How to Cite:
Andhare, M. S., Pal, T. L., Jayaram, V., Sreelekshmy Pillai, G., Tripathi, V., Krishnaraj, M., & Abhilash, K. S. (2022). Design and implementation of wireless sensor network for environmental monitoring. *International Journal of Health Sciences*, *6*(S4), 3158–3169. https://doi.org/10.53730/ijhs.v6nS4.9085

Design and implementation of wireless sensor network for environmental monitoring

Maithili Shailesh Andhare
Assistant Professor, PCET's Pimpri Chinchwad College of Engineering and Research, Ravet
Corresponding author email: maithili.andhare@pccoer.in

Triveni Lal Pal
Assistant Professor, Department of Computer Science and Engineering, Chandigarh University, Gharuan, Mohali, Punjab
Email: trivenipal@gmail.com

Jayaram V
Research scholar, Dept of mechanical engineering, Noorul Islam center for higher studies, Tamilnadu
Email: jayaramvijayan@gmail.com

Sreelekshmy Pillai G
Associate Professor In Civil Engineering, NSS College Of Engineering, Palakkad
Email: sreelekshmypillai@gmail.com

B Dr. Vikas Tripathi
Designation: Associate Professor, Department of Computer Science & Engineering, Graphic Era Deemed to be University, Dehradun, Uttarakhand, India, 248002
Email: vikastripathi.cse@geu.ac.in

M. Krishnaraj
Associate Professor, Panimalar Institute of Technology, Chennai
Email: monykrishnaraj@gmail.com

Dr. Abhilash. K S
Managing Director, EduCorp Centre for Research and Advanced Studies Pvt. Ltd. Thiruvananthapuram, Kerala
Email: dr.abhilashks@gmail.com

***Abstract*---**Wireless Sensor Networks (WSN) are being developed in the agriculture and weather station sectors to monitor and manage a number of objects. Sensor network hardware platforms are low-power

Manuscript submitted: 18 Feb 2022, Manuscript revised: 27 April 2022, Accepted for publication: 9 June 2022

embedded systems featuring a variety of sensors, such as on-board sensors and analogue I/O ports for adding sensors. The design of genuine environmental monitoring and communication systems is greatly aided by the creation of a WSN. A WSN is a collection of sensors that are geographically spread and specialized for monitoring and recording environmental variables and storing the findings in a central location. Limited power consumption as sensor nodes works on batteries, Nodes are mobile opposed to conventional wires, Usage in harsh environment, Nodes can be deployed in any fashion over an area, Easy to use and multi-layer design operation these are the main characteristics of WSN. Limits imposed on the energy storage device by their applications and deployment settings are less relevant to WSN environment-monitoring applications than controlling power consumption and optimizing data transmission. A WSN is used to record real-time traffic and environmental data in order to develop descriptive and predictive models for determining the optimum routes to reduce traffic congestion and, as a result, urban pollution. COOJA is a Java-based simulator designed to mimic sensor networks using the Contiki operating system. To make the infrastructure easy to install, the TelosB mote and TinyOS are coupled. The technique extends the network's lifespan while simultaneously conserving energy. Instead of cryptographic procedures, the lightweight cipher text addition operation is employed, which reduces the aggregator's workload. Using this aggregator also reduces the aggregator's risk and the network's lifetime.

***Keywords*---**wireless sensor networks, environmental monitoring, sensors, traffic congestion, cipher text, real time monitoring.

Introduction

Sensor nodes are often located randomly in the region of interest in a Wireless Sensor Network (WSN), which is widely used for monitoring and surveillance. Energy efficiency and network longevity are two important concerns in WSNs since sensor nodes are usually powered by batteries, which are difficult to replace. To ensure Quality of Service (QoS), latency, network coverage, and fairness across sensor nodes are also essential [2]. WSN includes devices with embedded sensors that may recognize the occurrence of an event and behave intelligently using Machine Learning (ML), Embedded Computing (EC), and Artificial Intelligence (AI) techniques [3]. Since industrial applications require a high level of reliability, the sensing processes must be prioritized and continuous [4]. Sensors with wireless communication capabilities can transmit data to users [5]. Due to the lack of cables, the use of inexpensive and compact sensor nodes increases the flexibility and energy efficiency of IAS [6]. The WSN sensor hub is made up of a variety of segments that are organized into four unique units: processing unit (PU), sensing unit (SU), transmission unit (TU), and power unit (PU) [7]. For social event information, several sensors in the Sensing unit are employed. Memory, microcontroller, and microprocessor are all included in the processing units. The transmission unit is made up of several handsets that are used to convey the data gathered by the sensors [8]. The control unit is in charge of ensuring that sufficient capacity is available to handle these tasks. The components of a sensing node are depicted in Figure 1.

