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Time Threshold- Based Energy Efficient Routing Protocol for Underwater Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) have potential in monitoring oceanic situations through remote data collection and exchange. Underwater Wireless Sensor Networks (UWSNs) are built for monitoring ocean currents, temperature, port security and armed monitoring. This study investigates UWSN architecture, characteristics, network protocols and applications, focusing on the energy-efficient routing protocols such as EEDOR, LFEER, Co-LFEER, DBR, Co-DBR, and our proposed Holding Sending Time Depth Base Routing (HSTDBR) protocol is comprised on five simulation parameters, including energy consumption, packet delivery ratio, transmission loss, number of alive nodes, and end-to-end delay, are considered. Results show that HSTDBR outperforms Co-DBR with a lower transmission loss, higher number of alive nodes, lower energy consumption, higher packet delivery ratio, and lower end-to-end delay. This study highlights the challenges and current research directions in UWSNs. The text discusses various metrics related to a proposed protocol for underwater sensor networks, including transmission loss, number of alive nodes, energy consumption, packet delivery ratio, and end-to-end delay. It notes improvements in some areas but challenges in others. The overall topic of the text is the difficulties faced by researchers in developing and implementing underwater sensor networks, and it provides a review of current research in this area.

Keywords: Holding time, sending time, depth-based routing, HSTDBR, depth base routing (DBR).

1. Introduction

Wireless Sensor Networks (WSNs) consist of randomly dispersed sensor nodes that work together to detect tangible objects and gather data. WSNs contain protocols and algorithms with self-organizing abilities and have three major applications: monitoring of objects, monitoring of areas with underwater environments, and monitoring of collective regions and objects. These applications are used broadly in modern times for various purposes such as precision farming, military surveillance, and intelligent alarms [1]. Wireless Sensor Networks (WSNs) have a wide range of applications including vehicle tracking [2], military surveillance [3], robotic farming [4], environmental monitoring (coal mining, forest fire, air pollution) [5,6,7], animal tracking [8], health care monitoring [9,10], and smart buildings [11]. Each application has its specific requirements and challenges. For instance, in animal tracking, WSNs require hybrid routing techniques to extend the network's lifespan, while in health care monitoring, the focus is on providing prompt medical assistance using WSNs parameters. Additionally, smart buildings combine traditional architectural technology and internet and communication technologies. WSNs are a vital component of smart transportation systems, helping to control car location**.** This paper discusses various types of Wireless Sensor Networks (WSNs) including terrestrial [12], underground [13], mobile, multimedia [14], and underwater WSNs [15]. Terrestrial WSNs are deployed on the surface of the ground and can use both free space optical (FSO) and radio frequency (RF) communication. Underground WSNs are used for safety and monitoring in underground environments, and an improved Distance-Vector hope (DV-Hop) algorithm is proposed for positioning and tracking in blind areas. Mobile WSNs are composed of movable nodes that are more adaptable, have greater range, and use less energy than static nodes. Multimedia WSNs use multimedia such as video and sound for recording and monitoring specific occurrences. Underwater WSNs are used for monitoring oceanic conditions and have great potential for exploring unexplored regions of the ocean [16].

A well-known type of wireless network called an underwater wireless sensor networks (UWSNs) connect undersea devices using wireless technology. These networks are utilized to keep an eye on and gather information from aquatic environments, such as lakes, rivers, and seas. For a number of uses, including environmental monitoring, oceanography, and military activities, UWSNs are becoming more and more crucial [17].

