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Network Lifetime extension of Underwater Acoustic Sensor Network through Network Coding

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Abstract

In this work, we propose a flooding-based routing protocol using network coding for underwater communications. Due to the large amount of duplicates that flooding-based protocols broadcast into the network, the sharing of information among the duplicates can enhance the packet delivery ratio (PDR). Our simulations indicate that network coding increases the Packet delivery ratio, but a cost is paid in terms of end-to-end delay and no. of sent duplicates, irrespective of other flooding-based protocols. For decreasing the no. of duplicates, whereas keeping the end to end delay and PDR constant, we introduce to enhance the protocol with particular nodes geographical information.

Keywords

Network coding, underwater communications, geographical routing, flooding-based routing.

I. INTRODUCTION

Today, underwater applications require an extension from an underwater acoustic connection to an underwater sensor *network* [1]. Because of the uniqueness of the acoustic connections [2] – [5], effective routing techniques must be discovered for delivering the packets to the destination node and increase the packet delivery ratio (PDR). Some are explained in [2] and [6]. Network coding (NC) has been introduced currently as a new scheme to increase the PDR in a sensor network [7], where every node does not simply store and forward the packets, but rather utilizes a store, encode and *forward* mechanism. Because of its advantages, in the last decade, *linear* NC has been introduced for NC technique for underwater sensor networks. Our proposal interrupts linear NC with the D flood routing protocol [11]. These writers have introduced a duplicate decrement flooding-based routing protocol for USNs. Assuming that the no. of packets broadcasted in the network is still large, even when utilizing the D flood rules,1 we believe that sharing the information by NC will support the destination node to obtain enough independent packets (not only replicas) and fetch the information. Irrespective of other NC papers for USNs, our proposal distinguishes in some points. Rather than [8], our concept does not consist of overlapping NC over the assumed protocol. Instead, we survey the protocol's rules, for fully exploiting the full NC potential. We further have formulated our protocol for implementation in real scenarios, and not in a chain configuration as in [9]. The difference from [11] is that our suggestion does not consider that the packets to be encoded reach simultaneously at the next relays. Instead, they reach with variable and different delay or some of the relays do not obtain any packet because of the connection losses.

In our proposal, we have assumed the linear NC technique introduced in [13], where the information packets of a generation that a source node has are linearly encoded into $h \geq g$ output packets. The selection of the encoding coefficient is performed following the rules of [14], where every node in the network chooses the coefficients randomly, uniformly distributed in $2s$ F. In this manner, all the operations are performed independently and in an entirely decentralized way. Since, choosing randomly the coefficients may result to linearly dependent combinations, which occurs with a possibility related to the size of $2s$ F [14], but [15] has indicated that, in practice, $s = 8$ is enough to have a full-rank decoding matrix with very high possibility. Assuming that the coefficients are selected locally at every node, the encoding vectors must be involved in the packet headers for decoding them and to permit for recursive encoding.

II. DESIGN COMPONENT FOR UNDERWATER SENSOR NETWORK

Various factors i.e. multipath, transmission loss, propagation loss and noise these are four major issues which comes in underwater sensor network.[13]

A. Transmission loss [13]: Transmission loss is integration of geometric spreading and attenuation. It is not dependent on frequency. Geometric spreading is expansion of wave fronts that increase the distance of propagation. Generally attenuation provoked by increasing frequency and distance, absorption because of conversion of acoustic energy into heat.

B. Noise [13]: It is classified into two ways as manmade noise and ambient noise. This mainly concentrates on the machinery noise and shipping activity.

C. High delay [13]: The propagation speed in the underwater sensor magnitude is less in comparison of radio channel.

D. Multipath[13]: generally this term is refer to as more than one way for reduction of the acoustic communication signal that creates that is refer to as Inter Symbol Interference. The more than one geometry depend on the connection configuration. There are two channels like horizontal channel and vertical. Horizontal channels may have long more than one way spreads while Vertical channels may have little time dispersion.

