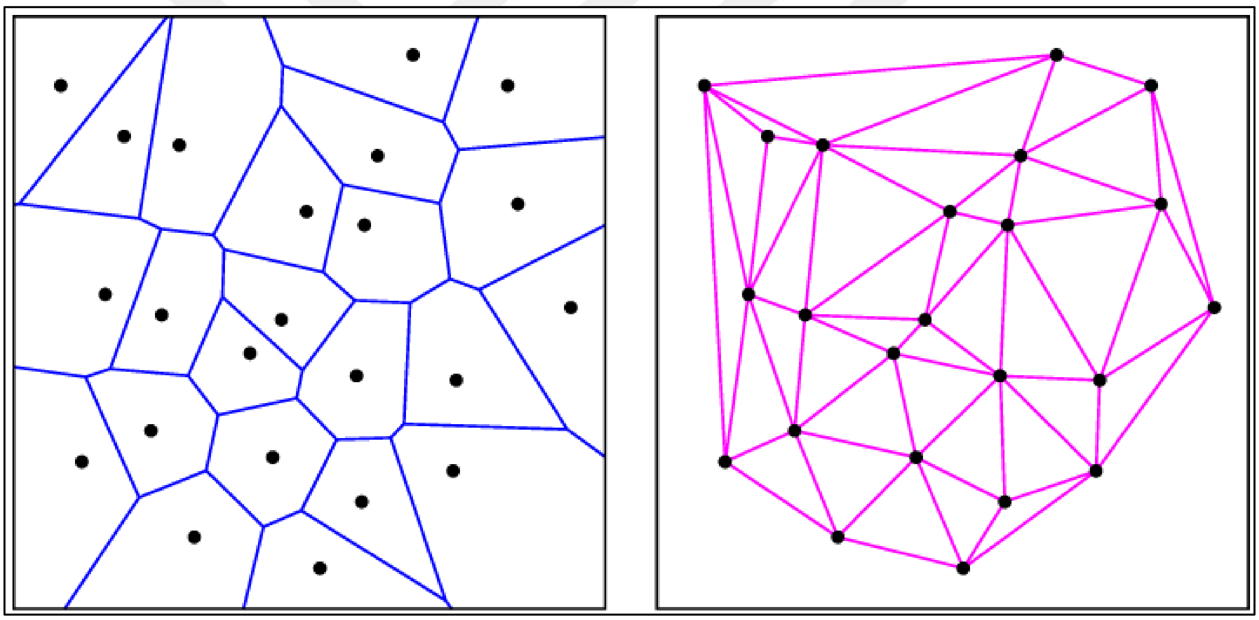

Figure 3.9: shows an example of a point Voronoi diagram for a set of 2D points

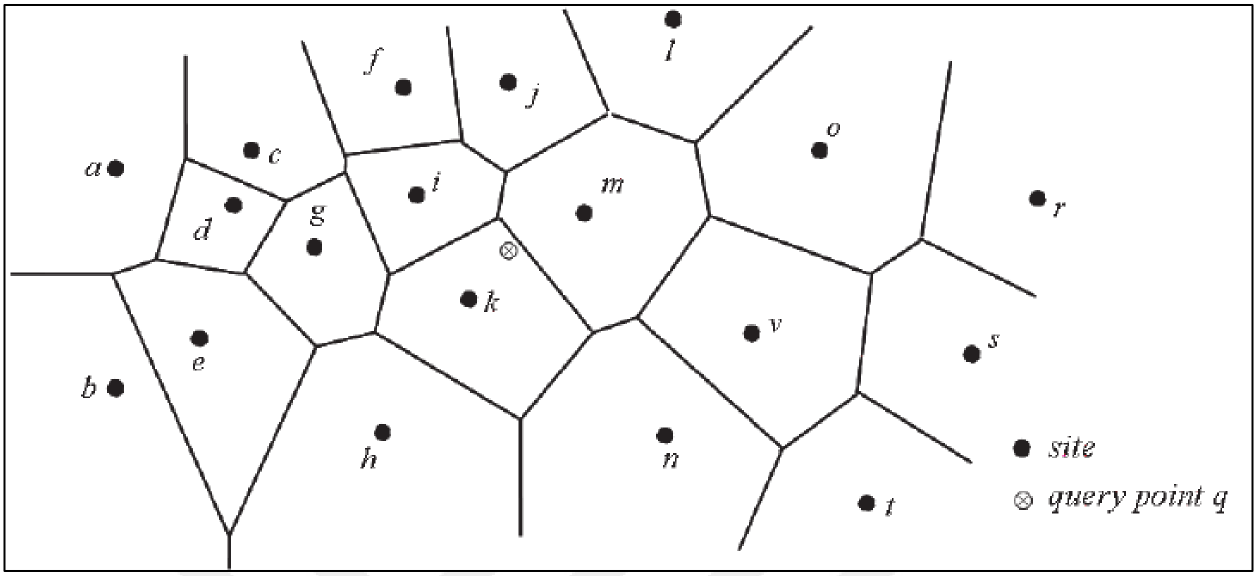

Figure 3.10: Voronoi diagram of a set of points in the plane

In this context, the Delaunay triangulation and the Voronoi diagram are instances of complementary structures. Each Voronoi cell and each Delaunay triangle have the same number of vertices, and each edge of each Delaunay triangle has the same number of vertices as the triangle itself. The centers of the circum-circles in a Delaunay triangulation correspond to the Voronoi vertices, and a Delaunay triangulation may be constructed by linking the nearest Voronoi generating points (Figure 3.11). Due to the fact that Voronoi diagrams are more complex to create, manage, and store than Delaunay triangulation, this duality is very advantageous, since all operations may be conducted on Delaunay triangulation, and the Voronoi diagram is only extracted when necessary.

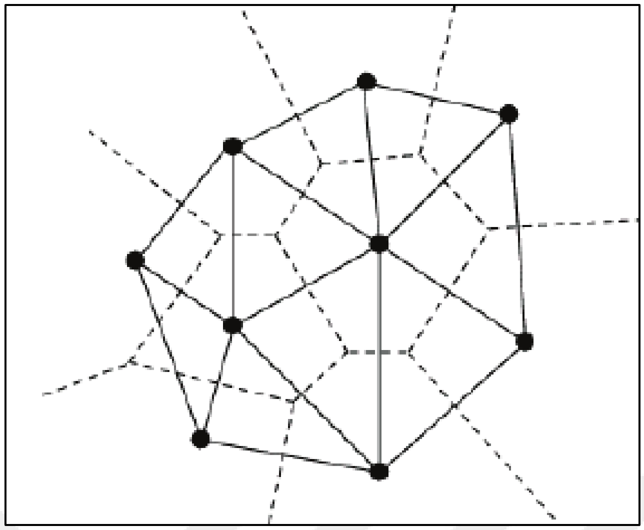

Figure 3.11: Duality of Delaunay triangulation (solid lines) and Voronoi diagram (dashed lines)

3.4.4 Spatial Coverage in Geosensor Networks

As used above, "visual coverage" refers to the radial distance from the source to the target. However, in sensor networks, if a site is covered, it means that at least one sensor node can reach there. The disk-like outline around the sensor represents a continuously detecting region. There will be gaps in the coverage if this condition is not met for all areas included in the study. In light of the discussion thus far, the coverage issue in sensor networks is the method of deploying a set of nodes inside a given environment so that every point in the sensing field is covered. Deployment strategies range from just dropping them to arranging them in certain patterns. It could be difficult to find a way to implement random scattering that satisfies all coverage and connectivity needs. With the help of a deployment model, sensors can be placed in the most optimal way or relocated to better locations.

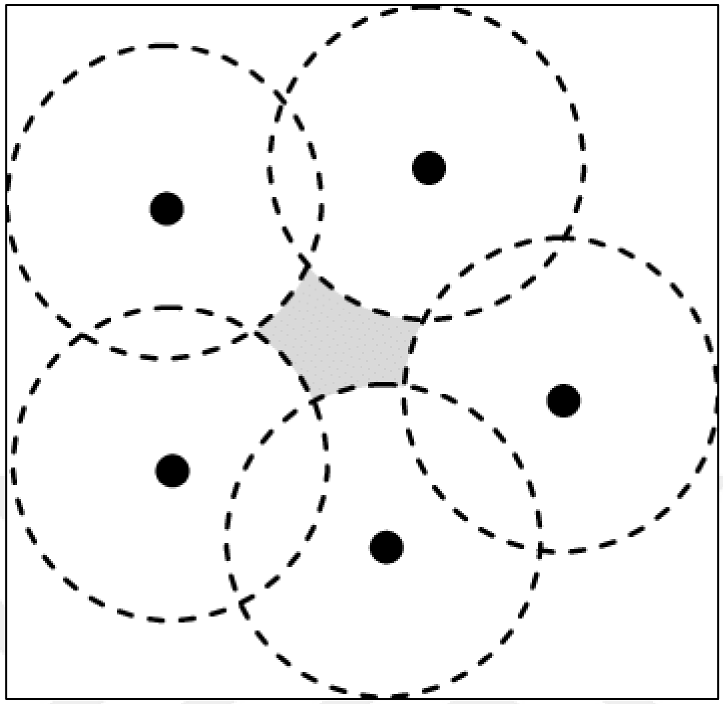

Figure 3.12: Overlaying the Voronoi diagram and sensor sensing regions to detect the coverage holes (shaded regions) in a sensor network

Some publications use the term "coverage estimate" to refer to an evaluation of a sensor's capacity to distinguish objects inside its field of view. Coverage estimates are the estimated usual capability of seeing a moving object inside a sensor field. This estimation is based on the notion of exposure.

There are several methods for estimating risk, such as "worst case" and "best case" insurance scenarios. Due to the path's location in an area where sensor nodes have limited visibility, there is a very little chance that any things travelling along it will be detected. Alternatively, optimal coverage is reached in places with more sensor visibility; hence, an item being moved along this path has the highest possibility of being identified. Together, these two measurements give useful insight into the quality of network coverage and may influence the choice to deploy more sensors. The research conducted to far has yielded a variety of possible solutions to the difficulties posed by both the worst-case and best-case coverage situations.

While a Voronoi-based exposure measure has been offered as a way to estimate the degree of coverage supplied by a sensor network, a maximum breach path technique has been presented as a way to handle the most probable coverage condition. It refers to the route in a sensing field that, while going from one position in the field to another, always follows the path that provides the shortest distance to the nearest sensor. Due to the fact that the line segments that represent the sensor nodes in a Voronoi diagram are furthest from the sites that are closest to them, the greatest breach route must be located here (Figure —-). A Voronoi diagram of the sensor nodes will be generated to begin. When this is complete, we may consider the resulting diagram to be a weighted graph, where the importance of each edge is proportional to its distance from the nearest sensor. In its last stage, the approach combines a binary search between the edge with the least edge weight and the edge with the biggest edge weight with a breadth first search to decide whether or not it is feasible to create a route from the initiation point to the termination location.

