Improvement of Energy, Lifetime and Delays in Underwater Wireless Sensor Networks by Effective Deployment of Relay Nodes

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ABSTRACT:
According to the importance of underwater exploration, the attention of many researchers has been attracted to underwater sensor networks (UWSNs). Problems of UWSNs are large propagation delay, low bandwidth, and limited energy. Because of these reasons, in this paper, we propose a new routing method in UWSNs that considers these factors and also achieves better load balancing in the network. In this method, relay nodes are used for routing. The relay nodes have a higher traffic load compared to the other nodes. They remove some burden from the overloaded nodes. The relay nodes shorten the transmission distance between source and destination. They have more energy compared to the other nodes. Our results show that the deployment of relay nodes in sensor networks helps to balance energy consumption and enhance the network lifetime. Nodes, after calculating the distance to the relay nodes and finding the nearest relay node, transmit packets to the nearest relay node for onetime immediately, so this method does not have *holding time* and it has less delay. The results are compared with DBR and CODBR. The results show that our method achieves more network lifetime, less delay and energy consumption compared to DBR and CODBR.

KEYWORDS: Underwater Wireless Sensor Networks, Relay Node, Load Balancing, Energy Efficiency.

1. INTRODUCTION

Most of the earth's surface is water that has not been discovered. Ocean discovery is important, however underwater environment is unsuitable for human. Due to wireless sensor networks and unique capabilities, this problem has been solved. Hence UWSN is used to investigate underwater earthquakes, the presence of fish, monitoring the passage of submarines and exploring the areas where oil and gas are located [1],[2].

UWSN is more challenging than land-based wireless sensor networks. UWSNs use acoustic signals in the underwater environment. Lower bandwidth and longer end to end delay are the problems of UWSNs compared to land-based wireless. Nodes in UWSNs tend to move so we must use these factors to design a routing protocol. Sensor nodes are powered by batteries[3]. they have limited energy. Changing batteries is hard so it is important to design a protocol that uses less energy and save energy. This prolongs the lifetime. When the underwater sensor nodes transmit a packet, they consume more energy. If the number of transfers is decreased, the energy consumption will be decreased. Balance energy consumption between sensors nodes will increase the network lifetime so the workload must be divided equally between all the sensor nodes in the network. At long distance, nodes consume more energy to transmit a packet. An effective protocol should be decreased the number of transfers and also distributes the load of work equally over the network [4].In this paper, we suggest a new routing method that uses relay nodes. The relay nodes in our method shorten the transmission distance and our method reduces the number of transmissions so energy consumption is saved and network lifetime is increased. The relay nodes remove some burden from the overloaded nodes.Energy is consumed in a balanced way and we have a load balancing overall network. Depth-Based Routing (DBR) and Cooperative Depth Base Routing (CODBR) are two of UWSNs protocols[5],[6]. In DBR and CODBR, routing is according to the depth of sensor nodes. The burden is on the nodes with low depth so they consume energy more than other nodes. The nodes near to sink die sooner than other nodes because they have more load so there is no load balance and unbalanced energy consumption in a sensor network creates coverage holes that mean nodes with no transmission energy. These holes reduce performance and lifetime. As mentioned earlier, we solved these problems in our method by removing the burden from the overloaded nodes. In DBR a node does not send a packet after receiving, it waits for a certain time called *holding time*[5]. In CODBR source node sends the same packet for the three-time so end to end delay of DBR and CODBR is high.in our method when a node receives a packet, sends the packet for one time immediately so our method does not have holding time.

The rest of the paper is organized as follows: In section 2, presents an overview of the relevant routing protocols and their problems. In section 3, we explain our proposed routing method in detail. Section 4 the performance of our method is appraised through simulations and in section 5 we present our conclusions.

2. LITERATURE REVIEW

In this section, UWSNs routing protocols and their problems are reviewed. We present some relevant routing protocols

The vector-based forwarding routing protocol (VBF) is one of the UWSNs routing protocols [7]. Each node knows its position in this protocol, the routing vector, and routing pipe are used for routing. In VBF, the source node calculates a vector from itself towards the destination[3]. The nodes located in the predefined radius of the calculated vector are qualified to forward the packet. In VBF a reduced number of nodes forward the packet[8] because of the utilization of the predefined radius so the energy of the network is saved. It is sensitive to the routing pipe's radius. The packet delivery ratio in sparse networks is less so VBF does not have good performance in sparse networks. To resolve these problems in VBF, Hop by Hop VBF (HH-VBF) was presented.

