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Event driven energy depth and channel aware routing for underwater acoustic sensor networks: Agent oriented clustering based approach

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ABSTRACT

An energy efficient channel aware and depth based scalable and multipath agent based routing protocol is proposed in this paper. We consider a scenario consisting of underwater sensor nodes, autonomous underwater vehicles (AUV), underwater gateways, and surface gateways deployed at the territory to monitor the ocean environment (temperature, salinity and pressure) and detect the intruder (moving or static object). Dynamic clustering process is initiated on occurrence of an event; sensor nodes in the event affected area facilitate collection and aggregation of data by the cluster head. The cluster head initiates routing scheme by using mobile agent and its clones to discover multiple paths to a surface gateway based on parameters such as node energy, hop count, propagation delay and channel quality. In order to improve network connectivity and reliability in case of network partitions, an agent based dynamic AUV traversal algorithm is proposed to reorient direction of AUV movement.

1. Introduction

The wireless sensor networks deployed underwater (i.e Underwater Wireless Sensor Networks (UWSNs)) act as a powerful technology aiding in exploration and monitoring vast unexplored underwater applications. The UWSNs use acoustic wave for underwater communication as the radio waves easily get absorbed and attenuated in underwater [1,2]. Hence the UWSNs employing acoustic mode of communication is termed as Under Water Acoustic Sensor Networks (UWASNs). The UWASN architecture can be classified as two dimensional (2D) and three dimensional (3D). The 2D architecture consists of sensor nodes anchored to the bottom of ocean; these nodes communicate to the underwater gateways (UW-GW) through acoustic links and UW-GW are responsible for relaying information to the surface gateway (SG). 3D architecture consists of sensors and autonomous underwater vehicles (AUVs) that float at different depths to observe a given phenomena. The sensor nodes and AUVs at different depths coordinate to carry the information to the SG.

The UWASNs are significantly affected by acoustic channel characteristics such as, 1) low bandwidth, 2) distance dependent bandwidth, 3) large propagation delay, 4) high channel error rates, 5) channel impairment, and 6) high energy consumption. The deployment and routing in UWASN pose various challenges like, data transmission reliability, network

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survivability, data forwarding and variation of link quality. In UWASNs, routing is one of the most difficult and challenging issue due to the channel characteristics and underwater environment.

The consideration of UWASN architecture aids in reducing the latency and increasing the life time of network. The 3D UWASN architecture integrates AUVs in underwater to communicate between the sensor nodes, AUVs and SGs. As AUVs have more features than sensor nodes and high battery power, they can reach the longer distance and energy consumption can be reduced by enhancing the network lifetime. The deployment strategy considering multiple SGs will also enhance the network lifetime. The battery driven underwater nodes will make replacement or recharging of the battery a difficult task; hence energy saving is a major concern. One way of addressing this issue is by reducing the number of transmissions when the network is monitoring the aquatic environment. This can be accomplished by data aggregation technique as the environment has the redundant information most of the time, while monitoring a common area.

We can summarise some of the open research issues at the network layer [1,2] as follows. 1) Development of healthy routing protocol considering intermittent connectivity. 2) Protocols and algorithms are required to address link failures and unforeseen mobility of nodes. 3) Algorithms for local route optimization has to be developed. 4) Integration of AUVs, sensor nodes and multiple SGs are required to enhance the network lifetime, and 5) Credible simulation models and tools are to be developed. Hence one has to consider proper network architecture, data aggregation, cross layer approach, agent technology and acoustic channel characteristics for the efficient design of routing protocol with the following features: increased network lifetime, reduction in latency and improved packet delivery ratio. In this paper, we propose an agent based event triggered clusters based routing scheme considering parameters, such as, energy, depth, hop count, queue size and channel condition.

1.1. Objectives of proposed scheme

The objective of the paper is to develop an agent based routing scheme with following features. 1) Enhance the lifetime of network. 2) Reduce latency. 3) Establish connectivity during link breakdown. 4) Void Avoidance, and 5) reliable neighbor discovery. In order to realise the objectives, we define an agent based routing scheme that has intelligence embedded in it to take autonomous decisions and act intelligently. The software agents are autonomous programs activated on an agent platform of a host (static or mobile) and these use the knowledge base to achieve specified goals. These have special properties such as autonomy, reactive, proactive, temporal continuous, communicative, mobile, learning and believable. In this paper, we use agents to identify event occurrence, collect data, form cluster, perform aggregation, discover the neighbors, find the connectivity and establish multiple routing paths from source (event node) to SG.

1.2. Our contributions

The literature survey reveals that most of the routing protocols consider the parameters such as node energy, link quality, and hop count to select the relay node. The link quality estimation is performed based on probabilistic values using cross layer approach with approximate analysis mechanism. However, in our approach, we consider multiple parameters such as node energy, propagation delay, link quality, hop count and queue size to select the relay node. We adopt a cross layer approach to estimate the quality of link which assures higher reliability than the probabilistic measure. The propagation time is also taken into account with varying depth, temperature, and salinity. The propagation time and quality of link are vital factors that ensure the speed of data transmission and reliability.

The novelty of the work can be noticed with respect to following features as compared to existing works. 1) Employment of multiple routing parameters such as energy, propagation time, link quality, hop count and queue size in an integrated manner. 2) The cluster heads (CHs) are selected based on the speed of data transmission that vary with the depth of node placement. 3) The depth, temperature, and salinity of water environment affect the speed of data transmission. 4) A cross layer approach is adopted to estimate the link quality. 5) To avoid the void conditions and improve the scalability, 3D deterministic deployment scheme is considered, and 6) adoption of agent based routing scheme with flexible and customized services. The rest of paper is organized as follows. The related works are discussed in Section 2 and the proposed work is covered in Section 3. Section 4 covers agent frameworks and Section 5 discusses simulation model and results. Finally, Section 6 concludes the work by highlighting the future enhancements.

2. Related works

In this section, we briefly present some of the related works on routing protocols for UWASNs and software agents. Vector based void avoidance proposed in [3] avoids the routing void by applying vector shift and back pressure. Inorder to reduce the delay in the network a protocol was proposed i.e Novel Vector Based Forwarding (N-VBF). The N-VBF [4] uses a vector based algorithm to find the forwarding nodes; the delay is reduced using this algorithm however the energy consumption is increased. An energy efficient routing protocol known as Life Extended VBF (LE-VBF) proposed in [5] envisages both position information and energy status of nodes to select a node as forwarder. The desirableness factor is calculated by considering the energy factor similar to position, and the transmitted packet contains both average energy and position information. The Energy Saving VBF (ES-VBF) was defined considering the residual energy and position of sensor nodes for computing the desirableness factor. The ES-VBF [6] protocol promises prolonging of the network lifetime where forwarding