Routing Improvement in Underwater Wireless Sensor Networks for Energy Saving Purposes

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ABSTRACT:
Underwater wireless sensor networks have attracted much attention in various applications such as natural disasters monitoring, defense, industries, etc. A new routing algorithm for underwater wireless sensor networks is developed and tested. The algorithm shows a better end-to-end delay yet less energy consumption. This was achieved by limiting the data transmission to a number of specific adjacent nodes to whom the transmitter is authorized to send the message. The algorithm performance was compared with other algorithms (depth based routing and cooperative depth based routing protocols) and the results show a better performance.

KEYWORDS: Underwater Communication, Wireless Sensor Networks, Routing Protocols, Energy Consumption.

1. INTRODUCTION

Underwater wireless sensor networks are widely used in defense applications, environmental and biological monitoring, under water exploration, natural disasters predication, equipment and structure monitoring, and exploration of underwater mines. They usually have numerous nodes that interact with the surrounding environment in order to measure the physical parameters around them. These networks are wireless and thus each node is human interference free. The sensors have limited processing ability, limited memory and limited power supplies.

In recent years, there has been substantial work on protocol design for these networks with most efforts focusing on MAC and network layer protocols. Some instances are on-demand data transmission [1], opportunistic routing based interference avoidance [2] and pressure-based routing protocols [3]. Furthermore, several protocols have been developed for energy saving and end-to-end delay reduction in under water wireless networks [4]. Many protocols have been thus developed namely vector base forwarding (VBF) [5], and depth based routing (DBR) [6].

There are several important routing factors involved in energy consumption improvement such as sensors relative distances, remaining sensor energy, access to nearby sensors data, and shortest direction finding. Any maladjustment in the above-mentioned parameters will result in energy consumption increase as well as data loss [7-9].

In this paper, we first investigate DBR and CoDBR (Cooperative DBR) in terms of energy consumption and end-to-end delay. Then a novel algorithm is developed in order to decrease the above-mentioned parameters.

2. CURRENT UNDER WATER ROUTING PROTOCOLS

2.1. DBR Protocol

DBR protocol was introduced by Boia et al [10] for three-dimensional networks. In brief, when a sensor receives a data packet, the transmitter sensor depth is measured. The routing procedure continues only if the transmitter sensors depth is higher than that of the receiver. The main disadvantages of this protocol are lack of management on the network blind spots (which leads to higher energy consumption and higher end-to-end delay), and energy imbalance in the sensor network [6].

Transmitter Sensor Identification Number	Broadcast Time	Data Request

Fig. 1. The format of the ‘Hello’ message

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2.2. CODBR Protocol

In wireless sensor networks, due to phenomena such as underwater currents, underwater living creatures, saltwater and due to dispersion and absorption of sound waves, distortion or partial data loss is quite possible. Hence, it would be possible that the data sent by the transmitter, will not match the received data. The CoDBR protocol is introduced in [11] in order to increase the correctness of received data. The main disadvantages of CoDBR is energy imbalance in the network and data receive uncertainty.

3. PROPOSED ALGORITHM

Whenever a sensor intends to send a message, first a ‘Hello’ message is broadcast to a defined region in which the transmitter sensor identification number and broadcast time are included. In addition, some information like depth, residual energy of each receiver sensor, and distance between the transmitter and each receiver sensor is requested to be sent to the transmitter. Fig. 1 shows the format of the ‘Hello’ signal. Each sensor that is located within the range and receives the ‘Hello message’, calculates the distance between itself and the transmitter using the TOA technique. Then, the depth and the remaining energy information together with the senders ID will be sent to the transmitter.

Fig. 2 shows the receiver response. The transmitter sensor will start data processing after receiving a few responses. The transmitter eliminates the sensors whose distance is farther than *R* using (1):

$$dis^2 - \Delta d^2 + (R - \Delta d) > R^2 \tag{1}$$

Transmitter Sensor Identification Number	Transmitter Sensor Depth	Transmitter Sensor Residual Energy	Distance between the Sensors	Receiver Sensor Identification Number

Fig. 2. The main message format.

Where, i and Δd denote the distance and the depth difference between the transceiver and the receiver, respectively. *R* is the coverage area of any sensor in the network.

