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# Review on MAC Protocols for Underwater Acoustic Networks

**Jil Barot[1], Prof. Samip A. Patel[2]**
[1] *P.G.Student, Birla Vishwakarma Mahavidyalaya, V.V Nagar, India*
[2] *Asst. Professor I.T. Department, Birla Vishwakarma Mahavidyalaya, V.V Nagar, India*

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**Abstract -** *Underwater Wireless Sensor Networks supported variety of application in various fields like military, scientific and civilian. In UWSNs, Main Issues are propagation delay, limited bandwidth, energy efficiency, high bit error rate and noise. MAC layer plays a major role in UWSN because it has large effect to the overall network performance. On other side UWSNs uses acoustic wave rather than radio wave as like terrestrial networks. Use of acoustic wave gives us new research challenges for the design of MAC protocols in UWSNs. As there are various issues, energy efficiency plays the major role because sensor nodes are equipped with batteries which are not easy to recharge. This paper gives brief overview of environment for UWSN and challenges related to create MAC protocols. There are various MAC protocols developed for UWSNs. This paper gives survey of some MAC protocol according to their existing implementation.*

***Key Words*: Underwater Wireless Networks, MAC protocols, underwater acoustic environment.**

## 1. INTRODUCTION

Underwater Acoustic Communication (UWC) is wide area for explore and observe the ocean because ocean covers two-thirds of the earth surface. In last few years, Research and development of Underwater Wireless Networks has been growing. In Underwater Acoustic Sensor Networks (UWSNs) have many number of underwater mobile sensor nodes with low bandwidth acoustic modems. These sensors are deployed as per the venue of interest for performing different monitoring and exploring tasks for underwater communication. For this objective, sensors additionally autonomous vehicles organize in network which can fulfil the characteristics of the ocean environment.

Underwater Wireless Networks has different applications:

- Ocean sampling networks: It is used to perform adaptive sampling of 3D coastal ocean environment by Network's sensors and vehicles.
- Environmental monitoring: UWNs can execute biological, chemical and nuclear pollution monitoring.
- Undersea explorations: UWSNs can assist detecting underwater oilfields or reservoirs which determine routes for laying undersea cables, and helped in exploration for important minerals.
- Disaster prevention: Sensor networks can measure seismic action through remote locations which can give tsunami warnings to coastal areas and also examine the special effects of submarine earthquakes.
- Assisted navigation: Sensors can be used to locate dangerous rocks or shoals in shallow waters which gives mooring positions, submerged wrecks.
- Mine reconnaissance: Multiple AUVs with acoustic and optical sensors can be used to carry out quick environmental evaluation and detect mine-like objects for simultaneous operations.

MAC protocols for UWSNs are an important design aspect to provide energy and high throughput in efficient way because the medium access layer protocol correlates nodes, which gives access to the shared wireless medium. Nodes in the networks require sharing the common broadcast channel which can be enabled by MAC protocols. MAC protocols is used to resolve transmission collisions or prevent simultaneous transmissions of data packets while maintaining and providing low channel access delays, energy efficiency moreover equity among nodes in a network. A MAC layer protocol in UWSNs has much importance on the network utilization in the presence of a harsh underwater acoustic channel [2].

Large quantity of research on design and performance UWNs has been done. These Various aspects of UWNs for work study are Medium access, network, transport, localization, synchronization protocols, and MAC protocols. There are some surveys on MAC protocols in UWNs [2, 3] that have been summarized the variations of designs and implementations.

In section II of this paper, I think the some factors that effected on design of underwater MAC protocols. In section III, I consider existing UWA MAC protocols based on survey of some papers. Ultimately, we conclude the survey in section IV.

## 2. FACTORS EFFECTED TO THE DESIGN OF MAC PROTOCOLS

MCA layer protocol plays a cardinal aspect to acquire the Quality of service (QoS) in UWANs. In underwater acoustic environment, attenuation of radio wave is very much. Therefore only short distances can be travelled by signals.

