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A Review of Wireless Sensor Network from Future Perspective

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ABSTRACT

WSNs have unique characteristics such as low-cost deployment, flexibility, scalability, low-power consumption, and robustness, which makes them well suited for a wide range of applications in different domains. Wireless Sensor Networks (WSN) are at the start of their evolution and have yet to overcome many research difficulties.WSN must still be able to operate on limited power and in remote or challenging environmental conditions, face issues of scalability and reliability, and have to be able to interpret complex data. Furthermore, the way information is processed, shared and used by the network is still being researched, as well as how to best use and organise the sensors that make up the system. In addition, security and privacy are important considerations and methods of constructing secure WSNs are being developed. Many of these research challenges are still being addressed and new ones appear as WSN make their way into different applications.

Keywords: Wireless Sensor Networks (WSN), Environmental Monitoring, Industrial Control, Applications, Challenges

INTRODUCTION

The first wireless trend marked the beginning of mobile devices and allowed people to communicate while on the go [1]. This trend continued to evolve throughout the 1990s with the development of the digital personal communication services (PCS) and the introduction of text messaging. By the early 2000s, the introduction of smartphones and other Internet-enabled devices allowed users to access data and use applications online, paving the way for the development of wireless data networks, such as 3G and 4G. These new advancements enabled a lot of uses including delivery of audio and video files, alongside Location-Based Services (LBS) [2]. In the past few years, the emergence of 5G networks, Smart Grids and IoT plummeted the use of wireless data networks and enabled new applications and services [3].

WSNs are networks of distributed, autonomous sensors used to collect data from its environment [4]. WSNs offer many advantages such as low-cost deployment, scalability, flexibility, robustness, and low-power consumption, making them well suited for a wide range of applications [5]. As WSNs become more advanced they open up new possibilities and are likely to become an integral part of many systems [6]. Despite the potential of WSNs, many research challenges remain, which continues to drive interest in this field.

As a result, they are more suitable for WSN deployments as they require less power and space and are easier to install and maintain [7]. Moreover, MEMS sensors have improved accuracy since they can measure and report multiple environmental factors more quickly and reliably [8]. Such sensors produce more reliable data, which can be used to make better informed decisions. As such, they can be used in a variety of applications such as monitoring water quality, traffic conditions, and structural stability, and can be combined with other technologies such as machine learning, cloud computing and image processing for further analysis [9].

Smart sensors are devices that use artificial intelligence (AI) and machine learning algorithms to automate the data collection and analysis process. They are able to take in data from multiple sources, process the information, and respond to the data in real-time with accurate results [10]. Smart sensors are highly customisable and can be programmed to effectively measure specific values. These sensors are typically used in industrial applications to measure and monitor important conditions, as well as having use as research and development tools. Traditional sensors require manual data input and, as such, are not adaptable to changing environments or conditions [11].

Smart sensors tend to be smaller, have less computing power, and are usually more cost-effective than traditional sensors. Additionally, they possess built-in intelligence that can adapt their behavior to changing conditions and environments, eliminating the need for manual input of data. Smart sensors are thus ideal for monitoring and tracking different parameters in a wide range of applications [12].They are also more capable of meeting the demands of modern digital systems, as they have built-in intelligence that allows them to automatically adjust their behavior according to the environment they are sensing and the data they are processing. Additionally, they can deploy algorithms on the edge, meaning that they don't need to rely on an external server for processing [13]. All of these features make them ideal for a variety of applications, from monitoring humidity levels in a greenhouse to tracking air quality in a home. A sensor node is a device that can sense, measure, and collect data from its surrounding environment. These nodes are typically equipped with one or more sensors and will use these to measure physical properties such as temperature, pressure, light and more. Sensor nodes are often used in applications such as IoT systems, industrial automation, and other areas where data collection and analysis is important. They are typically small, affordable, and provide a wide range of functionality. Additionally, these devices are designed to be low-power in order to reduce energy consumption and extend battery life [14].

Smart sensor nodes contain the necessary components to collect and analyze data from the environment. They are generally low-power devices and feature a radio and an actuator to facilitate communication with other nodes so that data can be wirelessly transmitted [15]. These sensors are typically used in applications such as IoT systems and industrial automation[16]. They are typically low power devices and are designed to use minimal energy consumption so they can extend the battery life of the device. Sensor nodes also have a radio and an actuator, which enable the device to wirelessly transmit data and complete other tasks. They are often used in applications such as IoT systems, industrial automation, and data measurement [17] .

Challenges

Data processing involves extracting useful information from collected data, as well as combining and analyzing it in a meaningful way. Communication is a critical component of sensors networks since it enables the nodes to form a network, exchange data with each other, and respond to external commands. Lastly, sensor management consists of configuring and deploying the sensors, ensuring their optimal operation, and maintaining their integrity [18]. All of these factors must be taken into consideration to ensure a successful integration of the sensors into an application. Wireless ad hoc networks require complex network discovery and control protocols to identify, locate, and activate available nodes [19]. In addition, the networks must be able to route information between nodes and support collaborative information processing and querying. Furthermore, the nodes must be able to process, store, and respond to task requests from other nodes. Finally, the nodes must manage their power resources optimally and use them efficiently in order to maintain network connectivity. All of these technical challenges must be taken into account when setting up and managing a wireless ad hoc network [20].