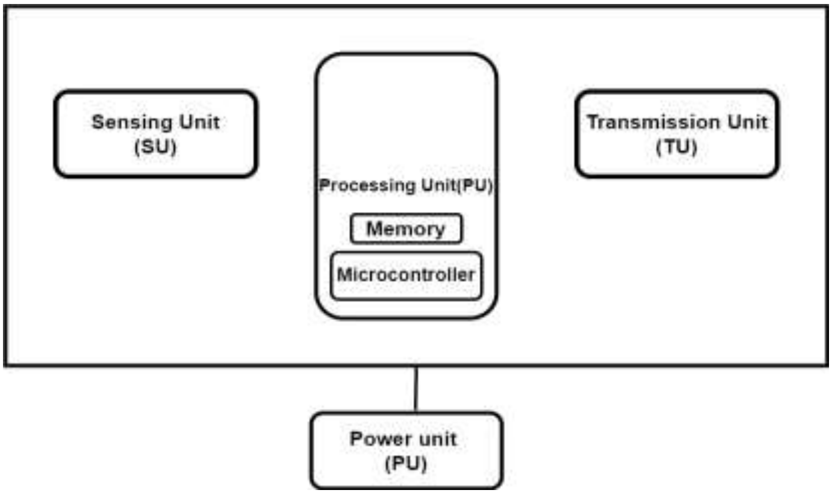

Figure 1: Components of WSN Sensor Node

Mohsen *et al* [9] proposed a solar-powered wireless sensor system for real-time monitoring of environmental physical parameters. A solar energy harvester, which comprises a DC-DC converter, a solar cell, and a rechargeable battery, provides the system's power. The atmospheric pressure, relative humidity, ambient temperature, and ultraviolet (UV) index are all measured by this system. A permanent solar energy harvester was introduced in this technology to power a WSN for environmental monitoring. The system is put to the test in order to measure the physical characteristics of an ambient environment in a continuous manner. A printed circuit board might be used to make the wireless sensor system's product. The WSN might be used to monitor pollution. The sensors might also be used in a humid environment. Huang *et al* [10] proposed a user-friendly sophisticated software framework for monitoring real-time environmental data from buildings. A wireless node module and an application point module are the two major physical components of a WSN system. WSN is made up of small, geographically dispersed sensors that collect significant volumes of real-time environmental data from buildings. Between data capture and transmission events, the MSP430 microcontroller allows for low-power operation. For indoor fire danger detection, the suggested WSN system has been deployed and tested in an office building.

Jaladi *et al* [11] introduced Wireless sensor networks (WSN) to monitor and regulate numerous parameters in agriculture and meteorological stations. A transceiver, external memory, power source, microcontroller and one or more sensors are the essential components of a sensor node. This approach creates a wireless sensor network system with a Raspberry Pi as the base station, XBee as the networking protocol, and sensor nodes made up of sensors, controllers, and ZigBee. The Internet of Things (IoTs) can be defined as linking ordinary devices to the Internet, such as smart phones, Internet TVs, sensors, and actuators. Moridi *et al* [12] proposed ZigBee network is being used to provide monitoring and communication system for underground mine sites. There are a variety of controllable and uncontrolled characteristics at the underground mine site. For the creation of a ZigBee network, the controllable and uncontrolled factors of both the subterranean environment and the network are also analyzed. The system under test is made up completely of ZigBee nodes, including coordinators, routers, and end nodes. This technology is used to set up a stable ZigBee network in an underground mine for monitoring and communication. Experiments for temperature, humidity, and lighting data, as well as texting messages and regulating ventilation fans via the subterranean mine, were used to validate the model.

