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A Prospective Study of Wireless Sensor Networks

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Abstract: *Because of their special qualities such as robustness, flexibility, scalability, low power consumption, and low deployment costs WSNs are ideal for a variety of uses across several industries. Wireless Sensor Networks (WSN) are still in their infancy and face numerous research challenges. Not only must WSN be able to function in harsh environments or with low power, but it also needs to be scalable, reliable, and capable of deciphering complex data. Additionally, research is still being done on how the network processes, shares, and uses information as well as how to effectively use and arrange the sensors that make up the system. Furthermore, privacy and security are crucial factors to take into account, and techniques for building secure WSNs are being developed. As WSN become more widely used, many of these research problems are still being worked on, and new ones are coming up.*

Keywords: Wireless Sensor Networks (WSN), Applications, Challenges.

I. INTRODUCTION

People were able to communicate while on the go thanks to the first wireless trend, which also signaled the invention of mobile gadgets [1]. With the advent of text messaging and the growth of digital personal communication services (PCS), this trend persisted throughout the 1990s. The advent of smartphones and other Internet-enabled devices in the early 2000s made it possible for people to access data and use online apps, which paved the way for the development of wireless data networks like 3G and 4G. Along with Location-Based Services (LBS), these new developments made a variety of uses possible, such as the distribution of audio and video files [2]. The rise of IoT, Smart Grids, and 5G networks in recent years has drastically reduced the usage of wireless data networks while opening up new opportunities for services and applications [3].

WSNs are networks of dispersed, independent sensors that gather environmental data [4]. WSNs are highly advantageous for a variety of applications due to their inexpensive deployment costs, scalability, flexibility, robustness, and low power consumption [5]. WSNs are expected to become an essential component of many systems as they develop and offer up new opportunities [6]. WSNs have great promise, but there are still a lot of unanswered research questions, which keeps people interested in this sector.

Because they are simpler to install and operate and require less power and space, they are therefore more suited for WSN deployments [7]. Furthermore, because MEMS sensors can measure and report various environmental parameters more quickly and reliably, their accuracy has improved [8]. These sensors generate data that is more trustworthy and useful for decision-making. As a result, they may be coupled with other technologies like machine learning, cloud computing, and image processing for additional analysis, and they can be utilized in a wide range of applications like monitoring water quality, traffic conditions, and structure stability [9].

Smart sensors are gadgets that automate data gathering and analysis through the use of machine learning algorithms and artificial intelligence (AI). They have the capacity to receive data from various sources, process it, and provide precise answers to the data in real time [10]. Smart sensors may be successfully configured to measure specific quantities and are very configurable. These sensors are commonly employed as research and development instruments as well as measuring and monitoring critical conditions in industrial settings. Conventional sensors are inflexible to changing circumstances or surroundings because they need human data entry [11].

Compared to traditional sensors, smart sensors are often more affordable, smaller, and have less processing power. Furthermore, they have inherent intelligence that enables them to modify their behavior in response to shifting

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circumstances and surroundings, doing away with the need for human data entry. For this reason, smart sensors are perfect for tracking and monitoring various parameters in a variety of applications [12].Because they have inherent intelligence that enables them to automatically modify their behavior in response to the environment they are sensing and the data they are processing, they are also better suited to satisfy the needs of contemporary digital systems. They can also implement algorithms on the edge, which eliminates the requirement for them to rely on an outside server for processing [13]. These attributes render them perfect for an array of uses, ranging from checking air quality in a house to keeping an eye on humidity levels in a greenhouse. A sensor node is an apparatus that is capable of sensing, measuring, and gathering information from its surroundings. Usually, these nodes have one or more sensors installed, which they employ to measure various physical attributes including light, pressure, temperature, and more. Sensor nodes are widely utilized in applications where data collecting and processing are crucial, such as industrial automation, Internet of Things systems, and other fields. Generally speaking, they are compact, reasonably priced, and offer a variety of features. Furthermore, low-power design is incorporated into these gadgets to minimize energy usage and increase battery longevity [14].

