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ENERGY EFFICIENT ROUTING WITH CORRELATION BASED DATA TRANSMISSION REDUCTION IN UASN

BUDDESAB[*1], REKHA .P[2], RAGHU RAMAMOORTHY[3] and SARAVANA KUMAR .E[4]

[1, 2, 3, 4] Department of Computer Science and Engineering, The Oxford College of Engineering, Bangalore, Karnataka, India.
*Corresponding Author E-mail: tonnur21@gmail.com

Abstract:

Under water Acoustic Sensor Networks (UASN) is a kind of wireless sensor networks deployed inside water for various applications like pipe line monitoring, under water aquatic life monitoring. Energy efficiency and reliability are two important challenges in UASN. This work proposes a energy efficient routing in UASN based on the concept of 3D cubes. The proposed solution conserves energy using the concept of clustering and aggregation. Further as extension, we implement a correlation based avoidance of unnecessary forwards. Due to this energy consumption is further reduced in UASN.

Keywords: EGRCs, efficient scheduling, Autonomous Underwater Vehicles, UASN.

1. INTRODUCTION

Underwater Acoustic Sensor Networks (UASNs), finds important application is areas of marine resources exploration and development, integrated ocean environmental monitoring and other related systems. Unlike wireless sensor networks, acoustic waves are used for communication in UASN. Due to nature of medium, the propagation speed is very low in UASN compared to WSN. Thus it becomes necessary to make use of the available spectrum efficiently.

The existing solutions can be categorized as below

1. Clustering protocols
2. Grid Routing protocols
3. Energy efficient scheduling

Many solutions have been proposed in literature in all these protocols in area of normal WSN and these solutions cannot be applied directly to UASN due to inherent nature of medium.

UASN has a important limitation in terms of energy consumption. Due to nature of medium, for achieving efficiency in transmission, the modems in the sensor node of UASN operate with high power and this reduces the life time of the sensor network. In under water deployments, it is not possible to recharge or replace sensor nodes frequently. The best way to prolong the operation of sensor node is using the available energy in an efficient manner. This project deals with this problem of optimum energy consumption in UASN.

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The proposed solution is based on integration of multiple techniques. A 3D big cube is provided with integration of multi-hop, duty-cycle and a proper energy-efficiency protocol altogether in network model. Further to it correlation based analysis to selectively decide to stop the transmission from node is also done to reduce the energy consumption. The proposed solution is implemented in NS2 and the energy efficiency of the proposed solution is verified through experiments.

1.1 Motivation

As an extension of wireless sensor network in underwater environment, Underwater Acoustic Sensor Networks (UASNs) have caused widespread concern of academia. In UASNs, the efficiency and reliability of data transmission are very challenging due to the complex underwater environment in variety of ocean applications, such as monitoring abnormal submarine oil pipelines. Motivated by the importance of energy consumption in many deployments of UASNs, we therefore propose an energy-efficient data transmission scheme in this paper, called Energy-efficiency Grid Routing based on 3D Cubes (EGRCs) in UASNs, considering the complex properties of underwater medium, such as 3D changing topology, high propagation delay, node mobility and density, as well as rotation mechanism of cluster-head nodes. First, the whole network model is regarded as a 3D cube from the grid point of view, and this 3D cube is divided into many small cubes, where a cube is seen as a cluster.

In the 3D cube, all the sensor nodes are duty-cycled in the media access control layer. Second, in order to make energy efficient and extend network lifetime, the EGRC shapes an energy consumption model considering residual energy and location of sensor nodes to select the optimal cluster-heads.

Moreover, the EGRC utilizes residual energy, locations, and end-to-end delay for searching for the next-hop node to maintain the reliability of data transmission. Simulation validations of the proposed algorithm are carried out to show the effectiveness of EGRC, which performs better than the representative algorithms in terms of energy efficiency, reliability, and end-to-end delay.

