Published in AJSE, Vol:23, Issue: 3
Received on 13th October 2024
Revised on 31st December 2024
Published on 31st December 2024

AIUB JOURNAL OF SCIENCE AND ENGINEERING
ISSN: 1608 – 3679 (print) 2520 – 4890 (Online)

A Novel Framework for Enhancing Data Collection Efficiency Through Multiple Mobile Sink Nodes in Wireless Sensor Networks

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***Abstract*— The transmission of oceanographic data and the existence of impurities in Submerged Wireless Sensor Networks (SWSN) have been the subject of a significant amount of research in recent years. Maintaining link stability, latency in establishing connections, data loss in real-time broadcasts, and limited transmission ranges are some of the difficulties these networks face. Several routing solutions have been proposed to address these issues, but none of them have been able to provide effective transmission. Supported by both simulation and experimental results, this research presents a framework for an all-inclusive data-collecting system. Our system uses intelligent cluster sensor nodes to successfully relay temperature, pH, and turbidity data in the Indus River; turbidity values range from 6.5 to 31 NTU. Our suggested approach considerably enhances data transmission performance in submerged wireless sensor networks, according to the experimental results. When combined with Zigbee technology, a Modified Pseudo Orthogonal M-Sequence Data Acquisition System can greatly improve the performance of Routing Protocols in Submerged Wireless Sensor Networks.**

***Index Terms*—** wireless sensor network, routing protocols, real-time broadcast;

I. Introduction

THE use of wireless sensor networks (WSNs) has become one major the most significant advancements for the next generation of submerged sensor networks. A Submerged Sensor Network (SSN) consists of a distributed system that includes numerous discrete, self-organizing, low-power devices known as sensor nodes. The SSN comprises an array of spatially distributed, battery-operated embedded devices designed to continuously gather, process, and transmit data to entities with limited computational and processing capabilities.

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Significant research and development has been conducted, especially in the areas of network infrastructure and communication improvements, which has opened up new possibilities for effective data transmission in SSNs. The applications of Submerged Wireless Sensor Networks (SWSNs) have expanded to include search and rescue operations, pollution detection, submerged seismic activity monitoring, and underwater instrument monitoring.

Routing serves as a mechanism for trust-based systems, facilitating hop-by-hop data transfer. A secure routing protocol addresses the challenges posed by malicious nodes and protects the network from external threats.

However, the design and implementation of underwater sensor network protocols encounter numerous challenges due to unique environmental conditions and constraints of acoustic channels. To ensure high reliability in message delivery, a retransmission mechanism is essential. Additionally, it is vital to prevent weak nodes from depleting network resources. Routing plays a crucial role in transmitting data from nodes to their intended endpoints and significantly impacts overall network performance. An efficient routing technique can offer multiple benefits to the network, including reduced energy consumption and minimized overhead.

Although extensive research has concentrated on designing protocols based on underwater communication characteristics, a robust routing algorithm should focus on minimizing energy expenditure by reducing overhead. Monitoring nodes are typically linearly distributed along rivers and channels, leading to a linearly deployed WSN. In this context, we propose a flooding-based routing protocol that focuses on energy efficiency and hop count (BEH-Flooding). This protocol facilitates effective and stable wireless data transmission within irrigation areas.

According to the principle of equivalent hop count, nodes are categorized into several levels. At each level, two routing nodes are selected based on the criterion of optimal remaining energy. Data packets are then transmitted solely between routing nodes of higher levels and those of lower levels. This approach retains the advantages of the flooding protocol while minimizing unnecessary data transmission.

To monitor an area, we can use two types of constraints: range-based and area-free. Both types of constraints fall under the category of static focal points. We also explore the Received Signal Strength Indicator (RSSI) model, integrating a logarithmic polynomial model alongside a Path Loss Exponent (PLE) change model, which considers variations in signal quality.

The network may be subjected to Byzantine attacks, resulting in a significant number of compromised nodes. In such scenarios, honest nodes transmit their binary decisions to a fusion center, while Byzantine nodes send misleading messages. To identify misbehaving nodes within the network, we utilize binary hypothesis testing, evaluating the performing characteristic curves using nodes to receiver operations

The inconsistency in signal quality has a significant impact on network performance, prompting us to utilize RSSI characteristics to improve measurement accuracy. We present a novel 3D weighted centroid localization algorithm derived from our research, which offers better precision compared to existing techniques. Moreover, our study examines data forwarding methods that have not been adequately addressed in previous literature, emphasizing the performance of routing protocols while leaving path optimization relatively unexplored.

