MAC Protocol Implementation on Atmel AVR for Underwater Communication

-Report 2-

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1. INTRODUCTION

Underwater acoustic communication is widely used in many areas to collect the data from different kinds of sensors deployed underwater or send control information to remote nodes. However, there are many challenges for underwater communication systems because of the characteristics of acoustic propagation in the underwater environment, such as doppler spread, ambient noise, fading, high propagation delay, limited bandwidth, wave effect and multipath [3]. MAC protocol, as a developed protocol for Ethernet networks, has been introduced into underwater communication by many researchers and lots of work has been done on the improvement of MAC protocol for throughput and energy efficiency purposes. In general, MAC protocols can be roughly divided into two categories: contention-free protocols and contention-based protocols. Contention-free protocols include TDMA,FDMA and CDMA, where communication channels are separated in time, frequency or code domains. It is common wisdom that FDMA is unsuitable for underwater sensor networks because of the narrow available bandwidth. There are some researches on TDMA and CDMA for underwater networks. However, some problems inherent in these methods have not been well addressed in acoustic networks. For example, the synchronization problem in TDMA and near-far problem in CDMA. Thus, the feasibility of these protocols in underwater sensor networks is unclear. Contention-based protocols includes random access methods and collision avoidance methods. In a random access protocol, the sender sends packets without coordination. Thus packet avoidance is totally probabilistic. While in a collision avoidance protocol, the sender and receiver capture the medium through control packet exchange before data transmission. There are many collision avoidance protocols, among which RTS/CTS-based protocols are widely used. The performance of random access methods and RTS/CTS-based approaches in underwater sensor networks is determined by many factors. In our implementation, we will develop a suitable protocol for our device in our targeted underwater network and evaluate the performance in the shallow water.

2. STUDY ON EXISTING PROTOCOLS

The random access and handshaking (i.e., RTS/CTS) techniques were studied in [6](based on formula simulation). Its results showed that random access is better than RTS/CTS for sparse network with low data rate and non-bursty traffic. The distance (less than 100 meters) and transmission range (50 - 1000 meters) have no effect on random access. It also pointed out that an adaptive MAC protocol is possible, adopting random access and RTS/CTS dynamically based on different networks conditions. However, there is no consideration on the impact of relaying traffic across more than one hop.

Based on the discussion in [6], for energy consideration, [7] proposed a R-MAC protocol for a dense underwater network with short transmission ranges and bursty traffic, in which it schedules the transmission of control packets and data packets at both the sender and the receiver to avoid data packet collisions. Also based on similar approachs, [2] employs RTS/CTS, but upon receiving a CTS, a node waits some time before transmitting the data packet because it may hear another CTS or a warning from the pervious sender, if so, the node aborts transmission. However, the target of these protocols is energy efficiency, which right now is not our major concern.

An analysis of the challenges of modeling contention-based medium access control protocols was reported in [4] (based on formula simulation) and it identified several issues complicating such contention-based protocols. This implies that the contention-based protocols with carrier-sense such as CSMA, may not be a good choice considering the nature of the wireless medium. It presented a model to analyze the suitability of Aloha variant protocols. But, the performance study of Aloha and model development was in the context of a simple string topology and simplified some assumptions.

In [1], it shows that without considering location-dependant propagation latency that introduces the spatial dimension of uncertainty, slotted ALOHA is significantly affected. The evaluation was based on a custom-built, packet-level simulator, transmission rate at 1kb/s. It pointed out that acoustic systems with low data rate 1kb/s can tolerate only 1ms or 1.5m in distance due to much slower speed of propagation (about 1500m/s). Their solution is to add guard bands. But the improvement depends on the choice of "beta" and the propagation delay regime "alpha" and it is not suitable for our case. And also pure Aloha and slotted Aloha are compared and studied in [5]. Their results were from Qualnets simulator with a bandwidth of 20Kps and a channel frequency of 50Khz. They indicated that the performance of Aloha and Slotted Aloha is about the same due to that long propagation delay of acoustic signals prohibits the coordination among nodes.

