Reliable And Greedy Routing To Optimize Energy Consumption In Underwater Wireless Sensor Networks

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Abstract: Various aquatic applications have been enabled with the help of Underwater Wireless Sensor Networks (UWSNs). But, it is very challenging to efficiently collect the data and routing schemes for the underlying environment. After the deployment of nodes, it is difficult to recharge or replace sensor nodes. So, it is essential for UWSN to have a maximum lifetime. . In this work, we have simulated and compared greedy routing approach and cluster-based routing approach. Greedy routing approach prefers the shortest route from source to destination. It may transfer data directly (single-hop) or through multiple SNs (multi-hop), if the base station is not in direct reach of SN. In greedy routing technique, a SN who wants to transmit the data will remain active and all other SNs will not participate in data transfer. Another strategy known as cluster based routing transmits the data through CH which will collect the data through other SNs, aggregate the data and transmit it to the base station. Simulation results showed that greedy routing approach is best suited for data transfer.

Keywords: Greedy routing, Reliable routing, Energy-efficient routing, UWSN.

I. INTRODUCTION

The unique features of UWSNs such as long propagation delays, low data transmission bandwidth, acoustic velocity inconstancy, constrained battery control and other ecological hindrances in water makes underwater communication quite challenging. In underwater, radio waves cannot be used for data transmission. The high-frequency radio wave causes the signal to attenuate in conductive ocean water. Low-frequency radio waves (30-300 Hz) can be used, but it requires huge transmission power and gigantic antenna [1]. On the other hand, the use of optical signals in underwater causes dispersion [2]. The average propagation velocity of acoustic waves is 1500 m/s. The radio wave velocity is 3×108 m/s, which is of the order of five times higher than the acoustic wave. As propagation time is inversely proportional to the velocity, the underwater channel suffers from the long delay. The nodes, deployed in underwater, freely float with ocean current. For that reason, the underwater environment is of 3D dynamic nature whereas Terrestrial Wireless Sensor Network (TWSN) is of two dimensions (2D) static in nature. Sensor nodes in underwater cannot be replaced or recharged easily. Hence, UWSNs are much more energy constraint compared to TWSNs.

II. LITERATURE REVIEW

In such situations, it is extremely challenging to give an energy efficient routing protocol for applications. The protocols discovered for wireless sensor network (WSN) give poor performance in the underwater environment. Consequently, the majority of the researchers have concentrated new techniques for designing protocols appropriate in UWSNs. In this paper, the authors introduce a new routing algorithm Energy Efficient Geographic Clustered Multihop Routing protocol. DRAMAC[1] is based on single transceiver in long-delay UWSNs. DRAMAC is only equipped with a single transceiver on each node reducing the hardware cost. It selects channel negotiation strategy according to packet size and the network load condition at the receiver at run time. It reduce the probability of collision and also obtains a lower delay. The simulation results show that DRAMAC can significantly improve the network throughput. In [2], authors presented a mathematical model (OPT) and a greedy heuristic (GAAP) for driving an AUV to collect and deliver data with decaying value from nodes of a UWSN. The aim is to find paths for the AUV that maximize the Value of Information of the data delivered to the sink. The performance of GAAP has been compared to that of other path finding strategies. Results showed that VoI-aware AUV mobility produces higher performance and delivers up to 77 percent more VoI than that delivered by the best of the other heuristics (TSP) and achieves better energy efficiency. An optimization problem is presented when the authors restrict the link schedules to be the kind of TDMA schedules [3]. Then, an iterative algorithm is proposed to solve the optimization problem. The authors evaluate their algorithm in various topologies under different network settings. Simulation results showed that their algorithm can efficiently extend the network lifetime, and constantly outperforms the uniform TDMA scheme and DER. In [4], the authors proposed two receiver-initiated duty cycle scheduling schemes (RidE and NeWT) with the aim to, (i) avoid packet re-transmission overhead, (ii) balance the energy consumption, (iii) and reduce the idle listening phase. Through simulations, the authors observed that both RidE and NeWT have low packet delivery delay and NeWT outperforms RidE due to its aggressive behavior. An information-centric technique to reduce potential security threats in UWSN is proposed in [5]. The authors construct a defensive algorithm to check for potential DoS attacks. This proposal analyzes focus and spread DoS attacks to, first, detect the attack and, second, either create pushback alerts or throttle the malicious node(s) entry point into the network. The authors also added machine learning concept to enhance the security [6]. The authors proposed an Energy Efficient logical Cubical layered Path Planning Algorithm (EECPPA) and Multiple Sink EECPPA (MSEECPPA) for acoustic 3D Under Water Sensor Networks (UWSNs) [7]. EECPPA and MSEECPPA performs much better as compared to existing energy efficient techniques due to cubical division of the network and pure distributed method of clustering. In [8], the authors proposed a novel energy-efficient tracking scheme for an AUV to locate itself in time by UWSNs. Simulation results demonstrates the effectiveness of the proposed tracking scheme, and reveal that the PDSR analysis provides a design guidance for parameter selection in system configuration. In [8], the authors proposed a new routing protocol, called balanced energy adaptive routing (BEAR), to prolong the lifetime of UWSNs. The proposed BEAR protocol operates in three phases: i) initialization phase; ii) tree construction phase; and iii) data transmission phase. Simulation result showed that BEAR outperforms its counterpart protocols in terms of network lifetime. Efficient energy utilization and balanced energy consumption in the network prolonged the network lifetime. A simplified optimization model was used to determine the sink sojourn times, data flow rates and number of MS cycles in order to maximize the network lifetime [9]. An energy efficient routing protocol plays a vital role in data transmission and practical applications [10]. However, due to the specific characteristics of UWSNs, such as dynamic structure, narrow bandwidth, rapid energy consumption, and high latency, it is difficult to build routing protocols for UWSNs. Enhanced CARP (E-CARP), which is an enhanced version of the channel-aware routing protocol (CARP) developed by S. Basagni *et al.*, to achieve the location-free and greedy hop-by-hop packet forwarding strategy [11]. DMM–MAC is suitable for a practical UWSN where traffic arrives irregularly. Utilizing multiple channels and duty cycling may help conserve energy because transmission collisions and idle listening can be reduced [12].

