Asian Journal of Computer Science and Technology
ISSN: 2249-0701 (P) Vol.3 No.2, 2014, pp.4-8

DOI: https://doi.org/10.51983/ajcst-2014.3.2.1741

An Overview of Under Water Sensor Networks Routing Protocols

A.Kathirvel
Professor, Computer Science and Engineering, Kalasalingam University, Anand Nagar, Krishnankoil, India
E-mail:ayyakathir@gmail.com
(Received 23 May 2014; Accepted 28 June 2014; Available online 7 July 2014)

Abstract - **Recently, sensor networks have emerged as a very powerful technique for many applications, including monitoring, measurement, surveillance and control. The idea of applying sensor networks into underwater environments (i.e., forming underwater sensor networks) has received increasing interests. Even though underwater sensor networks (UWSNs) share some common properties with ground sensor networks, such as the large number of nodes and limited energy, UWSNs are significantly different from the conventional ground sensor technology. First, radio communications do not work well under the water. They must be replaced by acoustic communications, which have very different travel time and characteristics. In particular, acoustic channels feature large propagation latency, low bandwidth capacity and high error rate. Second, while most ground sensors are static, underwater sensor nodes may move with water currents and other underwater activities. Due to the very different environment properties and also the unique nature of the aquatic applications, the protocols developed for ground sensor networks are not directly applicable to underwater sensor networks. Simple underwater monitoring systems have been introduced in the past. However, they are small-scale and rely on point-to-point, single channel techniques such as remote telemetry or sequential local sensing.**

In UWSN, the sensor nodes have a limited transmission range, and their processing and storage capabilities as well as their energy resources are also limited. Routing protocols for wireless sensor networks are responsible for maintaining the routes in the network and have to ensure reliable multi-hop communication under these conditions. In this paper, we give a survey of routing protocols for UWSN and compare their strengths and limitations.

Keywords: **Under Water Sensor Networks, Routing Protocols, Sensors and Networks**

I. INTRODUCTION

Under Water Sensor Networks (UWSN) has attracted momentous attention recently as it enhances people's ability to gain information and control [1]. Only less than one third of earth's plane is covered by land, and the rest is covered by sea water. Due to quite a lot of reasons such as vast area, high pressure, and harshness of underwater environment, human presence in this area is very limited. Hence, human knowledge about underwater environment is so negligible in comparison with land. In recent decades, since the use of WSNs in different applications has brought tremendous revolution, researchers have been interested recently in using these networks for gathering data from underwater environments [1, 2].

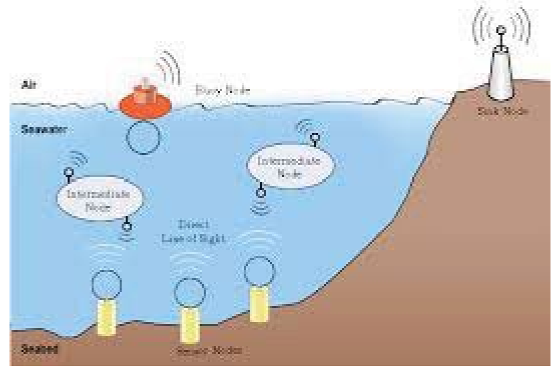

Fig. 1 Under water sensor networks

Due to water absorption, the transmission distance of radio in water from nodes with IEEE 802.11b and IEEE 802.11g or IEEE 802.15.4 protocol is about 50~100 cm, which is inapplicable to UWSN, so UWSN uses acoustic communication with more energy-consumption. The nodes in UWSN are battery-powered and harder to recharge and replace in harsh underwater environments as shown in the Figure 1. Acoustic channel is characterized by high bit error of 10^{-3}~10^{-7}, long propagation delay in the order of second and low bandwidth of scores of kbit/s. In addition, underwater nodes are usually deployed more sparsely, and most nodes can move passively with water currents or other underwater activity, resulting in highly dynamic network topology and great challenges to routing protocol for energy-restricted UWSN as shown in the Figure 2. So, terrestrial-based network protocols are inefficient for UWSN, and UWSN calls for adaptive, energy-saving and energy-balancing routing protocol tailored for dynamic and sparse network with 'void' zone.

