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Forwarding Nodes Constraint based DBR (CDBR) and EEDBR (CEEDBR) in Underwater WSNs

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Abstract

Underwater Sensor Networks (UWSN) has recently become an important field due to the importance of underwater exploration. The unique characteristics of underwater environment make the designing of routing protocol a challenging task. It is difficult to replace the batteries, therefore, it is very important to design a routing protocol that gives maximum network lifetime. Depth Based Routing (DBR) and Energy Efficient Depth Based Routing (EEDBR) are two such routing protocols which give very good performance in underwater environment. In DBR and EEDBR while forwarding the data all the neighboring nodes receive the data. In our work by limiting the number of forwarding nodes, we have extended the network lifetime and energy consumption of DBR and EEDBR. Extensive simulations have been conducted in which show considerable improvement in terms of network lifetime and energy consumption.

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Keywords: Underwater Wireless Sensor Network;

1. Introduction

In recent years, deep-sea exploration has caught a lot of attention because of its usefulness regarding availability of resources, defense and transportation. Traditional methods of ocean exploration are time consuming, incur high costs and human presence is also not possible due to harsh environment. For this reason, idea of terrestrial WSNs has been extended to underwater exploration and a new class of Underwater Wireless Sensor Networks (UWSN) has emerged [1].

The emergence of UWSN has opened many possibilities for underwater ocean exploration. There are many applications of UWSN which include environmental monitoring, sea-life exploration, seismic and tsunami detection, oil/spills monitoring, and so forth [1].

The study of Terrestrial WSN has been going on since many years. However, the ideas developed for Terrestrial WSNs cannot be directly applied to UWSNs due to environmental variables. Radio signals have high attenuation in

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water because of which they are unsuitable for communication. Alternatively, for underwater communication acoustic signals are employed rather than radio signals. Acoustic signals feature low speeds and low bandwidths because of which the design of routing protocols requires different approach than traditional ways applied to Terrestrial WSNs [1,2].

Another factor of critical importance is the energy efficiency of the routing protocol. Similar to terrestrial WSNs' power constraint, it is even harder to replace batteries in UWSNs. So longevity of network lifetime becomes of critical importance in many applications. This is only possible if we design a routing protocol which conserves energy and makes the network energy efficient [2].

The routing protocols developed for underwater data transmission are divided into two categories on the basis of location information. These are localization based and localization free. Localization based routing protocols rely on location information of sensor nodes. In Localization free routing protocols, nodes are only aware of their depth [3].

In this paper, localization free routing protocols are considered. Energy efficient routing schemes are proposed, called Constraint Depth Based Routing (CDBR) which is an extension of DBR [2] and Constraint Energy Efficient Depth Based Routing (CEEDBR) extended from EEDBR [1]. It has been attempted to improve the Network Lifetime and make the protocol more energy efficient. The main idea of CDBR and CEEDBR is to limit the number of data forwarding nodes, so that energy consumption can be reduced. This implementation significantly improves the lifetime of the network.

The rest of the paper is organized as follows: Section II briefly reviews related work. Section III presents motivation. Section IV presents the CDBR and CEEDBR protocols in detail. Section V is about simulations to evaluate the performance of CDBR and CEEDBR in comparison to DBR and EEDBR respectively. Finally, Section VI is the conclusion and future work.

2. Related Work

This section provides an overview of related work in the field of Terrestrial WSNs and UWSNs.

2.1. Routing Protocols for Terrestrial WSNs

Many Terrestrial Routing Protocols such as LEACH, TEEN, SEP and DEEC were investigated in [5,6,7,8]. These Routing protocols present an efficient solution to the problem of routing in the case of Terrestrial WSNs. For example in the case of LEACH cluster-heads are formed and updated in each round. Cluster-heads are rotated in each round based upon a Threshold Probability. This leads to an even distribution of energy consumption for all the sensor nodes. LEACH is an example of proactive protocols. In TEEN the idea has been further developed from LEACH to accommodate reactive networks. SEP and DEEC are heterogeneous aware protocols in terms of residual energy of the sensor nodes.

The main problem in direct implementation of these protocols to UWSN is that these protocols have been designed for static network topologies. In the case of UWSN the main feature is that the network topology is dynamic in nature. Our protocol can be easily adjusted to accommodate the dynamic nature of underwater sensor nodes.

