A Comprehensive Comparative Analysis of Two Novel Underwater Routing Protocols

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***Abstract*—The most unmanned area of this planet is sheltered with water; that is roughly 71.9% of the total area of this planet. A large quantity of marine life is present in this area. That is the reason underwater research is bounded due to unexplored benefits. Due to the addition of sensors and growing interests in the exploration and monitoring of marine life Underwater Wireless Sensor Network (UWSN) can play an important role. A variety of routing protocols has been deployed in order to get information between deployed nodes. Providing stable data transmission, maximum throughput, minimum consumption of the energy and delay are challenging tasks in the UWSN. These routing protocols can be Layer-by-Layer Angle-Based Flooding (L2-ABF) and Diagonal and Vertical Routing Protocol (DVRP). In order to get stable data transmission, the node density plays our role in shallow and deep water. Several parameters are employed to evaluate the output efficiency of these routing protocols. In this paper, like an end to end delay, loss of data packets during transmission and data delivery ratio within communication are considered the major parameters for evaluation. For this, the network simulator is used with the aqua sim package. The results, we have produced during this study; guides us about the best routing protocol for data transmission. It finally reveals that the L2-ABF performs better then DVRP in a different situation, further the tradeoffs relationship is achieved against multiple situations.**

Keywords*—Data transmission; throughput; end-to-end delay; energy consumption; L2-ABF; DVRP; Delay

I. Introduction

Providing stable data transmission, maximum throughput, less energy consumption and minimizing the end-to-end delay are challenging tasks in Underwater Wireless Sensor Network (UWSN). Data packets become loss or late delivery due to explosive characteristics of UWSN and continuous flow of water. Different types of systematic strategies and monitoring operations are introduced in this field to resolve these issues like explain in [1]. However; our novel Layer by Layer Angle Based Flooding (L2-ABF) protocol is proposed in [2]. It based on the concept of an angle-based cone that calculates the angle from the region before data flooding. It does not require the configuration and location information of the nodes for data flooding. The exclusivity of this protocol is that it measures the quick changes in the network and resolves the energy consumption and delay issues of the network. Depth-Based Routing (DBR) protocol is also very useful in UWSN, to provide the scalable and efficient routing services. In this approach, inexpensive depth sensors are required that gives the local depth information of the nodes. The similarity between the L2-ABF and DVRP (another proposed protocol is discussed in [3]) is that both do not require location information for routing. Dynamic Sink Mobility (DSM) that is equipped with DBR is also effective for data transmission in UWSN. It provides smooth routing by moving the sink node towards the source node. The advantage of DSM in comparison to DBR is that it enhances the stability period and network lifetime with smooth data transmission [4]. Comparison study of L2-ABF and DBR is done in [15]. The results concluded that L2-ABF is more efficient then DBR against the performance, implementation and routing techniques. Fig. 1 shows the possible scenario of data transmission in UWSNs.

A sensor cloud like, Swarm Sensor Equipped Aquatic (SEA) uses the L2-ABF protocol as groundwork. It flows with water and permits 4-dimensional screening of the local underwater atmosphere. It measures the pressure level of the water before transmitting the data from the source to the destination that increases the reliability of the UWSN environment. This approach works on the greedy method and selects the subsets of the forwarders that are helpful in the recovery process [13]. After an extensive literature review, a comparative analysis of L2-ABF and DVRP is decided in this paper. Both protocols are compared to the above-mentioned parameters. The major concern is the routing strategies that both protocols used to transmit the data from the source node to the destination node. Rest of the paper is ordered as: related work and comparative analysis are described in Sections 2 and 3, while simulation and performance analysis are discussed in Sections 4 and 5, respectively. At the end Section 6 deals the conclusion.

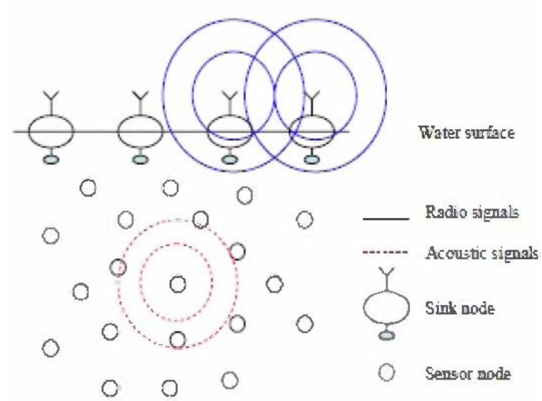

Fig. 1. Possible Scenario of Data Transmission in UWSN.