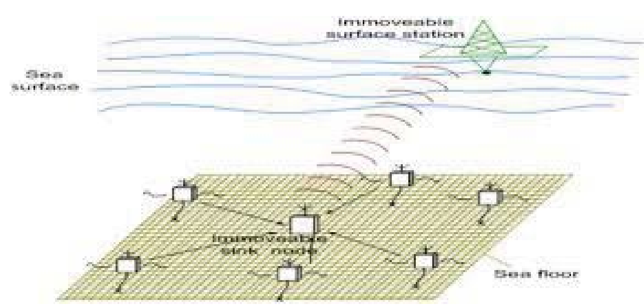

Fig.2 Communicate to the surface station

In this paper, overview of UWSN routing protocol are discussed in the brief. The remainder of the paper is organized as follows. Section 2 briefly reviewed some related work in the UWSN. Section 3 presented routing protocol for UWSN in detail. Finally, Section 4 concluded the paper and discussed future work.

II. RELATED WORK

Due to the unique characteristics of UWSN, traditional terrestrial WSN routing protocols expose many drawbacks in UWSN, and routing is one of the major issues to be addressed. Most routing protocols proposed for terrestrial sensor network s are mainly designed for stationary topology. They usually employ query flooding as a powerful method to discover data delivery paths. Directed diffusion [8] is such a query-routing that the sink sends interest message indicating query task s and the message is flooded over the whole networks. In UWSN, however, most sensor nodes are mobile, and the network topology changes very rapidly with displacements due to multipath. The frequent maintenance and recovery of forwarding paths is very expensive in high dynamic network s, and even more expensive in dense 3-dimensional UWSN. Location-based routing protocols employ the information of location or depth to forward packets, which is necessary naturally in terrestrial and underwater WSN, vector based forwarding (VBF) protocol [9] is one of them. VBF defines a routing pipe from the source to the sink as routing vector and floods packets inside the pipe. Moreover, VBF introduces a desirable factor to calculate the hold-time during which package is cached in order to suppress too much redundant pack ages and improve energy efficiency. Drum buffer rope (DBR) [10] routes pack ages based on depth information. Both VBF and DBR utilize distributed routing and broadcast forwarding with hold-time, and incur much collision, redundant forwarding and gratuitous delay. What's worse, VBF and DBR use greedy algorithm which is inapplicable for UWSN environment with 'void' zone.

One may modify existing terrestrial routing protocols in mobile underwater networks (e.g., OLSR [3], DSDV [4], AODV [5], DSR [6]) to support anycast routing by assigning a single virtual node ID to all sonobuoys [7]. However, the major shortcomings of this approach are two-fold at least: (1) these protocols require frequent systematic flooding and route maintenance with neighboring nodes, which are very expensive operations u nder water, and (2) it is challenging to incorporate opportunistic forwarding mechanisms (e.g., ExOR [11], LCOR [12]) into the state full routing protocols due to node mobility [13]—under unreliable acoustic channels, opportunistic forwarding can combat packet losses by taking advantage of simultaneous packet reception among one node's neighbors.

III. ROUTING PROTOCOLS FOR UWSN

Routing in wireless sensor networks differs from conventional routing in fixed networks in various ways. There is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements [2]. Many routing algorithms were developed for wireless networks in general. All major routing protocols proposed for UWSNs may be divided into eight categories as shown in Table 1. We review sample routing protocols in each of the categories in preceding sub-sections.

TABLE I CATEGORIES OF ROUTING PROTOCOLS FOR UWSN

State based Protocols: OLSR
Data-centric Protocols: SPIN
Hierarchical Protocols: LEACH
Mobility-based Protocols: SEAD, DSDV
Dynamic routing protocols: AODV, DSR
Multipath-based Protocols: Braided Multipath
Heterogeneity-based Protocols: CHR
QoS-based protocols: SAR

A. *State Based Protocol*

A link-state routing protocol is one of the two main classes of routing protocols used in packet switching networks for computer communications (the other is the distance-vector routing protocol). Examples of link-state routing protocols include open shortest path first (OSPF) and intermediate system to Intermediate system (IS-IS).

OLSR: The Optimized Link State Routing Protocol (OLSR) is developed for mobile ad hoc networks. It operates as a table driven and proactive protocol, thus exchanges topology information with other nodes of the network regularly. The nodes which are selected as a multipoint relay (MPR) by some neighbor nodes announce this information periodically in their control messages [14 – 15]. Thereby, a node announces to the network, that it has reachability to the nodes which have selected it as MPR. In route calculation, the MPRs are used to form the route from a given node to any destination in the network. The protocol uses the MPRs to facilitate efficient flooding of control messages in the net- work. OLSR inherits the concept of forwarding and relaying from HIPERLAN (a MAC layer protocol) which is standardized by ETSI.

