Underwater Acoustic wireless sensor Networks: A Review of UWAWSN Architecture, Applications, Design Challenges, MAC Protocols

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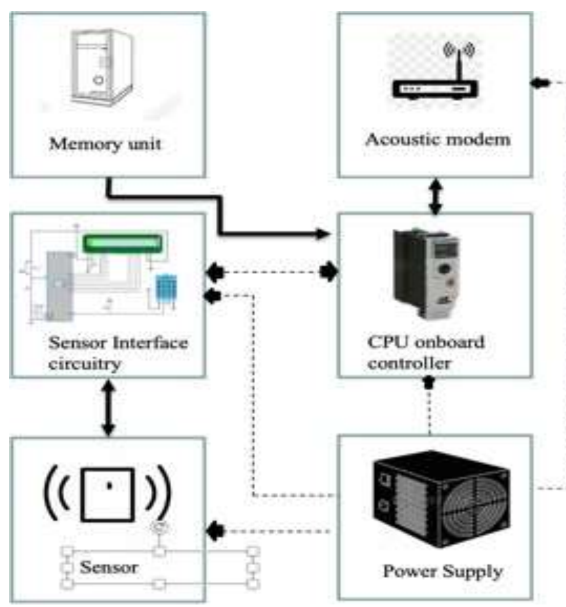
Abstract— It is expected that Underwater Wireless Sensor Networks (UWSNs) will support a range of civil and military applications. Due to its potentially large impact on overall network performance, Medium Access Control (MAC) protocol has attracted considerable attention in UWSNs. Unlike terrestrial networks, which rely primarily on radio waves for communication, UWSNs use acoustic waves which present a new research challenge in MAC protocol design. This paper surveys existing state-of-the-art MAC protocols for UWSNs in order to address the development of MAC protocols in UWSNs. The efficiency of the UWSNs in terms of delay and throughput was the major concern of the MAC layer protocol design in the early development. Subsequently, the design of energy-efficient MAC protocols becomes a new focus of research because sensor nodes are generally powered by batteries that are less likely to recharge. Within this paper we first describe the acoustic environment underwater and the challenges to the design of MAC protocols within UWSNs. We then include a comparative analysis of different types of MAC protocols based on current diverse implementations. That survey will hopefully inspire more active research in this area.

KeyWords— *UW-Under water, UAWSN-Underwater Acoustic Wireless Sensor Netrwork, MAC-Media Access Control, PSM-proNX Service Manager PMAC- Pattern-MAC, SMAC-SENSOR MAC,HMAC- hybrid medium access control protocol*

1 INTRODUCTION

Acoustic communication is defined by the use of underwater sound signals as the best means of communication from one point to the next. Acoustic signal is the only technically feasible device that operates underwater. Owing to the high attenuation and absorption effect in underwater environment, electromagnetic wave can only travel in water with a limited distance compared to it. underwater sound signals as the best means of communication from one point to the next. Acoustic signal is the only technically feasible distance compared to it. The absorption of electromagnetic energy in sea water is found to be about 45 f dB per kilometre, where f is the frequency in Hertz. In comparison, the absorption of acoustic signal is around three orders of magnitude lower for most frequencies of interest. There are some investigations regarding the use of optical signal for applications underwater.

Nevertheless, they find out that the optical signal can only pass in very clean water environment (for example, deep water) through a restricted range. It is therefore not a suitable tool for underwater long-distance transmission, even in a non-so clean water, e.g., shallow water, climate. Underwater Acoustic Networks, including but not limited to Underwater Acoustic Sensor Networks (UASNs) and Autonomous Underwater Vehicle Networks (AUVNs), are classified as networks of more than two nodes that use acoustic signals to communicate for underwater applications. UASNs and AUVNs are two major types of UANs. The former consists of many sensor nodes, mainly for the purpose of monitoring.



Typically, the nodes are without or with minimal movement capability. The latter is composed of autonomous or unmanned high mobility vehicles, deployed for mobility-needed applications, e.g., exploration.

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energy loss is directly controlled by the material imperfection. This material imperfection is the inelasticity for acoustic waves which converts the wave energy into heat.