Corbellin *et al* [13] proposed Cloud based sensor network for environmental Monitoring. The button-like sensor can measure temperature and humidity for more than a year without the need for human intervention. Environmental monitoring may be necessary for a variety of settings, but there are essentially two scenarios that can be imagined. They are "online" and "off-line" monitoring, respectively. Here is a µPanel environment that enables the deployment of complicated monitoring systems with extraordinary ease and speed. Ahmed *et al* [14] suggested robotized wireless sensor network for monitoring the environmental conditions. The mobile robots in this scenario respond according to predetermined priorities based on three major states: searching, reorientation, and observation. iRobot was used to create the robotized agents. The robotized agents have been built using iRobot Create mobile platforms that are additionally equipped with single-chip computers Gumstix Verdex pro TMXL6P with various expansion modules. Bajrami *et al* [15] proposed WSN and NodeMCU for monitoring the environmental conditions. WSN Monitoring is built using PHP technology, which is optimized for use in both desktop and mobile browsers. The NodeMCU is a microcontroller with built-in Wi-Fi, eliminating the need for a separate Wi-Fi chipset. The applications at QKM and Telcomm demonstrate that this technology is trustworthy and can be used to monitor air temperature and humidity.

Methodology

The design of effective environmental surveillance and communication systems is greatly aided by the building of a WSNs concept. This is owing to a diverse set of networking components, major technological advances in sensor nodes, and large changes in ambient elements between mining areas. WSNs monitor environmental factors such as temperature, humidity, wind, and so on. Humidity, temperature, light, and motion are the factors that the sensor network should measure and record. The TelosB could directly measure the first three characteristics. The nodes are fitted with passive infrared sensors to detect motion (PIR-sensor). After a defined time interval, known as the collection period, all nodes collect data and submit a data packet to a gateway node. In addition, for each node to transport packet to the gateway, other nodes must act as a bridge, relaying incoming messages. The whole WSN system is illustrated in Figure 2.

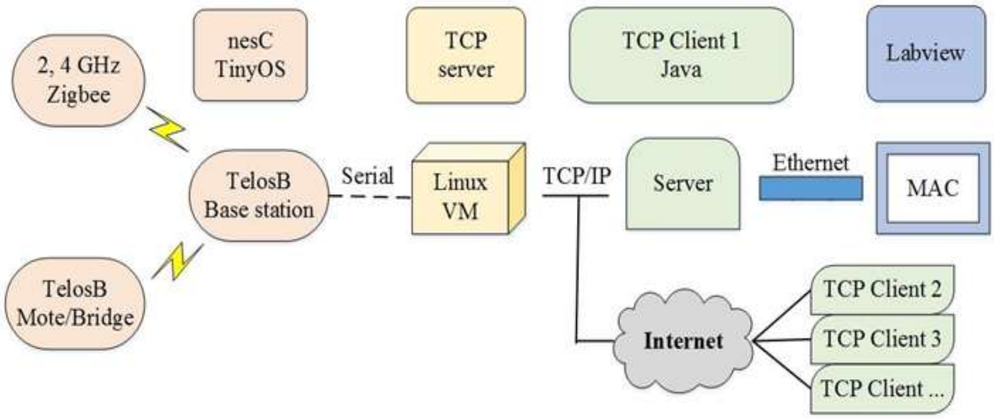

Figure 2: Whole measurement System for WSN.

The root, or gateway node, advances information bundles through techniques for progressive interface to a PC with the most recent gadget and a system association. The root node's data is obtained by PC software that examines data over a serial connection. It makes all acquired data available to customers through TCP/IP, allowing them to connect to the server and retrieve data packets. WSNs have the potential to collect ecological data and measure harvest progress. Because there is no power supply in the typical fields, WSNs should implement a battery-based function by limiting consumed power. Because a deep sleep state's operational period is determined by the amount of power utilized, hardware selection is crucial in lowering squandered power. Media access control approaches and routing protocols, as well as software, are important components because they affect the deep sleep phase. In real-time networks, nodes are grouped according to the framework that is connected with the gateway node, which may be anything from a headless Linux PC to an Android PDA with UMTS connectivity. Because of the Java Runtime Environment's conservatism, Java has always been chosen as a programming language (JRE). This provides the greatest flexibility in terms of hardware and working structure when it comes to implanting data into a framework. The sensor coordinates the requirements for several endeavors that are inextricably linked to one another.

