Prevailing Issues and Research Confront in Underwater Acoustic Sensor Networks

Manu Singh
Computer Science
GTBIT, Under GGSIPU
New Delhi, India

Tanu Singh
IT Department
Computal Systems Pvt Ltd.
New Delhi, India

***Abstract*— The focal point of this paper examines a variety of approaches and the challenges in the design and the implementation on the research area of underwater acoustic sensor networks. Research in an Ocean is still unexplored boundary in this planet as compared to terrestrial sensor networks. This paper highlights various applications like oceanographic data collection, offshore exploration, underwater robotics, disaster prevention, pollution monitoring. This paper deals with main features of underwater sensor networks, deployment analysis in Two-Dimensional and Three-Dimensional architecture and components. Also focus on the research issues like limited bandwidth, restricted battery power, propagation delay, high cost, failure of sensors due to fouling and corrosions cross layer protocol stack design in UASNs.**

Keywords-underwater acoustic communication, sensor network, deployment.

I. INTRODUCTION

In this globe, more than 70% surface of earth is sheltered with water. Still there are so many areas which are unexplored in underwater environment and many efforts can be done for further future researches in this field. Research on underwater networking has turn into an appealing, attracting and demanding field today due to its assorted applications like offshore exploration, pollution monitoring, oceanographic data collection, disaster preventions and tactical surveillance applications, etc [18]. The need of scientific, environmental, commercial safety, homeland security and for military awakens due to many natural and man – made disasters happening in the oceans. Underwater Wireless sensor networking is the facilitating technology for ocean applications. Underwater acoustic networks (UANs) are composed of underwater acoustic sensor networks (UASNs) and automated underwater vehicle networks (AUVNs) or the combination of both. UASNs are made of many sensor nodes used for monitoring and communication purpose [1]. AUVNs are composed of autonomous or unmanned vehicles with elevated mobility for exploration purpose [2].

In UASNs, acoustic communication is carried out with the help of acoustic signal from one node to another node. Acoustic signal is a sound signal that is produced by sonar for underwater communications or applications. The speed of acoustic signal is approximately 1500m/s which are lower than the speed of light and radio waves. But the sound signal travel through underwater is more appropriate than light and radio signals. Due to strong attenuation and absorption effects, electromagnetic waves can travel in water for a short range of distance. In other aspect, optical signal can travel through restricted range in an extremely fresh and clean water environment due to strongly scattered and absorption property [3][5]. But the absorption of acoustic signal is much lower than explained in above two signals [4].

A. Features of Underwater Networks

The research of underwater network reveals certain exclusive features as under [6]:

- Path Failure – Failure is due to strong attenuation and geometric spreading and increases with the propagation distance.
- Multipath and Noise – The multipath link depends on the network pattern. Horizontal channels may have elongated multipath link whereas Vertical channels need small time scattering for communication. This property may ruin underwater communication. Ambient noise is mainly caused by tide, current, storms, wind and rain which suppress the sound signal in underwater.
- Doppler Spread – Ruining the performance of digital communications is caused by Doppler frequencies. Parameters to predict Doppler spread are: key channel, mean angle of arrivals and angle spreads.
- Propagation Delay – Due to the presence of multiple paths, fading and limited bandwidth in underwater network, the receiver collects the transmitted signal with different delays. Large propagation delay affects energy efficiency and throughput in the underwater communications.

B. Comparision between UASNs and terrestrial wireless networks

Major comparison encountered between underwater network and terrestrial network are as follows [4][7][8][9]:

TABLE I.

Aspects	Comparison	
	Terrestrial Networks	***Underwater Networks***
Bandwidth	Not Limited	Limited
Communication	Electromagnetic Waves	Acoustic Waves
Propagation delay	Short	Long
Cost	Inexpensive	Expensive
Deployment	Dense	Sparse
Power	High	Low
Connectivity	Negilible	Maximum Loss
Noise	Limited	Maximum

C. Problems in Underwater Acoustic Sensor Networks

Major challenges encountered in the design of underwater acoustic networks are as follows [1] [10][12][13].