1.2 Problem Statement

Fig. 1 is a classic application scenario for marine oil pipeline monitoring. In this figure, many sensor nodes are deployed randomly in the ocean where oil pipelines are distributed all around. Nodes collect useful abnormal monitoring information of local scene, and send information to BS for analyzing the leaking of oil pipelines. In this paper, we are extremely interested in seeking a proper energy efficient data transmission scheme in duty-cycle based UASNs for this kind of monitoring applications. Particularly, our interests fall into the following two aspects:

- Will multi-hop, duty-cycle and an energy efficiency protocol be integrated for reliable underwater data transmission in monitoring applications?
- Will 3D Geospatial Division as well as other complex properties (such as three

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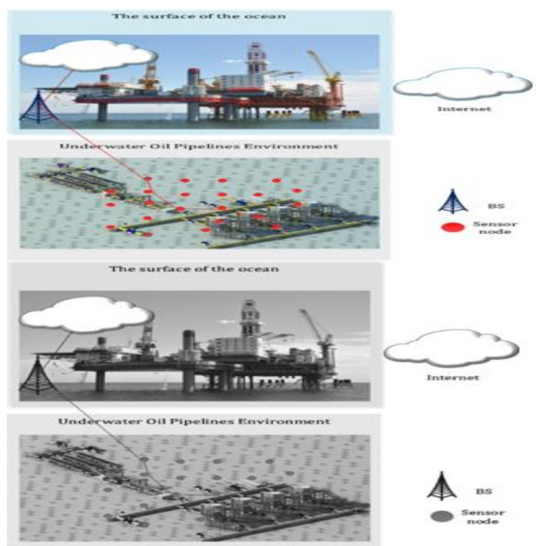
dimensional changing topology, high propagation delay, node mobility and density) of underwater medium be considered in UASNs?

To this end, An EGRC (Energy-efficiency Grid Routing based on 3D Cubes) in UASNs is proposed. First, the whole network, which can be viewed as a big cube, is divided into some SCs (Small Cubes), where a SC is a cluster. Second, we propose a novel approach to select the cluster-head node, namely, choosing a node in SC with the highest residual energy and the shortest distance to BS to take charge of data aggregation and transmission in SC. Finally, we adopt a data transmission mechanism with a combination of single hop and multi-hop, in which multi-hop routing also takes the residual energy, relative distance and end-to-end delay into account. Simulations show that this EGRC is characterized by energy efficiency, low latency and reliability with long network lifetime.

Figure 1: Classic application scenarios



2. RELATED WORK

The current solution for achieving energy efficiency in under water acoustic network is Delay-tolerant Data Dolphin (DDD) is an energy efficient routing algorithm proposed by Magistretti, et al. [7]. DDD is for the delay tolerant applications. The DDD routing algorithm is based on collector nodes called dolphin and stationary nodes; the dolphin nodes harvest the information sensed by the stationary nodes. The routing algorithm eliminates the energy expensive multi-hop communication. The stationary nodes are responsible to transmit its collected data to the nearest in the range of dolphins. The stationary nodes are deployed on sea bed area of interest. The authors have used the two components of the acoustic channel one is communication component and other is transceivers component for data forwarding. Through communication component the

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dolphin node is able to communicate and through transceivers component the presence of dolphin node is analyzed through beacon signal. The dolphin node forwards the collected packets to the base station which are deployed on water surface. In DDD the random movement of dolphin nodes will not able to collect all the data packets from the sensor nodes and in resultant the data delivery ratio will be degraded. In DDD; if the number of dolphins increases the overall cost of the network will also be increased.

Power-Efficient Routing (PER) proposed by Huang, et al. [8]. PER routing enhances the battery power of the sensor node. PER algorithm is based on two modules one is forwarder node selector and other is forwarding tree trimming. In PER the fuzzy logic system and decision trees based mechanisms are used for forwarder node selector, the forwarder node selection mechanism may be affected due to the water pressure and may reduce the data delivery ratio of PER. If forwarder node will come in the void region then it will drop the packets continuously and will die earlier.