2.2. Routing Protocols for UWSNs

Routing protocols of DBR, EEDBR and AMCTD were investigated for UWSNs. In DBR depth based routing is implemented. The nodes forward the data based upon their depth information. A node with less depth is the candidate for forwarding the data to its next-hop neighbor. In EEDBR, the forwarding nodes are selected based upon two criteria of depth and residual energy. AMCTD involves the mobility of Courier nodes for time critical data forwarding [1,2,3].

3. Motivation

In this section we thoroughly analyze the deficiencies of DBR and EEDBR which leads to the development of CDBR and CEEDBR protocols.

In DBR, all neighbor nodes, that are above the defined threshold receive data and only one node forwards the data. In case of large no. of neighboring nodes, there will be more energy consumption as all of them are receiving the data from the source node. Another problem with DBR is that, there is unnecessary data forwarding. DBR is a receiver based approach. When source node broadcasts data, all nodes above the depth threshold becomes optimal forwarder and the node with lowest depth wins the competition to become next forwarder and intimates rest of the forwarders to stop further transmission. However, because of long propagation delays, nodes may not receive the intimation on time and forward the data as well when their holding time expires.

Fig. 1 shows that the source node forwards data to all its neighbors. According to the figure, in case of DBR 8 neighbors receive data hence their receiving energy is consumed and only neighbor 2 will be the forwarder because it has minimum depth among all. Rest of the nodes will discard the data. This is not an optimal solution since lot of energy is wasted in this way. A better solution can be obtained by restricting the number of receiving nodes and ultimately selecting one to forward the data to the next hop neighbor. This approach has been followed in the case of CDBR and CEEDBR. Receiving nodes are restricted to n nodes. This set of receiving nodes is called optimal

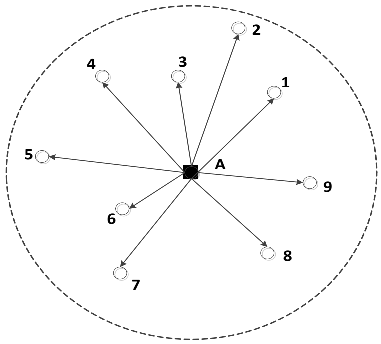

Fig. 1. No. of nodes receiving Data in DBR

forwarder node set. This not only increases network life time, but also restricts unnecessary data forwarding by selecting only one node as a forwarder. One forwarder is selected based on lowest depth among the forwarder node set that forwards data to the destination. This greatly enhances the network lifetime and makes the network more suitable for applications where network lifetime is of critical importance.

4. Proposed Scheme

In this section, we present the working of our protocol in detail.

4.1. Network Architecture

This protocol uses the same Network Architecture as that of DBR and EEDBR. The sensor nodes are deployed under the water randomly. It is assumed that the nodes do not change their depth and horizontal mobility of nodes is also ignored. A number of sinks are deployed on the water surface and the sensor nodes are responsible for delivering the sensed data to the sinks. The sinks are equipped with RF modems and Acoustic modems. The sensor nodes under the water are equipped with Acoustic modems. The nodes communicate with each other and the Sinks using the Acoustic Modems. The sinks communicate with each other and the on-shore data center using the RF Modems.

Data reaching any of the sinks is considered as data delivered. This is because the velocity of RF signals is very high as compared to Acoustic signals. So data reaching any of the sinks can be assumed to be efficiently transmitted to other sinks without much delay. This is obvious from the fact that sound propagates (at a speed of 1.5×10^3 m/s in water) five times to the power of 10 slower than radio (at a speed of 3×10^8 m/s in air).

Furthermore, it is also assumed that the sensor nodes are equipped with depth sensors which can be used to know the depth information. Just like DBR, the proposed protocol only needs to know the depth information of itself and the neighboring nodes.[2].

4.2. Protocol Details

This section elaborates the complete working of CDBR and CEEDBR. It is a localization free protocol and nodes are equipped with depth sensors only therefore it is important to exchange depth information among the local neighbors. For this purpose, all the nodes exchange their depth information among neighboring nodes at the start of the network. Once all nodes know the depth information of their neighboring nodes, a path is established from source to destination to transmit data as shown in Fig. 2.

