Proceedings of 20th International Congress on Acoustics, ICA 2010

23-27 August 2010, Sydney, Australia

A Comparison of Two Secure Routing Protocols in Underwater Acoustic Network

Yangze Dong, Pingxiang Liu

Shanghai Marine Electronic Equipment Research Institute, Shanghai, China

PACS: 43.30Nb

ABSTRACT

There is an increasing requirement of the application of Underwater Acoustic Network (UAN) both in many fields. In the commercial applications, terrorists may carry through destroy activities; while in the military applications, even it is an inevitable activity to degrade the adversary UAN. Thus it can be seen that security measures must be integrated into UAN. This paper tries to do some efforts in the security of UAN, presenting two secure routing protocols. Comparisons are performed via simulation. Selected features include throughput, average bit error rate, and average end to end time delay, etc.

INTRODUCTION

With the rapid progress of the supporting technologies, there is an increasing requirement of the application of Underwater Acoustic Network (UAN) both in many fields. In the commercial applications, terrorists may carry through destroy activities; while in the military applications, even it is an inevitable activity to degrade the adversary UAN. Thus it can be seen that security measures must be integrated into UAN.

In the terrestrial networks, many security measures have been adopted and show increased robustness. But in current studies on UAN, few attempts are pursued during the development. Though there are still some open research issues in this field, mature UANs should own the capability of counterworking against the hostile attacks somehow.

This paper tries to do some efforts in the security of UAN, presenting two secure routing protocols. The paper is consisted of the following main contents.

The state of the art of routing protocols of UAN is investigated. It shows that three kinds of protocols are of the dominant: proactive protocols, reactive protocols and geographical ones.

A distinct UAN model is established. The network is a typical two-branch-tree structure. One sink node leads two branch nodes; and each branch is divided into two branches again; and at the lowest level, there are eight leaves. Such a configuration is a concentrated network, and multi-hop information interchanging is needed.

Two secure protocols are developed based on the aforementioned network for its continue-to-pursue. The first is called PrePro, which is with a preset mechanism. It would automatically re-find the routes after partial destroy. The second is named CastPro, which would re-establish the necessary routes by broadcasting the new messages.

Within a simulation scenario, the performances of the two protocols are compared via computer simulation. Some of the characteristics of the network are selected.

At the last of the paper, prospect of some of the open research issues are listed, which will lead to a robust UAN.

OVERVIEW OF ROUTING PROTOCOL STUDIES IN UAN

Routing is the peculiar job of network layer in UAN for multi-hop strategy is adopted for long distance information conveying.

As mentioned in many literatures, there are many obvious but vast differences between UAN and other types of networks. Therefore, the existing protocols in Wireless Sensor Network (WSN) and Ad hoc Sensor Network (ASN) won't work directly into UAN.

The existing routing protocols are often divided into three types as follows.

Proactive Protocols

The goal of such protocols are to minimize the message latency induced by route discovery, by maintaining up-to-date routing information at all times from each node to every other node. This is obtained by broadcasting control packets that contain routing table information (e.g., distance vectors) [1].

Proactive routing protocols provoke a large signaling overhead to establish routes for the first time and each time the network topology changes.

Reactive Protocols

Reactive routing protocols only initiate a route discovery process upon request. Correspondently, each node does not need to maintain a sizable "look-up" table for routing.

The shortage of reactive routing protocols is its high latency to establish routing. Similar to its proactive counterpart, flooding of control packets to establish paths is needed, which brings significant signal overhead [2].

Geographical Protocols

With the help of positioning devices, geographical protocols could present promising routing schedules for their scalability feature and limited required signaling [3].

Brief Discussions

Both proactive protocols and reactive protocols are of the so-called packet-switch routing. The other category is called virtual circuit routing.

Packet-switch routing is not suitable for UAN because of large overhead. Virtual circuit routing protocols can be a better choice, but it usually lacks flexibility.

UAN MODEL AND ANALYSIS

A UAN Model

We now present a rather simple UAN model for further analysis.