II. Related Work

UWSNs are recently appeared as a promising field for several underwater applications. Due to the self-motivated structure, high power consumption and latency, designing an energy efficient routing protocol are the challenging tasks. Different researcher put their efforts in this field to resolve the above mentioned issues and to provide the stable data transmission. The energy consumption ratio for underwater environment is analyzed in [4]. Two parameters are under consideration: deep water and shallow water. Primarily energy consumption is calculated for fixed sensor nodes and then for the mobile sensor nodes as well. The results show that the energy consumption ratio is high in the mobile sensor nodes that require highest hope count. Focused Beam Routing (FBR) protocol is proposed in [5] that are based on the cross layer technique. The approach that makes it distinguished between others is its way of data transmission. The distributed nature of the FBR dynamically set the route as the data packets navigate for their target. Survey of different routing protocols is done in [6] in which routing protocols are differentiated in two categories: sender based and receiver based protocols. The differentiation process is done by the route decision maker. A novel underwater routing protocol called AUV-Aided Underwater Routing Protocol (AURP) is proposed in [7]. This protocol not only works for the acoustics communications, but it also controls the mobility of the autonomous underwater vehicle. The novelty of this protocol is that, it reduces the data transmission by replacing the relay nodes with ordinary nodes. These relays gather data from the gateways nodes instead of directly sensor nodes. Depth based multi-hop routing protocol is discussed in [8] based on the Depth Based Routing Protocol (DBRP) that provides the concept of depth for transfer the communication. Self-Organized Rapid Routing Protocol (SORRP) also recreates the radial topology with the gateway nodes. It always transmits the data to shortest path. This algorithm is compatible for both type of 2D and 3D environment. Survey of cross layer, non-cross layer and intelligent routing protocol is done in [10] Dynamic Based Multi Hop Routing Protocol (DBMRP) is proposed that use multi hop method for data transmission. Diagonal and Vertical Routing Protocol (DVRP) [3] proposed for diagonal and vertical communication in underwater moves. In order to discover the cosmic underwater environment, energy proficient localization free routing protocol is invented in [11, 12]. This protocol utilizes the less energy and provides the high data throughput that ultimately reduces the packet loss ratio in the UWSN. Different types of development trends of UWSN routing protocols are also discuss in this paper that provides the future directions to researcher. Role of proactive, reactive and geographical protocols for terrestrial environment are analyzed in [10]. DBFP is very useful to provide the reliability to the UWSN. The individuality of this protocol is that, it reduces the extensive transmission delay, narrow bandwidth and high packet loss. HH-VBF [5] technique uses the vectors from the source to the destination that resolve the energy and robustness issue of the network. Its performance is better than the DBR performance in the sparse network.

Angle based cone concept and its effects on end-to-end delay are introduced in [13, 14] to control the flooding in the UWSN. The use of angle makes the disaster pollution and submarine detection easier in compare to other techniques in the literature. This approach is familiar in UWSN, for the avidness of ocean accident. L2-ABF protocol is specially designed to control the continuous nodes movement. It reduces the network delay and energy consumption to provide smooth data transmission in the network. It has some advantages on other protocols in the network such that, it can measure the quick changes in the network due to the layer by layer deployment of the nodes [15]. The unique feature of this protocol is that it calculates their flooding zone by using their angle based approach and then transmits the data according to that zone. Position adjustment technique that is based on the location error is also contributed in the UWSN. This protocol works for the void hole avoidance in the network. The point of differentiation of this protocol is that it avoids the extra flooding in the network by using their repositioning ability. The position adjustment policy is works through the angle as described in [16, 24] and other reliable data recovery mechanism for underwater are discussed in our previous article [17, 18]. Furthermore; three hop reliability model [19] and the energy based comparison study of routing protocols [20] are another our achievements. Flood is a major issue in water areas so we have proposed the watchman nodes and flood recovery watchman based algorithm is discussed in [21] and its formal verification in [22]. Our two routing protocols like SMDBRP and AEDGRP are successfully compared in our previous article [23].

