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A Cross-Layer Predictive and Preemptive Routing Protocol for Underwater Wireless Sensor Networks Using the Lagrange Interpolation

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ABSTRACT

Underwater wireless sensor networks have become enabling technology for the seawater exploration. Since they raise numerous challenges and problems such as their limited battery and bandwidth, energy-constraint, 3D deployment, and temporary losses of connectivity or link failure, in this paper, a predictive and preemptive cross-layer protocol CLPP-VBF is proposed based on the vector-based forwarding protocol (VBF) for UWSNs, aimed to predict a future loss of connectivity or link failure problems using the Lagrange interpolation method, avoiding unnecessary transmission and rediscovering another new forwarder node in order to guarantee the data packets transmission reliability. The approach is a cooperation between the medium access layer (MAC) and network layer. The study has been implemented and evaluated using the well-known NS2 network simulator with an extension Aqua-sim; the simulation performance shows the merit of CLPP-VBF against VBF in term of delivered packets, average end-to-end delay, and energy consumption.

KEYWORDS

CLPP-VBF, Cross-Layer, Lagrange Interpolation, Link Failure, Underwater Wireless Sensor Network

INTRODUCTION

The exploration of ocean resources has paid more attention of several scientific researchers in those last centuries (Yu et al., 2015). The various application of the underwater wireless sensor network UWSNs have become now a very common and widespread (Khasawneh et al., 2018). Due to many advantages that UWSNs could brought to human society, such as the aquatic environment monitoring, natural disturbances of the ocean, disaster prevention and warnings such as seismic activity, assisted navigation for ship to prevent from dangerous rock and many others (Han et al., 2015) (Basit et al., 2015). Since the marine environment is considered as a large scheme where the deployment of sensors are in 3- Dimensional patterns (Khan et al., 2020), and due to many sea factors such as water current and pressure, the greatness of the ocean, the signal absorption, and their limited bandwidth and batteries, (Ahmed et al., 2017), UWSNs encounter many challenges (Feng et al., 2018), high propagation delay, high noise and interference (Khan et al., 2020), battery depletion, the costly deployment, frequent changes of sensor nodes position that can affect their localization, the

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temporary losses of connectivity and paths or link failure problems caused by the sensor mobility, or signal attenuation (El-Rabaie et al., 2015) (Jan, K. U. and Jan, Z., 2014), those cited issues can affect and degrades the routing performance. Due to the mobility of sensors, a node can move out the range that can affect the network topology causing a communication lost (Wang et al., 2016), in this case this node will be considered as disconnected or unavailable. This study has been focused on the link failure probability issue that can be caused by the mobility of nodes in a major time or water current, to distinguish from two situations that can occurs and corroborate the probability of a future link interruption: First when a node is moving out the transmission range of the sender node a link failure can be submerged, second the node can move far the sender range and can regains it current position, for that a cross-layer mechanism has been proposed and implemented to explore the advantages of the two layer: MAC-layer and Network layer, the purpose is to detect, predict and prevent if a loss of connectivity will occurs, or the node can simply regain it old position and became near the sender, by using a predefined threshold zone PZ_{TH} and the well-known formula Lagrange Interpolation, The method is divided in to three phases:

1. The determination phase where the sensor node has to determine it belongings to the pipeline and the source node transmission range using the orthogonal projection and the Euclidean distance respectively.
2. The prediction phase of a link failure probability by using the Lagrange Interpolation formula, our approach verifies if the node within the predefined threshold zone PZ_{TH}, could move outside the transmission range or it can regain it last position and continue it forwarding process.
3. The rediscovering phase where the policy of the forwarder selection is modified in such a way that the concerned node will not forward data packets in a case that it is moving out the sender range, and another available node near the sender which does not belongs to the PZ_{TH} zone will be elected as the new forwarder.

The paper is organized as follows: First start by presenting related works in section 2, This is followed by a brief description of the VBF routing protocol in section 3. The proposed protocol is presented in section 4 and its performance is evaluated and compared with VBF. Finally we conclude the paper and present some perspectives in section 5.

RELATED WORKS

Several proposed approaches were conducted to address the link failure issues in UWSNs. Since the mobility or frequent movement of nodes and their deployment in 3D way can affect network topology and performance. In (Han et al., 2016) researchers proposed a localization based routing protocol for a dynamic UWSNs in which nodes frequently change positions and can move out the range. Their method aims to select the suitable candidate route with a new forwarding mechanism based on the VBF routing protocol. In (Agarwal and Rakesh, 2017), the authors focus on the node's mobility issues by dividing the wireless network into four quadrants. The proposed approach is based on an Arc movement to evaluate how nodes can communicate with each other. Data packets are transmitted only if transferring time is less than a predefined threshold and it is depending also on the Euclidean distance between the nodes within the network In (Hwang and Kim, 2008), since the basic VBF does not take into consideration the link quality, there is no an accurate guarantee that data packets are all delivered, a directional flooding based routing protocol has been proposed, the technique use a packet flooding by nodes which are controlled, and the selected forwarder nodes decide to forward according to the quality of the link. In (Han et al., 2016), due to the frequent position change of sensors, by the movement caused by water current or the mobility, node can moves out the pipeline and affect the achieving data packets, based on hierarchical spreading localization, and by dividing the network into

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