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(REVIEW ARTICLE)

Emerging applications and ongoing challenges in WSN assisted IoT networks

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Abstract

In current scenario, Wireless Sensor Networks (WSN) based on Internet of Things (IoT) have seen a significant growth in research area. IoT is a network that enables sensors, and other events to interact with each other without human interference. In addition, wireless network is an essential part of the Internet of Things, generating an abundance of real-time applications. WS Ns can be recognized by their distributed sensor nodes and application fields including environmental monitoring, healthcare, agriculture, industrial automation, and smart cities. Therefore, an extensive usage of such networks is the outcome of their adaptability in variety of fields. The present study digs into the immense scope of WSN applications and the daunting challenges that come alongside. However, these applications face a slew of obstacles, including those related to energy, scalability, security, quality of service, network dependability, and data management. Further, the study focuses on gathering insights into the changing WSN technology environment by examining these applications and the issues they encounter, allowing to satisfy the demands of both existing and forthcoming deployments. As WSN technology is improving, the present study contributes by investigating prospective solutions, such as machine learning integration, energy harvesting, and standardization efforts.

Keywords: WSN; IoT; Applications; Challenges

1. Introduction

Nowadays, wireless sensor networks (WSNs) are becoming increasingly popular due to their versatility and capacity to serve a broad range of applications. WSNs are made up of spatially dispersed autonomous sensors that work together to monitor physical or environmental conditions, collect data, and wirelessly send it to a central point for processing and analysis [2-6]. This network consists of up of "nodes" ranging from a few to hundreds, with each node connected to one of the sensors. Transceiver, antenna, storage unit, and other components are often included in each sensor network node [7, 8]. Similar price ranges apply to sensor nodes, with prices varying from a few thousand to hundreds of dollars based on how complex each sensor node is. As a result, the architecture of WSNs can range from a simple star network to an elaborate multi-hop wireless mesh network. WSNs are becoming widely employed for commercial and scientific purposes, and in environments where battery replacement or reviving is challenging, it is critical that WSNs have extended and predictable lifetimes. As a result, we anticipate that energy management will become increasingly critical in meeting user demands. [8,9,10]

When a WSN deploys enough of these sensor nodes in an integrated manner, it may acquire data simultaneously at multiple points of interest spread over vast regions. The low-cost development of these kinds of sensor nodes—which have significantly advanced sensing, processing, and communication capabilities despite their relatively small size has become possible because of continuous technological breakthroughs. On that account, whereas WSNs were first utilised

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primarily for defense purposes, they now support an ever-expanding spectrum of applications of various types [6,13,14]. WSNs have evident potential benefits, but their successful deployment and functioning face major obstacles.

This review delves into the interesting world of WSN applications and the numerous issues they serve. We will investigate the wide landscape of WSN applications, highlighting their real-world impact and the unique solutions they provide. Furthermore, we will examine the various obstacles that WSNs confront, such as energy restrictions and data security, as well as scalability and reliability issues. As we go through the realm of WSNs, we will gain a better knowledge of their critical function in modern technology as well as the challenges that come with its deployment. The outline of article is arranged as: Section 2 illustrates the literature review, section 3 illustrates WSN-Based IoT Applications, and Section 4 discusses the application challenges in WSN-IoT. Finally, in section 5, the paper's conclusion and future work are provided.

2. Literature Review

WSN-based IoT applications are now gaining prominence in the field of research. There are numerous approaches that increase both the transmission process and the overall energy efficiency of nodes. This section examines the existing literature on WSN and IoTs.

A review of smart health apps that improved society by encouraging fitness, streamlining patient-physician communication, and monitoring patients' health online via wearable, implantable, or smartphone applications was presented by Sanghavi et al. [15]. Haseeb et al. [6] presented an IoT-based WSN framework with several design levels as an application to smart agriculture. When compared to other solutions, the simulated results showed that the proposed framework significantly improved communication performance by an average of 13.5% in throughput, 38.5% in packet fall ratio, 13.5% in latency, 16% in energy consumption, and 26% in routing overheads for smart agriculture. Onasanya et al. [11] concentrated on IoT-based healthcare systems for cancer care services and cloud services, as well as the acceptance and execution of IoT/WSN technologies to enhance existing treatment alternatives in order to give patients better health. Abuelkhail et al. [2] created a network of smart nodes, each of which contains a Radio-Frequency Identification (RFID) tag, an optimised function RFID reader (RFRR), and sensors. Sharif et al. [16] discusses the various technologies that can aid in traffic control in smart cities. It primarily considered technologies including IoT and adhoc networks. An overview of various technologies is provided, along with difficulties and communication equipment. Sunny et al. [22] explored the use of Commercial Off-The-Shelf (COTS) components to build an installed Internet of Things (IoT)-based general-purpose monitoring system for a specific nuclear storage situation that measures hydrogen concentration and temperature.