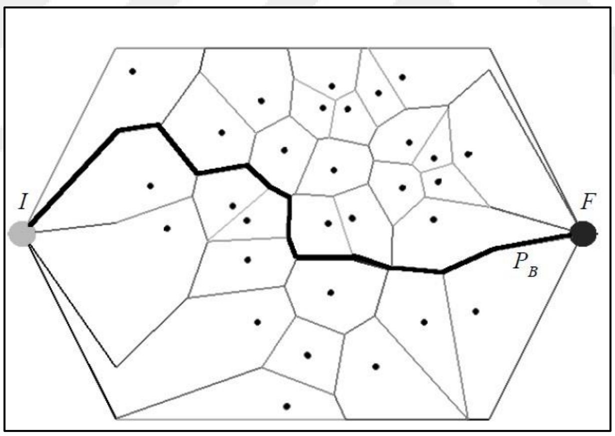

Figure 3.13: Sensor field with weighted Voronoi diagram and maximal breach path

Similarly, the notion of the largest support route is used to resolve the issue of optimal coverage. When the distance between any two locations within a sensing region is minimized, this is the shortest route between one point and another. Simply defined, this journey will include going along the straight lines connecting the various sensor nodes. Given its geometric limitations, the Delaunay triangulation creates triangles with the shortest edge lengths conceivable. Considering this, the lines of the Delaunay triangulation of the sensors should represent the most effective support route (Figure 3.14). This approach involves constructing a Delaunay triangulation of the sensor nodes and then treating it as if it were a weighted network. The length of each edge is the weight for the edge to which it belongs. A strategy that employs breath-first and binary searches for the best network coverage is used to determine the route that obtains the most support.

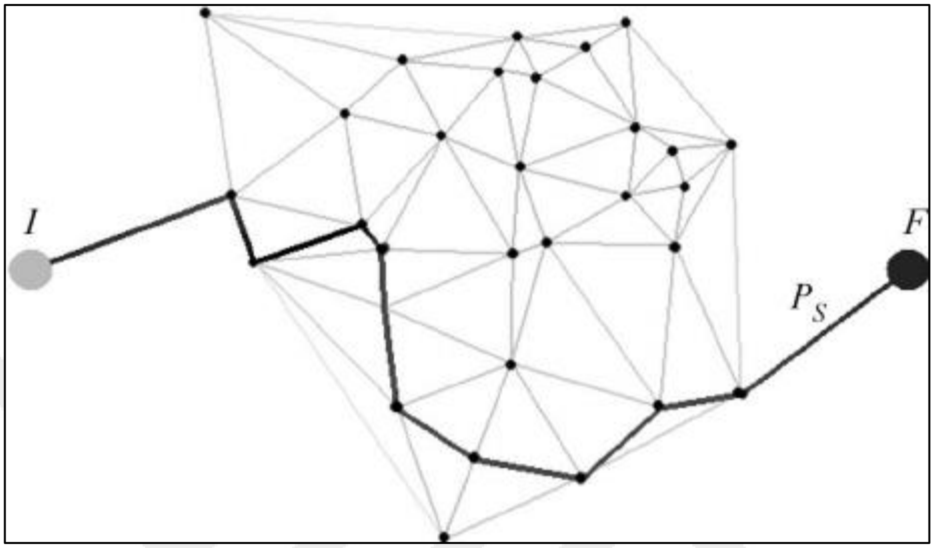

Figure 3.14: Sensor field with weighted Delaunay triangulation and maximal support path

3.4.5 Optimization Algorithms in Geosensor Networks Deployment

After using methods such as Voronoi diagrams to discover gaps in visual coverage, an optimization algorithm may rearrange sensors to fill the gaps. Depending on the breadth of the investigation, the currently used techniques for determining the optimal placement of sensors may be categorized as either local or global. Before digging into the particulars of these methods for installing sensor networks, it is important to define optimization and its umbrella categories.

a. General Concept of Optimization and Its Categories

There are a variety of techniques we may use to improve our performance. Figuring out how to go to work quickly, when to take the bus so as to spend the least amount of time waiting, and which of multiple daily responsibilities to do first are examples of choices that must be made. "Optimization" refers to the process of modifying the settings of a device, mathematical approach, or experimental design to get the best or smallest feasible outcome (Figure 3.15). The variables serve as input, and the associated process or function is either the cost function, the goal function, or the fitness function.

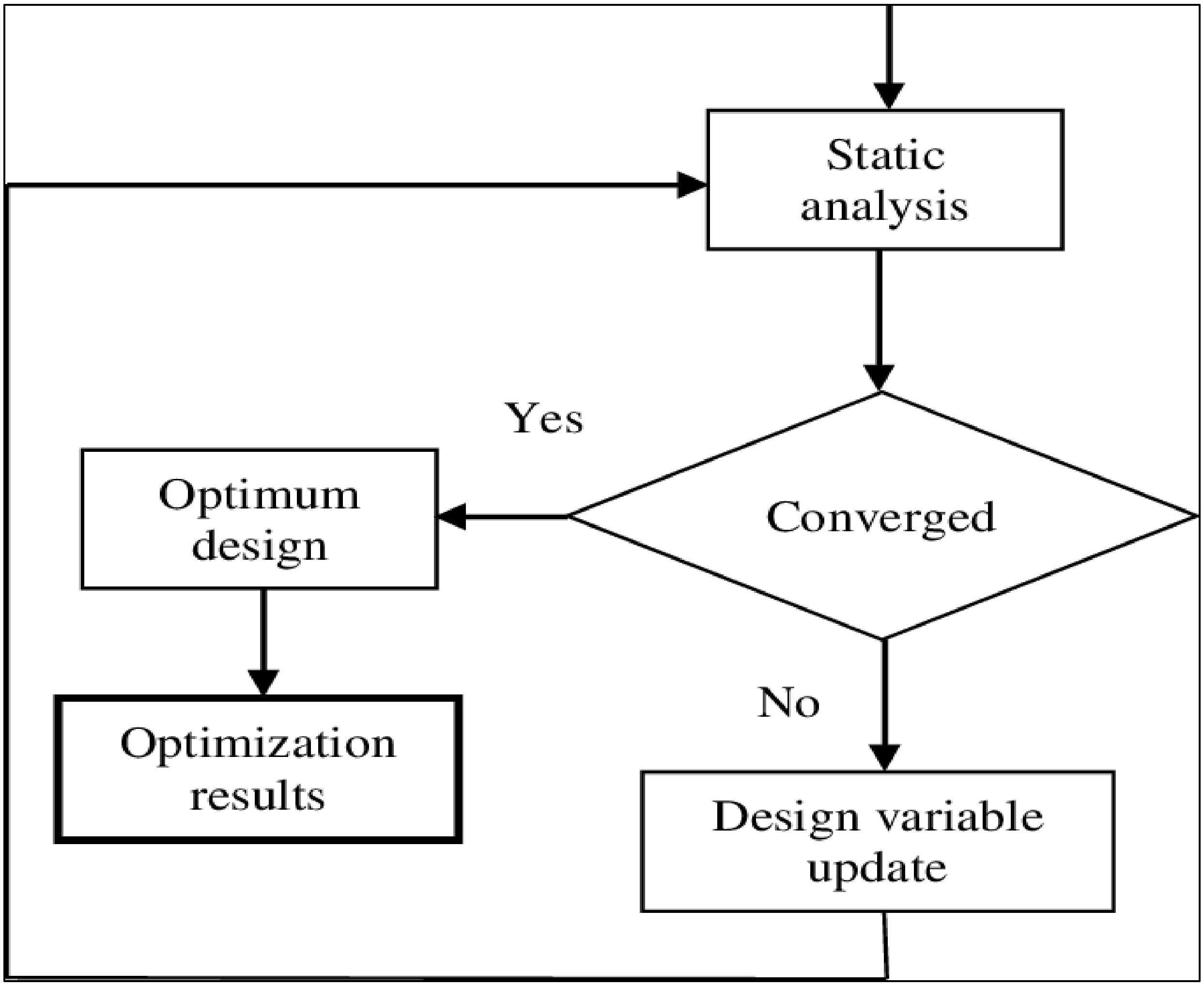

Figure 3.15: Diagram of an optimization process

There are six primary types of optimization algorithms, which are all interconnected. Depending on the circumstances, an optimization strategy for a single variable may be either limited or unconstrained. The following are short summaries of the various groups:

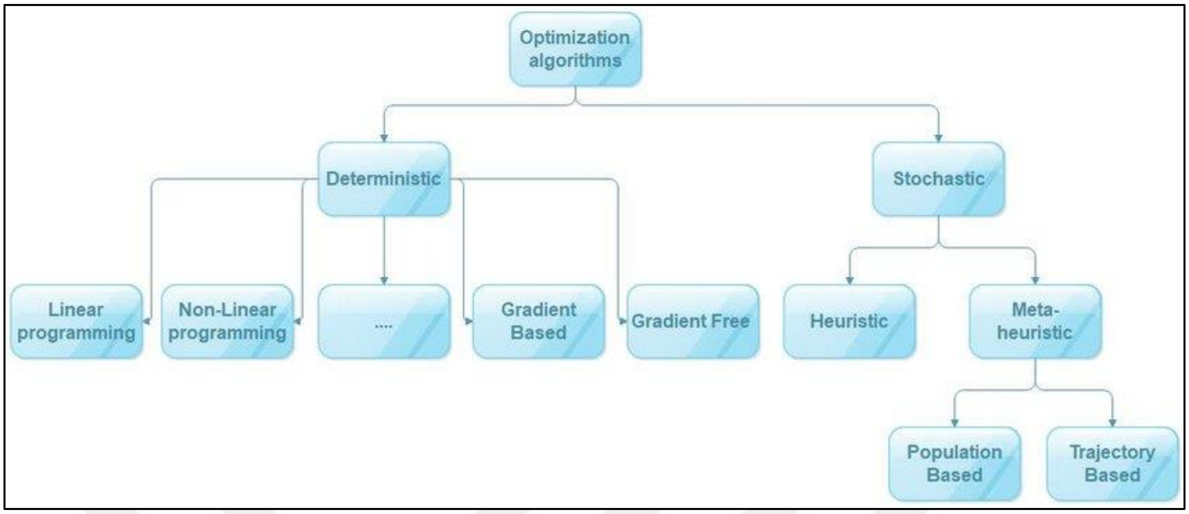

Figure 3.16: Categories of optimization algorithms

a. When improving a process by trial-and-error, the outputs are determined without a thorough understanding of the processes that result in the development of those outputs. In function optimization, formulas rather than verbal explanations are utilized to express the purpose of the procedure.

