Wireless Sensor Network in Environment Monitoring

Subjects: Engineering, Electrical & Electronic

Contributor: Shathya Duobiene, Karolis Ratautas, Romualdas Trusovas, Paulius Ragulis, Gediminas Šlekas, Rimantas Simniškis, Gediminas Račiukaitis

The Internet of Things (IoT) technology and its applications are turning real-world things into smart objects, integrating everything under a common infrastructure to manage performance through a software application and offering upgrades with integrated web servers in a timely manner. Quality of life, the green economy, and pollution management in society require comprehensive environmental monitoring systems with easy-to-use features and maintenance.

Keywords: Internet of Things ; wireless sensor network ; web server

1. Introduction

Wireless sensor networks (WSNs) are becoming increasingly common in various areas, including industry, transportation, environment, and healthcare. Furthermore, the growing use of Internet of Things (IoT) technologies in almost all sectors [1] supports this trend. Herein, the primary focus was on the embedded system of sensor nodes using Selective Surface Activation Induced by Laser (SSAIL) technology [2][3] for temperature and humidity monitoring. Using this technology, antenna and rf-harvesting circuits can be formed on various plastics, including the device's body. As a result, the device can be made smaller. The communication module that supports energy-harvesting antenna circuits enables the rapid, cost-effective fabrication of three-dimensional circuits on flexible material. Furthermore, even in harsh conditions, the long-term operation of distributed sensors can be achieved by collecting energy from various electromagnetic radiation sources [4]. In addition, collecting energy from the environment can reduce the need for sensor network maintenance by ensuring that they have sufficient energy for a longer lifetime, resulting in many convincing environmental and deployment benefits [5][6].

The rapid development of IoT devices has resulted in various embedded web server possibilities. Current technological advancements in industrial wireless monitoring networks (IWSNs) primarily deal with applications from emergency systems, regulatory control systems, supervisory systems, open-loop control systems, alerting systems, and monitoring systems [7]. In contrast, the installation of large-scale IoT devices complicates the use of control systems in production lines because their huge size and delicate structure make them more difficult. Therefore, one of the most affordable and widespread solutions to society's needs has been contributed through the research. The sensor system could be customised using software and hardware technologies, making it easy to deploy for environmental monitoring and providing an option for energy harvesting to power the node in locations that are sufficiently abundant with ambient RF signals for extended periods of time.

Analysing the characteristics and parameters of sensor network nodes distributed randomly saves a lot of time and money for the real-time deployment of IoT devices on a large scale. An architecture for the master and slave sensor nodes has been proposed for the monitoring system. The communication module and energy-harvesting antennas were designed and tested. The proposed sensor node's power consumption has been evaluated to ensure its long-term operation. An investigation into one of the commonly used communication protocols was carried out, and the findings were reported. The total power consumption of each sensor node was measured using a deterministic operating regime. The monitoring of the sensor nodes was accomplished independently through the high-level hosting application. The utilisation of solar and wind energy as a source of energy harvesting would be the superior choice in more remote open locations. WSNs built by this approach can be used to monitor the forest, including unmapped areas after installation.

2. Applications of WSNs

This section provides an overview of the most recent advancements that have been made in the application of WSNs. Precision agriculture, industrial, forestry, and weather monitoring systems can all benefit from the suggested method. Industry 4.0 categorises numerous wireless sensor networks [7][8] coverage approaches, deployment issues, sensing models, and research obstacles, including sensor networks, fog, edge computing, distributed control systems, digital twins, and cyber–physical systems. Due to the size and adaptability of the system, it is able to support the rapid deployment of IoT devices on conveyor belts for the purpose of monitoring the process of production lines or various areas for environmental monitoring.

The IoT application for forestry management involves data transfer to cover locations where 3G/4G signals are unavailable. The authors used low power wide area network (LPWAN), NB-IoT (NB—narrow band), LoRa (long-range), and appropriate sensors to convey data [9]. Using that approach, they employ two repeaters to cover the more considerable distance. In addition, the sensor network that they have works well for measuring air pressure, UV light, and carbon dioxide on hillsides. In light of the findings from earlier research, the decision was made to install retransmitters to cover the distance inaccessible to communication channels.

Atmospheric environmental monitoring plays a major role in monitoring the aerosol, particulate matter, haze, dust storms, straw burning, and gaseous pollutants that contribute to global warming. Three types of atmospheric monitoring use remote satellite sensing, and improved retrieval methods, product validation, local application, air quality monitoring, and control are all part of the network [10]. However, according to experts, the current monitoring precision is insufficient to meet the management demands of the atmospheric environment.

