Efficient Rerouting in Underwater Wireless Sensor Network through Void Node Discovery

[1]Sushmita Singh,[2]Prof. Reena Thakur
[1,2]Department of Computer Science and Engineering GNIT Nagpur Maharashtra, India

Abstract-Underwater wireless sensor networks (UWSNs) have been showed as a promising technology to monitor and explore the oceans in lieu of traditional undersea wireline instruments. Nevertheless, the data gathering of UWSNs is still severely limited because of the acoustic channel communication characteristics. One way to improve the data collection in UWSNs is through the design of routing protocols considering the unique characteristics of the underwater acoustic communication and the highly dynamic network topology. In this paper, we propose the GEDAR routing protocol for UWSNs. GEDAR is an anycast, geographic and opportunistic routing protocol that routes data packets from sensor nodes to multiple sonobuoys (sinks) at the sea's surface. When the node is in a communication void region, GEDAR switches to the recovery mode procedure which is based on topology control through the depth adjustment of the void nodes, instead of the traditional approaches using control messages to discover and maintain routing paths along void regions.

Keywords-*Underwater WSN; GEDAR.*

I. INTRODUCTION

OCEANS represent more than 2/3 of the Earth's surface.These environments are extremely important for human life because their roles on the primary global pro-duction, carbon dioxide (CO_2) absorption and Earth's cli-mate regulation, for instance. In this context, underwater wireless sensor networks (UWSNs) have gained the attention of the scientific and industrial communities due their potential to monitor and explore aquatic environ-ments. UWSNs have a wide range of possible applications such as to monitoring of marine life, pollutant content, geo-logical processes on the ocean floor, oilfields, climate, and tsunamis and seaquakes; to collect oceanographic data, ocean and offshore sampling, navigation assistance, and mine recognition, in addition to being utilized for tactic surveillance applications .Acoustic communication has been considered as the only feasible method for underwater communication in USWNs.High frequency radio waves are strongly absorbed in water and optical waves suffer from heavy scattering and are restricted to short-range-line-of-sight applications. Nevertheless, the underwater acoustic channel introduces large and variable delay as compared with radio frequency (RF) communication, due to the speed of sound in water that is approximately 1:5 103m/s (five orders of magnitude lower than the speed of light (3 108 m/s)); temporary path loss and the high noise resulting in a high bit error rate; severely limited bandwidth due to the strong attenua-tion in the acoustic channel and multipath fading; shadow zones; and the high communication energy cost, which is of the order of tens of watts.In this context, geographic routing paradigm seems a promising methodology for the design of routing protocols for UWSNs . Geographic routing, also called of position-based routing, is simple and scalable. It does not require the establishment or maintenance of complete routes to the destinations. Moreover, there is no need to transmit routing messages to update routing path states. Instead, route decisions are made locally. At each hop, a locally optimal next-hop node which is the neighbor clos-est to the destination, is selected to continue forwarding the packet. This process proceeds until the packet reaches its destination. Geographic routing can work together with opportunistic routing (OR) (geo-opportunistic routing) to improve data delivery and reduce the energy consumption relative to packet retransmissions.Using opportunistic routing paradigm, each packet is broadcast to a forwarding set composed of neighbors. In this set, the nodes are ordered according to some metric,defining their priorities. Thus, a next-hop node in the for-warding set that correctly received the packet, will forward it only whether the highest priority nodes in the set failed into do so. The next-hop forwarder node will cancel ascheduled transmission of a packet if it hears the transmis-sion of that packet by a higher priority node. In OR paradigm, the packet will be retransmitted only if none of the neighbors in the set receives it.The main disadvantage of geo-opportunistic routing isthe communication void region problem. The communication void region problem occurs whenever the current forwarder node does not have a neighbor node closest to the destination than itself, i.e., the current forwarder node is the closest one to the destination . The node located in a communication void region is calledvoid node. Whenever a packet gets stuck in a void node, the routing protocol should attempt to route the packet using some recovery method or it should be discarded.

