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Lifetime Responsive Depth Based Routing for Underwater Wireless Sensor Network using Hybrid Soft Computing Technique with Optimal Delay

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Abstract: Underwater wireless sensor network (UWSN) is an emerging technology that has been used for different applications such as warning systems for disasters, monitoring the ecosystem, drilling of the oil, defense surveillance. Although underwater communication may be accomplished using electromagnetic or optical waves, but these methods are not feasible for practical UWSN, due to signal attenuation. UWSN faces several issues like restricted bandwidth, irregular node mobility, increased delay etc. which affects the routing behavior. In this paper, an optimal delay and lifetime aware depth based routing (ODLDR) protocol is proposed. Protocol first introduced the group partitioning algorithm for cluster formation that minimizes the energy consumption of network then an efficient priority based scheduling algorithm is proposed for trust computation, which helps in finalizing the CH and routing path. The ODLDR protocol is tested with the high density nodes in Network Simulator (NS2) tool. The simulation results shows the effectiveness of the ODLDR protocol in terms of energy consumption, packet delivery ratio, positioning accuracy, end-to-end delay, throughput and network lifetime.

Keywords: ODLDR, CH, UWSN, Routing protocol, delay.

I. INTRODUCTION

Underwater monitoring and mapping is very complicated and still many approaches are manually executed at the seabed or if any special purpose vehicle is used for such execution then it is very costlier [1]. The sensor nodes in underwater sensor networks (UWSNs) [2-3] is covering some specific areas of any water body and Send the collected information to the respective base stations.

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The concept of Routing protocols is discussed in [4-5] suggesting the path is used to deliver the data more effectively.

As large part of the world is covered with the water and the challenging environment makes the UWSN more interesting to look out and solve the associated problems.

The energy consumption in terms of the modems is varies in terrestrial and underwater communications [6] due to which it effect the designing protocol of energy efficiency.

A concept of Shadow zone and delay aware routing (SZODAR) is discussed in [7] help in locating the route in shadow zones. As the characteristic of the UWSN is quite different from the terrestrial network hence it is very complicated to design the protocols for a network in terms of latency, bandwidth and power consumption.

(QELAR) Q-learning energy-efficient and lifetime-aware routing protocol a unique approach discussed in [8]. According to which the MAC protocol is responsible for increasing the network lifetime based on distribution of nodes in more effective way. The communication underwater so far is observed on traditional way like wired network etc. and there performance can be evaluated based on cross-layered design [9]. However it is very difficult to communicate underwater with such traditional approach. Hence the associated challenges of the UWSN motivate us to work in this area and come up with some better approaches to explore the other side of the world. Contributions of the work in this paper are as follows: This paper mainly focuses on the routing problem faced by the node when deployed underwater along with an approach to minimized the consumption of the nodes energy is discussed. The remaining paper is arranged as follows: Section-II helps us to know about the related work whereas section-III explains the problem statement/formulation of the work. The results and simulations to prove the work is discussed in section-IV, finally the work gets concluded in the last section-V.

II. RELATED WORKS

Darehshoorzadeh et al [10] Worked on the OR approach according to which packets are forwarded to the destination based on multiple candidates. The technique OR is discussed as it provides a clear picture of overcoming the weak virtual links with a strong link for any reliable sharing of the information.

Zenia et al [11] suggested the concepts of MAC, routing protocols and Energy efficiency in UWSNs. As underwater communication is not an easier task and due high propagation delay it leads to a loss of data packets. Therefore the authors are suggesting that in order to provide a better quality of services underwater, researchers need to come with an effective and efficient idea to overcome the different challenges.

Chao Li et al [12] proposed a depth based schedule transmission algorithm. In which a priority is given to the depth and angle to enhance the performance. The simulation shows the improvement in throughput and energy efficiency.

Rani et al [13] analyzes the methodology which suggests the energy efficiency. According to the author a network is divided into different clusters, and cluster head (CH) is responsible for gathering all the data during transmission and receiving. The concept is further explained the confidence level of the node based on location free communication.

Faheem et al [14] suggested a QERP which improves the energy in terms of data transfer and delay for application associated to the underwater exploration. Clustering mechanism is used for nodes to connect the network and if in case node fails to determine the route, then the suggested mechanism will help in finding a better way by avoiding the voids of connectivity.