It employs reasonably priced, high-performing XBee modules for wireless network connection. The majority of the sensors in our wireless sensor network that we employ for continuous data collecting are analog.

We describe a novel performance-parameter-aware method for effective data gathering and forwarding in this research. We successfully use hybrid routing protocols to Sensor Wireless Sensor Networks (SWSNs) and demonstrate their benefits over two well-known approaches: hierarchical and flat routing protocols. We conduct a thorough examination of the transmission efficiency of every routing protocol and present a hybrid routing model that includes an algorithm and an experimental configuration.

This paper is structured in the following manner: A survey of recent research on data transmission in SWSNs is given in Section I. The experimental setup and performance parameters are presented in Section II. The suggested algorithm for effective routing is explained in more detail in Section III. The procedures for gathering and sending data are described in Section IV. Section V looks at the methods our system uses. Finally, Section VI addresses the applicability and constraints of our technique before providing a summary of the findings..

II. REAL-TIME TESTING MODEL

The design describes the anticipated advancements in creating a sophisticated hybrid routing protocol. Within a mobility area of 30 m × 30 m, three cluster nodes are operational in the planned submerged network. Every node functions as the fundamental working component of the network, comprised of a wireless communication module, a controller, a sensor/actuator for gathering data, and a power supply. The nodes, being independent components, experience internal battery depletion as a result of duties like data processing, transmission, and reception as well as sensing. An adapter is used as a constant power supply to help with this problem.

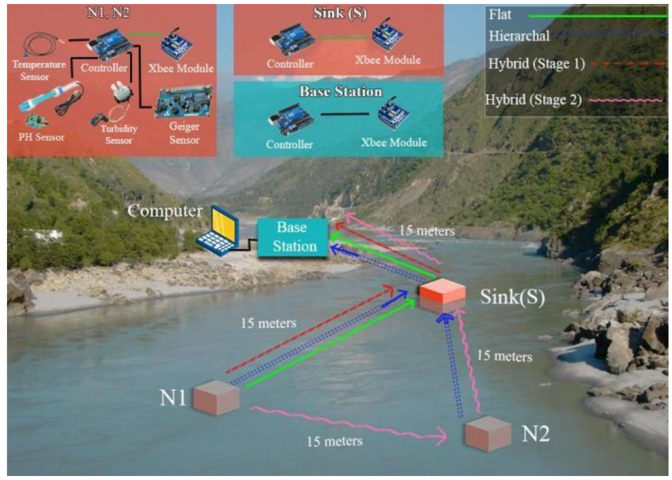

Fig. 1. System Model of Network Framework and Operation.

Turbidity, which is similar to smoke in the air, is the cloudiness or haziness of a liquid due to a huge volume of minute particles that are frequently imperceptible to the unaided eye. A Tsd-10 Turbidity Sensor is commonly used to measure turbidity, which is a crucial indicator of the quality of water. Another important factor in assessing the quality of water is temperature. A Ds1B820 Water Temperature Sensor measures the temperature, which has its own impacts and can change the chemical and physical characteristics of water in addition to influencing other parameters.

TABLE I
DESCRIPTION OF HARDWARE COMPONENTS

Manufacturer Part Number	Description	Units
Tsd-10	Water impurity testing	Count per volts
DSB180	Water temperature calculation	Count per volts
PH Sensor Circuit	Calculation of water quality testing	Count per volts
PH Sensor Probe	Water sampling for PH calculation	-
XBEE Modules	Trans-receiving Communication	802.15.4 RF
DC Adapter	5V DC Power Source	Volts
Arduino UNO	Controller	-
Computer	-	-

Radiation is present in all water, although the kind and quantity vary depending on a number of variables. The pH of pure water is 7, and as shown in Figure, water is commonly classified as basic if it is above 7 and acidic if it is below 7.

