SELF ORGANIZING TARGET- REPORTING SENSOR NODE SELECTION FOR UNDERWATER WIRELESS SENSOR NETWORK

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ABSTRACT

Under Water Sensor Networks UWSN are deployed to form distributed amorphous computing environments. While monitoring the ocean using UWSN, systematic approach has to be implemented inorder to forward data to the surface sinks. Forwarding of such data from ocean bottom to the surface sink is among the major challenges faced by UWSN. In this paper we propose a novel Self Organizing Target- Reporting Sensor Node Selection Algorithm TRSNSA, which makes the network an intelligent sentinel for monitoring Under Water UW environments. Furthermore, the residual energy of sensor nodes is also taken into account in order to improve the network lifetime. Our proposed self organizing algorithm when incorporated while routing can reduce the energy consumption of the network drastically. This algorithm is totally distributed. Each node takes a decision as to who amongst its neighbour those who have detected the target in their vicinity will participate in the routing algorithm. Our proposed technique avoids data packet flooding from source node to destination/ Surface station. Therefore energy of sensor nodes are conserved by avoiding broadcast of data packets to all the underwater sensor nodes.

KEYWORDS

Self Organizing, Energy efficiency, Routing, Under Water Sensor Network, Target Reporting, Distributed algorithm.

1. INTRODUCTION

Out of the 70% of earth's area covered by water volumes, only less than 10% has been investigated, while the remaining is still unexplored. A scalable UWSN provides a promising solution for discovering the aqueous environment efficiently and observing such location for different applications. The traditional approaches for monitoring oceans have many limitations such as no real-time intervention, high cost, time consuming delay for monitoring ocean environments, unsuitable circumstances imposed by underwater environment for human presence, and so forth. Hence, UWSNs are considered as important alternatives for exploring the oceans. The main advantage of using Under Water UW acoustic sensor networks is that conventional large, expensive, individual ocean monitoring equipment units can be replaced by relatively small and less expensive UW sensor nodes that are able to communicate with each other via acoustic signals.

UWSNs are collection of large number of sensor nodes which when deployed in the ocean emits acoustic waves to communicate with each other. These sensor nodes are responsible for collecting

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the sensed information and then relay it to surface station floating on the surface of the sea. The networked sensors coordinate to perform distributed sensing of environmental phenomena over large scale of physical space and enable reliable monitoring and control in various applications. In certain application [1][2] such as detection, classification and tracking of sea targets, each sensor nodes should be vigilant enough to observe the target.

In order to perform collaborative sensing tasks the sensor nodes must be able to communicate to the surface station by means of efficient routing algorithms. The UWSN routing protocols surveyed in [11] addresses various issues concerning network performance in UW environments. Particularly, improving the network lifetime is an important issue in UWSNs since the replacement of the batteries of underwater nodes is very expensive due to harsh underwater environment. In addition, one of the important issues for improving the network lifetime is to balance the energy consumption among the sensor nodes. The workload should be equally divided among all the sensor nodes over a path from a source towards a destination.

There has been a vast amount of research on routing algorithms for ad hoc networks to improve the network efficiency. But working other way round i.e before implementing the routing algorithm one should decide on a limited number of source nodes who can start the routing. The unique feature of our proposed work is that each sensor networks locally decides to be a source in the routing. Our proposed algorithm is event driven, which reduces the routing traffic amongst the deployed UWSN.

Outline of the paper: The remainder of the paper is organized as follows: In Section 2 we discuss the system architecture and challenges faced by UWSN. Our proposed technique, Self Organizing Target- Reporting Sensor Node Selection Algorithm, is described in Section 3. Experimental result of our proposed algorithm is presented in Section 4. The performance of the work is evaluated in Section 5, and Section 6 concludes this paper.