Low-cost Infrared Sensors

An electrical infrared sensor device that emits light to recognize a few natural objects. An IR sensor can scale the glimmer of an item in the same way as it detects motion. Rather than being transmitted as a separate IR sensor, these sensors check for infrared radiation. The bulk of the items emits some type of heated radiation when they are in the infrared region. These forms of radiation are undetectable to the human eye, but an infrared sensor can detect them. The creator is a simple Infrared Light Emitting Diode (IR LED), whereas the marker is an IR photodiode that detects IR light of a different wavelength than the IR LED.

Gateway Node

A gateway is a network's point of interaction with the outside world. In relation to the sensor node and cluster head, the code and data memory, the processing unit used, where the receiver goes, and the possibility of augmentation through external memory all appear to be different. It's best to go with a CPU with a clock speed of roughly 16 MHz, 512 KB of RAM, 2.4 GHz frequency, and 32 MB of flash memory.

TelosB Mote

WSNs are built using the TelosB sensor network. The covers information such as temperature, humidity, sound, and other factors at various locations are taken. A wireless sensor network's capacity to withstand extreme weather conditions is also linked. It may, for example, deal with node failures, communication failures, and even node heterogeneity. Wireless sensor networks encounter several obstacles, including node mobility, deployment, dynamic network topology, and synchronization. TelosB has a minimal current consumption, and all hubs are powered by two AA batteries, ensuring that the voltage remains nearly constant at around 3V. Programming, on the other hand, is made possible through a variety of advancements and approaches.

PIR Sensor Module

A Passive Infrared (PIR) sensor is used to determine if a human item has moved inside or beyond the range of the sensor. Every object emits a little quantity of radiation, and the hotter it becomes, the more radiation it emits. The ability of a PIR sensor to distinguish dimensions of infrared light is one of its features. When a PIR detects movement within its range, the yield stick will be "high." Whether or not a human has been discovered in the sensor location, PIR sensors allow, identify, and detect movement relatively often. A pyroelectric sensor detects infrared radiation levels and is used in PIRs. Low-level radiation is emitted by everything, and the hotter something is, the more radiation it emits. The sensor of a motion detector is really separated into two portions. Because we want to detect mobility (change) rather than average IR levels, we've done it this way. The two pieces are linked in such a way that they cancel each other out. If one portion receives more or less IR radiation than the other, the output will swing high or low.

TinyOS

TinyOS is a little, open-source, vitality productive programming working framework created by UC Berkeley which bolsters extensive scale, self-arranging sensor systems. It is a working domain intended to keep running on implanted gadgets utilized in remote sensor systems. TinyOS contrasts from most other working frameworks in that its structure centers around low power activities in remote sensor systems. It gives a lot of precarious administrations and negotiations, for example, detecting, correspondence, stockpiling and clocks. It is written in NesC programming Language. The bits must almost certainly measure the ideal parameters and speak with one another. The information flow in a WSN is illustrated in Figure 3.

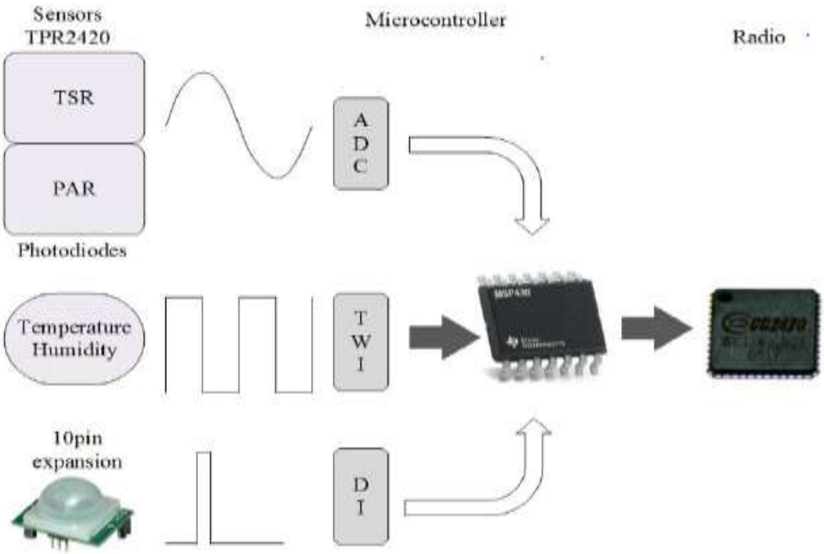

Figure 3: Information flow in a WSN

Network Embedded Systems C (NESC)