A pH Sensor kit is used to take this measurement. Selecting components that are widely available and well-regarded in the market is crucial to creating dependable hardware and guaranteeing that consumers may access the system affordably. Each component's specifics inside this network are described in Table 1.

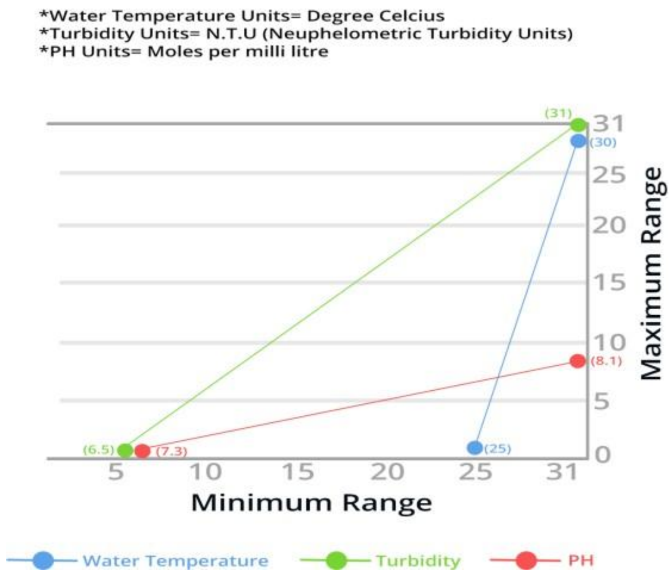

Fig. 2. Ranges of values in Water Parameters.

III. Algorithm Process

To perform software modeling and simulations, this algorithm is implemented on every node. In light of our limited resources, it is made to make sure the system runs with minimal power consumption. Reading parameters is the first step in the complete system. Information transfer requires accurate and trustworthy data. Which data is delivered depends on how the parameter measurements are evaluated. Figure 3 illustrates how the system saves power by evaluating the sleep mode and determining when to verify settings after waking up.

The Xbee modules' software configuration and connectivity are essential to the network procedures. In order to guarantee prompt data transfer, the Xbee modules are connected. One Xbee connects to another in API mode, one of the Xbee configurable modes, in order to take advantage of this feature. The network mostly focusses on analysing analogue parameters, hence API mode is crucial for processing. API mode is generally utilised for continuous data transfer. With the configuration freedom that Xbee offers, customers can develop settings that work for their particular needs. In order to maximise network performance, the command mode character limit is set to 2B in Hex, and the guard time for transmission operating modes is set to 1000 ms in the general Xbee settings. During the transmitting and receiving procedures, the Xbee modules are identified as the "Router" (Transmitter) and "Coordinator" (Receiver). Based on the unique setups of both Xbee modules, these identifications have been made. XCTU Software is used for the full module

```
Start
L← length
W← width
No: of Nodes← n
No: of Rounds ←R
~net
    [1….. n]
    Π [L] [W]
net = net1
subplot 231
    ⊕ (net↔2)
    ⊕ (net ↔3)
For
    i=1 and nume1= net (1)
    loop
    j = 1 nume1 = net * 1
    X1 = net(n, i)
    Y1 = net(3, i)
    X2 = net
    Y2 = net(3, j)
    j = xSide = abs(X2 - X1) k = ySide = abs(Y2 - Y1)
    d = (sum((j**2, k**2))) ** 0.5 d = [i for i in range(n)]
    if d < R and i == j: A = vertices1 = [X1, X2]
    B=vertices2 → [Y1, Y2]
⊕ (A ↔ B) & (W ↔ 0.1)
```

configuration process, including PAN ID assignment for the modules. To identify one another when data is being transmitted, both modules use the same PAN ID. The setup of the "Router" is configured to broadcast data at the maximum range that corresponds to the PAN ID. Addresses in the code must be applied in order to record and receive data from a dedicated port and guarantee precise and genuine data retrieval. Every item of data received over a serial communication link has a unique address. For reading data using controllers like Arduino, Xbee has created specific address formats for its ports. They also offer a handbook that users may use to verify the addresses and incorporate them into the algorithm code for data monitoring. The three Xbee pins we are using, AD1, AD2, and AD3, each have somewhat different addresses because of this. The mapping of the addresses follows the order of LSB (Least Significant Bit) + MSB (Most Significant Bit).