1.1. Fundamentals of Waves:

It is critically important to understand the first concepts of any physical wave used in UWSN wireless communication. In this section we model the basic physical properties and essential issues for each of the propagation of the acoustic and optical wave in underwater environments. We address the advantages and disadvantages of each physical carrier for effective wireless communication underwater.

Acoustic Waves:

Because of the relatively low absorption in underwater environments, acoustic waves are used as the primary carrier for underwater wireless communication systems among the wave types. We begin the discussion with the physical basics and the implications of using acoustic waves in underwater environments as a wireless communication carrier.

Physical Pro

Fig1: Block diagram of UWASN

The acoustic w es unique to other waves, two of which are illustrated below:

Propagation velocity:

The extremely slow speed of sound propagation through water is an important factor which distinguishes it from electromagnetic propagation. The speed of sound in water depends on the temperature, salinity and pressure properties of the water (directly related to the depth). A standard sound velocity in water near the ocean surface is around 1520 m / s, which is more than 4 times faster than sound velocity in air, but five orders of magnitude smaller than light velocity. Sound speed in water increases with rising temperature of the water, increasing salinity, and increasing depth. Most of the sound velocity changes in the surface ocean are due to the temperature changes. This is due to the slight influence of salinity on sound amplitude, and minor fluctuations in salinity in the open ocean. Near shore and in estuaries, where salinity varies greatly, salinity may have a greater effect on sound speed in water. As depth increases, Underwater Wireless Communication Network 43 has the greatest effect on sound speed. Under most conditions, sound speed in water is easy to understand. Sound will travel more quickly in warmer water, and more slowly in colder water. The sound velocity increases by around 4.0 m / s for water temperature. As the water depth (thus also the pressure) increases by 1 km, the sound velocity increases by about 17 m/s. It is worth noting that the above measurements are for rough quantitative or qualitative discussions only, and the differences in sound speed for a given property are usually not linear.

Absorption: Wave energy can be converted to other forms during propagation, and absorbed by the medium. For the type of physical wave that propagates through it, the absorptive

2.APPLICATION OF THE UNDERWATER COMMUNICATION:

2.1.Environmental Monitoring: -

- Track the dirt water and mineral substance for water system, soil conditions for sports field observing, soil development for avalanches expectation.
- Track the earthquake, glacier movement, coalmine.
- Track the fairway by observing soil saltiness, water substance and warmth.

2.2.Configuration(infrastucture) Monitoring: -

- screens the foundation of the funnel, wiring and underground parts like dams and the minefields.
- area assurance of items, which incorporates driver ready, independent manure unit, and if there should be an occurrence of building breakdown it finds individuals.

2.3. Border petrol (BP) and security monitoring (SM): -

- Track the home-security framework
- Detects the encroachment at border.

2.4. Seismic Monitoring: -

- Oil extraction control from underwater area.
- Very rarely can its survey be carried away, and it has the very high cost.

2.5. Underwater Discovery: -

- To discover oilfields or shops, find courses to put intercontinental submarine ties connections in place.
- We may even search for wrecks or antiquarianism or miss the urban sink Collectivity.

3.CHALLENGES OF THE UNDERWATER COMMUNICATION:

Underwater communication is a very intricate owing to the fact that many environment elements are affects the acoustic channels. These elements are as follows,

- Long propagation delay
- Path loss
- Doppler spread
- Multipath effect

Because of these factors influence the acoustic channel is highly changeable. They also establish bandwidth dependence between two nodes, on both frequency and distance. Ocean is usually considered as two different divisions; these are deep ocean and shallow oceans. Features of the Shallow and Deep Ocean are listed in Figure1. The shallow ocean has a big influence on the acoustic channel. High temperature gradient, multipath effect, noise at the surface, and significant delays in propagation affecting acoustic communication are defined in underwater environment.