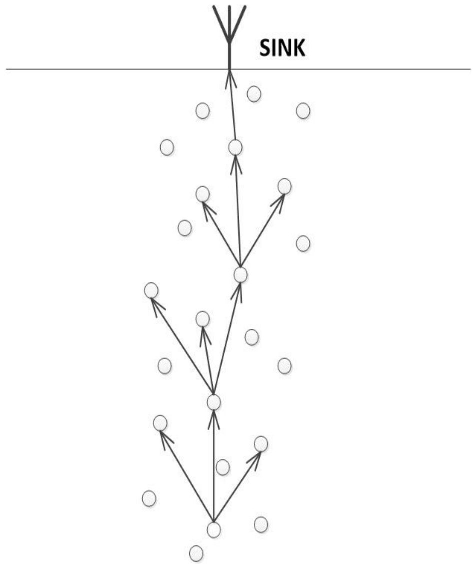

Fig. 2. Data transmission path in CDBR and CEEDBR

Both protocols consist of following phases:

1. Optimal forwarder node set selection
2. Forwarding node selection

4.2.1. Optimal forwarder node set selection

In this phase, source node identifies its neighbors. The nodes having depth lower than the depth of source node are identified as the neighbors. The number of neighboring nodes is further constrained by applying a global parameter of depth threshold (d_{th}). This allows only those nodes to receive the data which are at a depth difference more than d_{th}. Depth difference is defined as depth of source node minus the depth of neighboring node. Among the identified neighbors, source node identifies a set of nodes known as an optimal forwarder node set. These are called optimal forwarders because they are considered best candidates to receive data from source node and forward it to the destination. In the neighbor identification phase, it is important to know whether the Source is within the range of any sink or not. In case a sink is in its close vicinity, the data is delivered directly to the sink. If there is no sink in the range of source node, then it is forwarded to its next hop forwarder node set. Finally one node out of this node set is selected to broadcast data to the next hop forwarder node set.

The selection criteria for forwarder node set is based on key idea of DBR and EEDBR. For CDBR it is the nodes with minimum depth among the neighboring nodes and for CEEDBR it is nodes with maximum weight based upon depth and residual energy. The number of optimal forwarder node set can be adjusted depending on the application.

4.2.2. Forwarding node selection

In this scheme, the source first identifies a set of nodes in its transmission range known as optimal forwarder node set. All the nodes in this set receive the sensed information broadcasted by source node. In CDBR among the forwarder node set, a node with minimum depth is selected for data forwarding. In the case of CEEDBR, among the forwarder node set, a weight is assigned to the nodes based upon depth and residual energy. The node will have maximum weight if it has minimum depth and highest residual energy among the neighbor nodes. The node with maximum weight is the candidate for data forwarding. It is also important to check whether the node is alive or not. In this way data is forwarded from one group of forwarder node set to the next group until it reaches the Sink.[4].

5. Simulation and Results

The Simulations were performed in with initial energy of 40J per node, total number of nodes is 200 and maximum number of rounds is 8000. The total number of forwarding nodes is fixed at 5. There are total of 4 sinks at the surface.