The sensor hub is composed of a wake-up collector and an information transmitter. The information transmitter is turned off until the wake-up collector detects a wake-up signal from the cluster sink node. The wake-up signal receiver is set to a particular frequency band. The internal power supply triggers the data transmission module when the packet detection output surpasses a predetermined threshold.

IV. Experimental Software Setup

The proposed hardware model has effectively included the experimental algorithm. The programming language used to write this technique is C, which is similar to Arduino. Its operation is consistent with the simulated outcomes that the MATLAB program code produced. The algorithm also takes into account how an Xbee obtains the needed data, as was covered in earlier chapters. It obtains data using a Serial connection using the addresses from the Xbee's I/O ports, processes it, and shows the results to the user on the computer screen. The simulation algorithm's flow and the code's flow are identical. While the experimental technique gives actual data in real-time applications, the simulation algorithm shows how many turns the network has about dead nodes. In (1), the Turbidity Sensor is computed.

Turbidity = Analog*(5/1024)*100 (1)

The devices are initialized at the start of the code. Next, the code verifies if the PAN ID matches; if not, it reevaluates the PAN ID. After the PAN ID has been confirmed and identified, the address is checked to make sure it comes from the right and legitimate Xbee I/O port. Serial data helps to facilitate this process. In (2), the PH Sensor data is computed.

PH = buff [k] = Analog Reading (LSB+ (MSB*256)) (2)

Once the address is verified as correct, the received data is read and subsequently calculated using the formulas provided in the sensor data sheets. For instance, formula (3) calculates the data for water temperature.

PH = buff [k] = Analog Reading (LSB+ (MSB*256)) (3)

Data is now displayed in the Arduino Serial Monitor feature following data calculation.

V. Routing Techniques In SWSN

A wireless sensor network's nodes collect data and transmit it to the washbasin. Although the nodes can communicate directly with the sink, this connection needs a lot of transmission power, which is a major problem for WSNs. Data transmission must thus be done as energy-efficiently as possible. Direct communication is frequently substituted with a multi-hop method to gain greater energy efficiency. The next hop can be found by the source node dynamically using ad hoc routing or statically using pre-defined routing tables. This next hop helps forward the data towards the sink. Once a path is established, the data is sent to reach the sink with maximum reliability, minimal delay, or optimal security. The flat routing protocol is a communication method where all nodes treat each other as peers, sharing routing information without any hierarchical structure. In contrast, hierarchical routing organizes nodes in a structured manner, similar to a corporate intranet, where nodes connect to a central backbone and are grouped by specific work functions, such as the Sink Node. In order to identify the best network paths and report changes in network topology, the Hybrid Routing Protocol (HRP) incorporates elements of the Distance Vector Routing Protocol (DVRP) and Link State Routing Protocol (LSRP).

Compared to Flat and Hierarchical Routing, there are two primary methods for data transport using routing protocols.

Before delivering the data to Computer C, the Sink Node (S) in the Hierarchical structure gathers it from Nodes 1 (N1) and 2 (N2). The nodes in the hybrid route are set up to guarantee backup data reception. As shown in Figure 4, the system will switch to the alternate route (N1, S, C) if any failures occur in this channel (N1, N2, S, C) in order to preserve continuous data reception. As shown in Table 2, our

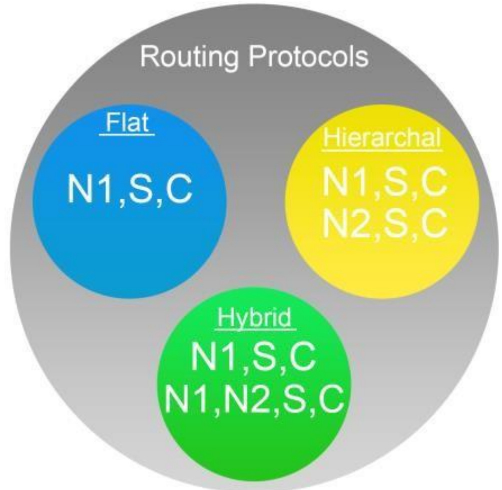

Fig. 3. Ranges of values in Water Parameters.