b. Unlike the output of a dynamic optimization process, the output of a static optimization process does not vary with time. The result of a dynamic optimization method, on the other hand, varies with time. Since the solutions to the issue of dynamic optimization vary with time, it may be challenging to identify a solution. In a dynamic optimization, for instance, while attempting to determine the optimal route, the shortest route is not necessarily the best one due to variables such as traffic, speed limits, weather, accidents, etc. Alternatively, the ideal route may be one that is longer but has fewer impediments.

c. It is not usually the case, however discrete variables are occasionally used instead of continuous ones when optimizing anything. While the potential range of values for a discrete variable is restricted, the possible range of values for a continuous variable is almost limitless. In contrast to continuous optimization, which is used to identify the function that yields the least value when evaluated over a collection of real numbers, discrete optimization is used to prioritize a succession of jobs on a list.

d. Regardless of the nature of the optimization issue, there will almost always be constraints imposed by the environment or easily available resources (e.g., physical limitations, time restrictions, etc.). If a solution satisfies all of these characteristics, we may consider it successful. Constraints are a more inclusive term that describes the interdependencies between the choice variables and the constants (or parameters) involved in the issue. In unconstrained optimization, variables may take on any value, but in restricted optimization, equality and inequality of variable values are included into the cost function. Unrestricted optimization permits variables to assume any value.

e. Utilizing fundamental calculus principles, convex optimization strategies aim to minimize convex functions over convex sets. These algorithms are provided with beginning values for the variables involved in the process. A function is said to be convex if the line connecting any two points on its graph in a two-dimensional or higher-dimensional Euclidean space is above the graph. These methods guarantee the finding of a global minimum whenever a local minimum is found. An additional characteristic of convex optimization is that, for every strictly convex function with a minimum value, the uniqueness of the function's minimum is guaranteed. The convex minimization problem is an extension of several other optimization problems. A problem requiring the maximizing of a concave function f may be restated as one involving the minimization of a convex function –f. This is because the domains of both functions are identical. The outputs of non-convex random algorithms may be determined by the use of probabilistic calculations. Contrary to convex techniques, gradient optimization is not required while using these methods. Because of this, they may be used to non-continuous and differentiable functions. These methods are also known as direct search, derivate-free, and black-box approaches, among others.

f. When just a single statistic must be improved, we refer to an optimization as having a single-objective emphasis. Multi-objective optimization aims to simultaneously optimize many unique measures while adhering to a predefined set of rules and constraints. As the number of dimensions increases, the complexity of the optimization procedure constantly climbs. Even when the optimization of one objective leads to the optimization of the other objectives, it is not necessarily appropriate to classify an issue as a multi-objective optimization problem. In a variety of contexts, such as network analysis, the financial sector, and the oil industry, these sorts of issues might arise.

After introducing optimization and its several subfields, the next part will discuss the global and local optimization techniques currently used in the design of sensor networks.

b. Global Optimization Approaches in Sensor Network Deployment

To determine the optimal or minimum value of a function on a global scale, global optimization approaches are used. In general, these strategies try to locate the best value of a function throughout the whole search space. Therefore, a comprehensive knowledge of the search space, its attributes, and its reaction to the optimization process may be necessary. Particularly, iterations of iterative algorithms may take the whole study domain into consideration.

Stochastic methods of optimization include the generation and use of random variables. The annealing procedure includes heating a material to a temperature at which its atoms may move freely and then cooling it, forcing the atoms to rearrange themselves into a lower energy state (i.e., a crystallization process). During this operation, the free energy of the material is diminished (the crystalline state is the state of minimum energy of a system). The timing of cooling is crucial: If the solid is cooled too quickly or if the initial system temperature is too low, the solid will not crystallize and will instead enter a higher-energy amorphous state. Instead of reaching the lowest potential energy state, the system approaches a local minimum with a higher energy level. In the relevant technique, first estimates are made about the cost function's variable values. Increasing the temperature suggests that the variables are being altered arbitrarily, resulting in more chaotic behavior. The output produced by entering a few variables into the cost function. A major premise of SA for constructing sensor networks is to randomly move sensors while optimizing coverage. Thus, new sensor sites are permitted if the coverage value improved as a consequence of each cycle's movements. The temperature function facilitates the acceptance of sensor sites with inadequate coverage in specific locations, hence preventing the sensor from being trapped in local optimums. The temperature function begins with higher values, enabling it to tolerate more worst-case situations as sensors are distributed across the network. Then, in future rounds, the values decrease, and the sensors are relocated to their ideal positions.

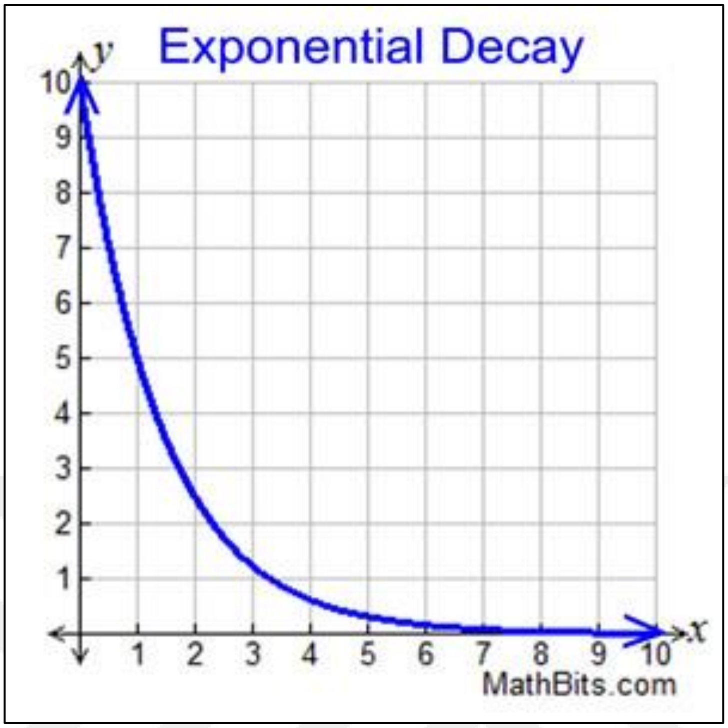

Figure 3.17: illustrates how the temperature function is defined as an exponential decay function

Genetic algorithms (GA) are gaining popularity as a kind of artificial intelligence used to optimize large-scale issues. The genetic algorithm is a heuristic approach to optimization inspired by the four stages of natural evolution: initiating, selecting, reproducing, and terminating. In the sensor deployment issue, sensors are positioned in an iterative fashion. At each iteration, only the sensor relocations that enhance the deployment objectives are kept via an evolutionary process, while the rest are discarded. In order to optimize a sensor network, an algorithm may place nodes so as to simultaneously improve coverage and reduce energy consumption. They proved that intelligent algorithms may extend the lifetime of a network by positioning nodes effectively, and they devised a genetic algorithm-based strategy for designing energy-efficient node placement in wireless sensor networks. Using GA, a WSN that can adapt to its surroundings on its own was created. They proved that evolutionary algorithms may generate optimal sensor network architectures that satisfy all application-specific requirements, all connection limits, and regulate energy consumption to guarantee the longest possible lifespan of nodes. To achieve optimal network coverage and longevity, a framework for evaluating multi-objective genetic algorithms for sensor placement has been devised.

c. Local Optimization Approaches in Sensor Network Deployment

Local optimization is a metaheuristic strategy that may be used to address optimization issues that require considerable computing labor. Metaheuristic strategies often discover excellent solutions while using less computing resources and making minimal assumptions on the optimization issue they are aiming to address. Local search is well suited for problems that may be defined as finding a solution that maximizes a criterion among a set of candidate solutions. These algorithms iterate over the many potential solutions until either the optimum answer is found or a certain amount of time has passed. Local optimization algorithms operate by iteratively proceeding from an initial or candidate value or solution to surrounding values or solutions. These procedures are referred to as "local search" and "local optimization" since each possible solution has several neighbors. This is because the selection of the next solution or value is dependent not only on the prior minimum or maximum value for the optimization target, but also on the neighborhood information of the presently chosen solution. Local optimization techniques are often used to handle computationally challenging optimization issues, which may be summed up as the selection of the best potential solution (based on a set of criteria) from a collection of candidates. This kind of optimization issue is described as follows: The best solution to purely convex optimization problems may be discovered by local search.

It is a common objective of many local optimization systems to move sensor nodes to optimal coverage sites. These systems frequently use the concept of mobility to make use of the movable qualities of the nodes in order to take advantage of the movable qualities to achieve improved coverage conditions. Random sensor placement is an alternate way of sensor deployment that may be used in scenarios in which there is a lack of information about the topography and geometry of the region that is to be examined. Using this technique does not ensure that the full sensing area will be covered. In order to expand the network's coverage, certain deployment tactics take use of the mobility options available and move sensors from their initial locations. This methodology is comparable to progressive self-deployment, virtual force-based techniques, and potential field-based procedures.

4. PROPOSED METHOD

4.1 INTRODUCTION

One of the most notable benefits of wireless sensor networks is their ability to monitor targets dispersed across a vast region in a cost-effective manner. In reality, wireless sensor networks are usually composed of relatively affordable sensors. These sensors have the advantage of being able to be dropped from an aircraft or helicopter across a region with inadequate or nonexistent monitoring infrastructure. Although the sensors can operate independently, they are often powered by a battery whose charge depletes over time. Consequently, the amount of electricity utilized is a crucial part of surveillance activities. In most instances, it is not advantageous to activate all of the sensors simultaneously in order to watch all of the targets in the observation area. This is owing to the fact that multiple sensors simultaneously monitor a large portion of the monitored region. Our aim is to build a timetable for sensor operations based on the assumed targets and the expected routes of those targets. The operator of the network of sensors must be a part of the scheduling process in order to keep as much of the network's present capacity as is humanly practicable. In addition, we would like the timetable to reduce the total amount of energy required for the duration of the monitoring mission.

