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RESEARCH ARTICLE

Design and Implementation of a Wireless Sensor Network for Real Time Monitoring Applications

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Abstract

This research highlights the importance of potentially using WSNs in real-world scenarios by employing low cost and scalable platforms. As WSNs increasingly used in many fields of applications such as automation, healthcare, and security, it is very crucial to understand the performance under different conditions of environment by employing low-cost platforms, especially in developed countries. Therefore, this study presents practical experiments to insight the efficiency and reliability of WSNs in monitoring dynamic changes in temperature, light, motion, and distance over the course of 24 hours. By leveraging a cost-effective and scalable setup involving Arduino, ZigBee and X-CTU software, this research demonstrates how WSNs can be optimized for diverse applications, paving the way for more robust and adaptable systems in the future. Furthermore, the findings contribute to the growing body of knowledge on WSNs, offering a foundation for further innovation and development in this field.

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Keywords: Wireless Sensor Networks (WSNs); ZigBee; Sensor Nodes.

1. Introduction

A Wireless Sensor Network (WSN) has three advantages: the use of low power, relatively low cost, and small size [1-3]. These nodes are immediately interactive. They sense and monitor and begin a cooperative process of data transfer through the main sink [4]. This monitor can be heat, light, humidity, motion, pressure, sound, or vibration. The base station (BS), or sink, is an interface between users and the network [5]. Sensor's nodes can receive and transmit information from a wireless network or a wired connection. Information passes between the nodes and the base station [6]. These nodes are extremely versatile and hold a wide range of applications, such as military, homeland security, smart homes, extreme weather, and medicine. The ability to detect pressure, temperature, and sound make them perfect for emergency or otherwise dangerous situations, including controlling and monitoring [7-10].

One of the most important technologies for data transmission between wireless networks is ZigBee. ZigBee is beneficial because of its low energy consumption, low cost, low duty cycle, and low latency [7, 11]. The low cost of this technology allows for a wider range of applications. This is most applicable for needs in home automation, health care, and temperature control. ZigBee technology is ready for immediate usage in the industrial, scientific, and medical sectors. ZigBee puts itself to sleep for several minutes before waking up and sending or receiving sample information [12-14].

WSNs are comprised of hundreds of nodes that connect to sensors. Each sensor has a specific purpose, such as memory communication, computing power, and limiting the use of energy. Radio signals transmit or receive information between the databases. The sensor node may communicate during the transmission, as there is a remote sensor that distributes computing power [15].

There are two aspects of the wireless data transfer, including wireless transceivers and sensing ability component parts. These elements respond to enquiries from the control site and provide samples. They can also process and deliver messages to a common sink. The nodes within the WSNs coordinate locally. As such, they can communicate and sense changes in the atmosphere. These changes are then sent to the control sensor for immediate analysis of the samples. The data is sent to computers on the network or to the control site for processing [5]. In setting up this experiment, much research was done into the various uses, functions, and established experiments of ZigBee technology and WSNs. Yi-Jen et al. [5] developed a WSN system with a monitor, controller, and sensor for specific applications. Their experiments highlighted the advantages of ZigBee technology, such as low cost and low power consumption. They also tested different design features, including motor control and an LCD monitor, concluding that WSN is highly effective for data transfer. Another study by Anas et al. [6] demonstrated the benefits of ZigBee for remote temperature monitoring in 2015. Their WSN design included a protective covering, extra data storage, and the ability to control temperature automatically using a fan or heater. They built a PC server and gateway to communicate with WSN, tested it in a house, and collected temperature data from different locations. The system stored data in a database and responded automatically to temperature changes. Another study by Singh and Kumar [7] studied data flow in an agricultural monitoring system. The research explored how WSN could measure and respond to humidity, soil moisture, and external temperature. These findings suggested that WSN could help farmers improve crop quality and reduce costs. Therefore, the current study describes an experiment with a small robotic vehicle connected to WSN using ZigBee Series 2. The vehicle, controlled by an Arduino board, collected data on temperature, light, motion, and distance over 24 hours. The data was then analyzed with X-CTU software and presented in charts.