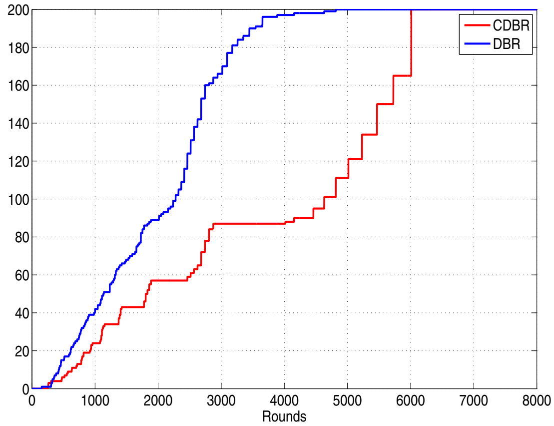

Fig. 3. CDBR Network Lifetime

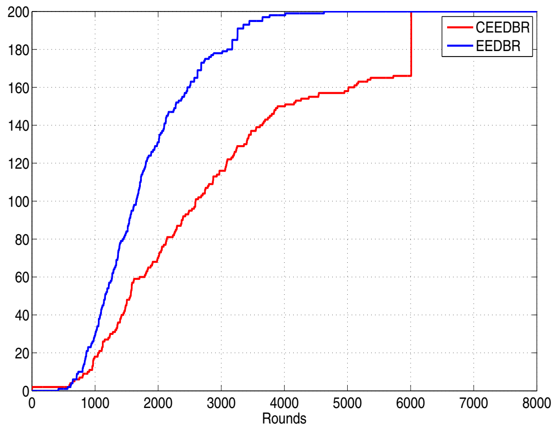

Fig. 4. CEEDBR Network Lifetime

In the above Fig. 3 and Fig. 4 the plot of Network Lifetime for CDBR and CEEDBR are compared to DBR and EEDBR respectively. The maximum lifetime for DBR and EEDBR is around 4000 rounds compared to CDBR and CEEDBR which is around 6000 rounds. There is a considerable improvement in the network lifetime as number

