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A Review on Void Avoidance Routing Algorithms in Underwater Acoustic Sensor Networks

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Abstract- The reason for Underwater Acoustic Sensor Networks (UWASNs) is to discover differed applications for sea checking and investigation of seaward. In bigger piece of these applications, the organization includes a couple of sensor nodes passed on at different profundities in water. The sensor nodes which are arranged inside and out, at the ocean bed can't discuss unswervingly with those nodes which are near the surface level; these nodes require multi-hop correspondence which is encouraged by appropriate steering plan. The working of UWASNs are influenced by certain limitations like high transmission delay, energy utilization, arrangement, long proliferation deferral and high weakening and so forth Aside from this, the presence of void node in the course can likewise influence the general exhibition of UWASNs. The determination of best forwarder node relies upon profundity fluctuation, profundity contrast, and residual energy. This paper focuses on the review of void node avoidance algorithms and makes a comparative study of various available algorithms which have been proposed earlier. Later on, these are characterized into various categories as per their attributes and functionalities that will help the researches to find the research gaps in void node avoidance routing algorithm.

Keywords: Underwater Acoustics Sensor Networks, Depth, Location, Void Node, Delay etc.

I. INTRODUCTION

Around 70 percent of the atmosphere of the Planet (almost all seas and oceans) is filled with water. New innovations have provided us with new ways of tracking and sensing marine ecosystems. The research, safety and commercial use of aquatic environment including underwater surveillance, river and sea pollution identification and control, as well as oceanography data collectivity. In all sorts of settings, the sensors technology has evolved enough for use. The industry provides smaller sensor devices with reduced power usage and better processing capability over time. In addition, modern physical sensors also expanded the spectrum of underwater data collection parameters. In addition, many of the sensor and sensor network functions must be addressed in such an environment: a large number of nodes are required, small node resources, short distance radio communications, high latency range, poor bandwidth capability and high error rates(Akyildiz et al., 2005).

Wireless data transmission through the ocean is one of the enabling advances for the improvement of future ocean insight structures and sensor networks. In present, a portion of the uses of submerged acoustic correspondence are oceanography, for filtering climate, atmosphere conditions and contamination, and transportation. In submerged condition normal assets are examined by unmanned underwater vehicles (UUVs) and autonomous underwater vehicles (AUVs). On account of exceptionally delayed in speed, acoustic wave submerged, and enormous number of multipath, there is long motivation reaction and huge time delays (Gola & Gupta, 2020). Acoustic correspondence is a key innovation to trade data submerged, since acoustic signs, as opposed to optic and radio signs, can spread in water for long range separations (Yoon et al., 2012). The decent variety of sea-going applications ranges from ecological checking, contamination control, forecast of and response to catastrophic events, eco-framework examination, and observation for protection applications and port security, seaward oil and gas industry, hydroponics, topographical and oceanographic science, sea life, science and paleontology(Kumar Gola, Dhingra & Gupta, 2020).

However, planning a UASN achieves a few new difficulties because of the power restrictions of underwater sensor node and the ominous attributes of the submerged acoustic channel, for example, restricted data transmission, multi-way impact, blurring, huge engendering deferral, and high piece mistake rate. Among many examination issues in this new and promising region, conveying bundles from a source node to objective, in particular steering, is one of the principal issues that should be read for developing the UWSN protocol stack (Faheem et al., 2016). Giving versatile and proficient directing assistance in UWSNs is astoundingly trying a result of the fascinating characteristics of submerged sensor organizations.

In the area of ocean research, the Underwater Acoustic Sensor Networks (UWASNs) has gained momentum during past few years- almost a decade. A concrete strategy is the need of the hour for developing various potential applications. It is highly risky, complicated and difficult to monitor the volatile and turbulent environment of the oceanic under-water. It is important to monitor the under-water oceanic environment for conserving and preserving the marine life and also to ensure the sustainable development. The problem of drastic climate change is looming large across the world. Moreover, several water based activities adversely impact the under-water ocean life and threaten the eco system by creating various types of imbalances thereby impacting the environment and the terrestrial life(Kumar Gola, Chaurasia, Gupta & Singh Niranjan, 2021).