III. ASSUMPTIONS FOR CLUSTER-BASED AND GREEDY ROUTING TECHNIQUES

The foundation of proposed routing technique lies in the realization that the base station is a high-energy node with a large amount of energy supply. Thus, proposed routing technique utilizes the base station to control the coordinated sensing task performed by the SNs. In proposed routing technique the following assumption are to be considered.

- A fixed base station is located far away from the SNs.
- The SNs are energy constrained with a uniform initial energy allocation.
- The nodes are equipped with power control capabilities to vary their transmitted power.
- Each node senses the environment at a fixed rate and always has data to send to the base station.
- All SNs are immobile.

The radio channel is supposed to be symmetrical. Thus, the energy required to transmit a message from a source node to a destination node is the same as the energy required to transmit the same message from the destination node back to the source node for a given SNR (Signal to Noise Ratio). Moreover, it is assumed that the communication environment is contention and error free. Hence, there is no need for retransmission.

A. Algorithm for Clustered-based Routing Protocol

1. Initially, base station is at position 100 X 100 and 200 nodes are setup in a particular region (50 x 100) and each node has equal energy (0.5 joule).
2. Low Energy Adaptive Cluster Hierarchy (LEACH) [7] based protocol is first hierarchical clustering energy efficient routing protocol that reduces the energy consumption of node by cluster formation so it directly increases network life. In LEACH, clusters are formed by dividing the network into small manageable no of units. And each cluster has a particular node called CH that has the responsibility to send the aggregated data from all nodes to the sink node. CH is selected randomly so that the energy dissipation among nodes can be balanced [7]. LEACH Algorithm contains a periodic process in which each round has two phases-

   Setup phase

   a) Advertisement Phase: In this phase, the CHs send advertisement packet to their neighborhood. By this packet, nodes get to know to which CH they are belonging. Every node n in the network chooses a random number k between 0 and 1. If $k < T(n)$ for node n, the node becomes a cluster-head. The selection of CHs will be done by the following equation (1):

   $$T(n) = \begin{cases} \frac{P}{1-P\left[r*mod\left(\frac{1}{P}\right)\right]} & if\, n \epsilon G \\ 0 & Otherwise \end{cases} \qquad (1)$$

   Where P = the desired percentage of CHs (e.g., P= 0.05),
   r=the current round, and G is the set of nodes that have not been cluster-heads in the last $1/P$ rounds [7].

   b) Cluster Set-up Phase: CH received information about its member nodes.

   c) Schedule Creation: CHs provide a time schedule for each node in which they can send their data to respective CH.

   Steady-State phase

   Data Transmission: In first transmission all nodes transmit their data to respective CH. In second transmission once CH received all data from its members it minimize the data without losing meaning of data so that it can save energy instead of sending the complete data. And then send minimized data to destination node (sink).
3. Although LEACH protocol reduces the transmission energy and does not require global knowledge of network but still it have problems like:

• CHs are randomly selected, so network cannot remain with uniform energy dissipation.
• Because LEACH uses single hop transmission so it is not able to cover a wide area.