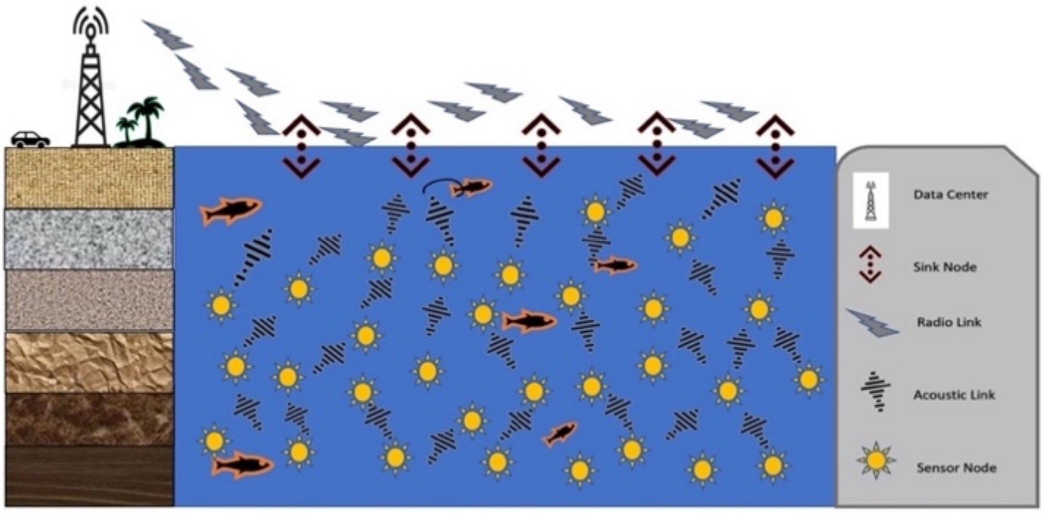

Figure 1. An Architecture of UWSNs

The various parts that make up UWSNs include sensors, transceivers, and communication protocols. Sensors are used to gather environmental data including salinity, pressure, and temperature. Transceivers move data from the sensors to the base station so that it can be examined. Information is consistently and securely transferred using communication protocols [17].

1.1. Architecture of Underwater Sensor Nodes

Underwater wireless networks are not complete without sensor nodes. They are utilized to collect ambient data and transmit it to a base station or other network nodes. Small, low-power sensors nodes are frequently created to be placed in challenging underwater conditions. Sensor nodes frequently include a range of sensors, including acoustic, pressure, and temperature sensors [18]. The base station or other network nodes receive data from the sensing nodes via protocol.

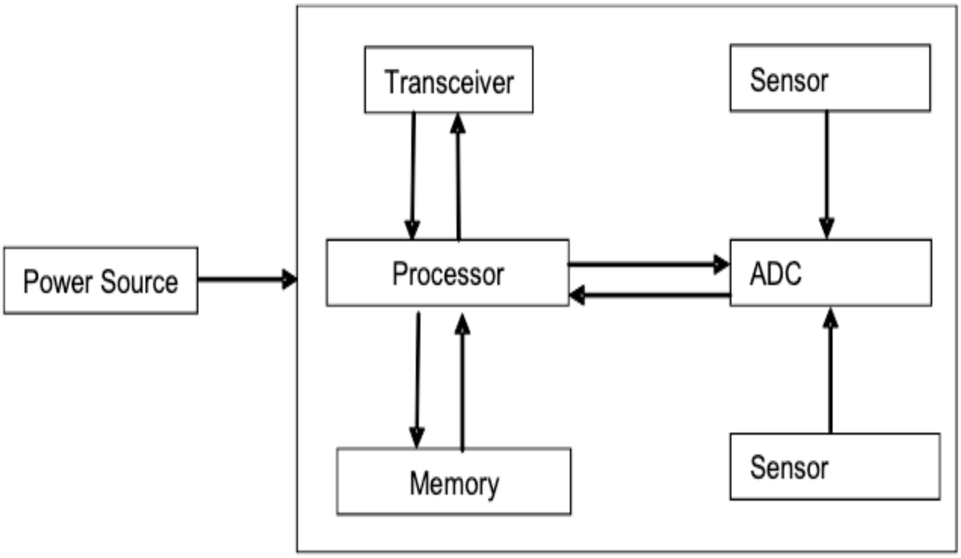

Figure 2. Block Diagram of Underwater Sensor Node

The processor manages and coordinates the many functions of the sensor node and processes data. The analogue data measured by the sensors is converted to digital format by the analog-to-digital converter (ADC) so that it may be stored and processed. A radio device that can both receive and broadcast data is a transceiver. The power supply, which consists of solar cells, provides energy to the sensors as well as to the other parts of the sensor node. Until it is sent to the following node, the CPU also keeps the gathered data in memory. Additionally, produces control messages that instruct the sensor to begin or stop data collection. The processor also stores data about the node's adjacent nodes when the node is a member of a network**.**

1.2. Characteristics of Underwater Sensor Node

This passage discusses the characteristics of underwater sensor nodes, including their computing capabilities, battery energy and small size [18], communication capabilities, self-organization, high accuracy and low cost, and multi-hop communication [19]. The passage also lists several companies that manufacture underwater sensor nodes, including Teledyne Marine, Aquabotix, Ocean Server Technology, and SAAB Seaeye [20,21]. The products offered by Teledyne Marine, which is a branch of Teledyne Technologies Incorporated, include sound Doppler, underwater autonomous vehicles, and remote-operated vehicles. Aquabotix focuses on creating underwater robotic systems, while Ocean Server Technology produces oceanic tools and underwater wireless sensor nodes. SAAB Seaeye is the leading manufacturer of autonomous underwater vehicles used for military, academic, and industrial reasons.