In this paper, we propose the GEographic and opportu-nistic routing with Depth Adjustment-based topology con-trol for communication Recovery over void regions (GEDAR) routing protocol. GEDAR utilizes the location information of the neighbor nodes and some known sono-buoys to select a next-hop forwarder set of neighbors to con-tinue forwarding the packet towards the destination. To avoid unnecessary transmissions, low priority nodes sup-press their transmissions whenever they detect that the same packet was sent by a high priority node. The most important aspect of the GEDAR is its novel void node recovery methodology. Instead of the traditional message-based void node recovery procedure, we propose a void node recovery depth adjustment based topology control algorithm. The idea is to move void nodes to new depths to resume the geographic routing whenever it is possible. To the best of our knowledge, this work is the first that consid-ers depth adjustment node capabilities to organize the net-work topology of a mobile underwater sensor network to improve routing task. Simulation results showed that

GEDAR is able to reduce the amount of void nodes through the depth adjustment based void node recovery strategy. Consequently, GEDAR improves the packet delivery ratio and decreases the end-to-end delay for the critical scenarios of low and high densities and diverse network traffic load, when compared with the state-of-the art routing protocols and the simple geographic and opportunistic routing (GOR) without any recovery mode.This work significantly enhances our previous solutions by investigating the routing problem and the maxi-mum local problem in mobile underwater network scenarios. Moreover, in this work we design an opportunistic routing protocol to cope with underwater acoustic communication impairments. In a static underwater sensor network scenario was considered with sensor nodes attached into buoys and anchors. In those solutions, routing decisions and the topology organization were done in a pro-active way, before the monitoring phase. The contributions of this work are i) an enhanced beaconing algorithm to disseminate the location of the neighbor nodes and known sonobuoys to avoid overloading the acoustic channel;ii) an anycast geo-opportunistic routing protocol advancing the packet, at each hop, in a directed way towards to the closest

sonobuoy;iii)a novel reactive maximum local routing strategy based on the depth adjustment of the nodes, to improve the packet delivery ratio by avoid long hop paths, which can increase packet collisions and, consequently, the packet error rate, end-to-end delay and energy consumption.

Moreover, this work extends our preliminary solution in that we include

A. an enhanced review of underwater sensor network routing protocols,

B. A more detailed theoretical framework and proposed algorithms description,

C. More simulation results including different traffic load analysis and topology related and opportunistic routing protocol related performance evaluation metrics.

II. RELATED WORK

A. Underwater acoustic sensor networks: research challenges

AUTHORS: Ian F. Akyildiz *, Dario Pompili, Tommaso Melodia.

Underwater sensor nodes will 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. In this paper, several fundamental key aspects of underwater acoustic communications are investigated. Different architectures for two-dimensional and three-dimensional underwater sensor networks are discussed, and the characteristics of the underwater channel are detailed. The main challenges for the development of efficient networking solutions posed by the underwater environment are detailed and a cross-layer approach to the integration of all communication functionalities is suggested. Furthermore, open research issues are discussed and possible solution approaches are outlined.

B. Data collection, storage, and retrieval with an underwater sensor network

AUTHORS: I. Vasilescu, K. Kotay, D. Rus, M. Dunbabin, and P. Corke

In this paper we present a novel platform for underwater sensor networks to be used for long-term monitoring of coral reefs and fisheries. The sensor network consists of static and mobile underwater sensor nodes. The nodes communicate point-to-point using a novel high-speed optical communication system integrated into the TinyOS stack, and they broadcast using an acoustic protocol integrated in the TinyOS stack. The nodes have a variety of sensing capabilities, including cameras, water temperature, and pressure. The mobile nodes can locate and hover above the static nodes for data muling, and they can perform network maintenance functions such as deployment, relocation, and recovery. In this paper we describe the hardware and software architecture of this underwater sensor network. We then describe the optical and acoustic networking protocols and present experimental networking and data collected in a pool, in rivers, and in the ocean. Finally, we describe our experiments with mobility for data muling in this network.