Energy Efficient Depth Based Routing (EEDBR) is proposed by Wahid et al. [9]. EEDBR protocol is based on knowledge acquisition and data forwarding phases. In EEDBR ordinary sensor nodes are placed from top to bottom of the water and sink nodes are placed on water surface and source nodes are placed at bottom of the water. In EEDBR from sink nodes to onshore data center the radio signaling are used whereas in underwater the acoustic signaling is used. In knowledge acquisition phase the Hello message is forwarded between sensor nodes and neighbor nodes the nodes which keep smaller depth Id may involve for data forwarding. In data forwarding mechanism the depth and residual energy parameters are considered. The nodes which keep high energy with smaller depth are only involved in data forwarding. The depth calculation mechanism adapted by authors is failure in sparse area network. No any proper algorithm is given by EEDBR for balanced energy consumption.

Energy efficient Mobicast routing protocol is proposed by Chen and Lin [10]. The Mobicast is power-saving 3D routing protocol which overcomes the problem of unpredictable 3D holes. In Mobicast the “apple peel” is proposed to resolve the problem of unpredictable 3D holes. The architecture of Mobicast is based on underwater sensor nodes which are deployed randomly in 3D area of water around the Autonomous Underwater Vehicles (AUV) in form of 3D zone of reference or 3D ZOR as shown in Figure 1 and Figure 2. The AUV travels along the user defined path and collects the information from the sensor nodes within different time intervals of 3D ZORs. The sleep and active nodes are used to resolve the problem of unpredictable holes. Active nodes are responsible to forward the sensed data to the AUV. Mobicast uses the geographic 3D Zone of Relevance (3D ZOR3) and 3D Zone of Forwarding (3D ZOF) which are created by AUV at time t to indicate which sensor node should forward the sensed data to the AUV.

Link-state Adaptive Feedback Routing (LAFR) algorithm is proposed by Zhang, et al. [11]. LAFR is energy efficient routing algorithm based on asymmetric link mechanism. The data forwarding mechanism is based on beam width with communication range up

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to 3600 angle. The complicated mechanism for data forwarding with calculation of angle will put the heavy load on ordinary sensor node; due to this network load the sensor node will die earlier and average energy consumption of LAFR will be increases.

Energy Efficient Depth Based Routing (EE-DBR) is proposed by Diao, et al. [13] which prolongs the battery life of the sensor node through reducing of multipath redundancy forwarding mechanism. The ToA ranging technique is used to measure distance between sensor nodes. If measured distance increases the node will stop the packets forwarding and can save its energy. ToA with measured distance technique of EEDBR controls the data packets on a fixed range data forwarding route, if distance increases from source to sink node the ToA with measured distance technique will enhance the end-to-end delay.

Energy-efficient Multipath Grid-based Geographic Routing (EMGGR) is proposed by Al Salti, et al. [15]. EMGGR is position based routing algorithm and is consists of 3D logical grid multipath approach. The EMGGR refers the three phases one is gateway election mechanism, second is updating gateways' information mechanism, and third is packets forwarding mechanism. EMGGR considers the geographic area of the network with 3D logical grid partitions. EMGGR considers the deployment of every sensor node with the single cell from the logical grid with xyz addressing mechanism and presumes that every sensor node is well aware about its location through built-in localization service. EMGGR is based on multipath route selection from source to virtual cell gateway node and virtual cells gateway nodes are responsible to relay the data packets to the surface sink node. The algorithm is based on single sink node only

3. PROPOSED SOLUTION

An Energy efficient routing with correlation based data transmission reduction is proposed in this work.