2. UNDERWATER SENSOR NETWORKS

2.1. Challenges faced

Underwater acoustic channels are characterized by harsh physical layer environments with stringent bandwidth limitations [6]. The available bandwidth is limited due to attenuation and high absorption factor of acoustic signals. The link quality is severely affected by the multipath fading and refractive properties of sound channels. Therefore, the bit error rates are typically very high [7, 8]. The variable speed of sound and the long propagation delays under water pose a unique set of challenges for localization in UWSN [9]. Radio Frequency RF can work at the most on the ocean surface but fails for underwater [1] hence RF is not preferred for underwater scenario. For UWSN acoustic communication is preferred over optical and RF communication. Following are the reasons why acoustic communication is preferred over RF and optical waves: RF waves can travel in sea only at extra low frequencies (30-300 Hz). Hence large antenna and high transmission power is required. Other reasons are limited bandwidth, propagation delay (5 orders of magnitude greater than on terrestrial), very high bit error rates and temporary loss of connectivity. Hence, message exchanges between submerged UWSN nodes and surface nodes must be carried out using acoustic communications.

There are many other challenges faced by UWSNs. The underwater channel is severely impaired, especially due to multi-path and fading. Battery power is limited and usually batteries cannot be recharged. Solar energy cannot be exploited. The issue of energy efficiency and the optimal data packet size/length in underwater wireless network communications in the context of effective and efficient data transmission is highlighted in [10]. UW sensors are prone to failures due of fouling and corrosion. Spatial correlation is more unlikely to happen in underwater networks due to the higher distance among sensors. Unfortunately, underwater acoustic channels are characterized by long propagation delays, limited bandwidth, motion-induced Doppler shift, phase and amplitude fluctuations, multipath interference, etc.

2.2. System architecture

In our proposal we consider the requirement for underwater sensor networks to be self-organizing which implies that there is no central control to control randomly deployed UWSN. Consequently, we assume that nodes are randomly distributed over an area in the ocean. Nodes are dropped into the ocean either by plane or ship. Each of the sensor nodes is equipped with pressure sensor, which gives its depth in the ocean. This actual mechanism is formulated very well in [3] [4][5]. Using this depth information, nodes can adjust themselves to different depths inorder to for a three dimensional architecture. Once they take their position, they start communicating to each other using acoustic signals. At present we assume that there are mild water currents.

Figure 1 shows the communication architecture of underwater sensor networks. Underwater sensor nodes are interconnected to one another by means of wireless acoustic links. Using acoustic communication the sensor nodes can relay data from the ocean bottom to a surface station. UW-sensors are equipped with two acoustic transceivers, namely a vertical and a horizontal transceiver. The horizontal transceiver is used to send commands and configuration data to the other sensors and the vertical link is used to relay data to a surface station. It is assumed that all the nodes have same communication range R. Our proposed Source selection algorithm executes without any centralized control with an aim to make an intelligent sentinel network.