C. Efficient Geographic Routing in Multihop Wireless Networks

AUTHORS: S. Lee, B. Bhattacharjee, and S. Banerjee

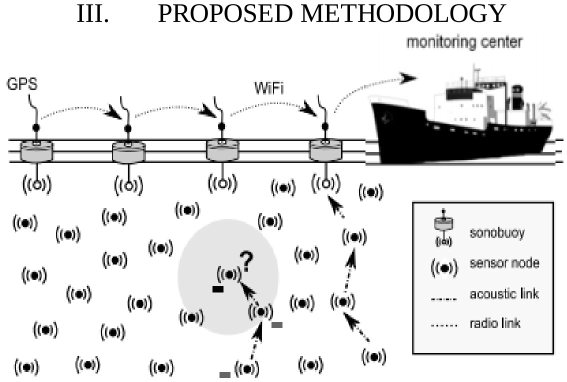
We propose a new link metric called normalized advance (NADV) for geographic routing in multihop wireless networks. NADV selects neighbors with the optimal trade-off between proximity and link cost. Coupled with the local next hop decision in geographic routing, NADV enables an adaptive and efficient cost-aware routing strategy. Depending on the objective or message priority, applications can use the NADV framework to minimize various types of link cost. We present efficient methods for link cost estimation and perform detailed simulations in diverse scenarios. Our results show that NADV outperforms current schemes in many aspects: for example, in high noise environments with frequent packet losses, the use of NADV leads to 81% higher delivery ratio. When compared to centralized routing under certain settings, geographic routing using NADV finds paths whose cost is close to the optimum.

D. On Geographic Collaborative Forwarding in Wireless Ad Hoc and Sensor Networks

AUTHORS: K. Zeng, W. Lou, J. Yang, and D. Brown

In this paper, we study the geographic collaborative forwarding (GCF) scheme, a variant of opportunistic routing, which exploits the broadcast nature and spatial diversity of the wireless medium to improve the packet delivery ef- ficiency. Our goal is to fully understand the principles, the gains, and the tradeoffs of the node collaboration and its associated cost, thus provide insightful analysis and guidance to the design of more efficient routing/forwarding protocols. We first identify the upper bound of the expected packet advancement (EPA) that GCF can achieve and prove the concavity of the maximum EPA. With energy efficiency as a major concern, we propose a new metric, EPA per unit energy consumption, which balances the packet advancement, reliability and energy consumption. By leveraging the proved properties, we then propose an efficient algorithm which selects a feasible candidate set that maximizes this local metric. We validate our analysis results by simulations, and justify the effectiveness of the new metric by comparing the performance of GCF with those of the existing geographic and opportunistic routing schemes.

III. PROPOSED METHODOLOGY



A. Topology Creation

In our simulations, the 32 number of sensor nodes are deployed and the number of sonobuoys is 6. They are randomly deployed in a region the size of 2265 X 1000. In each sensor, data packets are generated according to a Poisson process with the same parameter to very low traffic load; to simulate a mobile network scenario, considers the effect of meandering sub-surface currents (or jet streams) and vertices. We set the main jet speed range from max 5 m/s to min 2.70 m/s. the nodes have a transmission range (rc) of 250 m and a data rate of 50 kbps. The size of the packet is deter-mined by the size of the data payload and by the space required to include the information of the next-hop for-warder set. We consider that data packets have a payload of 150 bytes.

B. Enhanced Beaconing

Periodic beaconing plays an important role in GEDAR. It is through periodic beaconing that each node obtains the location information of its neighbors and reachable sonobuoys, where each node can be informed beforehand concerning the location of all sonobuoys (as long-term underwater monitoring architecture is formed by static nodes attached to buoys and/or anchors), we need an efficient beaconing algorithm that keeps the size of the periodic beacon messages short as possible. For instance, if each node ni embeds its known sonobuoy locations $|S_i|$ together with its location, the size of its beacon message in the worst case, without considering lower layer headers, $2(m+n) \times |N_s| + 2m + 3n$ bits,where m and n are the size of the sequence number and ID fields, and each geographic coordinates, respectively. Given that the transmission of large packets in the underwater acoustic channel is impractical , we propose an enhanced beacon algorithm that takes this problem into consideration. Similarly, each sensor node embeds a sequence number, its unique ID and X, Y, and Z position information. Moreover,