Ahmed et al [15] analyzes the designing issues in the routing protocols. According to the Ahmed et al. they tried to explain the concept of data aggregation protocols with the dynamic topology structure. The mechanism of data forwarding based on protocol operations is also discussed in their work.

Zhigang Jin et al [16] an EBOR protocol is proposed in their work, which use the DST. The concept suggests that the nodes are able to select the next hop when multiple metrics are facing. Majorly the source node considers residual energy, ETD and PDP for packet delivery ratio.

Yishan Su et al [17] propose (DQELR) Deep Q-Network-based energy and latency-aware routing protocol to increase the lifetime of the network. The globally optimal routing decision is based on Q-network algorithm. They had also designed the medium broadcast and unicast mechanism for communication which is used in order to reduce the network overhead.

Preetika et al [18] proposed an authentication protocol in wireless network along with the concept of cryptography. The work addresses the challenges and security issues associated with the wireless network; they compare their work with the EG-schemes in which they mainly focuses on connectivity.

Mukesh et al [19] explained the concept of the data sizes with nodes in context of TDMA and CSMA/CA protocols. There results show the quality of service which lowers the delay in CSMA/CA while transmitting the information.

Pushpendra et al [20] uses a 3D localization technique in which a mathematical model is discussed; the approach suggested the localization of the randomly deployed nodes along with the technique to minimize the power consumption. The simulation suggests a better network efficiency.

III. PROBLEM STATEMENT

This section, describes the problem statement of underwater wireless sensor networks with corresponding solutions is present in the subsection **A** and the proposed scenario is present in subsection **B**.

A. Problem identification and solution

Patil et al. [21] suggested the depth based routing (DBR) performance evaluation based on stochastic model. The proposed concept focuses on following metrics: packet delivery, power consumption, distribution of hop, delay. The mathematical formulation help in explaining the model and the analysis illustrated the hopping which can affect the performance.

An optimal delay and lifetime aware depth based routing (ODLDR) protocol is proposed for UWSNs. The main contributions are:

In order to minimize the power utilization for cluster formation, a group partitioning algorithm is introduced.

For trust computation, the CH and the routing path of an efficient priority based scheduling algorithm was proposed.

The proposed ODLDR protocol is implemented in Network Simulator (NS2) platform which compares the existing technique in terms of positioning accuracy, delay, energy consumption, lifetime (network), delivery ratio (packet), and throughput.

B. Network model of proposed ODLDR protocol

The scenario for our proposed network model is reflected in Fig 1. The proposed structure is having a base station, primary user nodes and cluster head nodes. Base Station is employed to gather the data from the primary user nodes. At the time of flood, earthquake etc. the deployed nodes sends the data to the allotted base station in more reliable mode with better efficiency. The every cluster is having a head of that cluster denoted as (CH) and it is the responsibility of the CH to gather the data from all the nodes. No nodes in any cluster can communicate with the CH of the different clusters, only CH is allowed to communicate with the cluster head of the other clusters and share their data before sending to the respective base station.

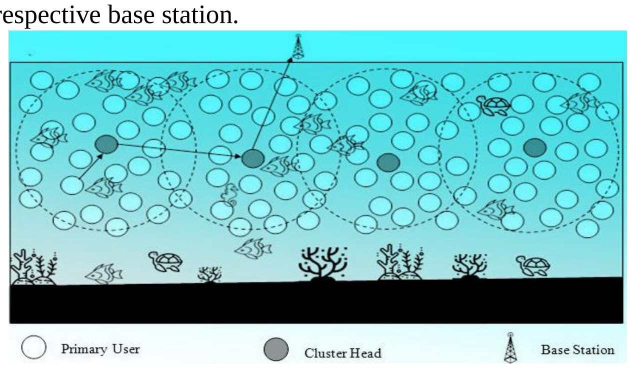

Fig.1 System model for our proposed work

IV. OPTIMAL DELAY AND LIFETIME AWARE DEPTH BASED ROUTING (ODLDR) PROTOCOL

The proposed concept is having algorithms, like as group partitioning algorithm and efficient priority based scheduling algorithm.

The cluster formation using swarm algorithm is discussed in subsection **A** and trust computation for CH and routing path is discussed in subsection **B**.

A. Clustering using group partitioning algorithm

The clusters are generally termed as residual nodes or individual nodes and it is capable of finding an optimal route to send the data. These residual nodes keep on vary in each cluster formation as a result it will help in maintaining the nodes power level.

