International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-7,July 2016
ISSN: 2395-3470
www.ijseas.com

A SURVEY ON RESEARCH CHALLENGES AT THE NETWORK LAYER OF UNDER WATER WIRELESS SENSOR NETWORKS (UW-WSN)

Shanthi M B[1], Dr. Dinesh K. Anvekar [2]
[1]Assoc. Professor, Dept. of CSE,CMRIT, Bangalore, shanthi.mb@cmrit.ac.in,
[2] Dean, Academics and Director, R&D at Alpha College of Engineering,Bangalore

Abstract: Underwater Wireless Sensor Network (UW-WSN) is a novel networking paradigm to explore the uninhabited and complex oceans. The networking paradigm poses inter-disciplinary challenges that will require new technological solutions. Under-Water Sensor Network (UW-WSN) consists of large amount of distributed, unmanned, and secure less underwater sensor nodes. These sensor nodes can collect the information in a timely manner and this network is used to explore, monitor and protect the ocean. In UW-WSN, low-frequency acoustic communication is deployed since RF radio does not transmit well because of underwater energy absorption. The underwater acoustic links provides very large latency and low bandwidth. In this paper, we have done a survey of interdisciplinary challenges that require new technological solutions. We have highlighted the research gaps where further exploration is required.

Key words: UWSN, research challenge, Sensor node, acoustic communications, exploration.

I.INTRODUCTION

The UW-WSN contains a set of underwater local area networks (UW-LAN) which is also called as clusters or cells. Inside the cluster, each sensor node can be linked with the sink via direct paths at multiple hops. The sink of each cluster will transmit the information gathered from the sensors to surface station via vertical links. The station at the surface is equipped with acoustic transceivers those are capable of handling multiple parallel communications with the deployed uw-sinks. Some of the architectures providing support for underwater sensor networks: static two-dimensional under water acoustic sensor networks (UW-ASNs) and static three dimensional under water acoustic sensor networks. Static two-dimensional UW-ASNs are established using sensor nodes fixed to the bottom of the ocean. Static three-dimensional UW-ASNs containing sensor networks are employed for surveillance applications or monitoring of ocean phenomena such as ocean bio–geochemical processes, water streams, pollution. Three-dimensional networks of autonomous underwater vehicles (AUVs) networks contain fixed portions containing fixed sensors and mobile portions containing autonomous vehicles. Recently, there has been a growing interest in monitoring the marine environment for scientific exploration, commercial exploitation and coastline protection.

In this paper, we review the types of UWSN architectures, characteristics of the acoustic communications; the challenges that are posed to satisfy the QoS parameters at the network layer and some of the methods that can be implemented at the network layer to enhance energy efficiency are discussed. The open issues for the research are discussed.

The rest of the paper is organized as follows. The types of UWSN architectures are discussed in the section II. The characteristics of the acoustic communications are discussed in section III. Section IV introduces the research gaps at the network layer. Section V, Concludes with the proposals of techniques for implementing the specified techniques.

II. TYPES OF UWSN ARCHITECTURES

In this section, we describe the communication architecture of underwater acoustic sensor networks. In particular, we introduce reference architectures for two-dimensional and three dimensional underwater Networks. The network topology is in general a crucial factor in Determining the energy consumption, the capacity and the reliability of a network. Hence, the network topology should be carefully engineered and post-deployment topology optimization should be performed. The communication architectures introduced here are used as a basis for discussion of the challenges associated with underwater acoustic sensor networks. The underwater sensor network topology is an open research issue and itself that needs further analytical and simulative investigation from the research community. In this section, we discuss the following architectures:

• Static two-dimensional UW-ASNs for ocean bottom monitoring: These are constituted by sensor nodes that are anchored to the bottom of the ocean. Typical applications may be environmental monitoring, or monitoring for underwater plates in tectonics.

• Static three-dimensional UW-ASNs for ocean column monitoring: These include networks of sensors whose depth can be controlled by means of techniques discussed in section 2.2, and may be used for surveillance applications or monitoring of ocean phenomena (ocean bio–geochemical processes, water streams, pollution).

