© 2016 IJEDR | Volume 4, Issue 2 | ISSN: 2321-9939

A survey on energy efficient MAC protocol for Underwater Sensor Networks

[1]Saranya P.R, [2]Dr. Binu G.S, [3]Prof.Vinod G.
[1]PG Scholar, [2]Assistant Professor, [3]Associate Professor
Department of ECE,
NSS College of Engineering, Palakkad, India

***Abstract* - Underwater sensor nodes find applications in oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications. Moreover, unmanned or autonomous underwater vehicles (UUVs, AUVs), equipped with sensors, will enable the exploration of natural undersea resources and gathering of scientific data in collaborative monitoring missions. Underwater acoustic networking is the enabling technology for these applications. Underwater networks consist of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area. MAC protocol ensures data reliability in UWSN. The main goal of MAC protocol for underwater sensor network is to solve the data packet collision in terms of energy consumption.**

***Index Terms* - Underwater Sensor Networks, Acoustic Underwater Networks, Medium access control, Autonomous underwater vehicle.**

I. Introduction

The earth is a water planet as 71 percent of its surface is covered with water. The oceans contain about 96.5 percent of all earth water. Surprisingly, only very little ie., less than 10 percent is known about the Earth's water bodies despite of its vital role for nourishment, transportation, presence of natural resources, defence and adventurous purposes, while a large area still remains unexplored. Recently, ocean bottom sensor nodes are deployed to facilitate scientific and commercial applications, environment and pollution monitoring disaster prevention, tactical surveillance and assisted navigation. To make these applications viable, underwater communication should be enabled among underwater devices. Typical underwater applications require multihop co-operative network where sensor nodes must be able to exchange confi guration, location and movement information and to relay data to an onshore station using satellite terrestrial network radio frequency (RF)[1]. However, RF can be propagated through conductive sea water only at low frequencies ranging from 30-300 Hz and requires large antenna and high transmission power. Optical signals also suffer from attenuation and scattering. So, these are not suitable in underwater environment. As an alternative, wireless acoustic sensor network (WASN) appears to be a feasible technology for underwater communication. Acoustic communications are the typical physical layer technology that propagates sound waves for communication. The typical frequency range is between 10 Hz to 1 MHz. The challenges in underwater sensor networks (UWSN) are as follows: The propagation delay is 5orders of magnitude higher than in radio frequency (RF) terrestrial channels, due to low speed of sound (1500m/s). Underwater accoustic channel is severely impaired especially due to multipath and fading problems. Available bandwidth is distance dependent and in general is limited to few tens of KHz due to high environmental noise at low frequencies and high transmission loss at high frequency. High bit error rate and temporary losses of connectivity can lead to the formation of shadow zone, underwater region, where the signal reception is impaired due to deep signal dips and fading caused by multipath.

Underwater sensors are prone to failures because of fouling and corrosion. Batteries are energy constrained and cannot be recharged. Data reliability is one of the most important requirements in underwater sensor networks. Energy efficiency is the major issue in designing an efficient reliable data transfer protocol. Accoustic transmission is not suitable for shallow water because of its poor performance. This is due to turbidity, pressure gradient ambient noise, salinity gradients. MAC protocol ensures data reliability in UWSN. Main goal of MAC protocol is to achieve high network throughput, low energy consumption and channel access delay. Another important attribute is the scalability to the change in network size, node density and topology. Some nodes may die over time; some new nodes may join later; some nodes may move to different locations. The network topology changes over time as well due to many reasons. A good MAC protocol should easily accommodate such network changes. Other important attributes include fairness, latency, throughput and bandwidth utilization. These attributes are generally the primary concerns in traditional wireless voice and data networks, but in sensor networks they are secondary[2].

II. Applications of Underwater sensor networks

A. Ocean sampling networks

Networks of sensors and vehicles can perform synoptic, cooperative adaptive sampling of the 3D coastal ocean environment.