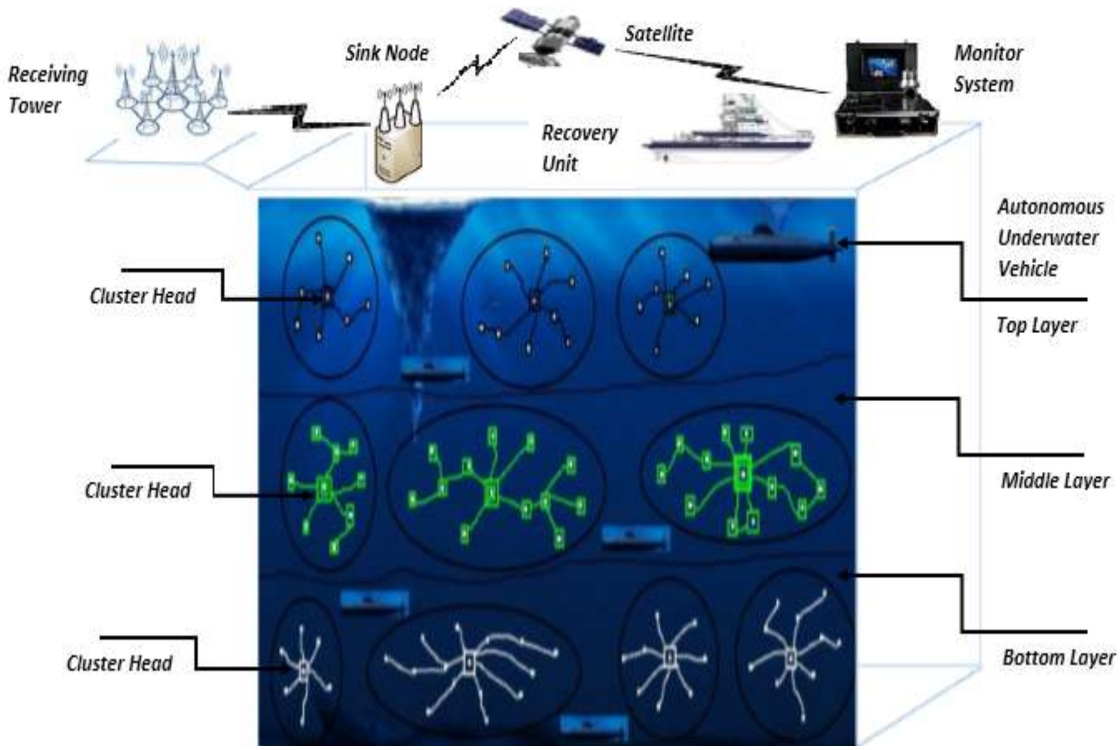

Figure 1. Underwater Sensor Network Architecture(Gola & Gupta, 2020)

Routing is one of the key issues in any network. Most of studies directed on UWASNs are centered on the physical and MAC layers. In any case, scientists have less regard for upper layers, for example, the network layer, and exploration in this layer is still in its earliest stages. Since the fundamental errand of the network layer is directing, planning effective and reasonable steering protocols for underwater condition that consider the submerged difficulties are basic (Han et al., 2018). In the greedy approach, correspondence void is one of urgent issues which steering approaches ought to have the option to deal with. The technique for dealing with the correspondence void is a specialized test for any eager directing protocol. All in all, eager directing protocols are made out of two modes, to be specific, avaricious mode and void taking care of mode. In the event that every node has at any rate one neighboring nodes with positive advancement towards the sink, it works in the eager mode; else, it faces correspondence void and changes the mode to void taking care of mode(Gola & Gupta, 2021).