TinyOS apps are written on a section-based Event programming language. TinyOS is being offered as a way to keep embedded devices functioning in coursed remote sensing setups. To operate TinyOS, nesC functions as a C programming language extension with sections "wired" together. The word nesC stands for "sort out embedded structures C" in abbreviated form.

COntiki Os Java simulator (COOJA)

COOJA is a Java-based simulator created to simulate Contiki-based sensor networks. COOJA simulates sensor networks in which each node can be of a different kind, including modifications to the onboard software as well as the imitated hardware. Many aspects of COOJA may be readily swapped or extended with extra capabilities, making it a versatile simulator. The three most important features of a simulated node in COOJA are node type, data memory, and hardware peripherals. Numerous nodes have the same node type, which provides properties that are shared by all of them. The energy calculation for the results obtained is based on the general formula given in Eqn. 1.

$$E = v \times I \times t \tag{1}$$

The formula for calculating the energy consumed by packet transmission is given in Eqn. 2

$$E_T = P_{sent} \times P_{length} \times T_B \times It \times V \tag{2}$$

Where, P_{length} is the length of the packet in byte, P_{sent} is the number of packets sent, I_t is the current drawn during transmission, V is the supplied voltage, T_B is the time to broadcast a single byte over the airwaves. Eqn. 3 is the formula for calculating the energy spent by receiving packets.

$$E_R = P_{rec} \times P_{length} \times T_B \times Ir \times V \tag{3}$$

To conserve imperativeness, the radio organization is periodically turned on and off (commitment cycle) to extend the season of the operational system. The information's social affair time is between 10 and 30 minutes. TELOSB's radion is switched off for the duration of this time to save battery power. After one social affair period is completed, each center's radio is switched on for a brief time period break, and supplied packs are sent to the root node. Similarly, the radio's on and off period is not covered by the orchestrating windows. The communication windows don't match, so no communication is possible which is shown in Figure 4.

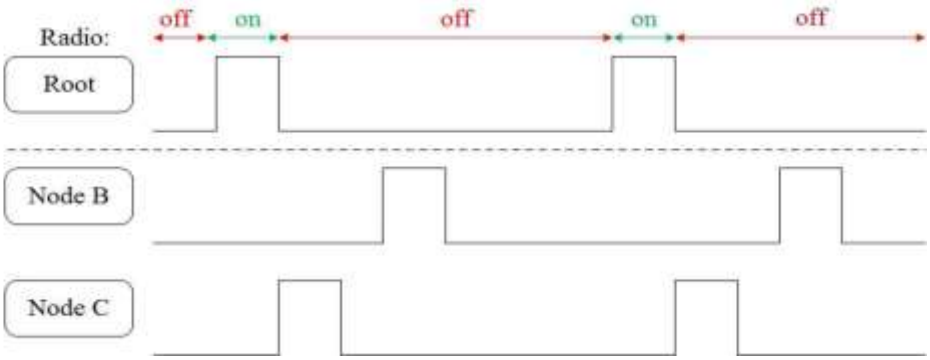

Figure 4: Communication Issues

The time synchronization module is responsible for determining the parameters that link the stage and recurrence of the bulk of the framework's timekeepers. The synchronization administration creates a database of transformation parameters that connects a significant number of the framework's various tests. To convert a timestamp in one time base to a timestamp in another, a series of transformations may be required. The synchronization must be rehashed on a regular basis to account for clock skimming between the centers. The microcontroller might be to blame for the quartz's small variations in resonation repetition.