- Most of the terrestrial sensor nodes are static but this is not the case with underwater sensor node. Mobility of sensors are big future problem.
- The underwater communication is done with acoustic waves as radio communication cannot propagate in the deep water. Propagation speed of sound is again a problem.
- Due to limited bandwidth in underwater, data rate is extremely low.
- Underwater communication is affected due to multipath and fading.
- Propagation delay in underwater is higher in some order than in Radio Frequency (RF) terrestrial networks.
- Cost of underwater acoustic components is another giant problem.
- Limited Battery Power is big constraints in underwater communications.
- Real time communication is not possible yet in underwater network.

II. UASNS ARCHITECTURE

A. Network Toplology

An underwater acoustic network faces many issues in the network topology or architecture than ground based network topology or architecture. The primary design purposes of both the terrestrial and underwater networks are same. It means offering reliable connectivity among various sensors nodes, maximum utilization of bandwidth, increasing network capacity; minimize energy consumption, low propagation delay and cost.

In underwater environment two types of network topology can be highlighted. One is peer-to-peer topology and other is hierarchal topology. Peer-to-peer topology is classified as point- to- point and multipoint connection topology. Point-to-point topology means a node is connected to another node directly, no need of routing. Multi-hop connection topology means a node is connected to many other nodes. Energy efficiency is more in multi-hop topology. In the case of hierarchal topology, a node is used to convey the message from source node to its destination node. Here routing is required. Different kind of topology is used in underwater sensor networks. A topology of peer-to-peer communications is shown in Figure 1.

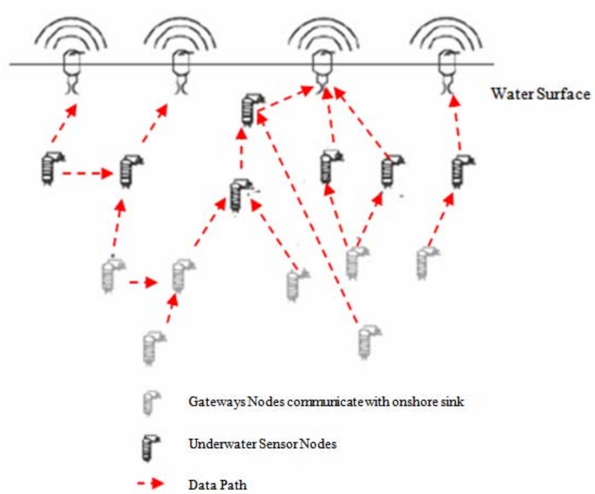

Figure 1. Peer-to-peer communications.

B. Static Two – Dimensional Underwater Sensor Networks

In static two dimensional UASNs, sensor nodes attached to surface buoys or anchored at the bottom of the ocean. In this network, sensor nodes are static. Underwater sensors are structured in cluster-based architecture. Various sensors are connected to underwater gateways (uw-gateways) by the use of wireless acoustic link. Various nodes convey the data and commands directly to uw-gateways through horizontal transceiver link. Uw-gateways are network devices which are used to relay data from the ocean bottom to ocean surface station through long range vertical transceiver signal. The surface station is equipped with acoustic transceiver for parallel communication from uw-gateways and in turn data conveyed to onshore sink through satellite or radio signals [14]. The Architecture of two dimensional underwater sensor networks is shown in Figure 2. The main issues in two dimensional architectures are listed below:

- Resolve minimum number of sensor nodes and uw-gateways that need to be arranged to attain communication coverage and sensing.
- Estimate the number of redundant sensor nodes to be arranged to reimburse for failure nodes.