The organization of the paper is done in the following way: Current studies in the area are mentioned in section 1 of the paper. An overview of the acoustic systems is shown in section 2; section 3 comprises the literature work with simulation parameters and finally section 4 show the conclusion of the paper with its future directions in the field of underwater acoustic sensor networks.

II. BASICS OF ACOUSTIC COMMUNICATION

As noted earlier, in the underwater world the microwave, radio and optical communication modes can also be used; but because of different aquatic properties, they are not acceptable. For terrestrial contact electromagnetic signals are better since they consume low energy, deliver high bandwidth, low latency in transmission and very low attenuation in signals. Thus the Sinks use the on-shore stations radio contact mode. The high attenuation which leads to severe absorption because of the water conductivity, however does not enable radiological communication in the aquatic environment. Thus the spectrum of transmissions in the aquatic environment is limited. Similarly, an exact viewing line between the recipient and transmitter node couples and a good visibility are required to interact optically. The water current and its turbidity make these two restrictions impossible to satisfy. Therefore, high data transmission over the long range cannot be accomplished by optical communication. The acoustical contact mode is commonly used in submarine networks because of these difficulties and limitations. However because of its intrinsic limitations, the processing and distribution of data solutions for land networks cannot be implemented explicitly throughout the underwater network.

The acoustic signal is the only practical means which have shown proven results of working satisfactorily in the under-water environment. Though, there are several other alternatives available in the form of underwater optical and electro- magnetic waves, but the features of underwater sensor requirements out rule those (Hollinger et al., 2012).

The high frequency electro-magnetic wave has a communication range which is quite limited due to absorption effect and high attenuation, being 1m in fresh water. Although, at low frequencies propagation can be accepted but, it comes with several problems like, requirement of very lengthy sized antenna and also a very high price of transmission power. Even though the technical details are not robust, the electro- magnetic modems used for the under- water communication have grown at a fast pace during the recent years (Felemban et al., 2015).

Generally we divide the link into two categories as Vertical and Horizontal .This categorization is on the basis of acoustic waves. Along with this we also define some parameters as following:

Path Loss: The first parameter which we need to consider is Path Loss. In the acoustic communication it depends on distance of packet transfer and the number of packets per time which we need to transfer known frequency. The expression of path loss is represented as:

$$P\_Loss\left(d,\, f\right) = PLoss_0 d^k a\left(f\right)$$

Here distance is denoted by d, f is for frequency of signal, the spreading factor is represented by k which is depends on the spherical ,cylindrical and practical spreading, PLoss0 is a constant and other coefficient is a(f) as absorption which is defined by mentioned expression:

$$10log_a\left(f\right) = 0.11\, f^2 \,/\, \left(1+f^2\right) + 44 \,*\, f2 \,/\, \left(4100+f2\right) + 2.75 * 10^{-4} f^2 + 0.003$$

The unit consideration of frequency, Absorption coefficient are KHz and db/km respectively. The above expression for the communication of high frequencies hence for small or low frequencies we use:

$$10log_a\left(f\right) = 0.11\, f^2 \,/\, \left(1+f^2\right) + 0.011 * f^2 + 0.002$$

Noise: The second parameter of UWSN communication is Noise which is also categories in two types as Man-made noise which is occurred by the ship movements or sometime we can say it as instrument's noise. The other category of noise is known as natural noise which is due to species of underwater as dolphins, fishes and mostly by tides rain.

Multipath: The next factor to be consider as parameter is Multipath. Generally two types of communication we defined as Single path and Multipath. The main difference in single and multipath is that multipath communication generates the Inter Symbol Interference(ISI) which is the form of distortion of signals. Another point of consideration is time scattering factor which is little in amount for vertical path transmission and large in horizontal channel transmission.(Islam & Lee, 2019).