Results and Analysis

Low-power wireless gadgets are becoming more common in daily life. Modern mechanization, home computerization, security, and the shrewd framework are only a few of the application areas. Sensor-based gadgets are resource-intensive due to their small size, low power, and low effort. Because sensor hubs are powered by a battery that cannot be recharged, it is critical that they function properly in all aspects of computation and correspondence. Calculation activities, as comparison to letters, do not consume as much energy. The activities of sending and receiving consume the bulk of one's energy. As a result, evaluating the asset usage and efficacy of the steering convention in these devices is critical. The goal of this project is to create energy-efficient data aggregation and compression techniques in both hardware and software. Software implementation includes software tools like COOJA and mini OS. TelosB hardware expansion is also possible without compromising the power reduction method. The energy comparison between transmission and reception time may be analyzed using both software and hardware tools, as shown in the figures below. Energy comparison graph with and without aggregation is given in Figure 5 and Figure 6. Fig 6.3 shows the lifetime of the sensor networks may without using the compression algorithm.

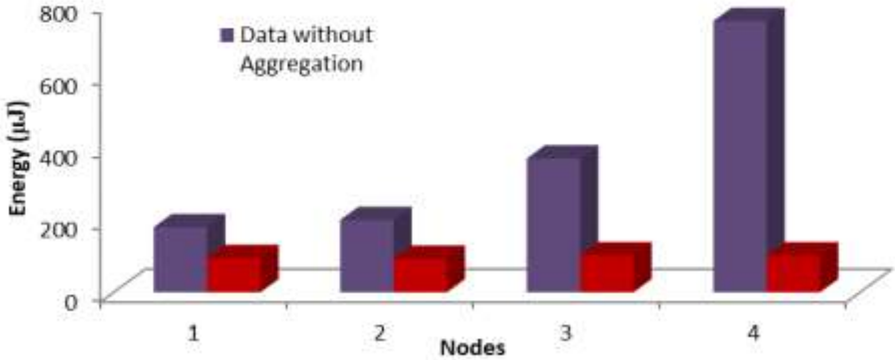

Figure 5: Energy comparison at the Transmission Side

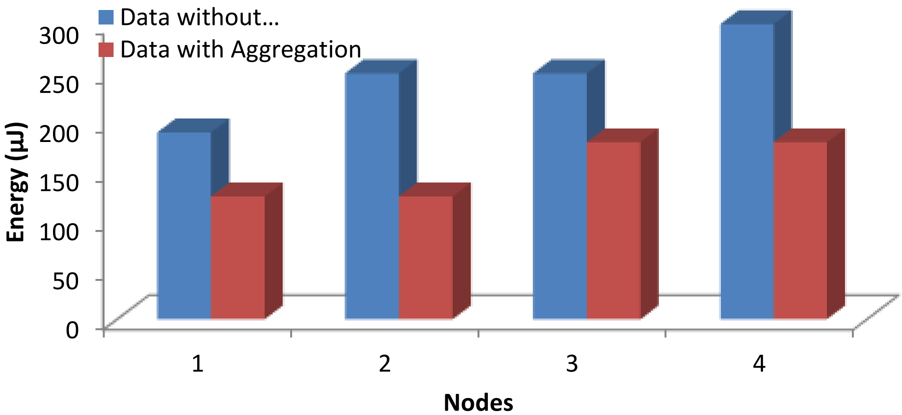

Figure 6: Energy comparison at the Receiving Side

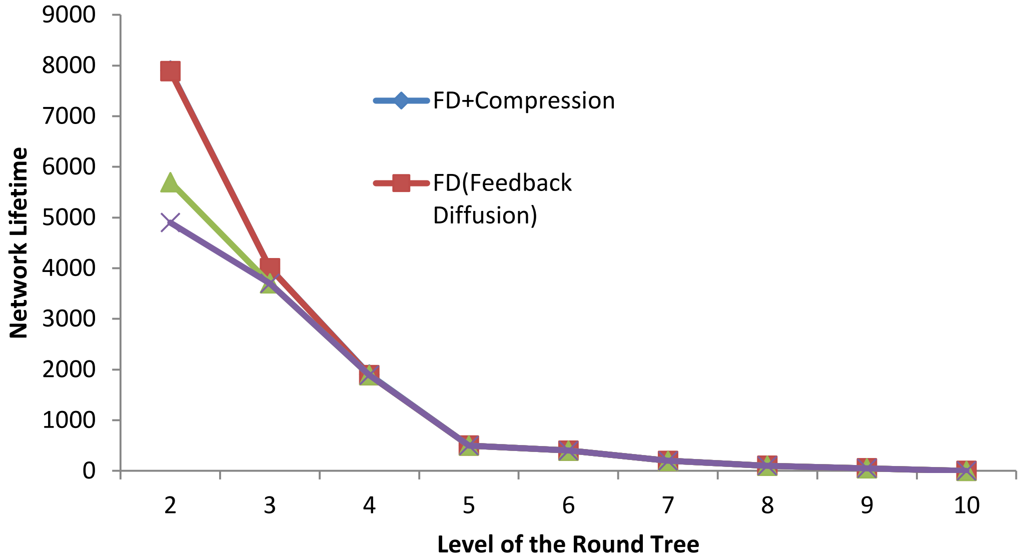

Figure 7: Analysis of Network Lifetime

Table 1 Tabular Representation of Serial Port Output

Node	Timestamp without aggregation (ms)		Timestamp with aggregation (ms)		Packet in Bytes	
	Transmission	Reception	Transmission	Reception	Before Aggregation	After Aggregation
1	2	6	1	3	60	50
2	3	8	1	4	93	85
3	5	11	2	6	119	102
4	5	14	2	10	160	115

Table 1 illustrates the duration it takes to transmit and receive a payload, as well as the energy used by the nodes throughout packet transfer. The internal timer is utilized to determine the time spent transmitting and receiving packets. The particular moment may be estimated by utilizing the nesC programme to call the gateway at a certain time. The time disparities among both sender and receiver must be analyzed. Amount of (Payload) in the nesC, may be verified out by examining the temporal variations between the start and finish of transmission. Figure 8 is the graphical representation of Table 1 which is taken between nodes and considered parameters. In the packet size comparison, the size of the packets is high for before aggregation than after the aggregation process.