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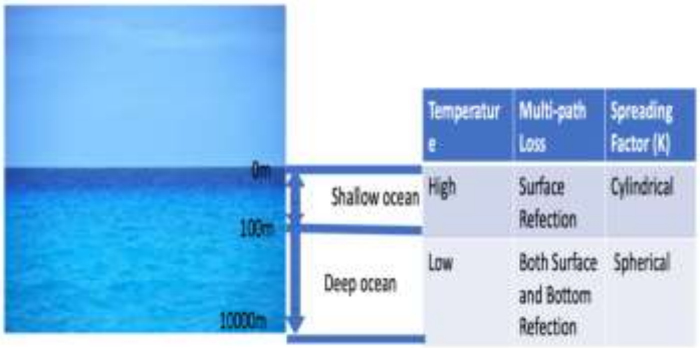

Fig2: Features of shallow and deep water

3.1.Path Loss:

As sound propagates from underwater space, some of its intensity is convert into heat. The energy loss of sound wave propagation can be classified into three major categories that are listed below.

3.2. Geometric Spreading Loss:

As host produces sound wave signal it penetrate in the form of wave fronts away from the source. Nevertheless, depending on the space converted through the wave front it is independent of frequence. The two different types of geometric spreading are as follows. First, spherical spreading depicting deep ocean communication; second, cylindrical spreading depicting flawless water communication.

3.3. Attenuation:

Attenuation is characterized as "wave energy converted into some other type of energy", such as temperature (heat energy), which is absorbed by the medium. This phenomenon is compassionate within acoustic communication. Because acoustic energy is transformed into heat. The transferred heat is drained by surrounding underwater. Attenuation is directly proportion to distance and frequency.

3.4. Scattering Loss:

Deviation with respect to the signal line of sight or angle shift is usually a physical property. Underwater medium also has this property which affects the transmission of data from the acoustic channel during communication. Roughness of the surface dispersing end product. Surface scattering causes not only delay but also power loss.

Noise can be defined as a communication system quality which will degrade the signal strength of any communication system.

Various types of noise exist int the case of underwater acoustic channels. Noises underwater can be classified into two main groups. Those are man-made, and ambient noise.in the following sections shows the details of these kinds of noises.

3.5. Noise by Human Beings.:

Which are because of the high noise Use equipment, ansportation operations, fshing, Combat operations, Sonar ıd Aircraft movements Since sending and receiving strong ıta trafc Causes various kinds of interruption and disruption ıring Acoustic transmission. Noises also attributable to ımans Beings also interfere with normal acoustic contact.

3.6. Ambient noise: is a dynamic phenomenon fecting contact underwater. This can also be characterized as combination of different sources, which cannot be described ıiquely. Background noise is also called ambient noise That is cause of unidentified sources. These are classified into four tegories as follows

1. wind,
2. shipping,
3. thermal,
4. turbulence.

Wind noise is caused by wave breakage, or by airborne bubbles. Noise can only be forecast and projected Weather forecasts due to noise dependence Wind velocity.

4.ARCHITECTURE OF THE UNDERWATER ACOUSTIC COMMUNICATION NETWORK:

Here we describe the communication architecture of underwater acoustic sensor networks. Mainly focus about the two different kind of architecture that are 1. two-dimensional 2. three- dimensional underwater networks. And also gives the details about the various kinds of autonomous uw(under water) vehicles. By using these vehicles improve the potential of underwater acoustic sensor networks. Energy consumption, reliability of the network, and the network capacity these three factors are confirmed by the network topology.

Network design (topology) should therefore be carefully planned and topographic optimisation after deployment should be achieved as much as possible.Due to the high cost of underwater equipment's surveillance work of underwater networks is highly overpriced.It is also critical that the network used is very stable to prevent the failure of monitoring tasks due to a single or multiple system failure. For example , must avoid the topology selection such as ,the desing to compramise the all systerm or node for single point failiure.

The network topology may affect the capacity of the network, Because the capacity of the underwater channel is strictly defined so, The network protocol that it is structured is very necessary so we can prevent communication bottlenecks.

To describe the challenges of underwater acoustic sensor networks the following architecture is used. The underwater sensor network design(topology) has the research issue in itself that needs further analytical and simulative investigation from the research community.

4.1Two-dimensional UW-ASNs (static)[for the ocean bottom monitoring]:-

They are made up of sensor nodes which are fixed to the bottom of the shore, environmental monitoring, or monitoring of underwater plates are the general usage of the two dimensional UW-ANs.

