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# Review on Underwater Networks using Deep Learning

**G. Prathyusha[1], G. Vamsi Krishna[2], G. Mohanlal[3], G. Hari Krishna Reddy[4], G. Jyothsna[5]**
GMR Institute of Technology, Rajam, Andhra Pradesh, India
20341A0568@gmrit.edu.in[1], 20341A0566@gmrit.edu.in[2], 20341A0567@gmrit.edu.in[3]
20341A0569@gmrit.edu.in[4], 20341A0570@gmrit.edu.in[5]

**Abstract:** *The development of effective underwater communication systems has become more crucial since, the recent increase in the number of submarine operations. Acoustic is related to a sound or sense of hearing. Underwater Acoustic sensor networks are used to transmit the signals over long distances from the instrument which is placed under the water to the control unit on the seashore. Acoustic signals are used to predict the climatic changes based on the waves produced in the sea/ocean. Different underwater acoustics network models have been tried using mathematical equations and approximations under certain assumptions to enhance the design and development of underwater communication systems by gaining a better understanding of the underwater acoustic channel. For a good and accurate model to design deep learning algorithms are used. Deep learning is a subset of machine learning, which is essentially a neural network with three or more layers. The purpose of the router, whether real or virtual, is to accept, examine and transfer packets of data between computer networks. In this work, deep learning methods such as "Deep Neural Network (DNN)" and "Long Short Term Memory (LSTM)" and some methods like SUN,VBF,DF are used to model the acoustic channel*

**Keywords:** Underwater Acoustic Channel, Deep Neural Network, Long Short Term Memory, acoustic signal.

## I. INTRODUCTION

In our earth 75% covered by water that could be rivers and ocean also. The ocean naturally cleans itself becauseit contains so many marine animals and plants. However, because of the damage that humans are causing to the oceanby discharging various waste products into it, the water has become contaminated and is no longer able to naturally clean itself, which is having an increasingly negative impact on human health. As a result, an instrument with a batteryand other components was introduced to record the elements impacting inside the ocean [1] as study on the oceans turned its attention there. They are unable to replace or replenish the batteries using terrestrial networks. They are unable to comprehend data loss, leading to underwater wired networks, which have a number of drawbacks like expensive network implementation. Later, they introduced wireless underwater communication. It can be done via optical, acoustic, radio frequency, or other signals. Due to their long range communications, they utilized acoustic transmissions [2]. A wireless network made up of separate devices for monitoring natural conditions such as temperature, sound, vibration, pressure, motion, or pollution at various locations is known as an Underwater Wireless Sensor Network (UWSN). The sensor nodes will gather the data, transmit it to the surface station via an underwater sink, and the satellite will control it via an audio medium. The long short-term memory (LSTM) architecture is appropriate for handling and predicting time series events with large intervals [3]. UWSNs have Media Access Control (MAC) protocols created to prevent collisions and reduces the transmission latency and each sensor node transmits the data based on the dedicated time slot so that the transmission collisions are avoided [4].

When the data is received or decoded by the control unit, it is verified to see if the unique code matches, ensuring that there hasn't been any data loss [2]. The noise created by natural disasters like rain, wind, earthquakes, and tsunamis generates a significant amount of data loss, which may have an adverse effect on aquatic life and resultin permanent damage to underwater divers' hearing and backbones [5]. To transmit data from one hop to the next, sensor nodes must have a certain amount of battery life, memory storage, and processing power. Due to the node's decreased battery capacity, they are unable to send data to the next hop so for that they are increasing the transmissionpower [6].

The capacity or replacement of batteries in an underwater environment required the introduction of energy- efficient communication sensor nodes utilising the MAC protocol, which lessens data packet collision and prevents the simultaneous overhearing of more data [7]. Batteries in a propelled underwater gadget can be recharged by solar energy anytime they reach the water's surface, negating the need for recharging on a regular basis [8]. It mostly emphasizes three qualities 1. Sound propagation is delayed 2. Swarm movement, which the marine environment causes 3. Partial Network because of the enormous ocean[9].