The parts required to gather and examine environmental data are present in smart sensor nodes. They are typically low-power gadgets with an actuator and radio to enable wireless data transmission by facilitating connectivity with other nodes [15]. Typically, these sensors are employed in industrial automation and Internet of Things applications[16]. They are usually low power gadgets made to consume the least amount of energy possible in order to prolong the life of the battery. In addition, sensor nodes feature an actuator and a radio, which allow the device to perform other functions and send data wirelessly. Applications including data measurement, industrial automation, and Internet of Things systems frequently use them [17].

Challenges

Data processing is the process of taking acquired data and turning it into relevant information by merging and analyzing it. Sensor networks depend on communication since it allows nodes to interact with one another, create networks, and respond to outside orders. Last but not least, sensor management includes setting up and utilizing the sensors, guaranteeing their best performance, and preserving their integrity [18]. To guarantee that the sensors are successfully integrated into an application, each of these variables needs to be taken into account. To find, locate, and activate available nodes in wireless ad hoc networks, sophisticated network discovery and control protocols are needed [19]. The networks also need to facilitate cooperative information processing and querying, as well as information routing between nodes. The nodes also need to be capable of processing, storing, and reacting to requests for tasks from other nodes. Ultimately, for the nodes to keep the network connected, they must use their power resources effectively and manage them properly. When establishing and maintaining a wireless ad hoc network, all of these technological difficulties need to be considered [20].

Network Protocol

In order to maintain network functionality, energy is required to power switches, routers, and other networking hardware [21]. To send and receive data across a network, bandwidth is required. Higher data transfer speeds can be attained with more bandwidth. In order to process data and keep the network operating, processing power, or computing resources, is required. For large amounts of data to be processed quickly and effectively, powerful memory and quick processors are necessary. These resources need to be properly maintained in order to maximize network performance [22].For the network to maximize efficiency and reduce traffic, it must be able to manage the constantly changing resources that are available. For instance, the system should automatically identify the more efficient path and route traffic accordingly if one path on the network has more bandwidth than another. To ensure maximum performance, the system also needs to be able to autonomously detect and configure changes in usage, user demands, and the networking environment [23, 24].

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COSIP

It describes a method in which a number of sensor nodes collaborate to gather, process, and send data to the sink node[25]. The goal of collaborative signal processing is to extract relevant information from the environment by merging the data gathered by several sensor nodes. Numerous methods, including data fusion, clustering, and classification, are used to do this. The accuracy and dependability of the system are increased by merging data from several sources [26]. Distributing the processing responsibilities among sensor nodes is known as collaborative information processing. By using this method, sensor nodes can process and make decisions locally before sending the data to the sink node [27].

In wireless sensor networks (WSNs), the idea of cooperation is to allow different nodes to work together to efficiently gather and process data [28]. This method prolongs the lifetime of the network, reduces communication overhead at individual nodes, and uses less energy. In wireless sensor networks (WSNs), collaborative signal processing integrates data gathered from various nodes to derive relevant contextual information. Numerous methods, including data fusion, clustering, and classification, are used to do this. The accuracy and dependability of the system are increased by merging data from several sources [29]. By using this method, the sensor nodes can process and make decisions locally before sending the data to the sink node. This lengthens the network's lifespan and lowers the power consumption of individual nodes[30]. In addition to being able to detect different kinds of signals like radio frequency signals, infrared radiation, or acoustic waves, sensors can be used to record a variety of physical attributes like sound, vibration, temperature, pressure, and electromagnetic radiation. Sensor networks are used in target detection to find objects or events of interest. In order to identify the target signal, this entails tracking and evaluating the data gathered by several sensors [31]. For example, a network of microphones and acoustic sensors can be used to detect the sound of an approaching vehicle, or a network of infrared sensors can be used to detect the heat signature of a person or animal. Target tracking is the process of continuously tracking the movement of an identified target over time. This is achieved by estimating the target's location and velocity by combining data from several sensors. For example, a surveillance network consisting of cameras, radar sensors, and acoustic sensors can be used to track the movement of a person or vehicle. Target categorization is the process of determining a target's type and attributes from its physical attributes [32]. This is accomplished by analyzing the sensor data to extract features that differentiate the target from other objects or events. For example, a network of chemical sensors can be used to classify the type of gas present in the environment [33].

