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Distributed Energy Efficient Clustering (DEEC) Protocol for Underwater Wireless Sensor Networks

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Abstract – *In this paper, we exploit cooperative communication for designing an energy-efficient routing algorithm in underwater wireless sensor networks (UWSNs). Each network node is equipped with a single omnidirectional antenna and multiple node coordinates while taking advantage of spatial diversity. This research work is limited in scope to amplify-and-forward (AF) scheme at the relay node and fixed ratio combining (FRC) strategy at the receiver node. The concept of smart environment envisions a world in which various kinds of smart devices collaborate towards a common objective. In this context, smart refers to the ability to acquire and apply knowledge autonomously to achieve this objective, while environment refers to the physical world. Therefore, a smart environment can be defined as one that acquires knowledge of its surroundings, and applying it can improve the experience of its inhabitants.*

Keywords*: Underwater wireless sensor networks, SEEC, DEEC, LEACH*

I. Introduction

Given these advances in underwater transmission capabilities, an increasing amount of research has been focused on building networks of underwater nodes. Because of the long propagation delays that exist in this environment, direct use of the medium access control (MAC) and routing protocols of conventional RF networks is not advisable. Hence, a great deal of research has been focused on this issue. Moreover, some of these protocols require time synchronization and localization. These problems must be revisited because propagation time is not usually taken into account in RF networks. The typical architecture of an underwater sensor node is depicted in Figure 1. It usually consists of a main micro-controller unit, which is typically a System-on-Chip (SoC) design, including RAM and flash memory and various input/output systems - SPI, UART, I2C, etc.

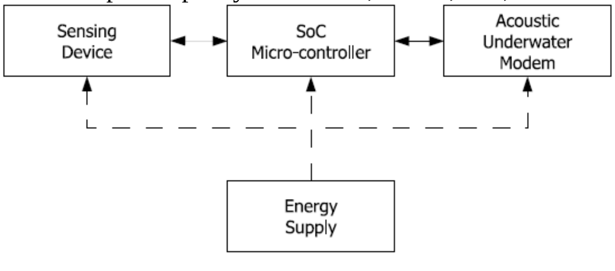

Fig.1 Underwater Wireless Sensor Network typical architecture

This micro-controller is connected to one or more sensing devices (CO_2, temperature, salinity, etc.) and to an acoustic modem. The micro-controller receives data from the sensors, which it processes prior to sending them via the acoustic modem to another device in the network, typically a sink node or an intermediate node, which in turn, has to perform routing.

Generally, for a typical UWSN to be successfully deployed, the following are requisite:

- Self-adaptation. A UWSN must be able to react to the continuously changing environment and perform in an autonomous manner giving self adapting decisions.
- Self-organization. The network should have self-organizing features in order to support node movements and topology changes.
- Self-configuration. In order to reinforce the self-organization capabilities, the communication protocols have to be able to adapt and reconfigure themselves autonomously to support the changing topology.
- Self-optimization. These types of networks are usually very resource constrained; hence, optimal usage of the computational power and energy supply are mandatory.
- Self-energy-harvesting. In always-available networks, battery powered devices are expensive to maintain and sometimes it may even be impossible to replace the batteries. Hence, in some applications, nodes might need to include energy-harvesting capabilities in order to build everlasting sensor networks.

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II. Wireless Sensor Networks

The wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound vibration, pressure, motion or pollutants. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance. They are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control.

III. Energy Efficient Cluster

There have been several network routing protocols proposed for wireless networks that can be examined in the context of wireless sensor networks. We examine two such protocols, namely direct communication with the base station and minimum-energy multi-hop routing using our sensor network and radio models. In addition, we discuss a conventional clustering approach to routing and the drawbacks of using such an approach when the nodes are all energy-constrained. Using a direct communication protocol, each sensor sends its data directly to the base station. If the base station is far away from the nodes, direct communication will require a large amount of transmit power from each node. This will quickly drain the battery of the nodes and reduce the system lifetime. However, the only receptions in this protocol occur at the base station, so if either the base station is close to the nodes, or the energy required to receive data is large, this may be an acceptable (and possibly optimal) method of communication.

IV. Method

This routing algorithm tries to minimize the end-to-end delay in underwater networks by sending the same packet through different routes in a 2-hops neighborhood using relay nodes. This algorithm achieves lower end-to-end delay than VBF with a better packet delivery ratio.

Energy-Efficient Adaptive hierarchical and Robust Architecture EDETA (Energy-efficient adaptive hierarchical and robust Architecture) is a routing protocol originally proposed for WSN and recently adapted to UWSN. It is a hierarchical protocol and nodes arrange themselves in clusters with one of them acting as a cluster-head (CH). The CHs form a tree structure between themselves in order to send the collected and aggregated data from the other nodes to the sink in a multi-hop manner. The protocol supports more than one sink in order to provide more scalability and some fault tolerant mechanisms.