Delay: Another important parameter is Delay. In UWSN routing like multi-hop causes packet failure with an expected delay parameter due to which there will be poor communication between nodes. Generally for acoustic waves of 1500 m/s face the delay of 0.67s/km.

$$C = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + \left(1.34 - 0.010T\right)\left(S - 35\right) + 0.016d$$

Here the temperature and pressure is given. As T denote the temperature which is in Celsius ($_0$C), S is percentage of salt in water parts per thousand. Here depth is calculated in meters and denoted by d. c is the velocity of sound in m/s.

The effectiveness of this expression is in situation as $0 \leq T \leq 35^{\circ}$C, $0 \leq S \leq 45‰$, and $0 \leq z \leq 1000$m.

III. UNDERWATER SENSOR NETWORKS ARCHITECTURE

Underwater sensor network is a special type of acoustic sensor network which is help us to collect the data and information of the ocean which is used in different application fields as monitor warship tracking in real-time bases, preventing from disaster or any environmental surveillance, seismic detection, monitoring of oceanographic data etc. According to deployment of wireless equipment we categorize the architecture into different categories defined by (Felemban et al., 2015):

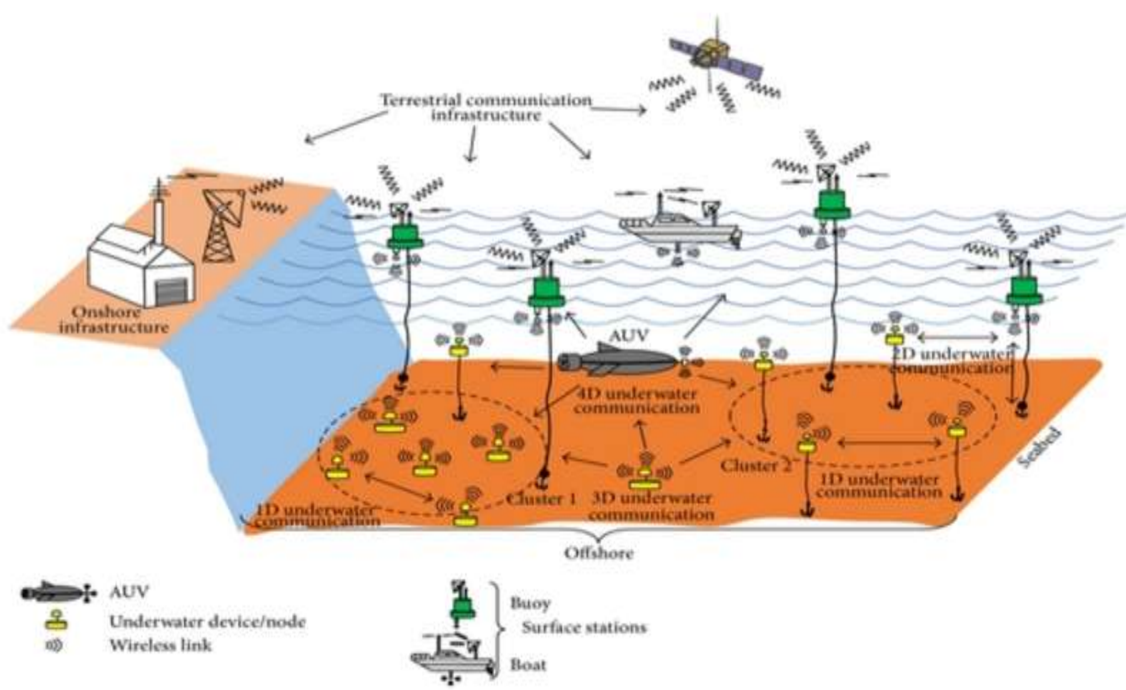

Figure 2. Underwater Sensor Network Architecture (Felemban et al., 2015)

1-D UWSN Architecture It's a simple deployment of sensor node where nodes are deployed separately and create standalone network in itself.in this architecture every node is responsible to process and transmit the information to remote station.in this network generally we use the star topology for communication where each node send the information in single hop manner directly to base station. It's very challenging in one dimensional UWSN to cover complex acoustic environment due to limited link reliability and transmission range.in this network architecture all components like acoustic channel, optical communication or radio frequency used single dimension structure for communication. Hence it's not suited for big data processing.