1.3. Challenges in UWSNs

UWSNs have been the subject of significant study and widespread application in both academia and business. There are several challenges which are being faced in UWSNs. Fig shows the existing challenges of UWSNs [23]. The challenges include multiple access, limited bandwidth, delay variance, propagation delay, support for real-time applications, transmission range, link reliability, heterogeneity in UWSNs, common standard and interface, sensor heterogeneity, complex acoustic environment, and big data-related challenges [24]. These challenges are hindering the effective implementation of UWSNs in various applications, including oil leak detection, earthquake and typhoon detection, and territory monitoring.

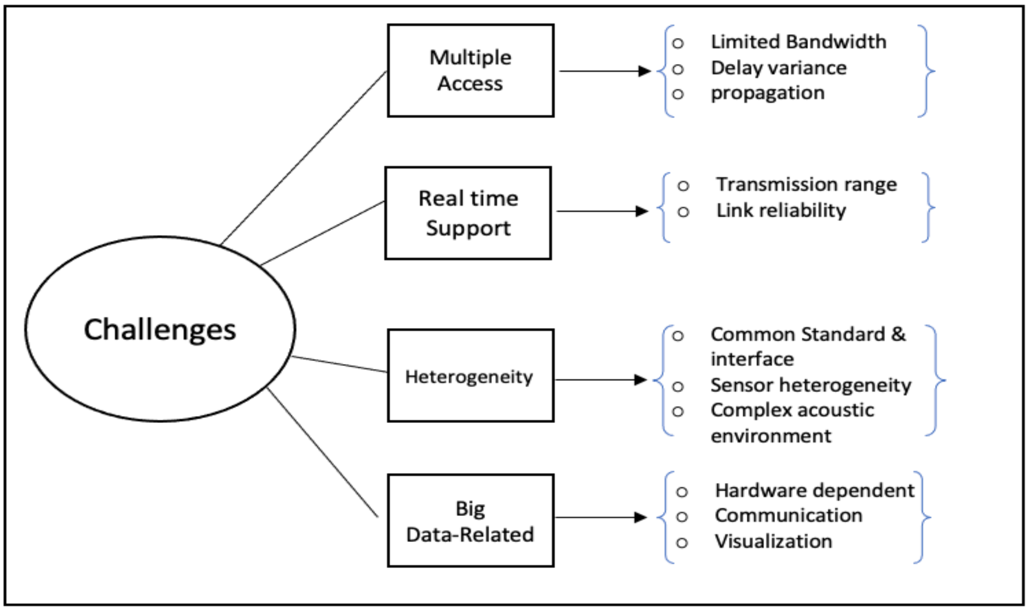

Figure 3. Challenges in UWSNs

2. Related Work

Paper [25] discusses the use of routing protocols for efficient energy usage and minimizing propagation delay in wireless sensor networks. Localized routing is suggested as the easiest way to forward information towards the destination, with a greedy forwarding approach used to choose the shortest path to the sink. However, this approach can result in high energy consumption and a void gap in the network. To overcome these issues, the paper suggests using a clustering strategy to minimize power consumption and communication while avoiding dependence on a single node. The importance of localization in wireless sensor networks (WSNs) for effective data classification and multi-hop information transmission [26]. In underwater WSNs (UWSNs), localization procedures are essential and assume the existence of specific devices with known locations, which are used as reference points to build the localization algorithm. Knowing the location of sensed data is crucial for geographic routing protocols in UWSNs. An improved Back Propagation Neural Networks (BPNNs) has also been proposed by authors to implement the data fusion. Transmission of data through multi-hop strategy had been demonstrated more successful to vitality preserving in long-distance transmissions as compare to the single-hop procedure which was examined in the paper [27]. The SN is known to be the destination node, and the CHN that holding data packets to be transmitted gets to be the source node. The transfer node must be chosen from CHNs instead of CMNs for the fruitful transmission of data to the SN. Authors proposed in paper [28] about Movement-Assisted Deployment (MAD) which is an additional chief node's deployment in pursuance of UWSNs. In this sensor were implanted in mobile platforms being per sovereign underwater vehicles (AUVs). These devices are driven through sensors. When dropped at random onto the water's surface, they can travel to their ultimate positions. The deployment of underwater sensor nodes in UWSNs is a critical issue that affects the network's performance and survivability [29]. A proposed node deployment methodology is vital for building efficient sensor networks. The node deployment problem is a combination of front-end data gathering and back-end data processing of the UWSNs architecture, which presents potential barriers for sensing networks. The shape-formed model of a node's seen zone is used to determine the coverage area, but the effects of volatility and irregular forms are not considered

3. Methodology

To increase the energy effectiveness of the designed protocol, we would like to create a routing protocol that combines the advantages of Co-DBR, or the depth base approach, and LFEER, or making decisions by selecting a relay based on its highest residual energy. The proposed routing protocol holding time (HT) and sending time (ST) based DBR routing protocol design for UWSNs would be more energy efficient than Co-BDR and LFEER with improved results. First, we identify the depth in three phases. In all papers nobody defines the depth into layering. Secondly, all the mentioned papers researchers have not defined the hard or soft concept of threshold. Therefore, our proposed concept is in this regard is different from others. We are not working on cooperative and clustering concept. Clustering concept is not fruitful in underwater environment, mostly researchers discourage the clustering concept. Therefore, we did not adopt the clustering methodology. All the researchers mainly working on energy efficiency concept. As energy efficiency is mainly focused that's why we preferred to work on energy efficiency because in underwater basically energy level needs to be improved. In our proposed work we utilized the idea of HT, ST and divide the depth in region which is not used by others papers as compare to modeling, clustering, cooperative.