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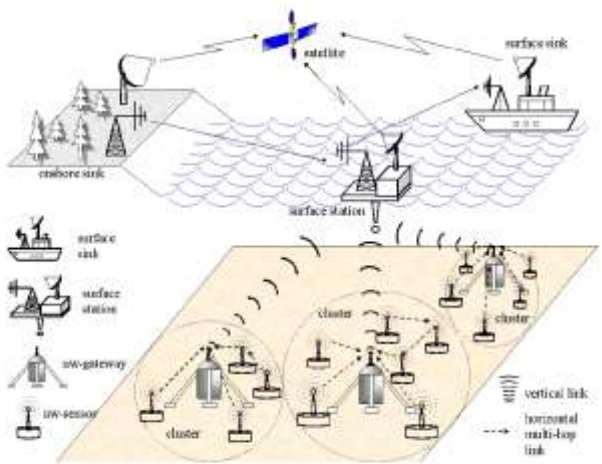

Fig3: Architecture of 2D UWSN

4.2.Three-dimensional UW-ASNs (static): for ocean column monitoring. Which include sensor networks which can be managed in depth and may be used for surveillance applications or monitoring of ocean phenomena (ocean bio–geochemical processes, water streams, pollution).

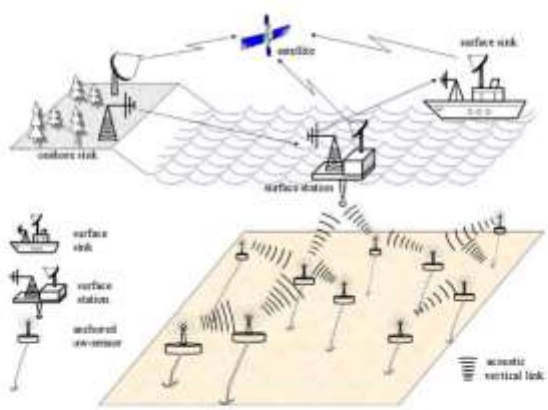

Fig4: Architecture of 3D underwater sensor networks

Three-dimensional networks of autonomous underwater vehicles (AUVs). These networks comprise fixed slices composed of anchored sensors and mobile portions constituted by independent vehicles. A community of sensor nodes with deep sea anchors are anchored at the bottom of the ocean.Underwater sensor nodes are interconnected to one or more underwater sinks (uw-sinks) by means of wireless acoustic links. Uw-sinks, are network devices in charge of relaying data from the ocean bottom network to a surface station. To obtain this goal, uw-sinks are equipped with two acoustic transceivers, namely a V-vertical trnsceiver and a H-horizontal transceiver. The uw- sink uses the H-transceiver to communicate with the sensor nodes to: (i) transmit commands and structure data to the sensors (uw-sink to sensors); (ii) collect controlled data (sensors to uw-sink).The vertical link is used by the uw-sinks to relay data to a surface station. In bottomless water applications, V-transceivers must be extended level transceivers as the ocean can be as deep as 10 km.

The surface station is fitted with an acoustic transceiver which can handle multiple simultaneous communications with the uwsinks that are deployed. To communicate with the onshore sink (os-sink) and/or a surface sink (s-sink), it is also fitted with a extended level RF and/or satellite transmitter. Sensors can be linked through direct links or via multihop paths to uw-sinks. In the former case, each sensor sends the collected data directly to the chosen uw-sink.

