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Adaptive routing protocol design for underwater wireless sensor network

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Abstract- The adverse environment of underwater sensor network has led to several problems in aquatic communication. The acoustic waves have low attenuation and supports long range of communication but have lower bandwidth and higher propagation delay compared to the radio frequency waves. The water current and channel impairment makes most of the sensor nodes mobile leading to the changing network configuration. Hence, it is very complex and expensive task to maintain or recover the forward path in the dynamic topological networks. Fading, link failure and sparse node density are also the unique characteristics of UWSN which has created challenges in the design of the routing protocol in UWSN.

In this paper an adaptive routing protocol is proposed which uses the water sweeper to activate the nodes in the particular region. As only few nodes are involved in routing, data traffic is reduced thereby conserving the energy. The use of directional antennas in the sensor nodes further reduces the energy consumption and enhances the lifespan of the network. The water sweeper overcomes the use of multiple-sinks and withstands the changing network configuration which makes it cost effective. The simulation result proves that the proposed scheme is successful in conserving the energy efficiently by with increased throughput and reduced jitter.

Keywords- Water sweeper, Dynamic topology, Architecture, Energy efficient, Adaptive antenna array.

1. Introduction

Under water environment is a vast area which has been unexplored for several years. The vast size of underwater with unknown area, dangerous species, unpredictable harsh environments such as Tsunami, Sea-quake, water currents, high pressure and variation in temperature makes it very difficult for human being to explore the underwater. Moreover continuous monitoring over the deep dark ocean is highly dangerous and unpractical for humans. All these features of underwater have led to the development of Under Water Sensor Networks (UWSNs). UWSNs consist of sensor nodes which are deployed at different depths to monitor the interested areas continuously and relay the collected information to the surface sinks. The sensors are used to study the characteristics of water such as salinity, acidity, chemical content, conductivity, pH values, oxygen, hydrogen, dissolved methane gas, temperature, density and turbidity [6]. The data from the surface sink is transmitted to onshore station through satellite or radio link. Acoustic signals are used for long range communication in underwater due to its low attenuation. The attenuation increases with increase in frequency leading to long propagation delay and limited bandwidth [1]. The water current and channel impairment makes most of the sensor nodes mobile leading to the changing network configuration. Acoustic communication experiences loss of connectivity due to multipath, fading and asymmetric links [2] [3].

The underwater sensor nodes are highly expensive due to the extra protection provided to the sensor nodes against corrosion and fouling. The sensors are battery operated and it is highly impractical to replace or replenish the batteries used in underwater sensor nodes [1]. Hence the energy of the sensor nodes must be utilized in a wise way so that the life span of the sensor can be increased.
Challenges to be faced in design of the protocol are:

(1) Limited battery power.
(2) Reduced network lifetime.
(3) Data traffic.
(4) Changing network configuration.
(5) Channel impairment due to multipath and fading.

Many methods have been proposed to overcome these challenges and increase the network reliability, capacity and decrease the energy consumption and still research is in progress.

Advanced aggregation technique is one of the approach in which the number of sensor nodes involved in transmission is reduced by aggregating the sensed data. This reduces the data traffic and early battery exhaustion, thereby conserving the energy.

Clustering and energy harvesting approach is also used to increase the overall efficiency and lifetime. Recent trend is towards the use of directional antennas to provide energy efficient low interference communication.

In the proposed scheme the water sweeper uses an adaptive antenna array to receive the data from the nodes in a desired region (specified by the beam direction and beam width of the transmit beam) and blocks the data from the nodes in other region. The sensor node uses directional antennas and selects the neighbor nodes with max residual energy to route the sensed data.

The remainder of this paper is organized as follows. Section 2 presents the literature survey. Section 3 presents the details of proposed adaptive routing protocol for UWSN with architecture and algorithm. In Section 4, simulation results for the performance evaluation in terms of number of sensing nodes and the resultant throughput, jitter and energy consumption are presented. Finally, the concluding remarks are given in Section 5.

2. Literature Survey

In any network designing an efficient and optimal routing protocol is very essential. Research has been carried out in designing protocol for physical layer and the research in the design of routing protocol is still in emerging state.

K. Ovaliadis presents a survey various methods of clustering which are used for balancing the traffic load between cluster head and cluster members. But clustering methods has issues such period of re-clustering to be adaptive depending on mobility of nodes and the time taken to form cluster becomes crucial when the number of sensors are large which causes more packet transmission and more power consumption[5]. Xie P Proposed vector based forwarding to handle the problems of packet losses and node failure. In VBF the data packets are forwarded in interleaved and redundant path. A localized and distributed self-adaptation algorithm is developed to improve the performance of VBF [6]. Ayaz M uses virtual pipe concept in his proposal on HH-VBF. The forwarder is defined by the virtual pipe. Every intermediate node decides the pipe direction based on its current location. It has good packet delivery ratio and more signaling overhead in sparse areas than VBF. Its performance is affected by the problem of routing pipe radius threshold [7].

