BEAR-MAC ROUTING PROTOCOL FOR UNDERWATER ACOUSTIC SENSOR NETWORKS

A. Albina Sneha
Department of Electronics and Communication Engineering
P.S.R.Rengasamy College of Engineering for Women, Sivakasi, Tamil Nadu, India

J. Maheshwari
Department of Electronics and Communication Engineering
P.S.R.Rengasamy College of Engineering for Women, Sivakasi, Tamil Nadu, India

Abstract

Environmental conditions are monitored by the Wireless Sensor Networks (WSNs) that are physically not connected to each other but transmit data through a network.WSN plays a vital role in under water acoustic networking to collect information regarding ocean for navigation and surveillance as well as disaster management. The WSNs has several challenges including limited bandwidth, long delays, high error rate, and more power consumption. As energy consumption stands as a critical challenge, several traditional approaches have adopted MAC protocols to design an energy efficient system. The major drawback of such protocols is that it requires intensive bandwidth during the handshaking mechanism. It also resulted in long propagation delays and it is difficult in finding the route. The BEAR protocol that works with MAC protocol result in high collision of transmitted packets. In this paper, Balanced Energy Adaptive Routing (BEAR) protocol is proposed to select a cost effective route that enhances throughput, and reduces energy and time consumption. RTS/CST mechanism is adopted to minimize collisions. The experimental results are compared with the existing MAC protocols by which the BEAR-MAC proved to be more efficient in terms of energy efficiency, time and throughput.

Index Terms: *Balanced Energy Adaptive Routing, Wireless Sensor Networks, Under Water Acoustic Networking, MAC protocols, energy efficiency, collision, handshaking mechanism.*

Introduction

Underwater Acoustic Sensor Networks are the recently emerging technology based on WSNs to study the oceanographic data and disaster management. The monitoring of under water in oceans are performed by numerous sensor and vehicles connected to each other by means of wireless networks [1]. The communication takes place in the physical layer, in which radio waves require more transmission power and optical waves would suffer from scattering. Hence, WSNs are adopted to monitor the underwater environment such as temperature, pollution monitoring, navigation, ocean resources and so on which makes use of sensors. WSNs involves a set of hundred to thousand number of nodes connected to each other to transmit information. The major components of WSNs include receiver, microcontroller, antenna, transmitter, sensors and energy source. The emergence of Micro-Electro-Mechanical Systems (MEMS) technology seeded the growth of WSNs. Data acquisition in WSNs are performed by the sensors and based on the local environment and the acquired data is transmitted for further processing [2] . A group of sensor nodes are collected as a single cluster to minimize the number of nodes that actively participate in data transmission. The node from which the data is transmitted is called as source whereas the node that receives data is known as sink. Each cluster is controlled by a Cluster Head (CH) to minimize energy consumption by efficient routing. It will localize the route setup among the cluster and so cut back the scale of the routing table keep at the individual node. It may conserve communication information measure as a result of it limits the scope of bury cluster interactions to CHs and avoids redundant exchange of messages among detector nodes.

Moreover, agglomeration will stabilize the constellation at the amount of sensors and so cuts on topology maintenance overhead. Sensors would care just for connecting with their CHs and wouldn't be suffering from changes at the amount of inter-CH tier. The CH may implement optimized management methods to more enhance the network operation and prolong the battery lifetime of the individual sensors and also the network time period. A CH will schedule activities within the cluster in order that nodes will switch to the low-power sleep mode and cut back the speed of energy consumption. what is more, sensors may be engaged in a very round-robin order and also the time for and reception may be determined in order that the sensors reties area unit avoided, redundancy in coverage may be restricted, and medium access collision is prevented [3].Fig 1 shows the architecture of Underwater acoustic sensor networks.

