An Extended DFR Protocol based on Geographical Information for Underwater Sensor Networks

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***Abstract*—In original directional flooding-based routing(DFR) protocols, a sender node determine its flooding area based on link quality only. Since location of its neighbor nodes are not reflected to this determination, unnecessary redundant packet transmission or void problem could be occurred. Hence, in this paper, we propose a new geographical information based extended DFR(GE-DFR). In GE-DFR, a sender node divides the initial flooding area based on location information of neighbor nodes. After then, the sender node adjusts these divided flooding areas based on accumulative link quality of forwarder nodes to avoid redundant packet transmission.**

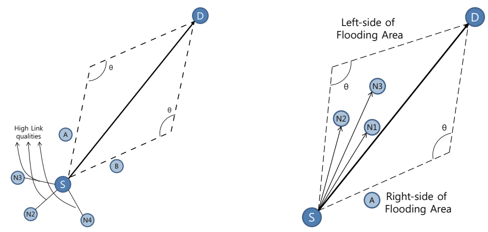
I. Introduction

Recently, researchers have paid much attention to underwater wireless sensor networks (UWSNs) in order to support a variety of applications such as seismic monitoring, tactical surveillance, etc. In such UWSNs, nodes use an acoustic wave to communicate with each other because the radio signal cannot be well propagated in the underwater environment. Due to intrinsic characteristics of the acoustic wave, UWSNs have distinctive limits like high propagation delay, limited bandwidth and a high error rate rather than terrestrial networks.

Due to these limitations, in routing layer, flooding-based routing protocols are known to be suitable for UWSNs since they can increase end-to-end reliability [1]. In the flooding-based routing protocols, source or intermediate nodes define a flooding area towards the sink based on geographical information. Intermediate nodes that are located in the flooding area can be participated in next forwarding. Therefore, multiple copies of data packets are transmitted along different paths without high routing overhead. In the routing protocols, how to determine the optimal flooding area is one of the most important issues [2].

Among various flooding-based routing protocols, Directional Flooding-based Routing (DFR) [3], which we considered as the conventional protocol, determines the flooding area based on link quality. In DFR, a sender node calculates a BASE_ANGLE which determines the flooding area of DFR based on link qualities of its neighbor nodes. If link quality is low, the flooding area is expanded to increase the reliability. Otherwise, if the link quality is high, the flooding area is reduced to decrease unnecessary packet transmission.

However, although not only link quality but also node deployment has high relevance to the reliability, it is not reflected in the BASE_ANGLE calculation scheme of the original DFR. Hence, when deviation of the link qualities is high, an appropriate BASE_ANGLE cannot be determined.



(a) Void Problem (b) Packet Collision

Fig. 1. Problems of Original DFR

For example, in Fig. 1-(a), node A and B which can be appropriate forwarder have low link quality. On the other hand, the other neighbor nodes have high link qualities, sender node determines a narrow BASE_ANGLE. Since all the forwarding candidate nodes(in Fig. 1-(a), node A and B) are located out of the reduced flooding area, packets are dropped. Moreover, if forwarding candidate nodes are located in dense area, redundant packet transmissions occur in that area(Fig. 1-(b)). Since the collision between multiple copies of the packet is increased at the left-side area, end-to-end reliability of packet transmission could be decreased.

In this paper, we therefore propose a new Geographical-based Extended DFR (namely GE-DFR). In GE-DFR, a sender node divides the flooding area based on geographical information. The sender node adjusts the each divide flooding areas accumulated link qualities to increase the end-to-end reliability.

II. Geographical based Extended DFR

In GE-DFR, sensor nodes piggyback location information on hello message, which is used to calculate ETX(expected transmission count). Based on the location information, a sender node S located at (X1, Y1) determines forwarding nodes that closer to the sink positioned at (X2, Y2) than the node S. After forwarding candidate node(s) determination, the node S sets a baseline from the node S to the destination node D. Afterwards, the node S estimates whether the forwarding candidate node F(X3, Y3) is placed on the left side or right side from the baseline according to the equation 1.

$$Di = (X2 - X1) * (Y3 - Y1) - (X3 - X1) * (Y2 - Y1) \quad (1)$$

If $Di > 0$, the node F is located on right-side of the flooding area (*r-flooding area*). Otherwise, if the $Di < 0$, the node F is considered to be on the left-side of the flooding area (*l-flooding area*).

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After this estimation, the node S calculates an initial BASE_ANGLE based on link qualities of only the forwarding candidate nodes only(no forwarding candidate nodes' link qualities are omitted). Based on the initial BASE_ANGLE, the node S estimates the number of forwarding candidate nodes located in each of left and right side of the initial flooding area. If no node exists in the *r-flooding area*, the node S extends the R_BASE_ANGLE as INC_ANGLE defined in the original DFR. This flooding area extension is repeated until at least one node is located in the *r-flooding area*.