Clustering shows better performance than the other transmission models, but still its performance is affected due to improper cluster formation. At the time of the cluster formation few nodes are left, as a result of which they are not considered as a member of any cluster. However once they become member of any cluster there are the probability that such node may become the head of the cluster.

The residual nodes transmit large number of messages to predict the nearest nodes location for sending the data and results in early node failure. Swarm optimization based clustering mechanism with minimized residual node formation scheme aims to overcome the drawback of residual or any node formation at the time of cluster formation. Swarm Optimization based clustering formation takes place on the basis of the fitness value in terms of position, velocity, energy of sensor node and distance between the sensor nodes.

The proposed group partitioning algorithm is inferred from the conventional swarm optimization algorithm.

[22] Suggest the selection of cluster head based on hierarchical topology. An algorithm is used based on fuzzy clustering to initialize the clusters according to the locations. A concept of cluster assistant is discussed in [23] in which cluster assistant is allotted to each head of the cluster to overcome the work load. Swarm optimization helps in clustering to make the entire node as a member. Hence individual node formation eliminated as a result of better and lifetime of the network. Swarm Optimization (SO) is a population based random technique of optimization inspired by the behaviors of flocking of birds or may be schooling of fish. (SO) also referred as a technique of computation that optimizes any issues based on series of iterations which enhances the solution of candidates, Swarm optimizes the issues based on mathematical formulation for particles velocity and position. At every iteration, current velocity helps in updating the velocity of each particle along with the local and global best positions, as a result the velocity and position is estimated. Normally particles are occupying with positions in search space. The quality of position is demonstrated by particles fitness which moves with a specific velocity in search space. Let's consider the flock of bird scenario, where birds are looking for the food and only single food piece is being searched in an area. The birds do not know where they get there food in that area but they know how far they found the piece of that food in every iteration of series. Now, the scenario lies in searching the most effective strategy to locate the food piece along with the solutions to follow the bird close to that food piece. Assume (Sr1, Sr2) as a region of sensing where r is the node coverage. Fig.2 indicates a sensed network area; where a large area is further divided into sub group of areas know a cluster with r as a distance of center most to outer most area. . Let (sr1, sr2) be the region of sensing of the cluster. N_c (number of clusters) calculated based on network area and cluster size

$$N_C = \frac{S_{r1} * S_{r2}}{sr_1 * sr_2} \quad (1)$$

Where, Sr1Sr2 considered as network area and sr1sr2 as cluster area. Suppose sr1=sr2= t, the eq.1 be

$$N_C = \frac{S_{r1} * S_{r2}}{t^2} \quad (2)$$

Fig.2 show the structure of triangle, r can be calculated,

$$r = \frac{t}{\sqrt{2}} \quad (3)$$

Hence, the formations of clusters are:

$$N_C = \frac{S_{r1} * S_{r2}}{2r_2} \quad (4)$$

The above eq. shows the clusters in lower bound area, whereas the clusters in upper bound area can be calculated based on eq. (5)

$$N_C = \left\{ \left(\frac{Sr_1 * Sr_2}{sr_1 * sr_2} \right) + \left(\frac{Sr_1}{sr_1} \right) + \left(\frac{Sr_2}{sr_2} \right) \right\} \quad (5)$$

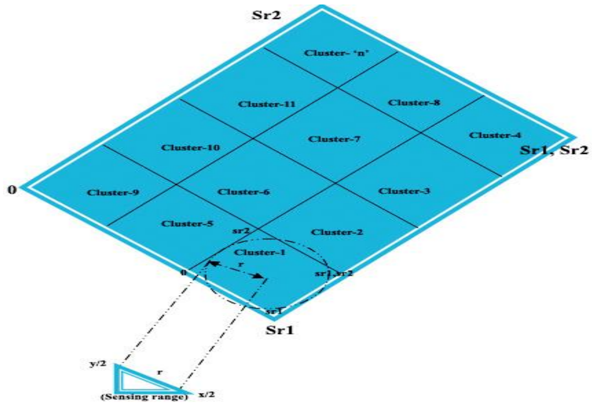

Fig.2 Clusters in Wireless Sensor Network

If sr1=sr2=t, & Sr1=Sr2, the equation will be,

$$N_C = \left\{ \left((Sr_1)^2 + 2\sqrt{2}\, sr_1 * r \right) \big/ 2r \right\} \quad (6)$$

Average formation of cluster in a network can be calculated as

$$N_C\, average = \left\{ \left((Sr_1)^2 + 2\sqrt{2}\, sr_1 * r \right) \big/ 2r \right\} \quad (7)$$

Soon after deployment of the nodes, it is the responsibility of the base station to broadcast a message to collect the information of the all deployed node, Base station will get revert message containing:

1. Location (position) of the node, Sr1= (sr1, sr2)
2. Node velocity (speed) S= (s1, s2), where s1 shows the velocity (average) of the node and s2 shows the current velocity.

c. Power (Energy) denoted as E.