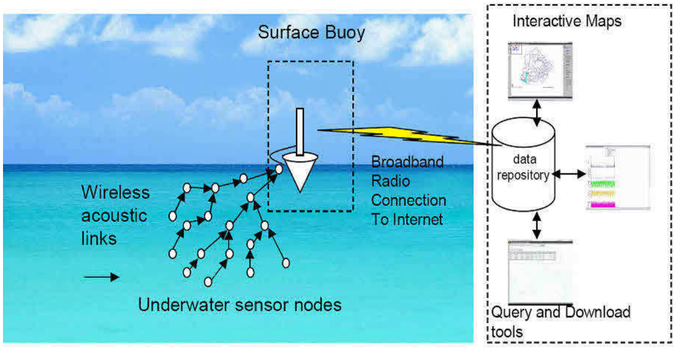

Fig.1: Architecture of Underwater Acoustic Sensor Networks

Several MAC based terrestrial sensor networks has been proposed for efficient energy consumption and minimized propagation delay but they are not best suited for under water acoustic sensor networks. The major classification of MAC includes contention based and contention free protocols. Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA) and Time Division Multiple Access (TDMA) are few examples of contention free multiple access control techniques [4]. These techniques resulted in high energy consumption and bandwidth scarcity. Collisions are the most limiting factor in the performance of the different ALOHA-based schemes. Although carrier sensing ALOHA offers a higher throughput, it consumes much more energy on collisions. Slotted ALOHA try to make the nodes send packets in pre-defined time slots, but the simple analysis and simulation results show that Slotted ALOHA achieves the same utilization as non-Slotted ALOHA [5].

The main limitation of MACA-MN is that consuming considerable bandwidth in the handshaking process which overburdens the already scarce bandwidth resources. The DOTS protocol harnesses both temporal and spatial reuse to improve channel utilization. However, the temporal and spatial reuse of DOTS is limited to the receiver side[6]. There is no support for a sender to open concurrent sessions to the same receiver. The paths established by face forwarding are not optimized. It cannot be applied to all sensor nodes when some routing based on virtual coordinate are adopted in the network. The average delay is increased and the packet delivery ratio is less. In order to overcome the drawbacks of the existing MAC protocols, the Balanced Energy Adaptive Routing (BEAR) protocol is proposed in this paper for effective route selection with minimized energy consumption. RTS/CTS handshake mechanism is adopted to avoid collisions.

The paper is organized as follows: Section II reviews the state-of-art techniques for discovery of routes and energy efficiency in under water acoustic networks. Section III explains the process of BEAR-MAC protocol and RTS/CTS handshaking mechanism. Section IV evaluates the performance of the proposed system in terms of throughput, delay, packet delivery ratio and energy efficiency. Section VI concludes the work with a highlight of the extension work.

Related Art

This section reviews the traditional works on under water acoustic sensor networks. This paper presents many elementary key aspects and architectures of WSNs, rising analysis problems of underwater detector networks and exposes the researchers into networking of underwater communication devices for exciting ocean observance and exploration applications. The application of wireless detector networks to the underwater domain has vast potential for observance the health of watercourse and marine environments. A detector network deployed underwater might monitor physical variables such as water temperature and pressure as well as variables such as conduction, turbidness and sure pollutants. The network might track plumes of silt due to dredging operations or pollutants owing in from land, and it might monitor and model the behavior of underwater ecosystems. Imaging sensors can be wont to live visible amendment within the setting or count, and maybe even classify species and conjointly helpful for disaster interference. Inter-symbol interference may be neglected in each sub band, greatly simplifying the receiver complexity of channel equalization but it does not hold good for underwater networks [7].

The gateway placement issue is reviewed to design a cost effective underwater wireless sensor network. A mixed integer programming (MIP) gateway deployment optimization framework is developed and the balance between the energy consumption and number of surface gateways are analyzed. MIP solver optimizes the problem and combines the results to provide input for evaluation. Multiple surface-level gateways are deployed to avoid the high propagation delay. The minimum number and the locations of surface gateway nodes required are determined using the optimization function. The drawback is that the electromagnetic waves cannot be adopted for long range transmissions because they may absorb the water very fast [8].

The coverage and connectivity issues of 3D networks are analyzed to minimize the number of nodes required to formulate the network. The kepler's sphere packing problem is eliminated. The truncated octahedron is identified as better volumetric quotient on comparison with four space-filling polyhedrons [9]. The connectivity issue has been addressed by determining the minimum transmission radius needed to maintain connectivity among neighboring nodes in various placement strategies. The solution of similar problems in 3D is not important for cellular networks since the radius is usually on the order of kilometers. However, the problem is important for other scenarios where nodes with limited sensing range are to cover a vast 3D space. [10].