Then, the transmitter sensor investigates the depth of each receiver sensor. In our algorithm, the network is divided into three major sections. We call them “very deep”, “deep” and “shallow” sections. The transmitter then assigns a time to each receiver sensor taking into account its remaining energy and its distance to the transmitter. This way the transmitter has a table in which the data transmission time to each receiver are placed. The smaller the transmission time is, the higher the receiver priority. In addition, at the transmission time, the transmitter checks the relative angle of the receiver. If the angle is more than 170 degrees, the receiver data will be deleted form the table. If the sensor is located at the very deep section, the data will be sent only to the first priority sensor. This is due to high density of deep sensors.

Furthermore, in order to have a correct identification of sensors at the data arrival time in the overhead section, a packet sticker together with a process sticker will be amended to the data.

Then, the transmitter sensor sends the main data together with the overhead within a single message to the receiver sensor. This is shown in Fig. 3.

This procedure will be repeated until reaching to very deep receiver sensors.

If the receiver sensor is located at the deep section, the data will be sent to the first and second priority sensors. The second priority sensor will transfer the data immediately to the first priority sensor without any further processing at all. Hence, the first priority sensor will receive two identical messages. Then using equations described in CODBR algorithm, the correctness of the received data will be compared with a threshold level. If the data correctness is higher than the threshold level, one of the two messages will be deleted and the other will be stored for future transitions. Otherwise, both messages will be removed.

In the overhead section, two packet stickers together with process stickers will be sent to the first priority sensor while not-process stickers will be sent to the second priority sensor. This way, the second priority sensor will be notified that process is not required when

CODE RANGE ABYSSAL
Check the depth from hello message
IF<sensor is abyssal> **THEN**
Check the remaining energy
Check the distance
Calculate time and priority
ELSE
GOTO another code
END IF
Check the angle
IF<angle<=170> **THEN**
Attach labeling one-time
Attach labeling processing
Attach data-base
Send data to sender first priority
ELSE
GOTO END
END IF
END

Fig. 3. Message transmission algorithm for the very deep section.

receiving data. If, for any reason, there were no two priorities, the data will be sent to the first priority sensor only. This procedure will be repeated until all receiving sensors will be located at the deep section.

Table 1. Parameters of the suggested algorithm.

Parameter	Value
Dimensions	300x300x500
Sensor #	300
Initial Energy	10 kJ
Operating Frequency	25 kHz
Sensor Delay	50 μsec
Surface Sink #	1
Data Transmission Range	120 m

If the receiving sensor is located at the shallow section, the data will be sent for the first, the second and the third priority sensors. The sensors with the second and the third priority will send the data to the first priority sensor immediately and without any processing at all. Thus, the first priority sensor will receive three identical messages. Again, using the CODBR algorithm, the data correctness will be analyzed and will be compared with a threshold level. If the correctness level is higher than the threshold level, two messages will be deleted and the remaining one will be stored for future use. Otherwise, all three messages will be deleted. In the overhead section, the packet stickers together with process and not-process stickers will be amended to the data for the first priority and the second and the third priority sensors, respectively. This way, the second and the third priority sensors will not take any action in order to process the data. In case if there are less than three priorities, the transmitter sensor will send the data only to the first or to the first and the second priority sensors. This procedure will be continued until the message will reach the surface station. Fig. 4 shows the main message format.

4. SIMULATION PARAMETERS

We implemented our algorithm using the NS tool. In addition, the DBR and CODBR protocols are implemented in the same network in order to enable comparison of the algorithm with the other works. We aim to compare the DBR and CODBR protocols with our algorithm in terms of energy consumption, and end-to-end delay. Table 1 shows the simulation parameters.

5. RESULTS

Fig. 4 (a) shows the end-to-end delay for DBR, CODBR and our algorithm versus the number of sensor nodes. It can be seen that the delay in our algorithm is less than the other two algorithm with one exception at the beginning. This can be attributed to the low sensor density of the network. With increase in the sensor numbers, the network will reach an equilibrium and the end-to-end delay will decrease tremendously. From Fig. 4 (a) results, it can be deduced that in case of moderate and high-density networks, our algorithm exhibits less delay. The delay enhancement has been enhanced 52.37% and 91.69% compared to DBR, and CODBR protocols, respectively.

Fig. 4 (b) compares the end-to-end delay with time increase. It can be seen that the end-to-end delay has remained always less than that of DBR and CODBR protocols. In addition, the increase rate of our algorithm is less than that of the others. After 1000 sec, the delay would increase due to the death of sensor nodes. Our algorithm shows 72.2% and 96.19% improvement over DBR and CODBR algorithms, respectively.

