Experiment Description

1. **Experiment time:** September 21th, 2015
2. **Experiment location**: APL (node1, node2), Pocock (node3)
3. **Experiment purposes**:
   a) Taking node-to-node baseline.
   b) Repeating test conducted on July 23rd, eliminating time synchronization issues to confirm pervious results.
4. **Performance Metrics and Measurements:**
   a. Measuring packets sent, received, and dropped in order to analyze the performance of UW-Aloha protocol including throughput and loss rate.
5. **Experimenters**: Noshad Bagha, Yanling Yin.
6. **Experiment procedure**:

   a . Baseline procedure: Node 1 at APL: set packet length to 400 payload + 162 header in bytes, tx-rate= 0.1packet/sec. Node 3 is receiving packets at Pocock. 30 minutes.

   b . CIR procedure: Transmitting m-sequence signals from node 1 to 3 then node 2 to 3, before and after each trial.

   c . Repeating pervious deployment procedures:

      i. Node 1: set packet length to 400 payload + 162 header in bytes, tx-rate=0.05, 0.08, 0.1, 0.15 packet/ sec.
      ii. Node 2: set packet length to 400 payload + 162 header in bytes, tx-rate=0.05, 0.08, 0.1, 0.15 packet/ sec (Table 1)

Table 1: Random Back off procedure

Trial	Transmission power(All modems)	Packet Size(Payload + Header) (bytes)	Transmission rate(pkt/sec)	Test time(mins)	Comments
1	-4 dB	562	0.05	64	2 CIR measurements
2	-4 dB	562	0.08	42	2 CIR meas.
3	-4 dB	562	0.1	33	2 CIR meas.
4	-4 dB	562	0.15	32	2 CIR meas.

7. **Experiment environment:**

Table 2 is the distance between each node plus water depth.

Table 2: Distance and depth

water depth at each site	Node1	Node2	Node3
	4.9m	4.9m	5.4
node1 depth (sender1)	3m		
node 2 depth (sender2):	3m		
node3 depth (receiver):	3.5m		
distance between node1 and node3:	189m		
distance between node2 and node3:	188m		
distance between node1 and node2:	2m		

According to Table 2, we can consider the testing side as shallow water due to short distance between modems and both bottom and surface of the lake. In addition, lake Union's bottom at the testing location is classified as hard bottom. Both these conditions should increase the multipath effect and delay spread in compare to sea testing (Ref. 1.)

Figure 1 is side view of experiment topology denoting the depth of each modem compared to the lake depth.

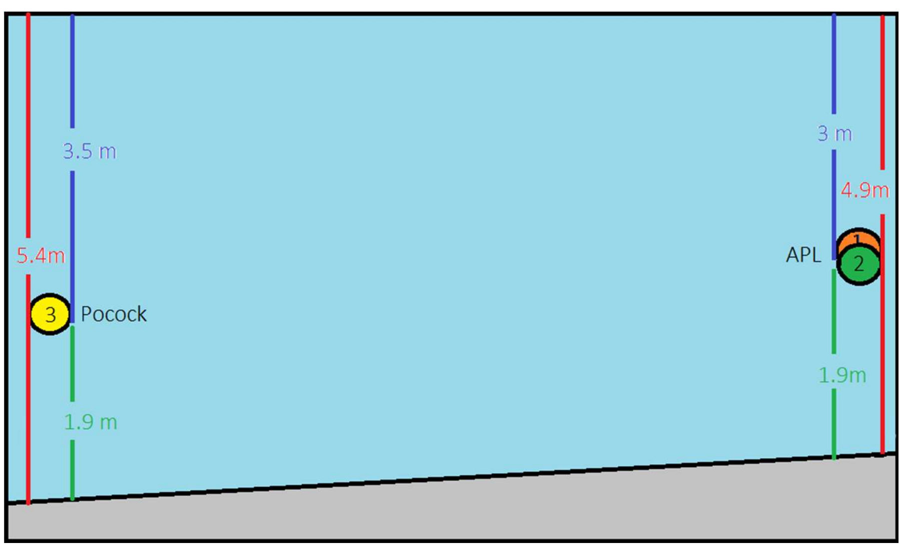

Figure 1: Side view of topology

Light boat traffic was observed during trials.