HH-VBF uses virtual pipe around the per-hop vector from each source to the sink[9]. HH-VBF can find a data delivery path in sparse networks, however, the number of qualified nodes may be small, so in sparse networks, data delivery ratio in HH-VBF is more than VBF. Energy consumption is high in the dense network. HH-VBF is not efficient with node mobility

As in[5] DBR(Depth Based Routing) was proposed. In DBR only the depth parameter is considered for transfer. Routing is according to the depth of the sensor nodes. Each node needs only its depth information. Nodes with higher depth send packets to the nodes with lower depth. The receiving nodes compare their depths to the depth of the sender. Each one has a lower depth, it sends the packet. When a node receives a packet wait for the time then forward it. The time is called holding time. Holding time depend on the depth of the node. The nodes with low depths have a short holding time compared to other nodes. It is calculated as[5]:

$$f(d) = \frac{2\tau}{\delta} \cdot (R-d), \delta \epsilon (0,R]\,, \tau = R/V_0 \qquad (1)$$

Where R is the maximum transmission range of a sensor node, V_0 is propagation speed in the water, d is the depth difference of the receiver node and previous forwarder node and δ is assumed to be constant.

As in [6]Cooperative Depth Base Routing(CODBR) was proposed. In CODBR, each source node must send its data to the two relays and a destination node. Data received are merged at the destination. The source node chooses two relays and a destination with the lowest depth to forward data to sink. They are chosen on the basis of the lowest depth. Although it sends the same packet three times and consumes more energy. Packet drop in CoDBR is less than DBR because CoDBR has three links to send packets. In the introduction section, we explained the problems of DBR and CODBR and also our motivation to present the proposed method.

3. MATERIAL AND METHODS

In this section, our proposed routing method is introduced in detail. In our method, the network contains nodes and relay nodes and sinks. Deployment of relay nodes in sensor networks is not always a positive effect on the network. There are several factors affecting the positive effect of the relay node on the network. These factors are: the correct use of the relay node, the number of the relay nodes, the placement of the relay nodes and initial energy of the relay nodes. We used these factors in the best way in the proposed method to get good results. We have several purposes in this proposed method. The main purposes of our method are: 1.shorten the transmission distance and reduces the number of transmissions to consume less energy. 2. Gathering data in a balanced way and reduce the burden from the overloaded nodes and prevent from the creation of a coverage hole in the network, and also, enhance network lifetime. 3. Reduce end to end delay by not using holding time and send a packet to the relay node for one time.

The relay node only relays data generated by other sensor nodes, without sensing the environment[10]. The maximum load will be on the relay nodes, so they should have the maximum energy as compared to sensor nodes. All nodes have the same priority for sending packets.

As the nodes move arbitrarily on the network, they must calculate the distance. First, each node calculates its distance to the relay node and finds the closest relay node to itself then it sends the packet to the closest relay node. The distance among nodes and the relay node is calculated from the distance formula as follows:

$$d = \sqrt{(x_r - x_n)^2 + (y_r - y_n)^2} \qquad (2)$$

Where (x_n, y_n) is the coordinate of node and (x_r, y_r) is the coordinate of the relay node.

For a short distance, we use the single-hop network. Nodes send their packets to the relay node and the relay node transmit them to the sink directly. This method of transfer cannot be used in long distances because relay nodes, which are farther away from the sink, deplete energy faster. For long distance, we use the multi-hop network. Each node sends data to the closest relay node to itself, then this relay node that far from the sink, relays data to the relay node that is closer to the sink and this relay node transmits received data to the sink. Relay nodes that are closer to the sink consume more energy than relay nodes that are farther away from the sink. The reason is that traffic on relay nodes that are closer to the sink is more than the relay node far from the sink, so we allocate more initial energy to relay nodes closer to the sink compared to other relay nodes. Fig. 1 shows the data path from a node to a sink in our method.

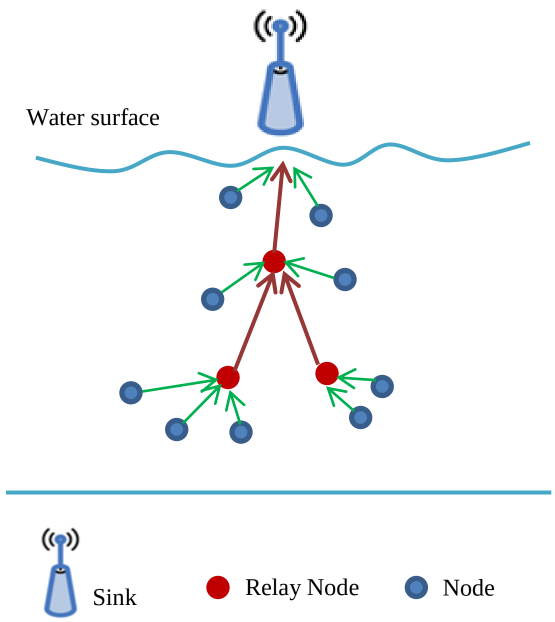

Fig.1. Proposed method Multi-Hop Path from source to destination.