One of the machine learning approaches called deep learning can be applied to a range of commonplace jobsas well as to other services that carry out physical chores, improve automated processes, and perform analytical workwithout the need for human involvement. It also assists in locating the network's top relay nodes and tracks nodes with high traffic densities by employing a highly dynamic biased track [3]. Deep learning can be used to automatically determine the meteorological conditions underwater, giving the control unit the best level of accuracy. When utilizedto retrieve the original characteristics of the underwater sound source, the deep neural network has demonstrated goodperformance.

## II. LITERATURE SURVEY

[1]. **Huang, L., Zhang, Q., Tan, W., Wang, Y., Zhang, L., He, C., & Tian, Z** proposed that they offered a frameworkfor Machine Learning(ML)AMCs for UACs. Then, they provided a straightforward and reliable attention-aided k- nearest neighbour (A-KNN) method, on which an ML AMC approach is built A-KNN-based AMC classifier offers notable advantages of both broad applicability to varied operational contexts and sustainable self-enhancement.. Theydemonstrated that the ML approaches which are proposed by them have superior performance over traditional model-based methods.

[2]. **Goutham, V., & Harigovindan, V. P**. proposed a full-duplex cooperative relaying with NOMA (FD-CR-NOMA) for Underwater wireless sensor networks by considering some characteristics, such as distance dependent usable bandwidth, acoustic spreading, propagation losses, and fading effects. full-duplex cooperative relaying with NOMA (FD-CR-NOMA) improves the performance of energy constrained and bandwidth-limited Underwater wireless sensor networks in terms of ergodic rate, outage probability, and energy efficiency.

[3]. **Hemavathy, N., & Indumathi, P**, discussed that the underwater acoustic sensor network has the features of fluidity, sparse deployment, and energy constraint due to the complexity and diversity of the underwater auditory environment, which poses certain difficulties for underwater location technology. This study has presented the deep learning-high dynamic biased track (DL-HDBT) approach to address the issue where node redundancy in the underwater sound sensor network results in low placement efficiency. A DL-HDBT combines the hybrid dynamic biased tracking method with deep learning. Identification is aided by deep learning (DL). Using a high dynamic biastrack, the network's best relay nodes and traffic-congested nodes are monitored. They compared DL-HDBT algorithm with SUN protocol; vector-based routing and traditional directional fooding protocol but DL-HDBT algorithm outputsthe best performance.

[4]. **Sun, N., Wang, X., Han, G., Peng, Y., & Jiang, J** addressed some of the characteristics of Underwater wirelesssensor network such as high bit error rate, very limited bandwidth and high transmission delay, the data transmissioncollision of underwater communication. To reduce the transmission collision and improve the performance of the network they proposed a collision-free time slot scheduling MAC protocol based on multi-level quorum system for high loaded Underwater wireless sensor networks. The MAC protocol has strong adaptability for various network topologies and can effectively minimize transmission collision, cut down on transmission delay, and increase systemenergy efficiency.

[5]. **Mishachandar, B., & Vairamuthu, S.** aimed at a spectrum usage model that respects the environment, with a focus on the main consumers, the marine species. In order to facilitate effective-spectrum use and allocation by numerous acoustic systems in the underwater environment, an underwater cognitive acoustic network-based spectrumchoice approach is suggested in this research. The suggested strategy exemplifies the idea of efficient spectrum use to address the issues of interference produced by secondary users to the prime users of the ocean and the temporally and geographically underutilised spectral frequencies.