The beacon message of each sensor node is augmented with the information of its known sonobuoys from its set $S_i(t)$ .Each node includes the sequence number, ID, and the X, Y location of the its known sonobuoys. The goal is for the neighboring nodes to have the location information of the all reachable sonobuoys. GPS cannot be used by underwater sensor nodes to determine their locations given that the high frequency signal is rapidly absorbed and cannot reach nodes even localized at several meters below the surface. Thus, each sensor node knows its location through localization services. Localization services incur additional costs in the network. However, the knowledge regarding the location of sensor nodes can eliminate the large number of broadcast or multicast queries that leads to unnecessary network flooding that reduces the network throughput. In addition, the location information is required to tag the collected data, track underwater nodes and targets, and to coordinate the motion of a group of nodes.In order to avoid long sizes of beacon messages, a sensor node includes only the position information of the sonobuoys it has not disseminated in the predecessor round (lines 5-12). Whenever a node receives a new beacon message, if it has come from a sonobuoy, the node updates the corresponding entry in the known sonobuoy set $S_i(t)$ (line 20). Otherwise, it updates its known sonobuoys |Si| set in the corresponding entries if the information location contained in the beacon message is more recent than the location information in its set Si. For each updated entry, the node changes the appropriate flag L to zero, indicating that this information was not propagated to its neighbors (line 25). Thus, in the next beacon message, only the entries in $S_i(t)$ in which the L is equal to zero are embedded (lines 7-10). We add random jitters between 0 and 1 during the broadcast of beacon messages, to minimize the chance of both collisions and synchronization. Moreover, after a node broadcasts a beacon, it sets up a new timeout for the next beaconing.

C. Neighbors Candidate Set Selection

Whenever a sensor node has a packet to send, it should determine which neighbors are qualified to be the next-hop forwarder. GEDAR uses the greedy forwarding strategy to determine the set of neighbors able to continue the forwarding towards respective sonobuoys. The basic idea of the greedy forwarding strategy is, in each hop, to advance the packet towards some surface sonobuoy. The neighbor candidate set is determined as follows. Let ni be a node that has a packet to deliver, let its set of neighbors be and the set of known sonobuoys $S_i(t)$ at time t.

We use the packet advancement (ADV) metric to deter-mine the neighbors able to forward the packet towards some destination. The packet advancement is defined as the distance between the source nodes and the destination node D minus the distance between the neighbor X and D.Thus, the neighbors candidate set in GEDAR is given as:

$$\mathcal{C}_i = \{n_k \in N_i(t) : \exists s_v \in S_i(t) \mid D(n_i, s_i^*) - D(n_k, s_v)$$

Where D(a,b) is the euclidean distance between the nodes a and b and $s_i^* \in S_i(t)$,is closest sonobuoy of ni as:

$$s_i^* = argmin_{\forall s_j \in S_i(t)} \{D(n_i, s_j)\}.$$

D. Next-Hop Forwarder Set Selection

GEDAR uses opportunistic routing to deal with under-water acoustic channel characteristics. In traditional mul-tihop routing paradigm, only one neighbor is selected to act as a next-hop forwarder. If the link to this neighbor is not performing well, a packet may be lost even though other neighbor may have overheard it. In opportunistic routing, taking advantage of the shared transmission medium, each packet is broadcast to a forwarding set composed of several neighbors. The packet will be retransmitted only if none of the neighbors in the set receive it. Opportunistic routing has advantages and dis-advantages that impact on the network performance. OR reduces the number of possible retransmissions, the energy cost involved in those retransmissions, and help to decrease the amount of possible collisions. However, as the neighboring nodes should wait for the time needed to the packet reaches the furthest node in the forwarding set, OR leads to a high end-to-end latency.

