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A Three Dimensional Design for Underwater Wireless Sensor Network

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ABSTRACT
A hierarchical Underwater Sensor Network architecture in which the sensors and the collector station operate in different layers is proposed. Underwater environments are very different from terrestrial environments if we consider communication and operating circumstances. As the sensor nodes are deployed in harsh underwater conditions, there is high probability of node failure. This paper presents an efficient approach for cluster based underwater sensor networks in order to prolong network lifetime and reducing the energy consumption.
***Keywords* -** Cluster Head (CH), Super Head (SH), Underwater Wireless Sensor Networks (UWSNs)

I. INTRODUCTION

The Earth is covering about 70 percent of water in form of undefined oceans and large water bodies. From the ancient era, water links provide great means of sharing the information and as the technology grows wireless information transmission through the ocean is the most significant technology for exploring the aqueous environment and monitoring various disaster prevention activities [1]. In this new technobabble world, there is a great need to monitor the aquatic environment not only for safety and military reasons but also for scientific, commercial and environmental reasons. Underwater Wireless Sensor Networks (UWSNs) are built up of sensor nodes that are deployed in an underwater environment and are capable of monitoring their nearby. Sensor node is a small device having limited energy stored in form of battery and has limited memory. The main work of sensor node is to sense the data from its surroundings and process that data with the help of sensing unit and processing unit respectively and to manage the energy dissipated for all such processes and units with the help of power unit. Underwater Acoustic Sensor Networks (UW-ASN) is defined as the collection of large number of sensors that are deployed underwater and on surface water to perform the collaborative monitoring and tracking tasks over the specified or target area. The communication underwater is also known as hydro-acoustics.

As the Underwater Wireless Sensor Networks are very vulnerable to the hard underwater conditions, a crucial issue for the efficient UWSN is to maximize the network lifetime [4]. Consequently, a new concept of low-cost easier deployable underwater networks having less constraints should be developed. This type of network should be mobile/dynamic, scalable and capable of self-build. UWSNs are a new research paradigm that poses exciting challenges due to the intrinsic properties of the underwater environments. Cabled framework is eliminated here and acoustic waves are used for propagation [2]. Major challenges in the design of underwater acoustic networks are [3]:

Battery: Battery power is limited and difficult to recharge as solar energy cannot be exploited.

Node deployment: It is application dependent and affects the performance of system. Deployment can be deterministic i.e. sensors are placed manually and data is routed through pre-determined paths, or randomized in which the sensors are scattered randomly creating an infrastructure in an ad hoc manner.

Bandwidth: The available bandwidth is severely limited.

Large propagation delays: In water the propagation speed of acoustic signals is about 1.5×10^3 m/s. The channel suffers from long and variable propagation delays.

Node mobility: Due to turbulence in water current underwater sensor networks are movable.

High error probability: Underwater acoustic channel has limited bandwidth capacity, variable delays suffers high bit error rates.

Environment: Underwater sensors are prone to frequent failures because of fouling, corrosion, etc.

Energy saving is a major concern in UWSNs as sensor nodes are powered by batteries which are difficult to replace or recharge in aquatic environments.

Clustering is a valuable technique to improve the network lifetime in UWSNs with sensor nodes that are densely deployed over a large area [5][6][[7]. Each cluster consist several cluster members like normal nodes and the Cluster Head (CH). After forming a cluster, a CH is responsible for collecting data from its cluster members and for transmitting the data to the Super Head (SH).

II. DESIGN MODEL

UWSNs have significant amount of drawbacks like high mobility, limited bandwidth, large propagation delays, weird environmental conditions, etc. Therefore, a technique is needed to improve energy utilization, scalability and the lifetime of the network. Network is deployed with the assumption that nodes are heterogeneous in term of energy. A node can perform dual role of being a normal sensor node or a cluster head which can be decided on the basis of energy level. A hierarchical arrangement is used because it is more energy efficient and easy to collect data. Data security is better as information is not disseminated through a path that goes through many nodes in the system. Instead of that, path is quite simple and comprising of cluster head and super head. Also flooding is avoided which was a major disturbance. To achieve energy efficiency, a hierarchical model is proposed where sensors are simple nodes and their task is to sense data only. If an intrusion or an event occurs in the field then sensors sense this and report to the cluster head. The role of cluster head is to control the sensor nodes under it. Whenever a report comes to cluster head it directly sends that report to super head. Super head is an energy rich device capable of processing the data send by the cluster head and route it to the desired direction. The architecture of underwater wireless sensor networks is presented in Figure 1.