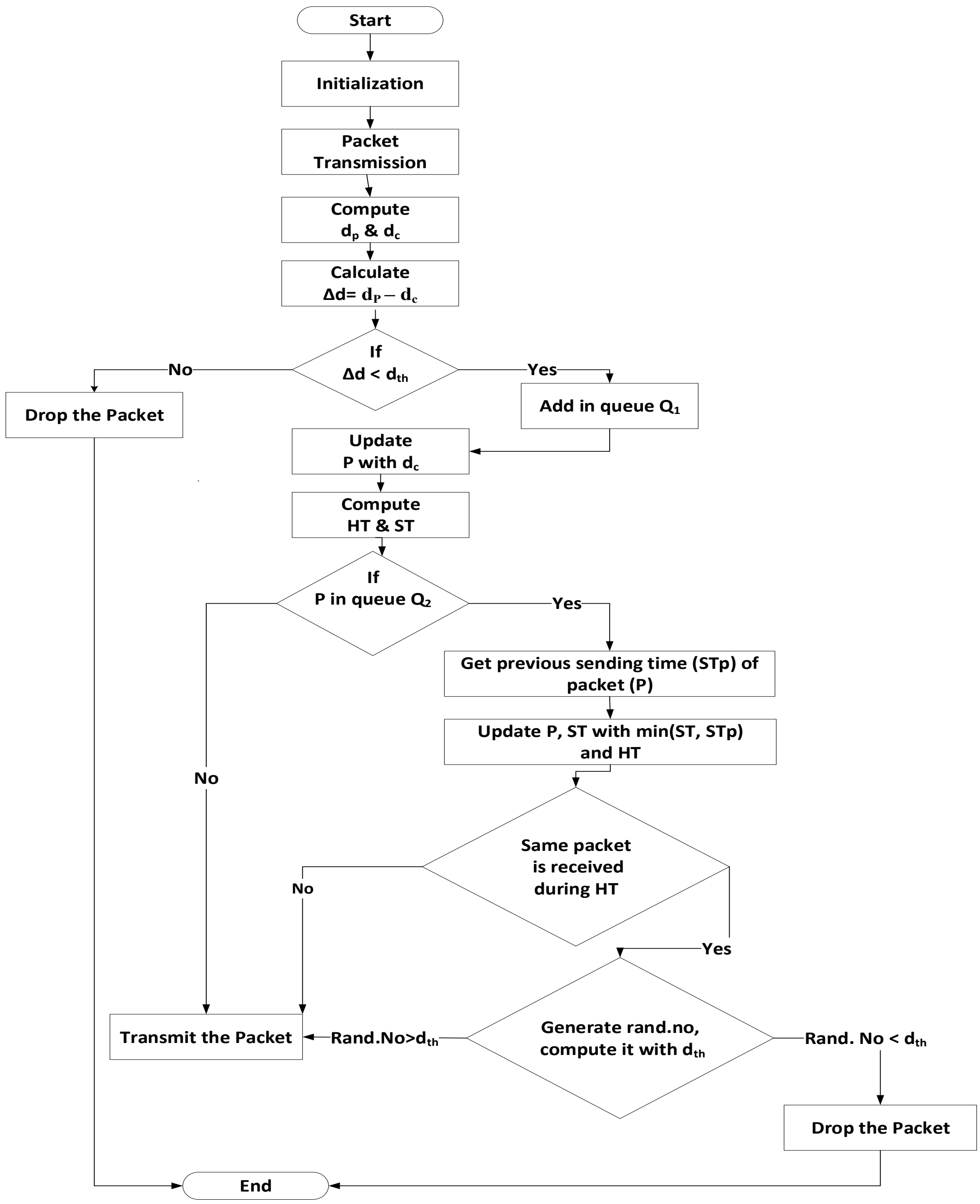

Figure 4. Flow Chart of proposed scheme Holding and Sending Time Depth Base Routing (HSTBDR)

3.1. Research Methodology

The first step is the initialization of the parameters. When the nodes have been deployed, pack transmission starts. After transmitting the packs, the next step is to compute d_P (Previous depth) of the bottom sensor node and after that compute d_c (Current depth) of the sensor node. Once d_P and d_c is computed, the next step to calculate the Δd (i-e $\Delta d = d_P - d_c$). If the Δd is greater than d_{th} (depth threshold) means condition is false drop the packet and get executed, but if Δd is less than d_{th} which means condition is true, add packet in queue Q_1. Once the packet has been transferred in Q_1, the next step is to update packet (P) with current depth (d_c). furthermore, in the next step HT (Holding Time) and ST (Sending Time) of the packet is updated, and it searches the packet in the packet history buffer that is known to as queue Q_2.