Jornet JM proposed Focused beam routing protocol where the source node must be aware of location of its own and the final destination. It avoids unnecessary flooding of broadcast queries. The throughput reduces due to uncertain location information of nodes in the overburdened networks. Lower flexibility is the drawback of FBR [8]. Jinming C proposed a Reliable and energy balanced routing (REBAR) algorithm which is a location based routing protocol. It uses adaptive scheme to define data propagation range to balance the energy consumption of the network. is used by The nodes uses geographic information between the source and sink to transfer the data. Every node is assigned a unique ID and fixed range [9]. Chirdchoo designed a Sector-based routing with destination location prediction (SBR-DLP) protocol for routing a data packet in mobile UASN where intermediate and destination nodes are mobile. It is assumed that each node knows its own location and pre planned movement of destination nodes. Data packets are forwarded in a hop by hop manner to avoid flooding. But the disadvantage is scheduled movements of destination nodes can be affected by underwater currents [10].

Carlson EA proposed depth based routing which is based on the depth of the sensor nodes. The node that has data to be sent determines its depth from the surface and places it in the header and broad casts. The node that receives the data packet determines its depth and compares it with the value embedded in the packet. If it is smaller it forwards else it discards the packet [11]. Uichin L proposed an pressure routing protocol that does not require distributed localization. The data packets are forwarded to a node with lowest pressure level. It is not affect by the void problem. Delivery of multiple copies of the same data and energy used by the pressure sensors must be overviewed [12]. UWSNs are intermittently connected networks (ICN) or Delay Tolerant Network (DTN). There is no persistent route from source to destination due the sparse deployment and node mobility. Hence normal routing techniques are not suitable for UWSNs [13].

Bin Z proposed an Adaptive routing technique. It is assumed that all nodes know their 3rd position. The characteristic of each node decides the route. The protocol is complex and has end to end delays [14]. Ayhan Erdogan proposed a Sector sweeper for WSN which uses adaptive antenna array at the central node. It selects the desired region by specifying the beam direction and beam width of the transmit beam and minimum and maximum RSSI. Only the nodes within the transmit beam are activated all other nodes are deactivated. It does not need any additional software or hardware for node management and location estimation in sensor nodes [15].

3. Adaptive Routing Protocol

Types of nodes

Water sweeper

It has high processing capabilities. It consists of acoustic transceivers for communicating with the acoustic sensor nodes and radio transmitters for communicating with the onshore station through radio link. It consists of adaptive array antenna which selects a particular region for collecting the sensed data by varying its beam width Δ and beam angle α. The water sweeper eliminates multi sink architecture and hence it is cost effective. The water sweeper activates the sensor nodes in it's transmit region by transmitting the broadcast message and deactivates by sending the terminate message.

Sensor nodes

It consist of directional antenna with radiation pattern 180 degree in the upward direction. Each sensor node saves its energy due to directional antenna transmission compared to omnidirectional antennas. Anchored or location based sensor nodes senses the underwater environment continuously and transmits the sensed data only after receiving the broadcast message. The mobile routing node relays the received data from neighbour nodes only after the reception of the broadcast message.

Architecture

The proposed architecture is as shown in the Fig.1 in which the subsea is divided into four layers.

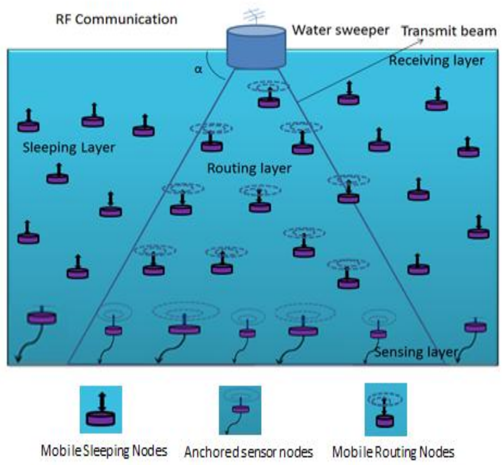

Fig.1: Proposed Architecture

Sensing Layer: Since most of sensor nodes in the sea bed are involved in sensing and forwarding the sensed data and are least involved in routing hence they are anchored to the sea bed. These nodes are also known as location based sensor nodes.

Routing Layer: It is the region located within the transmit beam of the water sweeper with beam angle α and beam width Δ. It consists of mobile sensor nodes that are involved in the routing process.