[6]. **Khan, Z. A., Karim, O. A., Abbas, S., Javaid, N., Zikria, Y. B., & Tariq, U.** addressed about two issues: First, the UASN network uses more energy because the nodes movement with the water current causes the distance between them to fluctuate. The presence of the void hole, which has an impact on the network's performance, is the second issue with UASNs. Due to the lack of forwarder nodes (FNs) in the network, nodes are unable to transport data to the destination. As a result, a Q-learning based energy-efficient and balanced data gathering (QL-EEBDG) routing protocol is suggested in this study to avoid void holes. It provides alternative neighbour routes for packet transmission and guarantees continuous communication in the network.

[7]. **Roy, A., & Sarma, N.** Since drained batteries cannot be recharged or replaced in the underwater environment, itis vital study to develop an energy-efficient Medium Access Control (MAC) protocol for the Underwater Wireless Sensor Networks (UWSNs). The Ordered Contention MAC (OCMAC) protocol is a synchronous duty-cycled reservation-based MAC technique that is proposed in this work. This protocol's fundamental working principle is the scheduling of Ready To Send (RTS) frames, which are used by transmitters to plan data delivery. The protocol increases communication efficiency by removing the possibility of collisions during data transfer.

[8]. **Toky, A., Singh, R. P., & Das, S.** Underwater Acoustic Sensor Networks (UWASNs) are becoming a challenging task due to different environmental conditions. For that they introduced a localization schemes for development of UWASNs . The Fundamentals of communication medium for UWASNs are presented.

[9]. **Li, C., Xu, Y., Xu, C., An, Z., Diao, B., & Li, X.** propose a novel delay tolerant Media Access Control(MAC) protocol applying for short-packet traffic, to overcome problems brought by long propagation delay and swarm mobility in sparse network. They set up a probability model for throughput of DTMAC, and then give the throughput- optimal value for m and p with the successful transmission probability as tuning parameter.

[10]. **Chen, Y., Tang, Y., Liu, J., Zhang, X**., & Xu, X**.** investigates, how to select the optimal number of relays for multi-hop UWA cooperative networks, by considering both the low probability of detection (PD) and energy consumption. They derive the relationship between probability of detection and the number of relays and then analyzethe relationship between energy consumption and the number of relays for the system. The number of relays must bereduced to maintain the same detection probability as the target SNR increases.

[11]. **Bharamagoudra, M. R., Manvi, S. S., & Gonen, B.** proposed the depth based scalable and multi-path agent based routing protocols. They introduced the Autonomous Underwater Vehicles(AUV) for to monitor the ocean environment.

[12]. **Jie Chen, Chang Liu, Jiawu Xie, Jie An, Nan Huang** discussed about a deep learning-based, data-driven method for separating underwater audio waves. They investigated the characteristics of the Time-Frequency (T-F) mask using the Bi-directional Long Short-Term Memory (Bi-LSTM), and They suggested a T-F mask aware Bi- LSTM for signal separation. The developed Bi-LSTM network is able to extract the discriminative features for separation by taking use of the T-F image's sparseness, which further improves separation performance.

[13]. **Petroni et al..** dicussed about a promising method which is able to fit with the multipath propagation commonly characterised by UWACs(Underwater acoustic communications) has emerged: spatial division multiple access, which is possible in Multiple-Input Multiple-Output (MIMO) systems. Author looked into the viability of an unique hybrid multiple access method for controlling access to undersea media that operates in a bi-dimensional resource domain, namely space and frequency. By utilising spatial variety and, when applicable, frequency reuse, thismethod aims to reduce multi-user interference**.**

[14]. **Jiang, S.** mostly discussed about the fundamental of network security in general and the main UWAN security threats faced by the physical layer to the transport layer.

[15]. **Cerqueira, L. S., Vieira, A. B., Vieira, L. F., Vieira, M. A., & Nacif, J. A.** proposed the COPPER, a Cooperative Protocol for Pervasive Underwater Acoustic Networks. COPPER considers LLC and MAC sub-layers and operates synchronously or asynchronously over Time Division Multiple Access using a selective repeat ARQ scheme.