A. Illustration

This is a typical dendriform structure, and often used in ocean sampling. Figure 1 gives an illustration.

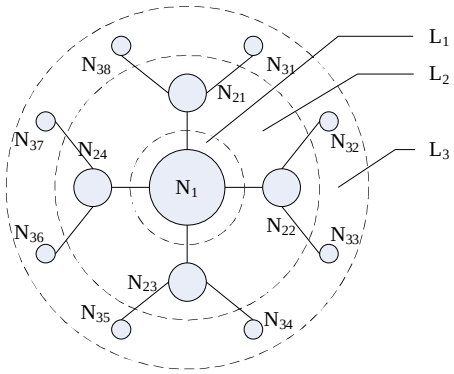

Figure 1. Illustration of a UAN Mode

B. Layers and Nodes

The network is divided into three layers, L_1, L_2 and L_3, and the nodes are within the three layers.

N_1 is the master node of the network. At the same time, it acts as the gateway, in charge of information exchanges with other networks.

Since it has the strongest capability, it is assigned 4 sub-nodes, which compose L_2. The sub-nodes are numbered as N_{2i} (I = 1, 2, 3, 4). L_3 consists of the leaf nodes of L_2, N_{3j} (j=1, 2, … , 8), which are attached to L_2. One node in L_2 is linked to two leaf nodes as depicted in Figure 1, respectively.

C. Geometric Parameters

For the ease of further processing, the acoustic link ranges are assumed the same, 3km. And the nodes are uniformly deployed at a depth of 50m, while the depth of sea is assumed 200m.

D. TDMA-based Media Access Control (MAC)

With the UAN model, a TDMA-based MAC protocol [4] is adopted. Figure 2 gives an illustration.

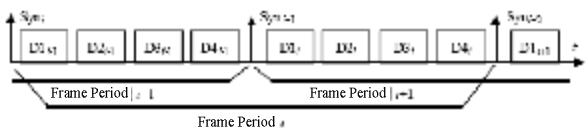

Figure 2. Illustration of a TDMA-based MAC Protocol

The feature of this MAC protocol is that it utilizes the idle time to transfer data to the central node, thus the efficiency is highly improved.

Model Analysis

A. An Asymmetric Network

Unlike in WSN and ASN, the above proposed UAN model is obvious an asymmetric network.

Firstly, the capabilities of the nodes in different layers are not equal. For example, N_1 is assumed the strongest node, while N_{2i} are with better performances than those of N_{3j}.

Secondly, the data streams are significant unbalance, which is more important circumstance worthy thinking about. Used as a sampling network, most of the dataflow are acquired data from nodes of lower layer to the upper ones. The inverse dataflow are mainly instructions to the lower nodes.

B. An Smooth Network

Compared with those surveillance networks, the proposed UAN is a kind of "consecutive" one, since the sampling is ongoing smoothly, not a burst.

C. An Centric Network

The proposed network is a centric one.

All the data in the nodes of the lower layers are congregated to its parent nodes. At last, they are gathered into the gateway for further processing.

D. An Multi-hop Network

Data from the lower layers can only be sent to its parent node. If the information goes on its trip, it needs an additional hop. For example, there would be a link $N_{33} – N_{22} – N_1$. In the network, the largest hop number is 2.

TWO ROUTING PROTOCOLS USED IN THE RE-ORGANIZATION OF UAN

UAN Re-organization

Literature [5] presented a reorganization scheme of UAN after partial destroy. The work of the procedure includes: UAN Destructing Extent Estimation, UAN Destructing Causation Analysis, UAN Auto-Reorganizing.

During the auto-reorganizing, a backup protocol is used. Simulation showed that the reorganizing is effective.

Now we will present two routing protocols used in the re-organization of UAN. One is named PrePro, the other is CastPro.

See Figure 1 again. Assume that node N21 goes out of service, information collected by node N31 and N38 would not be sent to N1 any longer. Measures must be taken to restore the data links.

PrePro – A Preset Routing Protocol

This protocol supplies a preset alternative routing scheme when necessary. A lookup table is formed for each situation.