Network Protocol

Energy is needed to power routers, switches, and other networking equipment to keep the network functioning [21]. Bandwidth is needed to transmit and receive data across a network. With increased bandwidth, higher data transmission speeds can be achieved. Finally, processing power or computing resources are needed to process data and maintain the functioning of the network. Powerful memories and rapid processors are required to swiftly and proficiently process massive volumes of data. In order to optimize network performance, these resources must be carefully managed [22].Network must be able to handle the changing resources that are available in order to optimize performance and minimize traffic. For example, if one path on the network has more bandwidth than another, the system should automatically determine the more efficient path and route traffic accordingly. Additionally, the system must be able to autonomously identify and configure changes in usage and user demands and networking environment in order to maintain optimal performance [23,24] .

CoSIP

It refers to a technique where multiple sensor nodes work together to collect, process and transmit information to the sink node[25]. Collaborative signal processing involves combining the data collected by multiple sensor nodes to extract meaningful information from the environment. This is achieved by various techniques such as data fusion, clustering, and classification. By combining information from different sources, the accuracy and reliability of the system are improved [26]. Collaborative information processing involves distributing the processing tasks amongst sensor nodes. This approach allows the sensor nodes to perform local processing and decision making before transmitting the data to the sink node [27].

The concept of collaboration in WSNs is to enable multiple nodes in the network to collaborate with each other to efficiently collect and process information [28]. This approach helps in reducing the communication overhead at individual nodes, conserves energy consumption, and increases the network lifetime. Collaborative signal processing in WSNs involves combining the data collected by multiple nodes to extract useful information from the environment. This is achieved by various techniques such as data fusion, clustering, and classification. By combining information from different sources, the accuracy and reliability of the system are improved [29]. This technique allows the sensor nodes to conduct local processing and decision making prior to transferring the data to the sink node. This reduces the power consumption of singular nodes and increases the lifespan of the network[30].
Sensors can be used to capture different physical properties such as sound, vibration, temperature, pressure, and electromagnetic radiation, and can be designed to detect various types of signals such as acoustic waves, infrared

radiation, or radio frequency signals. In target detection, sensor networks are used to detect the presence of objects or events of interest. This involves monitoring the data collected by multiple sensors and analyzing it to identify the target signal [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 involves the continuous monitoring of a detected target and its movement over time. This is accomplished by fusing data from multiple sensors to estimate the target's location and velocity. 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 classification involves identifying the type and characteristics of a target based on its physical properties [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

Knowledge of the network is critical for a sensor in the system to function correctly since it aids the sensor to grasp its role, estimate its position, and efficiently interact with other sensors in the network. Without this knowledge, the sensor may not be able to efficiently participate in the collaborative operations of the network and may not be able to perform its functions correctly [34].

Realizing why knowledge of the network is critical for a sensor in the system to run properly includes:

1. Role and task assignment: Every sensor node in a network is assigned specific roles or tasks, such as data collection or processing. Knowledge of the network helps the sensor understand its role and specific task assignment to ensure that it performs its function correctly.
2. Location determination: The location of a sensor node is critical for various reasons, including target tracking and data fusion. A sensor node should know its location accurately to participate in the collaborative operations of the network efficiently.
3. Communication: Every network has its communication protocol, and knowledge of this protocol is critical to establishing proper communication between nodes.
4. Network topology: Understanding the network topology is essential in optimizing communication between sensor nodes in the network. It enables the sensors to communicate effectively, reducing data transmission errors, and conserving energy [35].

These networks are self-organizing networks, meaning they do not rely on a predetermined structure such as a central controller, and instead they use distributed algorithms to form their own networks. The nodes in an ad hoc network must construct their own network topology in real time, meaning they need to continuously update information about their connectivity with other nodes. This includes updating the network when sensors fail, as well as when new sensors are added. This allows the network to remain up to date so it can continue functioning efficiently [36].

Congestion Control

Sensor networks use a combination of sensors and communication technologies to collect, process, and transmit data to a central system [37]. This technology has been used to monitor and control vehicle traffic in various ways. For example, sensor networks are useful in detecting and measuring traffic flow, speed, and vehicle occupancy. This information can then be used to optimize traffic signal timing and control, reducing congestion and improving overall traffic flow. Sensor networks can also provide real-time information about accidents or incidents on the road, allowing authorities to quickly respond and redirect traffic as needed [38]. In addition, sensor networks can be used to enforce traffic laws by detecting speeding or other violations. Overall, sensor networks offer a cost-effective and efficient way to monitor and control vehicle traffic, improving safety and reducing congestion on our roads [39,40].

Security

As sensors are often used to collect data from unfamiliar or potentially hostile environments, it is important to incorporate security measures from the start of the design process [41]. This includes designing the network with the highest level of encryption available, configuring the sensors to only report critical data, and ensuring that the network has appropriate authentication protocols in place [42]. By considering security issues at the design stage, it is possible to mitigate any potential threats that may arise during normal operation [43].

CONCLUSION

When digital sensors first emerged more than two decades ago, they were more of a concept than a practical application. Over time, technology has developed and we are now able to create networks that are advanced and precise. The idea of using networked sensors to monitor and collect data in environments was promising, but the technology was not yet advanced enough to make it a reality. As time passed, technology progressed and it became possible to design, develop, and deploy sensor networks with increasing levels of sophistication and accuracy. In the last decade, technology has seen significant advances which have revolutionized the capabilities of digital sensor networks. These advancements allow sensor networks to collect data with greater accuracy and precision while also being able to remain secure from potential threats. Furthermore, the networks are now far more efficient in terms of cost, time, and energy, making them more attractive for many applications.

The possibilities for digital sensor networks are almost endless; the only thing limiting their potential is our own imagination. For example, sensor networks can be used to monitor ecosystems, look for signs of disease in crops, detect vibrations in aircraft engines, or even track the movements of endangered species. As technology continues to evolve, the potential for sensor networks will continue to grow.

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