“Busy Terminal Problem” and Implications in Underwater Acoustic Networks

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1. INTRODUCTION

Underwater acoustic networks have become a very active research area during the past half decade. Compared with terrestrial radio networks, underwater acoustic networks are characterized by low available bandwidth, long propagation delays and high channel dynamics, which pose significant challenges to the design and analysis of almost every core networking problem [1], including medium access control (MAC), routing, and reliable data transfer. In this paper, we study a previously overlooked problem named the busy terminal problem, which is significantly impacts underwater MAC.

2. BUSY TERMINAL PROBLEM

In underwater networks, it has been noticed that underwater acoustic modems work in a half-duplex way. Most existing underwater MAC protocols follows the restrictions posed by the half-duplexity, i.e., an acoustic modem cannot send and receive simultaneously, but they assume that a modem can interrupt the sending and receiving states at will to send another packet. For example, as illustrated in Fig. 1(a), during the reception of the packet from A, node B can interrupt the packet reception at time t and switch to transmit its own packet to C. In fact, this is how existing MAC protocols handle the exposed terminal problem to improve the channel utilization [3]. However, according to a recent observation, all existing acoustic modems, like Benthos Modem [4], cannot be interrupted when receiving or sending a packet. In other words, an underwater node cannot switch between the sending and receiving states at will to transmit another packet. This is determined by the acoustic modem design.

For example, referring to Fig. 1(b), node A is transmitting a data packet and B can overhear it. Even if the packet is not for B, B cannot send during the reception of the packet from A. In addition, A cannot interrupt the current packet transmission for another packet. As we can see, the essential problem in both situations is that a modem cannot be interrupted when it is sending or receiving, and the modem appears to be too “busy” to send newly arrived packets.

Definition 1. In underwater acoustic networks, a node cannot interrupt the current packet reception/transmission to send another packet. We call this phenomenon the busy terminal problem (BTP).

Note that BTP differs from half duplexity. Half duplexity only prohibits a modem from sending and receiving simultaneously, but a modem can still interrupt the current packet reception/transmission. However, when the BTP arises, the modem is no longer able to interrupt the packet reception/transmission processes. To summarize, in addition to the constraints posed by half duplexity, the BTP does not allow a node to interrupt the packet reception/transmission procedures. The root causes of the BTP are the non-interruptability and half duplexity of acoustic modems.

3. IMPACT OF BTP ON MAC PROTOCOLS

BTP only impacts the performance of un-slotted MAC protocols. In slotted approaches, a packet can only be sent at the beginning of the slot and received by neighbors before the end of the same slot. Therefore, a node must not be in the receiving state when it is trying to send out a packet. That is, a node is able to send out packets at will and will not be affected by the BTP.

In existing un-slotted MAC protocols, BTP has not been considered. Instead, it is commonly assumed that a node can interrupt the current packet reception and switch to sending. However, this assumption does not hold because of the BTP. Due to the BTP, packets cannot be sent out as needed. Thus, the packet sending pattern is changed, which further affects protocol performance.

Specifically, in random access MAC protocols nodes cannot randomly access the channel by sending out packets at will. Thus, the BTP helps to reduce the rate that packets are actually sent to the channel and results in a lower collision probability. In other words, BTP may benefit random access MAC protocols.

As for reservation/scheduling based MAC protocols, BTP may cause disruptions. In order to improve the channel utilization, protocols like [3] handle the exposed terminal problem by scheduling the transmissions in advance. Because of the BTP, however, a node may not be able to send a packet at the pre-scheduled time point, which further disturbs the schedule and may cause collisions. Therefore, BTP may impair the performance of reservation/scheduling based MAC protocols.

4. HOW TO HANDLE BTP?
As discussed above, BTP does not affect slotted MAC protocols, so we only discuss the solution for un-slotted approaches. In MAC protocols, the propagation delays are undesirable. When the BTP is considered, however, in Fig. 2 we also observe that the classic model coincides well with the simulation results considering the BTP. Because BTP is the only difference between these two sets of simulations, the comparison results when BTP is ignored. Because BTP can help alleviate the collisions, especially when traffic is heavy. This occurs because nodes cannot send out packets as fast as they are generated due to BTP. That is the BTP reduces the effective rate that a node sends packets to the channel, and thus alleviates collisions in ALOHA.

6. PRELIMINARY RESULTS

We developed an analytical model of collision probability for ALOHA considering the BTP. In this section, we present the preliminary results of model verification. The simulation settings are as follows: there are 125 nodes uniformly distributed in a cube with edge $E=5000m$. The maximum node transmission range is 1100m. Nodes generate packets of length 500B following an independent identical Poisson process with rate parameter $\lambda$. We refer to Benthos modem to set the modem transmission rate and preamble, i.e., the effective transmission rate is 667bps in the horizontal channel and the packet preamble is about 1.5s. The bit error rate is $10^{-5}$.

Varying $\lambda$ from 0.01 to 0.2 in step 0.01pkt/s produces the simulation results in Fig. 3. In this figure, the proposed model coincides well with the simulation results considering BTP while the classic model still matches the simulation results when BTP is ignored. Because BTP is the only difference between these two sets of simulations, the comparison results when BTP is ignored. Because BTP can help alleviate the collisions, especially when traffic is heavy. This occurs because nodes cannot send out packets as fast as they are generated due to BTP. That is the BTP reduces the effective rate that a node sends packets to the channel, and thus alleviates collisions in ALOHA.

7. CONCLUSION

This paper formally defines a newly identified issue in underwater acoustic networks named busy terminal problem. We have also discussed its impact on MAC protocols. To study its impact, we have further proposed a new analytical model for the successful packet transmission probability of ALOHA, Simulations confirm that accurately captures the impact of the BTP.

8. REFERENCES