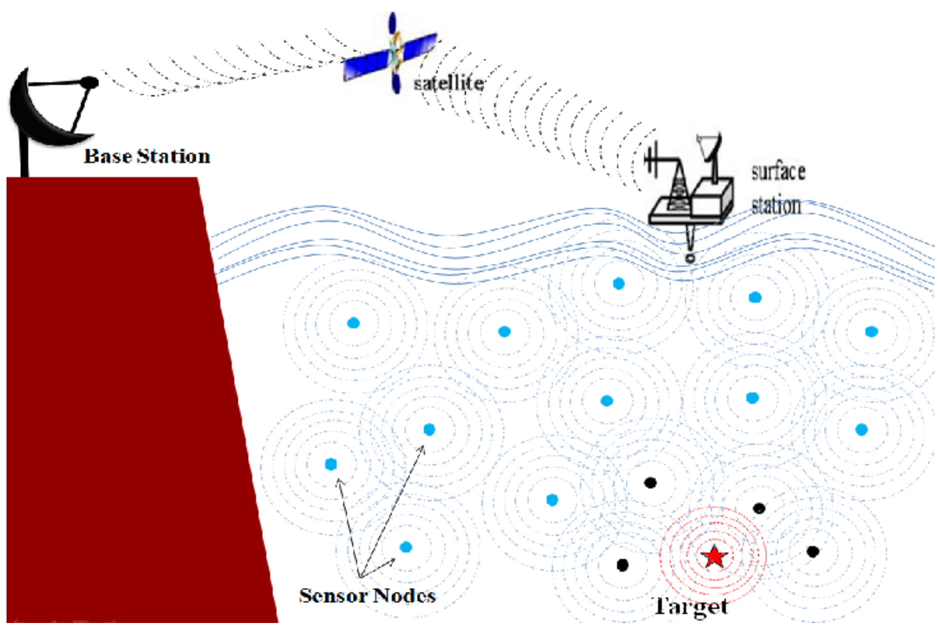

Figure 1. System architecture for UWSN

3. OUR PROPOSED WORK: TRSNSA

In our proposal we consider the requirement for underwater sensor networks to be self-organizing which implies that there is no central control to control randomly deployed UWSN. With the term self-organization, we mean the process of autonomous formation of connectivity, addressing and routing structures. Self-organization of UWSN is challenging. In such networks the mode of control and decision making is distributed and decentralized.

3.1. Assumptions

(a) Each sensor node comprises of an acoustic modem to communicate UW. The modem operates in Transmit, Listen or Receive state each of which is characterized by different power consumption [14]:

(b) Each route from a source to destination consists of at the most M nodes, where M is less than the total number of nodes N, in the deployed network.

(c) Sensor nodes can detect a target only if the target is in its sensing range Rs. Such a source node is called the Detector Node DN. The count of possible number of DNs in a network for a particular target instance is called Total Detector Node TDN.

(d) Neighbour nodes of a sensor node are set of nodes which are within its communication range Rc.

(e) Each node is aware about the information of its one hop neighbour.

(f) Target location is found out by existing localization algorithms (which itself is a different topic of research)[12][13].

(g) One hop neighbour node information is shared at the time of localization algorithm. Hence no separate request is required for data sharing.

(e) Source nodes are the one that detect the target in ocean and initiate routing algorithm so as to report the detection of target to the surface station.

3.2. Primitive Steps for TRSNSA

Step 1: Each node in the network transmit acoustic signals to monitor any target in its vicinity. In figure 2(a) we can see the randomly deployed active nodes for surveillance. We assume that that sensing range is equal to communication range $R_s = R_c$

Step 2: Once a target is detected the sensor node updates its target data and sets its target flag to 1. Target location is found by already existing localization algorithms like [12][13]. The Euclidean distance between the node and the target is stored in the target distance data structure. In figure 2(b) node S_1,S_2,S_3 and S_4 are the one which have detected the target and are ready to participate in routing. Each node keeps information of its immediate neighbours i.e one hop neighbour.