8. Field Experiment Data

Test duration considered for each tx-rate were determined so both nodes can have a chance to transmit at least 100 packets (Table 3.) As you can see there is a clear bias between Node 1 and Node2.

Table 3: Total packets send by MID and MID2

Tx-rate (pkt/sec)	Total Send Packets (Node1)	Total Send Packets (Node2)
0.05	133	122
0.08	112	92
0.1	97	82
0.15	98	88

Table 4: Data for transmitting modems

Node	rate(pkt/sec)	SEND	ACK REC	RETX	DROP	Test Duration(min)
1	0.05	37	36	18	0	61
1	0.08	60	58	41	2	39
1	0.1	29	29	15	1	33
1	0.15	38	38	23	0	32
2	0.05	45	41	18	1	61
2	0.08	56	56	48	1	39
2	0.1	26	25	19	0	33
2	0.15	29	26	24	3	32

9. Field Experiment Results

P2P Baseline:

We ran a 20 minutes baseline to determine the packet drop rate without modems competing for channel access. Baseline was ran at 0.15 packet/seconds where only MID2 is sending to MID1. Total of 74 packets was sent from MID2 to MID3 in which 1 packet failed to arrive at MID1. As it was expected, for this particular channel we have ~%99 success rate.

Back-off

Figure 2 shows throughput of back-off in compared to prior field experiment based.

$$Throughput = \frac{Packet\ size\ * \#\ ACK\ recived}{Test\ Duration}$$

Where packet size is a constant 562 Bytes.

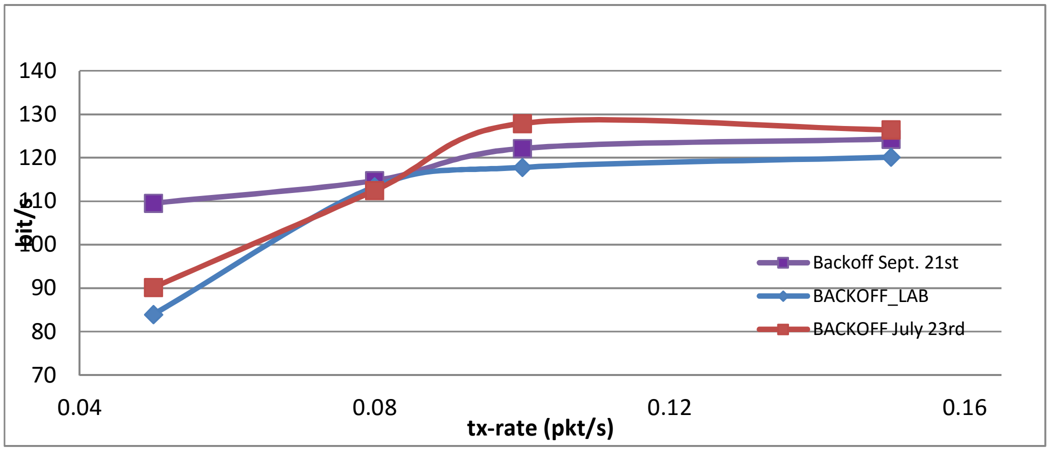

Figure 2: Throughput comparison between pure Aloha with no back-off and the new back-off scheme

Table 2 shows improved packet loss rate in the new algorithm.

$$Loss\ Rate = \frac{\#Packets\ Transmitted - \#\ ACK\ recived}{\#packets\ Transmitted}$$

Table 5: Packet Loss Rate Percentage

TX_Rate	Back-off July 23rd (%)	Back-off Sept. 21st (%)
0.05	31	31
0.08	44	39
0.10	39	39
0.15	44	41

10. Analysis

We have constructed a time-bar for the 0.1 packet/sec tx-rate. This trial ran for 950 seconds with Mode 1, which has transmission rate (R) of 1.38 kb/s. However, in Ref.2, 1.38 kb/s is calculated for time guard (Tg) = 50ms. Since nature of delay spread for Lake Union was unknown to us, we have set Tg =150ms for this experiment. Recalculating R for 150 ms time guard yields:

$$R = \frac{(rc\ .\ Kd\ .\ \log2\ (M))}{Ts+T} = 0.94\ kb/s$$

Where coding rate rc = ½ , # data subcarriers Kd = 672, Modulation M = BPSK , and symbol duration Ts = 170.7 ms (Ref. 2.)

