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Fuzzy Logic Optimized Vector Protocol for Underwater Sensor Network

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Abstract -Currently, there has been a growing interest in monitoring underwater mediums for scientific exploration, commercial exploitation, and attack protection. A distributed underwater wireless sensor network is the ideal vehicle for this monitoring. The current approach for ocean monitoring is to deploy underwater sensors that record data during the monitoring mission, and then recover the sensors. There are a lot of architectures for designing UWSNs. Nowadays, 3D architectures of sensor network under the sea are brought in to consideration. In this paper we present a Fuzzy Logic approach for the routing protocol formation process. We call our approach the Fuzzy Logic Optimized VBF Protocol (FLOVP) for WSN. To show the features of our FLOVP we compare it with VBF. Simulation results show that our approach degrade the network end-to-end delay significantly as compared to the VBF protocol.

Keywords- Underwater Wireless sensor network, Routing protocol, Fuzzy Logic, vector,

1. Introduction

Routing schemes that account for the 3D environment need to be developed. Especially currents should be taken in to account in the case of 3D environment which cause connectivity holes, especially when the sensor network is deployed in deep waters. Thus, to provide scalable and efficient routing in UWSNs ,we have to seek for new solutions[2].

In this paper we present a Fuzzy Logic approach for the routing protocol formation process. In this approach we consider three descriptors: the *depth* of selected node from the surface of the water (with regarding to defined radius), *closeness* in forwarding packets which can be calculated same as desirableness factor in VBF Protocol [3] and is the distance of node from the vector between source and sink and *Weight* which shows the number of times that each selected node has previous packet sending, this is useful to indicate the amount of remaining energy of a node . For forwarder selection, each node applies the three descriptors in the Mamdani Fuzzy Inference System [4], and the node that has the maximum chance value to forwarding packet is selected.

We call our approach the Fuzzy Logic Optimized VBF Protocol (FLOVP) for WSN. To show the features of our FLOVP we compare it with VBF. Simulation results show that our approach degrade the network end-to-end delay significantly as compared to the VBF protocol. In addition, our simulations show that the nodes consume energy in a more uniform fashion.

In chapter two , some related work is discussed, and our methodology is introduced in chapter three. then the experiment and simulation is discussed in chapter four and conclude our paper in chapter five.

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2. Architecture of Fuzzy Logic Optimized Vector Protocol

The three parameters of the fuzzy logic inference system include the depth and the closeness of sensors to vector from source and sink, and weight that is the number of times that each selected node has previous packet sending.

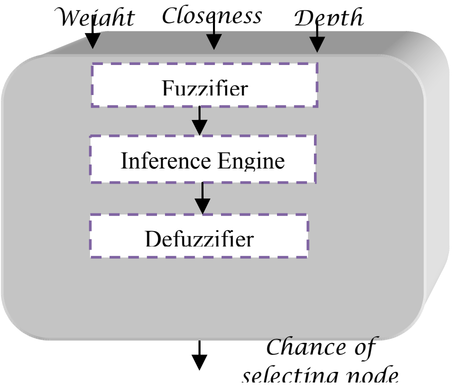

Fig.1: Fuzzy Architecture of proposed Protocol

The proposed protocol is different from VBF, as VBF just with one factor, called Desirableness factor decide whether the node can forward packet or must discard it. In this paper not only we consider the closeness to the vector but also the weight of the node (i.e. , the number of time that a node is selected as a forwarder until now) and also the depth of the node from the surface of the water must be brought in to consideration. Following this step the node that has the largest chance is selected as a forwarder.

2.1. Fuzzy system model

The model of fuzzy logic control consists of a Fuziffier, fuzzy rules, fuzzy inference engine, and a deffuzifier. In our proposed model we have used the most commonly used fuzzy inference technique called Mamdani method due to its simplicity. This method allows us to describe how our system is working in an easy and simplified mathematical way[4].

To show and clarify how we use FIS to determinate Forwarder node chance value, the following four steps are used which provide details for the calculation of chance value in the FIS.

2.2. Input of Crisp Value and Fuzzification

Node Closeness - this parameter is the same as Desirableness in VBF protocol [3], which computed from below expression. Where the proportional P (distance between selected node to routing vector) and w (the width of routing vector) shows the closeness of selected node to the routing vector and the second proportion refers to the location of selected node in the transmission area from forwarder node

.Closeness = $\frac{p}{w} + \frac{R - d \times \cos\theta}{R}$

Node weight – this parameter has a direct relation with energy consuming. It indicates that whether the node is selected as a forwarder before or not. If yes, its weight increases. This is used to determine the energy level of the node. The node which works as a forwarder and sends packets its energy will be degraded. The initial energy level and in another word the maximum energy level for each node is 10000. Furthermore, each forwarder consumes 10 J per packet. As a result, each forwarder can be selected 1000 times (regardless of other factors) .Thus, we use 1000 times for the maximum number of weight.