The energy consumption of sensors both in deep and shallow water has been studied. In acoustic networks the power required for transmitting is typically about 100 times more than the power required for receiving. The design of robust, scalable and energy-efficient routing protocols in this type of networks is a fundamental research issue. Most existing data forwarding protocols proposed for ground-based sensor networks cannot be directly applied because they have been designed for stationary networks[11]. The packet relaying technique results in energy savings in the deep water scenario and increases the network capacity, although it increases the complexity of a routing protocol based on this method, as well, and results in increased end-to-end packet delay [12].

The localization algorithms are reviewed for better transmission of packets through a proper route. Researchers classify these localization algorithms into two categories: distributed and centralized localization algorithms, based on where the location of an unknown node is determined. In distributed localization algorithms, each underwater unknown node collects localization information and then runs a location estimation algorithm individually [13].

In centralized localization algorithms, the location of each unknown node is estimated by a base station or a sink node. These two categories are further divided into subcategories of estimation-based and prediction-based algorithms. The depth information is used to transform the 3D underwater positioning problem into its 2D counterpart via the projection technique [14]. Several routing protocols used in underwater acoustic sensor have been studied. The planning of every protocol follows sure goals i.e. reduction of energy consumption, improvement of communication latency, action of strength and measurability etc.

This paper examines the most approaches and challenges within the style and implementation of underwater device networks. The careful descriptions of the chosen protocols contribute in understanding the direction of this analysis on routing layer in UWSN. When a CH receives data from all of its client nodes, it performs some necessary signal processing techniques on this data to compress it. After compression, this data is transmitted towards BS. During this whole process the radio interface of CH remained turned on, which consumes energy. When CH transmits information towards BS, it is also high energy transmission. This leads to the fact that being a CH puts a lot of energy burden on each node. That is the main reason behind rotating CHs during whole network operation [15]

Proposed System

This section describes in detail about the proposed architecture of BEAR-MAC protocol. The BEAR-MAC protocol reduces packet collision based on the following conditions

- RTS, the maximum propagation delay must be lesser that the RTS wait time.
- CTS wait time should be greater than the RTS transmission time plus twice the maximum propagation delay plus the hardware transmit-to-receive transition time.

Using time synchronization among nodes and a known transmission and propagation time for each control and the size of data packet is assumed to be fixed in this paper, each node can count its neighbors' transmission and reception schedules by overhearing the neighbor's transmissions. With the knowledge of neighbors' schedules, each node can schedule its own transmissions without collisions. For each node in BEAR-MAC, transmission and reception schedules affecting one hop neighbors, and a rank map including propagation delays between the node and its one-hop neighbors are used to avoid collisions. The type of MAC packet overheard (RTS, CTS, DATA, and ACK) and the rank map information of each node infer when its one-hop neighbors will be receiving transmissions. Similarly, based on the node's knowledge of its current sessions and the rank map information, a node can calculate the time when it will be receiving packets. When a node wants to send a packet, it calculates this transmission schedule and compares with neighboring and local reception times to detect possible collisions. Fig 2 shows the architecture of the proposed system.