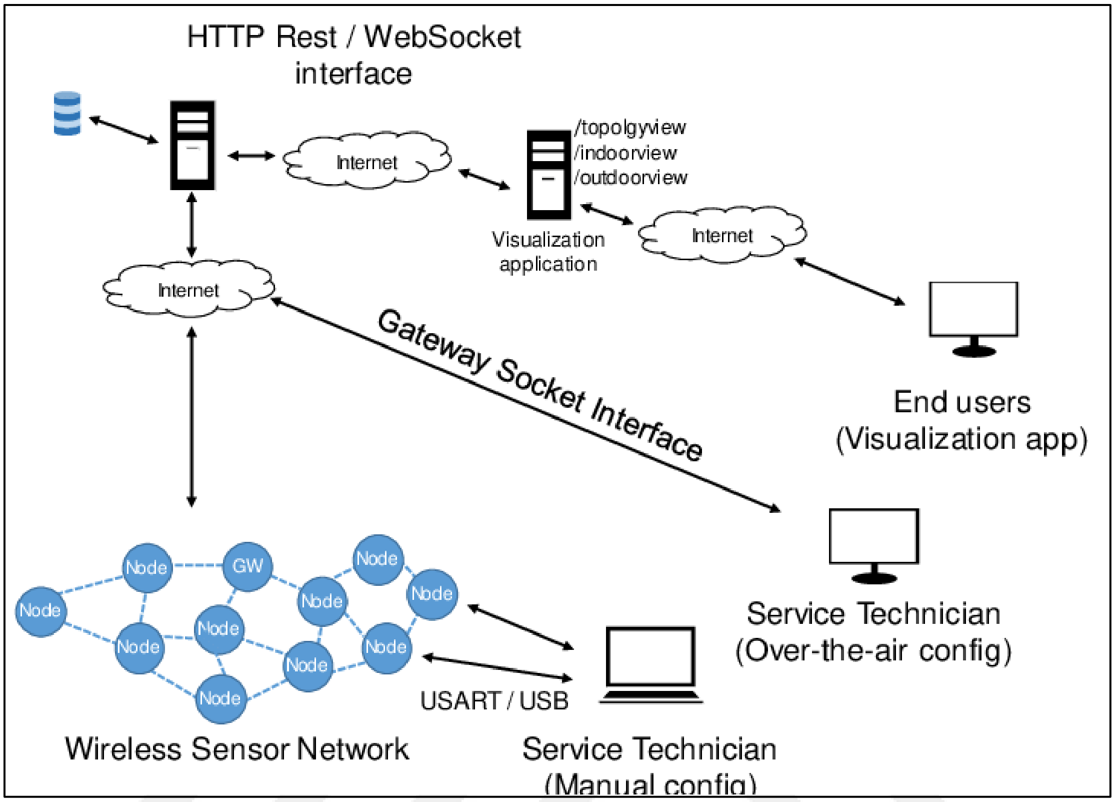

Figure 4.1: GIS deployment of WSN

It is currently normal practice to utilize a sensor network for multiple purposes simultaneously. Example: choosing solutions that demand the least amount of energy to fulfill the current aim while conserving the network for future monitoring missions. Our objective is to create a schedule for sensor activity whose timing can be predicted; we will achieve this by creating a schedule. The operator of the network of sensors must be a part of the scheduling process in order to keep as much of the network's present capacity as is humanly practicable. Since we want to use as little energy as possible for the monitoring mission, we must optimize our schedule. Now, it is crucial to prioritize solutions that require the least amount of energy to complete the current task while protecting the network for the future, so that it may be used for future surveillance missions. This will ensure that future surveillance missions may utilize the network. Our goal is to design a sensor activity plan based on what we already know to be true. The operator of the network of sensors must be a part of the scheduling process in order to keep as much of the network's present capacity as is humanly practicable. In addition, we would like the monitoring mission's entire energy budget to be utilized as little as feasible by the schedule. In today's society, sensor networks are extensively employed for multiple purposes. For example, sustaining the network for future surveillance missions may take precedence over determining the most effective strategy for executing the current operation. The operator of the network of sensors must be a part of the scheduling process in order to keep as much of the network's present capacity as is humanly practicable. Since we want to use as little energy as possible for the monitoring mission, we must optimize our schedule. Now, it is crucial to prioritize solutions that require the least amount of energy to complete the current task while protecting the network for the future, so that it may be used for future surveillance missions. This will ensure that future surveillance missions may utilize the network. The operator of the network of sensors must be a part of the scheduling process in order to keep as much of the network's present capacity as is humanly practicable. Since we want to use as little energy as possible for the monitoring mission, we must optimize our schedule. The sensor network is currently being utilized in the context of many missions, and the maintenance of the network for future surveillance missions takes precedence over the energy efficiency of the present mission's completion. As an additional objective, one of our goals is to have the scheduling reduce the monitoring mission's total energy consumption to a more tolerable level. Now that the network of sensors is being used for many purposes, it is more necessary to find solutions that lower the amount of energy needed to complete the present mission than to find solutions that guarantee the network will continue to function effectively for future surveillance missions. Since we want to use as little energy as possible for the monitoring mission, we must optimize our schedule. In the context of exploiting the network of sensors, several missions are now carried out. Priority will be given to options that use the least amount of energy to perform the current goal while ensuring the network's continued functionality for future monitoring purposes.

To begin, we will strive to achieve the maximum achievable level of coverage assurance for a specified zone of interest inside the monitoring zone. After the completion of the current mission, the coverage guarantee will be the minimum amount of time the sensor network will be able to monitor every region of interest. To effectively complete the current monitoring procedure, it is necessary to achieve the largest feasible sensor coverage while simultaneously minimizing the total energy utilized by the sensors. Assuming that the trajectories of the targets are known in advance, we will now assume that the actual and predicted positions of the targets may deviate by a certain amount.

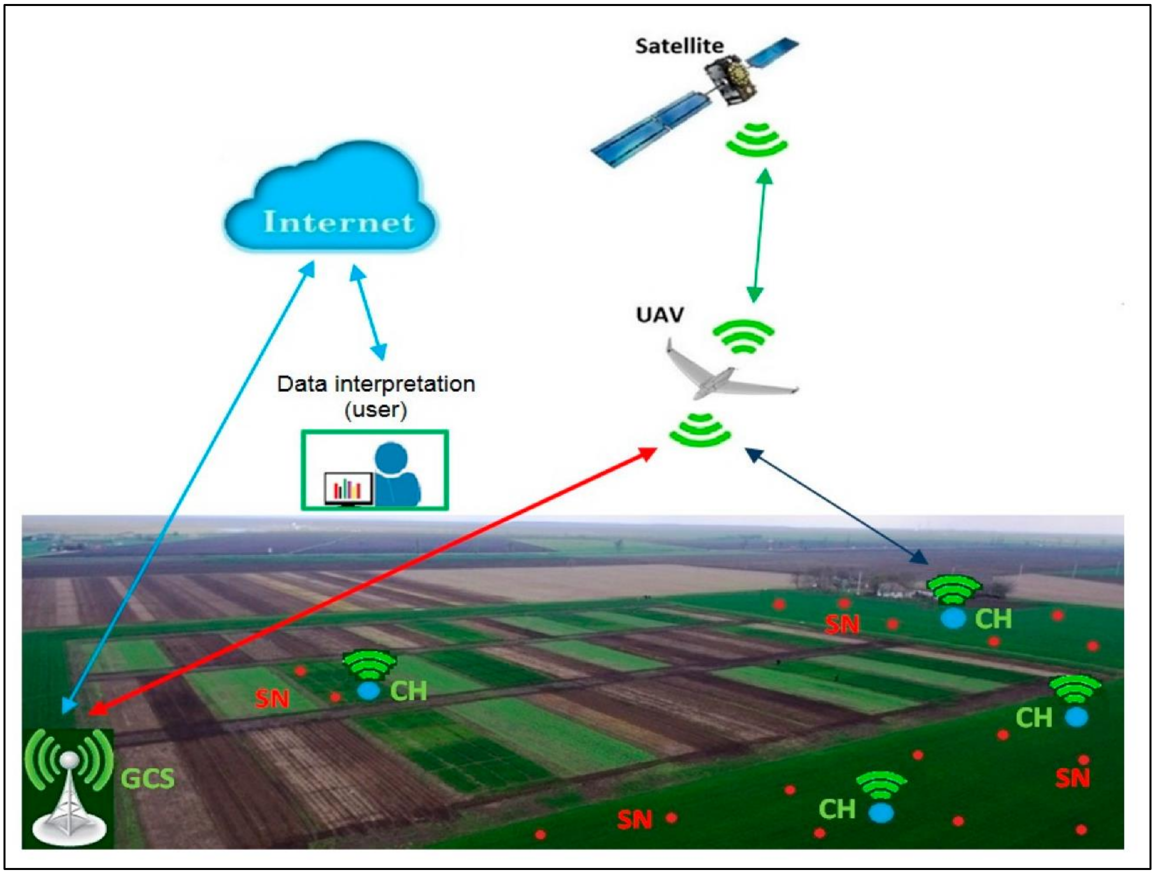

Figure 4.2: Choosing zone of interest ZOI

4.2 DESCRIPTION OF PROBLEM

A collection of m stationary sensors, denoted by the notation I = 1,...,m, will be randomly distributed across an area. Each sensor iI is powered by a battery with an initial capacity Ei, which is measured in time units, so that it can monitor the activities in its coverage area si. Let's assume, without giving it too much attention, that the disk with a radius of RS indicates the area that each sensor monitors. A sensor I will exhaust its given battery life for the duration of its activation, irrespective of the actual number of targets it is monitoring inside the boundaries of its coverage area si. The sensor has no impact on battery life when it is not being employed. Surveillance zone = coverage zones + overlap.

IJ *if*	Set of sensors {1,...,m} Set of targets {1,...,n} i-sensor coverage area
Hey	Capacitance of sensor i
Tj(t) *Z* *I∈isi*	Position of target j at time t Area of interest

A group of n objects, indicated by the notation J = [1,...,n], is in constant motion inside the observable region. Without sacrificing generality, we assume that the targets evolve on a two-dimensional plane and that the geometric data underlying the problem are similarly restricted to this plane. This assumption is made in conjunction with the problem's flat geometry foundation. Their voyage is represented by the continuous vector function Tj:RR2, where t is a time variable. Without limiting the scope of our inquiry, we will assume that the value of ta lies between 0 and H, where H is the projected duration of the mission. It is not always possible to predict the precise positions and directions of targets in every circumstance. In comparison to the predicted location of the target j at time t, the actual location of the target j at time t may differ by a certain amount (t). Then, let's assume that each target requires traversing a disc of uncertainty with a radius of and a center at Tj (t). Throughout history, worth has been susceptible to fluctuating values. In fact, we are able to account for the fact that the spatial uncertainty increases with time by taking into consideration that it is proportional to time and is zero at t = 0 at the start of the mission. We hope that after the mission is complete, we will be able to monitor the Z IIif region in greater detail. As a subset of the wider monitoring zone, the Z IIif region is of particular relevance to us.

The mission must comply to a number of criteria in order to be successful.

Throughout the course of the operation, each target must remain under the watchful eye of at least one sensor, and the total number of monitoring operations conducted by these sensors must not exceed their battery capacity.

Due to the fact that monitoring is an integral part of any mission, its execution must be meticulously planned in advance. To be more exact, the schedule must account for every probable circumstance. If the coverage guarantee for a specific mission is set to Tmin, then the sensor network will continue to monitor each point in zone Z for at least that many additional time units following the conclusion of the operation. Every location in Z has a monitoring potential proportional to the total amount of battery life remaining in the sensors covering that location. This scenario maximizes the lowest surveillance potential, which has the same effect as maximizing the coverage guarantee. A maximum coverage guarantee can be achieved by a variety of different schedules.

The general problem then breaks down into three successive sub-problems.