For each transmission, a next-hop forwarder set F is determined. The next-hop forwarder set is composed of the most suitable nodes from the next-hop candidate set Ci so that all selected nodes must hear the transmission of each other aiming to avoid the hidden terminal problem. The problem of finding a subset of nodes, in which each one can hear the transmission of all nodes, is a variant of the maximum clique problem,that is computationally hard. We use normalized advance (NADV) to measure the “goodness”of each next-hop candidate node in Ci.NADV corresponds the optimal trade-off between the proximity and link cost to determine the priorities of the candidate nodes. This is necessary because the greater the packet advancement is, the greater the neighbor priority becomes. However, due to the underwater channel fading, the further the distance is from the neighbor, the higher the signal attenuation becomes as well as the likelihood of packet loss.

E. Recovery Mode

Void node recovery procedure is used when the node fails to forward data packets using the greedy forwarding strategy. Instead of message-based void node recovery procedures, GEDAR takes advantage of the already available node depth adjustment technology to move void nodes for new depths trying to resume the greedy forwarding. We advocate that depth-adjustment based topology control for void node recovery is more effective in terms of data delivery and energy consumption than message-based void node recovery procedures in UWSNs given the harsh environment and the expensive energy consumption of data communication.The GEDAR depth-adjustment based topology control for a void node recovery procedure can be briefly described as follows. During the transmissions, each node locally determines if it is in a communication void region by examining its neighborhood. If the node is in a communication void region, that is, if it does not have any neighbor leading to a positive progress towards some surface sonobuoy (C¼;), it announces its condition to the neighborhood and waits the location information of two hop nodes in order to decide which new depth it should move into and the greedy forwarding strategy can then be resumed. After, the void node determines a new depth based on two-hop connectivity such that it can resume the greedy forwarding.

IV. CONCLUSION

I proposed and evaluated the GEDAR routing protocol to improve the data routing in under-water sensor networks. GEDAR is a simple and scalable geographic routing protocol that uses the position information of the nodes and takes advantage of the broadcast communication medium to greedily and opportunistically forward data packets towards the sea surface sonobuoys. Furthermore, GEDAR provides a novel depth adjustment based topology control mechanism used to move void nodes to new depths to overcome the communication void regions. Our simulation results showed that geographic routing protocols based on the position location of the nodes are more efficient than pressure routing protocols. Moreover, opportunistic routing proved crucial for the performance of the network besides the number of trans-missions required to deliver the packet. The use of node depth adjustment to cope with communication void regions improved significantly the network performance. GEDAR efficiently reduces the percentage of nodes in communication void regions to 58 percent for medium density scenarios as compared with GUF and reduces these nodes to approximately 44 percent as compared with GOR. Consequently, GEDAR improves the network performance when compared with existing underwater routing protocols for different scenarios of network density and traffic load.

REFERENCES

[1] I. F. Akyildiz, D. Pompili, and T. Melodia, "Underwater acoustic sensor networks: Research challenges,"Ad Hoc Netw., vol. 3, no. 3, pp. 257–279, 2005.

[2] I. Vasilescu, K. Kotay, D. Rus, M. Dunbabin, and P. Corke, "Data collection, storage, and retrieval with an underwater sensor network," inProc. 3rd ACM Int. Conf. Embedded Netw. Sensor Syst. 2005, pp. 154–165.

[3] J. Partan, J. Kurose, and B. N. Levine, "A survey of practical issues in underwater networks," inProc. 1st ACM Int. Workshop Underwa-ter Netw., 2006, pp. 17–24.

[4] J. Heidemann, M. Stojanovic, and M. Zorzi, "Underwater sensor networks: Applications, advances and challenges,"Philos. Trans. Roy. Soc. A: Math., Phys. Eng. Sci., vol. 370, no. 1958, pp. 158–175, 2012.

[5] M. Stojanovic and J. Preisig, "Underwater acoustic communi-cation channels: Propagation models and statistical character-ization," IEEE Commun. Mag., vol. 47, no. 1, pp. 84–89, Jan.2009.