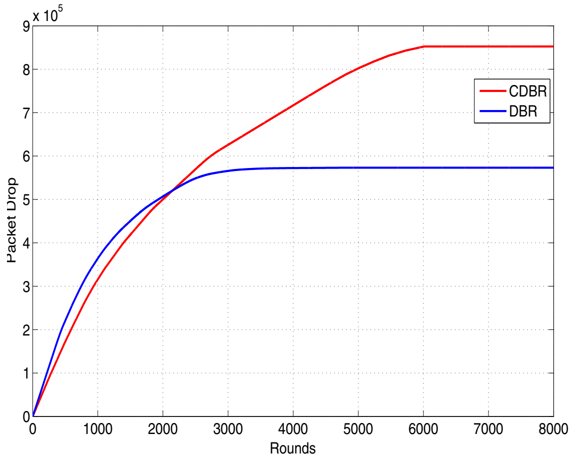

Fig. 5. CDBR Packet Drop

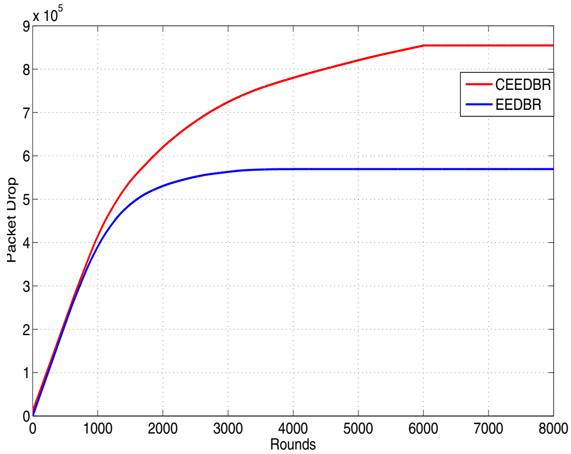

Fig. 6. CEEDBR Packet Drop

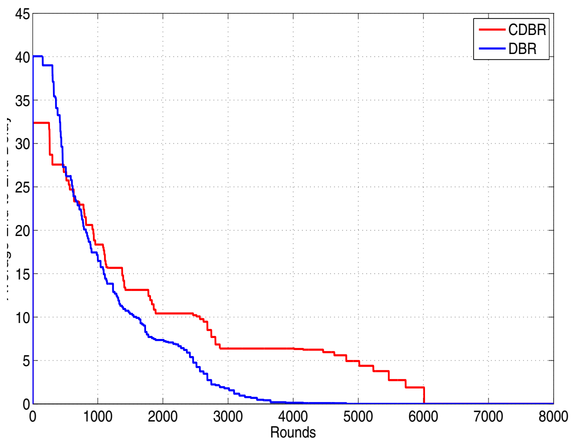

Fig. 7. CDBR End-to-End Delay

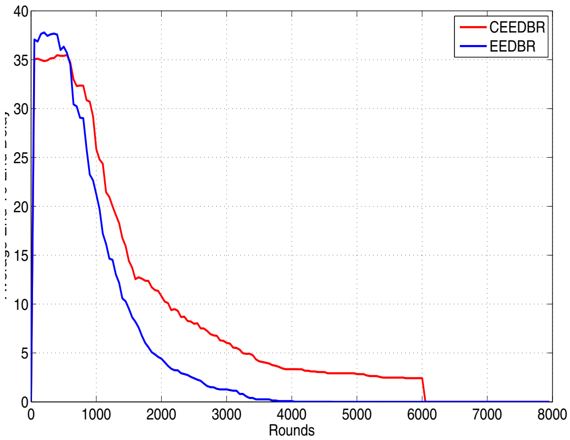

Fig. 8. CEEDBR End-to-End Delay

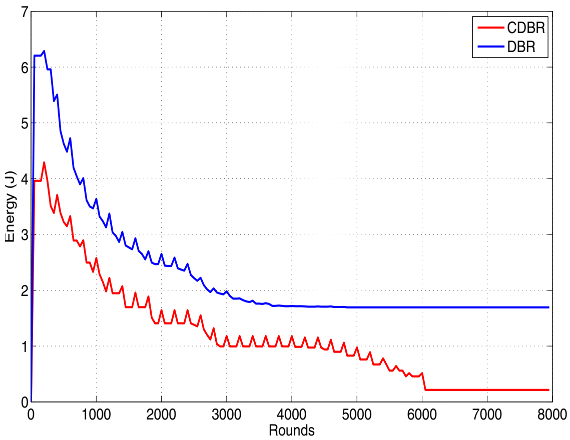

Fig. 9. CDBR Energy Consumption in Joules

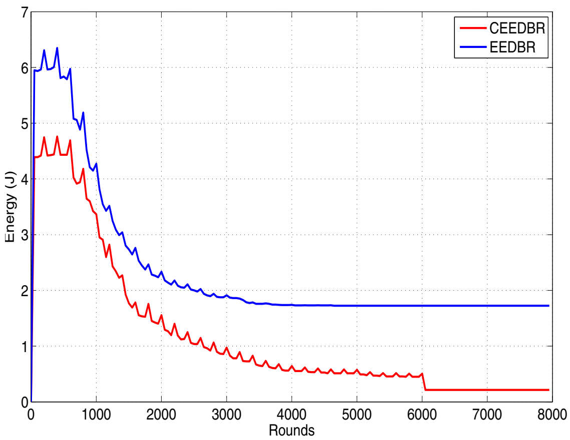

Fig. 10. CEEDBR Energy Consumption in Joules

of forwarding nodes is decreased. It can also be observed that the rate at which nodes die in case of CDBR and CEEDBR is lesser compared to DBR and EEDBR. This implies that considerable portion of network is alive for majority of the time. The increase in network lifetime is because less nodes are involved in data forwarding so total Energy consumption is less.

In Fig. 5 and Fig. 6, as the number of forwarding nodes in any given time within a round are decreased, the packet drop increases. This leads to less number of packets reaching the Sink. Network Quality can be improved by allowing more number of nodes to forward the data. Thus Network Lifetime is improving at the cost of Network Quality which cannot be improved by limiting the number of forwarding nodes.

From the plot in Fig. 7 and Fig. 8 of End-to-end delay it can be observed that the Delay for CDBR and CEEDBR is more than DBR and EEDBR respectively because more number of nodes are alive at any time within a given round. Since more nodes are present to forward the data so naturally delay time is increased.

From both the plots of Fig. 9 and Fig. 10 it can be observed that energy consumption in the case of DBR and EEDBR becomes constant at around 4000 rounds when all the nodes have died out. In the case of CDBR and CEEDBR the energy consumption becomes constant at around 6000 rounds when all the nodes have died out. The energy consumption at any given point in a particular round is less for CDBR and CEEDBR because less number of nodes are involved in data forwarding process. The plots show an increase in lifetime for CDBR and CEEDBR.

6. Conclusion and Future work

Improving battery lifetime to enhance the performance of UWSN is an important and challenging task. The nature of underwater environment makes it very expensive to replace the batteries of sensor nodes. So there is a need to design energy efficient routing protocols for UWSN.

We Introduced CDBR and CEEDBR in this paper and compared the performance of these routing protocols to DBR and EEDBR. It has been shown that by limiting the number of forwarding nodes based upon depth criterion it is possible to reduce energy consumption of sensor nodes and extend the network lifetime. To verify this we have conducted simulations and compared the performance of CDBR and CEEDBR with DBR and EEDBR respectively.

In our simulations we have considered the sinks located at the surface of the sea and static network topology. In future we can extend this work to multiple sinks with varying locations and dynamic network topology. We will also apply the technique to the improvement of AMCTD routing protocol.

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