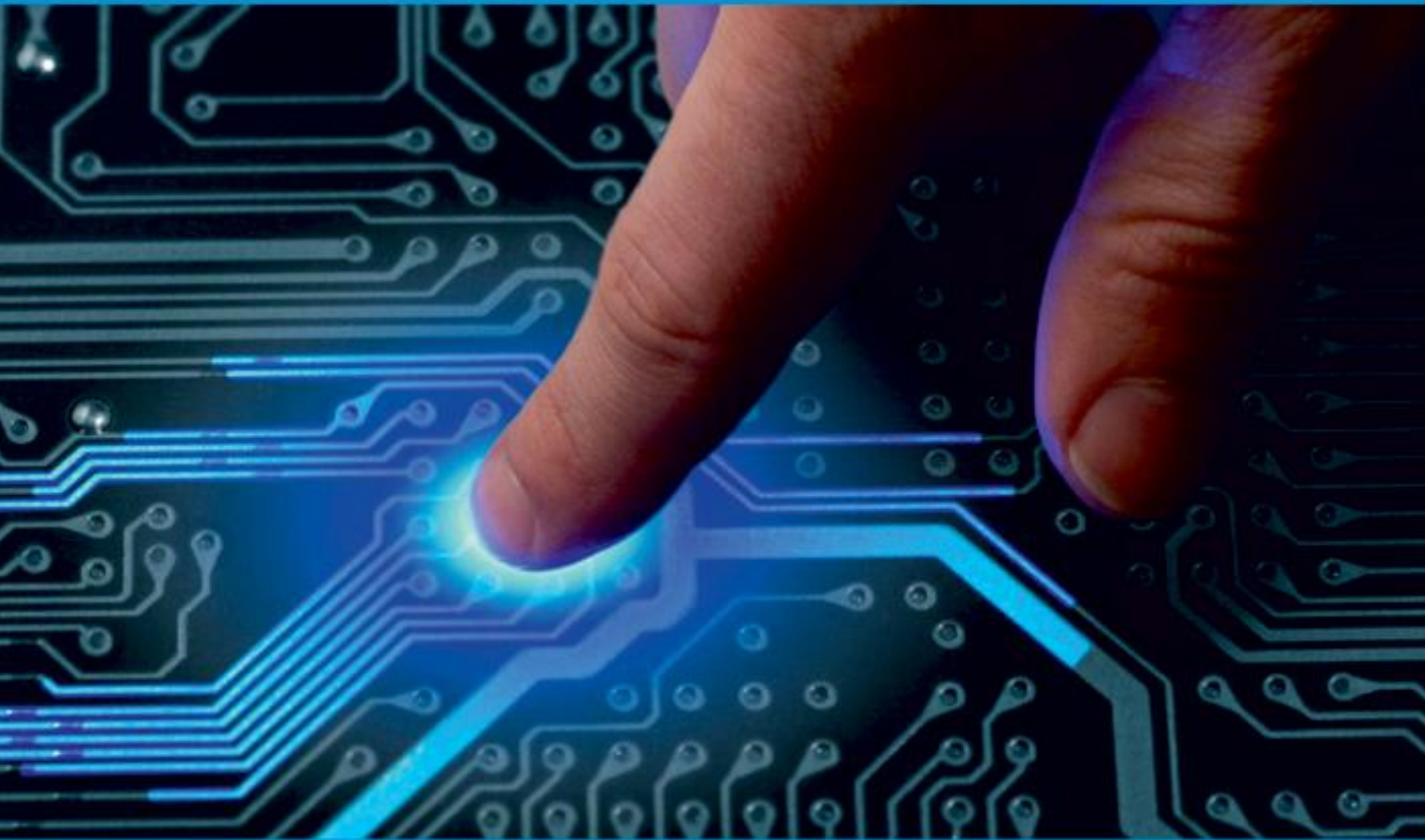
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 12, Issue 8, August 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.625

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.625| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

To Improve the Lifetime of Wireless Sensor Networks: A Review, Challenges, and Current Methods

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ABSTRACT: The potential for broad usage of wireless sensor networks (WSNs) across various areas, including health application, control monitoring safety and environmental tracking, and many others, has increased research interest in WSNs. The key challenges of WSNs (Wireless Sensor Networks) include gathering sensed data, transforming the data to the base station in an energy-efficient manner, and extending the network lifetime. This review methodically examines the body of literature, highlighting the main difficulties that WSNs confront and reviewing the strategies that are currently being used to increase their operational lifespan. These approaches are divided into three categories in the paper: energy harvesting techniques, routing algorithms, and energy-efficient protocols. In order to promote a greater knowledge of the difficulties and potential solutions to extend the lifespan of WSNs, the paper attempts to serve as a useful resource for researchers, practitioners, and policymakers engaged in the design and administration of WSNs. It does this by synthesizing the current state of research.