Additionally, acoustic waves attenuate less than radio waves. So we describe the factors that affect the underwater acoustic environment and challenges for the design of MCA protocols in this section [2, 3].

- **High and Variable Propagation Delay**: The propagation speed of acoustic signals in water is typically 1500 m/s. So the propagation delay in underwater is higher than that of radio frequency channel (RF) of the air. The propagation delay of underwater depends on salinity, temperature and depth of the water. For short range RF propagation delay is negligible, which can't achieve in underwater communications.

- **Limited Bandwidth and Data Rate**: The acoustic bandwidth depends on the transmission distance because of high noise at low-medium frequencies. The data rate of underwater acoustic sensors is maximally like 100 kbps. Therefore an acoustic channel requires careful design of MAC protocols due to limited bandwidth.

- **Noise**: Environment noises like man-made noise and ambient noise involved in underwater networks. Man-made noise like machinery noise of pumps and natural noise refers to seismic and biological phenomena which can cause ambient noise.

- **Energy consumption**: Sensors are equipped with batteries, which can't be charged easily.

- **High Bit Error Rates**: The underwater channel is impairing appropriate to multi-path and fading. Because of multi-path, acoustic channels have elevated bit error rates. It is a challenge for a MAC protocol to provide reliability and preserve connectivity in such propagation circumstances.

So it is essential to expand MAC protocols which can take all the characteristics into account suitable for underwater acoustic communications.

## 3. EXISTING WORK ON UW-A MAC PROTOCOLS

There are various issues as we discussed but long Propagation delay is the main issue in underwater acoustic networks. There are several protocols developed to resolve the issues, some of the protocols are given below.

Jin-Ki Yeo, Young-kon Lim, and Heung-Ho Lee [4], this paper is published in IEEE International Symposium on Industrial Electronics, 2001. In this paper, communication protocol recognized for underwater vehicles. Here acoustic-based underwater telemetry links was implemented, which include the subsystems such as transducer with filter and preamplifier, underwater acoustic modem, signal modulator or demodulator and digital signal processing module [4]. It ensures a definite level of highest throughput and allow rapid data transmission through the acoustic-based multiple channel.

Dario Pompili, Tommaso Melodia, and Ian F. Akyildiz [5], this paper is published in IEEE Transactions on Wireless Communications, 2009. These paper uses CDMA for closed loop distributed algorithm for setting optimal transmit power and code length. CDMA for UW-ASN increase channel reusability and reduce retransmission. It is, 1) Robust to frequency selective fading 2) Satisfy the effect of multipath at the receiver by exploiting Rake filters 3) Allows receivers to differentiate among signals simultaneously send by multiple devices.

Stefano Basagni, Chiara Petrioli, Roberto Petroccia, and Milica Stojanovic [6], this paper is published in IEEE Transactions on OCEANS 2010-Sydney. In this paper shows that to avoid data-data collision, RTS/CTS Packets are used but there is still collision between data-control packets. To overcome this collision, Distance Aware Collision Avoidance Protocol (combination of CSMA & Medium Access Collision Avoidance) is proposed which use the dynamic fragmentation and reduce the traffic. Data packet fragmentation gives benefits to throughput efficiency, end-to-end latency and energy consumption.

Stefano Basagni, Chiara Petrioli, Roberto Petroccia, and Milica Stojanovic [7], this paper is published in IEEE Journal of Oceanic Engineering 2012. In this paper selection of packet size for multi hops communication is done. This focuses on two Protocol CSMA and DACAP & investigates the matrices like throughput, latency & energy consumption. It shows that CSMA with short data packets and DACAP with long data packets give the best result.

Jiarong Zhang, Gang Qiao, and Can Wang [8], this paper is published in IEEE Transactions on Information and Communications Technology 2013. It gives Improved CSMA (Distance Aware CSMA) with characteristic of long propagation delay depends on both range & frequency. This protocol gives high throughput than tradition CSMA. In this Protocol also shortens the hand shaking procedure between sender & receiver by setting sending time in stagger.