Behera et al. [3] improved on the previous Stable Election Protocol (SEP), which enabled threshold-based cluster head selection in a heterogeneous network. The threshold ensured that energy is distributed uniformly between member and cluster head nodes. Malche et al. [9] presented an environment monitoring and alarm system based on the Internet of Things (IoT). The suggested system analysed the region's environment for air quality and noise pollution, while also enabled safe data transmission via the network, resolving security challenges in IoT systems. Furthermore, Qureshi et al. [13] formulated routing protocol which was used for WSN-based monitoring in Agriculture precision. Mohamed et al. [10] addressed the potential applications for integrating UAVs in smart cities, their ramifications, and the technical and non-technical challenges that such integration presents. It also discussed the policies and supporting technologies that are currently available and being developed to support such integration. Prathibha et al. [12] researched on environmental monitoring in smart agriculture using IoT. The purpose of this project was to monitor temperature and humidity in agriculture using sensors and a single CC3200 chip. The newly implemented strategy proved to be more favorable to farmers. Furthermore, Bandur et al. [4] investigated the use of WSN in smart agriculture. The authors concentrated on the energy usage of various WSN components on both a physical and functional level. In addition, Bharathi et al. [5] suggested a strategy for successful cluster head (CH) selection. In addition, the authors employed an ANN (artificial neural network) model to evaluate healthcare data. This surpassed various current models in various ways.

3. WSN-Based IoT Applications

Integration of WSN and IoT has benefitted a lot in building a smart environment. Nearly every aspect of contemporary life has been influenced, including healthcare, education, transportation, environmental monitoring, and agriculture. The sensor nodes deployed in different devices gather the information that can be extremely beneficial to take crucial decisions in any of such applications. Some of the IoT applications that play major role in building a smart environment are discussed below.