The resolution of the general problem proceeds in two phases. The first phase is discretization, it aims to format the data of the problem, while the second phase consists in successively solving the three sub-problems mentioned above. above, in order to schedule the activity of the sensors based on the results of the discretization.

4.2.1 Discretization

To our knowledge, no method allows to directly solve this problem from geometric data. This is why we resort to a preliminary stage of reformulation. This is explained in detail in the chapter2and summarized in this section for our problem. The monitoring area can be partitioned into a set faces F, where a face is a set of points covered by the same sensors

First, we assume that the position of the targets is not subject to uncertainty. Let us denote $F \subseteq Fb$ the set of faces crossed by the targets. The trajectory taken by a target can be described as a sequence of faces, where each element of the sequence is associated with a dwell time. To monitor a target, simply activate one of the sensors covering the face in which it is located. Thus, the exact position of the targets is no longer necessary to determine a schedule of sensor activities. We call ticks the instants when a target crosses the boundary of a face, and time windows the time intervals between two consecutive ticks. We denote by K the set of time windows, of cardinality p. Their respective durations are denoted Δk and the ticks are denoted tk. In this chapter, the variant of the discretization used is that according to the faces, The set of candidate sensors for the coverage of a face f is denoted S(f). The set of faces to be covered during the time window k is denoted by T(k). The faces overlapping the zone of interest Z form a set noted $F^* \subseteq fb$. Table4.2summarizes the result of the discretization.

F	Set of faces {f1,...,fq} visited by at least one target
F∗	Set of faces of interest {f1,...,fq′}
K	Set of time windows {1,...,p} *
S(g)⊆I	Set of candidate sensors covering face f∈F∪F
T(k)⊆F	Set of faces to cover during the time window k∈K
tk	Index tick k∈K∪{p+1}
Δk	Duration of time window k *K*

Figure 4.3: Data resulting from the discretization according to the faces

Let us consider the case where the position of the targets is subject to uncertainty, ie they can deviate by a distance δ from their expected position. In order to be certain to cover each target despite the uncertainty, the sensors must cover a disk of radius δ centered on the expected position of the target (figure 4.1). Unlike point targets, this disk can overlap multiple faces simultaneously. It follows that the number of faces to cover, and therefore the number of sensors to activate, can potentially increase. However, this does not modify the structure of the data resulting from the discretization. The ticks correspond to the times for which the uncertainty disc meets the boundary of one face or ceases to overlap another.

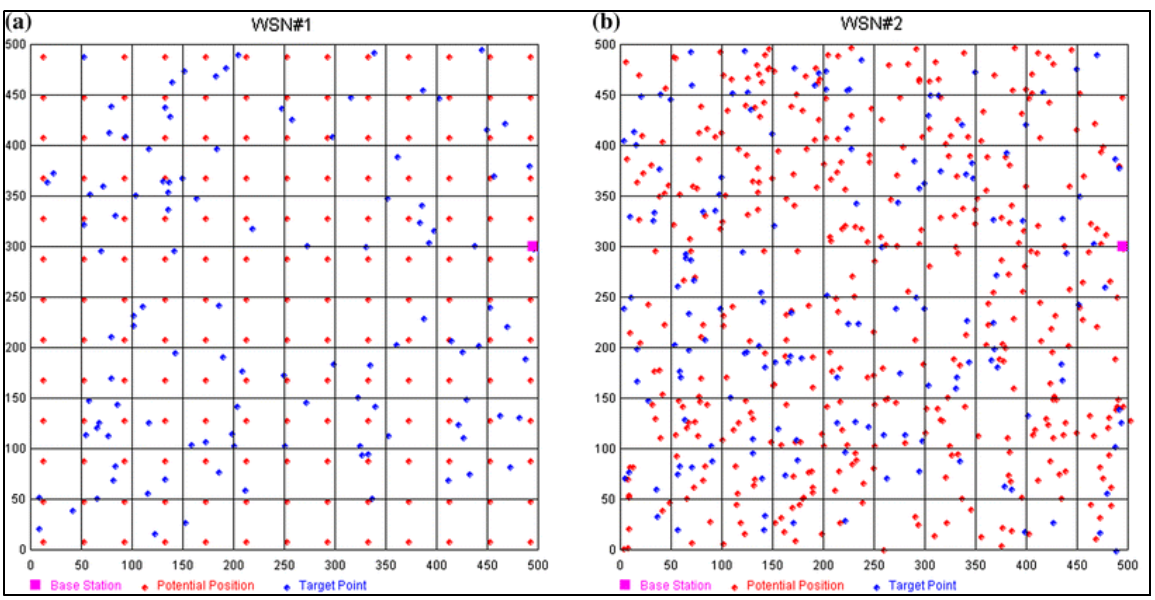

Figure 4.4: Potential positions of a target under uncertainty

Let be a time window of index k. A valid cover for the time window k is a subset of sensors capable of covering all faces of T(k). A cover is therefore valid if it contains, for each face $f \in T(k)$, at least one sensor of S(f). Thus, from the discretization data, the MRC, MCG and MEC subproblems can be seen as coverage activity scheduling problems.

Moreover, these data make it possible to define the notion of coverage guarantee in another way. Each face of the monitoring zone has a monitoring potential, that is to say a time during which the candidate sensors are able to monitor it. The coverage guarantee is thus defined by the minimum value of the monitoring potential of all sides of interest. Therefore, a coverage guarantee of a value Tmin ensures that one can monitor any face of F^* for a duration at least equal to Tmin time units. On the other hand, it does not guarantee the possibility of monitoring several faces simultaneously during Tmin units of time.

4.3 STUDY OF COMPLEXITY

The notions introduced by discretization make it possible to study the complexity of the general problem presented in this chapter, as well as particular cases where the problem admits a polynomial algorithm.

4.3.1 Case of Long-Range Sensors

First, consider the case where each sensor is able to cover all targets at each instant. This situation arises when the sensors have a very long range. In this case, the optimal value of the objective of MEC, which is the energy expended to accomplish the current monitoring mission, is H since only one sensor is used at each instant. Moreover, the discretization is not necessary since all the targets move together, inside the same face. In these circumstances, MCG is formulated by the linear program noted LPlong. Let xi be a non-negative continuous variable representing the total activation time of sensor i. The variable Tmin is the coverage guarantee offered for the faces of F^*.

LPlong model

max T min		(4.1)
Xxi = H *I*∈*I*		(4.2)
xi≤ E i	∀*I*∈I	(4.3)
$\sum_{i \in S(f)} (E_i - x_i) \geq T_{\min}$	∀*f*∈F*	(4.4)
*T*min ≥ 0		(4.5)
xi≥ 0	∀*I*∈I	(4.6)

It is impossible to realize LPlong if and only if PiIEi is true. In this case, MRC, MCG, and MEC are not possible due to the fact that the sensors do not have adequate energy to cover the targets for H units of time. If it is feasible to run LPlong, the optimal solution will permit the creation of an optimal schedule that takes into consideration MRC, MCG, and MEC. Each sensor receives a random quantity of power for xi seconds, and the activation order is entirely random. Given that constraint (4.2) ensures the lowest possible energy usage for the duration of the mission, this is the best option for MEC.

4.3.2 Case of Short-Range Sensors

Imagine for a moment that the targets are so far distributed that no single sensor can monitor more than one of them simultaneously. This condition is satisfied when the distance between any two targets exceeds twice the radius of the sensors' detecting zones. nH satisfies the MEC criteria in this instance to the maximum extent possible. Because no sensor can simultaneously monitor more than one target, exactly n sensors must be functioning at all times. This is true. Because nH is constant, the amount of energy necessary for the mission is also constant.

4.4 RESOLUTION

As a reminder, the sensor activity scheduling problem of this chapter can be broken down into three subproblems MRC, MCG and MEC. At the end of the discretization, the proposed method proceeds in three stages corresponding to the three sub-problems (figure4.2). This section introduces the solution method common to the three sub-problems.

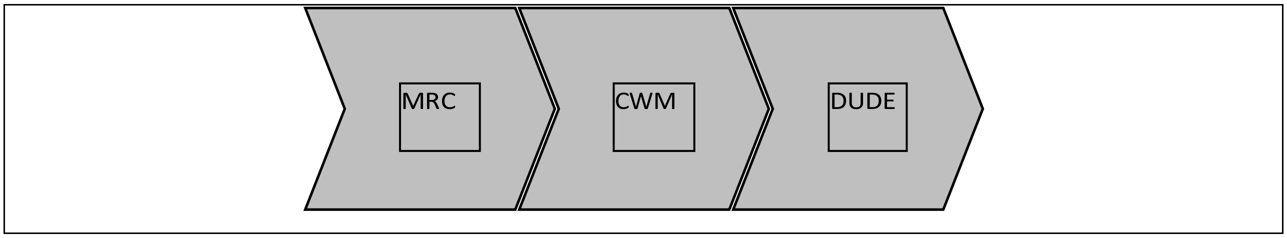

Figure 4.5: The three steps of the method

4.4.1 Column Generation Algorithm

Since the number of valid covers for these subproblems is in O(|K|2m), it is in practice impossible to enumerate them explicitly in a reasonable time. Therefore, directly solving their MPMRC, MPMCG and MPMEC models using a solver is not feasible.

This is why a method based on column generation is appropriate. Its main idea is that only a subset of the covers is required to solve linear programs, since most of the variables in the optimal solution will not be in the basis. Thus, MPMRC, MPMCG and MPMEC are formulated as the master problem of a column generation algorithm. Moreover, they are formulated in such a way as to share the same auxiliary problem, denoted AUX. Therefore, each subproblem is solved in the same way. The column generation algorithm is illustrated by the diagram in Fig.4.3and explained in more detail in this section.

Without loss of generality, we use the notation MP to designate indifferently one of the three linear programs MPMRC, MPMCG or MPMEC, including all the covers. Column generation starts with RMP, for Restricted Master Problem, a linear program identical to MP, except that it contains only a small subset of MP covers. The initial subset of covers that constitute the columns of RMP is chosen arbitrarily, so that RMP is feasible. The auxiliary problem, denoted AUX, consists in constructing profitable covers for RMP, ie finding variables of MP whose reduced cost is positive. It follows that adding such covers in RMP improves the value of its objective function. However, it is not necessary to solve AUX exactly, except to prove the optimality of the solution of MP, since a positive reduced cost cover is sufficient. Thus, to save computation time, AUX can be solved by a metaheuristic. The column generation algorithm is stopped when there is no more profitable hedge.

In this section, we present the auxiliary problem and then the way to generate initial covers.