III ROLE OF UNDERWATER SENSOR NETWORK

Underwater sensor network is capable to perform operations in broad range of applications that application perform different in USN some applications likes distributed tactical surveillance, mine reconnaissance, ocean sampling networks , seismic monitoring, environmental monitoring, equipment monitoring, Disaster prevention, assisted Navigation and undersea explorations these all are the benefits of the underwater sensor networks. however, no system is perfect, thus, even with all the above specified benefits of the system, a few drawbacks still available i.e. more power need, costly device, spatial correlation and Intermitted memory.

A. Fastest way for finding underwater information [1]: Underwater sensor is the fastest and latest manner of determining information which is existed in underwater sensor network. This information is not only useful for human being but also useful for researchers.

B. Monitor the environment & climate [13]: Most of researchers wish to know about what is taking place inside the water. It depends on the situation consider if water is less so monitoring is required. But if water is more like a ocean so monitoring is necessary because without monitoring we can never ever examine the problems. Underwater sensor network system is capable to solve the issues those issues are climate part. USN play major role in detection of climate change, enhance weather forecast. Generally underwater sensor network not only scan the climate but also useful in chemical, nuclear and biological activates.

C. Underwater device monitor system [13]: For monitoring the USN where as costly devices are there all these devices are more expensive that is play safety role in USN.

D. Undersea Explorations [13]: Underwater sensor network perform operation for finding the paths for laying undersea cables, eliminate underwater reservoirs.

E. Ocean Sampling Networks [13]: Autonomous underwater vehicles are capable for cooperative adaptive sampling of the 3D coastal ocean atmosphere.

F. Disaster Prevention [13]: Underwater sensor network system is capable to perform seismic activity that begins from remote locations which offer tsunami warnings to coastal regions.

G. Assisted Navigation [13]: Underwater sensors are capable to perform bathymetry profiling, also able to find location of dangerous rock, submerged wrecks.

IV. PROPOSED PROTOCOL

For our protocol (NC-Dflood), we have assumed that every packet has a source address, destination address and a *hop count*, and *a generation number*. The integration of the last three forms a unique identifier for the packets of the same generation. We will call innovative packets those that are not linear combinations of the packets available in the node's buffer keeping the same identifier. On the other side, the not-innovative packets are those that are linear combinations of the packets available in the node's buffer, as in [13]. When NC-Dflood is used, every network node adopts the following rules:

- When a *source* node has g packets to send, it encodes them into h output packets, and forwards them down to the MAC layer with hop count equal to one.
- Every time a *relay node* obtains a packet of a generation for the first time, such as an

innovative packet, it will send that packet randomly rafter a random back-off time drawn from [Tmin, Tmax].

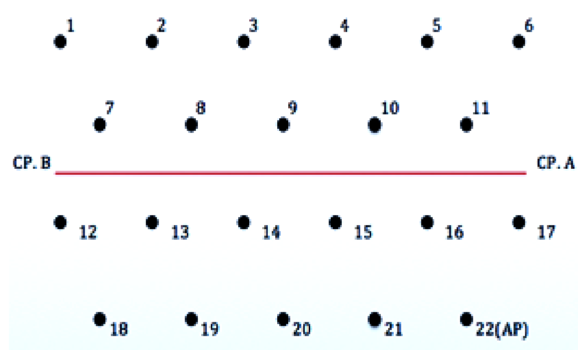
- -If during this time another innovative packet reaches, the relay node will encode these two packets in two other packets. One of them will substitute the packet ready to be transferred, while the second will be sent after the relative back-off time, still uniformly drawn from [Tmin, Tmax].
- If the back-off time expiries without obtaining an innovative packet, the relay will send the packet with the same encoding vector as obtained. In this manner, the end-to-end delay is kept restricted. Since, the packet will be conserved for doing the recursive encoding mechanism for the other innovative packets of that generation that may reach later.
- For every innovative packet obtained at a *relay node*, with hop count lesser than or equal to Hmax, another encoded output packet will be generated. This novel packet will have a hop count incremented by one with respect to the prior obtained packet. The other packets available in the buffer, not sent yet, will be updated considering also this packet in the encoding procedure. Hmax is the maximum no. of hops that a packet can traverse in the network.
- If a *relay node* obtains an innovative packet with hop count higher than Hmax, it will be taken for updating the encoding packets available in the buffer, and a new packet will not be generated.
- The *relay node* will behave as duplicates all the not-innovative packets with the same identifier, without regarding the hop count value they have.
- The *relay node*, after sending g packets of a generation, will not participate in the relay procedure for the packets with that unique identifier.
- All obtained duplicates at a *relay node*, before sending all the packets of that generation, will be counted. nd is the no. of duplicates obtained.