4. Based on above equations and conditions, nodes sends the data to their respective CHs and energy consumption will be calculated.
5. CH will aggregate the data and send it to the base station and energy consumption will be calculated for each node and CHs.
6. In round 2, the nodes will become CHs according to probability condition i.e. according to minimum distance from base station and threshold energy.
7. After selection of CHs, Nodes sends the data to their respective CHs, that will be selected according to the minimum distance of a particular node from CHs and energy consumption will be calculated.
8. CH will aggregate the data and send it to the base station and energy consumption will be calculated.
9. This process will be repeated until the whole network gets down or number of rounds finished. Performance will be evaluated according to parameters like network lifetime, energy dissipation, data packets sent etc.

B. Algorithm for Greedy-based Routing Protocol

Greedy routing is a very popular choice of sensor network routing algorithms due to the advances in Global Positioning System (GPS) and self-configuring localization mechanisms. In greedy routing, each node forwards a packet to a neighbor that is closer to the base station than itself. If such a neighbor does not exist, i.e. the node is the closest node to the base station among its neighbors, the node discards the packet. In greedy routing, a forwarding node transmits a packet only based on the positions of its one-hop neighbors [6]. Greedy forwarding is lightweight in the sense that it requires only information on the position of neighboring nodes. As information on the position of neighboring nodes is updated quickly and efficiently, greedy forwarding can adapt very well to network changes. By maintaining only local topology information, greedy forwarding copes with increases in the number of network nodes without problems. Upon success, greedy forwarding produces nearly shortest paths. It rarely fails in dense networks. In short, geographic routing based on greedy forwarding promises an efficient, adaptive and scalable approach to wireless sensor networks [7].

The basic steps of the greedy routing algorithm in WSN are as follows:

Step 1: Initialize the distance to parent node as zero,

$$dist[parent] \longleftarrow 0 \quad (2)$$

Step 2: Set all other distances to infinity,

$$dist[v] \leftarrow \infty \quad (3)$$

Step 3: Q, the queue initially contains all the nodes from 1 to n,

$$Q \leftarrow n \quad (4)$$

Step 4: While the queue is not empty, select the node with minimum distance from Q and add that to new set of nodes (u),

$$u \leftarrow \min\_distance(Q, dist) \quad (5)$$

Step 5: Check for all other neighbors of u, if

$$dist[v] > dist[u] + w(u, v) \quad (6)$$

then $dist[v] > dist[u] + w(u, v)$ (7)

Step 6: And if energy of the node u(source node) is greater than zero, trace the shortest path from u to destination till maximum number of rounds until all nodes become dead.

The energy used in transferring the data and receiving the data are respectively as follows [8]:

$$Etrans(k, dist) = Eelec * k + Emp * k * (dist)^3 \quad (8)$$

$$Erecv(k) = Eelec * k \quad (9)$$

Where k=size of data packets

dist=distance from source to destination
Eelec=energy consumed to transmit or receive 1 bit message
Emp=multipath fading signal amplification coefficient

IV. SIMULATION SETUP AND RESULTS

A. Parameter Value

Network field: 100x100m
N (Number of nodes): 100
Initial energy: 0.5 Joule
Eelec (E.Dissipation for E_{TX}&E_{RX}): 50 nJ/bit
ε_{fs} (free space): 10 pJ/bit/m^2
ε_{mp} (Multipath fading): 0.0013 pJ/bit/m^4
E_{DA} (Energy Aggregation Data): 5 nJ/bit/signal
Data packet size: 4000 bits
Tool used for implementation: MATLAB R2016a

B. Results

In this work, SNs are deployed randomly in underwater in an area (100m X 100m) to sense the data and send the sensed data to the base station. Two routing techniques, first greedy routing, and second, cluster-based routing have been considered for simulation. In this section, the results of both of the techniques are simulated and compared. Two scenarios have been considered for simulation. First, in which the number of nodes is 100 and second, in which 200 SNs have been considered.