4.4.2 Auxiliary Problem

The auxiliary problem AUX can be decomposed into |K| independent sub-problems denoted AUXk and formulated using linear programs in binary variables. For any time window k∈K, the linear program in binary variables formulating AUXk is:

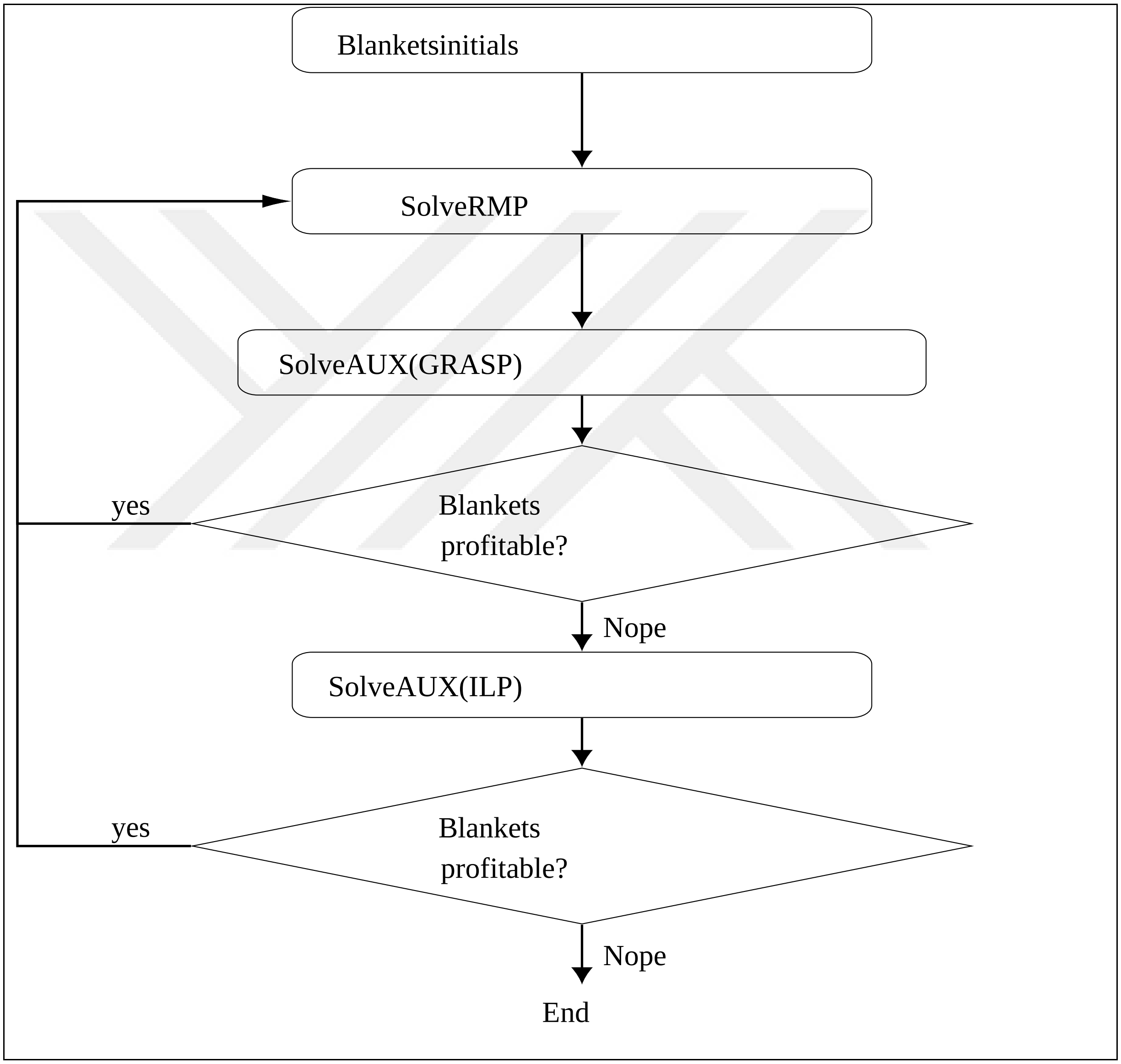

Figure 4.6: Column generation algorithm defined coefficients πi and μk are the values of the dual variables when RMP has been optimally solved. The variable aic is worth 1 if sensor i is selected in the new coverage c, 0 otherwise

PROPOSED ALGORITHM: GRASP

Input: $\alpha \in [0,1]$ GRASP parameter

$\forall I \in I$, $a_{ic} \leftarrow 0$// Set of selected sensors

$F \leftarrow T(k)$// Set of faces not yet covered

$F_i \leftarrow \{f \in F | i \in S(f)\}$// Faces not yet covered within range of sensor i

// As long as there are uncovered faces

while $|F| > 0$ **do**

//Calculationofutilities

$\forall I \in I, \quad a_I \leftarrow \frac{|F_I|}{\pi_I}$

//calculatethreshold a_{limit}

$a_{min} \leftarrow \min_{I \in I} a_I$

$a_{max} \leftarrow \max_{I \in I} a_I$

$a_{limit} \leftarrow a_{min} + \alpha(a_{max} - a_{min})$

//Creation of the list of RCL candidates

$RCL \leftarrow \{I \in I | a_I \geq a_{limit}\}$

//S Random election of an RCL sensor

$\mathfrak{p} \leftarrow$ ChooseRandom(RCL)

// Data update

$h_{he} \leftarrow 1$

$F \leftarrow F \setminus \{f \in F | \mathfrak{p} \in S(f)\}$

$F_I \leftarrow E_I \setminus \{f \in F | \mathfrak{p} \in S(f)\}, \forall I \in I$

return $(h_{1v}, \ldots, h_{asmc})$

In order to increase the chances of obtaining positive reduced cost coverage, GRASP can be coupled with a local search algorithm. Local search is an exploration algorithm that enumerates the neighborhood of the solution returned by GRASP in order to improve it. For this, we carry out exchanges of sensors likely to increase the value of the reduced cost. Several neighborhoods are tested successively, in ascending order of their size. First of all, we try to remove sensors, in other words, we try to perform 1-0-exchanges. Then we try to exchange a sensor with another more profitable one, by performing a 1-1-exchange. The exchange of two sensors for another is a 2-1-exchange. This can be extended to ab-exchange where a is the number of sensors to remove and b the number of sensors to add. However, the more the values of a and b increase, the larger the neighborhood is because of the number of possible combinations. This has repercussions on the computation times and can make the local search unproductive. Therefore, we suggest to limit the local search to the 2-1-exchange. Whenever a trade improving the reduced cost is found, it is immediately carried out, and the search is continued until all possibilities of trades have been found. been tried. This has repercussions on the computation times and can make the local search unproductive. Therefore, we suggest to limit the local search to the 2-1-exchange. Whenever a trade improving the reduced cost is found, it is immediately carried out, and the search is continued until all possibilities of trades have been found. been tried. This has repercussions on the computation times and can make the local search unproductive. Therefore, we suggest to limit the local search to the 2-1-exchange. Whenever a trade improving the reduced cost is found, it is immediately carried out, and the search is continued until all possibilities of trades have been found. been tried.

In summary, the auxiliary problem is solved using GRASP and a local search, as long as the latter find positive reduced-cost covers. If necessary, the generation of columns calls upon a solver of linear programs in binary variables, in order to find new covers, or to prove the optimality of the current solution.

4.4.3 Blankets Initials

The constraint of the MPMRC, MPMCG and MPMEC models cannot be satisfied without a set of initial covers, in the absence of left members in the equation. Therefore, it is necessary to generate a set of initial covers to start the column generation algorithm because by lemma6, determining whether MRC is feasible is an NP-complete problem.

Moreover, we do not have values of dual variables (π,μ) on which the auxiliary problems AUXk depend. For this, we choose to fix the values $\pi i = 1$ and $\mu k = -|T(k)|-1$ in order to reduce AUXk to a problem of covering sets at unit costs. This choice allows to first generate minimum cardinality covers, which are desirable for solving MEC.

However, the generation of the set of initial covers is not sufficient to obtain a feasible schedule. For example, it is possible to generate a coverage activating all sensors simultaneously, and to add it to all time windows. However, such a cover is very costly in terms of energy. Unless the sensors have a sufficiently large capacity, there is no feasible scheduling respecting the capacities. This justifies the role of the MRC subproblem, which temporarily allows negative residual capacities ri in the MPMRC model. Initially, the goal of MPMRC is usually negative and increases as columns are generated.

5. RESULTS AND DISCUSSION

The numerical tests are executed on a collection of one hundred examples that were generated at random in advance. The trajectories of the n targets, which are 5, 10, and 15, are provided within each of them while they are contained within a square zone that is 100 pixels on each side. The trajectories are represented as a polygonal line that may be broken up into four segments and contains five control points that connect all of the segments together. Every control point is linked to a specific length of time that has elapsed since the relevant target was first established. The trip times that are associated with the checkpoints are dispersed in a manner that is entirely uniform all the way along the time horizon, which has a value of H equal to one hundred time units. In other words, the first control point of a target corresponds to its location at the time t = 0, the second control point of a target corresponds to its position at the time t = 25, the third control point of a target corresponds to its position at the time t = 50, and so on. The amount of time that elapses between each pair of consecutive checkpoints is uniformly dispersed, which means that the rate at which the targets advance remains the same up until the next checkpoint in the sequence. Checkpoints are placed in arbitrary locations chosen at random. As a direct result of this, there is a good chance that the targets will come into contact with the same person on more than one occasion. By randomly scattering a collection of m sensors around the region to be monitored, it is ensured that the coverage area of each sensor will overlap a piece of at least one of the target trajectories (where m is one of the values 50, 100, or 150). The radius of the discs that comprise the coverage zones is equal to RS, which is 40. The initial capacity of the sensors is fully up to arbitrary choice and can fall anywhere in the range from 0 to 100. In a nutshell, we generate ten different instances for each distinct combination of the parameters m and n, and from these we derive three groups, each of which has ten different instances. In addition to this, we offer a set of ten more scenarios, each of which has m = fifty sensors and n = thirty targets. In each of these cases, we tested the performance of our algorithm. Following that, there will be a total of one hundred occurrences.

5.1 COMMUNICATION COSTS

In the problem presented in chapter 4, denoted MSR (Maximize Stability Radius), the mission of the sensors is to monitor a target, for which the spatial trajectory is known with certainty, but whose transit times at each of its points are uncertain. The goal is to build a robust schedule of sensor activities, guaranteeing the monitoring of the target, despite an advance or a delay with respect to the predicted passage times.