Sleeping Layer: It consists of mobile sensor nodes which are outside the transmit beam of the sweeper and does not participate in routing activity.

Receiving Layer: It consists of water sweeper which broadcasts the messages and receives the sensed data through routing nodes and then transmits it to the onshore station using the radio link.

Algorithm

1. The Water sweeper (WS) determines the beam direction (α) and beam width (Δ).
2. It sends a broadcast message using direction α and Δ for at least duration of T.

   (Broadcasting duration of WS [T] = Sleeping duration [TS] + Listening duration of sensor node [TL].)
3. If (sensor node is idle and has data to send) then Sends request signals to neighbor nodes
4. If (neighbor node is idle) then

   It sends grant signal along with its residual energy
5. SN determines its neighbor node with highest residual energy and transfers the data packet to the neighbor node.
6. Now the neighbor node that receives the data packet determines its neighbor node with max residual energy. The process continues until water sweeper is reached.
7. After enough data has been received the WS sends the terminate message which instructs the sensor nodes to turn-off their transceivers.

4. Simulation Results

NS-2 is a event simulator that supports simulation of TCP, routing and multicast protocols over wired and wireless networks. The proposed algorithm is implemented in NS2. The simulation topology includes the network with 60 sensing nodes. The simulation parameters were set as shown in Table 1.

TABLE 1.Simulation Parameters for NS2

Simulation Parameter	Value
Simulation Area	1000 m x 1000 m
Number of nodes	Mobile nodes = 60
Transmission Range	350 m
Traffic Flow	CBR
Transmission Power	0.4 mW
Reception Power	0.2 mW
Ideal	0.1 mW
Simulation time	3 min for each run

Average energy consumption: The average energy consumption with adaptive UWSN is reduced compared to without adaptive UWSN as shown inFig.2. It is measured in milli Watts.

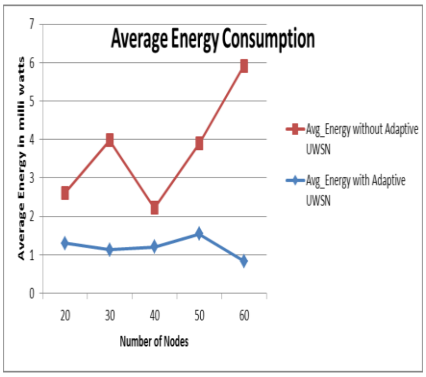

Fig. 2: Energy consumption with and without Adaptive UWSN

Jitter: Jitter is the variation in the time between packets ariving caused by network congestion,timing drift or route changes. It is observed that the jitter is reduced to almost zero with adaptive UWSN as shown in Fig.3.It is measured in milli seconds.

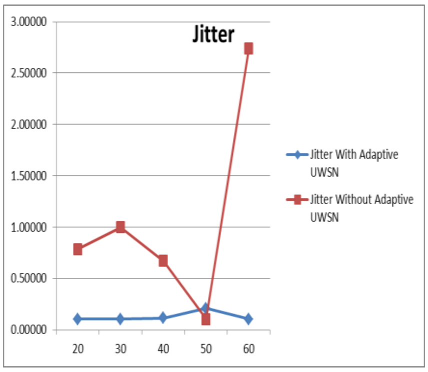

Fig. 3: Comparison of Jitter with and without adaptive UWSN

Throughput: It is a measure of successful delivery of data packet within the threshold time. It is the ratio of number of packets received to the total number of packets delivered. It is measured in terms of bits per second or data packets per second. It is observed that the throughput is increased by 30 % by using Adaptive UWSN as shown in Fig.4.

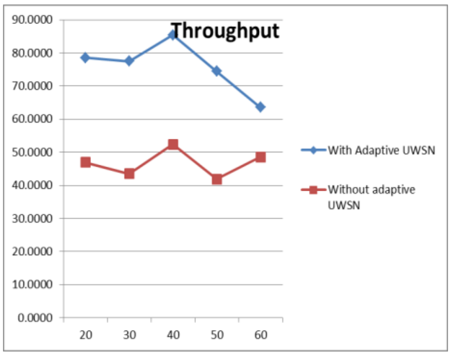

Fig. 4: Comparison of Throughput with and without Adaptive UWSN

5. Conclusion

Underwater sensor network finds its application in underwater monitoring and exploitation. It faces challenges in the design of protocol due to energy constraints of battery, mobility of nodes etc. In our work we propose an adaptive routing protocol which activates only the nodes in a particular region of interest. Our proposed approach uses water sweeper which avoids the use of multiple sinks. The result indicates that energy consumption is reduced with increased throughput and reduced jitter. Future direction is to develop a protocol for time critical applications.

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