- For every duplicate achieved, the *relay node* will delay the sending by Tdupl. In the NC-Dflood situation, we have different probabilities to delay the packet sending, where based on the particular scenario, one solution can be preferred over the other. We suggest two approaches:

That are broadcasted in the network, such as the energy consumption, it may still be too high for some scenarios. For reducing the no. of duplicates even more, we introduce to extend the suggested protocol with the node's position information. Our suggested protocol, named NC-Geographical Dflood (NC-GDflood), utilizes the node position information that is transferring and the final destination position. Utilizing this information during the relay, the relays that are farther from the destination node can be neglected.

V. SIMULATION RESULTS

For our simulations, we have taken the network configuration in Fig 1. The network is consisted of 22 bottom nodes and 1 AUV. The intra-node distance d is 3 km. The red line indicates the AUV trajectory, which builds a round trip initiating from checkpoint A to B (CP.A and CP.B in the figure) with a speed of 4 knots. We have assumed 3 source nodes: the bottom nodes 1 and 10, and the AUV, and the packets are targeted for node 22, i.e. the access point (AP). We have compared our proposed protocol with the D flood protocol. In the latter case, the application layer of the source nodes creates the packets with a constant bit rate for all of them. The packets arrival times are created from a Poisson process with the λ parameter represented as λ = Lb / bps, where Lb is considered to be 160 bits and bps (bits per second) is a simulation parameter that affects the traffic proposed in the network by the application layer of the source nodes. When NC is used, we employ a Poisson process to model the arrival times of a stock of g packets, with λ = (Lb g) / bps. Irrespective the D flood traffic model, when NC is utilized every source node waits to have g packets before forwarding them down to the network layer



.**Figure 1. Network topology used in the simulations, composed of 22 fixed nodes and one AUV. For simplicity, we have considered a regular grid with intra-node distance d = 3 km.**

In our simulations, we have considered a PER, p, common to all the connections available in the network. This parameter involves all the physical-layer errors because of fading, noise, Doppler impacts and other connection-loss phenomena. The transmission data rate in the physical layer is taken in such a manner that the packet duration is one second. This consideration is taken for simplicity. Nevertheless, it is justified in underwater acoustic (UW-A) interactions, however the packet lengths are very less and the bit rates are low, e.g. in [11] the writers assume packet lengths of 160 bits and a transmission rate of 200 bits/s for the Dflood simulations. All the network nodes are fitted with isotropic antennas with a transmission power such as to provide a PER = p for connections up to 3 km. Farther nodes obtain the packet erroneously with possibility one. In the MAC layer, we have assumed an unslotted ALOHA protocol, without collision avoidance, connection or end-to-end acknowledgments. With the consideration that the followed MAC protocol does not utilize any interference avoidance precautions, we have utilized a simple interference model for our scenario. If we take a sound speed of 1500 m/s underwater and the intra-node distances available in the scenario, then the packet will take some seconds to be completely achieved by the destination side of the connection. We have considered a total destructive interference if two or more neighboring nodes are transferring during this time. These nodes will not obtain any packet from their neighboring nodes, which were transferring during this time interval. Moreover, also the nodes that are neighbors with two or more transferring nodes will not achieve any of these packets. With the interference model implemented, in the NC case, we consider that the network layer forwards the packets down to the MAC layer with a back-off time uniformly drawn from [1 s, 10 s]. This is performed with the objective to neglect the interference that may influence all the packets of the same generation, if they are transferred in a row.