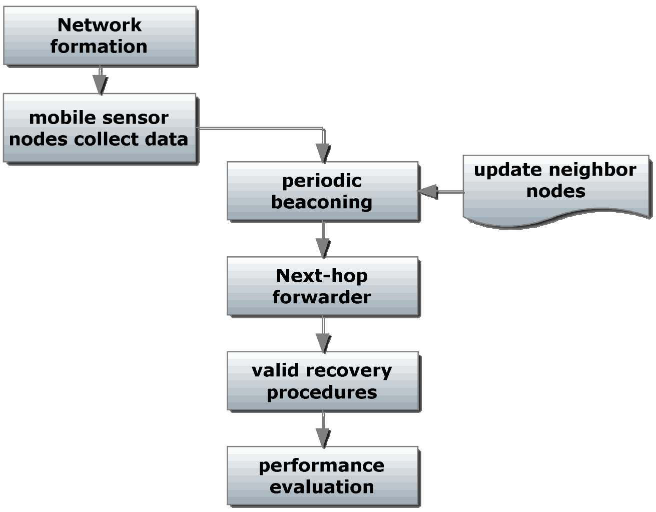

Fig.2: Architecture of the proposed system

If no collisions are predicted, the node begins its transmission; Otherwise, it backs off this transmission using the adaptive depth-based back off algorithm How to deliver data packets from an underwater source node to a surface sink node is one of the most important and fundamental problems in data collection network. In the single-sink scenarios, all the underwater sensor nodes must transmit data packets to the floating sink node. To improve energy and time efficiency, many protocols are proposed to deliver data packets using the shortest path. In these situations, deep nodes forward packets to shallow nodes along the direction towards the sink node greedily. The rank map of each node is consisted by the delay between its neighbors, depth information of its neighbors and its neighbors' angle information between neighbors and sink node. BEAR-MAC allows a sender to open multiple sessions to different receivers and avoiding collisions by careful calculating of neighbors' transmission schedules through the delay between nodes. The depth and angle information are used for achieving the depth-based scheme. By passively observing neighboring transmissions, each node maintain a rank map.

Network Formation

Network of 100 nodes is created using network simulator for wireless ad-hoc network is shown in Fig 3. Consider an underwater wireless sensor network sensor equipped aquatic (SEA) swarm architecture. Each node is equipped with various sensor devices and with a low bandwidth acoustic modem which is used to periodically report the sensed data to the destinations. Network formation involves creating nodes, sending packets and TCP handshake.

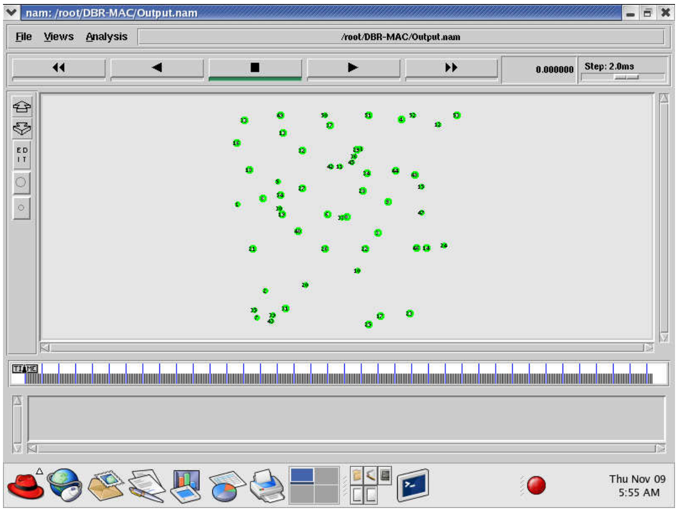

Fig.3: Network Formation

Data Acquisition

The data is collected from the environment by all the sensors in the network. The collected data is transmitted to the CH of each cluster. The CH groups the data collected by the neighboring nodes and forwards them to the sink node. The energy consumption is reduced by the CH. The node that has high energy will be chosen as the CH, in which the CH changes periodically based on the retained energy.

Periodic Beaconing

It is through periodic beaconing that each node obtains the location information of its neighbors and reachable sonobuoys. In the beacon messages, each sonobuoys embeds a sequence number, its unique ID, and it's X, Y location. Each sensor node knows its location through localization services. When a source node needs to find a route to a destination, it starts a route discovery process, based on flooding, to locate the destination node. Upon receiving a route request (RREQ) packet, intermediate nodes update their routing tables for a reverse route to the source. The periodic beaconing is shown in Fig 4.