Node framework architecture enables the examination of these metrics to assess how well different routing techniques function.

VI. Results

The framework was investigated utilizing flat, hierarchical, and hybrid routing techniques to evaluate the network's performance. The experimental setup results are presented within the framework of a sensor network scenario with stationary cluster nodes. We compare and analyze the protocols' performance using the measure of how many nodes are dead. The number of dead nodes in a flat algorithm every round is shown in Figures 4 and 5.

TABLE II
Comparison Analysis of Various Routing

Parameters	Unit	Flat	Hierarchal	Hybrid
Speed	m/ node /sec	1.2	>1.2	3
Depth	m	3	>3 or 5	>3 & < 6
Distance between nodes	m	5	7-10	>10 & <16

The efficiency of hierarchical routing is demonstrated by examining several scenarios in which each node is connected, or in which each node is connected to a sink node. As Figure 6 shows, by using this method, the network topology becomes simpler, networking nodes become more efficient, and congestion is much reduced because there are fewer routing displays.

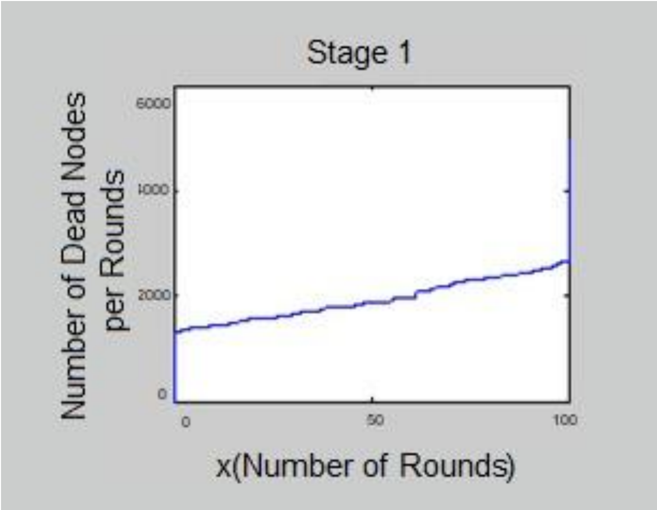

Fig. 4. Nodes dead during a round in Flat algorithm.

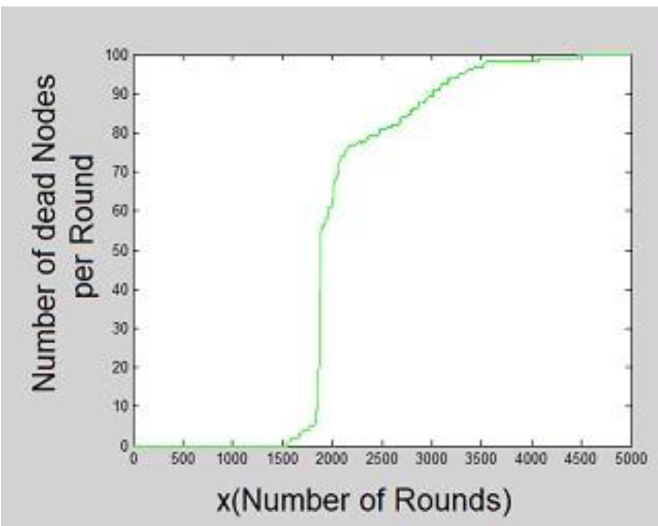

Fig. 5. Nodes dead during a round in the algorithm.

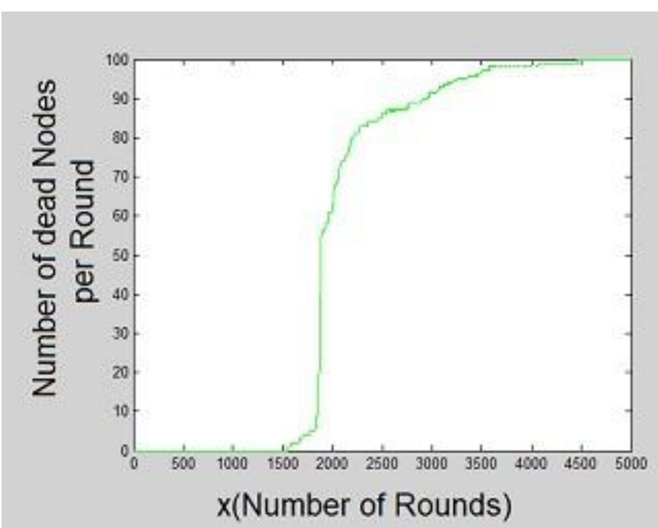

Fig. 6. Nodes dead during a round in Hierarchal algorithm.