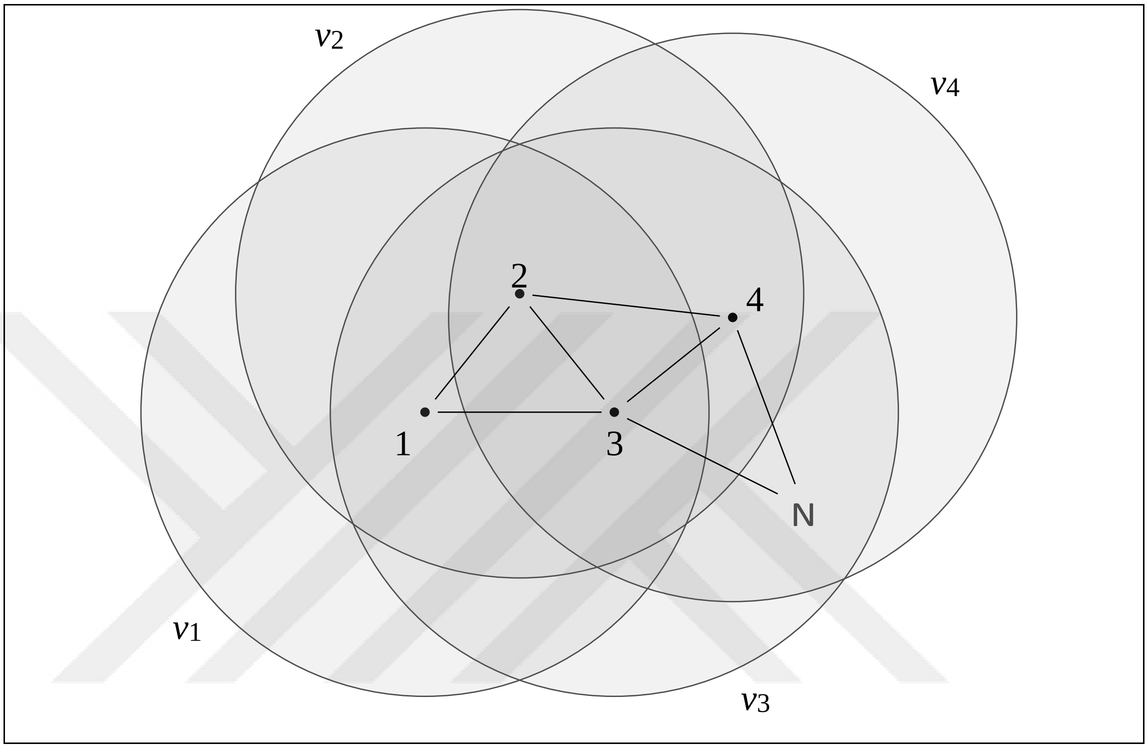

Figure 5.1: Example of a communication graph, where NOT is a base station.

In this section, we present an extension of this problem in which the costs of routing data to a base station are taken into account. The base station is typically a relay to a control center whose purpose is to collect and process the data sent by the sensors. The sensors have a wireless communication module capable of transmitting and receiving data (wifi, bluetooth, etc.). Sensor battery capacities are now expressed in units of energy. During a monitoring activity, a sensor collects β units of data per unit of

time, and consumes on its battery eS units of energy per unit of time (therefore it is a power). A sensor i is able to transmit data to the sensors located in its communication zone ci. Without loss of generality, we consider that the communication zone of a sensor is a disk of radius RC centered on the sensor. The transmission of a unit of data costs etT units of energy, and the reception eR. The base station is assumed to be positioned inside at least one communication zone. A summary of the input data is presented in the table 5.1.

Table 5.1: MSRC input data

I if	Set of sensors {1,...,m}
	i-sensor coverage area
this	Sensor communication area i
Hey	Capacitance of sensor i in units of energy
T(t)eS	Target position at time t
	Energy consumed by a sensor for monitoring a target
and	Energy consumed by a sensor for sending data
eR	Energy consumed by a sensor for receiving data
β	Amount of monitoring data per unit time

For this extension, which will be noted as MSRC (Maximize Stability Radius with Communication), the proposed method is based on that of chapter 3. It takes place in two phases: the discretization, and the resolution of a sensor activity scheduling problem.

Table 5.2: Data resulting from the discretization.

K	Set of time windows {1,...,p}
sj(k)⊆I	Set of candidate sensors covering the target during the window
tk	of time k∈K∪{0,p + 1} Tick of index
σk	k∈K∪{p+1}
	Value determining the category of the tick k (incoming or outgoing)
ΔkN(i)	Duration of time window k∈K
	Set of nodes (sensors, base station) capable of communicating with sensor i

The objective of MSRC is identical to that of MSR, namely to maximize the radius of stability, denoted ρ. The stability radius of a schedule S is defined by the largest tick variation tk that does not compromise the ability of S to continuously cover the target without losing sight of it. In other words, the objective is to construct a schedule which resists as best as possible any advances or delays of the target in relation to the forecast transit times.

In order to solve MSRC, we add to the discretization the construction of a communication graph, in order to determine between which sensors can pass the data flows. The set of vertices is made up of the sensors and the base station. The edges represent the communication links. The discretization then produces the sets N(i), set of nodes (ie sensors and/or the base station) capable of communicating with sensor i. A sensor j belongs to N(i) if the distance between sensors i and j is less than the RC communication radius. Thus, an edge is created between two distinct nodes i and j if and only if j∈Neither). The data resulting from the discretization are summarized in the table 5.2.

At the end of the discretization, the resolution of MSRC proceeds according to the same scheme as the method proposed for MSR. This consists of a dichotomy on the radius of stability ρ. First, an upper bound UB on ρ is computed in order to reduce the search space of the dichotomy to the interval [0, UB]. The search space is then represented by an ordered list D containing all the positive distances tk′ − tk < UB where tk is an incoming tick and tk′ an outgoing tick. Then, at each iteration of the dichotomy, a decision problem is solved. The decision problem consists, for a given value of ρ, in determining whether there exists a feasible schedule whose stability radius is at least ρ.

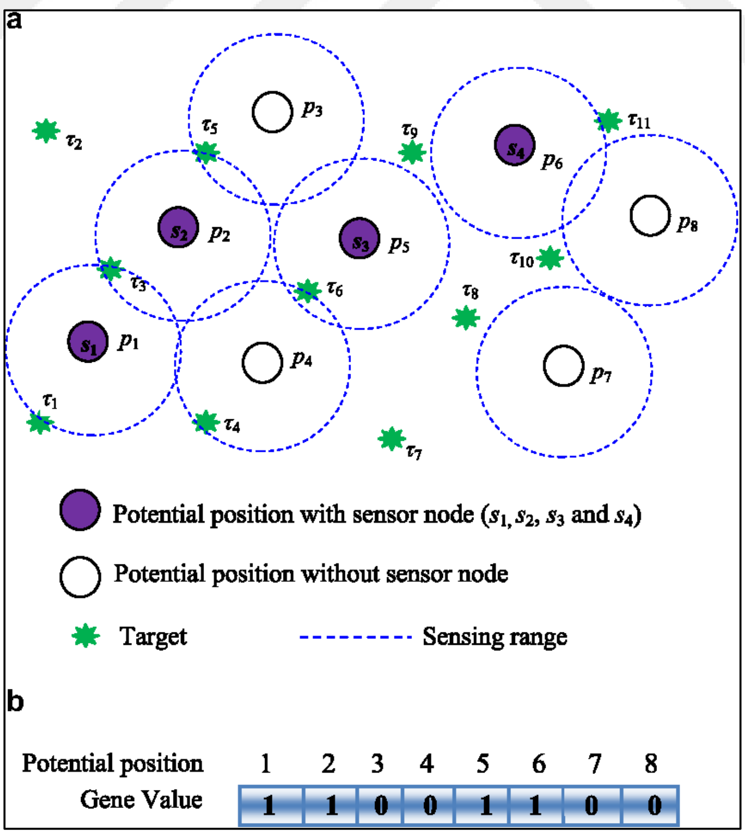

Figure 5.2: Optimal deployment of the GRASP algorithm.

5.2 UNCERTAINTYSPATIAL AND TEMPORAL

The problems presented in the chapters3and4introduce temporal and spatial uncertainty respectively. In this section, we present an extension of MSR (chapter3) which also takes into account the spatial uncertainty. This extension is denoted MSRSU (Maximize Stability Radius under Spatial Uncertainty). The sensor network must monitor a target whose trajectory is modeled by a continuous vector function $T:R \rightarrow R^2$, defined by T (t) where t is a time variable. The position of the target is subject to uncertainty: at each instant t, it can be located at a distance δ from its expected position T (t). We then consider an uncertainty disk of radius δ to be covered at each instant, where δ is an input parameter of the problem. The transit times of the target are also subject to uncertainty: the target (as well as its uncertainty disc) may arrive earlier or later by a period ρ with respect to the forecast dates. The goal is to build a schedule with minimum energy, able to cover the target despite this advance or this delay, and despite the spatial uncertainty. In order for the network of sensors to consume as little energy as possible, only one sensor can be activated at any time.

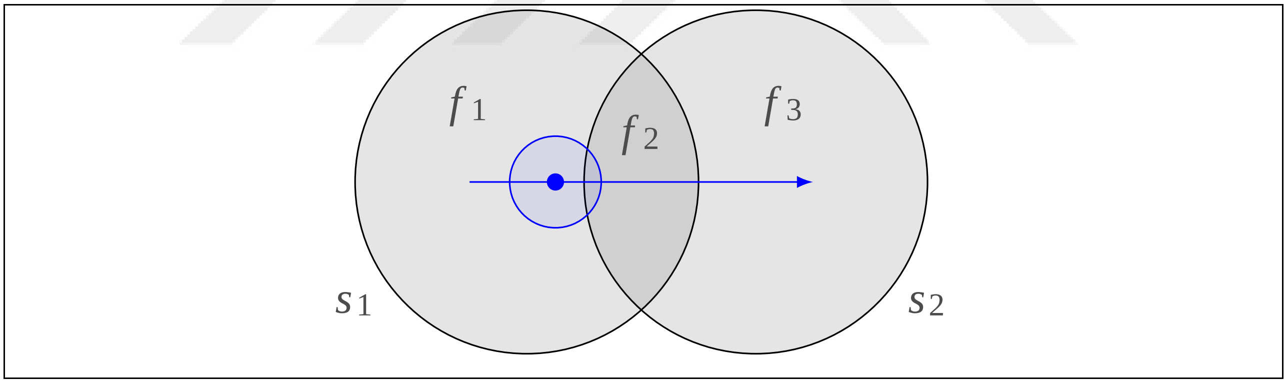

Figure 5.3: Example of a simple instance of MSRSU.

Like the previous problems studied, this one is reformulated thanks to discretization (chapter2). Recall that the monitoring area can be partitioned into disjoint surfaces called faces. In the case where the positions are not subject to uncertainty, the trajectory of the target can be formulated as a sequence of faces crossed. Otherwise, the trajectory is a sequence of sets of faces crossed by the uncertainty disc. Each time the disc of uncertainty crosses the boundary of a face, the discretization creates a tick, the date of this crossing noted tk where k is its index.

