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Routing Conflict In Underwater Acoustic Sensor Networks and Feasible Challenges

U.D. PRASAN | Dept of CSE, Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh

Dr. S. MURUGAPPAN | Department of Computer science & Engineering, Annamalai University

ABSTRACT

With the advancements of acoustic modem technology that supports better data rates with reliable communications, current research focuses on algorithms those can support such technology in a better way. During the last two decades, many protocols suggested in order to handle the adverse environment of underwater communications. This continued research results in improved performance as compare to initial communication systems. But still underwater issues like limited bandwidth, high propagation delays and 3-D topology as well as power constraints of the sensor nodes are challenges for the successful routings. A series of survey papers provide an excellent comparison of such algorithms and different networking challenges during the current decade, but still a lot left to investigate. In this paper we will explore the developments of some of the important routing algorithms, and a survey with different comparisons, those have been proposed for the partially connected underwater environments. In addition, at the end we will give some future directions, which can be helpful in order to construct the algorithms for such environments.

KEYWORDS | acoustic communications, propagation delay, bandwidth, underwater sensor networks , routing protocols, propagation latency.

I. INTRODUCTION

At the end of 20th century, wireless sensor networks became hot research area. At starts, it covers only terrestrial applications, but we know the Earth is a water plant as more than 70 % of the surface is covered by the water and the largely unexplored vastness of the oceans has attracted human's attention. From many decades, there have been significant interests in monitoring aquatic environments for scientific, commercial exploration and as well as for military operations. A highly precise, real time and continuous monitoring systems are extremely important for various applications, such as offshore oil fields monitoring, pollution detection, and oceanographic data collection. So all these important applications, call for the need of building Underwater Wireless Sensor Networks (UWSN). The traditional approaches for the underwater monitoring has several drawbacks like; there were no support for the interactive communications between the different ends, secondly, in most of the cases the recorded data can only be retrieved at the end of mission, which can take several months, and any failure during the mission can be lead to the loss of all the collected data. Also, the concept of an ad- hoc and sensor networks for underwater is very attractive, because it can be helpful easily to extend the range of current acoustic modems and offers distributed communications with less deployment time.

A scalable UWSN provides a promising solution for discovering efficiently and observing the aqueous environments for different applications, which operates under the many important constraints. At one side, these environments are not feasible for human presence as the unpredictable underwater activities, high water pressure and vast areas of water are major reasons for unmanned exploration. On the same time, localized exploration is better than remote sensing due to the more precise results, as remote sensing technologies may not be able to find appropriate knowledge about the events happening in the unstable underwater environment.

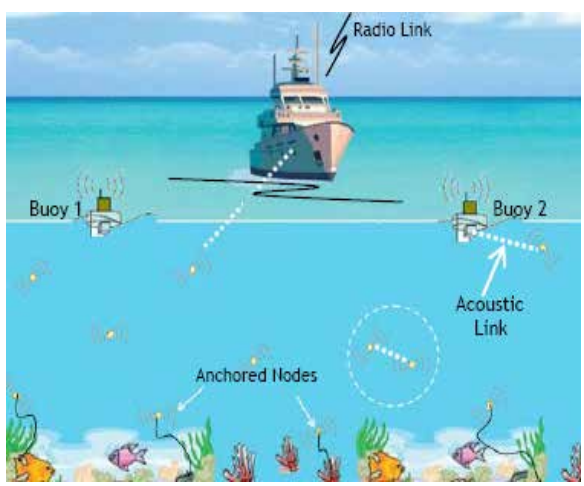


Fig. 1. Underwater sensor networks

Radio waves can travel for longer distances but due to salty characteristics of water, it works at very low frequencies, and these low frequencies require large antennae as well as high power for communications. For example, experiments conducted at University of Southern California, shows that, only 120 cm communication range were possible at the high frequencies of 433 MHz [1]. On the other hand, optical waves don't have the problem of such a high attenuation, but suffer from the scattering, and require high precision of the pointing beam as well. Based on the communication range and different requirements of various underwater applications, there has been proposed two network architectures [2], one for short-term (ST-UWSN) aquatic exploration applications like, submarine detection, loss treasure discovery, hurricane disaster recovery and the other for long-term (LT-UWSN) aquatic monitoring applications includes, oceanographic data collection, pollution monitoring/detection and off-shore oil/gas field monitoring. Fig.1 illustrate both architectures, as small ship or boats can be used in case of short term applications, while water buoys,

equipped with both acoustic and radio communications [4], are deployed on the sea surface and are used as a gateway for permanent or long term applications. The short term applications are time critical, and mostly require interactive communications, but on the other hand, long term applications can be delay tolerant [12] as they have to continue for months or even for the years.