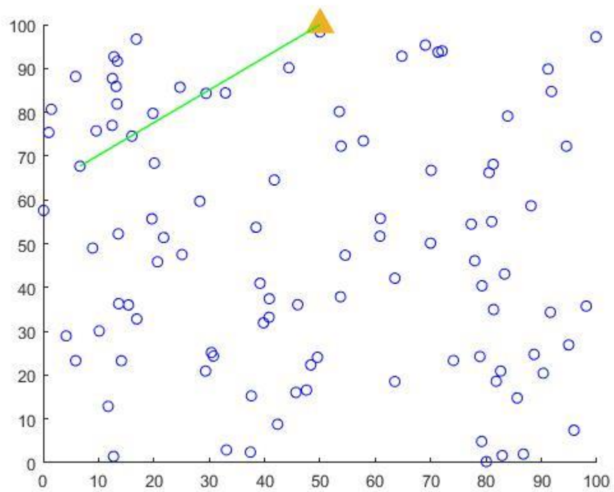

Figure 1 (a) Single-hop Data transfer from SN to Sink through Greedy Routing

Figure 1 (a-b) showed the data transfer from SN to base station through different routes. Greedy routing strategy has been used for data transfer from SN to base station. Greedy routing prefers the shortest route from source to destination. It may transfer data directly (single-hop) or through multiple SNs (multi-hop), if the base station is not in direct reach of SN. Another strategy known as cluster based routing transmits the data through CH which will collect the data through other SNs, aggregate the data and transmit it to the base station.

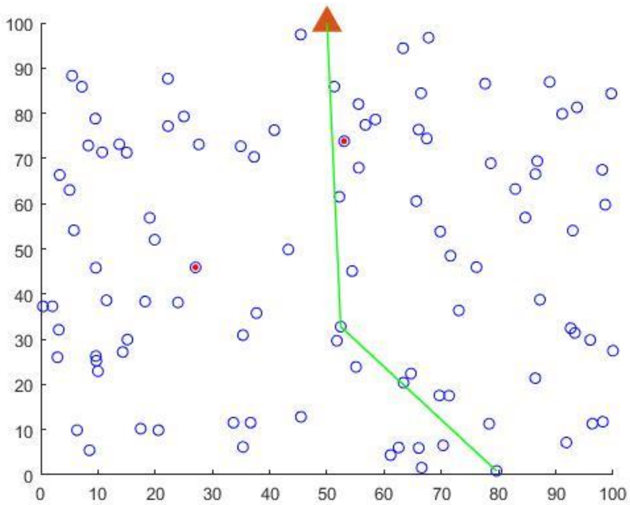

Figure 1 (b) Multi-hop Data transfer from SN to Sink through Greedy Routing

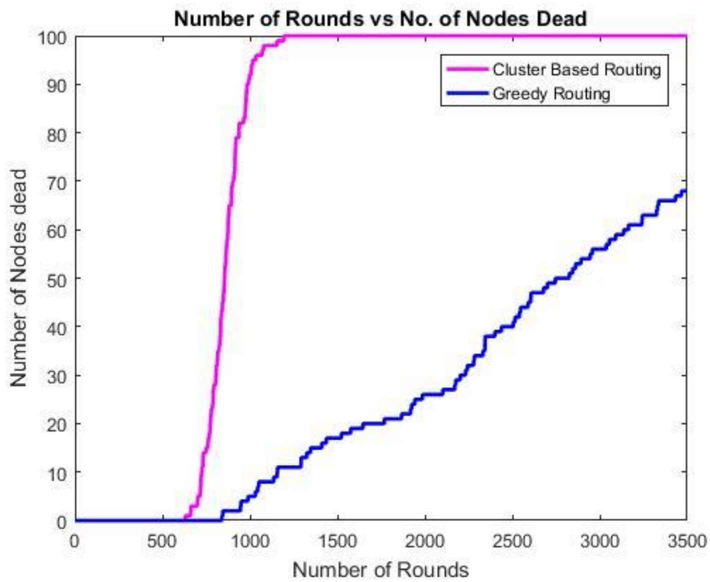

Figure 2 Comparative Analysis of Cluster Based Routing and Greedy Routing with respect to dead nodes

Figure 2 showed the comparative analysis of cluster-based routing and greedy routing with respect to dead nodes. In greedy routing technique, a SN who wants to transmit the data will remain active and all other SNs will not participate in data transfer. while, in cluster-based technique, all the SNs will take part in data transfer. It has been observed in figure 2 that greedy routing approach increases the network lifetime because a single SN will be active in a particular round. Hence, greedy routing will increase the network lifetime.