B. *Data Centric Protocols*

Data-centric protocols differ from traditional address-centric protocols in the manner that the data is sent from source sensors to the sink. In address-centric protocols, each source sensor that has the appropriate data responds by sending its data to the sink independently of all other sensors. However, in data-centric protocols, when the source sensors send their data to the sink, intermediate sensors can perform some form of aggregation on the data originating from multiple source sensors and send the aggregated data toward the sink. This process can result in energy savings because of less transmission required to send the data from the sources to the sink.

Sensor Protocols for Information via Negotiation (SPIN): SPIN protocol was designed to improve classic flooding protocols and overcome the problems they may cause, for example, implosion and overlap. The SPIN protocols are resource aware and resource adaptive. The sensors

running the SPIN protocols are able to compute the energy consumption required to compute, send, and receive data over the network. Thus, they can make informed decisions for efficient use of their own resources. The SPIN protocols are based on two key mechanisms namely negotiation and resource adaptation. SPIN enables the sensors to negotiate with each other before any data dissemination can occur in order to avoid injecting non-useful and redundant information in the network. SPIN uses meta-data as the descriptors of the data that the sensors want to disseminate. The notion of meta-data avoids the occurrence of overlap given sensors can name the interesting portion of the data they want to get. It may be noted here that the
size of the meta-data should definitely be less than that of the corresponding sensor data. Contrary to the flooding technique, each sensor is aware of its resource consumption with the help of its own resource manager that is probed by the application before any data processing or transmission. This helps the sensors to monitor and adapt to any change in their own resources.

C. Hierarchical protocols

It is nothing new, but provides an interesting approach to the balance between scalability and performance. The most well known service in use today that uses a hierarchical protocol is DNS.

LEACH: LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compresses the data and forward it to the base station (sink). Each node uses a stochastic algorithm at each round to determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the base station or the nearest cluster head, but that using this radio at full power all the time would waste energy. Nodes that have been cluster heads cannot become cluster heads again for P rounds, where P is the desired percentage of cluster heads. Thereafter, each node has a 1/P probability of becoming a cluster head in each round. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster. The cluster head then creates a schedule for each node in its cluster to transmit its data. All nodes that are not cluster heads only communicate with the cluster head in a TDMA fashion, according to the schedule created by the cluster head. They do so using the minimum energy needed to reach the cluster head, and only need to keep their radios on during their time slot. LEACH also uses CDMA so that each cluster uses a different set of CDMA codes, to minimize interference between clusters.

D. Mobility based Protocols

Mobility brings new challenges to routing protocols in WSNs. Sink mobility requires energy efficient protocols to guarantee data delivery originated from source sensors toward mobile sinks.

SEAD: Ad hoc networking is a networking principle based on each machine being a host, but none being a server. This requires a versatile routing algorithm that allows communication of a highly dynamic network with no central authority. This is provided by SEAD, which is based on DSDV-SQ. A number of features of DSDV are not provided in SEAD. These include such concepts as settling time and even/odd sequence numbers. For more information on the DSDV-SQ algorithm, please see reference [4].
The easiest way to understand the basics of the protocol is to break down its name, which describes the way each node in the networks stores it shortest path route to a node. Destination Sequence describes the fact each route stores the full name of the destination and the next hop towards it. Distance Vector illustrates that only the source node knows only the distance to the destination. These three units form the shortest path routing tables for each node. SEAD then adds security features to the DSDV-SQ algorithm. The authentication process of SEAD greatly improves the security of the network's routes without sacrificing computational overhead and battery life, which is critical in mobile ad hoc networks.

E. Dynamic routing protocols

Dynamic State Routing (DSR): The DSR protocol [5] requires each packet to carry the full address (every hop in the route), from source to the destination. This means that the protocol will not be very effective in large networks, as the amount of overhead carried in the packet will continue to increase as the network diameter increases. Therefore, in highly dynamic and large networks the overhead may consume most of the bandwidth. However, this protocol has a number of advantages over other routing protocols, and in small to moderately size networks (perhaps up to a few hundred nodes), this protocol performs better. An advantage of DSR is that nodes can store multiple routes in their route cache, which means that the source node can check its route cache for a valid route before initiating route discovery, and if a valid route is found there is no need for route discovery.

This is very beneficial in network with low mobility, because the routes stored in the route cache will be valid for a longer period of time. Another advantage of DSR is that it does not require any periodic beaconing (or hello message exchanges), therefore nodes can enter sleep node to conserve their power[14 – 15]. This also saves a considerable amount of bandwidth in the network.