KEYWORDS: WSN, Routing protocol, Machine Learning, network lifetime, challenges

I. INTRODUCTION

Each sensor node in wireless sensor networks (WSNs) has a fixed supply of energy, finite computational capacity, and controlled communication capabilities. As a consequence, in WSNs, network durability becomes the main concern. The vast majority of recent research defines network lifetime as occurring when the first sensor node consumes up all of its energy. Such an amount of time is not necessarily essential, however. This is because if a sensor node doesn't work, the network as a whole is likely to continue to function. Most WSN applications focus on whether the network can deliver an acceptable service, which might involve the percentage of live nodes, the connectivity to the sink, or other factors or the status of packet delivery. Researchers have suggested strategies including mobile sink, cross-layer architecture, MAC protocol, and routing protocol to extend the network lifetime of WSNs [1].

A sensor network's lifetime has been defined in a number of ways, but one that is frequently accepted is when the network declines to the point where it can no longer serve its intended function. This might happen when any of the following things happen: the initial sensor node dies, a certain number or percentage of the nodes die, the network is divided and connection between the subnetworks is cut off, or coverage is lost. An attempt is made to reduce the amount of energy the unit uses.

This review paper is organized as follows. Section I presents the theoretical background of WSN & Motivation. In Section II discusses the various challenges to prolong the life time of WSN. Section III various current techniques. Proposed algorithms is discussed in Section IV. Section V presents the concluding remarks with research direction.

1.1 Elements of WSN:

Typically, a wireless sensor network consists of two components. They're: (i) Sensor Node (ii) Network Architecture. In a WSN, a sensor node is made up of four fundamental parts. They are: Power Supply, Sensor, Processing unit and Communication system.

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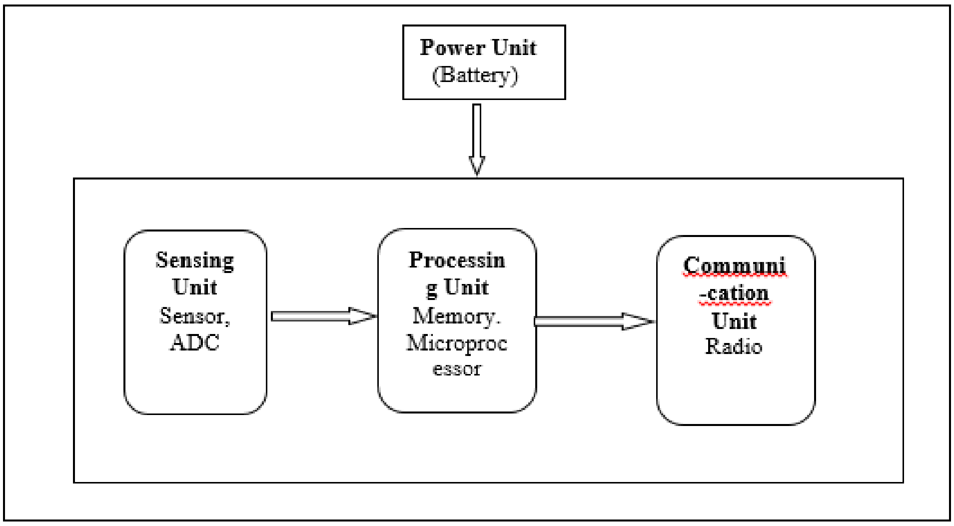

Figure 1.1 Basic Components of WSN

II. PROPOSED ALGORITHM

The information collected is transformed into a digital signal via an analog to digital converter (ADC), and then it is processed before being sent to the main server, also referred to as the base station (BS). After doing an analysis of the facts, BS made the decision. Nodes function as both source and sink nodes in WSN [3]. The battery is the important unit of sensor nodes, which meets the power needs of processors, transmitter & receiver, but the limited battery life can result in exhausts network [5]. hence prolong the network life by utilizing node energy effectively.

Architecture of Wireless Sensor Network:

1. Sensor Nodes: These are small, low-power devices equipped with sensing, processing, and wireless communication capabilities. They are typically battery-powered and often deployed in large numbers.

2. Base Station (Sink): This is a central node that collects data from sensor nodes. It may have more computational power and energy resources compared to sensor nodes. It aggregates the data received from sensor nodes and can relay it to other networks or systems for further processing.