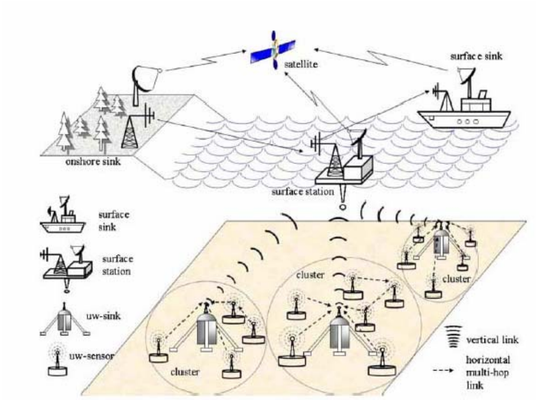

Figure 2. Example of 2D hierarchical architecture.

C. *Three-Dimensioanl Underwater Sensor Networks*

Three dimensional ocean phenomena cannot be effectively observed by the means of ocean bottom underwater sensor networks. In this architecture, sensors float at different depth to study 3D ocean phenomena [16]. Various sensor nodes are attached to surface buoys by the use of wires whose length can be synchronized to change the depth of each sensor nodes. The floating buoys are vulnerable to climate and tempering. This approach is very easy and enables quick deployment of sensor networks but various floating buoys can be easily detected and deactivated by the enemies in the ocean environment. A winch-sensor based device is used to solve the above problem. Deployment of winch-based sensor devices to the bottom of ocean is shown in Figure 3. Each sensor node is attached to the bottom of ocean and is outfitted with floating buoys that can be overblown by a pump. The buoys drag the sensors towards the surface of ocean and the depth of the sensor can be changed according to the length of the wire that joins the sensor to the anchor by the use of electronic engine [17]. The main issues in three dimensional architectures are listed below:

- Network device should organize their depths in such a way to assure that the network topology always be associated.
- Sensor nodes should be able to convey message to the surface station by the use of multi-hop paths to attain 3D sensing exposure of the ocean discourse.

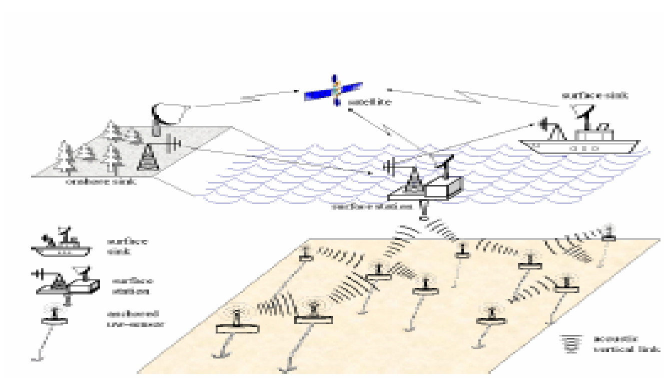

Figure 3. Example of 3D architecture.

III. UNDERWATER APPLICATION DOMAINS

There are numerous applications in several fields for monitoring and exploration purpose in underwater environment. But regular monitoring is not possible for human beings and also very expensive. A sensor network is deployed to solve the monitoring problem like pressure, temperature, salinity, pollutants, ecosystem etc. By this way, natural and manmade disaster can be prevented. The applications of underwater are specified below [10]:

A. *Short-tenure Critical applications*

There are some applications which are very restricted to real time and play an important role in underwater environment [19].

a) Diaster Prevention: By arranging acoustic sensor networks in distant positions to examine seismic actions like tsunami, submarine earthquakes in real era to warn the nearby areas from any huge tragedy.

b) Assisted Navigation: Acoustic Sensors can be utilized to identify danger on the ocean floor, find hazardous rocks in below the surface and etc.

c) Civilian Security: One of the important applications among all applications of UASNs is Civilian security. It deals with tourist's safety and security, rising ocean temperature, storms or tsunami, ship cracks, fresh water of ocean etc.

d) Tactical Survielliance: Permanent underwater sensors and autonomous underwater vehicles (AUVs) are fixed sensors networks to control the areas for tactical surveillance, aiming and interruption detection systems.