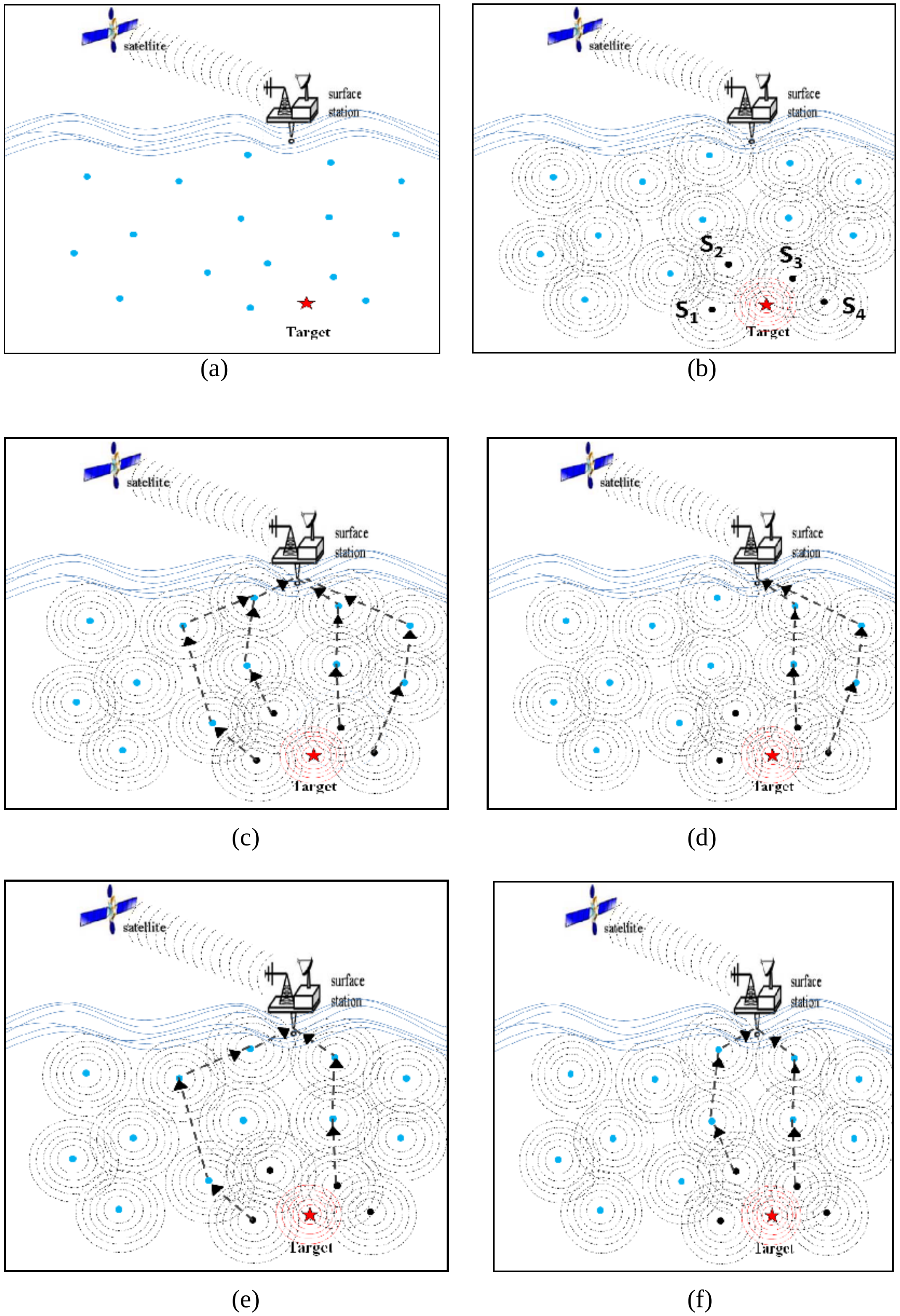

Figure 2 (a) - (f). Technique for selection of source nodes

Step 3: In our example figure 2(c) shows that there are four sensor nodes that are ready for initiating routing of data to the surface sink. Therefore there are atleast four redundant paths to the surface sink.

Step 4: Implementing our proposed Algorithm eliminates the redundant paths. Figure 2(d)-(f) depicts some of the possible scenario where network efficiency is increased by selecting only few source nodes.

3.3. Data Structures

Each node is equipped with a data structure to facilitate the execution of the proposed algorithm.

Data Structure	**Type of Data Store**
<*network_id*>	A deployed network is identified by its network identification code: <*network_id*>
<*node_id*>	All the sensor nodes belonging to a network bear a unique node identification code : <*node_id*>
<*target_flag*>	This flag is set to ‘1’ if the node detects a target in its communication range. And set to ‘0’ if no target is detected
<*target_location*>	Location of the detected target is stored in this field
<*target_distance*>	Stores the distance estimated from itself to the target
<*Neighbour Node*>	A table which maintains the record of all one hope neighbours in its communication range. These neighbour nodes contains the target information with respect its one hop neighbour.
<*transmit_flag*>	This flag is set to ‘1’ if the node is selected for forwarding data to the sink.
<*source*>	Contains the <*node_id*> of the node who will participate as a source node for routing.