As mentioned above, there are several factors affecting the positive effect of the relay node on the network. We used these factors in the best way in the proposed method to get good results and we achieve algoritm1. Algorithm 1 shows how to deploy relay nodes. Fig. 2 shows the flowchart of our method.

Algorithm 1. Coverage

INPUT:
$\boldsymbol{D}$ ←water depth
$\boldsymbol{n}$ ← number of nodes in each level
$\boldsymbol{d}$ ←depth of levels
OUTPUT:
$\boldsymbol{N}$ ← maximum covering nodes
$\boldsymbol{R}$ ← number of required relay nodes
$\boldsymbol{L}$ ←number of layers

$\boldsymbol{L} = 0$
$\boldsymbol{N} = 0$
$\boldsymbol{R} = 0$
do
$\boldsymbol{N} = \boldsymbol{N} + \boldsymbol{n}$
$\boldsymbol{R} = \boldsymbol{R} + \boldsymbol{2}$
$\boldsymbol{L} = \boldsymbol{L} + \boldsymbol{1}$
$\boldsymbol{D} = \boldsymbol{D} - \boldsymbol{d}$
while $\boldsymbol{D} > \boldsymbol{0}$

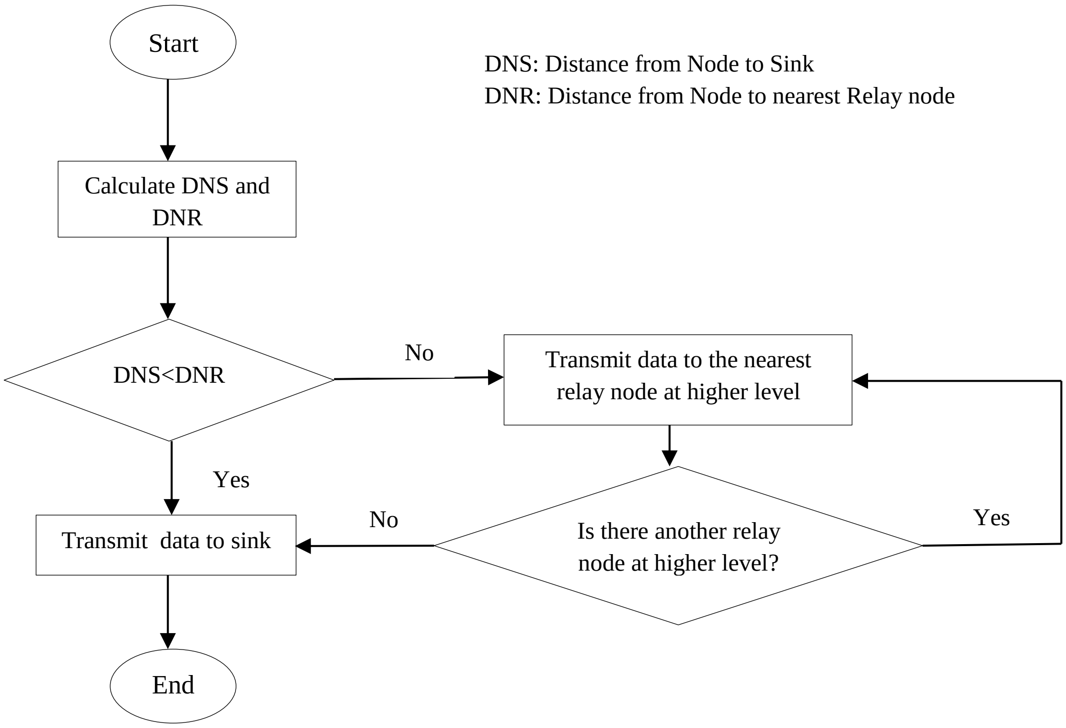

Fig. 2. Flowchart of transmission data from a node to a sink.

4. RESULTS AND DISCUSSION

We appraised the efficiency of our proposed method with DBR and CODBR. Simulations were performed using ns2. We deploy a different number of sensor nodes (25, 49, and 100) randomly. In this simulation, we considered two relays for up to 50 nodes at a depth of 400 meters. Data packet size is 64 bytes. The initial energy value of all the sensor nodes is 70 joule.