**[16].** **Su, R., Gong, Z., Zhang, D., Li, C., Chen, Y., & Venkatesan, R**. discussed about an important problem that can be solved by the cyclic difference set (CDS)-based coordination asynchronous wake-up strategy is the restricted energy supply of underwater sensor nodes. While improving packet delay and network longevity, the CDS-based asynchronous wake-up approach unfortunately introduces significant delays in neighbour finding.

**[17].** **Jie Chen, Chang Liu, Jiawu Xie, Jie An, Nan Huang** discussed about a deep learning-based, data-driven method for separating underwater audio waves. They investigated the characteristics of the Time-Frequency (T-F) mask using the Bi-directional Long Short-Term Memory (Bi-LSTM), and They suggested a T-F mask aware Bi- LSTM for signal separation. The developed Bi-LSTM network is able to extract the discriminative features for separation by taking use of the T-F image's sparseness, which further improves separation performance.

**[18].** **A. Petroni et al..** dicussed about a promising method which is able to fit with the multipath propagation commonly characterised by UWACs(Underwater acoustic communications) has emerged: spatial division multiple access, which is possible in Multiple-Input Multiple-Output (MIMO) systems. Author looked into the viability of an unique hybrid multiple access method for controlling access to undersea media that operates in a bi-dimensional resource domain, namely space and frequency. By utilising spatial variety and, when applicable, frequency reuse, thismethod aims to reduce multi-user interference**.**

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**Table 1:** Literature Survey

| S. No | Technique | Year | Description | Limitations | Advantages | Performance Metric | Gaps |
|---|---|---|---|---|---|---|---|
| 1 | Deep learning based hybrid dynamic biased track (DL-HDBT) routing for under water acoustic sensor networks. N.Hemavathy, P. Indumathi | 2021 | deep learning-high dynamic biased track (DL-HDBT) ,Deep-Q Network, SUN, DF, VBF. | Data collision, multipath fading, hidden nodes, and other transmission media can contribute to packet loss. | The performance of the network improves With an increase in Throughput. | Throughput, packet delivery ratio (PDR), packet loss ratio, end to end delay (EED) and residual energy. | |
| 2 | A synchronous duty-cycled reservation based MAC protocol for underwater wireless sensor networks HH Ng et al | 2021 | It describes about the depleted batteries which cannot be replaced at underwater environments and the solution for to reduce the data collision. | The energy wasted in overhearing and the idle state. | Eliminates the possible collision during data transmission and improves communication efficiency. | Providing good throughput and reliability, achieve energy saving. | They focus on simulation-based performance evaluations of the OCMAC protocol and compare it with the DL-MAC protocol. |
| 3 | Collision-free and | 2021 | MAC protocol | Transmission | avoid packet | MAC protocol can | |

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| | low delay MAC protocol based on multi-level quorum system in underwater wireless sensor networks. N. Sun, X. Wang, G. Han et al. | | based on a multi-level quorum structure to reduce transmission collision and enhance network performance. | of data,a retransmission mechanism is not reliable. | transmission collisions, reduce data transmission delay, and improve system energy efficiency. | effectively avoid transmission collision and Good adaptability for different network topologies. | |
| 4. | Full-duplex cooperative relaying with NOMA for the performance enhancement of underwater acoustic sensor networks V.Goutham and V.P.Harigovind-an | 2021 | full-duplex cooperative relaying with NOMA (FD-CR-NOMA) ,particle swarm optimization (PSO) algorithm. | The energy efficiency performanc-e of FD-CR-NOMA slightly degrading. | optimise the signal frequency and power allocation coefficient for the full-duplex cooperative relaying with NOMA (FD-CR-NOMA) and also minimizes the energy consumption | FD-CR-NOMA significantly reduced with the increase in the impact of residual SI i.e., f ¼ 1 * 10^-2 . | Signal frequency and power allocation can be enhanced further for efficiency of FD-CR-NOMA. |
| 5. | Q-learning based energy-efficient and void avoidance routing protocol for underwater acoustic sensor networks. Z.A. Khan et al. | 2021 | Sensor nodes are unable to deliver data towards the destination due to the absence of forwarder nodes (FNs) in the network. | It will not help to find more optimal paths for reliable data delivery. | To avoid void holes the proposed routing protocols are used so that it provides alternative neighbour routes for packet transmission. | Static sink is to be introduced to transfer the data to the control unit without fail. | |
| 6. | An underwater cognitive acoustic network strategy for efficient spectrum utilization. Xiaolin et al | 2021 | It mostly describes about the marine life gets mostly affected by the sounds produced in surroundings. | Underestimate d issues in Underwater cognitive acoustic networks (UCAN) . | Effective spectrum utilization to overcome the problems of interference caused by secondary users to the primary users of the ocean. | Environmentally friendly spectrum utilization model with much emphasis given to the primary users. | To implement the proposed ideas like Underwater cognitive acoustic networks (UCAN) is developing as a growing area of research and research efforts in the future. |
| 7 | Optimizing the number of relays for energy efficient multi-hop covert | 2021 | the optimal number of relays for multi-hop UWA | If no of hops are not reduced there will be a | By reducing the no of hops/relays makes system energy | The number of relays should be increased appropriately to | |