The remainder of this paper is summarized as follows. Section 2 summarizes the methods and materials used, including hardware and software setup and configuration and system framework. Section 3 presents experimental results and discussion. Finally, section 4 presents the conclusion.

2. Methods and Materials

2.1. Hardware Setup and Configuration

In order to achieve a cost-effective solution, the configuration used in this experiment is set up with the following components, including the Arduino Mega Board 2560, ZigBee (XBee S2), and sensors for motion, distance, lighting, and temperature. The hardware had to be configured. Specifically, the sensors were connected, and the robotic vehicle was built to hold them, as shown in Figure 1.

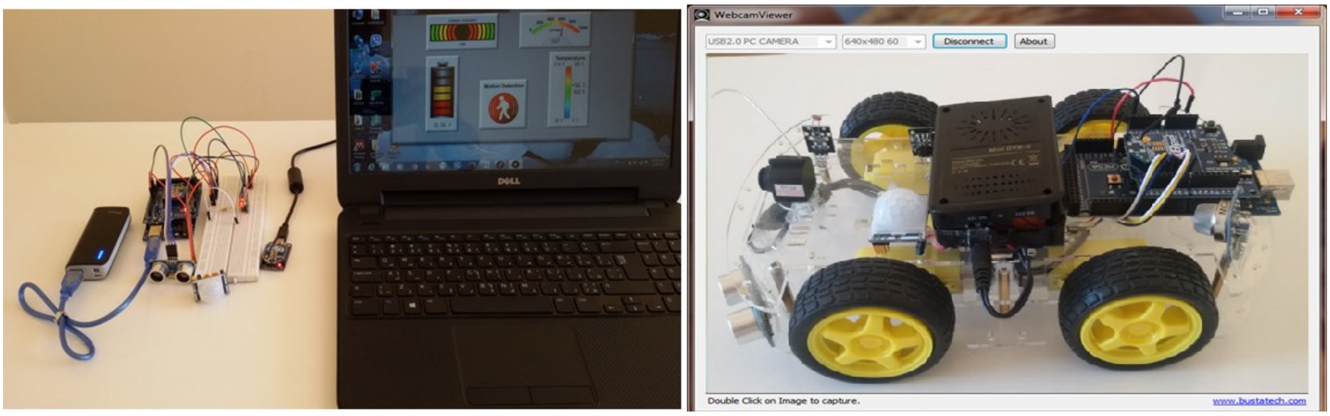

Fig. 1. The hardware setup and car application with sensors devices.

2.2. Software Setup and Configuration

The software setup and configuration process are essential for programming all devices to ensure smooth operation. This includes configuring the X-CTU program to define ZigBee communication settings, allowing efficient wireless data transfer between devices. Additionally, the Arduino program is set up to control and manage hardware functions, ensuring proper execution of commands. Lastly, the process control software is configured to streamline operations and enhance system performance. Each step in the setup ensures seamless communication, accurate data processing, and efficient functionality, making the system reliable and effective for its intended applications in automation, monitoring, or control processes.

2.3. System Framework

This section presents the block diagram of the designed modeling WSN hardware and sensor nodes, including motion, distance, lighting, and temperature, as shown in Figure 2. This work focuses on the design and implementation of a wireless sensor network and how it has been configured to the designed hardware. The lighting and temperature sensors in the configuration are connected to the microcontroller unit (Arduino) through the analog port pins. The motion and distance sensors are connected to Arduino through digital ports.