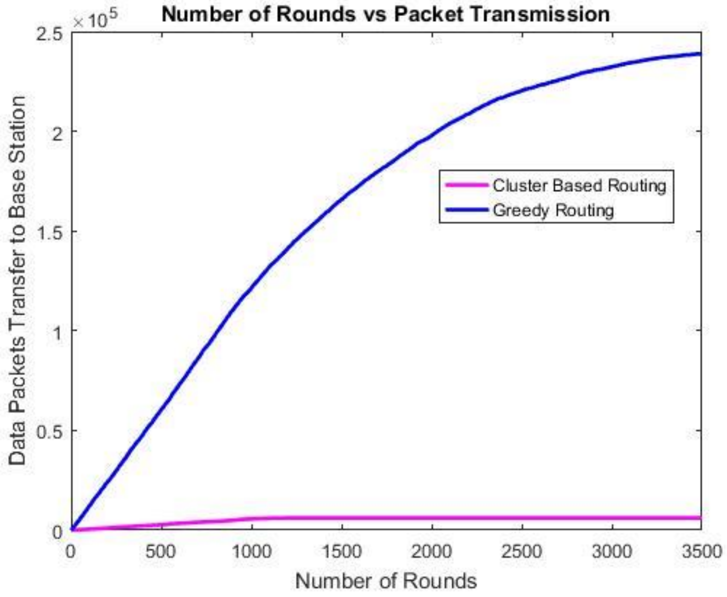

Figure 3 Comparative Analysis of Cluster Based Routing and Greedy Routing with respect to Data Packet Transfer

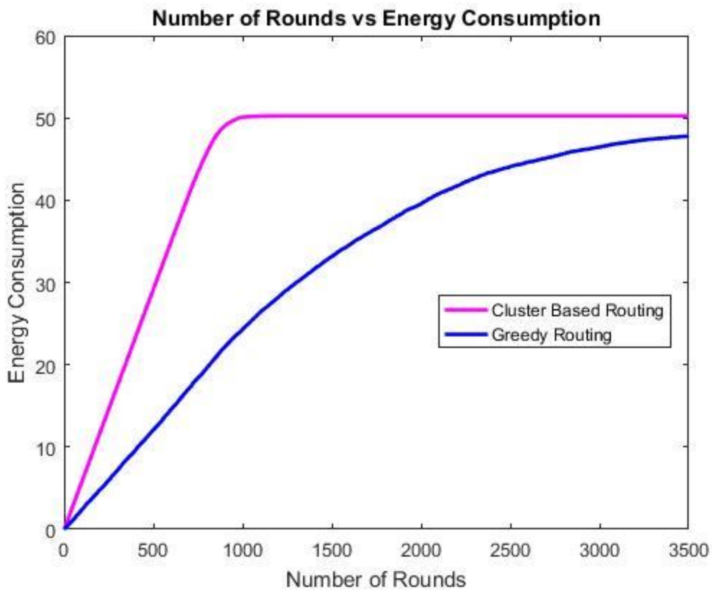

Figure 4 Comparative Analysis of Cluster Based Routing and Greedy Routing with respect to Energy Consumption

Figure 3 showed the comparative analysis of cluster-based routing and greedy routing with respect to data packet transfer to the base station. Due to single-hop and multi-hop transfer from SN to the base station, the packet transfer rate of greedy routing approach is much higher than the cluster-based approach. Figure 4 showed the comparative analysis of cluster-based routing and greedy routing with respect to energy consumption. In cluster-based routing, as all the SNs are participating in data transfer so energy consumption is much higher. While in greedy routing, only SN who wants to transmit the data will remain active and all other SNs will not participate in data transfer so energy consumption is much lower. It can be observed in figure 4 that a stable amount of energy has been consumed in the greedy routing approach as compared to cluster-based routing.

IV. CONCLUSION AND FUTURE WORK

In UWSN, energy efficient routing protocol plays a vital role in data transmission. However, due to the specific characteristics of UWSNs, such as dynamic structure, narrow bandwidth, rapid energy consumption, and high latency, it is difficult to build routing protocols for UWSNs. Various aquatic applications have been enabled with the help of UWSNs. But, it is very challenging to efficiently collect the data and routing schemes for the underlying environment. After the deployment of nodes, it is difficult to recharge or replace sensor nodes. So, it is essential for UWSN to have a maximum lifetime. In this work, we have simulated and compared greedy routing approach and cluster-based routing approach. Greedy routing approach prefers the shortest route from source to destination. It may transfer data directly (single-hop) or through multiple SNs (multi-hop), if the base station is not in direct reach of SN. In greedy routing technique, a SN who wants to transmit the data will remain active and all other SNs will not participate in data transfer. Another strategy known as cluster based routing transmits the data through CH which will collect the data through other SNs, aggregate the data and transmit it to the base station. Simulation results showed that greedy routing approach is best suited for data transfer.

Although, the reliability and network lifetime has been increased but security is still a major concern and to be addressed in future.

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