Node depth - a value which classifies the nodes based on the height from the surface of the water .If the node has a lower height it means that it close to the sink. The depth value is scaled while representing in the fuzzy set.

2.3. Rule Evaluation

To study how much they are effecting the lifetime of the network, and to make these parameters more flexible, we divided each linguistic variable that we used to represent these parameters into three levels : *close, medium, far* for the closeness level of node the routing pipe; and *low ,medium, high* for the weight and depth of every nodes .

The outcome to represent the forwarder selection chance was divided into nine levels: *very weak, weak, little weak, medium, low medium, medium, and high medium, little strong, strong and very strong*. The fuzzy rule base currently includes rules like the following: if the closeness is *close* and the weight is *high* and the depth is *high* then the forwarder node selection chance is *very strong*.

After the fuzzification step has been completed and the membership values have obtained, we supply/feed fuzzified inputs to our IF-THEN rules to determine our new fuzzy output set.

There are some approaches to combine expressions for the result of rules. We use SUM-PROD inference; which utilize multiply for AND operand and sum for OR operand.

Table 1: Linguistic sets for membership function

	Weight	Closeness	Depth
1	Low	Far	Low
2	Low	Far	Medium
3	Low	Far	High
4	Low	Medium	Low
5	Low	Medium	Medium
6	Low	Medium	High
7	Low	Close	Low
8	Low	Close	Medium
9	Low	Close	High
10	Medium	Far	Low
11	Medium	Far	Medium
12	Medium	Far	High
13	Medium	Medium	Low
14	Medium	Medium	Medium
15	Medium	Medium	High
16	Medium	Far	Low
17	Medium	Far	Medium
18	Medium	Far	High
19	High	Close	Low
20	High	Close	Medium
21	High	Close	High
22	High	Medium	Low
23	High	Medium	Medium
24	High	Medium	High
25	High	Far	Low
26	High	Far	Medium
27	High	Far	High

2.4. Aggregation of the rule outputs

After the fuzzification and rule evaluation have been done, the aggregation step will start. The aggregation is a process of the union of all the outputs obtained from applying all rules (27 rules in our FIS model). Since we are looking at aggregating all our rules we have used an (OR) Fuzzy Logic operator.

2.5. Defuzzification

The last step is defuzzification, where we will obtain our chance value. The process of transforming a fuzzy output of a fuzzy inference system into a crisp output is called defuzzification. the Center Of Area (COA) will be used in the centroid defuzzification, which we can compute by the following equation .

$$R = \sum_{i=0}^{n} W_i \mu_A(W_i) \ / \ \sum_{i=0}^{n} \mu_A(W_i)$$

where W_i is the domain value corresponding to rule i, n is the number of rules triggered in the fuzzy inference engine and $\mu_A(W_i)$ is the predicate truth for that domain value [4].

3. Simulation Result

In this section, with the use of simulation, the performance characteristics of Fuzzy logic optimized vector protocol , which is discussed in previous sections is studied . The proposed routing method is planned simulated using NS2 modeler.

Most of the experiment in these scenarios used general parameters described as follow: a network of N sensor node are randomly distributed in a 3D field of $1000m \times 1000m \times 500m$ .There are one data source and one sink . The source is fixed at location (900, 900, 500) near one corner of the field at the floor, while the sink is at location (100, 100, 0) near the opposite corner at the surface. Besides the source and the sink, all other nodes are mobile as follows: they can move in horizontal two-dimensional space, i.e, in the X-Y plane (which is the most common mobility pattern in underwater applications).

Metrics, Totally, three metrics are considered in this thesis: *Packet Delivery ratio*, *Delay*, *Energy Cost*. Packet Delivery Ratio (PDR) is the ratio of the number of packets successfully received by the sink to the number of packets generated by the source. Delay refers to two assumptions: Delay Per Packet (DPP) which refers to the time that the packet is held by the node, and the Network Total Delay (NTD). Energy cost is divided in to two definition; Total Energy Consumption (TEC) and Average Energy Consumption (AEC) for each successfully received packet. Meanwhile, the effect of network size and mobility of the node on the three metrics is measured and analyzed.

The result for PDR, DPN, NTD, TEC, AEC are plotted in Fig. 9, Fig. 10, Fig. 11, Fig 12, Fig. 13 respectively.