Ad hoc On-demand Distance Vector Routing (AODV): The AODV routing protocol [6] is based on DSDV and DSR algorithm. It uses the periodic beaconing and sequence numbering procedure of DSDV and a similar route discovery procedure as in DSR. However, there are two major differences between DSR and AODV. The most distinguishing difference is that in DSR each packet carries full routing information, whereas in AODV the packets carry the destination address. This means that AODV has potentially less routing overheads than DSR. The other difference is that the route replies in DSR carry the address of every node along the route, whereas in AODV the route replies only carry the destination IP address and the sequence number [14 – 15]. The advantage of AODV is that it is adaptable to highly dynamic networks. However, node may experience large delays during route construction, and link failure may initiate another route discovery, which introduces extra delays and consumes more bandwidth as the size of the network increases.

F. Multipath-based Protocols

Considering data transmission between source sensors and the sink, there are two routing paradigms: single-path routing and multipath routing. In single-path routing, each source sensor sends its data to the sink via the shortest path. In multipath routing, each source sensor finds the first k shortest paths to the sink and divides its load evenly among these paths.

Braided Paths: Braided multipath is a partially disjoint path from primary one after relaxing the disjointedness constraint. To construct the braided multipath, first primary path is computed. Then, for each node (or sensor) on the primary path, the best path from a source sensor to the sink that does not include that node is computed. Those best alternate paths are not necessarily disjoint from the primary path and are called idealized braided multipaths. Moreover, the links of each of the alternate paths lie either on or geographically close to the primary path. Therefore, the energy consumption on the primary and alternate paths seems to be comparable as opposed to the scenario of mutually ternate and primary paths. The braided multipath can also be constructed in a localized manner in which case the sink sends out a primary-path reinforcement to its first preferred neighbor and alternate-path reinforcement to its second preferred neighbor.

G. Heterogeneity-based Protocols

In heterogeneity sensor network architecture, there are two types of sensors namely line-powered sensors which have no energy constraint, and the battery-powered sensors having limited lifetime, and hence should use their available energy efficiently by minimizing their potential of data communication and computation.

Cluster-Head Relay Routing (CHR): CHR routing protocol uses two types of sensors to form a heterogeneous network with a single sink: a large number of low-end sensors, denoted by L-sensors, and a small number of powerful high-end sensors, denoted by H-sensors. Both types of sensors are static and aware of their locations using some location service. Moreover, those L- and H-sensors are uniformly and randomly distributed in the sensor field. The CHR protocol partitions the heterogeneous network into groups of sensors (or clusters), each being composed of L-sensors and led by an H-sensor. Within a cluster, the L-sensors are in charge of sensing the underlying environment and forwarding data packets originated by other L-sensors toward their cluster head in a multihop fashion. The H-sensors, on the other hand, are responsible for data fusion within their own clusters and forwarding aggregated data packets originated from other cluster heads toward the sink in a multihop fashion using only cluster heads. While L-sensors use short-range data transmission to their neighboring H-sensors within the same cluster, H-sensors perform long-range data communication to other neighboring H-sensors and the sink.

H. QoS-based Protocols

In addition to minimizing energy consumption, it is also important to consider quality of service (QoS) requirements in terms of delay, reliability, and fault tolerance in routing in WSNs

Sequential Assignment Routing (SAR): SAR is one of the first routing protocols for WSNs that introduces the notion of QoS in the routing decisions. It is a table-driven multi-path approach striving to achieve energy efficiency and fault tolerance. Routing decision in SAR is dependent on three factors: energy resources, QoS on each path, and the priority level of each packet [11, 13]. The SAR protocol creates trees rooted at one-hop neighbors of the sink by taking QoS metric, energy resource on each path and priority level of each packet into consideration. By using created trees, multiple paths from sink to sensors are formed. One of these paths is selected according to the energy resources and QoS on the path. Failure recovery is done by enforcing routing table consistency between upstream and downstream nodes on each path. Any local failure causes an automatic path restoration procedure locally. The objective of SAR algorithm is to minimize the average weighted QoS metric throughout the lifetime of the network. If topology changes due to node failures, a path re-computation is needed. As a preventive measure, a periodic re-computation of paths is triggered by the base-station to account for any changes in the topology. Ahandshake procedure based on a local path restoration scheme between neighboring nodes is used to recover from a failure. Failure recovery is done by enforcing routing table consistency between upstream and downstream nodes on each path. Simulation results showed that SAR offers less power consumption than the minimum-energy metric algorithm, which focuses only the energy consumption of each packet without considering its priority. Although, this ensures fault-tolerance and easy recovery, the protocol suffers from the overhead of maintaining the tables and states at each sensor node especially when the number of nodes is huge.