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| | underwater acoustic cooperative networks. Y.Chen , Y. Tang, J.Liu et al | | cooperative networks, by considering both the low probability of detection (PD) and energy consumption. | decrease in efficiency of the system. | consumption is relatively low. | reduce the overall energy consumption of the multi-hop system. | |
| 8 | Event driven energy depth and channel aware routing for underwater acoustic sensor networks: Agent oriented clustering based approach. M.R. Bharamagoudra et al. | 2017 | An energy efficient channel aware, depth based scalable , multipath agent based routing protocol, Autonomous Underwater vehicles. | low bandwidth, large propagation delay, high channel error rates, | Improve network connectivity, reliability. | Packet delivery ratio, energy consumption and latency | propose an agent based secured routing to increase reliability and privacy. |
| 9 | Adaptive modulation and coding in underwater acoustic communications: a machine learning perspective. Huang et al | 2020 | Underwater acoustic communication (UAC), A KNN methods are included. | A-KNN is more complex . | They proposed ML approaches have superior performance over traditional model-based methods | The performance metric of training dataset is of prediction accuracy of about 90.4%. | They further Present the DRDC-A-KNN classifiers for the easier implementation of the AMC'S which increases the complexity. |
| 10 | DTMAC: A Delay Tolerant MAC Protocol for Underwater Wireless Sensor Networks | 2015 | Delay tolerant MAC protocol applying for short-packet traffic, to overcome problems brought by long propagation delay and swarm mobility in sparse network. | Data packet loss, Deployment costs are high. | Give the throughput optimal. | Better performance . high network bandwidth and pay less attention on the single data packet transmition. | They will implement DTMAC in real modems and plan to conduct a series of field testes to evaluate and fine-tune the design, shooting for a functioning MAC protocol in the real world. |
| 11 | Localization schemes for Underwater Acoustic Sensor Networks - A Review | 2020 | localization schemes for development of UWASNs .The Fundamental-s of | It does not provide the self-correction scheme in case of the fault | Propelled Underwater Device is introduced . | 3D-MASL, UDB, and TSL achieve 100% localization success | |