A comparison of DBR and L2-ABF is mentioned in [14]. End to end delay, delivery ratio, and energy consumption are the parameters that are under consideration for the comparison. The results conclude that L2-ABF is more efficient than the DBR protocol. Stratification based data collection technique is used in acoustic sensor networks to observe the abnormal ocean environment and to explore the resources in the ocean [9, 10]. This technique is based on the layer by layer approach in which the upper layer is called the ekman layer in the network and bear large water velocity. Message Priority Based Protocols (MPBP) is designed for the aquaculture application in the UWSN. This protocol is capable to handle the emergency and regular packets based on the assigned priority.

III. Comparative Analysis

This section covers the comparative analysis of two underwater routing protocols like L2-ABF and DVRP. Both protocols are well-known and working great, but no one has compared these two protocols in such detail. These two protocols are performing well for underwater scenarios for better performance in deep water distribution where node density plays a parcel role. To further enhance the performance, we can configure the parameters like packet loss, delay and throughput; these are very effective for evaluation purposes. In this study, we have evaluated the output efficiency by using TCP and UDP connections; also remember about the energy consumption because these networks are very limited to energy so conservation should always be considered on high priority. The distribution of the mobility model is random. The foremost objective for this study is to evaluate the performance of routing protocols by using the NS-2 simulator. The parameters for experiments are described in Table I, while the formula of throughput and delay is shown below.

$$Throughput = \frac{\sum (Packets\ received\ at\ receiver)}{\sum (Packets\ initiated\ by\ sender)} * 100$$

The duration of time started from the sender node when it through data and ending at when the data is received by the receiver is called propagation delay.

$$Delay = \frac{\sum (arrival\ time\ packet - transmit\ time\ of\ packet)}{\sum (Packets\ at\ destination\ caught)} * 100$$

It is observed that both protocols work well in the UWSNs environment and provide a high data transmission rate in comparison to other routing protocols. The major difference between these two protocols is the selection of a path to transmit data to the targeted node. L2-ABF uses the layer by layer approach for routing but DVRP performs with the diagonal and vertical routing-based flooding. The similarity between these two protocols is that both use the location-based local information for data gathering.

TABLE I. SIMULATION PARAMETERS

Simulation Parameters	Value
Type of Channel	Wireless channel
Propagation	Two Ray Ground
Network type	Wireless Phy
Mac type	802_11
Maximum packet in ifq	50
Number of Nodes	50
Number of iterations	25 iterations for each
Packet size	1000 bytes
Traffic Type	CBR, FTP
Agents	TCP and UDP
Routing Protocol	L2-ABF, DVRP
The topography of X dimension	1800
The topography of Y dimension	2000
The topography of Z dimension	2400

IV. SIMULATION USING NS-2

In this section, simulation analysis of L2-ABF and DVRP are done by using the NS-2 simulator. To compare both protocols, initially, 500 numbers of mobile nodes are deployed in the network (with random topology). In order to evaluate the other remaining parameters, the same iterations are repeated. It has been observed that L2-ABF is comparatively better than the DVRP for the above-mentioned parameters.

V. PERFORMANCE ANALYSIS

In performance Analysis, the result for each experiment is explained with their corresponding graph. In each experiment, different variables are considered like throughput, loss of packets, delay, node density etc. The first section covers the effect on the performance in terms of delay, throughput and packet loss for TCP and UDP over L2-ABF, if the thickness of nodes varies.

A. Analysis of DVRP against Throughput, Delay and Packet Loss vs. Node Density

For the DVRP, as it used diagonal and vertical path selection, therefore, the throughput is steadily fast under the TCP as compared to UDP. The middle of the network it deviates through some extent, it is due to insufficient to take the angle between a maximum number of nodes quantity. Therefore, 600 kbps is achieved through TCP while the difference between UDP and TCP is only about 200 kbps as shown in Fig. 2. As node density is increased, the throughput is increased, so directly proportional relation exists between these two terms. Only 40 nodes are under consideration to take the first iteration, by the way, due to the directly proportional relationship this is increased when nodes are increased in our experiment. Fig. 3 illustrates the delay analysis under TCP and UDP, in TCP the delay is maximum because due to three handshake mechanism while the delay is minimum in UDP as UDP does not use such a technique. Due to the increase in the number of nodes in water, the packet loss ratio is also increased. Many reasons for this, as the distance between source and sink, is increased the route length increased. From Fig. 4, it has been found that under UDP the packets are much greater than as compared to TCP, only 40% packets are achieved while the rest of the amount has been lost at sink end.