Figure 3 presents the flowchart of the protocol for new routing.

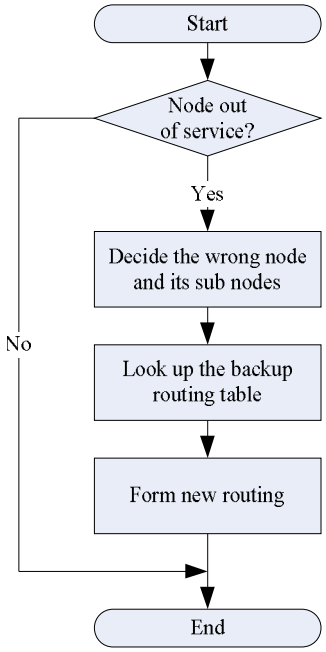

Figure 3. Flowchart of PrePro Routing Protocol

In figure 3, the judgement of which node is out of service is an important stage, because the ongoing procedures are base upon this decision. The method can refer to [5].

Table 1 gives the routing lookup table, supposing that layer L2 is prone to be destroyed.

Table 1. Lookup for New Routing in UAN of Figure 1

L_3 Nodes	Original Parent Node	New Parent Node
N_{31}	N_{21}	N_{22}
N_{32}	N_{22}	N_{21}
N_{33}	N_{22}	N_{23}
N_{34}	N_{23}	N_{22}
N_{35}	N_{23}	N_{24}
N_{36}	N_{24}	N_{23}
N_{37}	N_{24}	N_{21}
N_{38}	N_{21}	N_{24}

If the scale of UAN is much large (including geometry and node numbers), Table 1 might become bigger.

CastPro – A Broadcast Routing Protocol

In the beginning of a network preparing, broadcast is the main method to establish acoustic links.

If one or some nodes in UAN is/are destroyed during its running, the new routing may take the same measure in the reorganization.

The flowchart resembles that of PrePro, except that broadcast replaces the preset table lookup procedure.

Figure 4 presents a broadcast stage [6] in CastPro routing protocol. Corresponding to Figure 1, Figure 4 shows that Layer 2 node N_{21} receives the broadcast from center node N_1 and the peer layer nodes N_{23}.

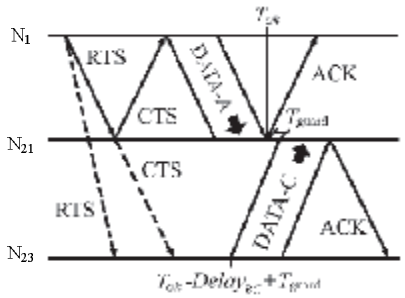

Figure 4. Broadcast from N_1 to N_{21} and N_{23} in CastPro Routing Protocol

With this scheme, N_{21} is always in operation, thus reduces the idle time after N1 makes a RTS – CTS cycle. In this period, N_{23} also gets the channel status (idle or busy), so the RTS – CTS cycle between N_{21} and N_{23} is omitted.

COMPARISON OF THE TWO PROTOCOLS VIA SIMULATION

Now the comparison between the two proposed protocols is to be engaged.

Simulation Condition Settings

A. Network and Node Model

The network model is presented in Figure 1.

Figure 5 gives the node model used in the simulation created by Opnet.

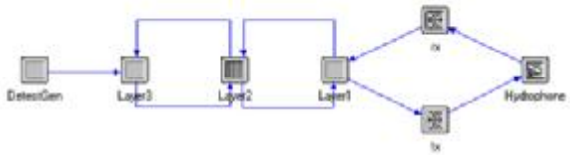

Figure 5. UAN Node Model

B. Sea Environment Settings

Ambient Noise: 55dB (Sea state 3)

Sound Speed: 1500m/s

Sound Absorption [7]:

$$a(f) = 0.11 \times \frac{f^2}{1+f^2} + 44 \times \frac{f^2}{4100+f^2} + 2.75 \times 10^{-4} f^2 + 0.003 \quad (1)$$

where f is the frequency of the carrier.