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|---|---|---|---|---|---|---|---|
| | | | communication medium for UWASNs are presented. | occurrence. | | | |
| 12 | A Stratification-Based Data Collection Scheme in Underwater Acoustic Sensor Networks. Xie et al. | 2018 | Multi-hop Forwarding Algorithm, Vector Based Forwarding (VBF) | void phenomena and backtrackin-g problems. | Reduce network consumption, improve network lifetime. | Good Performance, collection delay decreases, data rate is 20kbps. | Decrease the collection delay, AUVs for collaborative data collection |
| 13 | A Node Location Algorithm based on Node Movement Prediction in Underwater Acoustic Sensor Networks Cheng et al. | 2019 | MPL (movement prediction location) algorithm, | location coverage rate is not high. | Improves the network location coverage and node location accuracy, low location error. | MPL algorithm has higher localization performance. | |
| 14 | A load-adaptive fair access protocol for MAC in underwater acoustic sensor networks W. Zhang et al | 2021 | underwater adaptive contention window(UACW ) | Conflict of Data on the channel. | Reduces the collision rate of data frames, and increases network throughput, better performance. | End-to-end delay decreased, | |
| 15 | Survey on High Reliability Wireless Communication for Underwater Sensor Networks Jornet et al. | 2019 | Underwater acoustic communicati-on, optical communicati-on, media access control (MAC) protocol | Complex, High delay, Low speed | High reliability, a low bit error rate, low power consumption. | Build a network among ocean | |
| 16 | An Adaptive Asynchronous Wake-Up Scheme for Underwater Acoustic Sensor Networks Using Deep Reinforcement Learning | 2019 | cyclic difference set (CDS)-based coordination asynchronous wake-up scheme with LSTM in deep reinforcement learning | It cannot handle more complicated cases. | They formulate to obtain the optimal policies of underwater sensor nodes. | EACDS-based and MACDS-based wake-up scheme | |
| 17 | Time-Frequency Mask Aware Bi-directional LSTM: A Deep Learning Approach for | 2022 | Bi-LSTM(Bi-directional Long Short Term Memory) | More complex | Improves signal separation performance. | Preserved-Signal Ratio, Signal-to-Interference Ratio, similarity coefficient | |

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|---|---|---|---|---|---|---|---|
| | Underwater Acoustic Signal Separation | | | | | | |
| 18 | Hybrid Space-Frequency Access for Underwater Acoustic Networks | 2022 | spatial division multiple access achievable in Multiple-Input Multiple-Output (MIMO)systems | Complex | More feasible and potential | Spatial and Frequency division multiple access are calculated. | |
| 19 | On Securing Underwater Acoustic Networks: A Survey | 2018 | Q-learning-based anti jamming method is proposed | limited communica-tion capacity | Avoid transmissions during a jamming period. | Improve detection accuracy and the utility of UWANs | |
| 20 | A cooperative protocol for pervasive underwater acoustic networks | 2021 | They proposed the COPPER, a Cooperative Protocol for Pervasive Underwater Acoustic Networks. | Large packet error rate and low throughput. | Improves network performance | Improve the UWSN goodput by 17% and decrease the packet error rate by 65%, consuming less than 1% more energy | |

## III. RESULTS AND DISCUSSION

The performance of the proposed schemes like DL-HDBT algorithm is compared with some other algorithms like QL-EEBDG, A-KNN, AHH-VBF, QUORUM SYSTEM. Among which the QUORUM SYSTEM ALGORITHM will efficiently sends the data to the destination in underwater acoustic sensor networks and allocate the different time slot for each and every node and removes the data congestion in the network. It is working efficiently by passing a vector a message with the data packets by which it increases the throughput.

The DL-HDBT reduced energy consumption by 34%, 45%, 53% when compared to SUN, VBF and DF schemes. Figure 13 shows the energy consumption of various techniques with the number of nodes. Each node has some capability to transmit the data through the relay node. Energy consumption of node to transmit the packet to the destination is very low in compared proposed scheme. In QUORUM SYSTEM algorithm they evaluated the energy consumption of four MAC protocols. Similarly, compared the changes in energy consumption under different number of data packets, and under different time slot size.