Fig. 4 (c) shows the energy consumption of the three algorithms versus sensor nodes. Again, it can be seen that our algorithm exhibits less energy consumption compared with the others. Furthermore, the energy consumption increase rate (with node number increase) is less than those of the others. In addition, it can be observed that with the increase of node numbers, the energy consumption is increased. This could be attributed to the increase of calculation volume. However, in our algorithm after 250 nodes, the trend stops and the energy consumption reaches a flat level, which can be attributed to the node saturation. This identifies another benefit of our algorithm over the others. A 25.97 and 67.82 improvement over DBR and CODBR protocols in energy consumption is calculated, respectively.

Fig. 4 (d) shows the energy consumption of the three algorithm versus time. While the energy consumption level is similar at 250 sec, after this we can see a huge increase for CODBR protocol. Our algorithm shows less energy consumptions at all times. Moreover, after 1000 sec, increase rate of our algorithm becomes less compared to the other algorithms. This is also attributed to the increased rate of node death in DBR algorithm. Our algorithm shows 33.21% improvement over DBR protocol and 66.56 improvement compared to CODBR protocol.

6. DISCUSSION AND SUGGESTIONS FOR FUTURE WORK

Having had the distance data of receiver sensors, our algorithm prevents sending messages to sensors whose distance are beyond a specific limitation. Those far sensors are located at so-called blind spots of the network and sending messages to them will increase energy consumption. This is why our algorithm exhibits far less energy consumption.

In addition, our algorithm avoids multicasting that results in further decrease in energy consumption compared with DBR protocol. In addition, transmission segmentation will help more decrease in energy consumption compared with CODBR.

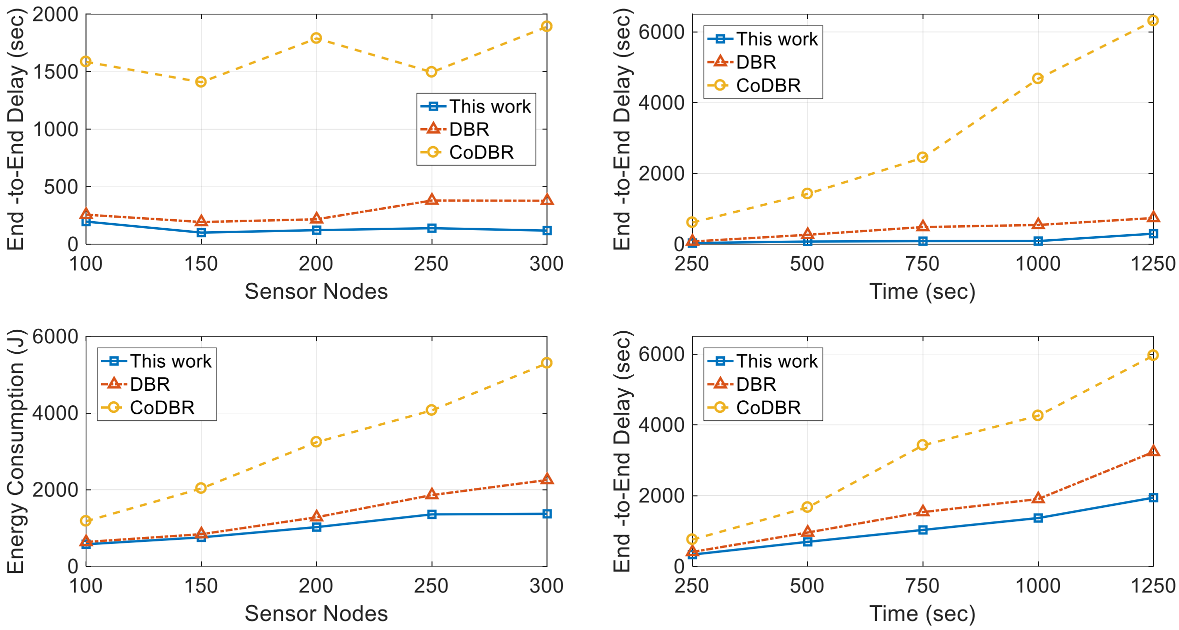

Fig. 4. a) end to end delay versus node numbers, b) end-to-end delay versus time, c) energy consumption versus node numbers, d) energy consumption versus time.

Furthermore, double and triple message transmission will result in an increase in correctness of received data. Moreover, our algorithm avoids horizontal routing by enforcing angular limits in routing, which would decrease the end-to-end delay.

7. CONCLUSION

An algorithm to enhance the routing parameters in an underwater network is presented. The algorithm features are better energy consumption as well as less end-to-end delay.

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