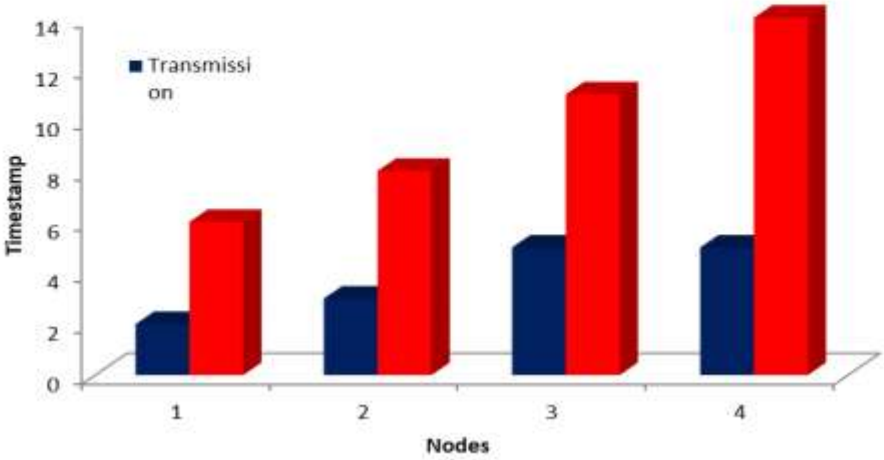

Figure 8: Comparison of Timestamp

Conclusion

WSN environment-monitoring applications are focused less on the limits that their applications and deployment circumstances place on the energy storage device and more on lowering power consumption and optimizing data transfer. External effects of urban and extra-urban mobility include traffic congestion, increased logistic flows, acoustic and atmospheric pollution, and other factors. A WSN is used in particular to collect real-time traffic and environmental data in order to create descriptive and predictive models for planning the optimal routes to decrease road congestion and, as a result, urban pollution. The TelosB mote and the TinyOS are combined to easily implement the infrastructure. The algorithm increases the lifetime of the network and also it saves energy. Instead of cryptographic processes, the lightweight cypher text addition operation is used thus aggregators work is reduced by using this aggregator it offers risk from the aggregator and lifetime of the network. Data aggregation enables in-network processing, which results in fewer packet transfers, lowers redundancy, and extends the total lifespan of WSNs. By implementing aggregation functions such as MAX, Average, and Sum, data sensed by numerous member nodes may be merged into one. Finally, the wireless link is used to send it to the base station. Only the aggregated result is forwarded to the base station, therefore communication overhead seems to be reduced. As a result, data aggregation is beneficial in extending the WSN's overall lifespan. A probability is deactivating all movement of the sensors. If the neighboring bits recognize any movements the sensors send a flag to the nearby sensors. The speed of the moving item will be calculated by the output from the nearby sensors the straightforward separation for every time estimation. Another approach to enhance the framework is by extending it with camera modules. The infrared movement discovery and the low-power picture catching from the camera, which is not conceivable.

References

1. Jia, Y. (2020). LoRa-based WSNs construction and low-power data collection strategy for wetland environmental monitoring. Wireless Personal Communications, 114(2), 1533-1555.
2. Sangeethalakshmi, K., Ganesh, S. J., Dhivya, K., Kannagi, V., & Rajkumar, M. (2022, March). Internet of Things Assisted Wireless Environment Monitoring System using Smart Sensors Supportivity. In 2022 International Conference on Electronics and Renewable Systems (ICEARS) (pp. 628-632).
3. Kho, E. P., Chua, S. N. D., Lim, S. F., Lau, L. C., & Gani, M. T. N. (2022). Development of young sago palm environmental monitoring system with wireless sensor networks. Computers and Electronics in Agriculture, 193, 106723.
4. Zou, P., & Ji, G. (2022). Design and Implementation of Node of Wireless Network Environment Monitoring System Based on Artificial Intelligence. Wireless Communications and Mobile Computing, 2022.
5. Kang, T. (2022, January). Wireless Sensor Network in Environment Monitoring. In 2021 International Conference on Social Development and Media Communication (SDMC 2021) (pp. 1435-1439). Atlantis Press.
6. Wang, Q., Xia, M., Chen, Y., & Yu, Y. (2022, April). Design and Implementation of WSN-based Warehouse Temperature Sensor Monitoring System. In Journal of Physics: Conference Series (Vol. 2246, No. 1, p. 012006). IOP Publishing.
7. Lanzolla, A., & Spadavecchia, M. (2021). Wireless sensor networks for environmental monitoring. Sensors, 21(4), 1172.
8. Pusatkar, A. C., & Gulhane, V. S. (2016). Implementation of wireless sensor network for real time monitoring of agriculture. IRJET) ISSN, 2395-0072.
9. Mohsen, S. (2022). A Solar Energy Harvester for a Wireless Sensor System toward Environmental Monitoring. Proceedings of Engineering and Technology Innovation, 21, 10-19.
10. Huang, Q., & Rodriguez, K. (2019). A software framework for heterogeneous wireless sensor network towards environmental monitoring. Applied Sciences, 9(5), 867.
11. Jaladi, A. R., Khithani, K., Pawar, P., Malvi, K., & Sahoo, G. (2017). Environmental monitoring using wireless sensor networks (WSN) based on IOT. Int. Res. J. Eng. Technol, 4(1), 1371-1378.
12. Moridi, M. A., Sharifzadeh, M., Kawamura, Y., & Jang, H. D. (2018). Development of wireless sensor networks for underground communication and monitoring systems (the cases of underground mine environments). Tunnelling and Underground Space Technology, 73, 127-138.
13. Corbellini, S., Di Francia, E., Grassini, S., Iannucci, L., Lombardo, L., & Parvis, M. (2018). Cloud based sensor network for environmental monitoring. Measurement, 118, 354-361.
14. Ahmed, S. A., Popov, V. L., Topalov, A. V., & Shakev, N. G. (2018). Environmental monitoring using a robotized wireless sensor network. AI & SOCIETY, 33(2), 207-214.
15. Bajrami, X., & Murturi, I. (2018). An efficient approach to monitoring environmental conditions using a wireless sensor network and NodeMCU. e & i Elektrotechnik und Informationstechnik, 135(3), 294-301.