B. Undersea explorations

Underwater sensor networks can help detecting underwater oil fields or reservoirs, determine routes for laying undersea cables, and assist in exploration for valuable minerals.

C. Environmental monitoring

UWSNs can perform chemical, biological and nuclear pollution monitoring.

D. Disaster prevention

Sensor networks that measure seismic activity from remote locations can provide tsunami warnings to coastal areas, or investigate the effects of submarine earthquakes.

E. Assisted navigation

Sensors can be used to identify hazards on the seabed, locate dangerous rocks or shoals in shallow waters, submerged wrecks.

F. Distributed tactical surveillance

Fixed underwater sensors can collaboratively monitor areas for surveillance, reconnaissance, targeting and intrusion detection systems.

G. Seismic Monitoring

Frequent seismic monitoring is of great importance in oil extraction from underwater fields to access field performance. Underwater sensor networks would allow reservoir management approaches.

H. Equipment Monitoring

Sensor networks would enable remote control and temporary monitoring of expensive equipment immediately after the deployment, to assess deployment failures in the initial operation or to detect problem.

III. Network Model of UWSN

UWSNs have emerged to be an ideal type of systems for efficiently exploring and observing the ocean. An UWSN consists of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area. To achieve this objective, sensors and vehicles self-organize into an autonomous network which can adapt to the characteristics of the ocean environment[3].

Fig 1 shown below is the network model of UWSN. The network is composed of underwater sensor node, underwater sink node and surface sink node. The underwater sensor nodes are deployed at the bottom of the monitored environment such as ocean and river. The underwater sink nodes takes charge of collecting data of underwater sensor deployed in the ocean bottom and send into the surface sink node. The surface sink node is attached to a floating buoy with satellite, RF or cell phone technology to transmit data to the shore in real time.