B. *Long-tenure non-time Critical Applications*

In UASNs, applications are critical but not restricted to time for monitoring and exploration purpose. In these underwater networks, a local sensor collects the information from the other sensors and conveys this information to surface node which transmits the data to on-shore centre by satellite [18]. The applications related to non-time critical scenario are as follows:

a) Ocean Sampling: The goal of ocean sampling is to access genetic diversity in marine community. It deals with time, space and environmental parameters to understand role of natural fundamental process in the marine environment. So sensors and underwater vehicles can perform adaptive sampling to explore the ocean environment [6][20].

b) Environmental Monitoring: UASNs can accomplish environmental or pollution monitoring i.e. biological, chemical and nuclear. Monitoring such as tracking of fishes, microbes etc. falls in biological monitoring. Nuclear monitoring includes weather forecast, detecting climate change, ocean currents and winds etc. Chemical monitoring deals with the condition of water relative to the requirements of species or to any human need or purpose [21].

c) Underwater Exploration: Detecting oilfields in underwaters, finding out routes to arrange underwater cables and helping in exploration for important minerals in underwater sensor networks.

d) Mine Detection: Underwater sensor networks can detect mine-like substances in marine. The real-time instantaneous operation of various underwater acoustic vehicles with optical and acoustic sensors can be used to complete quick environmental estimation [15].

IV. FUTURE RESEARCH CHALLENGES

Open research challenges are discussed as under:

- It is necessary to design real time underwater communication system with declined energy expenditure.
- Consider mobility of sensors to make deployment algorithms more effective.
- To analyze the performance of different underwater deployment algorithms, it is vital to design some estimation criteria of throughput.
- A design should be proposed to minimize the cost of underwater networks.
- Recovery algorithms for failure node are needed in order to avoid network loss.
- Network management protocol should be designed to handle an effective network management.
- Energy regeneration is highlighted challenge in future.
- Deployment algorithm should be designed for large scale networks.

V. CONCLUSION

In this paper we investigate certain problems of deployment in underwater acoustic sensor networks. We have discussed the challenges issued by carrier communication, propagation delay, bandwidth, cost, etc. We also have presented the basic comparisons of ground based and underwater sensor networks. Focus on network architecture, main characteristics of the underwater networks. We may conclude the research for underwater network is still in progress.

REFERENCES

[1] I. F. Akyildiz, D. Pompili, and T. Melodia. Underwater Acoustic Sensor Networks: Research Challenges. Ad Hoc Networks(Elsevier), 3(3):257–279, May 2005.

[2] H. Schmidt, "Autonomous underwater vehicle networks as integrated acoustic observation systems", Acoustical Society of America Journal, Vol. 117, Iss. 4, pp. 2409 – 2410, April, 2005.

[3] N. Farr, A.D. Chave, L. Freitag, J. Preisig, S.N. White, D. Yoerger, and F. Sonnichsen, "Optical Modem Technology for Seafloor Observatories", In Proc. IEEE OCEANS'06 Conf., pp. 1 – 6, Boston, MA, Sept. 2006.

[4] A. Quazi and W. Konrad, "Underwater acoustic communications," IEEE Commun. Mag., pp. 24–29, Mar. 1982.

[5] J. Partan, J. Kurose, and B. N. Levine, "A Survey of Practical Issues in Underwater Networks, International Conference on Mobile Computing and Networking", Proc. of the 1st ACM international workshop on Underwater networks, pp. 17 – 24, Los Angeles, CA, USA, Sept., 2006.

[6] Ocean Engineering at Florida Atlantic University, Available online at: http://www.oe.fau.edu/research/ams.html.

[7] L. Berkhovskikh and Y. Lysanov, "Fundamentals of Ocean Acoustics". New York: Springer, 1982.

[8] R. Coates, "Underwater Acoustic Systems", New York: Wiley, 1989.