3.4. Algorithm

Source Selection Algorithm is an distributed algorithm. This algorithm is run by each Senor Node SN_i where i=1 to N those who have detected the target and target_flag is 1. Assuming there are j neighbouring nodes detecting the same target.

// Update Data structure if target is detected

```
if target is in communication range R
        begin
        target_flag=1;
        target_disatnce= x,y,z coordinates of target
        target_location= Euclidian distance between target and node
        end
```

//Select the source node from its neighbouring node

```
5       for each of its one hop neighbours j
                begin
6               source = SNi
7               if SNi transmit_flag!=1
8                       source = SNj
9               else
                        begin
10                      if SNi < SNj        source = SNi
11                      else   source = SNj
                        end
12              if source == SNi
13              transmit_flag = 1
14              Set time stamp to reset the flag of transmit flag
                end
```

4. EXPERIMENTAL RESULTS

We propose a Source Selection Algorithm which can efficiently work for 3D UWSNs. In our simulation nodes ranging from 50 to 250 were deployed over an area of 500 x 500 x 500 meters. The communication range of every sensor node 'R' was taken to be 200 meters. Nodes are deployed randomly to form a 3 Dimensional architecture. The sensor nodes were placed at varying depth. An average of 50 simulation results are considered for studying the results.

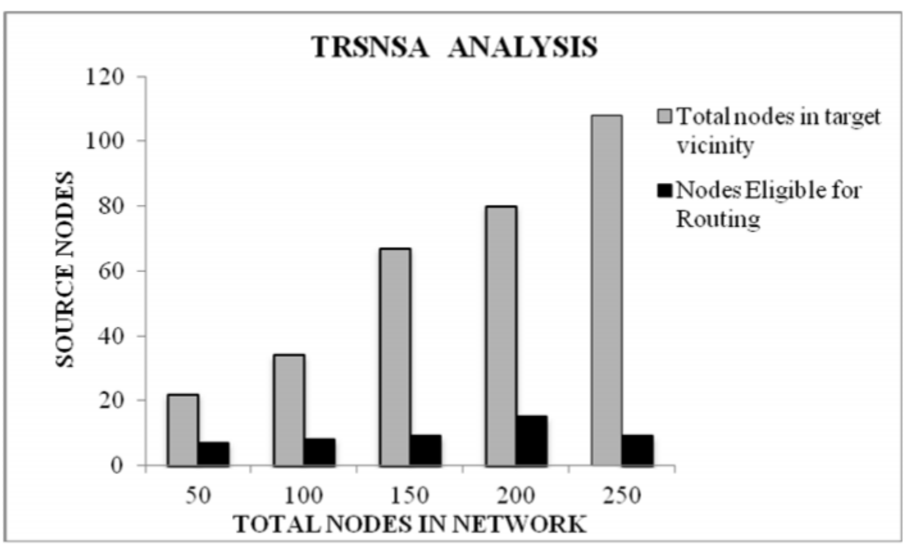

Figure 3. Comparison between total source nodes and selected source using TRSNSA

Figure 3. summarizes our simulation results. The graph depicts a comprehensible success of our proposed algorithm. The light shaded bar in the graph are the total number of nodes that detected the target and can actually participate in the routing. Dark shaded bar is the filtered out sensor nodes which will now participate in routing.

5. PERFORMANCE ANALYSIS

In this section we elucidate as to why our proposed algorithm is an efficient one for performing data routing.