IV. CONCLUSION AND FUTURE WORKS

One of the main challenges in the design of routing protocols for UWSNs is energy efficiency due to the scarce energy resources of sensors. The ultimate objective behind the routing protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. The energy consumption of the sensors is dominated by data transmission and reception. Therefore, routing protocols designed for UWSNs should be as energy efficient as possible to prolong the lifetime of individual sensors, and hence the network lifetime.

In this paper, we have surveyed a sample of routing protocols by taking into account several classification criteria, including location information, network layering and in-network processing, data centricity, path redundancy, network dynamics, QoS requirements, and network heterogeneity. For each of these categories, we have discussed a few example protocols. Although some efforts have been devoted to the design of routing and data dissemination protocols for 3D sensing applications, we believe that these first-step attempts are in their infancy, and more powerful and efficient protocols are required to satisfactorily address all problems that may occur.

REFERENCES

[1] F. Akyildiz, D. Pompili, and T. Melodia, “State-of-the-art in protocol research for underwater acoustic sensor networks,” in Proceedings of the 1st ACM International Workshop on Underwater Networks, pp. 7–16, September 2006.

[2] J.Heidemann,W.Ye,J.Wills,A.Syed,andY.Li,“Research challenges and applications for underwater sensor networking,” in Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC ’06),vol.1–4,pp.228–235,April 2006.

[3] T. Clausen and P. Jacquet, “Optimized Link State Routing Protocol (OLSR),” IETF RFC 3626, 2003.

[4] C. E. Perkins and P. Bhagwat, “Highly dynamic destination sequenced distance-vector routing (dsdv) for mobile computers,” in SIGCOMM, 1994.

[5] C. E. Perkins and E. M. Royer, “Ad-hoc on-demand distance vector routing,” in IEEE Workshop on Mobile Computing Sys. and Apps. ,1997.

[6] D. B. Johnson and D. A. Maltz, “Dynamic source routing in ad hoc wireless networks,” Mobile Computing , pp. 153–181, 1996.

[7] V. D. Park and J. P. Macker, “Anycast routing for mobile services,”in Conf. Info. Sci. and Sys , 1999.

[8] Intanagonwiwat C, Govindan R, Estrin D. Directed diffusion: a scalable and robust communication paradigm for sensor networks. Proceedings of the 6th Annual International Conference on Mobile Computing and Networking (MOBICOM’00), Aug 6-11, 2000, Boston, MA, USA. New York, NY, USA: ACM, 2000: 56-67

[9] Xie P, Cui J H, Lao L. VBF: vector-based forwarding protocol for underwater sensor networks. Proceedings of the 5th International IFIP-TC6 Conference on Networking Technologies, Services, and Protocols; Performance of Computer and Communication Networks; Mobile and Wireless Communications Systems (NETWORKING’06), May 15-19, 2006, Coimbra, Portugal. Berlin, Germany: Springer-Verlag, 2006: 1216- 1221.

[10] Yan H, Shi Z.J, Cui J H. DBR: depth-based routing for underwater sensor networks. Proceedings of the 7th International IFIP-TC6 Networking Conference on Ad Hoc and Sensor Networks, Wireless Networks, Next Generation Internet (NETWORKING’08), May 5 9, 2008, Singapore. Berlin, Germany: Springer-Verlag, 2008: 72-86.

[11] S. Biswas and R. Morris, “Opportunistic Routing in Multi-Hop Wireless Networks,” in SIGCOMM, 2005.

[12] H. Dubois-Ferriere, M. Grossglauser, and M. Vetterli, “Least-Cost Opportunistic Routing,” in Allerton , 2007.

[13] U. Lee, P. Wang, Y. Noh, L. F. M. Vieira, M. Gerla, and J.-H. Cui, “Pressure routing for underwater sensor networks,” in INFOCOM, 2010.

[14] A.Kathirvel, and Dr. R. Srinivasan, “ETUS: An Enhanced Triple Umpiring System for Security and Performance Improvement of Mobile Ad Hoc Networks”,ACM Guide to Computing Literature, 2011, pp. 341 - 359.

[15] A.Kathirvel, and Dr. R. Srinivasan, “An Enhanced Triple Umpiring System for Security and Performance Improvement of Mobile Ad Hoc Networks”, International Journal of Network Management, John Wiley & Sons, Vol. 21, No. 5, September/October 2011, pp. 341 - 359.