A portable weather-monitoring system for greenhouses to measure temperature, humidity, and moisture is presented in [11]. The solution provides a simple gadget that could measure such characteristics reliably and practically. The gathered sensor values are regularly updated using the ThingSpeak IoT's web service. However, this approach is unreliable in a larger region. The proposed system is using the PHP application and MySQL database results in easy time-series management and can forecast future sensor values in the web server, and the real-time charts can display a maximum of 150 data points.

Traditional farmers gain a valuable technological tool by using the IoT to monitor and control environmental variables in a coffee crop via a wireless sensor network. This allows them to increase their economic benefits, reduce environmental impact, and improve the quality of life. The Zigbee protocol by Zigbee Alliance was suggested in [12] over other wireless technologies with equivalent capabilities because of its low cost. However, due to the excessive humidity in coffee plantations, the failure to execute all of the anticipated measurements causes difficulties with the sensors and the readings of this monitoring system.

The energy optimisation of the quality of service (QoS) in wireless sensor networks is highly essential and depends on different routing protocols such as the RPAR (real-time power-aware routing) protocol, GRPAR (greedy real-time power-aware routing) protocol [13], and the low-energy adaptive clustering hierarchy (LEACH) protocol. The latter is based on clustering, and the nodes can only send to the cluster head (CH). Since WSNs interact with the environment, their characteristics are expected to differ from conventional data networks. QoS support for the network has to consider a few of the unique challenges such as severe resource constraints, unbalanced traffic, data redundancy, network dynamics, energy balance and scalability, multiple sinks, traffic types, and packet criticality. When the application of the sensor network is specified, QoS helps support and overcome the challenges mentioned above.

Firstly, the applications that run on WSNs are not end-to-end applications like they used to be. Secondly, the bandwidth is not the main concern for a single-sensor node [14]. However, the bandwidth may be an essential concern for a group of sensors for specific periods due to the burst nature of sensor traffic. Thirdly, packet losses in traffic generated by one sensor node can be tolerated to a certain extent, since there is always redundancy in the data. Finally, most applications in WSNs are mission-critical, reflecting the importance of applications. Consequently, they are confident that the QoS support in WSNs cannot be gauged using end-to-end network QoS metrics alone. Thus, there is a knowledge gap for non-end-to-end QoS parameters that must be proposed. QoS parameters are collectively called "collective QoS parameters", referring to these non-end-to-end characteristics. These are collective latency, collective packet loss, collective bandwidth, and information throughput [14].

The hybrid cluster approach for homogeneous and heterogeneous networks to increase the QoS parameters of wireless sensor networks based on MATLAB simulation results is devised in [15]. Based on throughput and network lifetime parameters, the proposed WSN QoS-based energy-efficient protocol outperforms ATEER (average threshold energy-efficient routing), DEEC (developed distributive energy-efficient clustering), and EDDEEC (enhanced developed distributive energy-efficient clustering) by 10%, 26%, and 63%, respectively. The study concludes that the protocol based on throughput and network lifetime parameters is well suited and well positioned for designing WSNs in real-world and real-time scenarios.

In the node status and score-based route optimisation protocol (NSSROP), each node stores some additional data to balance the routing burden among all nodes [16]. A sensor node may have the shortest route to a base station in an IoT configuration. The WSN's block-listing method is established to cope with non-cooperative nodes and the NSSROP has achieved exceptional results in terms of average energy usage, throughput, and end-to-end delay [16]. Unlike other standard routing protocols, the proposed technique considers various QoS criteria related to routing and energy optimisation in WSNs. To determine the node densities, each node is evaluated based on its energy consumption and closed neighbours (CNs).

A hybrid method for obtaining the probability distribution of report latency in random access (RA) WSN protocols [17] is studied and it is beneficial for assessing the QoS of WSNs in time-critical applications. In this manner, event reporting is time-constrained and fault-sensitive. In specific applications such as target tracking and positioning, transmitting a certain number of event packets is required to characterise the occurring phenomena accurately. The methodology considers a basic structure, and the distribution of the number of detecting nodes is obtained by simulation, allowing the analysis of the desired QoS parameters.

Most WSN technologies are designed to monitor and manage various processes effectively. A "smart environment" is equipped with sensors, microcontrollers, and adaptive software programs for self-protection and self-monitoring. For designing a WSN, several factors need to be considered. Such factors include scalability, fault tolerance, high sensing accuracy, inexpensive deployment costs, rapid scaling up, and application needs. The sensor networks will become an integral part of our lives in the future because of their wide range of applications. However, before sensor networks can be implemented, constraints such as cost, hardware, topology alteration, environment, and power consumption must be addressed. In addition, sensitive networks demand particular wireless ad hoc networking protocols because of the tight restrictions.

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