DEEC uses the initial and residual energy level of the nodes to select the cluster-heads. To avoid that each node needs to know the global knowledge of the networks, DEEC estimates the ideal value of network life-time, which is use to compute the reference energy that each node should expend during a round.

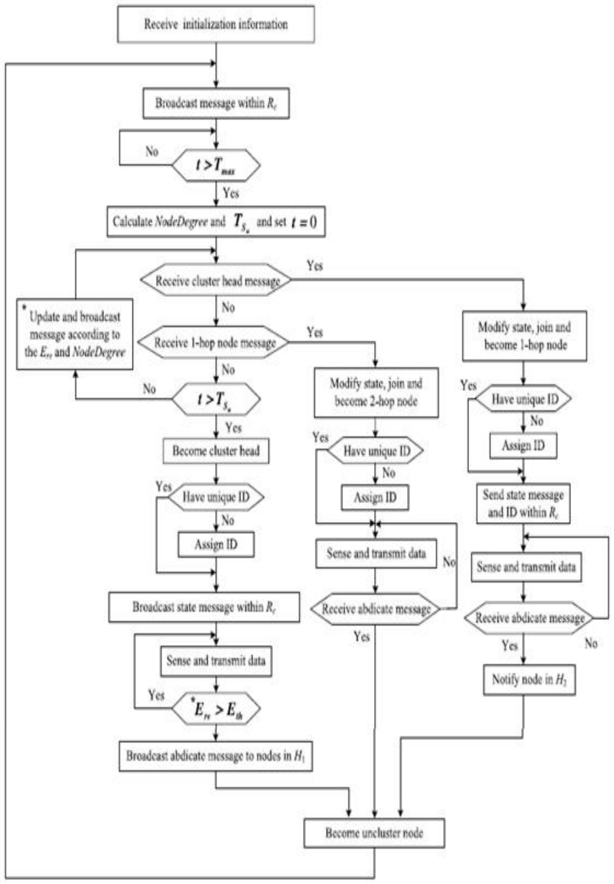

Fig.2 Flow chart of DEEC

Algorithm 1: Algorithm for cluster head migration phase

// Each CHi and its members perform the following

if $E_{re\,(CHi)} < E_{th\,(CHi)}$ **do**

broadcast Msg (ID, Eth, ABDICATE-MSG, $M_{1\text{-hop}}(CH_i)$)

if $H_{1j} \in M_{1\text{-hop}}(CH_i)$ and received **ABDICATE-MSG then**

forward Msg (ID, Eth, ABDICATE-MSG, M2-hop (H_{1j}))

end if

end if

if $\forall S_n \mid S_n \cap (H_1 \cup H_2) \;/\!= \varphi$ **do**

wait T = 0

S_n broadcasts Msg (ID, STATE-MSG, R_c)

10 forward Msg (ID, STATE-MSG, R_c) // when a **STATE-MSG** is received

11 S_n tabulates the entire received message

12 N_{UN} (S_n) ← count ($UN_{1\text{-}hop}(S_n) \cup UN_{2\text{-}hop}(S_n)$)

13 $T = T_{max}$

14 **end if**

15 if $E_{re\,(Sn)} \geq E_{th\,(CHi)}$

16 broadcast Msg (ID, **DEGREE-MSG**, R_c)

17 **if** S_n has the maximum N_{UN} in the nodes broadcasting **DEGREE-MSG** during (0, T_{Sn})

18 become cluster head and broadcast Msg (ID, STATE-MSG, Rc)

19 **end if**

20 **end if**

V. Simulation Result

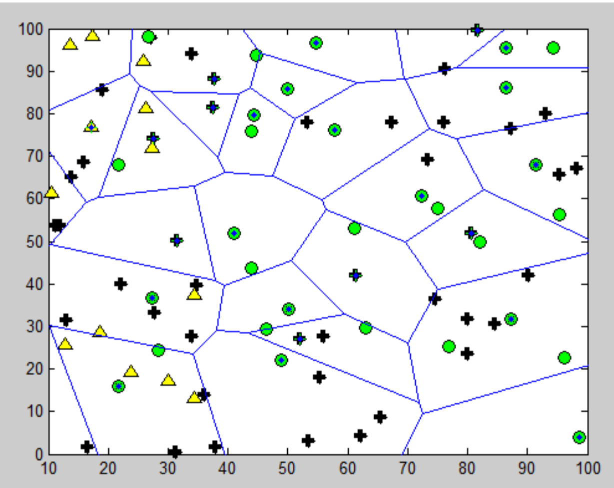

Fig.3 Cluster head in WSN

Fig.3 shows the cluster head in the wireless sensor network. The cluster heads can be selected randomly or based on one or more criteria. Selection of cluster head largely affects WSNs lifetime. Ideal cluster head is the one which has the highest residual energy.