B. Analysis of DVRP against Throughput, Delay and Packet Loss vs. Node Speed

From Fig. 5, 6 and 7 shows the throughput, delay and packet loss analysis of DVRP under the same traffic agents. It is observed that throughput is increased in TCP while the delay and packet loss are decreased against UDP. The effect of node speed is a concern when the throughput is increased because the simulation time of each node with respect to speed is uniform but due to two-way communication between the source and sink this is possible and it affects the other parameters.

C. Analysis of DVRP against Throughput, Delay and Packet Loss vs. Pause Time

Pause time is the time when communication is disturbed due to some reasons. Many reasons for this, for example, when the node or link failure between the node and the overall pause time is inserted in the network or when the 3D dynamic environment the mobile water also has enough current to create the possible pause between the nodes. In Fig. 8, 9 and

10 the same analysis is conducted against the pause time. The throughput fluctuated against TCP and UDP with pause time while the delay is measured in seconds as UDP effect the overall performance of the routing protocol of DVRP.

D. Analysis of L2-ABF against Throughput, Delay and Packet Loss vs. Node Density

As the name comes layer by layer approach it first computes the layer model of the deployment of the nodes. Properly make the angle to the different numbers of nodes, a large number of nodes are covered when the angle is broadcast. Therefore, the throughput is maximum as compared to our other protocols like DVRP. The figure shows the effect of UDP and TCP both of them are easily copied and no such large difference between these two traffic agents. Fig. 11 shows the throughput analysis of L2-ABF about 500 kbps. In Fig. 12, the delay is measured, no such delay is to be noted. The packet loss analysis of L2-ABF in TCP and UDP is measured against node density is shown in Fig. 13.

E. Analysis of L2-ABF against Throughput, Delay and Packet Loss vs. Node Speed

From Fig. 14, 15 and 16 the same analysis has been performed against node speed. In Fig. 14, the throughput analysis is measured and it shows the deviation for both UDP and TCP agents. While the delay is represented in Fig. 15 against UDP the delay is maximum and for TCP the L2-ABF shows the minimum delay. The packet loss analysis of L2-ABF is measured against both these two traffic agents as UDP has more than packet loss as compared to TCP. The same analysis of DVRP is shown above, it has been seen that the DVRP not as much packet loss as compared to L2-ABF due to its angle-based flooding, while the diagonal and vertical routing scheme also shows its effect when the UDP have large delay analysis.

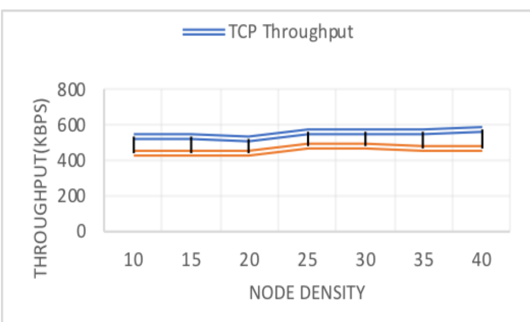

Fig. 2. Analysis of DVRP Throughput for TCP and UDP with Respect to Node Density.

F. Analysis of L2-ABF against Throughput, Delay and Packet Loss vs. Pause Time

From Fig. 17, 18 and 19 shows the detailed analysis of the same parameters against pause time. The pause time is the effect for DVRP so it is bad as L2-ABF. Most of the situations where the angle based approach is not worked as work in DVRP. The delay is minimum for TCP and maximum for UDP, but for the throughput, it takes the reverse situation. When we talk about the packet loss the major window of network simulator is also displayed in which 607 packets ate sent while the 478 packets are received for both DVRP and L2-ABF in Fig. 20.