4.1. Network Lifetime

Fig. 3 shows that the network lifetime of CODBR is lower than DBR and our method because CODBR dies sooner than DBR and our method. DBR and our method transmit data to its next hop neighbor for once but CODBR transmits to the two relay nodes and next hop hence CODBR consumes energy more than DBR and our method so decreases network lifetime. In CODBR and DBR, there is no load balancing in the network. The traffic load is on certain nodes. Energy consumption is not balanced. This reduces the network lifetime. As mentioned earlier our method has more network lifetime.

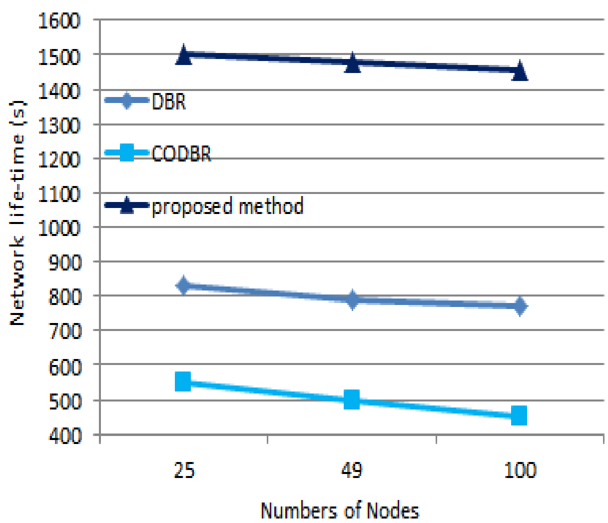

Fig. 3. Network lifetime.

4.2. Energy Consumption

CODBR consumes three times more energy than DBR and our method as shown in Fig. 4. DBR consume more energy than our method because DBR is a receiver-based protocol. The receiving nodes decide which the received packets to forward. Receiving nodes do not have information about the depth of the neighboring nodes so DBR has redundant transmissions and the energy consumption is higher than our method.

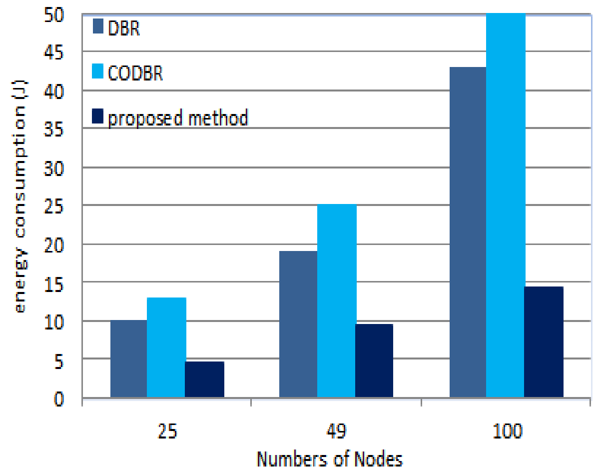

Fig. 4. Energy consumption.

4.3. End-to-end Delay

The end-to-end delay of the three methods is shown in Fig. 5. Delay in CODBR is more than DBR and our method because CODBR sends the packet three times. The end to end delay of DBR is more than our method because in DBR when a node receives a packet does not send instantly. It waits for a certain time proportionate to the depth of the node.

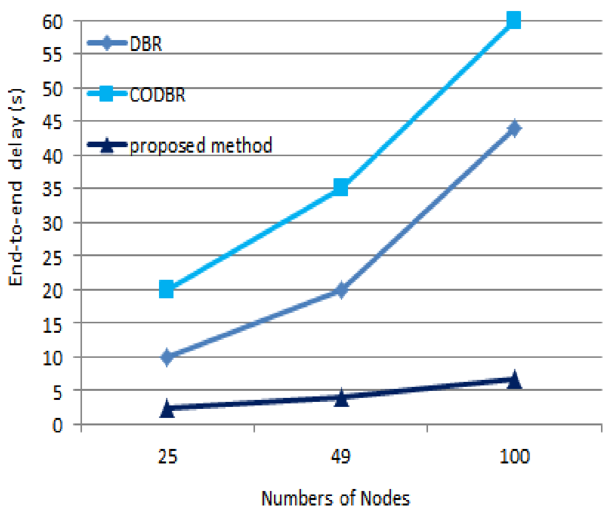

Fig. 5. End-to-end delay.

5. CONCLUSION

In this paper, an effective routing method is presented to achieve better load balancing of the network. Our method reduces the number of transmissions to consume less energy and also distributes the load of work over the network. The proposed method uses the sufficient number of relay nodes in a suitable location with sufficient energy of relay nodes. The nodes send their packets to the nearest relay node and finally, closer relay nodes to the sink transfer the information to that. Packet drop in our method is more than CODBR because CoDBR drops packet only when none out of 3 links are available. Results show that the proposed method enhances network lifetime and minimizes the delay. In this way, sensor nodes consume less energy.

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