First, the whole network, is viewed as a big cube, is divided into some SCs (Small Cubes), where a SC is a cluster. Second, we propose a novel approach to select the cluster-head node, namely, choosing a node in SC with the highest residual energy and the shortest distance to BS to take charge of data aggregation and transmission in SC. Finally, we adopt a data transmission mechanism with a combination of single hop and multi-hop, in which multi-hop routing also takes the residual energy, relative distance and end-to-end delay into account. In addition to this data from each cluster head is done correlation analysis over a period of time and if the data can be predicted easily based on past observation, the aggregated data is stopped transmission from cluster head to sink.

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Figure 2: Network model of the System 3D

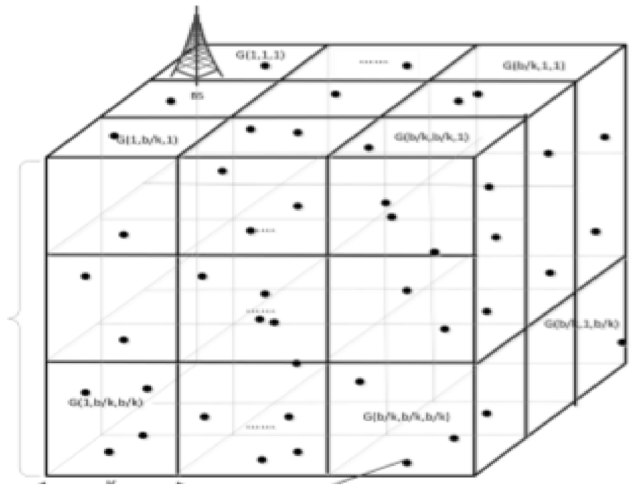

Figure 2 shown The network model of the system 3D underwater network is set and divided into SCs. Data packets are collaboratively transmitted as units of SC spaces logically, while in fact data packets are still transmitted between sensor nodes in both single-hop and multi-hop mode. Node density varies with the changing of SC's size. Nodes in one SC select the cluster head node with our proposed algorithm and send the collected nodes' information2 to cluster-head node. After sending the data, nodes recalculate the value (m, n, h), mark a new SC, and reselect cluster-head node of this new SC. Cluster-head node has the information of all nodes in local SC which is stored in Cluster-List.

As for cluster-head node, each SC selects its own cluster-head node. This cluster-head node takes charge of information of all the nodes in SC, and is responsible for aggregating the data that nodes in SC collect, selecting the best route to BS and transmitting data as a relay node. The cluster head node selects other nodes in SC to collect information according to the residual energy of nodes. When a cluster-head node aggregates or transmits data packets, other nodes go into sleep mode. This connected K-Neighborhood sleep scheduling algorithm (CKN) aims at allowing a part of sensor nodes go to sleep while at least K of those nodes' neighbor awake to keep those nodes all K-connected. Therefore, the number of sleeping nodes in our algorithm can be adjusted when changing the value of K.

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4. PERFORMANCE EVALUATIONS

4.1 Simulation Setup

Number of Nodes	200
Communication range	100m
Area of simulation	1000m*1000m
Node distribution	Random distribution
Simulation time	18 minutes
Interface Queue Length	50
MAC	802.11
Number of Base station	1
Location of Base station	Moving on surface
Initial energy of nodes	100 joules
Node movement	2-5 m around a center point

4.2 Performance Analysis

The proposed solution was compared against [16] in terms of following parameters

1. Residual energy
2. Alive Nodes
3. Delay

4.2.1 Residual Energy

Figure 3: Comparison of Average residual Energy between [16] and Proposed

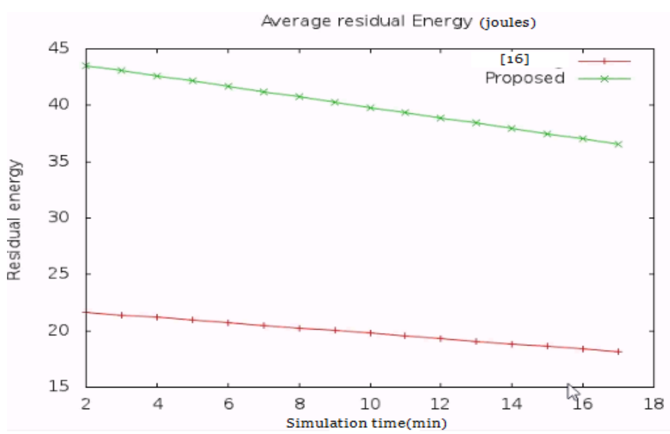

Figure 3 shows Average residual Energy between [16] and Proposed. Since due to increased energy savings achieved is node due to routing and selective transmission. So Average residual Energy higher than in [16].