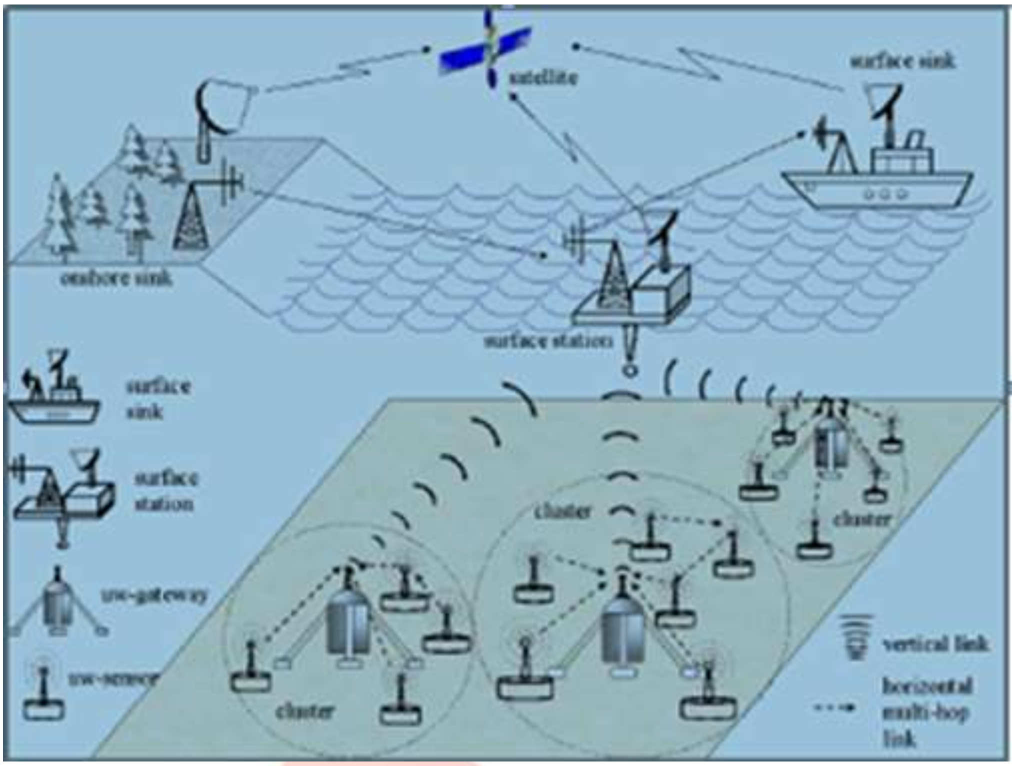

Fig1: Network Model of UWSN

MAC layer has the objectives of managing and controlling communication channels, which are shared by many nodes to avoid collisions and maintain reliable transmission condition. Due to the dense deployment of sensors in UWSNs, it is necessary to design an efficient medium access control (MAC) protocol to coordinate the communication among sensors. Major challenges in the design of underwater sensor networks are:

- Limited battery power because the batteries can't be recharged and the solar energy cannot be exploited.
- The propagation delay is higher than in radio frequency terrestrial channels.
- Available bandwidth is limited.
- Due to multipath and fading the underwater channel is severely impaired.
- Due to the extreme characteristics of underwater channel there will be temporary losses of connectivity and high bit error rates.
- Because of fouling and corrosion, underwater sensors are prone to failures.

IV. DELAY TOLERANT MAC PROTOCOLS

A. Latency tolerant MAC protocol

A MAC protocol is proposed that is based on reserved time slot. Design of MAC protocol in UWSN is a challenging issue because of limited energy source and high propagation delay. The main goal of MAC design for UWSN is to resolve data packet collision efficiently with respect to energy consumption and it has significant impact on the system efficiency. The factors that affect the MAC protocol are fairness, energy consumption, latency and throughput. The bandwidth of accoustic links is very low because of the characteristics of UWSN. Time slot is allocated to each node for sending data such that data does not collide with another node's data. Synchronization algorithm is employed which synchronizes all the nodes in a distributed manner. Listen/sleep periodic operation is used for saving energy due to long propagation delay and limited energy. This results in increased overall throughput of network and reduced energy consumption. UWSNs consist of stationary and mobile nodes which are equipped with sensors, sonar's and video cameras. System architecture consists of 4 different types of nodes. They are sensor nodes, control nodes, super nodes and robotic submersible nodes. Sensor nodes collect data through attached sensors. Accoustic modem communicates with other nodes. Control nodes are connected to internet on the platform which is connected to accoustic modem with wires for communicating with the sensor nodes. Super nodes constitute a large network. Access to network with high speed that can relay data to the base station very efficiently. Robotic submersible nodes interact with the network via accoustic communication (less attenuation). Proposed protocol has 2 phases: Initialization phase and transmission phase. In the initialization phase node randomly selects a schedule and broadcast it to its neighbours. The neighbours follow and store schedule in tables. In the transmission phase each node reserves a time slot to transmit data. Three control packets with same size is defined: REV, ACK-REV, ACK-DATA. Using short ranges of UW acoustic communication links to achieve higher throughput is also used. Here, fixed nodes with 2D architecture are used. More studies can be done according to the movement of the nodes in 3D architecture. Communication between the nodes is single hop. It was suggested that research can be continued with improving the latency caused by periodic sleep of each node in a multihop network[4].

B. UWAN-MAC

This protocol is used for delay tolerant applications. This protocol operates under large propagation delays and focus on delay tolerant such as CTD (Conductivity-temperature-depth). Power consumption during the sleep mode is less compared to the idle listening mode. Facilitates the deployment of hundreds of nodes in harsh communication medium [5].