Fig.4 shows average energy of each node v/s round number. In this figure x axis show round number and y axis show average energy of each node.

Fig.5 shows average energy of each node v/s round number. In this figure x axis show the round number and y axis show average energy of each node.

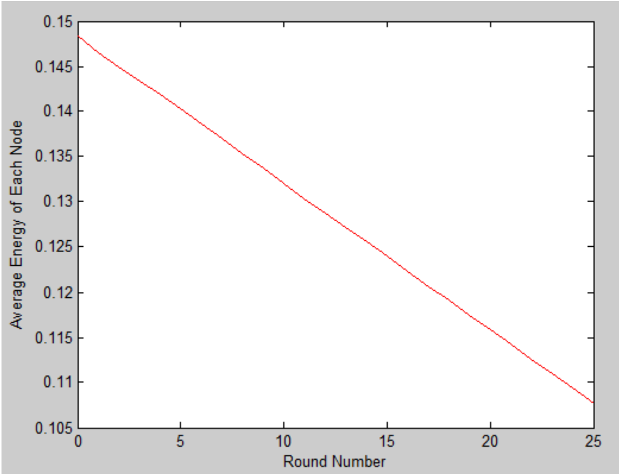

Fig.4 Average energy of each node v/s round number

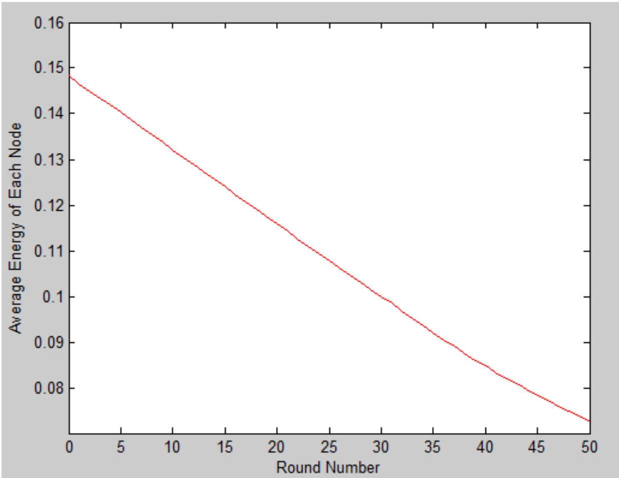

Fig.5 Average energy of each node v/s round number

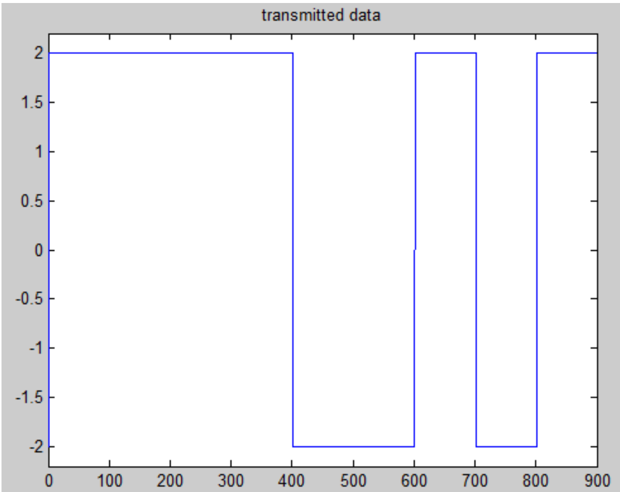

Fig.6 Transmitted data

Fig.6 shows the transmitted data for the proposed research work.

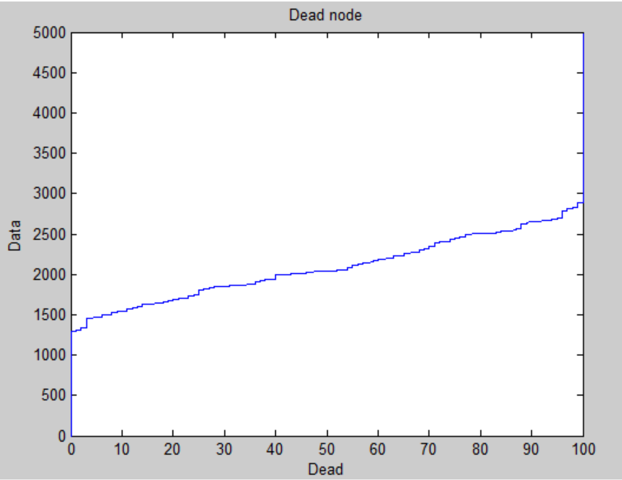

Fig.7 Dead Node in WSN

Fig.7 shows the dead node. In this x level shows dead node and y level show data.