5.1. Energy Analysis

The underwater sensor nodes consume more energy in transmitting than receiving a packet. Therefore, in order to reduce energy consumption, consequently improving network life-time, the number of transmissions needs to be reduced. Therefore, the network protocol in UWSNs should be designed considering the energy efficiency to improve the network life-time. Moreover, in UWSNs, improving the energy efficiency is one of the most important issues since the replacement of the batteries of underwater sensor nodes is very expensive due to the unpleasant underwater environment.

Reduction of transmissions can be done effectively by reducing the nodes that initiate the routing. Refer to the assumptions made in section 5.1. We can calculate the total energy consumed by a network to report a target to the destination (surface sink). For analysis purpose we assume that each node consumes μ units of power to listen, receive and transmit. The equation is given as:

$$E = \mu * M * TDN \quad (1)$$

Where E is the Energy consumed by the network for detecting a target.

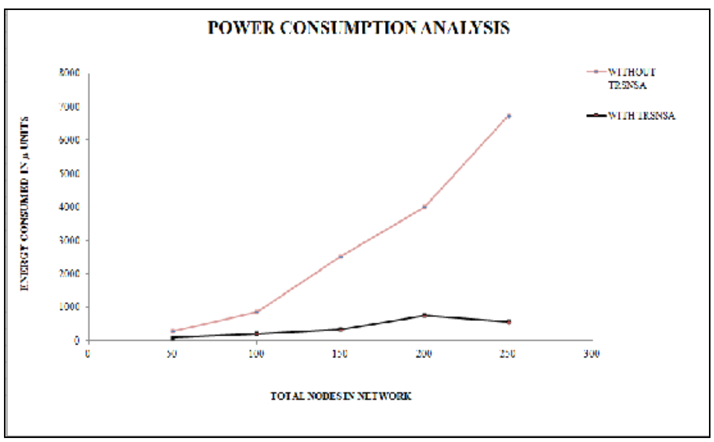

Figure 4. Comparison of Energy Consumed by the network

Total energy that may be consumed by a network for routing data to the sink with and without using our proposed algorithm is depicted in figure 4. Here we assumed M to be N/4. From this figure we can analyse that the amount of energy consumed by network without including TRSNSA increases rapidly with incraese in nodes in the network. The power consumption was reduced by 70% for 50 nodes and 92% for 250 nodes when our proposed algorithm was concidered.

Apart from power consumption there are other reasons for our algorithm to improve network efficiency.

(a) Distributed decision making: Our algorithm is fully distributed i.e there is no centralized control required to perform our algorithm. Each node independently takes a decision to choose itself to be a source node.
(b) Reduce Redundancy: The numbers of routes used to pass on the data to the surface sink are reduced significantly. For a small scale network like the one explained in section 4.2, the difference may not be felt. But for a large scale network the redundancy in data route can affect the network performance severely.
(c) Avoids congestion in network : limiting the source nodes who initiates routing will reduce the congestion in network.
(d) Increase life time of sensor nodes : When numbers of routes are reduced, automatically the number of nodes to be disturbed will be reduced. The energy of node not involved in routing at a given instance will be conserved. Hence life time of sensor node will be increased.
(e) Effecient utilization of limited storage capacity : Sensor nodes have very limited storage capacity. Flooding of too many massages in the network will demand for more memory space in the sensor node. Our proposed algorithm works efficiently to reduce the load on each sensor as well as the network.

6. CONCLUSION

We proposed a novel TRSNSA that reduces traffic in the network for reporting a target by multiple source nodes to the base station. The proposed algorithm was simulated to analyze its impact on number of source nodes shortlisted to forward the target data to surface sink.
Improving the energy efficiency in UWSNs being one of the important issues, we employed our TRSNS algorithm to analyse reduction in power consumption while routing the data of detected target to destination/sink. Further it was found that our algorithm worked out to be very efficient for dense networks.

Our proposed algorithm is totally distributed, where independent decisions are taken by each sensor. This helps to reduce redundant routing path which carries same data thereby reducing data flooding in the network.

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