• Three-dimensional networks of autonomous underwater vehicles (AUVs). These networks include fixed portions composed of anchored sensors and mobile portions constituted by autonomous vehicles.

Two-dimensional underwater sensor networks: A reference architecture for two-dimensional underwater networks is shown in the bellow given figure.

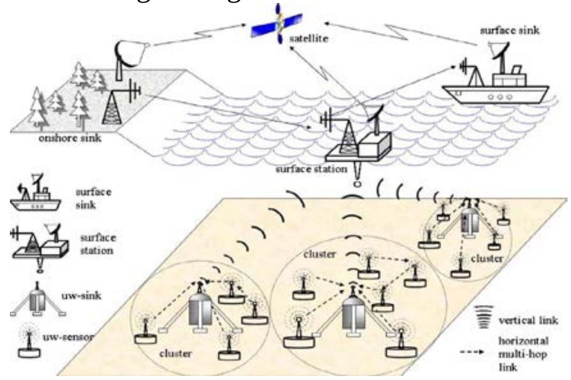

Fig 1. 2D underwater wireless sensor network

A group of sensor nodes are anchored to the bottom of the ocean with deep ocean anchors. Underwater sensor nodes are interconnected to one or more underwater sinks (uw-sinks) by means of wireless acoustic links. Uw-sinks, as shown in Fig. 1, are network devices in charge of relaying data from the ocean bottom network to a surface station. To achieve this objective, uw-sinks are equipped with acoustic transceivers, namely a vertical and a horizontal transceiver. The horizontal transceiver is used by the uw-sink to communicate with the sensor nodes in order to: (i) send commands and configuration data to the sensors (uw-sink to sensors); (ii) collect monitored data (sensors to uw-sink). The vertical link is used by the uw-sinks to relay data to a surface station. In deep water applications, vertical transceivers must be long range transceivers as the ocean can be as deep as 10 km. The surface station is equipped with an acoustic transceiver that is able to handle multiple parallel communications with the deployed uw-sinks. It is also endowed with a long range RF and/or satellite transmitter to communicate with the onshore sink (os-sink) and/or to a surface sink (s- ink). Sensors can be connected to uw-sinks via direct links or through multi-hop paths.

. In case of multi-hop paths, as in terrestrial sensor networks, the data produced by a source sensor is delayed by intermediate sensors until it reaches the uw-sink. This may result in energy savings and increased network capacity, but increases the complexity of the routing functionality This process involves signaling and computation. Since energy and capacity are precious resources in underwater environments, in UW-ASNs the objective is to deliver event features by exploiting multi-hop paths and minimizing the signaling overhead necessary to construct underwater paths at the same time.

Three-dimensional underwater sensor networks: In three-dimensional underwater networks, sensor nodes float at different depths in order to observe a given phenomenon. One possible solution would be to attach each uw-sensor node to a surface buoy, by means of wires whose length can be regulated so as to adjust the depth of each sensor node. However, although this solution allows easy and quick deployment of the sensor network, multiple floating buoys may obstruct hips navigating on the surface, or they can be easily detected and deactivated by enemies in military settings. Furthermore, floating buoys are vulnerable to weather and tampering or pilfering. For these reasons, a different approach can be to anchor sensor devices to the bottom of the ocean. A reference architecture for the 3D UWSN is given bellow.