C. RMAC-M

Proposed protocol is a hybrid protocol, which employs a combination of schedule based access among the stationary nodes along with handshake based access to support mobile data mules. The new protocol, RMAC-M is developed as an extension to the energy efficient MAC protocol R-MAC by extending the slot time of R-MAC to include a contention part for a hand shake based data transfer. The mobile node makes use of a beacon to signal its presence to all the nearby nodes, which can then hand-shake with the mobile node for data transfer. The new protocol provides efficient support for a mobile data mule node while preserving the advantages of R-MAC such as energy efficiency and fairness[6].

D. NOGO-MAC

NOGO-MAC (Node Grouped Ofdma MAC) which is based on orthogonal frequency division multiple access (OFDMA) is proposed, which exploits the physical characteristic that propagation loss of acoustic wave depends on the distance more heavily at high frequency than at low frequency. Sensor nodes are grouped according to the distance to sink node. Each group uses a different frequency band in such a way that sensor nodes which are closer to the sink node use higher frequency band and farther ones use lower frequency band**.** Proposed scheme not only enables all sensor nodes to maintain the signal-to-noise ratio above a certain required level , but also reduces overall transmission power consumption[7].

V. MULTICHANNEL MAC PROTOCOLS

Multi-channel media access control (MAC) is important in wireless sensor networks because it allows parallel data transmissions and resists external wireless interference. Existing multi-channel MAC protocols, however, do not efficiently support delay-sensitive applications that require reliable and timely data transmissions. In addition, multi-channel operation is inherently deficient for supporting multi-hop broadcasting, due to independent wake-up schedules on sensors[8].

A. RM-MAC

A routing-enhanced multi-channel MAC (RM-MAC) which allows nodes to coordinately select their channel polling times based on cross-layer routing information is proposed. RM-MAC also supports a ripple broadcast mechanism which achieves efficient multi-hop broadcast among sensors. RM-MAC provides significant improvement in terms of end-to-end delay, under a wide range of traffic loads including both unicast and broadcast traffic. RM-MAC attempts to reduce delivery latency and provide multi-hop broadcast support in an energy efficient fashion. The proposed protocol effectively addresses sleep delay and multi-channel broadcast problem. Nodes in RM-MAC calculate channel polling subslot based on its hop distance to sink node. The ripple broadcast mechanism makes broadcast period of nodes sequentially distributing in a frame. In addition, RM-MAC considerably reduces redundant broadcast reception [9].

B. CUMAC

A new protocol called CUMAC (Co-operative underwater multichannel MAC) is proposed. CUMAC utilizes the co-operation of neighboring nodes for collision detection and a simple tone device is designed for distributed collision notification. It provides better system efficiency while keeping overall cost low. In CUMAC, when a node has packets to send, it will initiate channel negotiation process which consists of a RTS/beacon/CTS control message exchange on the control channel. During this process, the receiving node co-operates with its neighboring nodes for channel selection and collision detection. After a data channel has been successfully selected both the sender and the receiver switch to the selected data channel for data transmission. As a future work, the optimal bandwidth allocation strategy for the control channel and data channels is investigated. Implementing CUMAC in UWSN testbeds and evaluating its feasibility and practicality in the real world is also done. Investigation can be done in other collision free multichannel MAC protocols such as TDMA/CDMA based MAC protocols for static UWSN[10].

C. MM-MAC

Most of the existing UWSN medium access control protocols handle the collision problem in a single hop or light loaded environment. They fail to function effectively in a multihop network consisting of more sensor nodes with heavier traffic loads. Using the concept of cyclic quorum systems, a distributed multiple rendezvous multichannel MAC protocol to reduce collision probability is proposed. Advantages of the proposed protocol are threefold:

- Only one modem is needed for each node to solve the missing receiver problem which is often encountered in multichannel protocols.
- Multiple sensor node pairs can complete their channel negotiations on different channels simultaneously.
- Data packets will not be collided by control packets and vice versa.

MM-MAC speed up the channel negotiation and prevents the contention problem. The separation of control and data transmission also helps to reduce the collision probability of data packets. MM-MAC[11] has better performance in that it achieves higher throughput.