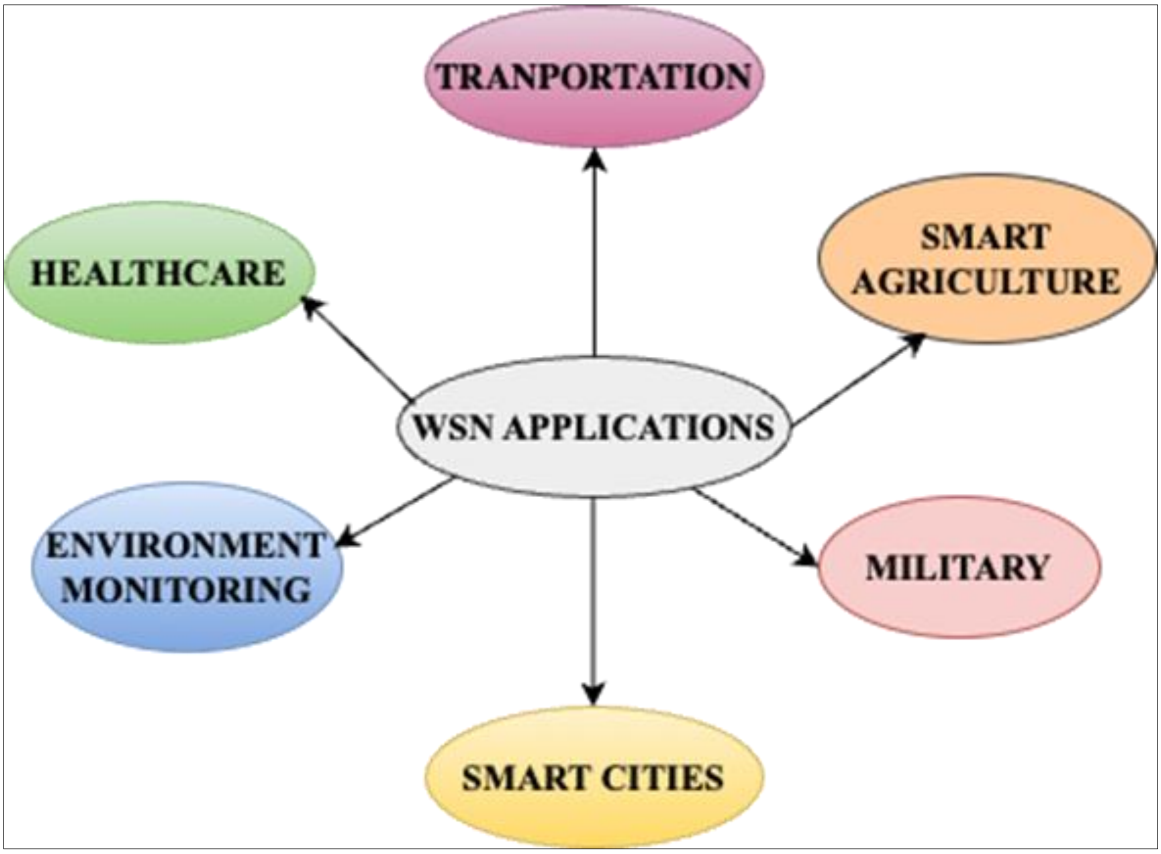

Figure 1 WSN-IoT based applications

3.1. Healthcare

Healthcare is one such field where WSN and IoT has proved to be life-enhancing. Due to aging of population, scarcity of healthcare resources and increase of medical expenditures, IoT-based technology was required to solve these difficulties in healthcare. According to [1] home healthcare service is the main application field of IoT in healthcare. This service has proved to be outstanding application of WSN. Home healthcare gave the solution to overcome the problem of population aging. Cancer Care service is one of the services that is pertinent to smart healthcare delivery and patient monitoring. IoT devices create a plethora of new opportunities for patients to monitor themselves and for healthcare providers to keep track of their patients. Among the most popular uses of Internet of Things (IoT) devices that may automatically gather health measurements are remote patient monitoring, glucose control, and heart-rate monitoring. With the availability of a variety of small Internet of Things heart rate monitoring devices, patients can now move anywhere they want while having their hearts constantly monitored. "Mood-aware" IoT devices are used in depression and mood monitoring [17]. In chronic conditions, being aware at all times is crucial. Medical IoT devices collect vital indications of any ailment and provide them to clinicians for real-time monitoring, as well as sending out alerts to people about essential portions via mobile apps and smart sensors [23].

3.2. Agriculture

Agriculture farming has recently undergone technological transformations. It has become more technologically advanced and industrialized in recent decades, bringing a plethora of benefits to farmers. The ever-increasing demand for food has transformed agriculture into an industry in which farmers now have complete control over crop production and sale. The Internet of Things (IoT) and sensor network has the potential to revolutionize agriculture technology; it is a highly promising family of technologies that offers solutions to a variety of existing agricultural problems. It monitors various factors such as humidity, temperature, soil, so on and provides a crystal clear real-time observation.

Sensors are installed within and around agricultural fields. They collect data from the environment, which is then used to select crops that can grow and thrive in the specific climatic conditions. One of the most well-known applications of IoT in agriculture is precision agriculture. It improves the precision and control of farming practices by implementing smart farming applications such as livestock monitoring, vehicle tracking, field observation, and inventory monitoring [18]. The analysis of soil quality aids in determining the nutritional content and relatively dry areas of farms, soil drainage capacity, or acidity, allowing the amount of water required for irrigation to be adjusted and the most beneficial type of cultivation to be chosen. Agricultural drones are also used to enhance the farming practices. Both Ground-based and aerial-based drones are used in agriculture for crop health assessment, crop monitoring, pesticide spraying, irrigation, planting, and field analysis. During flight, these drones collect multispectral, thermal, and visual imagery [19].

3.3. Transportation

Smart transportation is the need of an hour due to its major issue in traffic congestion. Heavy traffic congestion causes delay, tends to increase pollution, wastes fuel, raises transportation costs and driving-related stress, and even has a negative impact on the economy [21]. Therefore, integration of WSN and IoT attempts to provides an appropriate solution to all such problems.

Intelligent traffic management (ITS) helps to eliminate traffic congestion by gathering information via Wireless Sensor Networks (WSNs), RFIDs, ZigBee [11], Vehicular ad-hoc network (VANETs) [21], Bluetooth devices, cameras and infrared signals. The authors in [15] proposed "TRAFFIC" as a solution to inter-vehicle communication so that congestion level could be estimated for increasing traffic flow. IoT applications enable users to have entertainment connectivity in their vehicles. Users employ Automotive Telematics to remotely monitor the condition of their vehicle. A smartphone-enabled dashboard ensures safety of a driver. External cameras and sensors monitor the vehicle's condition and transmit data to an app [20]. The vehicular ad hoc networks enable vehicles to avoid issues by assessing any suitable activities or by observing the drivers, for example, in case of mishaps in roadways, a notification may be uniformly distributed to inform all other vehicles. In [20] authors suggested a smart parking scheme that uses IoT to recognise unoccupied and occupied positions, eliminating the need to waste valuable time looking for a suitable parking spot for the cars. According to the authors, the IoT and WSN are promoting a wide range of applications such as logistics support, emergency services, and a variety of other applications. Not only are vehicles equipped with sensors, but a variety of sensors are also used on the roads to improve road safety and conditions [5].