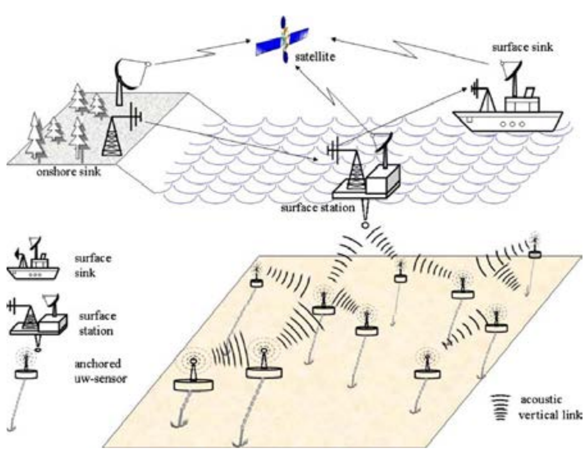

Fig 2. 3D underwater wireless sensor network

In this architecture, each sensor is anchored to the ocean bottom and equipped with a floating buoy that can be inflated by a pump. The buoy pushes the sensor towards the ocean surface. The depth of the sensor can then be regulated by adjusting the length of the wire that connects the sensor to the anchor, by means of an electronically controlled engine that resides on the sensor. A challenge to be addressed in such architecture is the effect of ocean currents on the described mechanism to regulate the depth of the sensors. Many challenges arise with such an architecture, that needs to be solved in order to enable 3D monitoring, including:

• Sensing coverage. Sensors should collaboratively regulate their depth in order to achieve 3D coverage of the ocean column, according to their sensing ranges. Hence, it must e possible to obtain sampling of the desired phenomenon at all depths.

• Communication coverage. Since in 3D underwater networks there may be no notion of uw-sink, sensors should be able to relay information to the surface station via multi-hop paths. Thus, network devices should coordinate their depths in such a way that the network topology is always connected, i.e., at least one path from every sensor to the surface station always exists.

III. CHARACTERISTICS OF ACOUSTIC COMMUNICATIONS.

In underwater acoustic channels, the signal propagation speed in underwater acoustic channel is about $1.5*10^3$ m/sec, which is five orders of magnitude lower than the radio propagation speed ($3*10^8$ m/sec). The available bandwidth of underwater acoustic channels is limited and dramatically depends on both transmission range and frequency. The acoustic band under water is limited due to absorption; most acoustic systems operate below 30 kHz. Underwater acoustic communication channels are affected by many factors such as such as path loss, noise, multi-path, and Doppler spread. All these factors cause high bit-error and delay variance. Acoustic links are also roughly classified as vertical and horizontal, according to the direction of the sound ray. Their propagation characteristics differ consistently, especially with respect to time dispersion, multi-path spreads, and delay variance. The difference is caused by the chemical-physical properties of the water medium such as temperature, salinity and density, and by their spatio-temporal variations. These variations, together with the wave guide nature of the channel, cause the acoustic channel to be temporally and spatially variable. In particular, the horizontal channel is by far more rapidly varying than the vertical channel, in both deep and shallow water. In short, underwater acoustic channels are featured with large propagation delay, large delay variance, limited avail- able bandwidth and high error probability. Furthermore, the bandwidth of underwater acoustic channels is determined by both the communication range and frequency of acoustic signals. The bigger the communication range, the lower the bandwidth of underwater acoustic channels.

III. THE NETWORK LAYER CHALLENGES

The network layer is in charge of determining the path between a source (the sensor that samples a physical phenomenon) and a destination node (usually the surface station). In general, while many impairments of the underwater acoustic channel are adequately addressed at the physical and data link layers, some other characteristics, such as the extremely long propagation delays, are better addressed at the network layer. In the last few years there has been an intensive study in routing protocols for ad hoc wireless networks and sensor networks. However, due to the different nature of the underwater environment and applications, there are several drawbacks with respect to the suitability of the existing solutions for underwater acoustic networks. The existing routing protocols are usually divided into three categories, namely proactive, reactive and geographical routing protocols.

• **Proactive Protocols:** These protocols attempt to minimize the message latency induced by route discovery, by maintaining up-to-date routing information at all times from each ode to every other node. This is obtained by broadcasting control packets that contain routing table information (e.g., distance vectors). These protocols provoke a large signaling overhead to establish routes for the first time and each time the network topology is modified because of mobility or node failures, since updated topology information has to be propagated to all the nodes in the network. For this reason, proactive protocols are not suitable or underwater networks.