Considering 0.94 kb/s transmission rate, transmission time for 562 bytes of data is **4.8** seconds and for 162 bytes of ACK is **1.4** seconds. We have confirmed this timing empirically in the lab settings.

Table 6 is a color map for the time-bars in Figure 3 and **Error! Reference source not found.**.

Table 6: Time-bar color map

Description	MID 1	MID2
Successful Transmission		
Packet was received by MID3 but ACK was not received		
Packet was lost without getting to MID3		

only two ~ 200 seconds section has been chosen for this analysis. The full plot can be seen in Excel format [here.]

Figure 3 shows the time-bar from time 0 to 130 seconds. The first and second rows correspond to data sent by MID1 and MID2 and last row is the ACK sent by MID3 to either MID1 or MID2.

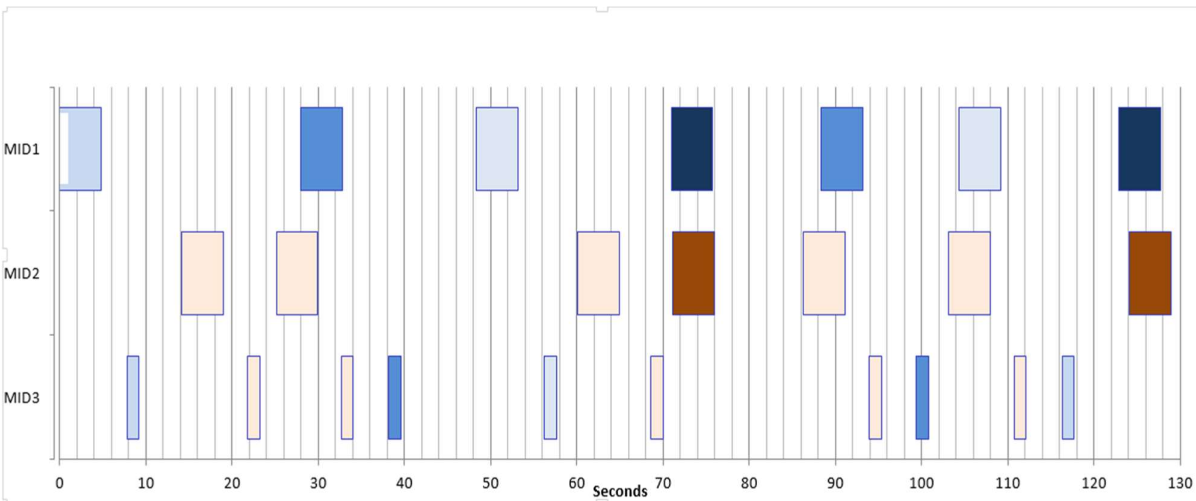

Figure 3: Time bar from 0 to 130 seconds

Table 7: Packet Loss Explanation

Time (seconds)	Behavior	Explanation
30 and 90	Data packet from MID2 is overlapping with MID1 data packet.	Both packets are decoded correctly, however second ACK is not received by MID1. This is a known issue, which needs to be solved.
72 and 125	Total packet overlap	Both packets are lost. Expected.

Figure 9 plot shows ordinary behavior expected. Other plot from this run shows similar trends and every packet can be explained. For example, in figure 10, you can see whenever data packets overlap the ACK for the second packet will be dropped.