If packet (P) is not in queue Q_2, transmit the packet to final state, or if the packet is in queue Q_2 means condition is satisfied, get previous sending time (ST_P) of the packet and calculate it. Next is to update the sending time of packet i- e min (ST, ST_P). After updating ST, update holding time of packet and in next step. If same packet is received during holding time, condition comes to false, transmit the packet when time expires. And if condition comes true that is same packet is received during holding time, generate random no. and compare it to packet's depth threshold (d_{th}). In this condition if the random no is less than d_{th} (i-e Rand. No < d_{th}), drop the packet. And if the random no. is greater than d_{th} (i-e Rand. No > d_{th}), transmit the packet to final state and execute.

4. Results and Discussion

The relevant simulations for a certain task can be chosen using MATLAB. We utilized MATLAB for simulation. Additionally, it provides the option to alter the simulation's parameters, including the number of runs, the kind of parameter values, and the kind of equation or system. Our literature review served as the justification for choosing MATLAB over other simulation tools on the market. Additionally, Co-DBR and LFEER researchers use MATLAB for simulations in their work. The third factor that led to our choice is MATLAB's capacity to make the implementation of mathematical functions simple.

4.1. Energy Consumption

The quantity of energy consumed to carry out a specific action is known as energy consumption. The amount of energy used by a sensor node change based on a number of factors, including the hardware it uses, the environment, the transmission distance, the type of communication protocol, and the processing load.

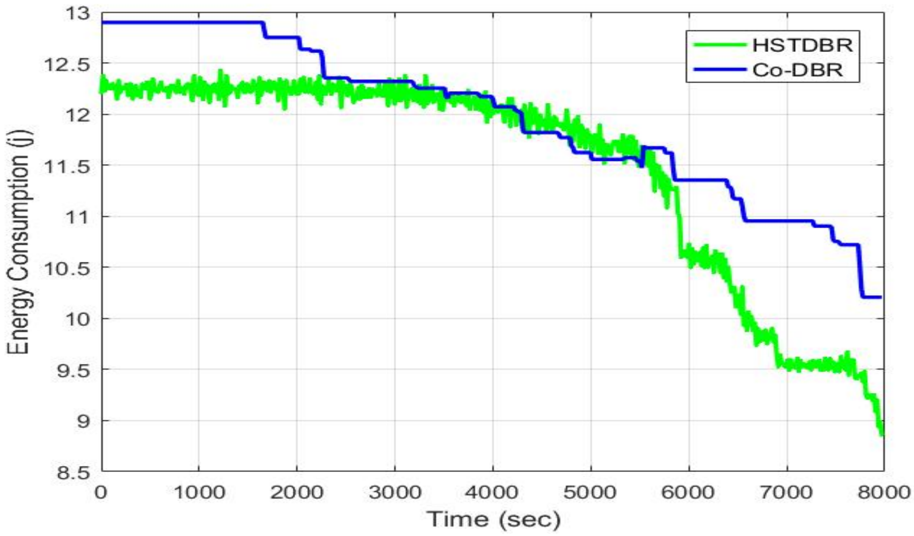

Figure 5. Energy Consumption

Figure 5, displays how much energy each procedure uses. DBR displays a high degree of energy usage, 13.56, as non-continuous approaches to distributed sensor nodes in an underwater setting, as shown in table. Whereas, HSTDBR is started at low level energy consumption particularly 12.48. That shows our proposed protocol is consuming low computing the average values in table our proposed protocol produced 1.99% improved results than DBR. Energy subsequently which increase the live of sensor node, and eventually sensor node will last for long period of time which reduces the deployment expanse of sensor node. Table precisely shows the difference after 1000 rounds to 8000 rounds HSTDBR is more consistence in energy consumption of sensor nodes after encountering data activity. Whereas, DBR reflects less consistency in energy consumption. After computing the average values in table our proposed protocol produced 1.99% improved results than DBR.

4.2 Packet Delivery Ratio

The packet delivery ratio (PDR) of sensor nodes in a wireless sensor network (WSN) refers to the proportion of data packets that effectively reach their target. It is determined by subtracting the number of packets the destination got from the overall number of packets delivered. Additionally, it provides information on the reliability and efficiency of the network.