Some comparison between multi-channel MAC protocols was studied in [10]. It analyzed the performance of three different multi-channel MAC protocols: 1) Random multichannel aloha access protocol; 2)Multi-channel protocol with

RTS/CTS on a dedicated control channel; 3)Split phase multi-channel access protocol. The simulation results show that the throughput of RTS/CTS degrades with the distance increasing from 150m to 900m, but still better than the other two, while the random Aloha scheme has a relative better performance but the worst energy consumption per packet. It is not suitable for physical layer of our transceiver.

A much closer study focusing on Physical and Datalink layers was conducted in [8]. It implemented three variant of MAC protocols in Datalink layer, which are simple Aloha, Aloha with ACK and retries, and MACA using RTS/CTS, and used two variant - orthogonal and non-orthogonal in Physical layer. From its results, Aloha with ACK has a better performance for smaller packet size (¡500 bytes) and less nodes while MACA overcomes for larger packet size and denser networks.

3. SHALLOW WATER PROBLEMS

Different from deep water acoustic communication, there are more problems for shallow water communication, such as long delay-spread due to sparse multi-path arrivals and rapid time-varying channel. In [9] the relationship between transmission loss and typical channel parameters, such as sound-speed gradient, sea bottom fluctuation, source depth and propagation distance is studies, which provides a guide to design a practical device design and to choose a suitable protocol.

4. PROTOCOL IMPLEMENTATION

In our case, the underwater network is relatively small and sparse. The application packet size is not large. As is usually the case in many commercial acoustic modems/transceivers, the physical layer in our device is a half duplex system, which means listening while transmitting is not possible. It does not transmit while reception is in progress and does not receive while transmitting. Based on the above analysis, Aloha with ACK is a good start for our case.

The basic idea of an Aloha system is simple: senders transmit whenever they have data to be sent. Sender waits for a maximum Round Trip Time (RTT) for an ACK. If there is no ACK back, the sender just waits a random amount of time and resends it. The waiting time must be random or the same frames will collide over and over. At the receiver end, it sends an ACK to the sender if the received packet is error free. Figure 1 is a state diagram.

The system will model three layers of the OSI stack - Network, Datalink, and Physical. Network layer generates the packet to Datalink layer or gets the packet from Datalink layer. Datalink Protocol layer follows the state diagram above to process the packets. Physical layer is responsible to encode and send signals, or receive and decode signals.

5. PERFORMANCE METRICS

There are several metrics to estimate the performance of the protocols, as follows:

Throughput: the number of effective bits, i.e., the size of all the data packets successfully received in one second, or the ratio of successful received packets to the total packets transmitted from the transmitter, or the ratio of total correct data to the simulation time, or even to assess the throughput by determine the utilization.

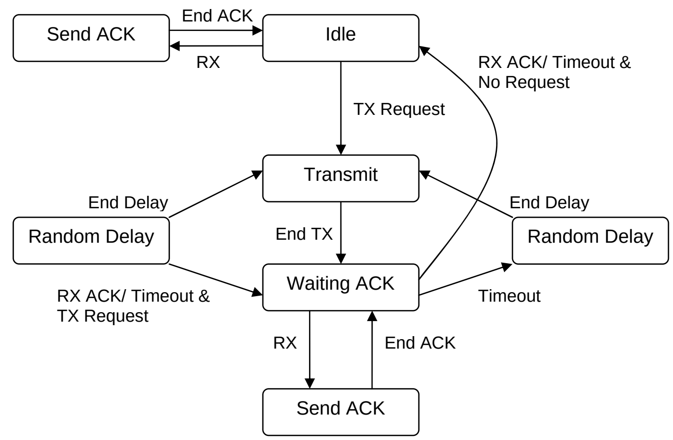

Figure 1: Aloha State Diagram

Communication overhead: the ratio of the total number of bits sent by sender to the number of effective bits received by the receiver.

Energy: energy consumption per successfully delivered packet.

In my later test I will mainly focus on the throughput, which we define as the average successful received packets per minute.

6. SCHEDULE

Week 1 (-07/4): Implement and finish the protocol

I am working on the protocol implementation and have started the system design. Try to finish the debugging and test it next week.

Week 2 (-14/4): Finish the system implementation with the protocol

Week 3 (-21/4): Test the protocol and collect the result to finish the report

7. REFERENCES

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