Ad-hoc Network Emulation Framework for Underwater Communication Applications

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1.1 Background

There is an increasing amount of research worldwide in the field of underwater communication networks. The reasons are on going scientific exploration of oceans, area protection, resource exploitation, and these call for underwater sensor network protocol design to support wide area aqueous environmental monitoring.

Underwater networking scheme is mostly ad-hoc in nature since, set of underwater vehicles along with fixed nodes are used. It is expensive to build real underwater network systems and perform experiments in real underwater scenarios, e.g. ship time, therefore there exist methods for prototyping such ad-hoc underwater networks. One of them is based on network simulators with underwater acoustic channel model. Another way is to emulate the underwater acoustic channel by air acoustic channel in quasi real time. This task in progress presented here consists of designing and implementation of emulator to emulate realistic point to point underwater acoustic network with a facility to handle traffic collisions.

1.2 Simulation

Network simulation tools facilitate prototyping of network protocol and evaluation of network performance. For example NS2 [1] is one of the widely used terrestrial wireless network simulator containing implementation of terrestrial channel model. Underwater channel is characterized by large delay spreads due to multipath propagation, presence of Doppler spread, and frequency dependence of propagation loss, making it impossible to reuse the existing terrestrial channel models. Terrestrial network simulators are adapted to underwater acoustic networks and it involves challenging tasks to build multistatic coherent 3D underwater channel model incorporating features such as, simulating transmission collisions, propagation delay, noise, absorption and bit error rate [2]. Due to these reasons we have chosen to emulate underwater acoustic channel by air acoustic channel.

1.3 Emulation by Air

To emulate underwater acoustic channel by air acoustic channel we have established a point to point communication in the air. We have implemented acoustic modem based on FH-BPSK (Frequency Hopping –Binary Phase Shift Keying) and DTMF (Dual-tone multi-frequency) schemes as shown in Fig.1 and Fig.2 respectively into the GNU Radio [3] framework.

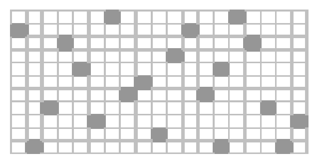

Fig.1. Frequency hop pattern: FH-BPSK[4]

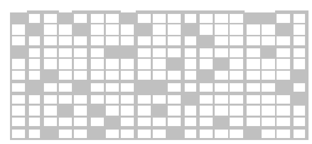

Fig.2. Frequency hop pattern: DTMF[4]

Modem implementation is very similar to underwater acoustic communication protocol JANUS [5] with the only difference, instead of using 3 wake-up tones and hyperbolic frequency modulated (HFM) sweep of entire band for time synchronization, our implementation has preamble generated by FH-BPSK modulation of gold sequence. Preamble sequence is followed by node id. Each node is assigned 5 bit node id with the facility to accommodate 32 nodes in network. 5 bit node id is spread with repetition coding of 1/3 rate. Also, each node has unique hop pattern therefore, transmission collision and multiple access inference from different nodes are taken care as they affect the bit error rate. Data payload of variable size is appended to the node id. Data is convolution encoded to improve data reliability, block interleaved to achieve uniform distribution of errors. System parameters are shown in Fig.3. The spectrogram of transmission frame is shown in Fig.4.

Sampling frequency	12800Hz
Center frequency	3200Hz
Effective Bandwidth	2500Hz
No of carriers	26
Carrier spacing	100Hz
Symbol duration (Tsym)	20ms
Mapping	BPSK (M=2)

Fig. 3 System parameters

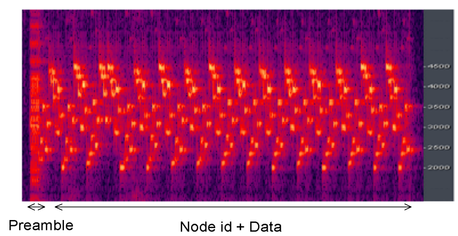

Fig.4. Spectrogram of transmitted frame

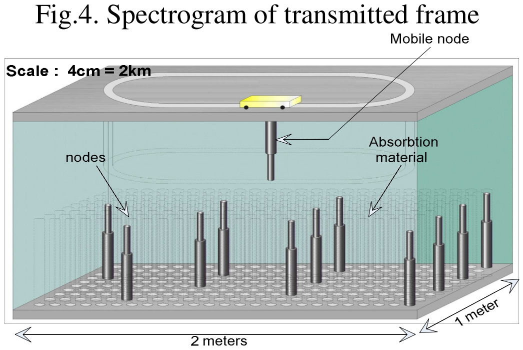

Fig.5. Emulator [6]

$$TL_{air}[dB] \approx 2.2125 * dist[km] + 51.975 \approx TL_{water}[dB]$$

(Eq .1)

Propagation speed of acoustic signal in water is about 1500 m/s. This typical low sound speed in water is emulated by introducing sleeping interval calculated with given geometric distance in an initial emulation phase. So every node is supplied with a scenario file which contains node IDs of surrounding nodes, the geometric distances in km and given mean sound speeds. Table sized Emulator box shown in Fig.5 consist of fixed nodes and mobile node. Node is composed of microphone and loudspeaker. These nodes are separated by material with absorption properties similar to water medium. The amount of absorption in water after travelling 2km is achieved by travelling an interval of 4cm in Emulator box. This arrangement models absorption loss equivalent to absorption loss in water as given by Eq.1 [4]. In this initial emulation phase certain features of underwater channel like multipath and Doppler are not considered but, with this simplified implementation of acoustic communication system it is a good start towards a complete emulator. With netbooks and small blade cluster as acoustic communication transceivers and emulation topology, ad-hoc network protocol prototyping is possible.

1.4 Summary

In this paper we have presented the emulation of underwater acoustic channel by air acoustic channel. Emulator is a form of distributed system consisting of multiple autonomous nodes capable of communicating with each other. On the other hand network simulator is form of a centralized system and the computation complexity increases with the increase in number of network nodes making it difficult to realize real-time performance. In the emulator design presented here, netbooks can be easily replaced with embedded processors like DSP as they are capable of running Linux and GNU Radio. This simplifies the testing and deployment of underwater network protocol stack in the practical scenario, whereas networks simulation tools use metalanguage to build the system resulting in extra effort for a practical deployment. In case of simulation, the design and testing of routing protocols in the network layer are on simulator like NS2 [2] whereas, our emulator supports design and testing of network layer within the GNU Radio frame work with reduced practical deployment cost. Using low cost audio devices we have designed acoustic modem which has non linear Doppler effect due to mismatch of sampling rates. This causes occasional data frame corruption during communication between nodes. We have been improving our work to achieve reliable acoustic link among the nodes.

1. 5 References

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[5] Kim McCoy, JANUS: From Primitive Signal to Orthodox Networks
[6] FWG Emulator