3.4. IoT in Disaster management

IoT and WSN play a major role in disaster management scenarios. Disaster is totally unpredictable and it gives no time to respondents for decision making. Technology, particularly the Internet of Things (IoT), can acknowledge and predict key situations and crises, as well as prepare for and manage potential post-disaster situations.

By installing sensors in high-risk areas, it is possible to manage environmental and atmospheric conditions and, in the case of a disaster, reduce the amount of money lost and human casualties by taking early preventative measures. It is possible to detect aberrant temperatures, floods, earthquakes, and fires by continuously monitoring a temperature, humidity, ultrasonic, gyroscope, or smoke sensor [11]. When used together, IoT and big data analytics (BDA) provide enormous benefits for disaster management. One of the primary benefits of a BDA and IoT-based disaster management environment is that it may provide reliable connectivity due to the availability of numerous communication technologies. Connectivity is the cornerstone of effective operations among the interconnected data nodes and the DMS [21]. In previous years, the wireless sensor network was one of the most significant emerging technologies for predicting forest fires [17]. Raspberry is a type of lightning detector connected with a lightning sensor and can detect a little change in the gamma from a range of about kilometer's , the information is transferred to a remote server every 15 minutes. To adequately identify the case, artificial illumination and high-power transmissions are attenuated at the same time [24].

3.5. IoT in Environment monitoring

Pollution related to air, water, and land are major environmental problems that require attention. In order to maintain a healthy society and attain sustainable growth, appropriate monitoring is necessary. In recent years, environmental monitoring has transformed into a smart environment monitoring (SEM) system thanks to developments in the internet of things (IoT) and the development of advanced sensors. Environment monitoring (EM) includes planning and mitigating disasters, reducing pollutants, and effectively resolving issues that arise from hazardous environmental situations [22]. The author emphasized the role of indoor air quality to one's health and well-being. To enhance occupational health and well-being, ambient-assisted living technologies are essential as the proportion of elders grows. Wireless Sensor Networks (WSNs) have been an effective technology for its use in extreme climate conditions like those found in nuclear power plants [8]. Furthermore [16] research offers an environment monitoring and alarm system based on the Internet of Things (IoT). The suggested system analyses the environment for air quality and sound pollution in a given region while simultaneously permitting secure data transmission over the network, resolving security challenges in IoT systems.

4. Challenges for WSN-IoT applications

WSN and IoT applications discussed in previous section face multiple challenges as discussed below:

- **Energy consumption:** In order to operate and carry out numerous tasks, sensors need power or a backup source of energy. As nodes are powered by an embedded battery with a limited capacity for power backup, this becomes an issue. Sensing, data collecting, processing, and data transmission all use up this energy. The network's lifespan can be extended by optimizing energy-efficient data transmission.
- **Scalability:** WSNs might consist of several hundreds of sensor nodes. Data transmission from numerous cluster heads to a single base station while maintaining effective communication might lead to scalability problems.
- **Security:** One of the most essential challenges in a wireless sensor network is privacy and security. Because data travels wirelessly across the air, wireless signals are available to anyone, allowing anybody to watch and engage in conversation. To prevent hostile attacks, security has become extremely vital in commercial specifically military applications.
- **Reliability:** Numerous applications, such as environmental monitoring and tracking, necessitate reliable information delivery. Numerous applications, such as environmental monitoring and tracking, necessitate reliable information delivery. Combating challenges such as packet loss, interference from other devices, and node breakdown while retaining data integrity is critical for network reliability.
- **Quality of Service (QoS):** Specific QoS assurances, such as low latency and high dependability, are required for some WSN applications, such as healthcare, smart farming and industrial usage. These conditions must be met by routing protocols.
- **Network Topology:** WSNs are frequently employed in dynamic contexts in which nodes shift, break down, or join the network. Routing protocols face substantial challenges in dealing with dynamic topologies, including the capacity to respond to variations in real time.
- **Communication in Real Time:** Some applications necessitate real-time data transfer, which presents difficulties in latency-aware circumstances. Applications' effectiveness may suffer as a result of delayed data delivery.
- **Cost and deployment:** Sensor nodes and IoT devices, as well as deployment costs, might be prohibitively expensive. It is critical to identify economical approaches and deployment methodologies.

5. Conclusion

This study has witnessed that WSN and IoT have the potential to revolutionise a wide range of industries and sectors due to their diverse applications. However, solving issues such as energy efficiency, finances, scalability, security, data management, QoS, and deployment is critical to their continued viability. By overcoming these obstacles, WSNs can realise their full potential and play a larger role in determining the future of technology and society. Future study and advancement activities should focus on addressing these problems as WSN technology evolves. Energy harvesting innovations, enhanced security procedures, and scalable network architectures will be essential. Exploring fresh applications and interdisciplinary cooperation will also broaden the frontiers of WSNs.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest.

Availability of data and material

Data will be made available on request.

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