Fig.2 illustrate the SEA swarm architecture, each sensor monitors local underwater activities and reports time-critical data to any one of the sonobuoys using acoustic multi-hopping; then the data are delivered to a monitoring center using radio communications. The main focus of this paper is to design an efficient anycast routing protocol from a mobile sensor to any one of the sonobuoys on the sea level. However, this is challenging due to node mobility and limited resources (bandwidth and energy) of mobile sensors.

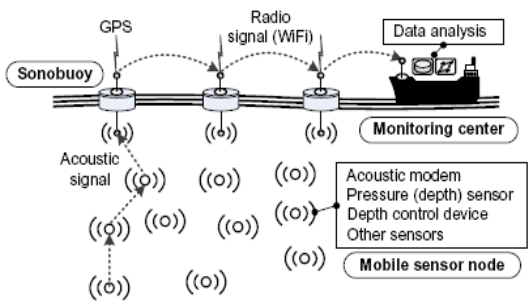


Fig. 2. SEA swarm architecture

An underwater acoustic channel has low bandwidth and propagation latency five orders of magnitude higher than the radio channel [27]. Acoustic transmissions consume much more energy than terrestrial microwave communications. Such severe limitations in communication bandwidth coupled with high latency and limited energy make the network vulnerable to congestion due to packet collisions. Under these circumstances, minimizing the number of packet transmissions is important for at least two reasons: minimizing congestion and minimizing energy consumption.

II. BACKGROUND

The existing routing protocols developed for terrestrial sensor networks are usually divided into two categories, Proactive and Reactive. But both of these extremis has some problems like, Proactive or Table Driven protocols provoke a large signaling overhead in order to establish the routs, especially for the first time and every time when the topology is modified. So, due to the continuous nodes movements, topologies changes continuously. Then, if we talk about the Reactive scheme, it's no doubt that protocols belong to this category are more suitable for the dynamic environments, but they incur large delays and also require source initiated flooding of control packets in order to establish the paths. Plus experiments show that, they give better results when links are symmetrical throughout the network. But for underwater environments we know that, propagation delays are already high and mostly the links are asymmetrical, so the protocols of the both of these types are not suitable for the underwater networks [3].

In Ad hoc networks, communication schemes, those relies on ToA (Time of Arrival) and ToDA (Time of Difference Arrival), must require strict synchronization between the sender and receiver clocks [5]. For ground based networks, it's not a problem as radio signal can be used for time synchronization. But, the luxury of the radio signal is not available during the underwater communications. In order to handle this problem of time synchronization, many algorithms have been proposed in [6]. All of these algorithms consider the propagation latency as an important factor and the localization accuracy depends on how we estimate ToA or TDoA. The speed of sound is assumed to be constant in many schemes under the normal conditions, approximately 1500 m/s. But actually, the speed of sound depends on temperature, salinity and the depth of the water, and it can vary with the variation of any of these factors. Speed of sound increases with the increase in temperature and decreases in colder water. Approximately, the rise of 1°C can increase the speed of 4.0 m/s. The increase of 1 practical salinity unit (PSU) can increase the speed of sound nearly 1.4 m/s. As we go deep, the pressure of water continue to increase, so every 1km depth will increase the speed of sound nearly 17 m/s. Now the schemes, those consider such variations, are expected to generate the better results as compare to those, who just assume the uniform speed.

III. RELATED WORK

Underwater Sensor Networks are attracting the attention of industry and academia as well [2], [7], [8]. At one side, it can enable a wide range of aquatic applications, and on the same time, adverse environmental conditions create a range of challenges for underwater communication and networking. The node mobility and sparse deployment can create problem for underwater sensor networks. Due to the continuous node movements with water currents, there may not be a persistent route from a source to a destination. That's why; an underwater sensor network can be viewed as a partially connected network, and the traditional routing protocols developed for terrestrial sensor networks, usually are not practical for such environment. Due to this intermittent connectivity, packets can be dropped when no routes are available to reach the destination. A review of underwater network protocols till the year 2000 can be found in [8]. Several routing protocols have been proposed for underwater sensor networks. Vector Based Forwarding (VBF) protocol has been suggested in order to solve the problem of high error probability in dense networks. Here an idea of routing pipe like circuit switching, from the source to the destination is proposed, and all the flooding are carried out through this pipe. By using this approach, the retransmissions will decrease; so VBF can significantly improve energy efficiency. A two-phase flexible routing solution [9] for long-term monitoring applications with an idea of centralized planning network routings and data paths has been proposed. Later on, proposed a protocol that can handle both delay sensitive and delay tolerant applications. In this protocol, a cross-layer approach has been used in order to create an interaction between the routing functions and underwater characteristics. Gibson and L. Diaz-Gonzalez gave an idea of clustered based topology[10], where each node in a cluster will communicate with the gateway node, all the nodes of same cluster will communicate using one hope with that gateway. Gateway node is responsible for all the routings of the network, and manages route discovery through the use of probe messages to its neighbors, cached the route information unless errors are reported in future relaying. Dynamic Source Routing (DSR) is a protocol originally for terrestrial networks and a modification of DSR is proposed, where Carlson, P.P. Beaujean discussed location aware source routing for dynamic Acoustic Underwater Vehicle (AUV) networks [11]. It uses TDMA approach for multiple access and known TDMA frame timings to compute ranges based on propagation delay, and then routes are determined by using these ranges.