Loreto Pescosolido, Chiara Petrioli, and Luigi Picari [9], this paper is published in IEEE Transactions on International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob) 2013. In this paper, Nodes are equipped with Multiband Modems. So whenever Nodes detected noise in the band, it switched the frequency band. If noise increased above some threshold level, the nodes migrate to new frequency band which has better SNR. As soon as noise is not present, switch back to default one. This protocol can detect noisy vessel in advance. Network disconnected is drastically reduced by NAMAC.

Jiarong Zhang, Gang Qiao, and Feng Zhou [10], this paper is published in IEEE Transactions on OCEANS 2014 - TAIPEI. In this paper, all nodes mapped the network schedule on its local clock according to the relative propagation delay and worked on it. It is designed for the Centralized networks. The Gateway makes the sub-nodes work in parallel according

their propagation delays and fixes the clock offset during data transmission.

Yu Han, Yunsi Fei [11], this paper is published in IEEE Transactions on International Conference on Computing, Networking and Communications 2015. In this paper, they eliminated the hand shaking procedure and achieved parallelism between multiple senders for higher channel utilization. It is utilizing long propagation delay as exclusive channel access where multiple senders send packets can arrive at same receiver at different time and can be decoded.

Baoru Gao, Ling Zhang, Dongsheng Chu, Jiucai Jin, Lanjun Liu [12]. This paper is published in IEEE Transactions on OCEANS 2016 IEEE-Shanghai. In this paper, It worked in two phases: 1) Restructuring, recluster the mobile node as the cluster head. This cluster head calculates the delay of every sensor node to decide when to transmit data. 2) Data Transfer Phase, based on Improved TDMA Protocol, which doesn't require synchronization. It used personalized time compensation mechanism for every sensor node to predicted distance. This protocol improve throughput and reduce the packet collision rate in moving process.

**Table -1: DIFFERENT MAC PROTOCOLS FOR UWSNS**

| Protocol | Year | Topology | Advantage | Disadvantages |
|---|---|---|---|---|
| Modified MAC(Media Access Control) [4] | 2001 | Peer to peer | Ensures a certain level of maximum throughput and allows fast data transmission | Use of handshaking, acknowledgement and retransmission needed |
| CDMA-Based Medium Access Control [5] | 2009 | Closed-loop distribution | Increase channel reusability and reduce retransmission | Need to set optimal transmit power and code length. |
| Distance-aware collision avoidance protocol (DACAP) [6] | 2010 | Multi-hop | Increases throughput efficiency simultaneously, reducing end-to-end latency and energy per bit consumption. | Need to decide fragments size |
| Carrier sense multiple access (CSMA) and Distance-aware collision avoidance protocol(DACAP)[7] | 2012 | Multi-hop | CSMA with short data packets and DACAP with long data packets give the best result | Choosing packet size a priori, , in an ad hoc manner, may severely penalize the overall throughput performance. |
| Distance Aware CSMA [8] | 2013 | Distributed | Gives high throughput than tradition CSMA | Validation through semi physical simulation platform. |
| Multi-band Noise-aware MAC [9] | 2013 | Multi-hop | Can detect noisy vessel in advance & Network disconnected is drastically reduced by NAMAC. | It is not easy to switch the frequency band |
| Relative clock based and energy sense TDMA (RE-TDMA) [10] | 2014 | Centralized | Clock synchronization and signal broadcasting synchronization is not needed | Need to chose a proper guard interval and work duration. |

## 4. CONCLUSIONS

In recent years, so many works is done in Underwater Acoustic Networks (UWANs) because ocean covered most of the earth's surface. There are sensor nodes and Autonomous Underwater Vehicles (AUVs) used to gather information about natural underwater resources and scientific data for monitoring mission, which are connected via acoustic links. After surveying these papers, we can conclude that if we can use limited channel resources in efficient manner, we can resolve the performance issues in MAC Layer of Underwater communication.

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