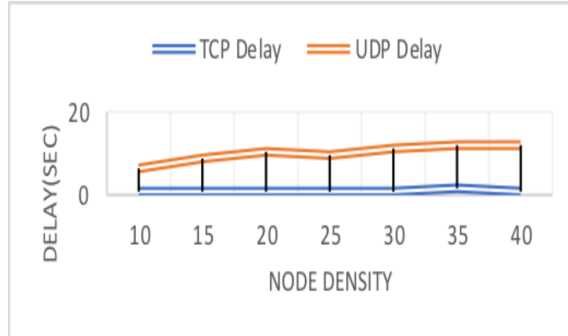

Fig. 3. Analysis of DVRP Delay for TCP and UDP with Respect to Node Density.

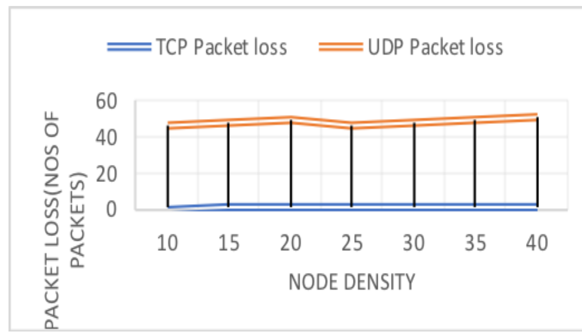

Fig. 4. Analysis of DVRP Packet Loss with Respect to Node Density.

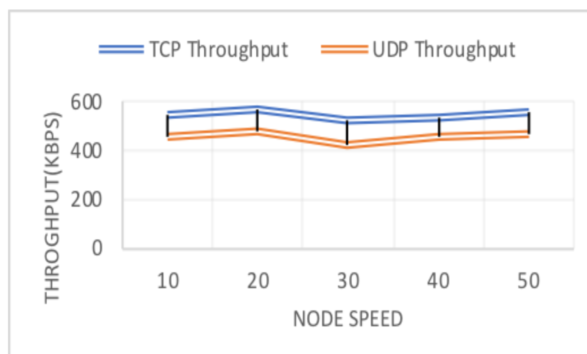

Fig. 5. Analysis of DVRP Throughput for TCP and UDP with Respect to Node Speed.

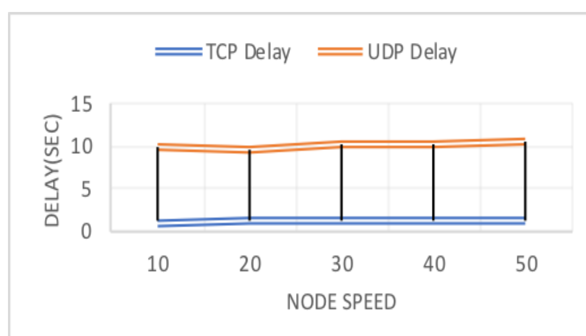

Fig. 6. Analysis of DVRP Delay for TCP and UDP with Respect to Node Speed.

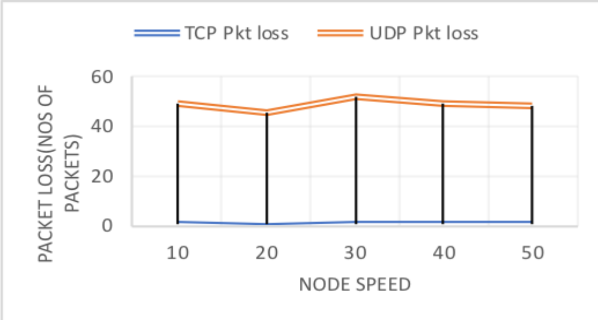

Fig. 7. Analysis of DVRP Packet Loss for TCP and UDP with Respect to Node Speed.

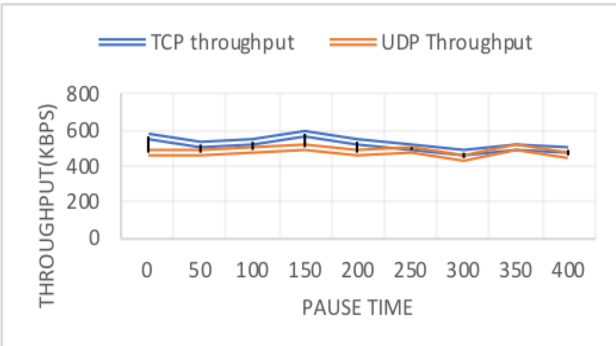

Fig. 8. Analysis of DVRP Throughput for TCP and UDP with Respect to Pause Time.