The velocity along with the position and the power consumption is regularly updating at the BS. BS soon after getting all the update from the node allowed the nodes to form a cluster; the formation is performed by Swarm optimization. Each node is supposed to be a particle and preventing the individual node to form the cluster.

This can be done in more efficient way when each node find their nearest node and formed a cluster, however with this all deployed node will become a part of the cluster.

Hence, once the entire node become member the residual value can be predicted for each particle.

Consider deployed particles in a space, where M= {1, 2, 3, …, n} are the particles in that space. Parameters used to create a particle are:

1. Location(position) (sr1, sr2)
2. Velocity (Speed) (s1, s2)

The factors used to calculate the fitness value.

1. Node (particle) energy
2. Node in a range of particular particle
3. Distance of particles in a range of particular (node) particle

Formation of the cluster is based on fitness value of particle mention above. Head of the cluster is accessible to large number of other deployed nodes and it is referred as cluster (particle).

B. Trust computation using efficient priority based scheduling algorithm

The power consumption is basically used from the energy model. The consumption of the node is based on the data aggregation, transmission; receiving etc. the consumption of the node is proportional to square of distance (D_s^2) whenever the distance of propagation (D) is less then (Do) threshold distance. Total consumption of power in any network for n bit:

$$E_{total} = E_{fwd.t}(n,d) + E_{rcd}(n) \quad (8)$$

Where $E_{fwd.t}$ (n,d) and E_{rcd} (n) are consumption of forward transmission and receiving energy nodes respectively.

$$E_{fwd.t}(n,d) = \begin{cases} n*E_{Dsp.egy} + n*\varepsilon_{spc.mdl}*D^2 ; if D \pi D_0 \\ n*E_{Dsp.egy} + n*\varepsilon_{mpmdl}*D^2 ; if D \geq D_0 \end{cases} \quad (9)$$

$$E_{rcd}(n) = n * E_{dsp.egy} \quad (10)$$

Where $E_{dsp.egy}$ is the dissipated energy for transmitter circuit or may be for receiver circuit and the free space $\varepsilon_{spc.mdl}$ and ε_{mpmdl} for multi-path model is based on amplification energy that depends on the amplifier model of transmitter. (D0) is considered to be as threshold distance transmission.

The concept of received signal strength (RSS) is to be determined by the transmission energy along with the distance, if any node send the packets of data with an energy (n,d) then the RSS with a distance (D) can be computed as

$$RSS = \frac{E_{fwd.t}(n,d)}{4\Pi D_i^2} + T\frac{a * a_1}{a_2} \quad (11)$$

The relative speed and the distance are accurately determined based on current signal strength, the samples are selected to meet the limitation $\Delta t1 = \Delta t2 = \Delta t$ but the samples did not have such points. To approximate the actual RSS of the node, different reference point are used.

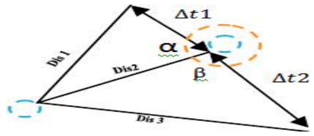

Fig.3. Node computation

Consider the figure3. Where Dis1; Dis2 and Dis3 are obtained from above eq., whereas the modification in the distance can be computed based on cosine law:

$$Dis_1^2 = Dis_2^2 + a_1 a_2^2 - 2Dis_2 * a_1 a_2 * \cos(\alpha) \quad (12)$$

$$Dis_3^2 = Dis_3^2 + a_1 a_2^2 - 2Dis_2 * a_1 a_2 * \cos(\beta) \quad (13)$$

Let the position is 'a' of a node, which can be able to move to a1 and a2 at different reference points. Let $\cos(\alpha) = -\cos(\beta)$ and calculate the velocity (v) :

$$2a_1 a_2^2 = Dis_1^2 + Dis_3^2 - 2Dis_2^2$$

$$v = \sqrt{\frac{2\left(Dis_1^2 + Dis_3^2 - 2Dis_2^2\right)}{2\Delta t}} \quad (14)$$