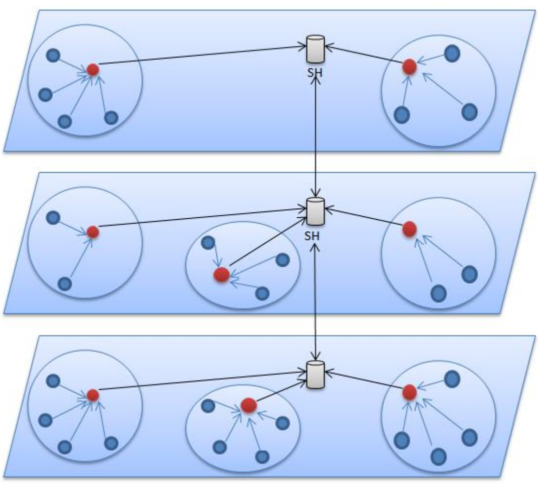

Fig 1: System Structure

2.1 Network deployment

How to deploy the nodes is the first task in design of any network? Our network is heterogeneous. In the initial stage, sensors can be dropped from an aircraft in a random fashion. The node having high energy acts as a cluster head when compared to other nodes. Each layer has a high powered device known as super head (SH). In our proposed model, three layers are designed: at the bottom bed level (layer 1), at the middle level (layer 2), at the top surface level (layer 3). Sensors at the bottom layer are relatively less mobile then the middle layer as middle layer sensors are more prone to the underwater current and other activities. We use the concept of clustering at each level.

2.1.1 Cluster Formation

Cluster formation and the cluster head selection is the very crucial phase. To form the clusters, cluster head sends the hello message in the network. Normal sensor nodes which have received hello message from cluster heads joins the clusters based on RSS (Received Signal Strength) value of the hello message. If a node receive hello message from more than one CHs then it will join the cluster having high RSS value.

2.1.2 Isolated node trying to ping Cluster Head

If due to some circumstances any sensor node is not able to join any cluster, then the isolated node will increases its transmission range and try to ping cluster heads. The ping message is send to the CHs around it and it keeps on increasing its power until it reach its maximum limit or some CHs replies back as shown in the Figure 2.

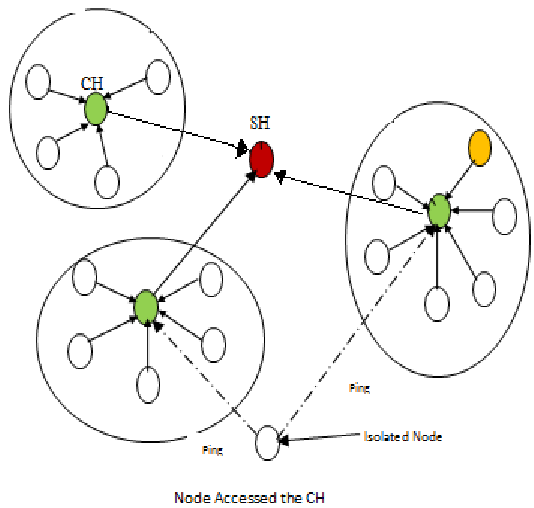

Fig 2: Isolated Node Ping Mechanism

2.1.3 Isolated node as cluster member

After an isolated node sends join message to any of the cluster head then that CH also increases its transmission range to accommodate that node. If more than one CHs are accessed by the isolated node then the cluster head having more energy and better node count will be selected. Energy level and the member count are the two parameters of the reply message of CHs on the basis of which the isolated node will take decision to join one of them. CH also increases its transmission range equals to that node's transmission range so that CH can provide accommodation to that node. Thus isolated node becomes active member of that cluster as shown in Figure 3.