3. Communication Protocols: WSNs utilize various communication protocols to facilitate data transmission between sensor nodes and the base station. These protocols must be energy-efficient and robust to handle the challenges of wireless communication, such as limited bandwidth, variable signal strength, and potential packet loss.

4. Routing Algorithms: Routing algorithms determine how data is forwarded from sensor nodes to the base station. They need to optimize energy consumption, minimize latency, and ensure reliable data delivery.

5. Data Fusion and Processing: Since sensor nodes may generate redundant or correlated data, data fusion techniques are used to combine and analyze this data to extract useful information while reducing redundancy and noise.

6. Energy Management: Energy efficiency is crucial in WSNs due to the limited energy resources of sensor nodes. Techniques such as duty cycling, data aggregation, and energy-aware routing are employed to prolong the network's lifetime.

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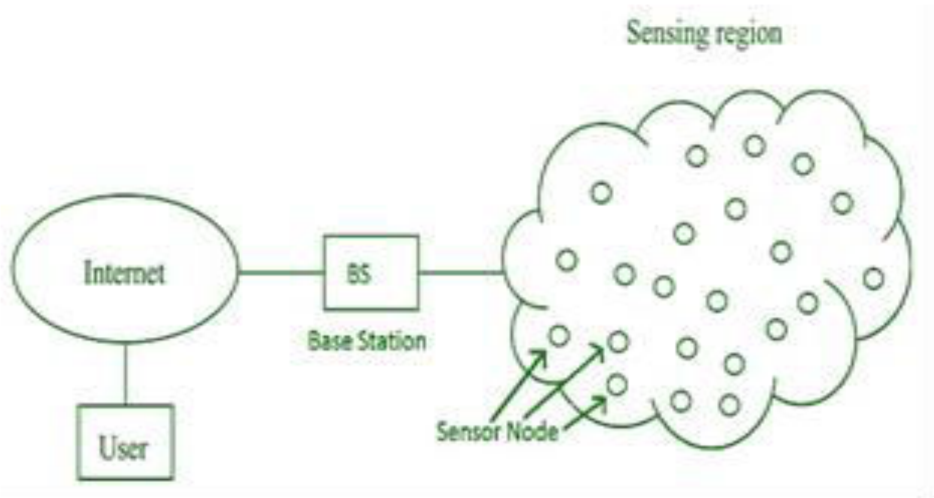

Figure no. 1.2 WSN Architecture

The motivation for WSN:

Modern advances in the fields of digital communications, networking, and design have produced new wireless system designs with innovative sensors. These sophisticated sensors can serve as a link between the digital and physical domains. Sensor nodes are placed in a variety of settings, mostly in isolated locations that are inaccessible to humans. These sensors assess the surrounding environment and assist humans in the event of an accident or infrastructure failure, preserve natural resources, and safeguard wildlife. Because of the processing, computing, and sensing technologies' downsizing, tiny, low-cost sensors, controllers, and actuators have been made.

III. CHALLENGES OF WSN

Modern challenges associated with extending the lifetime of wireless sensor networks (WSNs) tend to focus on solving new problems including security, scalability, and interoperability with newer technologies. Here are a few current difficulties are given below:

Scalability and Heterogeneity: With the proliferation of IoT devices and the deployment of large-scale WSNs, scalability becomes a significant challenge. Managing a heterogeneous network with various sensor types, capabilities, and communication protocols adds complexity. Addressing these issues requires scalable algorithms and protocols that can handle large-scale deployments efficiently [7].

Energy-Efficient Communication Protocols for IoT: As WSNs become an integral part of the Internet of Things (IoT), energy-efficient communication protocols are crucial for prolonging the lifetime of sensor nodes. Recent research focuses on developing lightweight protocols optimized for IoT applications, considering factors such as low latency, reliability, and energy consumption [8].

Edge Computing and Data Offloading: Leveraging edge computing capabilities to process and analyze data closer to the source can reduce the energy consumption associated with transmitting raw sensor data over long distances. Designing efficient data offloading techniques and edge processing algorithms is essential for energy-efficient WSNs [9].

Security and Privacy in IoT-enabled WSNs: With the increasing deployment of WSNs in critical applications such as healthcare, smart cities, and industrial automation, ensuring the security and privacy of sensor data is paramount.

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Recent challenges involve developing lightweight security mechanisms tailored for resource-constrained sensor nodes while addressing threats such as unauthorized access, data tampering, and privacy breaches [10].