D. ROM-MAC

Proposed a multichannel MAC protocol in underwater acoustic sensor networks for transmitting monitoring data. To increase the bandwidth utilization, multichannel concept is proposed but suffers from the rendezvous and complicated hidden terminal problems. The negotiations and communications are based on the channels and the time of receivers. The bandwidth utilization and throughput in the networks are increased as well as the waiting time of each node is decreased by ROM-MAC protocol[12].

E. DMM-MAC

Another way to conserve energy is to reduce the idle listening. Sensor MAC (S-MAC), quorum-based MAC (Q-MAC), load-aware energy-efficient MAC (LE-MAC), and staggered scheduling (SS) apply duty cycling, ie., sensor nodes go to sleep periodically to save energy. In UWSN, duty cycled mechanism for power saving protocols such as Underwater acoustic wireless sensor network (UWAN-MAC), latency tolerant MAC (L-MAC) has been applied. There are many reporting models for sensor networks such as periodical reporting, reporting by querying and event-driven reporting. In periodical reporting, sensor nodes report sensory data to sink node periodically which provides stable and predictable traffic. In reporting by query and event driven re-porting, nodes report to the sink node when a query is received or a particular event is triggered and they provide bursty traffic. There is a dynamic-duty- cycled protocol, LE-MAC in traditional WSN. However, LE-MAC achieves dynamic duty cycling with possibly many unnecessary transmissions. This makes LE-MAC unsuitable for UWSNs wherein transmissions consume a lot of power. Here a dynamic duty-cycled multiple-rendezvous multichannel medium access control (DMM-MAC) protocol is used which effectively transmit bursty traffic in a multihop and duty-cycled UWSN. Nodes running DMM-MAC deliver bursty traffic by dynamically adjusting their duty cycles[13].

VI. COLLISION FREE MAC PROTOCOLS

A. ERMAC

ERMAC protocol reduces delay. Energy efficiency can be achieved by switching one sensor node to transmission mode and the other nodes to sleep mode. This protocol groups the sensor nodes according to their directions to the sink. Collision free and pipelined way of packet transmission can be done to the nodes belonging to the same group. TDMA time slot allocation mechanism (WA-TDMA) is been proposed. Wave like proliferation is formed when the slot allocation starts from the node[18].

B. Ordered CSMA

An ordered CSMA protocol is proposed, in which each station transmits data frame in a fixed order. Each station transmits immediately after the data frame transmission of last station in order, instead of waiting for a period of maximum propagation delay. To achieve this, each station is constantly sensing the carrier and listens to all the received frames. Network simulator with graphic user interface written in .NET framework is used here. This protocol improves throughput, delay and fairness. Ordered CSMA lacks ability in multihop routing. The protocols in network layer combined with ordered CSMA can be developed. This protocol may not only be implemented in underwater accoustic networks. The radio network with long propagation delay like satellite communication also can be investigated[16].

C. RMAC

RMAC protocol is used for long term aquatic monitoring applications. For same length of periods each node operates in listen and sleep modes periodically. Throughput and efficiency is increased by the usage of burst based acknowledgment technique. Centralized scheduling and synchronization is not required. Data packet collision can be avoided and fairness can be increased by transmission of control and data packets scheduling at both sender and receiver. Higher overheads are present in the form of control packets which make it inefficient in terms of bandwidth and energy. When a new node joins or a node failure occurs or a node wants to change its transmission schedule, no technique is been proposed. When all the nodes are static and no new node joins the network the protocol works in a satisfactory manner[17].

D. CMAC

C-MAC (cellular MAC), a TDMA based MAC protocol which divides networks into many cells is proposed. Each cell is distributed in a time slot. Nodes in a cell can only transmit packets in the cell's time slot. This protocol can avoid collision, minimize the energy consumption and increase throughput efficiency. The time is segmented into many cycles and each cycle consists of 7 time slots. A time slot consists of data transfer phase and protection phase. Length of protection phase is equal to the largest expected propagation delay in the network. Synchronization is used to predict when it has to send and when to receive. A long time slot minimizes the effect of clock drift and synchronization inaccuracy[21].