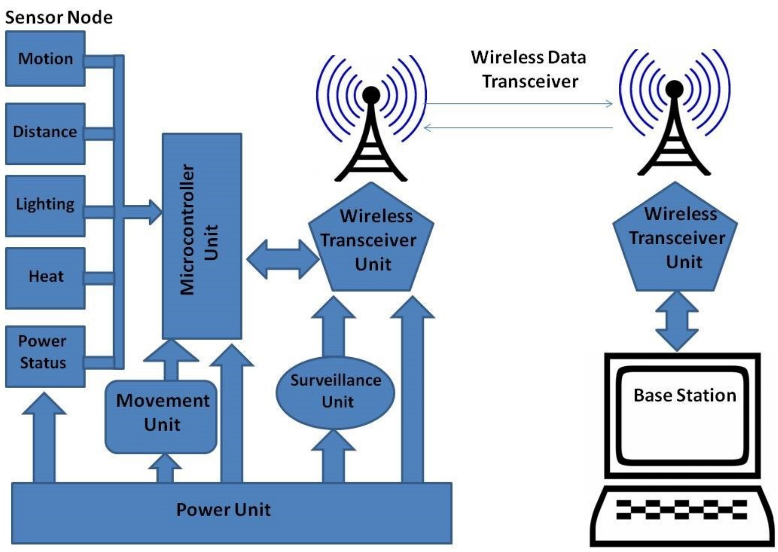

Fig. 2. Block diagram of the proposed WSN.

The system framework in this study consists of a coordinator node, router node (XBee protocol IEEE 802.15.4), and four sensor nodes used as the end devices. Each of these end devices communicate to the coordinator node either directly or through a router node using the ZigBee protocol (XBee S2). The sensor in each end node collects information about the surrounding environment and sends it to the microcontroller (Arduino), which then processes it or stores it in the memory. The processed information is then sent to the XBee router which is connected to Arduino through XBee shield. Information is sent wirelessly through the XBee adapter to the base station and any monitoring computers, storing and displaying data as shown in Figure 1 (left). Each of the end devices communicates with the coordinator node using the ZigBee protocol (XBee S2). Each of the nodes (coordinator, router, and the sensor devices) are powered either through the USB port or an external power supply. The processing program also displays the power supply status.

3. Results and Discussion

This section focuses on a WSN using sensors to detect and analyze motion, distance, lighting, and temperature. For motion, the vehicle was stationary beside a door for a period of one hour. It detected motion at a rate of once per second and showed it in the created GUI. The results of the information received are displayed in a curve shown in Figure 3.

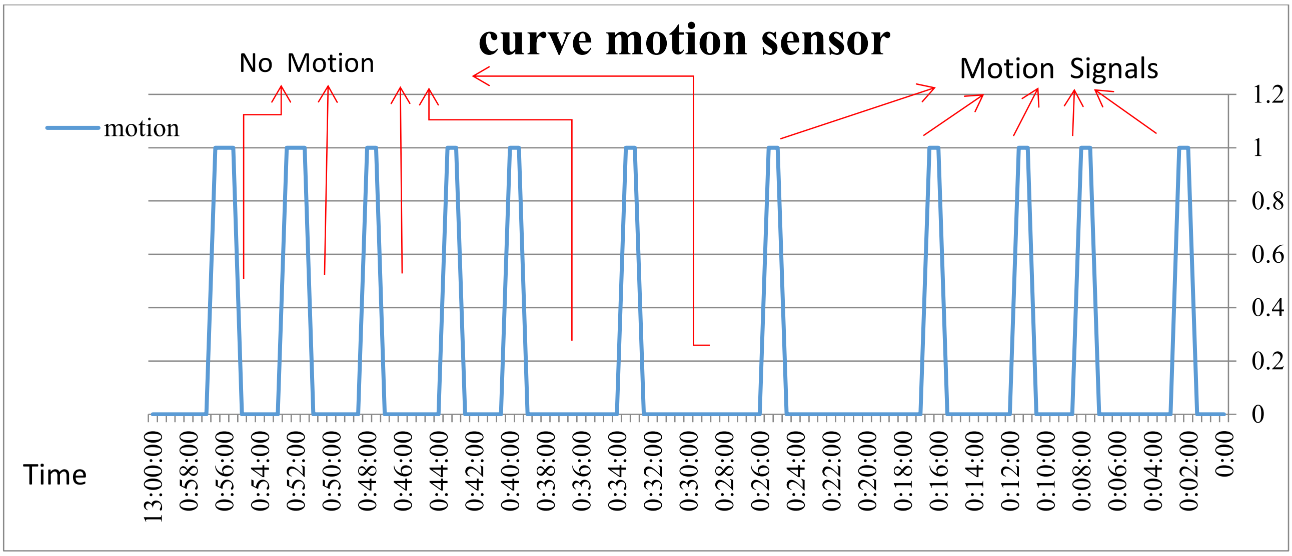

Fig. 3. Motion sensor results curve.