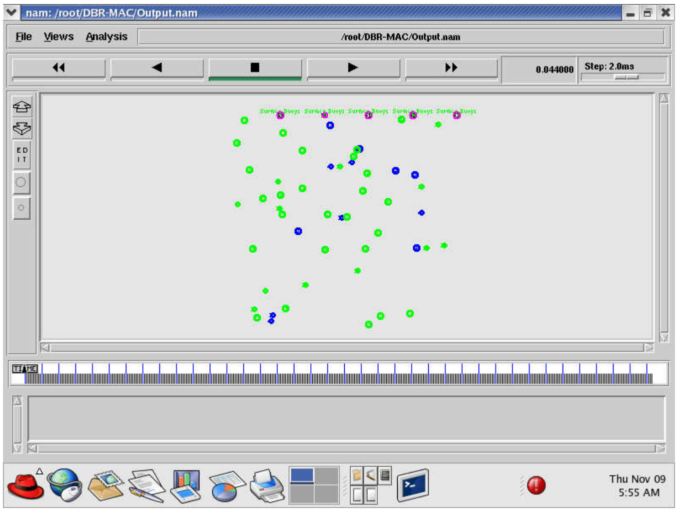

Fig.4: Periodic Beaconing in network

Next Hop Forwarder

Once the next node that is ready to receive the data is identified via periodic beaconing, the data is transmitted to the determined node. Sensors and the data collectors are shown in Fig 5.

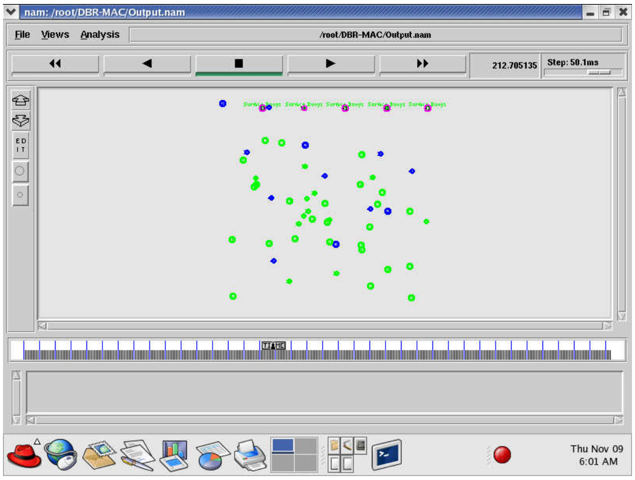

Fig.5: Sensors and the data collectors in the network

The RREP is obtained from the node to confirm its presence. The data is transmitted on the reception of RREP packet. If there is response, the route fault mechanism is undergone to recover the repaired node.

Performance Evaluation

In this section, the performance of the proposed BEAR-MAC protocol is evaluated in terms of throughput, delay and energy efficiency.

Throughput

The time taken by the network to transmit number of packets from the source to destination is defined as throughput. For an optimal network, the throughput must be high. Fig 6 shows the comparison of throughput of the proposed and existing system. It is clear from the plot that the throughput of the proposed system is higher than the existing system. For 80 nodes, the throughput of the existing system is 4700bps and the proposed system is about 5100 bps. When the number of nodes reaches 100, the throughput of both proposed and existing system gets reduced.

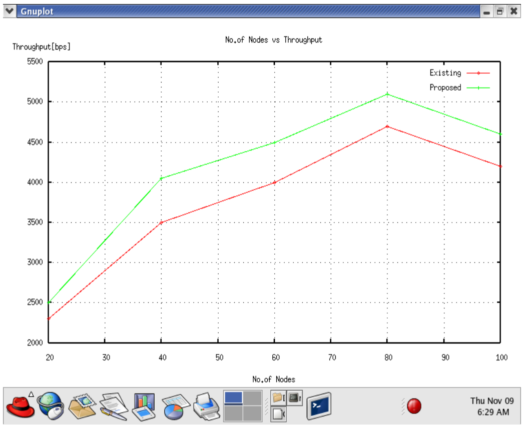

Fig.6:Comparison of throughput of the proposed and existing system

Delay

Delay is defined as the ratio between the number of packets sent and the time taken for the packet to transmit.

$$Delay = \frac{No.of\ Packets\ Received}{Time\ Taken}$$

The comparison of the proposed and the existing system is depicted in terms of delay in Fig 7. The proposed system experienced minimum delay than the existing system.