2-D UWSN Architecture In multi-dimensional architecture of UWSNs we defines the network as 2-D,3-D and 4-D. In such architecture we use the form of clusters to deploy the sensor node in depth of ocean. In this architecture we create one or more underwater sinks (UW-Sinks) which are responsible to transmit the data and information from depth to the surface of ocean. For this purpose we used two types of acoustic transceiver known as vertical and horizontal transceivers. In which horizontal transceivers are to send commands and configuration data to the sensors (uw-sink to sensors) and collect monitored data (sensors to uw-sink). The horizontal transceivers are the long range transceivers and used to relay data to surface station. Generally for communication in underwater sensor network of 2-D architecture take place by RF, optical or acoustic communication. We decide the topology by analyzing the underwater application, it may be mesh, star or ring in two dimensional architecture.

3-D UWSN Architecture In the form of 3-D architecture a group of sensor nodes are used to makes a cluster for underwater environment at different level of depth. It's helpful to do cooperative sampling of 3-D environment.in this architecture we divide the cluster on the bases of division of work as cluster head collect the data from their respective member and forward that data to the base station. Three types of communication between the nodes of cluster is defined as intra-cluster communication which is held between sensor node and anchor node, second type is inter-cluster communication by nodes at diverse depths and last is between anchor to buoyant communication.

4-D UWSN Architecture This kind of design alludes to the organization having the blend of fixed 3-D underwater sensor networks and mobile underwater sensor networks. The mobile underwater sensor networks having remote operative underwater vehicle used to collect the information from anchor node and forward that information to the remote/base station.These vehicles can be independent vehicles, sub robot, boat or submarine. Every sensor node can send the data straightforwardly to Remotely Operated Vehicle (ROVs) in light of the distance that the amount it is shut to the ROVs. The information and distance in underwater environment characterize what kind of communication will happen: RF communication or optical communication or acoustic communication between underwater sensor nodes and ROVs. Radio connection can likewise be utilized if a sensor node having a lot of data and near ROVs while acoustic connection is utilized when sensor node having little information and a long way from ROVs.

IV. RELATED WORK

Lot of published material is accessible nearby UWASNs and various scientists have directed and are completing their explores nearby. All things considered, there is a ton which stays neglected and unidentified. Since the exploration nearby underwater sensor network isn't new, an investigation was done just about thirty years back on which specialists have gotten concentrating going late in this space. The greatest test in the method of steering convention in the event of submerged sensor networks is the presence of void locale. This presence of void may prompt loss of information during information transmission starting with one node then onto the next or sink node. The opening framed during the directing impacts the organization execution concerning lifetime of organization, spread deferral and energy utilization. The simulation parameters used by most of the void node avoidance routing algorithms are mention by Table 1.

Table 1. Simulation Parameters

Parameter Name	Parameter Values
Water Surface	1000 * 1000 m

Depth of Water	2000 m
Ex	50W
Erx	158 mW
Number of Sensor Nodes	60-180
Acoustic Propagation Delay	1500 m
Ideal Energy	58 mW
Header Size	88 bits
Payload Size	576 bits
Neighbours Request	48 bits
Acknowledgement	48 bits
Data Rate	$16*10^3$ bits
Packet Generation Rate	0.2 packet/sec
Weighting Factor α	0.5 range (0,1)

(Yu et al., 2016) have proposed a routing protocol for sparse networks. The principle objective of this work is to lessen the likelihood of experiencing void openings. Here, the determination of next sending node depends on the weighting amount of profundity distinction of two bounces. Aside from current profundity, this work likewise think about the profundity of expected next jump. This assists with diminishing the likelihood of meeting the void opening. This work likewise proposes the instrument for sending region division and neighbor node expectation that defeat the issue of force utilization brought about by duplicated bundles and neighbors demand. The examination of proposed work is mimicked on NS-3. The boundaries utilized for examination are start to delay, energy utilization, and packet delivery ratio so forth.