All of the mentioned protocols till here are based on dense deployments and completely connected sensor networks, which are dramatically different from Intermittently Connected Networks (ICT) and Delay/Disruption Tolerant Networks (DTN). Delay Tolerant Networking allows the nodes to communicate with the help of asynchronous messaging without the existence of end-to-end paths. Routing is a very challenging process for such operation and message replication while the traditional terrestrial routing protocols works on "forward-or-drop" bases, cannot provide better results for this new type of networks because packets will be lost due to the unavailability of stable end to end routes.

Z. Zhang, surveys many protocols [13], proposed for DTN networks based on store-and-forward techniques, such as Epidemic or Partial, SWIM, CAR, MBR, PROPHET, and MEED.

All these protocols can be mapped to a routing spectrum, depending on the message redundancy. From this spectrum one extreme is the Epidemic routing protocol [14], which uses a flooding approach. Here, each node forwards the packet to every encountered node, so get more chances for a packet to deliver its destination. At one side, Epidemic maximizes successful delivery ratio, then at the same time, it minimizes the average end-to-end delay in unconstrained networks. But clearly, this routing protocol consumes too many resources, so this approach can not suitable for underwater sensor networks. Then the other extreme is the idea of Single copy routing protocol [15], where only one copy is kept in the network during all the times till the delivery of the packet. Obviously, this approach can help to reduce energy consumption and other resource utilization; however, the average end-to- end delay can be very long. Many other protocols fall among both of these two extremes.

For any location based routing, most of the protocols require and manage full-dimensional location information of the sensor nodes in the network, which is also a challenge to be solved for UWSNs. Instead of requiring complete localized information, protocol in [16], needs only the local depth information and obtaining the depth is not a problem. Their simulation results show that, DBR can achieve high packet delivery for the dense networks with less communication cost. But the problem here is that, it doesn't show good results for sparse networks due to its greedy nature. In order to achieve same performance as for dens deployments, some recovery algorithms need to explored, where its greedy strategy fails.

Most of the routing protocols, even for terrestrial or underwater sensor networks, use separate packets for control information and data transmission. But Wei Liang, Haibin Yu, Lin Liu, Bangxiang Li and Chang Che, proposed a novel reactive protocol [17] for underwater communications. The Information-Carrying based Routing Protocol (ICRP) used for energy efficient, real-time and scalable routings as here the control packets used for routings, are carried by the data packets. Most importantly, it doesn't require the location information of the nodes as well as, only a small fraction of the nodes are get involved for the routing process. Their simulation results show that, ICRP can effectively achieve the goals for the energy efficiency and less delays for the data delivery.

Hoan Anh Nguyen, Silvia Giordano, Alessandro Puiatti proposed PROPICMAN protocol [18] for the probabilistic networks. This protocol uses the node profiles and the packet information to decide about the routes with highest delivery probability. Results show that, PROPICMAN gives better results as compare to available similar approaches like Epidemic and Single Copy routing protocols. Arshad Islam Marcel Waldvogel provide the comprehensive comparisons and the analysis of some of the routing strategies [19] for the DTN networks like Direct Delivery, First Contact, EBEC and MaxProp. Their simulation results show that, these simple strategies give the good performance especially where small bandwidths and low connectivity is available.