However, the power needed for transmitting in UW-ASNs may decrease with power better than 2(two) of the distance, and the uw-sink may be far from the sensor node. Therefore, while direct connection to network sensors is the easiest way, it not be a most energy-efficient solution. However, due to increased acoustic nosiness due to high transmission capacity, direct connections are more likely to diminish the network throughputIn the case of multi-hop routes, as in earth sensor networks, intermediary sensors convey the data produced by a source sensor until it reaches the uw-sink. It can result in energy savings and augmented network efficiency but it increases the routing functionality intricacy. In reality, each network system classically takes part in a collaborative process whose aim is to disseminate design(topology) information so that it is possible to make effectual and loop-free routing decisions at each intermediary node. This method includes the processing and signaling. Since energy and power are precious properties in underwater situations as discussed above, the target in UW-ASNs is to convey event features by leveraging multi-hop lanes and lessening the overhead signaling required to simultaneously construct underwater paths. Three-dimensional underwater sensor networks Three-dimensional underwater networks are used to distinguish and track anomalies that cannot be sufficiently spotted by ocean foot sensor nodes , i.e. to perform mutual selection of the Three Dimention ocean surrounding. Sensor nodes drift at various intensities in 3-dimensional underwater networks, to notice a given spectacle. One potential solution will be to connect each uw-sensor node to a surface boom using wires whose length can be changed to change each sensor node's depth. While this solution tolerates the sensor network to be deployed certainly and rapidly, numerous floating sustains can block ships traversing on the marine, or adversaries in military locations can easily discover and disengage them. In addition, floating buoys are vulnerable to weather and pilfering or hacking. For these purposes, the anchoring of sensor instruments to the bottom of the ocean may be another solution. Every sensor is fastened to the foot of the ocean, and is fitted with a fluctuating buoy which a pump can escalate. The sustain pushes the sensor hooked on the water surface. The sensor deepness can then be adjusted by changing the rope length that fixes the sensor to the anchor, using an automatically operated motor that inhabits on the sensor. One problem that needs to be talked in such an architecture is the impact of ocean flows on the mechanism defined to regulate the sensor deepness. Many challenges arise with such a planning, that need to be solved in order to enable 3D monitoring,

Sensing coverage: To attain three-D exposure of the ocean floor, sensors will collaboratively control their deepness conferring to their recognizing ranges. Therefore sampling of the anticipated spectacle must be possible at all distances.

Communication coverage: Because the concept of uw-sink does not occur in three-D uw networks, sensors should be competent to convey information through multi-hop lanes to the surface station. Therefore network devices should synchronize their distances in such a method that the topology of the network is forever coupled, i.e. there is forever at least one lane from each sensor to the surface location. Attention of suspecting and interaction is thoroughly studied in a three-D situation. The width, lowest and highest unit of the reachability table that expresses the network is imitative as a purpose of the communication range, whereas differing grades of attention are defined as a function of the suspecting scope for the area. UW-ASNs may use these techniques to examine the attention concerns

5.MAC PROTOCOLS FOR UNDERWATER ACOUSTIC SENSOR NETWORK

5.1Design challenges of mac protocol Underwater acoustic sensor networks:

Differences with terrestrial sensor networks: The main differences between terrestrial and uw sensor networks are:

Cost. Whereas surface-dwelling sensor nodes are expected to become increasingly inexpensive, underwater sensors are expensive devices. This is especially due to the more complex underwater transceivers and to the hardware protection needed in the extreme underwater environment.

Deployment. Although heavily organized land-dwelling sensor networks, uw organization is known to be sparser owing to the costs intricate and the difficulties accompanying with the organization itself.

Power. Owing to greater distances and more complicated signal treating at the receivers to recompense for the channel's deficiencies, the power desirable for acoustic uw communications is greater than in land-dwelling radio communications.

Challenges to MAC Protocol design for UWSNs Conceiving a MAC protocol is a major challenge for UWSN deployment. Ideally, keeping in mind the harsh characteristics of the underwater acoustic environment, an ideal underwater MAC protocol would have higher network efficiency and lower energy consumption.

Network Topology and Deployment in UWSNs.:

MAC protocol efficiency for UWSNs is highly dependable on the deployment of underwater nodes which may be sparse or dense. Event readings of sparsely dispersed nodes will be extremely uncorrelated due to the availability of long- range acoustic modems, since the sensor nodes can track and communicate at long distance.

Synchronization.: Synchronization is a crucial problem in the design of MAC protocols, as MAC protocols such as the duty cycling approach usually operate on the basis of node time synchronization. The task cycling method cannot ensure successful operation of sensor networks by managing time variability between sensor nodes without precise synchronization. This is because the delay in propagation is much higher and changes occasionally.

Hidden Node and Exposed Node Problem:

Hidden node and revealed node issues appear more explicitly in MAC protocols for contention-based collision avoidance. A hidden node situation occurs when one node is unable to sense one or more nodes which can interfere with its transmission. An exposed node situation arises when a station delays the transmission due to another overheard transmission that would not collide with it. In the first case, collision will occur, and the nodes will continue to attempt positive transmission

High Delay Associated in Handshaking:

Conventional handshaking schemes may reduce the impact of secret terminals and exposed terminals that take time and energy to share information on controls. The sharing of control information takes the most time to communicate. It results in the nodes not getting much time for delivery of the payload. The use rate for channels is very low. The handshaking schemes have a high delay in propagation, which is a major challenge to effective protocol design.