(Bouk et al., 2017) have explored the avoidance of void region in UWASNS with the usage of depth based and energy schemes. The information packets are shipped off the sink dependent on the profundity of node based sending measure. Void district was totally dodged in this paper by considering the leftover energy alongside the nodes' profundity boundary. The holding season of the nodes was determined utilizing the distinctions of forwarder nodes and the lingering energy. This methodology helps in adjusting the energy close by taking consideration for keeping away from the void area. Likewise, it helps in adjusting the energy hence maintaining a strategic distance from the void district. Consequently, it helps in up flooding the lifetime of the organization.

(Shah et al., 2018) have proposed four UWSN routing protocols for example, Mobile Sink-based LETR (MSLETR), Mobile Sink-based Geographic and Opportunistic Routing (MSGER), Modified MSLETR (MMS-LETR), and Location Error-strong Transmission Range change based convention (LETR). The adjoining contiguous nodes were found by contemplating the reach levels. In the event that on the off chance that a node won't recognize the nearer node, it is viewed as an extraordinary restriction of move. It attempts to emerge from the void territories of correspondence by utilizing the inventive methods with respect to profundity changes. The profundity is disposed of by MSGER and MSLETR. Despite the fact that MMS-LETR takes into perception the constriction of clamor made at different levels, still the finish of retransmissions were considered by using multi way correspondence and change of burdens was additionally contemplated.

(Wang et al., 2018) have proposed the energy-mindful and void-avoidable steering convention (EAVARP). There are two phases that finishes the working of EAVARP. The first is layering stage where the concentric shells are utilized with the sink node. All the sensor nodes are spread in the different shells. The subsequent stage is known as information amassing stage. Here, Opportunistic Directional Forwarding Strategy (ODFS) is utilized to send the information bundles. The essential goal of ODFS is to keep the record of energy of node and data move in the shell which further serves to disposes of the void, flooding and cycle moving.

Gola, K., & Gupta, B. (2019) have proposed a Quality of Services (QoS) void avoidance routing algorithm to select the best forwarder node.This work uses the QoS parameters such as holding time, depth information, residual energy and distance to next to avoid the void region. Two hop node information is also used by this work to avoid the void region. The proposed work has been simulated on the MATLAB platform. Comparative metrics are energy tax, packet delivery ratio and average number of dead nodes. The comparison has been done with Energy-Efficient Void Avoidance Routing Scheme for Underwater Wireless Sensor Network (E2RV). Simulation results show better performance as compared to existing one.

(Lu et al., 2020) have proposed a routing algorithm with Q learning approach that guarantees the reliable data transmission and energy saving.The benefits of pioneering steering and Q learning are consolidated to upgrade the organization execution. In this methodology, profundity data, remaining energy and void recognition factor are considered to characterize the Q esteem work that assists with distinguishing the void node ahead of time, in the interim it additionally decreases the energy utilization. This work additionally proposes a basic and versatile void node recuperation mode to choose the up-and-comer set to save the information bundle that are stuck in void district. To plan the information bundle sending, a Q esteem based holding time is additionally set to lighten the information parcel impact and repetitive transmission. The recreation has been done on Aqua-sim stage (NS-2) to break down the exhibition of the proposed calculation. The exhibition lattices like energy productivity, normal parcel postponement, PDR and normal organization overhead are utilized for correlation.

(Khan et al., 2020) have proposed an adaptive hop by hop cone vector based forwarding protocolthat expands the transmission dependability particularly in meager sensor locales by changing the base point of the cone according to the organization structure. This work additionally lessens the start to finish postponement and copy information parcel transmission by decreasing the base point with savvy determination of best forwarder node. This work fundamentally improve the presentation as far as start to finish delay, energy assessment and bundle conveyance proportion.