**Table 2:** Comparison of Performance Metrics

| Algorithm/ Metrics | Throughput | End-to-end delay | packet size | Energy |
|---|---|---|---|---|
| DL-HDBT | low | Low(42) | large(160B) | reduced |
| QL-EEBDG | High | Low | Small | Increased |
| A-KNN | High | High | Small | increased |
| AHH-VBF | High | High | High | Reduced |
| QUORUM SYSTEM | high | low | Small(160bit) | reduced |

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Q-learning based energy-efficient and balanced data gathering (QL-EEBDG) routing protocol is show high energy dissipation when network radii and consumes less energy. Adaptive hop-by-hop vector -based forwarding(AHH-VBF) routing protocol is not no more effective on adverse underwater environments because of the low bandwidth results in the increase of collision probability at receivers, a node cannot even know the currentchannel condition of a remote one-hop neighbor because of the long propagation delay etc..

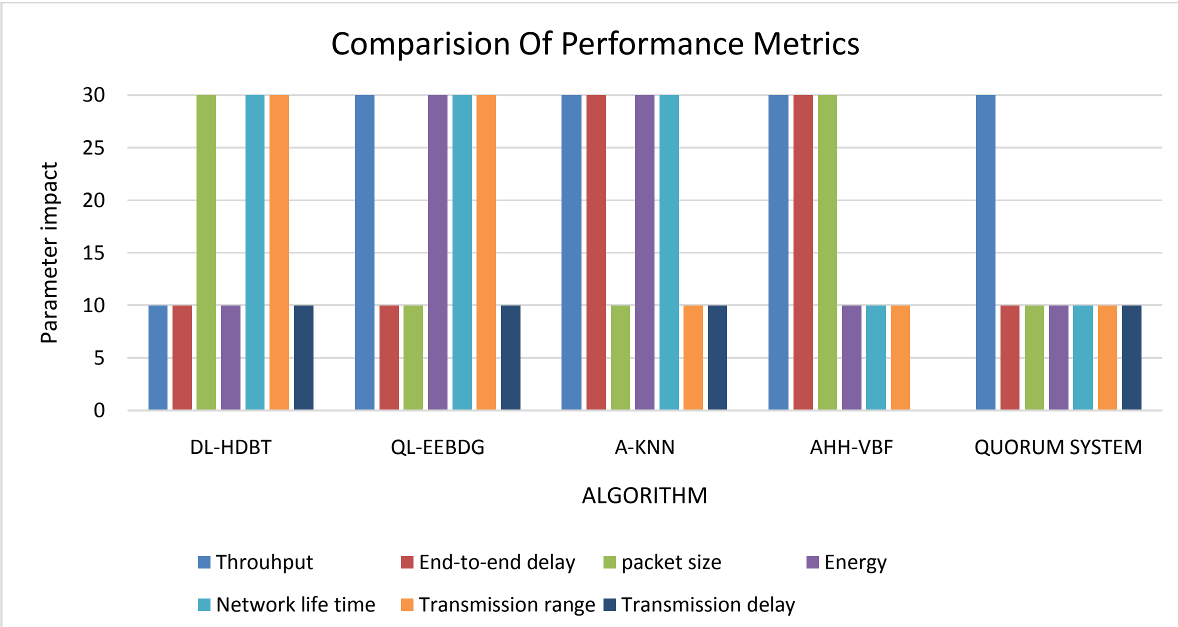


Fig: Comparison of Performance

## IV. CONCLUSION

Underwater acoustic channels, data packet transmission rates, and other factors make underwater wireless sensor networks (UWSNs) generally reliant on acoustic communication. The underwater acoustic data transmission collision has a high transmission latency and space-time uncertainty features. In order to avoid data transmission collisions and improve network performance in this paper, the collision-free scheduling protocol based on quorum system which allocates different time slots for pair of nodes in the same collision area, and realizes space reuse fornodes in different collision areas. As compared to the other Algorithms like DL-HDBT, AHH-VBF, QL-EEBDG it will work more effectively on underwater acoustic networks. The review on this paper has observed that the quorum system algorithm can effectively avoid packet transmission collisions, reduce data transmission delay, and improve system energy efficiency in different network topologies and communication conditions among all other different algorithms.

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