Power Waste in Collision:

It is observed that a node consumes more transmission power than reception power. The power ratio required for transmission reception usually is 1/125. In addition , the ratio gets worse as collisions often occur due to the lack of an effective mechanism for preventing collisions. Therefore a MAC protocol provision should be able to avoid or mitigate collisions.

Near-Far Effect. :

At the transmitter the transmission power should be selected so that the signals transmitted from the transmitter to the intended receiver should be received correctly with the desired SNR which is neither lower nor higher than the required SNR. The near-far effect occurs when the signals transmitted by a receiver from a transmitter near the receiver are stronger than those obtained from another transmitter located further away. Nodes 1 and 3 are far apart, and can therefore simultaneously communicate without triggering collisions. At node 2, the node 1 originating SNR level of the signals is higher than that of node 3 due to the high noise level generated by the node 1 originating signals. So node 2 can receive all signals, but it cannot decode the messages from node 3. As a result node 1 shows the transmissions from node 3 accidentally

Centralized Networking :Centralized solutions over an acoustic channel are not appropriate in UWSNs. In a centralized network situation, node-to - node communication takes place through a central station. A big downside of this configuration is the existence of a single fault point. The network also can not reach wide areas due to the restricted range of a single modem

5.2. Mac protocols for underwater acoustic communication

H-MAC:H-MAC(media access control) is established on the IEEE 802.11's PSM mode and slotted aloha. In H-MAC, time is separated into huge frames, each frame has 2 slices: an active (on-time) portion and an inactive portion(sleeping-time). Active part is like ATIM window in proNX Service Manager (PSM) mode and the sleeping part is further split into N slots, where each slot is slightly larger than the data frame. The nodes which have packets to transmit negotiate slots during active time with the destination nodes and transmit / receive the data packets during sleep time in pre-negotiated slots. If the nodes do not have to send or receive any data packets during the sleep-time slots go to sleep.

PMAC

PMAC: It's the slotted time protocol, like SMAC. In SMAC, a node can remain awake for a certain time slot duration, and go to sleep for the remaining duration; while in PMAC, a node can either be awake or sleep for a time slot. In PMAC, through patterns, a sensor node gets knowledge about the behaviour in its neighbourhood beforehand. Based on these patterns, if there is no traffic in the network a sensor node can put itself in a long sleep for several time frames. If there is some activity in the area, through the patterns, a node will recognize this and wake up once appropriate. Thus, PMAC aims to conserve more power than SMAC and TMAC, without sacrificing on the transmission.

TMAC:

TMAC prevents overhearing, crashes, and constant switching between the active and sleep modes. In heavy traffic conditions of wireless sensor networks, these problems are generally considered to be the most important reasons behind energy waste. Reservation- MAC (R-MAC), uses two separate periods during the process of communication. In the first cycle, nodes battle for the allocation of time slots for their future transmissions, and in the second period, each node transmits its data or receives data from a sender. When a node is aware of its time slot for transmission and/or reception, it remains active for these time slots only and re-enters the sleep mode during the remaining transmission cycle

UWAN-MAC

The key assumption in the UWAN-MAC protocol design is that the power consumption in the sleep mode is lower than in the idle listening mode, at each node. Therefore, there is an incentive to put the nodes to sleep for energy conservation. UWAN-MAC merely addresses stationary node networks. Node sends the SYNC packet at the beginning of the cycle time in this method and then goes to sleep by turning off its transceiver to conserve energy. A collision can occur in the following two ways, in this protocol. Next, there could be a "transmit – receive collision" in which a node is transmitting while the packets of other nodes arrive at its receiver and interfere with the node's own transmission. Seeing that the transmit power is typically much greater than the power needed for effective packet reception, in this case the received packet will not be properly decoded at the node. Second, if

SMAC

The basic concept of SMAC is periodic sleep listening schedules which the sensor network handles locally. Nodes that are virtually adjoining custom clusters, and share a shared schedule. That is once two nodes are side by side and fall hooked on 2 dissimilar clusters, both clusters wake up on listening schedule. When nodes wake up to two separate schedules, this often results in greater energy consumption. It is also necessary to communicate the schedules to different simulated cluster nodes which are consummate by SYNC data packets and the time it is directed is known as the harmonization era. CS aids in stopping accidents. CS stands for the method of preventing collisions by carrier sense. Additionally, transmission of unicast data-packets is complete by means of RTS / CTS. A new and revolutionary function of Sensor-MAC is the message passing through which, by splitting it into small messages, a lengthy communication is directed in eruption. Using raising overhead helps in energy saving.