For distance, the car was left beside a door for one hour. Using ultrasonic sensors, the vehicle detected distance over time at a rate of every second. The base distance of 15cm was set, which read any natural motion during the test. The data is explained in a curve as shown in Figure 4.

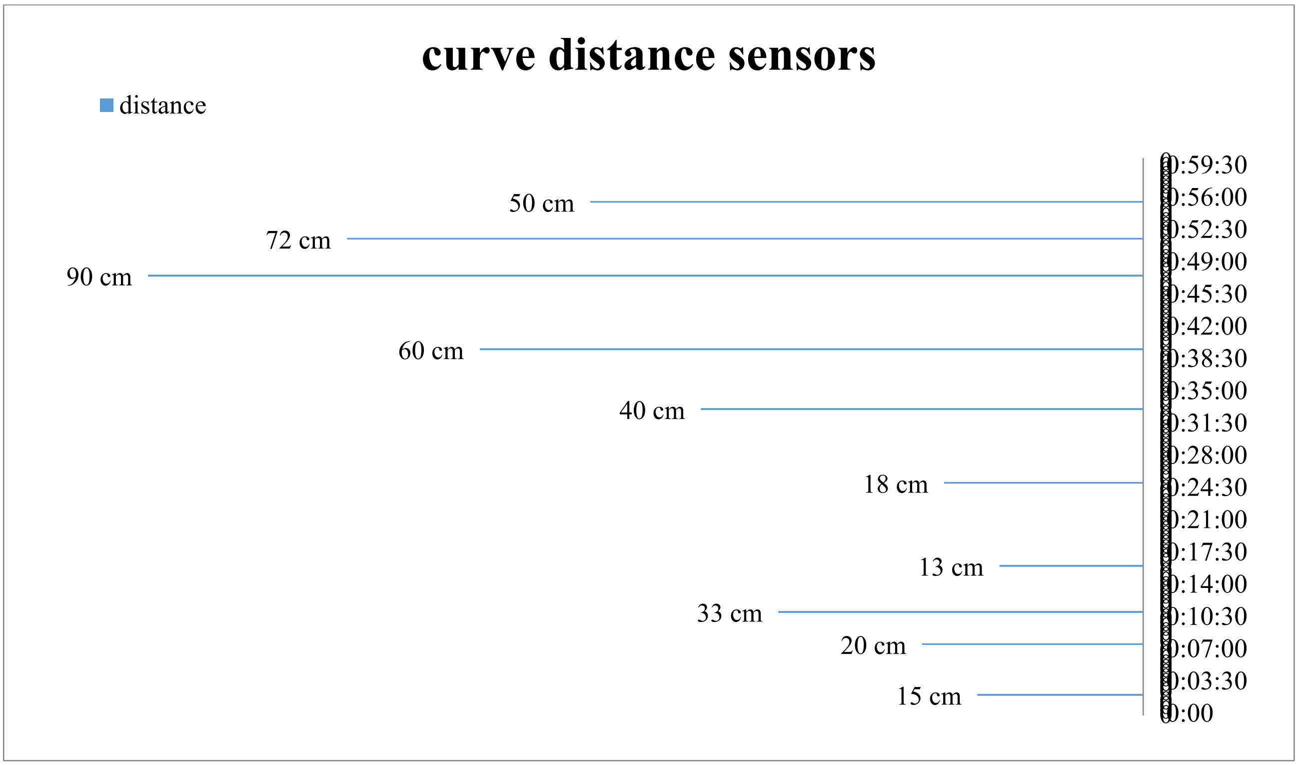

Fig. 4. Curved results in a distance sensor node.