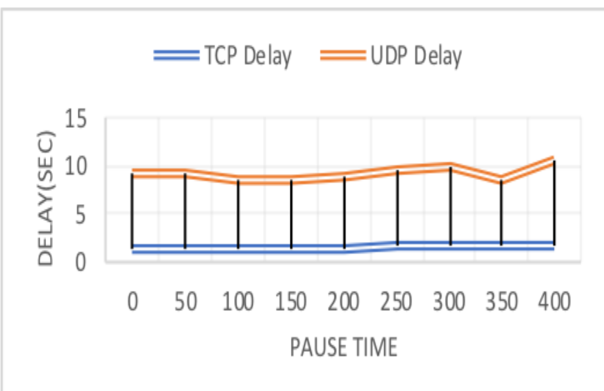

Fig. 9. Analysis of DVRP Delay for TCP and UDP with Respect to Pause Time.

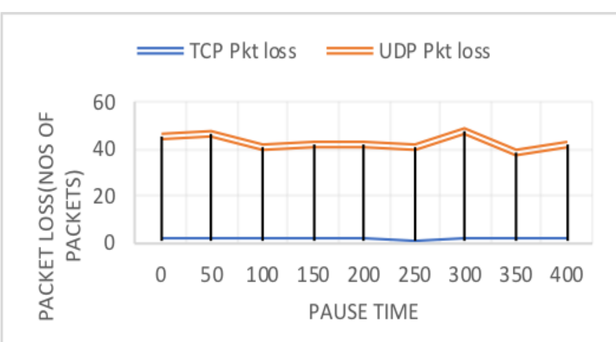

Fig. 10. Analysis of DVRP Packet Loss for TCP and UDP with Respect to Pause Time.

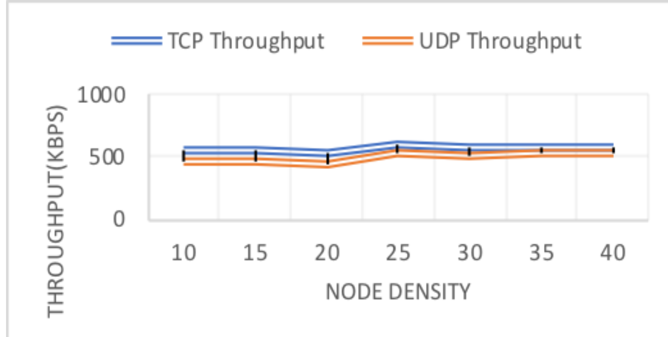

Fig. 11. Throughput of L2-ABF in TCP & UDP Connection using Node Density.

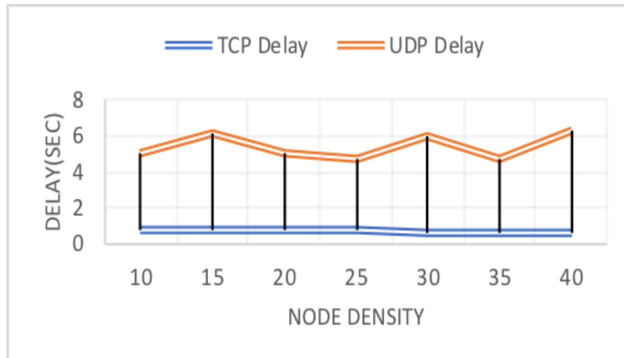

Fig. 12. Delay of L2-ABF in TCP & UDP Connection using Node Density.

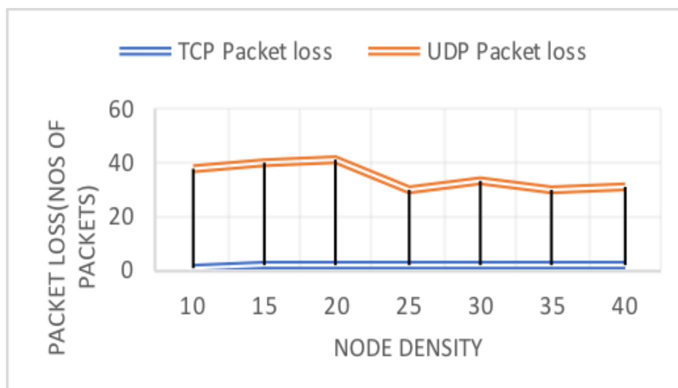

Fig. 13. Packet Loss of L2-ABF in TCP & UDP Connection using Node Density.