(Rathore et al., 2020) have proposed an underwater networking framework based on whale and wolf optimization. This work centers on the attributes of dynamic submerged climate by using submerged whale-driven streamlining viably to choose the hand-off node choice. A submerged node improvement numerical model is inferred for submerged transfer node which centers around submerged whale elements to join sensible submerged attributes. This advancement model is utilized to choose an ideal and stable transfer nodes by receiving whale and dark wolf enhancement for driven submerged correspondence ways. This work additionally presents a total work process of the proposed system with an advancement flowchart.

(Alasarpanahi et al., 2020) have proposed an energy effective void evasion geographic directing convention. This work consider less measure of energy utilization to deal with the void area shirking. A weight work is utilized to choose the reasonable arrangement of sending nodes. Information parcel transmission is done inside the set. The computation of weight work incorporates the profundity of the competitor adjoining node and burned-through energy where the choice of applicant adjoining node relies upon the parcel progression of the adjoining node toward sonobuoys. The presentation of the proposed work accomplishes better outcomes as far as parcel drop, energy utilization and steering overhead when contrasted with comparative existing directing convention.

(Ahmed et al., 2020) have recommended a reduced and energy effective directing convention with high throughput known as Energy Harvesting in UWSN (EH-UWSN). As name shows, every sensor node is able to re-energize their battery from the external climate. The primary target of this convention is to improve the organization lifetime and forward the information bundles through participation with less energy utilization. The examination is done on the bases of organization lifetime, energy use and organization throughput with the current convention known as Cooperative Routing for UWSN (Co-UWSN). The proposed convention accomplishes better outcomes and burn-through less energy when contrasted with agreeable steering convention.

Table 2. Performance Comparison of Underwater Sensor Network Protocols

Authors and Year	Packet Delivery Ratio	Energy Efficiency	Reliability	Delay Efficiency	Throughpu t	Performance
(Yu et al., 2016)	Fair	High	Fair	Low	High	Fair
(Bouk et al., 2017)	High	Low	High	High	Low	High
(Shah et al., 2018)	Fair	High	Fair	Low	High	Fair
(Wang et al., 2018)	High	Low	High	High	Low	High
Gola, K., & Gupta, B. (2019)	High	Fair	Low	Fair	Fair	Fair
(Lu et al., 2020)	High	Fair	Low	Low	High	Fair
(Khan et al., 2020)	Fair	Low	Fair	High	Low	Fair
(Rathore et al., 2020)	High	Fair	Fair	High	Fair	High
Alasarpan ahi et al., 2020	Fair	Fair	Fair	Low	Fair	Fair
Ahmed et al., 2020	High	Low	High	High	Low	High

V. CONCLUSION AND FUTURE WORK

The principle motivation behind this investigation is to deliver the issue identified with void node evasion under various conditions. During the examination of writing survey it is discovered that the vast majority of the steering approaches utilizes just leftover energy of the nodes and profundity distinction to advance the information bundle. Aside from this, a few calculations consider the connection quality to choose the forwarder node. As we realize that UWASNs are utilized in different application situations and consider a different component while proposing another steering calculation. As examined in the writing survey, parcel of works have been done in this field. Still this field conveys certain difficulties like information retransmission, geography the executives, way misfortune and security which needs scientist's consideration. In UWASNs, sensor nodes are haphazardly sent in submerged climate at different profundity. To secure the submerged nodes has become the most testing task in this field. Indeed, even some security calculations have been recommended to get the UWASNs, yet the majority of them are in the hypothesis stage and observational examination is uncommon. The exploration of UWASNs security is as yet in the beginning phase. Besides, cell phones like Unmanned Aerial Vehicles (UAVs) Unmanned Underwater Vehicles (UUVs) have gotten more well-known and assume a significant part in our day by day life.

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