Although the sensor works well for human distance, as it sends a sharp signal that recognizes a human figure, it can detect wrong information otherwise. To measure light intensity, the results were recorded over a period of 48 hours. It tested the lighting in the environment every five minutes. The first day of the experiment had cloudy weather. On the second day, it was sunny with scattered clouds. It detected both the presence and absence of light. The strongest readout was during the day while indoors, as it read a figure of 840 illuminations because of both sunlight and light bulbs as shown in Figure 5.

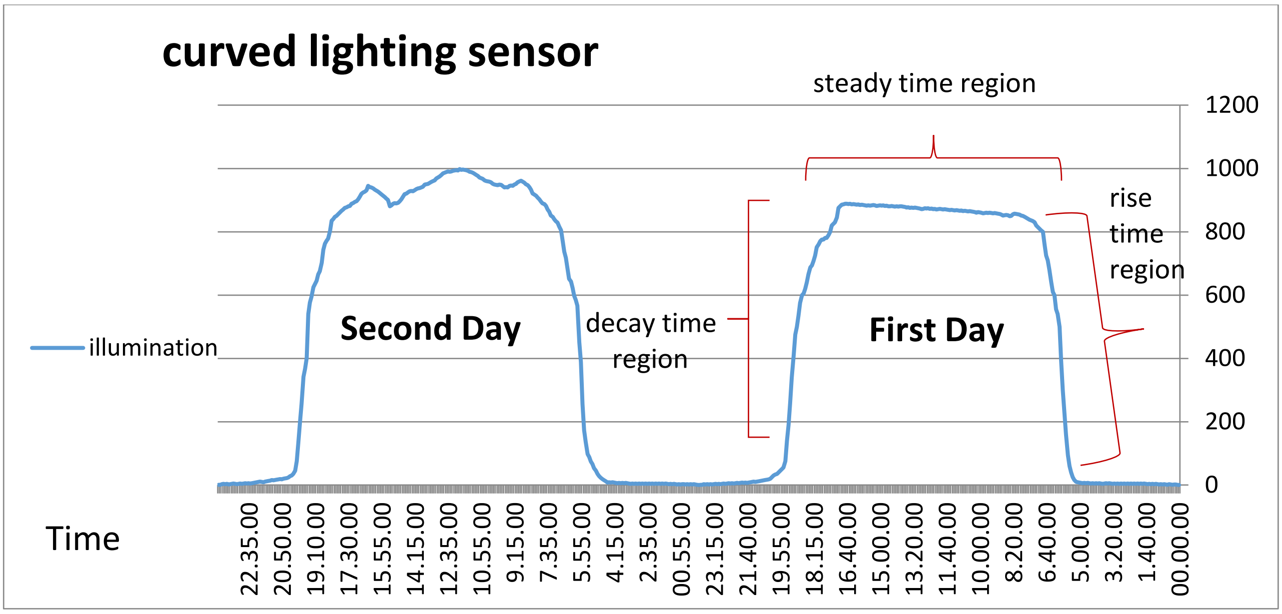

Fig. 5. Lighting results curve.

Lastly, the temperature was experimented with. At the start of the test, the external weather was 22 degrees. The vehicle was left outdoors on a humid day, and the readouts were compared with the information from the AccuWeather service. Data was received every hour. The initial readout was indoors, and it showed a temperature of 16 degrees, as shown in Figure 6.

