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An Approach of Data Aggregation base on A Geographic Cluster for Underwater Wireless Sensor Networks

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Abstract
Underwater wireless sensor network (UWSN) plays important role in collecting potential real-time sensing data over a large area below the sea surface. However, the deployment of an UWSN faces many challenges due to the special characteristic of acoustic communication. Data aggregation is researched as a promising method for reducing energy consumption, redundant data transmissions as well as prolongs the network life time, especially for cluster based UWSN. In this paper, we suggest utilizing the data aggregation for both cluster head and cluster members in a cluster. Depend on the role of a sensor node; we apply different data aggregation method to improve the data transmission from a cluster member to its cluster head and from the cluster head to the base station. The simulations show that our suggestion generates better results in term of network throughput and energy consumption.

Keywords: Clustering, Data Aggregation, Similarity Functions, Underwater Wireless Sensor Network.

1 Introduction

The ocean occupies over 70 percent of the surface of the earth and most of which are unexplored. Underwater wireless sensor network (UWSN) is state-of-the-art technology to enable application such as oceanographic data collection, disaster prevention, undersea exploration, tactical surveillance system for homeland security, etc. [1][2][3]. However, the propagation speech of an acoustic signal (1500 m/s) is much slower than the speed of a terrestrial signal (3×10^8 m/s) due to the physical characteristics of an underwater acoustic channel. This large propagation delay is one of the significant challenges need to be overcome to develop an effectiveness wireless network for underwater.

There are many protocols for underwater acoustic sensor networks have been proposed by researchers. One of famous approaches is cluster based networks and many clustering scheme in various context have been proposed [3][4][5][6][7][8]. Cluster based network is the way to make the network looked smaller, and then sensor nodes can communicate in a short distance reduce the propagation delay for the network. Clustering divides the network nodes into different smaller groups due to specific criteria and helps to organize the networks hierarchically.

Data aggregation is one of the promising approaches to collect the data in the network. It has been known as a vital technique for reducing energy consumption, redundant data transmissions as well as improving the overall network lifetime [9][10]. Several data aggregation protocols have been proposed, such as tree-based data aggregation protocols [11] and cluster-based data aggregation protocols [12][13]. Our paper will focus on the cluster-based data aggregation approach.

In this paper, we suggest to apply data aggregation functions for both cluster head and cluster members in a cluster. The aggregation functions are different due to specific roles between cluster head and cluster members. We applied a geographical clustering scheme to cluster the network then only emphasized the usage of data aggregation tasks of both kinds of sensor nodes.

2 Related Researches

Authors in [3] proposed and developed a Cluster based delay-tolerant protocol (CBDTP) in order to eliminate RTS/CTS and ACK handshaking and avoid the collision in underwater wireless sensor network. In this paper, authors started to summarize some key issues and challenges in MAC protocol design in underwater wireless sensor networks due to long and consistent delay time. Then, they proposed their own protocol that is use for cluster-based networks. They tried to avoid collision at the cluster head without using RTS/CTS, and used a self-adaptive algorithm to adjust estimated-RTT in each data collection round to eliminate the ACK handshake and data retransmission. Their results showed that CBDTP increase channel throughput and resource utilization in a volatile deployment environment for underwater wireless sensor network applications

In paper [9], the authors formulate the aggregator node selection as a top-k query problem, and applied Sort-Filter-Skyline (SFS) algorithm to solve it. The proposed method constructs the skyline of the sensor nodes that allows obtaining a set of sensor nodes that are potential candidates to become an aggregator node. For example, using proposed method, you can select the aggregator node considering

various attributes (i.e. distance from the base station, power consumption, battery life, communication cost, etc.) that suits to the current state of the WSN. If the current state of the WSN requires sending the sensor data a short time, then the proposed method selects aggregator nodes that have the highest communication power.

Author in paper [12] proposed a two-level cluster based protocol for wireless sensor networks to minimize the energy consumption and maximize the lifetime of wireless sensor network. The key goal of this paper is to improve the data transmission mechanism from the cluster heads to the base station via constructing a cluster among the cluster heads. Their simulation results prove that their proposed protocol has better performance in term of network lifetime, stability period, instability period, energy consumption and network throughput.

Author of [13] proposed a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks, stand by HEED. The proposed approach selects cluster heads randomly based on probability but it distributes cluster heads more uniformly across the sensor network by multiple iterations and smaller cluster ranges. The approach sets the probability of selecting cluster heads by each node's residual energy at the first iteration of each round, doubles the probability before going to the next iteration, and terminates the operation when the probability reaches 1. At any iteration, each node can become a cluster head with its own probability if hearing no cluster head declaration from its neighborhood.

3 Review of Geographical Clustering Scheme

In this section, we will take a brief discussion on the geographical clustering scheme that mainly utilizes the geographical information of sensor nodes to cluster a network. The clustering scheme consists of three main stages: Scenario Division, Network Classification, and Network Clustering. First stage is to collect geographical position of sensor nodes, and divide the scenario into four particular areas. Second stage measures the skewness of the overall network to classify them to even-distributed or skew-distributed for a later decision. Last stage, clustering stage, clusters the network base on the sensor nodes' distribution and the classification of the network which done by the two previous stages.