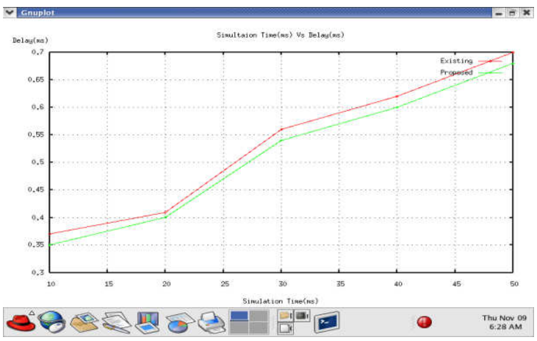

Fig.7: Comparison of Delay of the proposed and existing system

Packet Delivery Ratio

The number of packets delivered in a given amount of time is defined as the packet delivery ratio. The comparison of proposed and existing system in terms of packet delivery ratio is depicted in Fig 8. The result shows that the packet delivery ratio of the existing system is lower than the proposed system.

$$Packet\ Delivery\ Ratio = \frac{No.of\ Packets\ Delivered}{Time\ Taken}$$

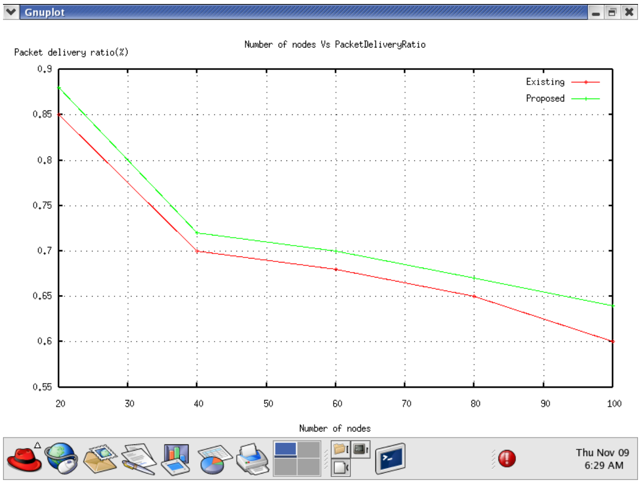

Fig 8 Packet Delivery Ratio of the proposed Vs existing system

Energy Efficiency

The energy consumed by the network to transmit the packets from source to destination is energy consumption. The consumption must be reduced to make network energy efficient. The energy consumption plot is depicted in Fig 9

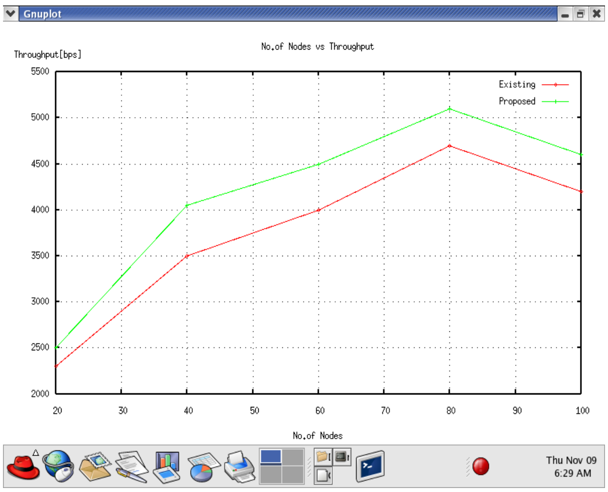

Fig.9: Energy consumption of the proposed and existing system

Total energy is the amount of consumed energy.

$$TE = TE + CE[i]$$

Where CE is

$$CE = \sum_{i}^{n} (initial\ energy - final\ energy\ [i])^{n}$$

In which ‘i’ is initial energy and n is the number of nodes.

Conclusion

In this paper, BEAR-MAC protocol is proposed to route the packets in underwater acoustic sensor networks in an energy efficient manner. The energy consumption during handshaking mechanism of MAC is resolved using RTS/CTS handshaking. Periodic beaconing is performed in the formulated network to check the availability of node for next hop transmission of packets. The RREQ and RREP messages are exchanged between the cluster heads to confirm its validity. BEAR exploits the location information, selects the Neighbours, chooses the facilitating and successor nodes based on cost function value and, finally selects the forwarder node, one having residual energy more than the average residual energy of the network. The results are compared in terms of delay, throughput, and packet delivery ration and energy efficiency. The simulation results demonstrated that BEAR improved the network lifetime by approximately 55%.

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