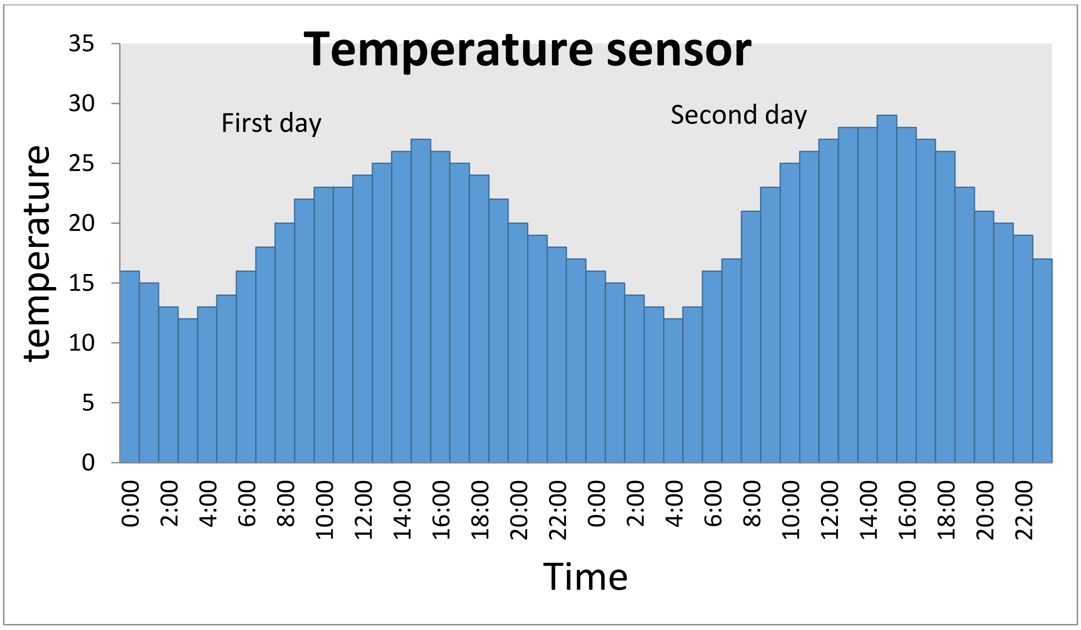

Fig. 6. Temperature results curve.

Figure 7 shows the display screen of the output sensor device. It presents data from all used sensors, including motion, distance, lighting, and temperature. The screen helps monitor sensor readings in real time, making it easier to analyze changes in the environment and ensure accurate performance of the system.

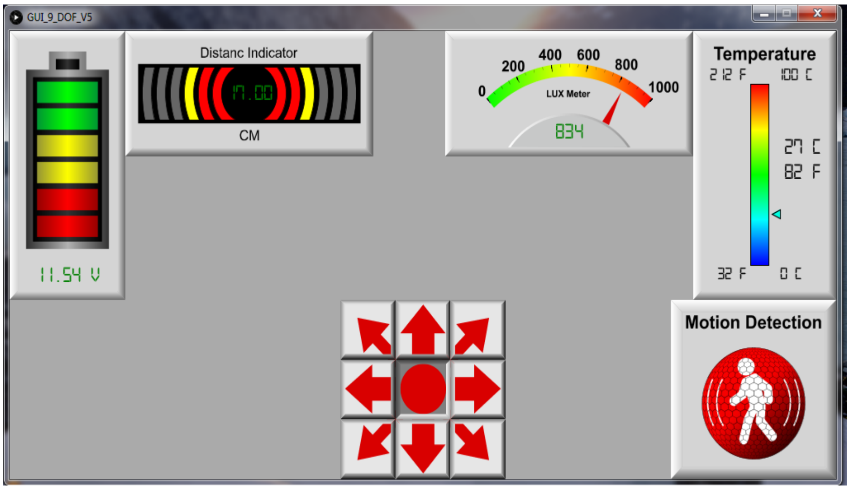

Fig. 7. Output sensors device display screen.

4. Conclusion

This paper tested how well a wireless sensor network (WSN) works and how it can be used. The sensors measure things that humans cannot detect on their own. More importantly, this type of vehicle can go into dangerous places and check for light, temperature, motion, and distance. It could be useful in the military, construction, fumigation, and other fields. Among all the tested factors, measuring distance was the hardest and least reliable. These sensors can also detect carbon monoxide, gunfire, explosives, drugs, and more.

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