The duration of the node movement from a, to the a1 or a2 is computed as the distance $T_{a.a1/a2}$ which divide the velocity of the node and it can be obtained by sign law:

$$T_{a.a1/a2} = \frac{R\sin\theta}{\sin\beta.v}$$

From eq. (14) and {15) (15)

$$T_{a.a1/a2} = \frac{\Delta t.R.\sin\theta}{\sin\beta * \sqrt{\frac{Dis_1^2 + Dis_3^2 - 2Dis_2^2}{2}}} \quad (16)$$

V. RESULT ANALYSIS

This section reflects the simulation results performed in Network Simulator platform. The proposed protocol is analyzed based on different parameter.

An optimal delay and lifetime aware depth based routing (ODLDR) protocol for UWSNs is proposed. First, group partitioning algorithm for cluster formation that minimizes the energy consumption of network is introduced. Second, an efficient priority based scheduling algorithm proposed for trust computation is introduced, which finalize the CH and routing path. The simulation result shows the effectiveness of proposed ODLDR protocol in terms of energy consumption, packet delivery ratio, positioning accuracy, end-to-end delay, throughput and network lifetime.

A.Performance Analysis of Number of Depth level

In this section, we are going to compare the result of proposed and existing algorithms with 6 performance metrics namely: positioning accuracy, end-to-end delay, energy consumption, network lifetime, packet delivery ratio, and throughput and shown in Fig.4 (a-f). The depth levels are set from 20 to 140 randomly. The accuracy of proposed and previous routing protocol has been increased from 100% to 120% and shown in Fig.4 (a).

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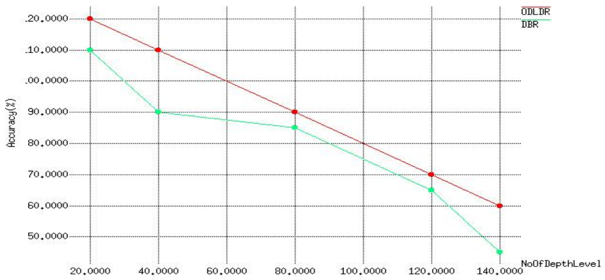
Our ODLDR algorithm reduced a delay when compare to previous one. From 20 to 140 depth nodes the delays were minimized 42% and results given in Fig.4 (b). The energy consumption is decreased upto 75% when compared with the previous protocol and the result is shown in Fig.4 (c). By using 20 to 140 depth nodes, we are going to maximize the network lifetime with our proposed model and compared with previous method.

The performance evaluation of our model generated 75% and shown in Fig.4 (d). In previous protocol, we have more loss in packet delivery ratio to overcome this problem; we used our proposed technique to increase a delivery ratio of packet to 20% and results shown in Fig.4 (e). We maximized the throughput with our proposed method, when compared to previous protocol. The performance evaluation of 20 to 140 depth nodes again from 8,000 to 9000 and results are shown in Fig.4 (f).



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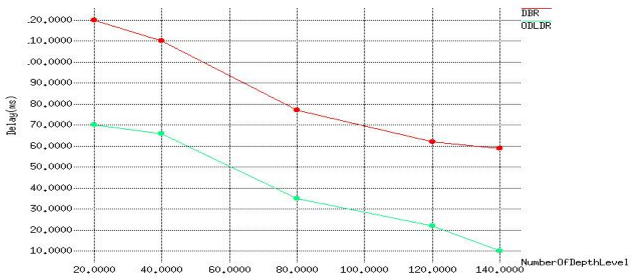

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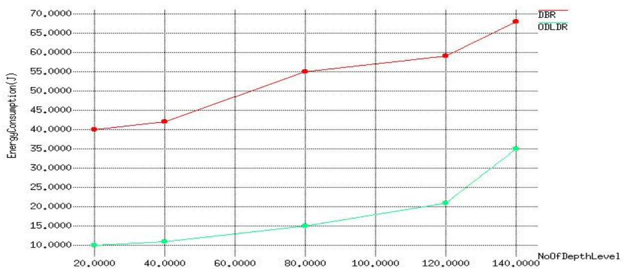

