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REPORT

Optimization of Data Link Protocol for Underwater Acoustic Channel

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Certificate

This is to certify that this is a bonafide record of the project presented by the student whose name is given below during the Even Semester 2017-18 in partial fulfillment of the requirements of the degree of Bachelor of Technology in Computer Engineering.

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Abstract

Acoustic modems typically operate in half-duplex, which limits the choice of a data link control protocol to the Stop and Wait (S&W) type. Unfortunately, on channels with poor quality and long propagation delay-such as the majority of acoustic channels-S&W protocol has low throughput efficiency. The basic S&W can be improved by using a modification in which packets are transmitted in groups and acknowledged selectively. Throughput efficiency can now be maximized by selecting the optimal packet size, which is a function of range, rate, and error probability. Quantitative analysis for typical acoustic links shows that modified S&W protocols offer good performance, provided that packet size is chosen close to optimal. In addition, as the group size increases, sensitivity to packet size selection is reduced. To ensure best ARQ performance in mobile acoustic systems where link conditions vary with time, future generation of acoustic modems must focus on adaptive selection of protocol parameters.

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1. INTRODUCTION

With the advent of acoustic modem technology, the number of applications in which underwater sensors and robots are connected through a communication network is growing. One such application, which directly motivated this work, is the search for deep-sea hydrothermal vents by a small group of autonomous underwater vehicles (AUVs). By enabling a communication between vehicles and the mother ship, the efficiency of search is greatly enhanced.The majority of underwater acoustic channels are characterized by a poor quality physical link, caused by time-varying multipath propagation and motion-induced Doppler distortion. As a result, the bit error rate (BER) of an acoustic link is often high. Moreover, it can vary with time as the propagation conditions change. Errors in the received bit stream are thus inevitable, and to establish reliable communication over such a channel, an automatic repeat request (ARQ) procedure must be in place by which erroneously received data packets are retransmitted.

The task of the data link control (DLC) is to format the packets and to implement an ARQ protocol. Packet formatting includes addition of error control bits, typically in the form of a cyclic redundancy check (CRC). These bits are used at the receiver to check for errors. A packet is found erroneous if it fails the CRC test. The task of an ARQ protocol is to organize retransmission of erroneously received packets. A retransmission can be performed as many times as necessary, until a packet is declared correct (in practice, a limit is imposed on the maximal number of retransmissions). The design and analysis of data link protocols for use with an underwater acoustic system are the focus of this work, whose goal is to develop a protocol that is as efficient as possible, but simple to implement.

The simplest ARQ protocol is the Stop and Wait (S&W) protocol. In this protocol, the transmitter sends a packet and waits for the acknowledgment (ACK). If the ACK does not arrive in a pre-specified amount of time, called the time-out, or a negative acknowledgment arrives, the packet is retransmitted. When the ACK arrives, the transmitter moves on to a new packet. The S&W protocol is well suited for half-duplex operation, which is the mode typically supported by current acoustic modem technology. However, it has poor efficiency on links where the propagation delay is long compared to the packet size (which notably is the case for underwater acoustic channels). The efficiency of an ARQ protocol is measured by the time spent in waiting, and it can be improved if the idle interval between packet transmissions is used to transmit new packets.

To satisfy the half-duplex requirement, but increase the efficiency of the S&W scheme, several versions of this method have been proposed. This implementation of paper compares the various versions of S&W scheme and determines the best version.

The efficiency of the S&W protocol depends on the packet size, the link delay, and the packet error rate in such a way that there exists an optimal packet size for which the efficiency is maximized.

2. TECHNOLOGIES USED

The paper titled “Optimization of Data Link Protocol for an Underwater Acoustic Channel”, authored by Milica Stojanovic has been implemented by me. I have used C for implementing the paper.

C : C is a general-purpose, imperative computer programming language, supporting structured programming, lexical variable scope and recursion, while a static type system prevents many unintended operations. The main features of C language include low-level access to memory, simple set of keywords, and clean style, these features make C language suitable for system programming like operating system or compiler development.

3. WORK DONE

There exist three versions of S&W protocol apart from the normal S&W protocol. The three versions are:

1)Sastry Scheme (S&W-1)

- When retransmission is needed, instead of one, several copies of same packet are sent
- Another retransmission is needed only if all copies are received in error.