• **Reactive protocols** (e.g., AODV DSR). A node initiates a route discovery process only when a route to a destination is required. Once a route has been established, it is maintained by a route maintenance procedure until it is no longer desired. These protocols are more suitable for dynamic environments but incur a higher latency and still require source-initiated flooding of control packets to establish paths. Thus, both proactive and reactive protocols incur excessive signaling overhead due to their extensive reliance on flooding. Reactive protocols are deemed to be unsuitable for W-ASNs as they also cause a high latency in the establishment of paths, which may be even amplified underwater by the slow propagation of acoustic signals. Furthermore, links are likely to be asymmetrical, due to bottom characteristics and variability in sound speed channel. Hence, protocols that rely on symmetrical links, such as most of the reactive protocols, are unsuited for the underwater environment. Moreover, the topology of UW-ASNs is unlikely to vary dynamically on a short time scale.

• **Geographical routing protocols** (e.g., GFG ,PTKF):These protocols establish source–destination paths by averaging localization information, i.e., each node selects its next hop based on the position of its neighbors and of the destination node. Although these techniques are very promising, it is still not clear how accurate localization information can be obtained in the underwater environment with limited energy xpenditure. In fact, fine-grained localization usually requires strict synchronization among nodes, which is difficult to achieve underwater due to the variable propagation delay. In addition, global positioning system (GPS) receivers, which may be used in terrestrial systems to accurately estimate the geographical location of sensor nodes, do not work properly underwater.. Some recent papers propose network layer protocols specifically tailored to underwater acoustic networks The protocol relies on a centralized network manager running on the surface station. The manager implements network management and routing agents that periodically probe the nodes to estimate the channel characteristics. This information is exploited by the manager to establish efficient data delivery paths in a centralized fashion, which allows avoiding congestion and providing forms of quality of service guarantee. The performance evaluation of the proposed mechanisms has not been thoroughly carried out et. In a framework is provided for 3D position based routing in ad hoc networks. It is assumed that each node knows its 3D position and the position of the destination node, and a cell structure is leveraged n order to aggregate the topological information at each node. Although it is claimed that the mechanism can be applied to ocean sensor networks, all the experiments performed assume radio frequency communications among terrestrial mobile devices. In it is shown with simple acoustic propagation models that multi-hop routing saves energy in underwater networks with respect to single hop communications, especially with distances in the order of some kilometers. Based on this, a simple ad hoc u underwater network is designed and simulated, where routes are established by a central manager based n neighborhood information gathered by all nodes by means of poll packets. In general, while most enveloped protocols for terrestrial ad hoc networks, mostly due to scalability and mobility concerns, re based on packet switching, i.e., the routing function is performed separately for each single packet and paths are dynamically established, virtual circuit routing techniques can be considered in UW-ASNs. In these techniques, paths are established a priori between each source and sink, and each packet follows the same path. This may require some form of centralized coordination, and implies a less flexible architecture, but allows exploiting powerful optimization tools on a centralized manager (e.g., the surface station) to achieve optimal performance at the network layer (e.g., minimum delay paths, energy efficient paths), with minimum communication signaling overhead. Furthermore, routing schemes that account for the 3D underwater environment need to be revised. Especially, in the 3D case the effect of currents should be taken into account, since the intensity and the direction of currents are dependent on the depth of the sensor node. Thus, underwater currents can modify the relative position of sensor devices and also cause connectivity holes, especially when ocean-column monitoring is performed in deep waters

Open research issues: There exist many open research issues for the development of efficient routing solutions for underwater acoustic sensor networks, s outlined below:

• There is a need to develop algorithms to provide strict or loose latency bounds for time critical applications. To this respect, it should be considered that while the delay for an acoustic signal to propagate from one node to another mainly depends on the distance of the two nodes, the delay variance also depends on the nature of the link, i.e., the delay variance in horizontal acoustic links is generally larger than in vertical links due to multi-paths .

• For delay-tolerant applications, there is a need to develop mechanisms to handle loss of connectivity without provoking immediate retransmissions. Strict integration with transport and data link layer mechanisms may be advantageous to this end.