[6] P. Xie, J.-H. Cui, and L. Lao, "VBF: Vector-based forwarding pro-tocol for underwater sensor networks," in Proc. 5th Int. IFIP-TC6 Conf. Netw. Technol., Services, Protocols, 2006, pp. 1216–1221.

[7] H. Yan, Z. J. Shi, and J.-H. Cui, "DBR: Depth-based routing for underwater sensor networks," inProc. 7th Int. IFIP-TC6 Netw Conf. Ad Hoc Sensor Netw., Wireless Netw., Next Generation Internet, 2008, pp. 72–86.

[8] U. Lee, P. Wang, Y. Noh, L. F. M. Vieira, M. Gerla, and J.-H. Cui, "Pressure routing for underwater sensor networks," inProc. IEEE INFOCOM, 2010, pp. 1–9.

[9] Y. Noh, U. Lee, P. Wang, B. S. C. Choi, and M. Gerla, "VAPR: Void-aware pressure routing for underwater sensor networks," IEEE Trans. Mobile Comput., vol. 12, no. 5, pp. 895–908, May 2013.

[10] D. Chen and P. Varshney, "A survey of void handling techniques for geographic routing in wireless networks," IEEE Commu Surveys Tuts., vol. 9, no. 1, pp. 50–67, First Quarter 2007.

[11] F. Kuhn, R. Wattenhofer, and A. Zollinger, "Worst-case optima and average-case efficient geometric ad-hoc routing," inProc. 4th ACM Int. Symp. Mobile Ad Hoc Netw. Comput., 2003, pp. 267–278.

[12] R. W. L. Coutinho, L. F. M. Vieira, and A. A. F. Loureiro, "DCR: Depth-controlled routing protocol for underwater sensor networks," in Proc. IEEE Symp. Comput. Commun., 2013, pp. 453–458.

[13] R. W. Coutinho, L. F. Vieira, and A. A. Loureiro, "Movement assisted-topology control and geographic routing protocol for underwater sensor networks," inProc. 6th ACM Int. Conf. Model.,Anal. Simul. Wireless Mobile Syst., 2013, pp. 189–196.

[14] R. W. L. Coutinho, A. Boukerche, L. F. M. Vieira, and A. A. Loureiro, "GEDAR: Geographic and opportunistic routing proto-col with depth adjustment for mobile underwater sensor networks," inProc. IEEE Int. Conf. Commun., 2014, pp. 251–256.

[15] Z. S. M. Zuba, M. Fagan, and J. Cui, "A resilient pressure routing scheme for underwater acoustic networks," in Proc. 57th IEEE Global Telecommun. Conf., 2014, pp. 637–642.

[16] P. Xie, Z. Zhou, Z. Peng, J.-H. Cui, and Z. Shi, "Void avoidance in three-dimensional mobile underwater sensor networks," in Proc. 4th Int. Conf. Wireless Algorithms, Syst., Appl., 2009, vol. 5682 pp. 305–314

[17] M. O'Rourke, E. Basha, and C. Detweiler, "Multi-modal commu-nications in underwater sensor networks using depth adjust-ment," inProc. 7th ACM Int. Conf. Underwater Netw. Syst., 2012, pp. 31:1–31:5.

[18] M. Erol, F. Vieira, and M. Gerla, "AUV-Aided localization for underwater sensor networks," inProc. Int. Conf. Wireless Algo-rithms, Syst. Appl., 2007, pp. 44–54.

[19] M. Erol-Kantarci, H. Mouftah, and S. Oktug, "A survey of archi-tectures and localization techniques for underwater acoustic sen-sor networks," IEEE Commun. Surveys Tuts., vol. 13, no. 3, pp. 487–502, Third Quarter 2011.

[20] Z. Yu, C. Xiao, and G. Zhou, "Multi-objectivization-based localiza-tion of underwater sensors using magnetometers," IEEE Sens. J., vol. 14, no. 4, pp. 1099–1106, Apr. 2014.