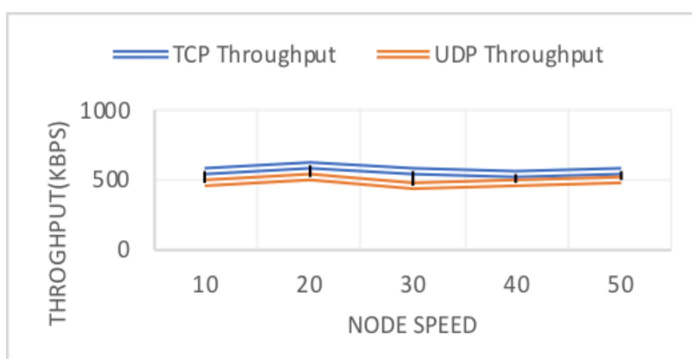

Fig. 14. Throughput of L2-ABF in TCP & UDP.

Connection using Node Speed

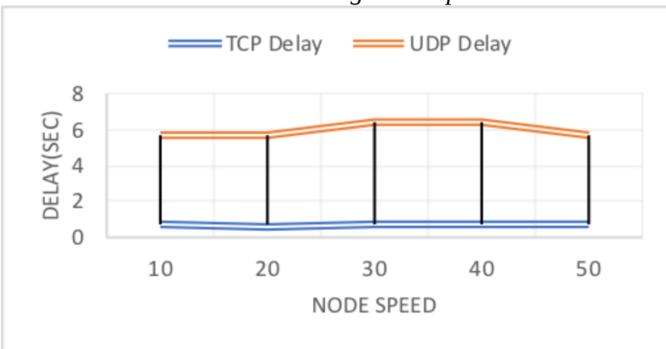

Fig. 15. Delay of L2-ABF over TCP & UDP Connection using Node Speed.

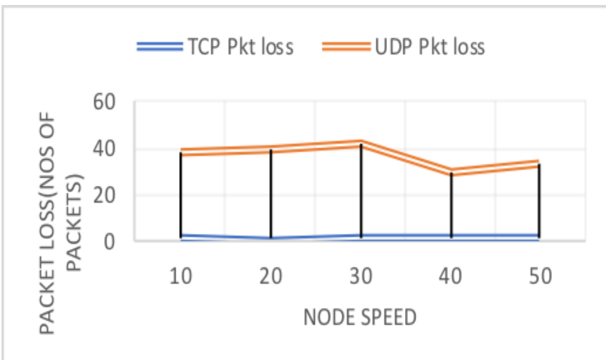

Fig. 16. Packet Loss of L2-ABF in TCP & UDP Connection using Node Speed.

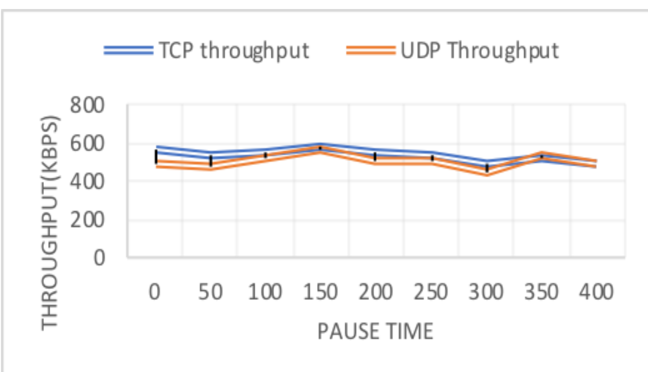

Fig. 17. Throughput of L2-ABF in TCP & UDP.