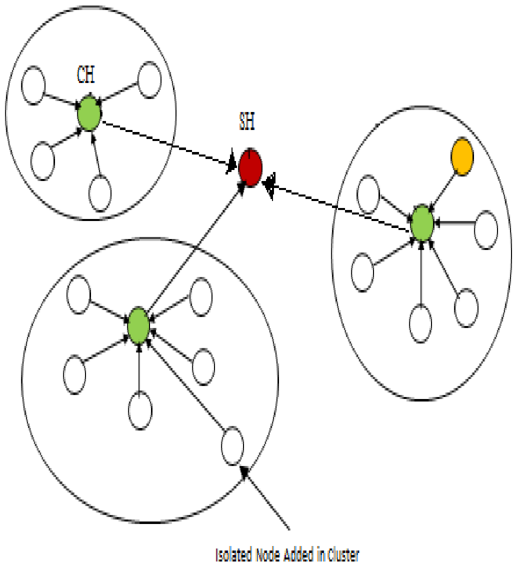

Fig. 3: Isolated Node as Cluster Member

2.1.4 Cluster Head Failure

As we know that energy is the major issue and due to dissipation of energy cluster head fails after sometime and another high energy node will take charge of being a cluster head. If cluster head goes down and it does not have any heterogeneous node as a member then it will try to find another node in the cluster as its descendent to be the next cluster head. If it has energy next best in the cluster and also more than the threshold energy then it will be appointed as the cluster head and the previous CH will become a normal member node. If there is not any node in the cluster whose energy is greater than the threshold energy then re-clustering is done.

2.2 Data Aggregation

In a typical sensor networks, different nodes collect data from its surroundings and then send it to some central node for processing and analysis of data and then send it to the application main center. The main goal of data aggregation here is to gather and aggregate data in an energy efficient manner so that network lifetime can be enhanced [3]. Data gathering is defined as the systematic collection of sensed data from multiple sensors to be eventually transmitted to the super head for processing. Since sensor nodes are energy constrained and data collected is often redundant and correlated so we require such mechanism that can output quality information. This can be accomplished by data aggregation.

2.3 Energy saving through sleep/active mode

As UWSN is divided into layers and further divided into clusters for better performance [8]. But it is not necessary that all the clusters are doing their task all the time. In such cases keeping the nodes in the active mode is the wastage of energy. Hence nodes may be put into sleep mode during idle time to save energy. Whenever any event takes place CH send wakeup call to nodes and after completing the required task it again goes into sleeping mode.

III. LIFECYCLE

In our protocol methodology there are four phases in each layer.

Phase 1: Cluster Head Selection

1. Energy level of each node is checked.
2. Energy levels are compared to the threshold value.
3. Node having energy level equal to or more then the threshold level value is assigned as cluster head.

Phase 2: Cluster Formation

1. CH broadcast JOIN-REQ message to from the cluster.
2. After receiving the message, the neighboring nodes within the range respond by sending JOIN-REPLY message.
3. If any node remains isolated, it may be a member of any cluster according the process explained in design model.

Phase 3: Data Reporting

1. All the nodes report to CH on TDM basis.
2. CH received the sensed data from the cluster member nodes.
3. CH forwards the data to the super head where the data aggregation is achieved.
4. Then the aggregated data is processed and routed to the other layer's SH towards the destination BS.

Phase 4: CH Alteration

1. CH regularly checks its residual power and compares it with the threshold power.
2. If finds energy below threshold level, new CH search takes place.
3. Now CH selects its descendent having the highest residual energy.
4. Nodes update their CH information and start reporting to new CH.
5. Old CH works as the normal node.

IV. APPLICATIONS

This field possesses a wide area of applications. Ones of the main places where it can be used are:

Environment Monitoring: Pollution is now days one of the greatest problems, oil spills or broken underwater oil tubes can make lot of harm to marine biological activity [4]. Monitoring ecosystem can help understanding and predicting the human and climate effect in underwater environment.

Prevention of natural disaster: By measuring the seismic activity from different remote location the sensors could alert about tsunami or submarine earthquakes alarms.

Underwater navigation: The sensors can be placed to identify hazards on the sea floor, rocks or shoals in shallow water.

Assisted Navigation: Sensors can be used to identify hazards, discover new locations or seeking lost areas and drawing the bathymetry profile of the area [5].

Underwater Autonomous Vehicles: Distributed sensors in movement can help in monitoring area for surveillance, recognition and intrusion detection.

V. FUTURE TRENDS

A lot of advantages can be achieved by using underwater sensor networks, but lot of research must be done in next years. It is necessary to improve the physical layer performance in terms of efficiency, building low power acoustic modem that are able to make best use of bandwidth and reducing error rate. The development of new strategies and research in this open field can be able to provide more reliable and efficient way to communicate in the network.

VI. CONCLUSION

In this paper, a layered clustering hierarchical strategy for the deployment of sensors in underwater scenario is proposed for longevity of the network. A clustering or hierarchical strategy can improve scalability, energy efficiency and the life time of the network. To achieve energy efficiency hierarchical model is used. Less amount of energy is consumed in transmitting the data from underwater to the upper station as the data is routed only through CH and SH. Moreover to save energy during the idle state i.e. when the sensor nodes are not doing any activity, sensor nodes goes into sleep mode and whenever any event occurs it goes into active state to perform its task. Hence, this approach will save energy and improves lifetime of the network.

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