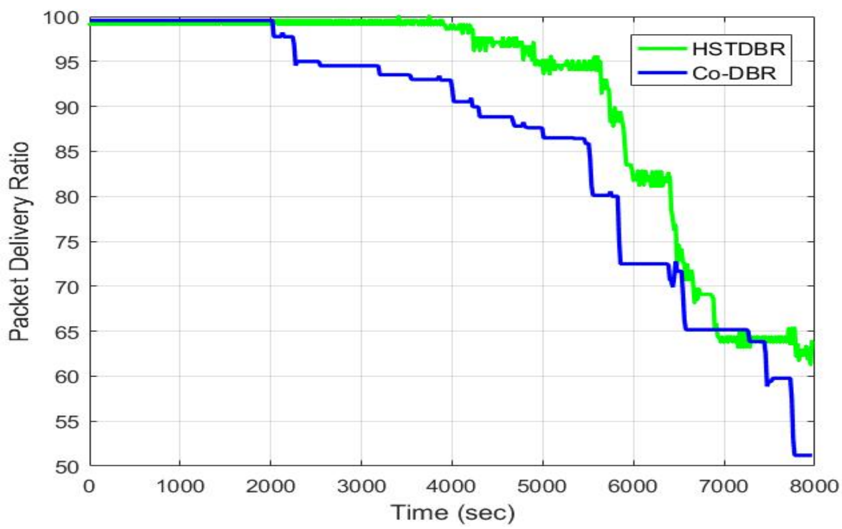

Figure 6. Packet delivery Ratio

Figure 6 defines the packet delivery ratio of both protocols. Although DBR started at high pitch of packet delivery in comparison of HSTDBR, but after 2000 rounds BDR packet delivery ratio decreases with high rate as the time passes. Our proposed protocol HSTDBR sustain the balance packet delivery ratio as table shows that after 4000 rounds the packet ratio decreases. The decline of packet ratio in HSTDBR protocol is comparatively lower than DBR. Consequently, table conclude that maximum number of packet ratio has been delivered to sensor node to sink node by the HSTDBR protocol. Hence accurate data is transmitted to destination sink node. In computed values of table, our protocol HSTDBR showed 6.85% overall improvement in packet delivery ratio than DBR.

4.3 End-To-End Delay

The amount of time it takes a data stream to travel from one end of the network to the other is known as end-to-end delay or latency. The time it takes for a data packet to leave its source, travel through the network, and finally reach its target is used to calculate the delay. The figure 7 shows the simulation results that clearly tells that end-to-end delay in packets of algorithm HSTDBR proposed by us is a much better as compare to Co-DBR protocol.

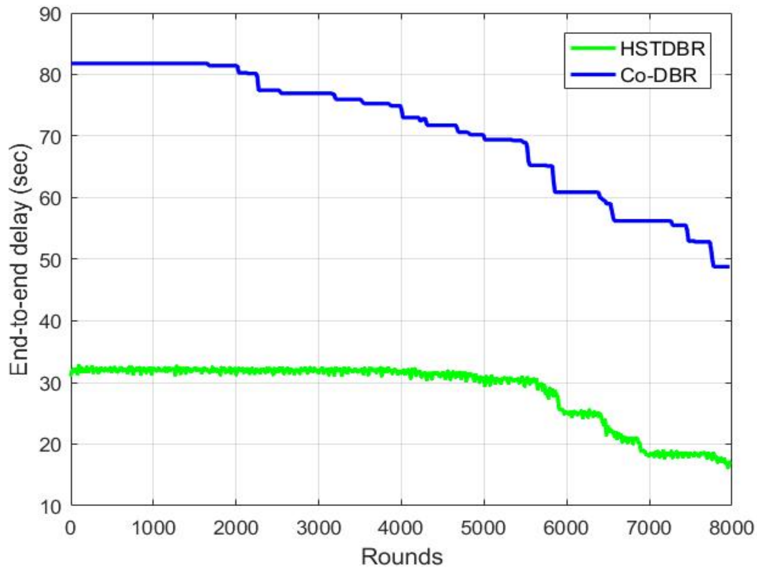

Figure 7. End-To-End Delay (sec)

Due to the fact of non-continuous data transmission in HSTDBR and Co-DBR, HSTDBR packets transmission is started at less time interval as compare to Co-DBR, which is surely encounters the speedy transmission rate. HSTDBR is also on a better node at consistency period which is cleared through the figure 6 and table. The sink node receives the data forwarded to it only when the current value and value recorded previously is changed. Our suggested protocol retained that consistency and decreased the end-to-end delay, which produced a difference of 0.41, at the first and second periods, which are after 1000 and 2000 cycles, respectively. Furthermore, a level of consistency is quite satisfactory till the last round (after 8000 rounds). Whereas, Co-DBR is consistence at the beginning i-e after 1000 and 2000 rounds, but later on after 2000 rounds consistency of end-to-end delay in packets of data transmission felt down till the last rounds. Values are computed at all the eight rounds from the given graph and mentioned in table. Eventually HSTDBR showed the remarkable improvement along with 48.08% in end-to-end delay.