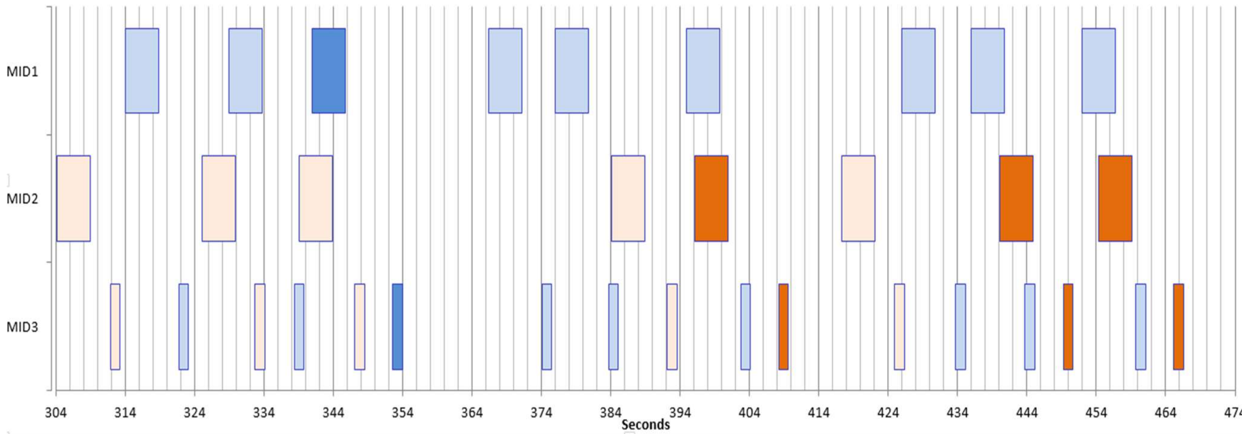

Figure 10: ACK drops only on the overlapping packet that starts later.

Also another expected behavior is seen in figure 11 which shows timebar from 470s to 700. At times 480, 580 and 680 seconds are instances where data packets are overlapping with ACK packets. In these three cases both overlapping packets are lost.

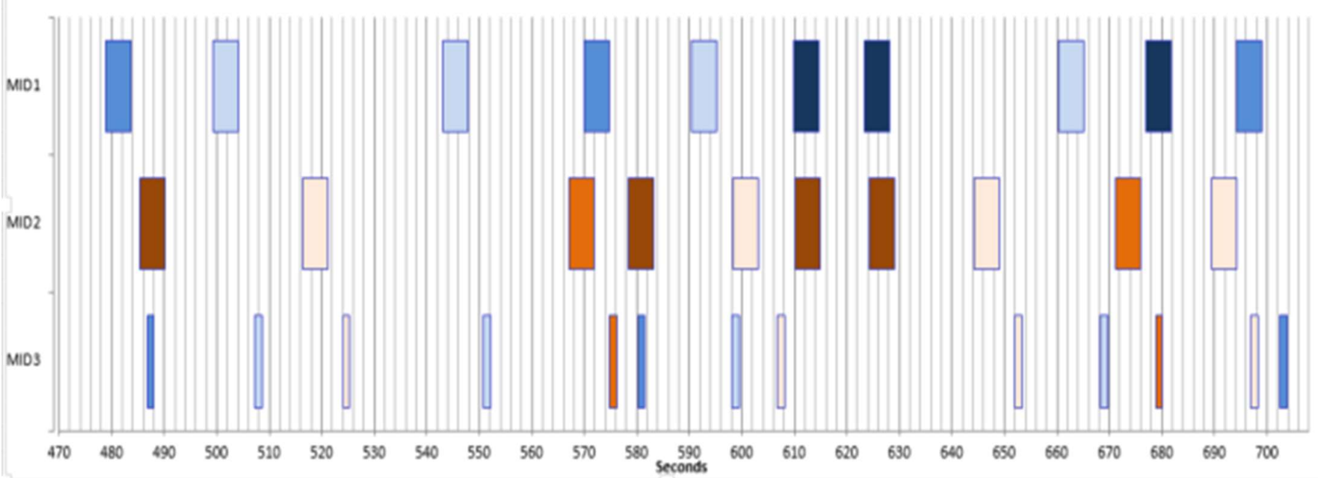

Figure 4: Overlapping ACK and DATA packets

References

[1] Stojanovic, M., "Underwater Acoustic Communications: Design Considerations on the Physical Layer," *Wireless on Demand Network Systems and Services, 2008.*

[2] Wan, Lei, et al. "Adaptive modulation and coding for underwater acoustic OFDM." Oceanic Engineering, IEEE Journal of 40.2 (2015): 327-336.