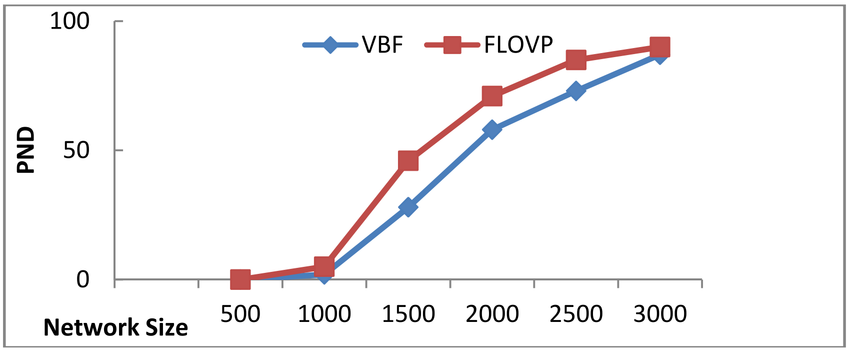

Fig.9: Packet Delivery ratio

Fig.9, demonstrates the general trend of Packet Delivery ratio for both VBF and FLOVP. From the figure, we can see that, with the increasing network size, the packet delivery ratio is enhanced. In other words, for any node in the network, as the network size becomes larger, more nodes are selected as the best and qualified packet forwarder. Furthermore, we can see that the packet delivery ratio of Proposed FLOVP is considerably improved upon VBF, especially in sparse network.

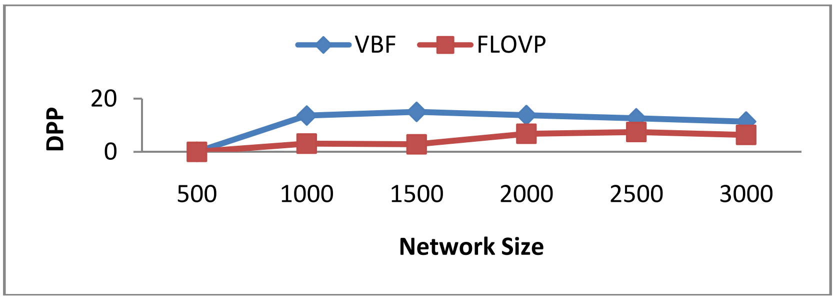

Fig.10: Delay Per packet

Fig.10, shows us that the delay per packet of FLOVP is significantly lower than of VBF, and the gap becomes more in sparse network size. From the figure, the amount of average delay that each packet needs to reach the destination successfully is observed.

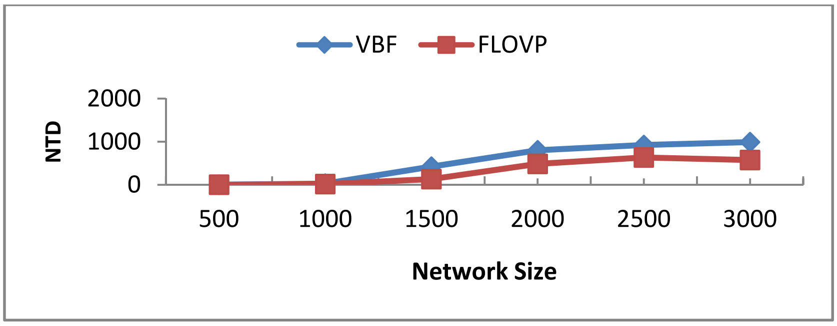

Fig.11 End-to-End Delay

In Fig.11 , NTD is demonstrated. It is observed that the FLOVP could optimize the total amount of delay in VBF. It is reasonable as in VBF when multiple packets are sent to the qualified node; they stay in a queue in order to compare their desirableness factor. This issue causes waiting time and as a result, the whole traffic in network becomes higher. In our Fuzzy algorithm we consider the weight parameter which if the node receive high packets, its number will be increase to a high level. So the energy of the node will decrease and it creates queues or congestion in a specific path in a qualified node.

4. Conclusion

In this Paper we discussed the design details of our proposed FLOVP. The new proposal introduces a Fuzzy Logic approach, which is simple while novel and it can significantly improve the robustness of packet delivery in sparse networks. The proposed algorithm improved packet delivery ratio in the range of 10% to 20% compared to VBF. This is reasonable because our approach used three parameters in routing scheme compared to VBF that uses only one. Relying on one parameter (Desirableness factor) is not suitable to produce optimal routing path because packet delivery behavior in underwater WSNs is a very complex phenomenon. In future work, we may choose different parameters such as alternative paths or/and Clustering nodes instead one or more of the chosen parameters.

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