• It is necessary to devise routing algorithms that are robust with respect to the intermittent connectivity of acoustic channels. The quality of acoustic links is highly unpredictable, since it mainly depends on fading and multi-path, which are hard phenomena to model.

• Accurate modeling is needed to better understand the dynamics of data transmission at the network layer. Moreover, credible simulation models and tools need to be developed.

• Algorithms and protocols need to be developed that detect and deal with disconnections due to failures, unforeseen mobility of nodes or battery depletion. These solutions should be local so as to avoid ommunication with the surface station and global reconfiguration of the network, and should minimize the signaling overhead.

• Local route optimization algorithms are needed to react to consistent variations in the metrics describing the energy efficiency of the underwater channel. These variations can be caused by increased bit error rates due to acoustic noise, or relative displacement of communicating nodes due to variable currents.

• Mechanisms are needed to integrate AUVs in underwater networks and to enable communication between sensors and AUVs. In particular, all the information available to sophisticated UV devices (trajectory, localization) could be exploited to minimize the signaling needed for reconfigurations.

• In case of geographical routing protocols, it is necessary to devise efficient underwater location discovery techniques.

V. CONCLUSION

In this paper, we have presented an overview of an underwater acoustic sensor network. We have discussed characteristics of 2D and 3D underwater Network architectures. We have described the challenges posed at the network layer as open research issues and outlined future research directions for the development of efficient and reliable underwater acoustic sensor networks. The main objective of this paper is to encourage research efforts to lay down fundamental basis for the development of new advanced communication techniques which will enhance energy efficiency and fault tolerant communications across the network for ocean monitoring and exploration.

REFERENCES

[1] M. Abolhasan, T. Wysocki, E. Dutkiewicz, A review of routing protocols for mobile ad hoc networks, Ad Hoc Networks 2 (1) (2004)

[2] Dario Pompili, Tommaso Melodia and Ian F. Akyildiz “Distributed Routing Algorithms for Underwater Acoustic Sensor Networks” *IEEE transactions on Wireless Communications*, vol. 9, Sept 2010

[3] J. Heidemann, Y. Li, A. Syed, J. Wills, and W. Ye, “Research challenges and applications for underwater sensor networking,” in *proceedings of the IEEE Wireless communications and Networking Conference (WCNC)*, 2006

[4] J. Partan, J. Kurose, and B. N. Levine, “A Survey of Practical Issues in Underwater Networks,” in *Proc. of ACM International Workshop on UnderWater Networks (WUWNet)*, September 2006

[5] L. Liu, S. Zhou, and J.-H. Cui, “Prospects and problems of wireless communication for underwater sensor networks,” *Wireless Communications & Mobile Computing*, vol. 8, pp. 977–994, 2008.

[6] Zhong Zhou, Zheng peng, Jun-Hong Cui, Zhijie Shi “Efficient Multipath Communication for Time critical Applications in Underwater Acoustic Sensor Networks” *IEEE/ACM Transactions on Networks, Vol 19 No. 1, Feb 2011*

[7] Ian F. Akyildiz, Dario Pompili and Tommaso Melodia, “Underwater acoustic sensor networks: research challenges”, ELSEVIER, Ad Hoc Networks, pp- 257–279, 2005

[8] Manjula.R.B and Sunilkumar S. Manvi, "Issues in Underwater Acoustic Sensor Networks", International Journal of Computer and Electrical Engineering, Vol.3, No.1, February, 2011

[10] Xiping Yang, Keat G. Ong, William R. Dreschel, Kefeng Zeng, Casey S. Mungle and Craig A. Grimes, "Design of a Wireless Sensor Network for Long-term, In-Situ Monitoring of an Aqueous Environment", Sensors, pp- 455-472, 2002

[9] Zheng Peng, Zhong Zhou, Jun-Hong Cui and Zhijie Jerry Shi, "Aqua-Net: An Underwater Sensor Network Architecture: Design, Implementation, and Initial Testing", MTS/IEEE Biloxi - Marine Technology for Our Future: Global and Local Challenges, (OCEANS '09), pp-1-8, 2009