VII. CONTENTION FREE MAC PROTOCOLS

A. PLAN

PLAN is a MAC *P*rotocol for *L*ong-latency *A*ccess *N*etworks that is designed for use in half-duplex underwater acoustic sensor networks. CDMA is used due to its resilience to multi-path and Doppler's effects prevalent in underwater environments, coupled with an RTS-CTS handshaking procedure prior to the actual data transmission. This protocol is able to achieve high throughput performance as it uses minimal overheads in view of severe energy constraints faced by sensor nodes. As a future work, performance and the incorporation of a power control scheme to combat the near-far problem that is inherent in CDMA-based networks can be investigated[19].

B. TDMA based MAC protocol

A TDMA-based approach is proposed which is easy to dispose and energy-efficient. In this protocol a lightweight synchronization for all nodes is needed, which is achieved by the super frame. Defer time is used here instead of allocating time slots to each node. Guard time after every packet is used to avoid collision, and compute the optimal length of the guard time which is affected by the package length and the covariance of underwater propagation latency. As a future work, deployment of underwater sensor network to measure the propagation delay and test the performance of TDMA-based MAC protocol can be investigated[20].

C. OFDMA based MAC protocol

The channel is converted into parallel independent accoustic sub-channels that undergo flat fading. Multipath characteristics of a fading accoustic channel are exploited. This protocol reduces energy consumption. Collision avoidance method is not proposed here[21].

D. FDMA based MAC protocol

FDMA divides the available frequency band into sub bands and assigns each sub band to an individual user. The channel is used only by the user until it is released. The bandwidth of the FDMA channels is smaller than the coherence bandwidth of original transmission channel. Due to the limited bandwidth of underwater acoustic channels and the vulnerability of limited band systems to fading and multipath, the simple FDMA multiple access technique is not suitable for UWSNs [22].

REFERENCES

[1] Pei Huang, Li Xiao, Senior Member, Soroor Soltani, Matt W. Mutka, and Ning Xi," The Evolution of MAC Protocols in Wireless Sensor Networks: A Survey," IEEE Communications Surveys & tutorials, vol. 15,NO. 1, first quarter 2013.

[2] Farizah Yunus, Sharifah H.S.Ariffin and Yasser Zahedi, "A survey of existing Medium access control(MAC) for Underwater Wireless Sensor Network(UWSN),"Fourth Asia International conference on Mathematical/Analytical Modelling and computer simulation,2010,pp 544-549.

[3] J .Heidemann e t al.,"Underwater sensor networks: Applications, advances and challenges", Philos. Trans. R. Soc. A 2012, 370, pp. 158-175.

[4] Z. Azar and M. T. Manzuri; A latency-tolerant MAC protocol for underwater acoustic sensor networks; in Proc. IEEE Int. Conf. Control Autom. Syst., 2010, pp. 849-854.

[5] Min Kyoung Park and Volkan Rodoplu,"UWAN-MAC: An energy efficient MAC Protocol for Underwater Acoustic Wireless Sensor Networks,"IEEE Jounal of Oceanic Engineering,vol 32 ,No:3,July 2007, pp. 710-720

[6] S. A. Samad, S. K. Shenoy, G. S. Kumar, and P. R. S. Pillai,"RMAC- M: Extending the R-MAC Protocol for An Energy Efficient, Delay Tolerant Underwater Acoustic Sensor Network Application with A Mobile Data Mule Node, " Proceedings of Ocean Electronics (SYMPOL), Nov. 2011, pp.217 223.

[7] Jinyong Cheon, Hoi-Shin Cho, "A delay tolerant OFDMA based MAC protocol for underwater sensor networks," IEEE symposium on scientific use of submarine cables and related technologies (SSC),2011,pp.1-4.