The clustering stage is applied for each separate area. Instead of select cluster head directly, the clustering scheme first choose a group of cluster head candidates base on the residual energy, distance to neighbor nodes within the certain area, distance to the middle point of the scenario, and the node identification. The chosen criteria must greater than their threshold, such as threshold of residual energy, threshold of neighbor-distance, and threshold of middle-distance. The thresholds are evaluated and decided through the examination process. All cluster head candidates have a role to become a cluster head for one time and the network is reconstructed only if new cluster head candidate groups are re-selected. The order for cluster head candidates to be cluster head is sorted by the highest residual energy, smallest average distance to neighbor, and closest to the middle point.

4 Data Aggregation Functions for Geographical Clustering Scheme

As cluster heads and cluster members have different roles in collect and transfer data, we suggest using different data aggregation functions to improve the data transmissions. This section will describe our suggested data aggregation functions for different type of sensor nodes.

A cluster member continuously senses the nearby environment and frequently reports that sensed data to its cluster head. It may cause the duplicate data transmitted to the cluster head and generate unnecessary data transmissions. Hence, we recommend applying a small timer to each member node. Moreover, a member node should regularly checks the similar between the current sensed data and the previous sent data to the cluster head. Concurrently, it listens to the channel if there is a close-member-node has already sent the same data to the cluster head. Therefore, it will merely send a very new data to the cluster head reduce significantly duplicate data and data transmissions.

A cluster head plays a role to aggregate data from cluster members and transfers to the sink/ base station node. At the beginning of data aggregation process, a timer is set for cluster head to transfer aggregated data. Every time a new data set is collect, a cluster head do comparison between current data and new coming data. If they are different, a cluster head accept the new coming data and transmit to the sink when timer expires. Otherwise, it denies the new coming data and wait for another.

5 Simulation Configurations and Performances

We configure the simulation parameters that closely reflect the shallow underwater wireless sensor network for monitoring and detection. We use Qualnet5 simulator for running our simulations. The energy consumption parameters were set according to the UWM100 LinkQuest Underwater Acoustic Modem [14]. Dimensions of the scenarios are 5000m × 5000m with 20 sensor nodes deployed randomly 200m below the sea level. In order to replicate a shallow underwater environment, channel frequency and propagation speed were set at 35 KHz and 1500 m/s, respectively. Transmission power of sensor nodes is set 30 dBm. All sensor nodes operate with a data rate in the LinkQuest UWM100 equal 7 Kbps, and use the same AODV routing protocol. The time for each run of simulation is 30 minutes.

In the simulations, we study on the performances of network throughput and network energy consumption. We evidence that the geographical clustering scheme will achieve better performances when it applies data aggregation functions to both cluster heads and cluster members. Figure 1 shows the throughput of the network. The blue bar represents the throughput when we apply data aggregation mechanism (ex. Euclidean function) to cluster heads only. The green bar represents the throughput when we apply data aggregation mechanism to both cluster heads and cluster members (ex. Euclidean for cluster heads, simple checking similarity for cluster members). The graph in the figure shows that the throughputs are almost better when we use data aggregation function for both type of nodes.

In Figure 2, the blue bar represents the energy consumption of the network when we apply data aggregation mechanism to cluster heads while the green bar represents the results of applying data aggregation mechanism to both cluster heads and cluster members. The results show that the energy consumption is reduced due to the eliminating of redundant data transmissions in the network.

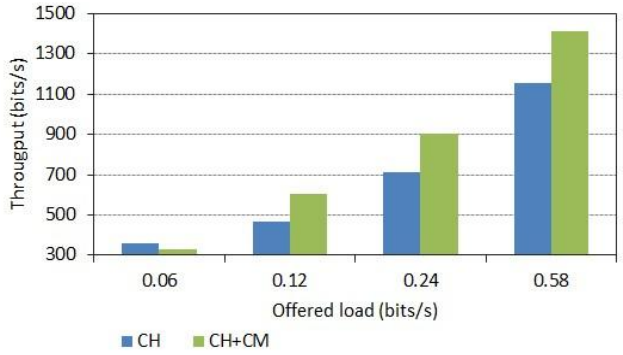

Figure 1. Network throughput

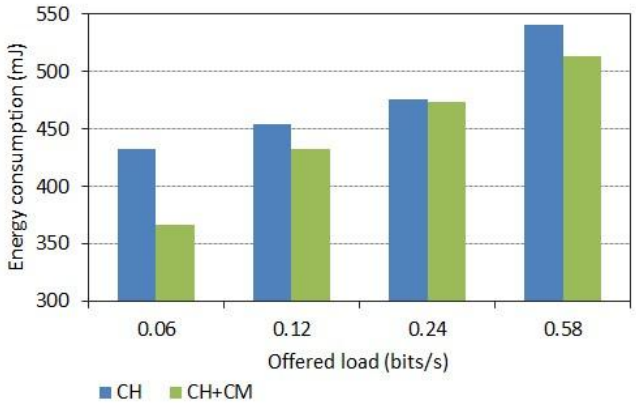

Figure 2. Energy consumption of network

6 Conclusions

In this paper, we suggested to apply aggregation mechanism for all sensor nodes either it is cluster head or cluster member. We assumed the network is clustered by geographical clustering scheme, and then investigated the performance between applying data aggregation mechanism for either cluster heads or cluster heads and cluster members. The results show that our suggestion results in better network performance in term of network throughput and energy consumption.

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