C. Applying Condition

For the use of PrePro and CastPro protocols, suppose that during the operation, N_{24} goes out of work. So its sub nodes N_{36} and N_{37} both need find out new routes to N_1.

Simulation Results and Analysis

Figure 6 shows the simulation results.

Figure 6 (a) presents the throughputs of the original network and the reconstructed network with PrePro and CastPro routing protocols. Figure 6 (b) shows the average BER of three networks. Figure 6 (c) is the comparison of average ETE delay of the networks.

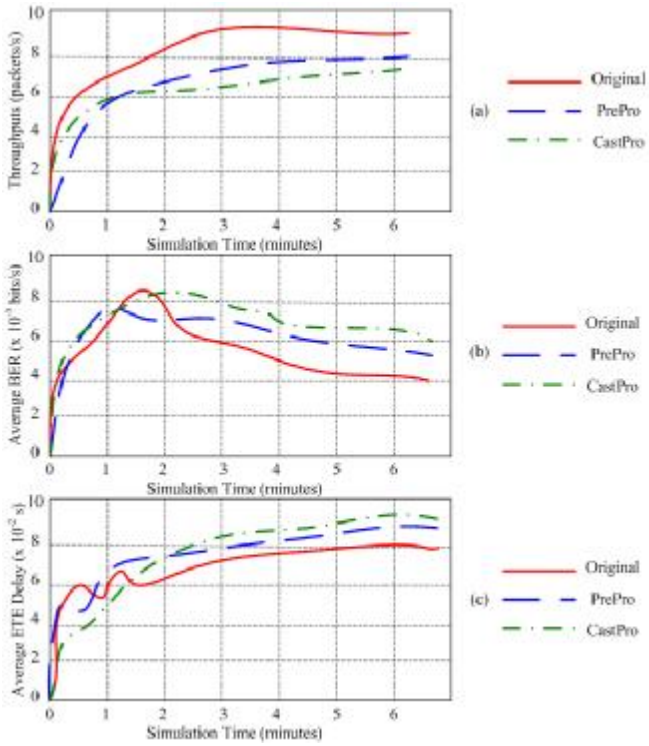

Figure 5. UAN Node Model

It can be seen that the performances of the reconstructed network is lower than the original one, but are rather good. During the first 2 minutes of the simulation, when the network is in the establishing stage, there are some differences of the three selected features. With the time elapses, the reconstructed networks reach the near same performances because of the same topologies.

SUMMARY

In this paper, two secure routing protocols in the reconstruction of UAN – PrePro and CastPro – are investigated. Based on the concrete network topology, the procedures of two protocols are depicted and simulations on their performances are accomplished.

Simulations show that the proposed protocols are effective in the reconstruction of UAN.

REFERENCES

1 Zaihan Jiang, "Underwater Acoustic Networks – Issues and Solutions" *Journal of Intelligent Control and Systems*. **13**(3), 152–161 (2008)

2 Ian F. Akyildiz, Dario Pompili, et al. "Underwater acoustic sensor networks: research challenges" *Ad hoc Networks*. **3**(3), 257-279 (2005)

3 Ian F. Akyildiz, "State of the Art in Protocol Research for Underwater Acoustic Sensor Networks" in *Proceedings of WUWNet'06*, September 2006, Los Angeles, USA

4 Tong Feng, "A TDMA protocol for underwater acoustic network" *Journal of China Institute of Communications*. **24**(4), 104-109 (2003)

5 Dong Yangze, Liu Pingxiang, "Study on Security of Underwater Acoustic Networks" in *Proceedings of ICIS 2005*, December 2005, Kuala Lumpur, Malaysia

6 Zhang Hongtao, "A Multiple Access Protocol for Underwater Acoustic Network" *Journal of Circuit and Systems*. **9**(3), 46-49 (2004)

7 L. Berkhovskikh and Y. Lysanov, *Fundamentals of Ocean Acoustics* (Springer, New York, 1982)