4.4 Number of Alive Nodes

In a network of sensor nodes, the term "alive sensor nodes" refers to the count of sensor nodes that are operational or active. It reflects the number of nodes that are capable of sending and receiving data, interacting with other nodes, and carrying out their assigned functions. Depending on the environment and the application, different numbers of sensor nodes can be alive.

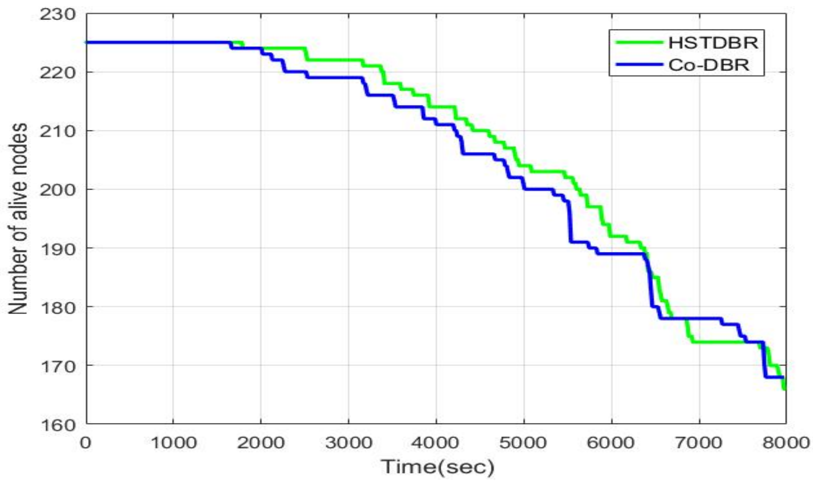

Figure 8. Number of Alive Nodes

Figure 8 reflects the impact of alive nodes. It precisely shows that almost same amount of alive nodes be activated i- e about 225 when the activity is performed. Furthermore, up to 1000 rounds the number of alive nodes is same in our proposed protocols HSTDBR and Co-DBR. Afterword as the time passes after 1000 rounds our proposed protocol sustained the integrity of alive nodes whereas, Co-DBR started to decrease the number of alive nodes. This sustainability impact can be observed in table after 1000 rounds to 8000 rounds. The average values of both protocols are computes in table, where our proposed protocol found better to keep the more alive nodes till the last rounds, and presented 3.78% overall improvement.

4.5 Transmission Loss

The signal intensity that is lost during long-distance transmission is known as transmission loss. Attenuation, scattering, and dispersion are only a few of the many causes of transmission loss. Typically, a logarithmic unit of measurement, like as decibels, is used to describe transmission loss (dB).

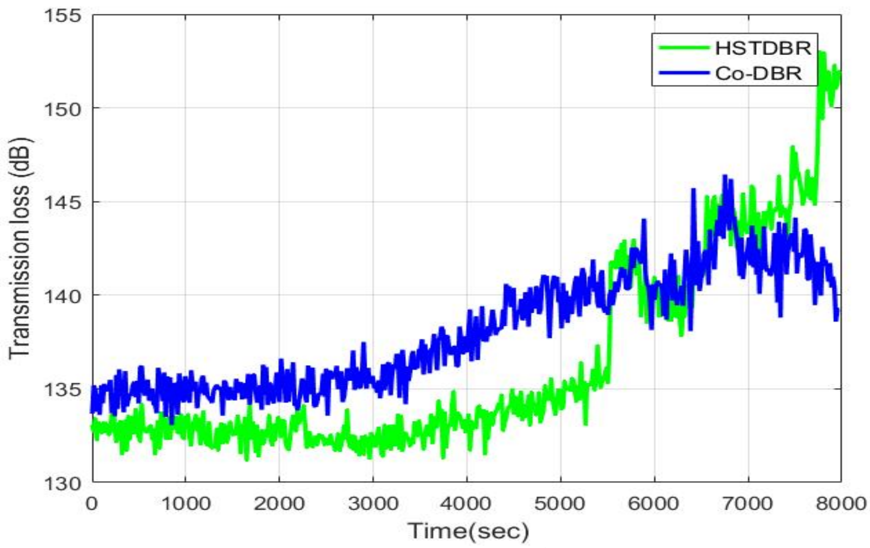

Figure 9. Transmission Loss (dB)