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4.2.2 Alive Nodes

Figure 4: Comparison of alive nodes between [16] and Proposed

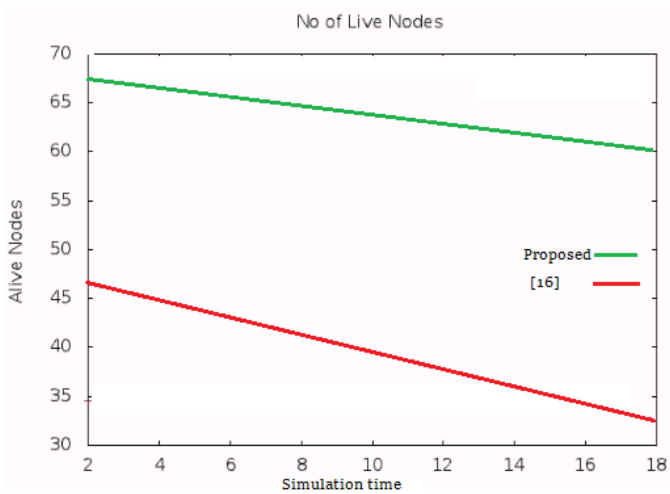

Figure 4 shows the number of alive nodes over a period of time is an indication of life time of the network. The number of alive nodes whose energy has not dropped to zero is measured and plotted below from the results, it can be seen that number of alive nodes is higher in proposed solution and it falls at a slower rate compared to [16].

4.2.3 Delay

Figure 5: Comparison of Delay between [16] and Proposed

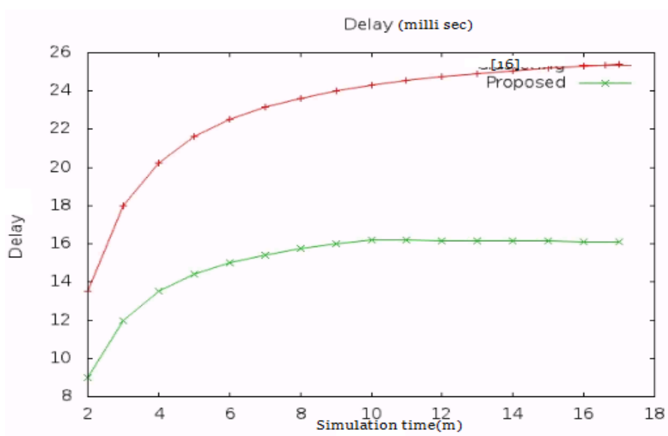

Figure 5 shows the delay for the simulation time is given below from the results, it can be seen that delay is lower in the proposed solution compared to [16]. The reason for the reduced delay is due to reduction in number of packets in the network due to correlation analysis.

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5. CONCLUSIONS

In this work a new energy-efficient data transmission scheme is proposed, in which the whole 3D network is divided into several SCs and each SC forms a cluster. There is a cluster-head node in each cluster in charge of the data aggregation and transmission of cluster members. A novel algorithm for cluster-head selection is proposed, which selects the node with the highest residual energy and the shortest distance to base station as a cluster-head node. To reduce the energy consumption further, this work proposed a correlation based analysis to stop transmission of data from a cluster head whose data can be predicted with less error based on past data. The proposed solution is implemented in NS2 and performance is measured. The performance results shows that proposed solution is able to increase the life time and reduce the delay

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