This idea of sleeping schedule, however, will overly consequence in a great interval called latency, which would be important for multi- hop routing algorithms, since every node in among will have its individual sleep schedules. This is called sleep break. Using adaptive listening technique can overcome this drawback, and therefore the complete suspension can remain upgraded as suggested in Timedout-MAC next justified. With that procedure, the eavesdropping node wakes up at the end of the transmission for a short time. And, if this node is the next-hop node, the transmitting / passing node will take the data from it immediately.

Advantage: Use of the battery is improved with the introduction of sleep schedules. This protocol is humble to enforce, long messages can be transmitted effectively by means of the technique of data forwarding.

Disadvantage: RTS / CTS are not castoff because of which broadcast might outcome in collision. Adaptive attending origins eavesdropping or lazy attending which leads to ineffective use of the power. Since cycles of sleep and listening are static variable traffic weight creates the algorithm well-organized.

6.COMPRESSION OF MAC PROTOCOLS: TABLE-1

MAC PROTOCOLS FOR UWSNS Protocol	Topology	Advantage	Disadvantages
Modified MAC (Media Access Control)-2001	Point to point	Guarantees a minimum overall degree of Drive and permit fast data broadcast	Using handshakes, Reconnaissance and retransmission required
CDMA-Based Medium Access Control-2009	Closed-loop delivery	Upsurge re-usability of the channels and diminish re-broadcast	Requires optimal setting Provide power and length of code.
Distance-aware collision avoidance protocol (DACAP)-2010	Multi-hop	Upsurges performance at the same time, diminishing bottom-to-end inexpression and energy per bit Ingesting.	Have to determine the scale of the pieces
Carrier sense multiple access (CSMA) and Distance-aware collision avoidance protocol (DACAP)-2012	Multi-hop	The best findings come from CSMA with tiny data packets and DACAP with extended data packets	Choosing a priori package size, which can significantly punish the overall Power act.
Distance Aware CSMA -2013	Distributed	Contributes high performance than CSMA practice	Validate via semi-physical simulation stand.
Multi-band Noise-aware MAC-2013	Multi-hop	Could track loud vessels in encroachment & NAMAC significantly decreases network disconnections.	Switching the Frequency Band isn't easy-going
Relative clock based and energy sense TDMA (RE-TDMA)-2014	Centralized	The harmonization of the timer and the transmission of signals is not Requires	Need to choose a sufficient set of guards

TABLE:2

Protocol	S-MAC	T-MAC	D-MAC	P-MAC	H-MAC
Time-Sync	✓	✓	✓	✓	✓
Point to Point	✓	✓	x	✓	✓
Broadcast	x	x	x	✓	✓
Convergecast	x	x	✓	✓	✓
Mobility	x	x	x	✓	✓
Type	Using Carrier Sense Multiple Access	Using Carrier Sense Multiple Access	Using Time Division Multiple Access/ Slotted Aloha	Usin SA (Slotted Aloha)	Using Carrier Sense Multiple Access/ Slotted Aloha
Adaptive to change	ok	good	Poor	Good	Good

Half/Full Duplex	Send or receive at a time	Send or receive at a time	Can send and receive simultaneously	Can send and receive simultaneously	Can send and receive simultaneously

7.CONCLUSION

In this paper here we presented the comprehensive survey of Underwater acoustic wireless sensor network and its MAC protocols. The main objective of this review is to understand the underwater wireless communication and its challenges of making the network and the different type of communication mediums. Also, we presented the details of media access control protocols and its design challenges. Based on this mac protocol review we have the future work to investigate the mac protocol using stochastic network calculus and underwater simulators

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