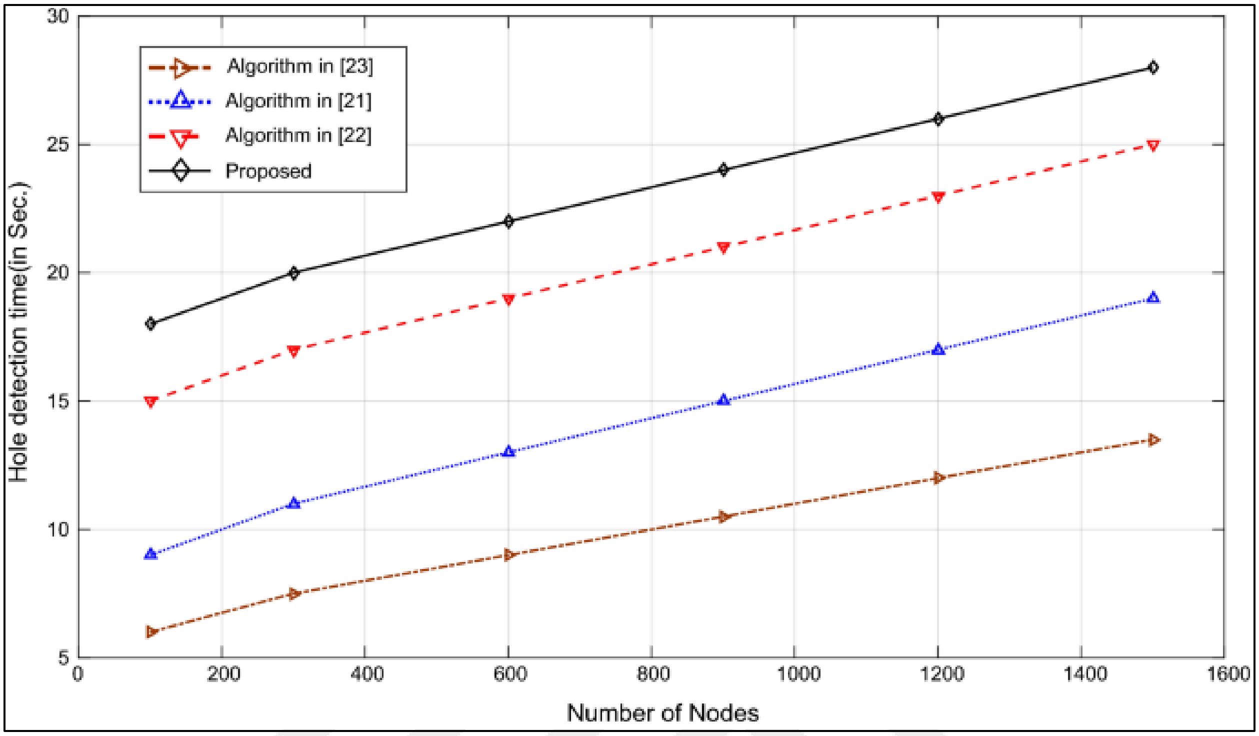

Figure 5.4: Hole detection comparison.

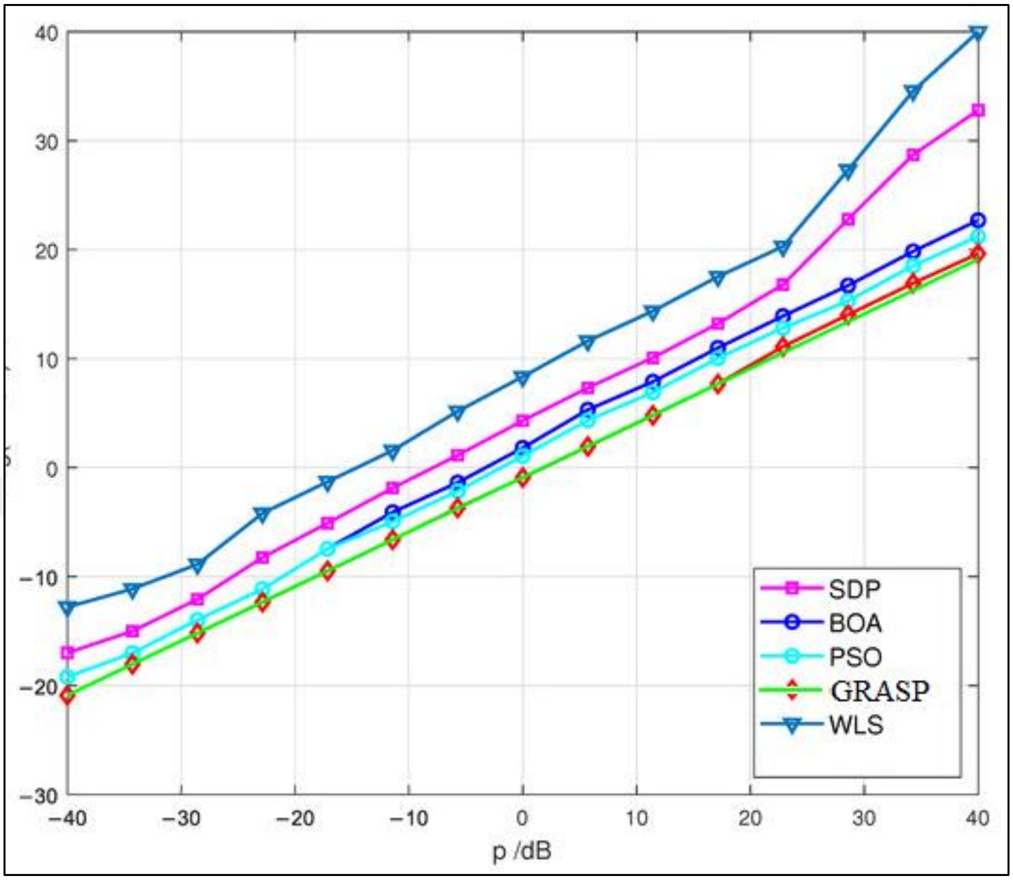

Figure 5.5: consumption after deployment by the Grasp algorithm.

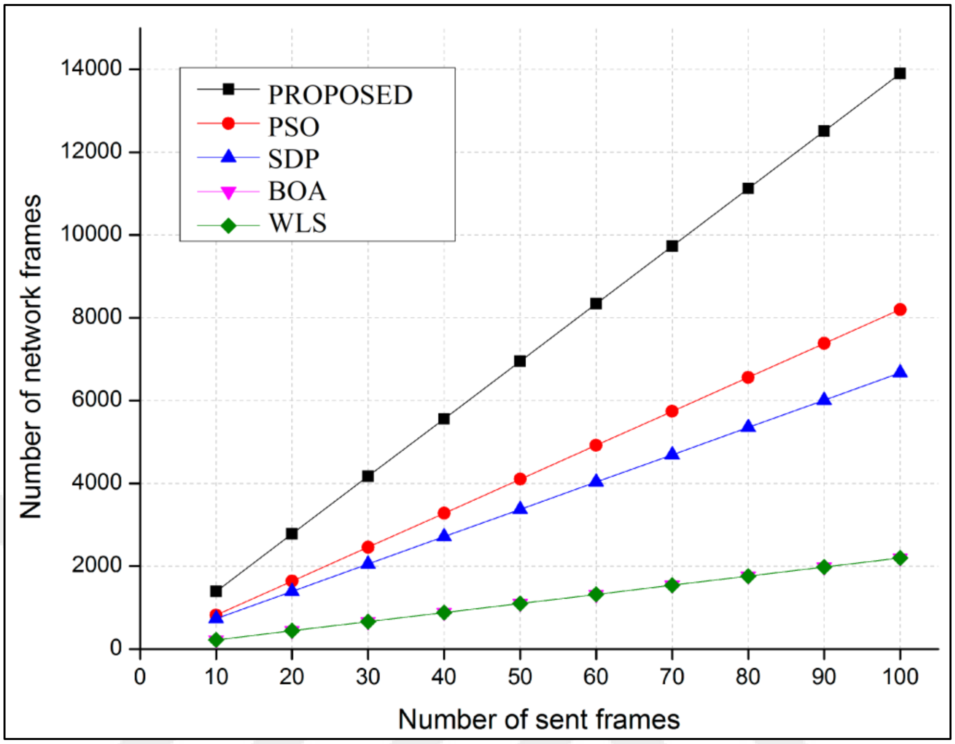

Figure 5.6: packet success rate of the proposed algorithm compared.

6. CONCLUSION

It is a common objective of many local optimization systems to move sensor nodes to optimal coverage sites. These systems frequently use the concept of mobility to make use of the movable qualities of the nodes in order to take advantage of the movable qualities to achieve improved coverage conditions. Random sensor placement is an alternate way of sensor deployment that may be used in scenarios in which there is a lack of information about the topography and geometry of the region that is to be examined. Using this technique does not ensure that the full sensing area will be covered. In order to expand the network's coverage, certain deployment tactics take use of the mobility options available and move sensors from their initial locations. This methodology is comparable to progressive self-deployment, virtual force-based techniques, and potential field-based procedures To achieve this purpose, it is necessary to incorporate adequate models of the phenomenon type, the accessibility or inaccessibility of the observation region, environmental factors, and geographical connections between places. The following are instances; however, they are not exhaustive: The location of sensors and the quality of the initial datasets used to set up sensors are two components that add to the complexity of wireless sensor networks. Because there are a variety of deployment algorithms to choose from and a trustworthy, durable, and resilient network must be constructed, determining the most efficient method for deploying sensors may be challenging. Therefore, the research of wireless sensor networks is a challenging endeavor that requires a wide range of specialized knowledge in addition to a great deal of practical experience. The installation of sensor networks has two key challenges, the first of which is ensuring enough coverage, and the second of which is sustaining effective communication between sensors. Utilizing node sensors enables continuous monitoring of the surrounding environment. Each device is expected to have a range, the details of which will vary depending on what is being detected and the limits of the surrounding environment. It is possible for obstructions to reduce network coverage and produce blind spots in the field of view. The information that has been gathered in the area must be delivered immediately to a processing center or, at the very least, to a sensor positioned near to the processing center through communication between the nodes. The second circumstance necessitates that each sensor be informed of the positions of other sensors in its near vicinity. Due to the near closeness of the sensors, this is the case. It is possible to increase the coverage of sensor networks by strategically installing additional sensors, which may be done in a variety of ways. In a broader sense, the recommended techniques may be categorized into two distinct groups: global and local. Some of the suggested approaches in both categories use computational geometry in the form of Delaunay diagrams and Voronoi triangulations, respectively. Using these frameworks, an evaluation of the sensor locations may be conducted. The geographical dispersion of sensors that are implanted in the surrounding environment has a substantial impact on the ability of sensor networks to cover a particular area. The deployment optimization algorithms attempt to position the sensors in the field such that they give sufficient coverage for the activities that are presently being carried out. Although these approaches are applicable to basic sensor networks, further research is required before they can be used to sensor networks that are subject to environmental constraints, such as sensor networks that are influenced by environmental obstacles.

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