2)Morris Scheme (S&W-2)

- Transmitter sends group of M packets and waits for acknowledgement.
- Receiver checks each packet individually and sends ACK in group
- Negatively ACKed packets are placed in group of M packets to be transmitted in next cycle.

3)Turney Scheme (S&W-3)

- Here also, group of M packets is transmitted.
- Only packets which are negatively ACKed are retransmitted in next cycle. No new packets are added.

I have implemented all the three schemes using C. I have tried to find out the number of transmissions required to send a particular number of frames through a particular channel (noise remains constant). Lesser the number of transmissions required, better is the S&W scheme.

4. CODE

```
#include<stdio.h>

int main()
{
int n,frame,count;

printf("Normal Stop and Wait\n");
printf("Enter number of frames\n");

scanf("%d",&n);

frame=1;
count=0;

while (frame<=n)
{

printf("Transmitting Frame %d\n",frame);

int s=rand()%10;

if (s<1)

printf("TIME OUT\n Retransmit");

else if (s>2)
{
printf("PAK of Frame %d Received\n",frame);
frame=frame+1;
}

else
{
printf("NAK of Frame %d Received\n Retransmit",frame);;
}

count=count+1;

}
printf("\n\nTotal number of transmissions is %d\n",count); }
```

5. RESULTS

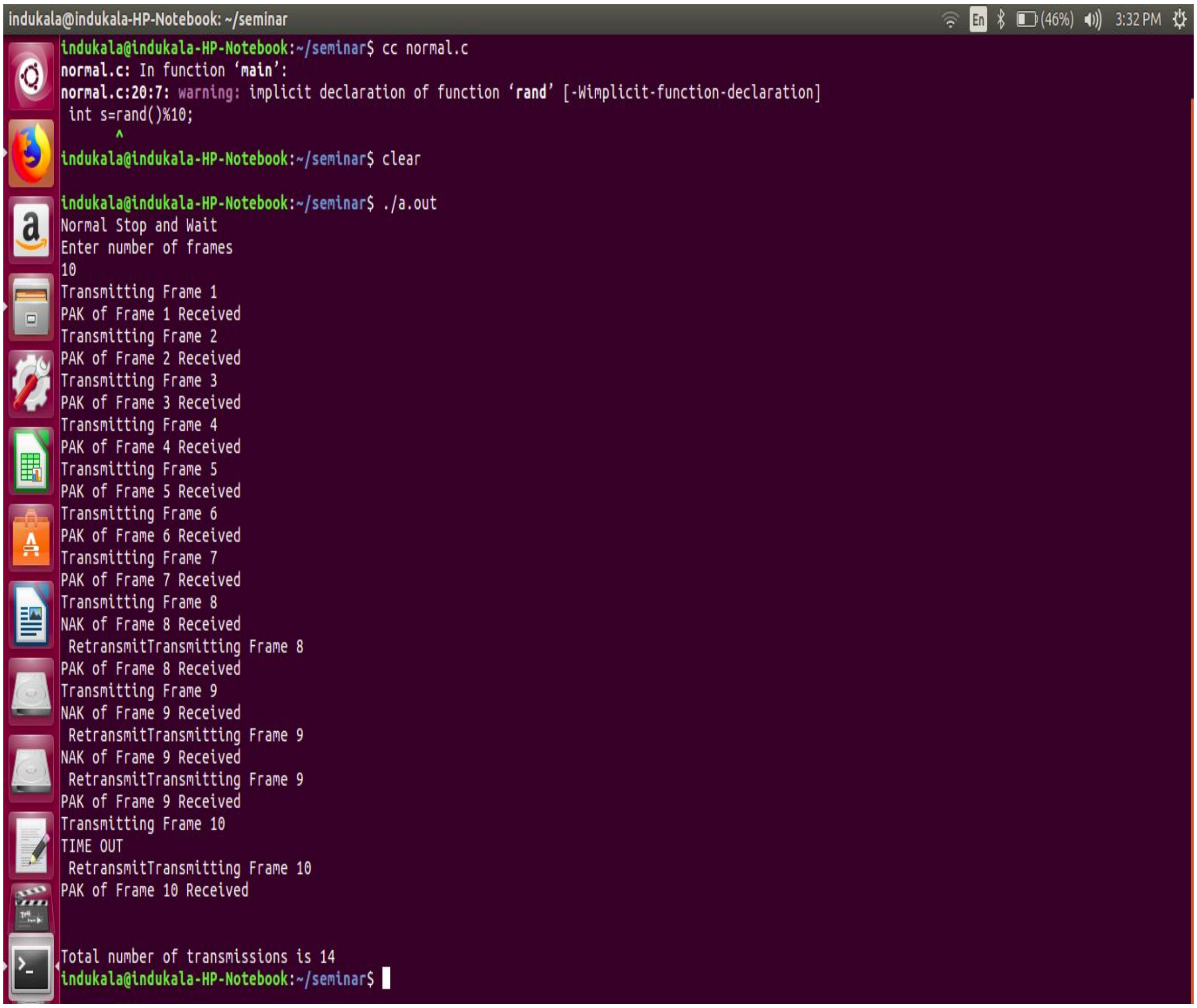
Usefulness of S&W-1 protocol is limited to situations with a low range-rate product. At higher values of the range-rate product, the S&W 1 efficiency drops to an unacceptably low level, making the effective bit rate practically useless. Except at very low rate (<100 bps) and very short distance (<500 m), its throughput efficiency is limited. Choosing shorter or longer packets will result in a serious further loss in performance, The efficiency of S&W-1 can be improved by using either S&W-2 or S&W-3. These protocols show substantial improvement for an optimally selected *Nd*. As expected, S&W-2 always outperforms S&W-3, and notably so for higher range-rate products. Similarly as the basic S&W-1, S&W-2 and S&W-3 exhibit high sensitivity to the choice of packet size.