Otherwise, if one or many forwarding candidate nodes are located in the *r-flooding area*, the node S calculates an accumulated forwarding probability of the *r-flooding area* (AFP_R) as follows :

$$AFP_R = 1 - \prod_{i=1}^{n}(1 - (Pr_{\overrightarrow{SF_i}}) \quad (2)$$

Where n and $Pr_{\overrightarrow{SF_i}}$ are the number of neighbor nodes in the *r-flooding area* and a probability of successful packet transmission, respectively. Since the $Pr_{\overrightarrow{SF_i}}$ is already estimated to calculate ETX, $Pr_{\overrightarrow{SF_i}}$ estimation does not requires additional overhead.

If Pr_r is low, packets cannot be well-propagated in the *r-flooding area*. Hence, the packets could be propagated along the *l-flooding area* and reliability of end-to-end packet transmission is decreased. To increase reliability of the *r-flooding area*, node S increase the R_BASE_ANGLE as INC_ANGLE until the Pr_r is larger than a threshold (Th_{Pr}) that is application dependant. Of course, the node S applies these operations not only *r-flooding area* but also the *l-flooding area* and calculates L_BASE_ANGLE that determines the *l-flooding area*.

After computation of both R_BASE_ANGLE and L_BASE _ANGLE, the node S includes these angles into the packets. Based on these angles, the forwarding candidate node(s) which are located in the *l-flooding area* or *r-flooding area* participate(s) in the next-forwarding.

III. Performance Evaluation

A. Simulation Environments

The proposed GE-DFR is compared with the original DFR. In an 1500m $\times$ 1500m network topology, the sink was placed at the center of surface. Source nodes were randomly chosen from the nodes that are five hops away from the sink. The transmission range was set to 250m and we assumed that the QoS requirement of an accumulated forwarding probability (Th_{Pr}) was 80%. Each sensor node was set to have a bandwidth of 10 kHz. Link error rates were selected randomly between 10% and 40%.

First, we evaluated the probability of void problem when all sensor nodes are deployed randomly (refer Fig. 2). As node density increases, the probability consistently decreases in both of DFR and the proposed GE-DFR, since the number of forwarding candidate nodes increase. Moreover, regardless of the node's density, GE-DFR has low void probability than

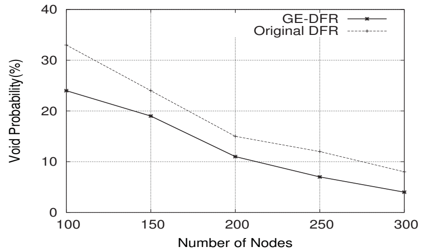

Fig. 2. Void Probability

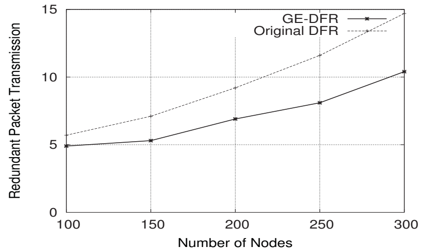

Fig. 3. Redundant Packet Transmission

the original DFR since it can determine an appropriate flooding area based on location of the forwarding candidate nodes to remove the void areas.

We also investigated the number of redundant packet transmission of GE-DFR and the original DFR (refer Fig. 3). As node density increases, the redundant packet transmission consistently increases in both the GE-DFR and original DFR because the number of next forwarder increases. Moreover, compared with the original DFR, GE-DFR achieves redundant packet reduction since it divides its flooding area into and sets different flooding area.

IV. Conclusion

In this paper, we proposed a geographical information based extended DFR protocol for underwater sensor networks. In GE-DFR, a sender node divides its flooding area into left or right side of flooding areas. After the flooding area division, the sender node adjusts BASE_ANGLEs of each flooding area to provide reliable packet transmission based on link quality and location information of neighbor nodes.

In addition, when GE-DFR is applied to 3-dimension (3D), projection onto X-Y plane also be used to divide the flooding area. In future, we will conduct research on the optimized 3D flooding area division schemes for UWSNs.

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References

[1] I. F. Akyildiz, D. Pompili, and T. Melodia, "Challenges for Efficient Communication in Underwater Acoustic Sensor Networks," *ACM SIGBED Review*, vol. 1, July 2004.

[2] H. Yan, Z. Shi, and J.-H. Cui, "DBR: Depth-Based Routing for Underwater Sensor Networks," in *IFIP Networking'08*, Singapore, May 2008, pp. 16–1221.

[3] D. Hwang and D. Kim, "DFR: Directional Flooding-Based Routing Protocol for Underwater Sensor Networks," in *MTS/IEEE OCEANS*, Quebec City, Canada, 2008.