For seeing the protocols performance, we will represent our results in terms of end to end delay, PDR, and average no. of packets sent by the network (Av. PKT), for every information packet created by the source nodes. The Dflood parameters utilized are: Tmin = 0 s, Tmax = 50 s, Tdupl = 35 s and Ndupl = 2. For the NC-Dflood protocols, we have taken the following parameters, Tmin = 0 s, Tmax = 70 s, Tdupl = 30 s, added only to the first packet ready to be forwarded, Ndupl = 2.5×g, common to all the network nodes, Hmax = 15, a generation size g = 2, and h = 3. In NC-GDflood, an inaccuracy is assumed when evaluating the distance D. We have considered D = Dreal + u, where u is uniformly disseminated as u □ U[□100 m, 100 m], and Dreal is the real distance in meters among the node that is transferring and the AP. The parameters fn and fs are 0 and 1, respectively. For both protocols, the parameters are chosen as a trade-off between the three evaluation standard, paying more care to the PDR. For NC-GDflood, we utilized the same parameters as for NC-D flood, however, we assume it as an upgrade of the latter. The choice of these parameters in both protocols is performed by a heuristic technique. After several simulations, we may conclude that the interval boundaries [Tmin, Tmax] affect the interferences in the network, as required. Regarding their respective value, we may have more or less interference. Meanwhile, Ndupl, Tdupl, and Hmax affect more the no. of packets sent in the network. A higher value of Ndupl brings us to a pure broadcasting technique, and the consideration of Tdupl attempts to permit the nodes to gather more duplicates before sending the packet or arriving the Ndupl value. We have chosen a generation size of g = 2 due to a few reasons. First and foremost, to keep the overhead in the packet header restricted, however, for every packet it increases by 8 bits. Second, we have viewed that with an increasing generation size, the end-to-end delay and the Av. PKT increases as well.

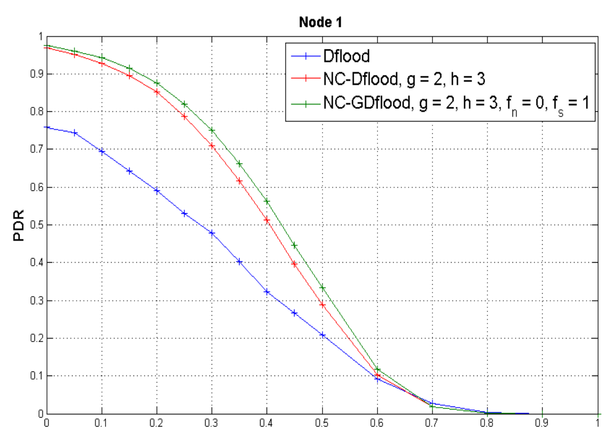


Figure 2. PDR vs. p for node 1's transmission.

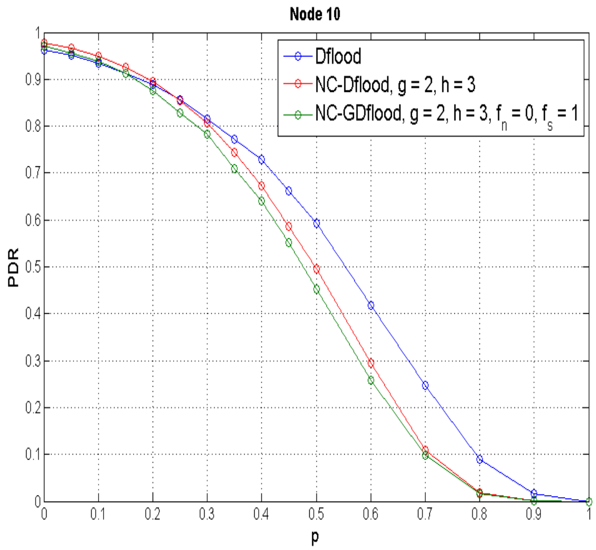


Figure 3. PDR vs. p for node 10's transmission.

We have modeled both protocols for various values of p and bps. The first simulations are performed to measure the protocols robustness (Figures 2-6). In this case, we have considered a bps = 1 bit per second for all the source nodes. During this time, the simulations performed for various values of bps are done with the objective to examine how the performance varies when the network becomes overloaded. In this case, p is chosen 0.1. The simulation results have indicated that the NC technique obtains the objective to increase the transmission robustness, in terms of the PDR. The cost to pay in this case is an increment of the Av. PKT and end- to-end delay. The upgrade with position information decreases the no. of packets sent, conserving the end to end delay and PDR of the NC-Dflood.