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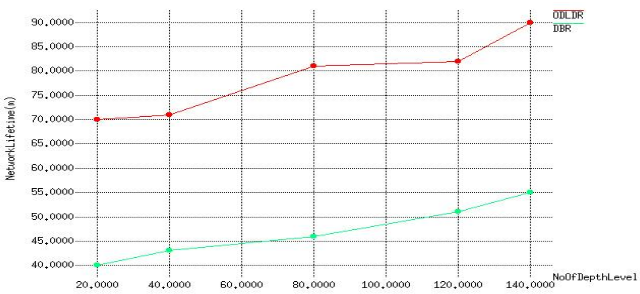

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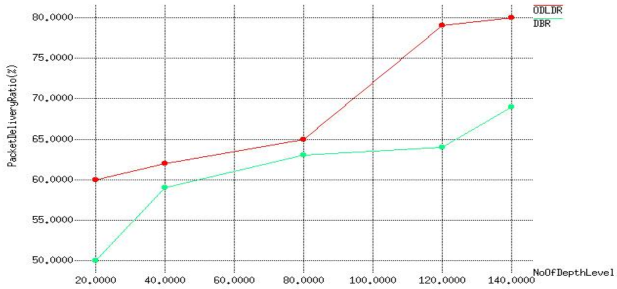

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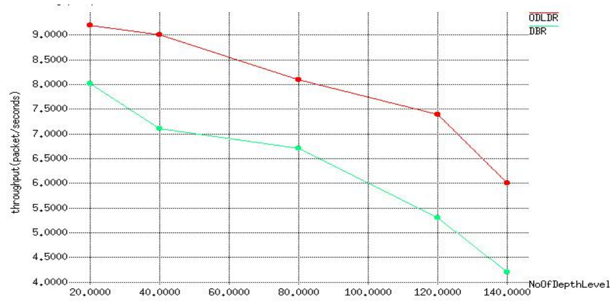


(f)

Fig. 4. **Number of depth level performance analysis of (a) positioning accuracy, (b) end-to-end delay, (c) energy consumption, (d) network lifetime, (e) packet delivery ratio, and (f) throughput**

B. Performance Analysis of Number of Nodes

This performance is used to analysis the number of node on the ODLDR performance, a set of experiments are performed and compare with the DBR. Simulations are conducted by varying the number of nodes to 50, 100, 150, 200 and 250 in each case. The result of proposed and existing algorithms with 6 performance metrics namely: positioning accuracy, end-to-end delay, energy consumption, network lifetime, packet delivery ratio, and throughput and shown in Fig.5 (a-f). The nodes are set from 50 to 250 randomly. The accuracy of proposed and previous routing protocol has been increased to 20% and shown in Fig.5 (a). Our ODLDR algorithm reduced a delay when compare to previous one.

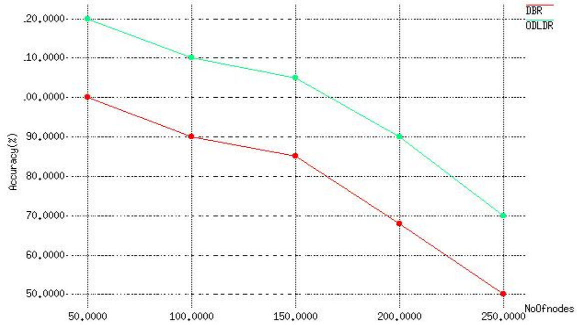
From 50 to 250 nodes the delays were minimized to 8% and results given in Fig.5 (b). The energy consumption is decreased to 67% when compared with the previous protocol and the result is shown in Fig.5 (c).

By using 50 to 250 nodes, we are going to maximize the network lifetime with our proposed model and compared with previous method. The performance evaluation of our model generated 6% and shown in Fig.5 (d).

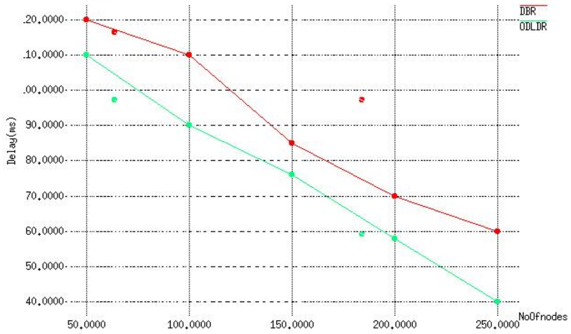
In previous protocol, we have more loss in packet delivery ratio to overcome this problem; we used our proposed technique to increase a delivery ratio of packet to 37% and results shown in Fig.5 (e).