It is worth noting that although the efficiency varies considerably with the packet size for all protocols considered, its shape is relatively flat for some range of packet sizes in the vicinity of optimum. This range is wider for a better quality link.

The fact that there is a range of packet sizes for which near-optimal performance can be achieved is encouraging from the viewpoint of a practical implementation where only a few packet sizes could be available to accommodate varying link conditions (distance, error rate). We must also recall that the best efficiency is obtained when the time-out is set close to the round-trip time. In a mobile scenario, the distance between the transmitter and receiver changes, and so does the optimal time-out. If a fixed time-out is used, its value must be setin accordance with the maximal distance between vehicles to prevent occurrence of false time-outs. Using a greater-than-necessary time-out will cause additional loss in efficiency. If the round-trip time is estimated (which is easily performed and is also used to aid the navigation system in the present application) the time-out can be adjusted accordingly.

The use of S&W-2 improves performance and also reduces sensitivity of the optimal packet size to both the link distance and the BER. As far as the practical system design is considered, where various factors may dictate a fixed packet size, or selection from a few different sizes, we note that good performance can be achieved with a reasonably small group size for the system parameters considered.

The following is a simulation of packet transmission when Normal S&W is used. The code is slightly modified to check packet transmission for the other S&W schemes.



The best S&W scheme is Turney scheme while the worst scheme is Sastry scheme.

6. CONCLUSION

Because the acoustic modems typically operate in half-duplex, selection of the ARQ scheme is limited to the Stop & Wait class of protocols. High latency of the acoustic channel renders the basic S&W protocol extremely inefficient, and limits is usefulness to systems that transmit at low bit rate over very short distances. For a multiple-vehicle search system that is of interest to the present project, this standard protocol is not a good choice. Instead, S&W schemes based on transmitting groups of packets for which selective acknowledgments are generated should be used. Throughput efficiency of these protocols can be maximized by selecting an optimal packet size as a function of the acoustic link parameters (transmission rate, link distance, and error probability) and the group size (*M*). In addition to increasing the throughput efficiency, modified S&W protocols offer lower sensitivity of packet size selection to both the range-rate product and the error probability.

To fully utilize the limited resources of an acoustic channel, future system design should focus on implementing an adaptive ARQ scheme. Two aspects can be considered in doing so:
(1) adaptive adjustment of the time-out in accordance with the measured instantaneous round-trip time
(2) adaptive adjustment of the packet size in accordance with the measured instantaneous error probability and link delay.

7. REFERENCES

M. Stojanovic, “Optimization of Data Link Protocol for an Underwater Acoustic Channel”