As we have discussed that, the traditional flooding techniques create many problems for successful routings. In order to overcome these drawbacks, Ze Li and Haiying Shen present a hybrid technique of Epidemic and Single copy flooding [20], named as Utility based Distributed routing for intermittently connected Networks (UDM). The basic idea behind the UDM is that, when a node wants to forward a packet to the destination, then it floods the packet to a certain number of its neighbor nodes. The encounter nodes use the "store and forward" idea and holds the copies till they contact the nodes with higher packet utility for that destination. This flooding continues until one of the packets reached the destination. The benefit of UDM is that its transmissions are robust with a constrained amount of overhead. Plus it uses buffer management techniques those helps, to replace the low utility packets with the higher ones, delete the out dated packets, and increase the priorities of the delaying packets. The simulation results show that, the UDM is good for the ability of packet delivery and for the delays. High error probability is a major problem for the dense networks, in order to handle this issue, Peng Xie, Jun-Hong Cui and Li Lao present a position based routing[21] approach. Here an idea of routing pipe like circuit switching, from the source to the destination is proposed, and all the flooding are carried out through this pipe. Nodes closer to this pipe or "Vector" from source to destination can forward the messages. By using this approach, the retransmissions will decrease; plus fewer nodes will involve for the routing process. In order to increase the robustness, an enhanced version of VBF was presented by Nicolas Nicolaou, Andrew See, Peng Xie, Jun-Hong Cui, Hop-by-Hop Vector-Based Forwarding (HH-VBF) [22]. Simulation results shows that, HH-VBF is simple, and significantly produce better results for packet delivery ratio with less energy consumptions.

Dongkyun Kim, Dongseung Shin and Hongseok Yoo proposed DTN architecture [23] in order to provide the connectivity for the legacy applications in the DTN environment. Their architecture is composed of a DTN-layer (at both server and client sides), a routing protocol named as AODV-DTN and a transport protocol called DTcp. At any stage, if the source cannot continue its communications with the receiver, then the DTcp of the source will stop transmitting the packets immediately. First it will try to get the connectivity and then acquire the route with the help of AODV-DTN. The DTN client will register the both, sender and receiver with the DTN server. When the receiver is reachable, then the DTN client subscribes itself with DTN server. DTN server informs the DTN client about its availability, which help the AODV-DTN at source side to retry for a route. Then at the end, DTcp from the source can resume its transmissions. Without any prior location information of the nodes, a large number of broadcast queries can be the burden on the network, which can result in reducing the overall expected throughput. In order to reduce such unnecessary flooding, Josep Miquel Jornet, Milica Stojanovic and Michele Zorzi, give an idea of Focused Bream Routing Protocol [24] for acoustic networks. Their routing technique assumes that, every node in the network has its own location information, plus they also assume that, source node knows about the location of the final destination. Routes are established dynamically, during the traversing of data packet for its destination, and the decision about the next hop is made at each step on the path after appropriate nodes have proposed themselves. During simulations, the protocol performance remains close to the ideal case due to the minimum additional burden and less dynamic route discoveries [26].

Zheng Guo, Gioele Colombi gave a new idea of adaptive routing [25] for Underwater DTN Sensor Networks. Here routing decisions are made according to the characteristics of data packets and the network conditions. The packet priorities are calculated from the, packet emergency level, packet age, density of the neighbors around a node and the battery level of the node. They divide the whole routing spectrum into 4 states and then the routings are conducted according to calculated results. Their simulation results show that, such a strategy can satisfy different application requirements like delivery ratio, average end-to-end delay and energy consumption.

IV. FUTURE WORK

Based on the work discussed in previous sections, it is clear that many issues are left to be solved. Here in this section, we are listing some of the open research issues, those must be considering during the future work for underwater environments. As the available data rates are extremely low, so the routing overheads for the protocols of such networks should be kept as minimum as possible. Research required on variable packets lengths in order to increase the channel utilization. The routing must be self configuring in case of any failure because; equipment is deployed far from the experts. Take the routing decision on the latest available information. Idea of Per-contact routing is better, instead of source routing or per-hope routing, although it can require more processing

for large networks, but for short networks, it can helpful for optimal paths. For delay-tolerant applications, try to develop mechanisms to handle loss of connectivity without immediate retransmissions. Integration of transport layer with the data link layer can be helpful about this. For energy efficiency, local route optimization algorithms are needed in order to manage the consistent variations of the network. For energy concern, its better to develop a routing protocol that sends message over multiple short steps, instead of sending over long links.

V. CONCLUSION

In this paper, we have presented an overview of the current routing protocols for the underwater wireless sensor networks, especially proposed during the last couple of years. We discussed characteristics of the underwater communications and practical issues; those differentiate the underwater communications from the ground based networks. In short, here is no single and complete solution for such networks due to wide ranges and the problems discussed. Its fact that, most of the underwater networks will remain more mobile and sparse with the different considerations than the terrestrial sensor networks, so the efficient routings for acoustic networks will remain an open research challenge during the coming decade.

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