We maximized the throughput with our proposed method, when compared to previous protocol.

The performance evaluation of 50 to 250 nodes again from 9,000 to 10,500 and results are shown in Fig.5 (f).



(a)



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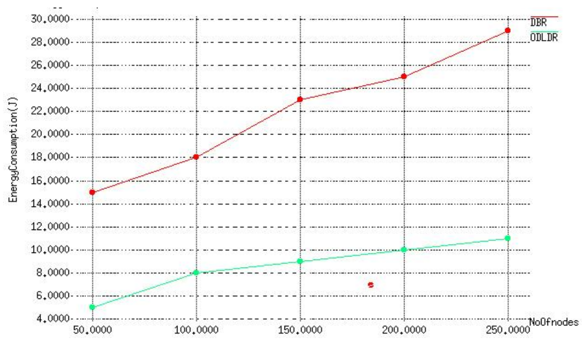

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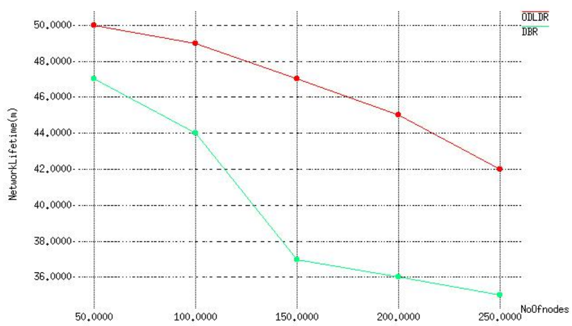

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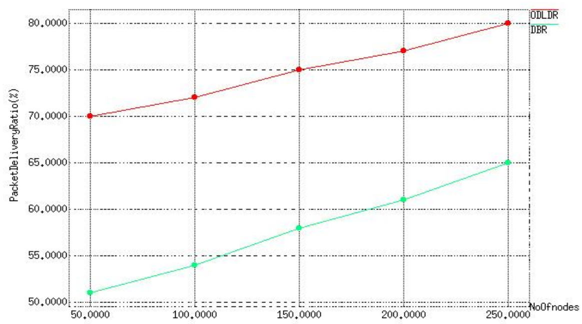
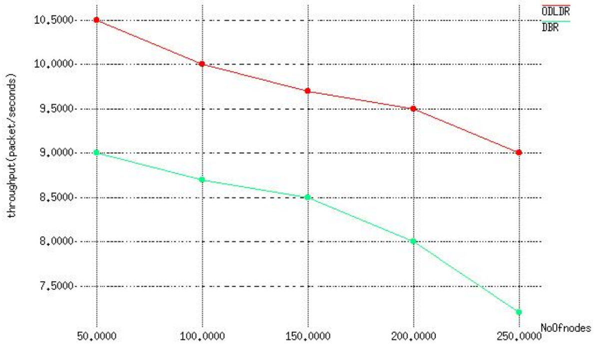


(e)



(f)

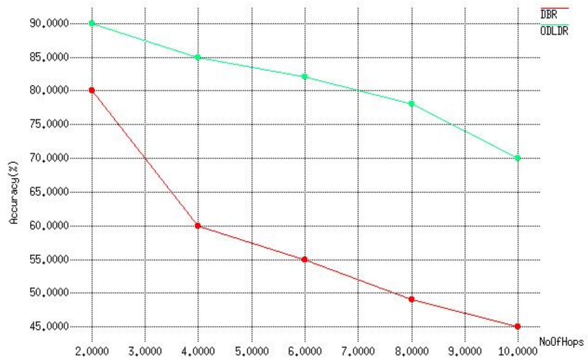
Fig.5. Number of node performance analysis of (a) positioning accuracy, (b) end-to-end delay, (c) energy consumption, (d) network lifetime, (e) packet delivery ratio, and (f) throughput

C. Performance Analysis of number of hops

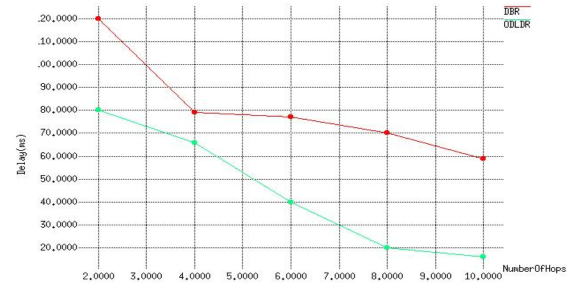
The simulation result of proposed and existing algorithms with 6 performance metrics namely: positioning accuracy, end-to-end delay, energy consumption, network lifetime, packet delivery ratio, and throughput and shown in Fig.6 (a-f). The number of hops is set from 2 to 10 randomly. The accuracy of proposed and previous routing protocol has been increased from 80% to 90% and shown in Fig.6 (a). Our ODLDR algorithm reduced a delay when compare to previous one. From 2 to 10 hops the delays were minimized to 33% and results given in Fig.6 (b).