An underwater remote sensor network (SWSN) is characterized by its ability to organize several sensor nodes to monitor an object, environment, or event. The lifespan of an SWSN can be greatly increased over time by utilizing the proper routing protocols, as opposed to that of any single node. This is accomplished by only turning on one node at a time, even with multiple node configurations, inside a designated coverage area and by putting the nodes into sleep mode when not in use. As shown in Figure 6, the routing protocol can be categorized as flat, hierarchical, location-based, or direct, depending on the network architecture utilized for WSN routing.

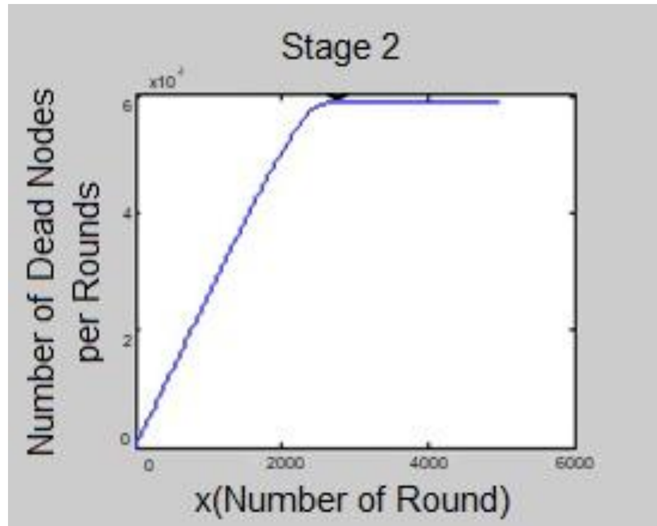

Fig. 7. Stage 2 of Hybrid Routing in SWSN.

The route's initialization is demonstrated by the simulation statistics in Figure 7. After establishing the path with dead nodes, the routing signal starts to take rounds, which increase concurrently. The number of rounds increases quickly after this.

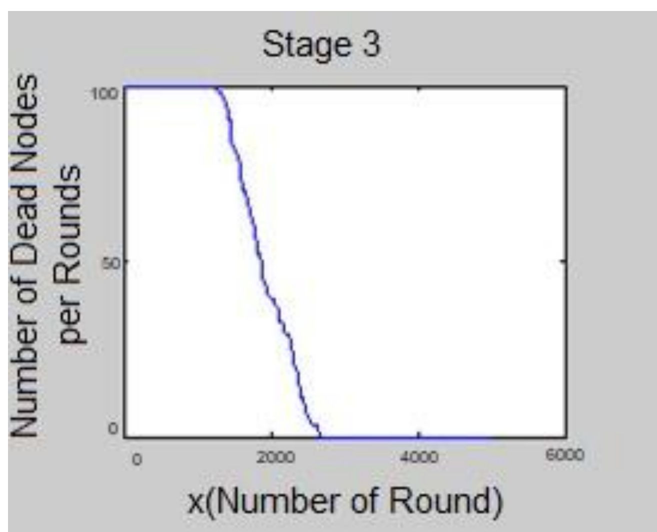

Fig. 8. Stage 3 of Hybrid Routing in SWSN.

The following phase of the hybrid route is depicted using the simulation data from Figure 8. Both the number of dead nodes and the stability of the rounds are now displayed by the signal. In this case, the number of rounds stays constant and the signal no longer makes use of the inactive nodes, leading to stronger network connectivity.

Figure 8 shows the last phase, which is the delay. In stage three, a decision is made regarding whether to regenerate the link or finish the network condition. The route is more effective because of this procedure.