Connection using Pause Time

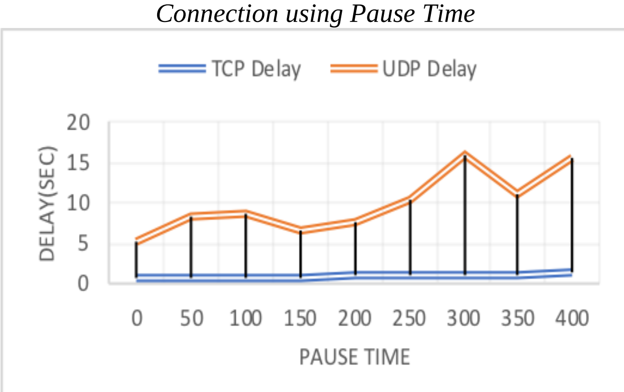

Fig. 18. Delay of L2-ABF over TCP & UDP Connection using Pause Time.

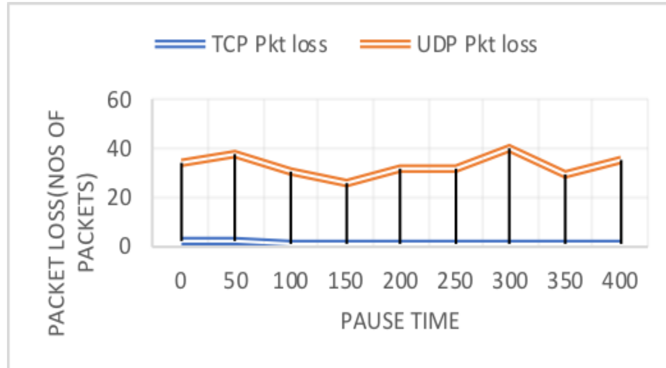

Fig. 19. Packet Loss of L2-ABF in TCP & UDP Connection using Node Speed Time.

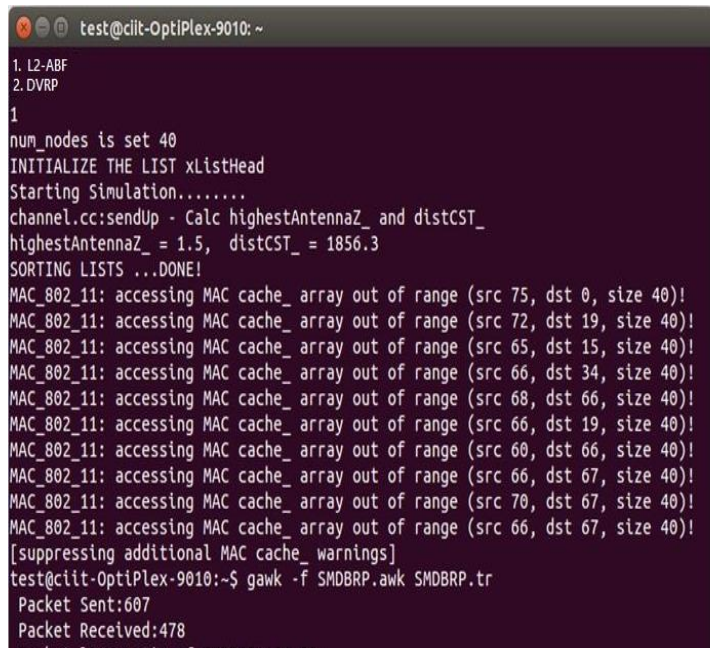

Fig. 20. TCL File for Total Packet Analysis and Sent for L2-ABF and DVRP.

VI. Conclusion

This study is based on a realistic scenario for the evaluation of UWSN's routing protocols such that L2-ABF and DVRP under traffic agents TCP and UDP. Results for each experiment are available for study in detail, to support our word, the L2-ABF is comparatively better then DVRP against different factors like node density and pause time. Meanwhile; the delay and throughput analysis of DVRP performs better under TCP as compared to L2-ABF. Because of this study including all the experiments, we can say the routing protocol L2-ABF is better than DVRP in most of the situations, and to get maximum output under both traffic agents TCP and UDP. We can also conclude DVRP can be used to carry useful information in UWSN, due to its performance against delay but it might not be used when we need to carry information in a small amount of time because it has propagation delay in maximum.

In our future study, try to simulate the behavior of other different underwater protocols that best suited for the underwater deep and shallow environment.

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