[8] Zhong Zhou, Zheng Peng and Jun-Hong Cui and Zhjie shi, "Analyzing Multichannel MAC Protocols for Underwater acoustic sensor Networks," Computer science and engineering, university of Connecticut,storrs, CT0629,USA, pp. 1-20.

[9] Yang Yu, Jie Shi, Ke He,"A multichannel MAC protocol for underwater acoustic sensor networks," WUWNET'14, Proceedings of the international conference on underwater networks and systems, 2014.

[10] Z. Zhou, Z. Pengt, J.-H. Cui, and Z. Jiang; Handling triple hidden terminal problems for multi-channel MAC in long-delay underwater; in Proc.IEEE INFOCOM, 2010,DOI10.1109/INFCOM.2010.5462209.

[11] C.M. Chao and Y.Z. Wang," Multiple rendezvous multichannel MAC protocol design for underwater sensor networks,"IEEE Trans. Syst. Man Cybern.Syst., vol. 43, no. 1, pp. 128-138, Jan. 2013

[12] Li-Ling Hung, Yung-Jeng Luo, "ROM-MAC: A receiver oriented multichannel protocol for Underwater sensor acoustic sensor networks,"Consumer electronics Taiwan(ICCE-TW) IEEE international conference,2015,pp. 506-507.

[13] Chih-Min Chao, Ming-Wei Lu and Yu-Cheng Lin, "Energy-Efficient Multichannel MAC Protocol Design for Bursty Data Traffic in Under-water Sensor Networks," IEEE Journal of Oceanic Engineering, Vol.40, No. 2, April 2015

[14] V. Rodoplu and M. K. Park. "An Energy-Efficient MAC Protocol for Underwater Wireless Acoustic Networks", OCEANS, 2005 Proceedings of MTSIIEEE, 17-23 Sept. 2005, pp. 1198-1203.

[15] J Xiong et ai., "A Reliable and Efficient MAC Protocol for Underwater Acoustic Sensor Networks" , International Journal of Distributed Sensor Networks, vol. 2011, Article ID 257101, pp. 12.

[16] Y.-J. Chen and H.-L. Wang; Ordered CSMA: A collision-free MAC protocol for underwater acoustic network; in Proc. IEEE OCEANS Conf.,2007, DOI: 10.1109/OCEANS.2007.4449386.

[17] P. Xie and J. H. Cui, “R-MAC: An Energy-Efficient MAC Protocol for Underwater Sensor Networks,” Proceedings of the IEEE WASA’07 .

[18] T. H. Nguyen, S.-Y. Shin and S.-H. Park, “Efficiency Reservation MAC Protocol for Underwater Acoustic Sensor Networks,” Proceedings of IEEE NCM, Sept. 2008, pp. 365-370.

[19] Hui-Jin Cho, Jung-II Namgung, Nam-Yeol Yun, Soo-yun Park, “Contention free MAC protocol based on priority in underwater acoutic communication,”OCEANS, 2011 IEEE Spain, June 2011, pp.1-7.

[20] L. Hong, F. Hong, Z. Guo, and X. Yang, “A TDMA-based MAC Protocol in Underwater Sensor Networks,” Proceedings of IEEE WiCOM, Oct. 2008, pp. 1-4.

[21] Y. Ma, Z. Guo, Y. Feng, M. Jiang, and G. Feng; C-MAC: A TDMA based MAC protocol for underwater acoustic sensor networks; in Proc. IEEE Int. Conf. Netw. Security Wireless Commun. Trusted Comput.,2009, vol. 1, pp. 728-731.

[22] M. Hayajneh, I. Khalil, and Y. Gadallah, “An OFDMA-based MAC Protocol for Underwater Acoustic Wireless Sensor s Networks,”Proceedings of the 2009 International Conference on Wireless Communication and Mobile Computing, IWCMC’09, June.2009, pp.810-814