Energy Harvesting and Self-Powered WSNs: Energy harvesting technologies, such as solar, kinetic, and thermal energy harvesting, offer opportunities to create self-powered WSNs that eliminate the need for battery replacement. Challenges include designing energy-efficient harvesting circuits, maximizing energy extraction from ambient sources, and integrating energy harvesting techniques with sensor node operations [11].

Machine Learning for Energy Optimization: Integrating machine learning algorithms into WSNs for energy optimization and predictive maintenance can enhance energy efficiency and prolong the network's lifetime. Recent research explores the application of machine learning techniques, such as reinforcement learning and neural networks, for adaptive energy management, anomaly detection, and fault prediction in WSNs [12].

Standardization and Interoperability: Ensuring interoperability among heterogeneous sensor devices and WSNs from different vendors is essential for seamless integration and scalability. Standardization efforts such as IEEE 802.15.4, Zigbee, and 6LoWPAN aim to define common protocols and communication standards for WSNs, but challenges remain in achieving full interoperability and compatibility [13].

IV. CURRENT METHODS

Certainly, here are some recent approaches to improving the lifetime of wireless sensor networks (WSNs) along with accurate references:

Energy Harvesting and Management: Integrating energy harvesting techniques such as solar, kinetic, and RF energy harvesting with efficient energy management strategies to extend the lifetime of WSNs. Research explores novel approaches for maximizing energy extraction from ambient sources and optimizing energy utilization at the node level [15].

Deep Learning-Based Energy Optimization: Employing deep learning algorithms for optimizing energy consumption in WSNs. Recent research focuses on using neural networks for predicting energy consumption patterns, adaptive duty cycling, and optimizing communication protocols to prolong network lifetime [16].

Topology Control and Routing Optimization: Developing advanced topology control algorithms and routing protocols to minimize energy consumption and prolong network lifetime. Recent approaches leverage techniques such as network coding, geographic routing, and reinforcement learning for efficient data forwarding and aggregation [17].

Low-Power Hardware Design: Designing energy-efficient hardware components and communication modules for WSNs to reduce power consumption. Recent advancements focus on developing low-power microcontrollers, energy-efficient transceivers, and ultra-low-power sensors to extend battery life and enhance overall network reliability [18].

Dynamic Energy Management: Implementing dynamic energy management strategies that adapt node operations based on changing environmental conditions, network traffic, and application requirements. Recent research explores adaptive sleep scheduling, dynamic transmission power control, and task offloading techniques for energy-efficient WSNs [19].

These recent approaches offer innovative solutions to address the challenges of improving the lifetime of wireless sensor networks, reflecting the ongoing efforts to enhance energy efficiency and prolong network operation in various IoT applications.

V. PROPOSED ALGORITHM

Based on the study and recent trends, a proposed method using machine learning to improve the lifetime of wireless sensor networks (WSNs) could involve the following steps:

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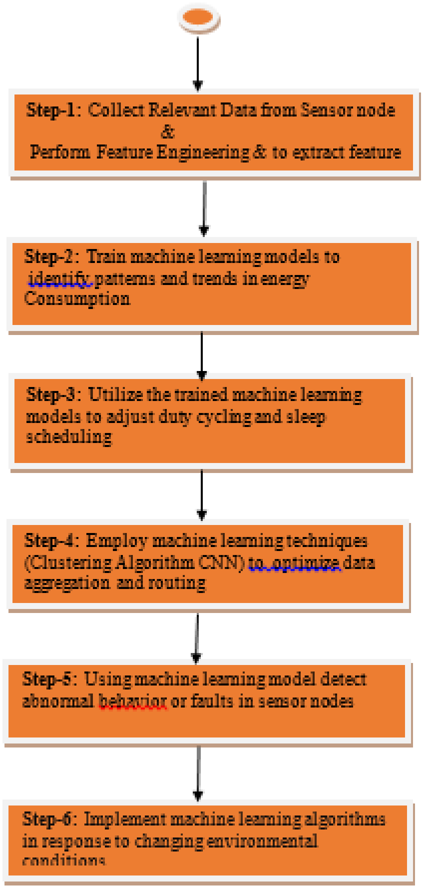

Figure 3.1: Proposed Algorithm

VI. CONCLUSION AND FUTURE WORK

The simulation results showed that the proposed algorithm performs better with the total transmission energy metric than the maximum number of hops metric. The proposed algorithm provides energy efficient path for data transmission and maximizes the lifetime of entire network. As the performance of the proposed algorithm is analyzed between two metrics in future with some modifications in design considerations the performance of the proposed algorithm can be compared with other energy efficient algorithm. We have used very small network of 5 nodes, as number of nodes increases the complexity will increase. We can increase the number of nodes and analyze the performance.

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