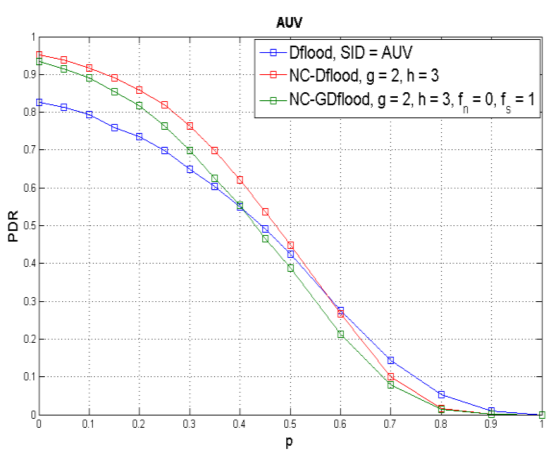


Figure 4. PDR vs. p for the AUV's transmission.

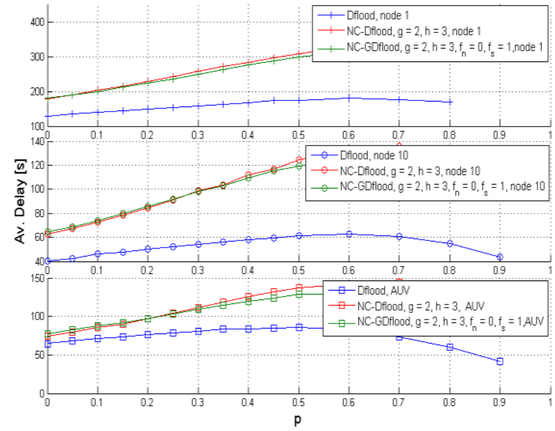


Figure 5. End-to-end delay vs. p of all the transmissions for all the protocols, and for different values of the link PERs.

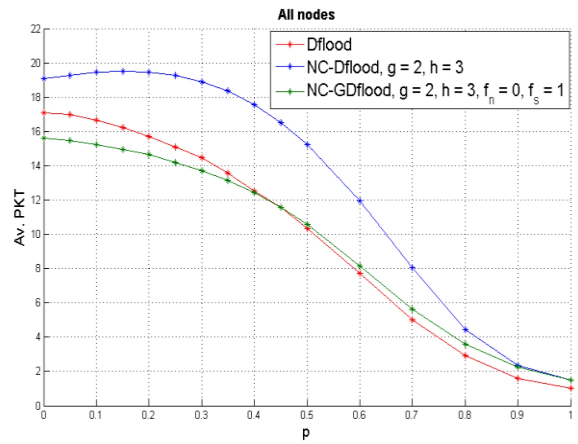


Figure 6. Average number of packets forwarded vs. p for each information packet produced by the source nodes.

Conclusions

In this work, we have introduced a new mechanism on how to utilize network coding in underwater communications. Our suggestion contains a different use of the duplicates sent in the network by flooding-based protocols. Assuming the large no. of packets that are sent by the flooding-based protocols, if they share and carry information about the actual packets created by the source nodes, then the system performance increases. Our proposal, NC-Dflood, increases the transmission PDR, with an increment of the end-to-end delay and the no. of duplicates in singular transmissions. Better results are achieved for nodes that are comparatively far from the destination node, for which the no. of relays that can use network coding is higher. For reducing the no. of duplicates sent in the network, we introduce to extend the NC-Dflood concept with node position information that is transferring and the final destination position. In this manner, mainly nodes in the destination direction will take part in the routing procedure, by encoding and sending the packets. We have indicated that this upgrade, known as NC-GDflood, manages the same end to end delay and PDR of NC-Dflood, but it gains in terms of the no. of duplicates. For low connections PERs and low traffic, being features of most USNs, it can decrease the no. of packets even below those of the Dflood protocol.

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