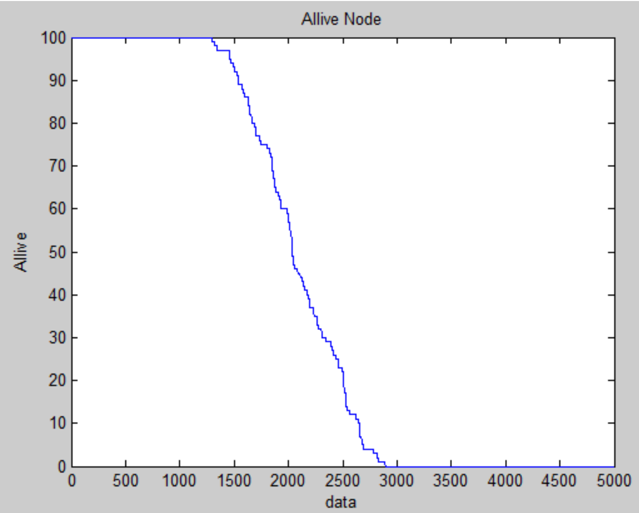

Fig.8 Alive node in WSN

Fig.8 shows the alive node in WSN. In this figure x level shows data and y level shows alive node.

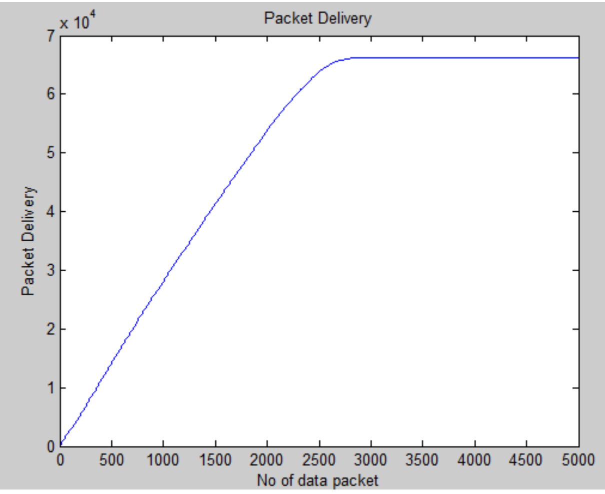

Fig.9 Packet delivery

Fig.9 shows packet delivery. In this figure x level show number of data packet and y level shows packet delivery.

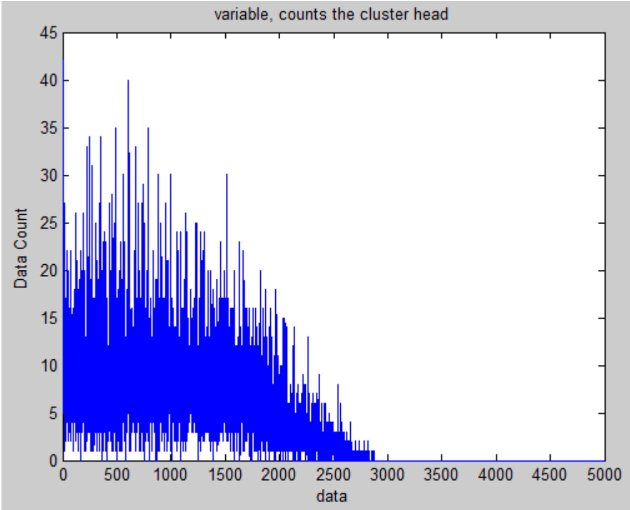

Fig.10 Variable, counts and cluster head

Fig.6.8 shows Variable, counts and cluster head. In this figure x level shows data and y level shows data count.

VI. Conclusion

The research work presents a novel routing protocol for underwater wireless sensor networks. EDETA-e is a power-aware routing protocol which minimizes the energy consumption. The results show high reliability in terms of no data packet loss due to collisions and an optimal energy management during the normal operation phase, allowing the nodes to remain in a low-power state when they have no data to deliver to the sink. Moreover, different scheduling and retransmission techniques applied to an EDETA-e have been simulated and their performance in terms of energy consumption, delays, packet lost rate and duplicate packets has been analyzed. Results show that, taking advantage of the transmission delay when performing the scheduling can significantly reduce the energy consumption and delays, maintaining the same packet delivery ratio when packet errors are introduced.

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