The energy consumption is decreased to 33% when compared with the previous protocol and the result is shown in Fig.6 (c). By using 2 to 10 hops, we are going to maximize the network lifetime with our proposed model and compared with previous method.

The performance evaluation of our model generated 25% and shown in Fig.6 (d). In previous protocol, we have more loss in packet delivery ratio to overcome this problem; we used our proposed technique to increase a delivery ratio of packet to 20% and results shown in Fig.6 (e). We maximized the throughput with our proposed method, when compared to previous protocol. The performance evaluation of 20 to 140 depth nodes again from 8,000 to 9,500 and results are shown in Fig.6 (f).



(a)



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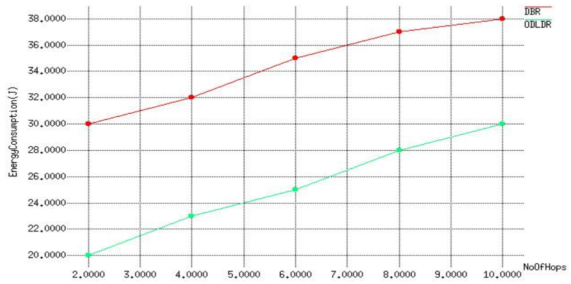

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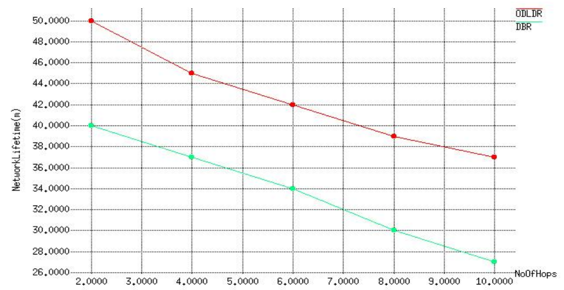

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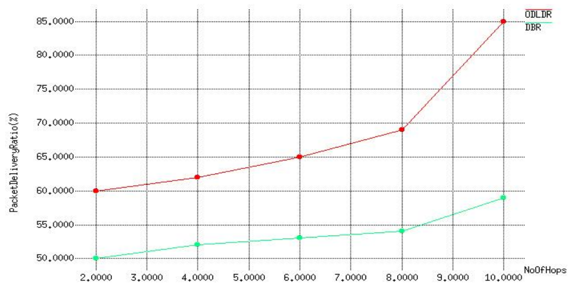

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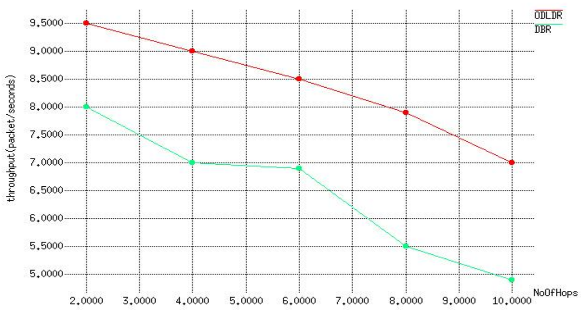

(f)

Fig.6. Number of hops performance analysis of (a) positioning accuracy, (b) end-to-end delay, (c) energy consumption, (d) network lifetime, (e) packet delivery ratio, and (f) throughput

VI. CONCLUSION

In the paper, routing protocol based on mobility aware is proposed for (UWSN) using hybrid optimization (ODLDR) algorithm. The ODLDR algorithm consists of efficient data gathering to maximize the lifetime of a network. It is further used to achieve the exact quality requirement of data transmission, the result and performance analysis shows the improvement of the proposed ODLDR algorithm in terms of positioning accuracy, end-to-end delay, energy consumption, network lifetime, packet delivery ratio, and throughput over existing state-of-art protocols.

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