Peer to Peer Networks

A sensor's ability to comprehend its job, determine its location, and effectively communicate with other sensors in the network depends on its understanding of the network. Without this information, the sensor might not be able to effectively engage in the cooperative network activities and might not be able to carry out its duties accurately [34].

Understanding the following reasons why a sensor's ability to function correctly in the system depends on its network knowledge:

Assignment of roles and tasks: In a network, each sensor node is given a specific duty or task, like processing or gathering data. Understanding the network enables the sensor to comprehend its specific role and task assignment, ensuring proper function.

Determining a sensor node's location is essential for a number of purposes, including data fusion and target tracking. For a sensor node to effectively engage in cooperative network operations, it must have precise location knowledge.

Communication: To ensure that there is appropriate communication between nodes, each network has a specific communication protocol that must be understood.

Network topology: Improving communication between sensor nodes in the network requires an understanding of the network topology. Effective communication between the sensors is made possible, which lowers data transmission mistakes and saves energy [35].

These networks are self-organizing, which means they use distributed algorithms to create their own networks rather than depending on a predefined structure like a central controller. Ad hoc networks require the nodes to build their own network architecture in real time, which means they must constantly update data regarding their connectivity to other

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nodes. This involves upgrading the network when new sensors are introduced or when existing ones stop working. This keeps the network current and enables it to keep operating effectively [36].

Congestion Control

Sensor networks gather, process, and send data to a central system using a combination of sensors and communication technologies [37]. There are several ways that this technology has been applied to monitor and manage automobile traffic. Sensor networks, for instance, can be used to measure and identify vehicle occupancy, speed, and traffic flow. Afterwards, by optimizing traffic signal timing and control, congestion can be decreased and overall traffic flow can be improved. Additionally, real-time information on events or accidents on the road can be obtained by sensor networks, enabling authorities to react swiftly and reroute traffic as necessary [38]. Additionally, through the detection of speeding and other infractions, sensor networks can be utilized to police traffic rules. In general, sensor networks provide an economical and effective means of tracking and managing automobile traffic, enhancing security and lessening gridlock on our roadways [39, 40].

Security

Since sensors are frequently used to gather information from strange or perhaps dangerous locations, security precautions should be included from the beginning of the design process [41]. This entails setting up the sensors to only report vital data, building the network with the highest level of encryption possible, and making sure the network has the proper authentication methods in place [42]. It is feasible to lessen any prospective hazards that can emerge during regular operation by taking security concerns into account throughout the design phase [43].

II. CONCLUSION

More than 20 years ago, digital sensors were mainly considered a notion rather than a useful tool. With the advancement of technology, we can now design sophisticated and accurate networks. The concept of employing networked sensors for environment monitoring and data collection seemed intriguing, but the technology was not developed sufficiently to make it a practical use case. Technology developed over time, making it feasible to design, create, and implement sensor networks with ever-higher degrees of precision and sophistication. Significant technological advancements during the past ten years have transformed digital sensor networks' capabilities. Sensor networks may now gather data more precisely and accurately while staying safe from possible attacks thanks to these developments. In addition, the networks are now significantly more energy, time, and cost efficient, which increases their appeal to a wide range of applications.

Digital sensor networks have practically limitless potential; our imagination is the only thing holding them back. Sensor networks, for instance, can be used to track the movements of endangered animals, monitor ecosystems, search for symptoms of disease in crops, and detect vibrations in aircraft engines. Sensor networks will have more possibilities as long as technology keeps developing.

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