[9] M. Stojanovic, "Underwater Acoustic Communications," in Encyclopedia of Electrical and Electronics Engineering, John G. Webster, Ed., John Wiley & Sons, 1999, Vol.22, pp.688-698.

[10] J.H. Cui, J. Kong, M. Gerla, and S. Zhou, Challenges: Building scalable mobile underwater wireless sensor networks for aquatic applications, IEEE Network, Special Issue on Wireless Sensor Networking, pp. 12-18, 2006.

[11] Zaihan Jiang, Underwater Acoustic Networks – Issues and Solutions, International journal of intelligent control and systems, VOL. 13, NO. 3, SEPTEMBER 2008, 152-161.

[12] T. S. Rappaport, ―Wireless Communications ▪ , Englewood Cliffs, NJ: Prentice Hall, 1996.

[13] Lanbo Liu, Shengli Zhou, and Jun-Hong Cui Prospects and Problems of Wireless Communication for Underwater Sensor Networks, WILEY WCMC SPECIAL ISSUE ON UNDERWATER SENSOR NETWORKS (INVITED),pp.977-994 July 2008.

[14] L. Freitag, M. Grund, C. V. Alt, R. Stokey and T. Austin, A Shallow Water Acoustic Network for Mine Countermeasures Operations with Autonomous Underwater Vehicles, In Underwater Defense Technology (UDT), 2005.

[15] L. Freitag and M. Stojanovic, Acoustic Communications for Regional Undersea Observatories, In Proceedings of Oceanology International, London, UK, Mar. 2002.

[16] V. Ravelomanana. Extremal Properties of Three-dimensional Sensor Networks with Applications. IEEE Transactions on Mobile Computing, 3(3):246–257, July/Sept. 2004.

[17] M. Stojanovic. Acoustic (underwater) Communications. In J. G. Proakis, editor, Encyclopedia of Telecommunications. John Wiley and Sons, 2003.

[18] Vasilescu.K.Kotay and D.Rus, Data Collection, Storage and Retrieval with an underwater Sensor Network, ACM SenSys'05 pp.154-165, 2005.

[19] N.N. Soreide, C.E. Woody, and S.M. Holt, Overview of ocean based buoys and drifters: Present applications and future needs, In proceedings 16th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, Long Beach, CA, USA, January 2004.

[20] AUV Laboratory at MIT Sea Grant, Available online at: http://auvlab.mit.edu/.

[21] X. Yang, K.G. Ong, W.R. Dreschel, K. Zeng, C.S. Mungle, and C.A. Grimes, Design of a wireless sensor network for long-term, insitu monitoring of an aqueous environment, pp. 455-472, Sensors 2, Vol. 11, 2002.

AUTHORS PROFILE

Manu Singh – Currently working as Assistant Professor in Guru Tegh Bahadur Institute of Technology under GGSIPU, New Delhi.

Engineering postgraduate with hands on experience of nearly seven years, in the challenging and competitive environment of IT education, with various skills (quick learning, good communication, technical expertise).

Area of interest includes underwater acoustic wireless networks, Vehicular Ad-hoc Networks (VANETs) and Wireless Communication.

Tanu Singh – Currently working with an Industry named Computal Systems as a Sr. Technical Expert Executive in IT Department from March 14 to till date.

Regular M.Tech Scholar with various computer as well as technical Skills with first class in Feb 2014 from Punjab Technical University, Jalandhar.

Completed B.Tech from Punjab Technical University, Jalandhar with first class in 2011.

During my training era of 6 Months, I worked in an organization to develop the eLearning Platform for students i.e. Skylearning.in – learning for anywhere at any time. Indulge in the portion of feasibility study of the product, Modeling, creating documents, testing portion. Also indulge to provide Telephonic as well as Client Site Support to the learners and Users.

During my training era of 2 Months, Worked on Online Shopping Module for Book Marketing using ASP .Net 2008. Designed all module of online book shopping for users and admin.

Active member of various cultural activities & educational clubs in college.