In Figure 9 shows the transmission loss of non-continuous data, where our proposed protocol HSTDBR is started at comparatively at low audible node 126.65 dB, where Co-DBR started at high audible node 136.45 dB. The mentioned values are taken from table 5.2. Furthermore, Co-DBR started at high frequency node, but subsequently, with the passage of times it is very much clear form table 5.3 that intensity of sounds increases after 8000 rounds up to 146.78 dB, which causes transmission loss. Our proposed protocol HSTDBR, comparatively shows much improved results. It starts at low intensity level and as the pass passes it managed to decrease the acoustic barriers. In table 5.3 it clearly shows that after 8000 rounds the intensity level is decreased 126.65 to 122.30 which causes loss transmission loss. Our proposed protocol produced 16.68% improved as compare to DBR protocol.

5. Conclusion

UWSNs have been the subject of extensive research in recent years, which has resulted in the development of innovative routing protocols. Network routing, however, continues to be a huge area of study. UWSNs are utilised for a variety of applications since they are deployed in various submerge regions and depend on the submerge environment. The main objective of this thesis was to develop an energy-efficient routing strategy. Energy consumption, end-to-end delay, the proportion of alive nodes, transmission loss, and packet delivery ratio have also received notice.

This thesis' first chapter provides an introduction of wireless sensor networks (WSNs), along with a quick look at UWSNs and the various WSN kinds and their uses. Further information on UWSNs is provided in the next chapter, including the architectural of underwater sensor nodes, their characteristics, how they are made, how they compare to TWSNs, and a detailed discussion of their applications. The third chapter focuses on the most important phase of our research, which was the analysis of the UWSN routing protocols that are currently in use, or literature review.These routing protocols are then classified according to the applications they are used for and how they operate. These protocols are also divided into four categories: flat, clustering, multi-hop, and direct communication. These protocols are further divided into hierarchical, interface-aware, and location-based categories. The energy efficient depth-based opportunistic routing protocol (EEDOR) and the depth base routing (DBR), cooperative depth base (Co-DBR), localization free energy efficient routing (LFEER), cooperative localization free energy efficient routing (Co-LFEER), are all thoroughly explored. However we have selected two protocols, Co-DBR and LFEER, for comparison with our suggested protocol, HSTDBR. UWSNs can be categorised as either general-purpose or application-oriented. While general-purpose UWSNs can be customised to a larger variety of applications, application-oriented UWSNs are created to handle a particular set of issues and duties. Additionally, because UWSNs are application-oriented and we might claim that this protocol is superior, we shouldn't stick with a single protocol.

The issue description, our goals and objectives, the research methodology, and the algorithm for our preferred protocol are covered in the next chapter. For our suggested scheme, we eventually reach the stage when we create a mathematical model. In this chapter, the models created for route loss, packet holding, sending ratios, as well as node energy usage per bit. Moreover, we ran simulations based on that mathematical model and contrasted the performance of our suggested scheme with the DBR protocol. Our suggested scheme performed better than the alternatives.

On the basis of these simulation results, MATLAB simulator is used for simulation and Co-DBR, LFEER and HSTDBR comparison analysis. In our simulation, various input parameters are employed and comparison done for such parameters include; Transmission loss (the signal intensity that is lost during long-distance transmission) and end-to-end delay of the network (it refer to the time required for the to be transferred across the network from source to destination). Attenuation, scattering, and dispersion are transmission loss factors), number of alive nodes (it refers to the count of sensor nodes that are operational or active after number of rounds), packet delivery ratio (The amount of data packets in a wireless sensor network that are successfully delivered to their source to destination) and most significant parameter was the consumption of energy of that network (it refers the quantity of energy consumed to carry out a specific action). The simulation results demonstrate that our proposed scheme HSTDBR performs better then in terms of Co-DBR and LFEER.

The plots produced by our simulation demonstrate that, compared to DBR, the number of active nodes for HSTDBR is comparatively high after the time periods shown. This occurred as a result of our suggested scheme's reduced energy loss, which also results in an increased network lifespan and low spending rate. In terms of end-to-end delay HSTDBR performance is remarkably improved than the other protocols. On the phase of transmission loss proposed protocol achieved high rank and high frequency ration packets have been transmitted to the destination. Similarly, in packet delivery ratio parameter the maximum amount of data packets are delivery to desire destination, which encounter the high accuracy rate as compare to DBR. Eventually, in term of our last compared parameter energy consumption HSTDBR performed better and improved results after several intervals in simulation with contrast to DBR. We conclude and confirm from our research that HSTDBR reduce energy consumption of nodes by extending the lifetime of network and there is an increase in the amount of data delivery.

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