The count per round for the hybrid procedure is shown in Figure 9. According to the findings, the network can have up to 35 dead nodes at any given time while still completing more than 2000 cycles. The results of this routing protocol are superior to those of both flat and hierarchical methods. The edge work model is used to create the selection of signals and the verification of signal heads, which adds a substantial degree of unpredictability. In Figure 10, the variations in the number of cluster heads are shown. The range of dead nodes is 0–40, and the range of rounds is 0–6000.

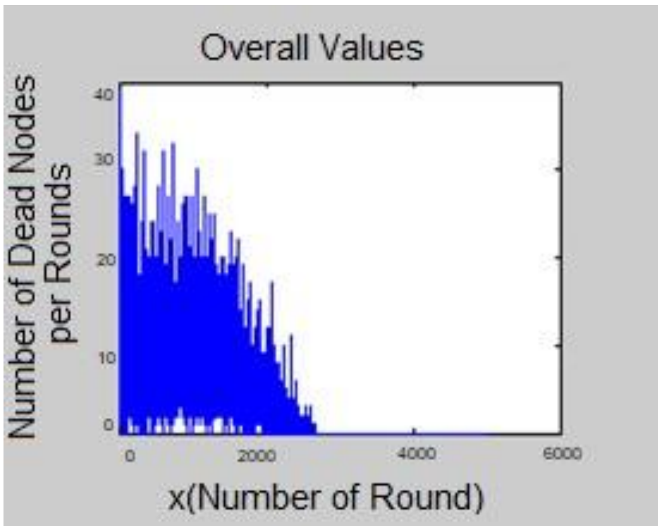

Fig. 9. Overall values of Collected Hybrid Routing in SWSN.

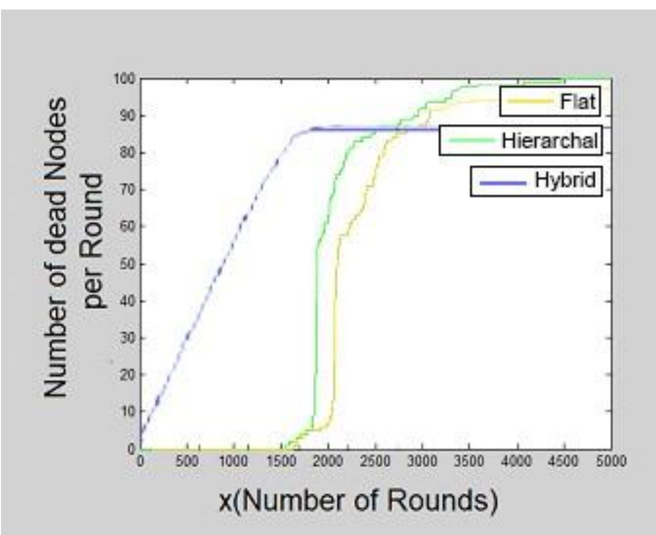

Fig. 10. Comparative Graphs between Routes.

Figure 10 shows the routing strategies' respective performances (Flat, Hierarchical, and Hybrid). When generating rounds in the network, the Flat and Hierarchical routes frequently exhibit some degree of instability. On the other hand, although requiring more nodes than the other routes, the Hybrid route produces superior rounds. The Hybrid route is also more stable in constructing rounds and has a lower rate of dead nodes than the other routes, which makes it a more effective choice. We discovered that the protocols' stability period lengthens when the sink is fixed at the network's center because it keeps the same distance from every node and uses the same amount of energy.

The nodes farther distant from the sink will run out of energy faster if the sink is placed at the top of the network. Nodes' energy consumption rises with distance, which causes earlier failures. Only the Hybrid routing protocol may prolong the life of a network since it minimizes communication delays and lessens the burden on the nodes.

VII. Conclusion

One of the main areas of research has always been efficient data transfer in Sensor Wireless Sensor Networks (SWSN). Via simulations and real-time trials, the network's performance was assessed. Two nodes were used to detect their surroundings, gather data, and transmit the analyzed information back to the base station within a 10-meter range. By using an upgraded routing protocol, as explained in the experimental equations, this work provides an algorithm that addresses the shortcomings of conventional flat and hierarchical protocols. The outcomes show that the hybrid routing strategy is more precise and effective for transmitting and gathering data. Hybrid routes were carried across up to 15 meters at a speed of 3 m/node/sec in the context of SWSN.

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