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E-DSDV routing protocol for mobile ad hoc network for underwater electrocommunication

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Dear editor,

We realized the dynamic networking of underwater electrocommunication for the first time through experiments [1–3]. The E-DSDV routing protocol based on underwater electrocommunication also belongs to the proactive routing protocol [4]. In the E-DSDV protocol, each node needs to establish and maintain a routing table, which contains the source node, destination node, next-hop node, the total number of hops to the destination node, and node sequence number [5–7]. The E-DSDV protocol can transform the voltage signal detected at the receiver and transmitter into the distance information between neighbors on time and the distance information between neighbors into the sequence number required in the protocol. After topology transformation of nodes in the network, they can update their sequence numbers in time and give the updated information to neighbors, so as to change the routing information of the network and timely change the routing table to maintain accurate routing information. The principle of the E-DSDV protocol is as follows.

Determination of sequence number. In the dynamic networking of underwater electrocommunication, when the node moves randomly, each unit node will increase two sequence number (Seq) values, that is, the sequence number value of the node in the network during normal communication is always even. When the node fails and cannot communicate normally, the sequence number of the node will increase by 1, and the sequence number of the faulty node increases by 1 to become an odd number. In the E-DSDV protocol, the serial number is odd when the nodes cannot communicate with each other. The agreement also sets the hop number between two nodes that cannot communicate to infinity. The hop count is set to an infinite number. Formulas (1) and (2) describe the relationship among voltage, distance and sequence number:

$$\mathrm{Seq} = 2 \cdot \left[\frac{[2000 \cdot (U_c - \min(U_c))]}{2} \right] + 6, \tag{1}$$

$$\begin{aligned} \mathrm{Seq} &= 2 \cdot \left[\frac{1}{2} \cdot \left[2000 \cdot \left(\frac{4.337}{295.5 + d} - \min\left(\frac{4.337}{295.5 + d} \right) \right) \right] \right] + 6 \\ &= 2 \cdot \left[\frac{1}{2} \cdot \left[8674 \cdot \left(\frac{1}{295.5 + d} - \frac{1}{295.5 + \max(d)} \right) \right] \right] + 6, \end{aligned} \tag{2}$$

where U_c represents the received voltage, $\min(U_c)$ represents the minimum voltage received, and the function $[X]$ represents the largest integer that does not exceed X, where Seq represents sequence number, d represents the distance between nodes. From the relationship among the voltage and sequence number and distance in the system in Figure 1(a), it can be seen that the serial number in the block surrounded by the voltage and distance is constant. So if the voltage is disturbed within a certain range of fluctuation, or the node position changes within a certain range, the system still works normally, improving the robustness of the system.

Route establishment and update. The establishment of routes by mobile nodes follows the following two principles.

(1) Compare the routing information carried in the update packet with the routing entries stored by the node. If the route sequence number received by the node is greater than the route entry sequence number stored in the routing table, it will update the old routing information in its own routing table, and use the updated route to delete the previously stored route with the old sequence number.

(2) If the sequence number of the node after routing update is the same as that in the existing routing table, the network node will compare the hop number of nodes under the same serial number when selecting the target node for communication. After comparison, the node with a smaller

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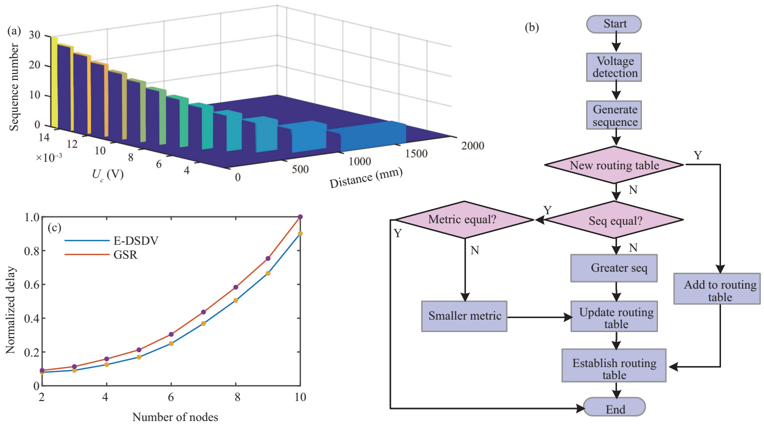

Figure 1 (Color online) (a) The relationship between the sequence number and voltage and distance; (b) routing table creation process; (c) simulation results.

hop number will be selected for communication to update the routing information, and the routing table of each node will be automatically updated.

There are two types of route update methods. One method is partial data packet update, that is, partial update, which only updates the changed part of the routing table. The other method is full update, that is, global update, which contains all the information of the node routing table. The E-DSDV protocol will update a part of the data packet after a certain time, and will perform a complete update to completely replace the routing information in the network with a new route to ensure the reliability of the network routing. Figure 1(b) shows the process of route establishment and update. First, the voltage detection creates a sequence number, based on the size of the sequence number to determine whether it is a new route, thereby deciding whether to add a routing table, and then, based on the sequence number and the number of route hops equal to update routing table information.

Simulation. We use two protocols to perform simulation tests in the same environment, and calculate the average end-to-end delay of the E-DSDV and GSR protocols respectively [8]. For a network of N nodes, their average end-to-end delay time is

$$T_{\text{E-DSDV}} = \frac{\sum_{i=1}^{N-1}(i+1)\cdot S_i^{\text{E-DSDV}} + t_1^{\text{connect}}}{N} + \frac{\sum_{i=1}^{N-1} t_1^{\text{test}} + t_1^{\text{update}} + t_1^{\text{calculate}}}{N}, \tag{3}$$

$$T_{\text{GSR}} = \frac{\sum_{i=1}^{N-1}(i+1)\cdot S_i^{\text{GSR}} + t_2^{\text{connect}}}{N} + \frac{\sum_{i=1}^{N-1} t_2^{\text{test}} + t_2^{\text{update}} + t_2^{\text{calculate}}}{N}, \tag{4}$$

where i is the number of hops; S is the number of network types under the corresponding hops; t^{connect} is the time to establish a connection; t^{update} is the update time; t^{test} is the detection time; $t^{\text{calculate}}$ is the calculation time. Figure 1(c) shows that in the average end-to-end delay, the average end-to-end delay of the E-DSDV protocol is less than that of the GSR protocol, thereby reducing networking time, speeding up the establishment of routing tables, and improving networking efficiency. At the same time, each node in the E-DSDV protocol of underwater electric field dynamic networking has a self-test function, which makes the sequence number remain unchanged under the condition that the received voltage fluctuates in a small range, and reduces the detection time at the same time. So the test time is less than that of the GSR protocol and the efficiency of dynamic networking is improved.

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