Extended Abstract: An Extension of Node-Grouped OFDMA MAC into Multi-Clustered Networks

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ABSTRACT
Energy efficiency is the most important issue that needs to be considered when designing medium access control (MAC) protocols for underwater acoustic sensor networks (UWASNs). In this paper, we present the basic concept of a multi-cluster node-grouped OFDMA medium access control (McNOGO-MAC) protocol as an energy-saving solution for underwater MAC protocols. This is an extended version of the node-grouped OFDMA medium access control (NOGO-MAC) protocol that is designed for use on a single-cluster network [1]. Unlike NOGO-MAC, McNOGO-MAC utilizes two different frequency channels for uplink and downlink and schedules them alternately on the time axis such that the up/down scheduling is synchronous so that they cross each other between contiguous clusters so as to avoid inter-cluster interference. Computer simulation is underway to evaluate this protocol in terms of its energy efficiency, throughput, and latency.

Categories and Subject Descriptors
C.2.2 [Computer Communication Networks]: Network Protocol

General Terms
Algorithms, Design

Keywords
Underwater acoustic sensor networks, MAC protocol

1. INTRODUCTION
There has been growing interest in underwater acoustic sensor networks (UWASNs), along with the rapid development of the underwater industry. However, underwater acoustic channels suffer from long propagation delay, narrow bandwidths, severe multipath fading, Doppler spreading, and high bit error rates (BERs) [2]. These difficult channel conditions require us to design a medium access control (MAC) protocol using a completely different method from that used for terrestrial radio MACs. In particular, because of the inability to recharge the battery, highly energy-efficient MACs are essential if we are to increase the network lifetime.

In [1], a novel energy-efficient MAC protocol, called node-grouped OFDMA MAC (NOGO-MAC), was proposed both to employ the orthogonal frequency division multiple access (OFDMA) scheme and to exploit the physical characteristics of underwater channels, for example, to exploit the fact that the propagation loss of acoustic waves depends on the distance more strongly at high frequencies than at low frequencies.

In this paper, an extended version of NOGO-MAC, called multi-cluster node-grouped OFDMA MAC (McNOGO-MAC), is proposed to allow the core concept of NOGO-MAC to operate in a multi-clustered network. Both scheduling conflict and interference between contiguous clusters are avoided by utilizing two separate frequency channels for uplink (member-to-sink) and downlink (sink-to-member) and scheduling them alternately on the time axis in such a way that the up/down transmission is synchronous and transmissions cross each other between contiguous clusters.

2. PROBLEM STATEMENT REGARDING THE NOGO-MAC IN MULTI-CLUSTER NETWORKS
NOGO-MAC uses the topology shown in Figure 1. The cluster consists of one sink node and several member nodes, which are in charge of monitoring events and environmental conditions and reporting them to the sink node. The sink node collects all of the data sensed by the member nodes inside the cluster and possibly processes them to deliver data to a surface buoy node. Finally, the buoy node transfers the collected data to a control center via a radio link.

The basic operation of the NOGO-MAC protocol is as follows [1]. First, the sink node broadcasts the reservation request message $R_{req}$. Then, the ordinary member nodes that have packets to transmit try to respond to the reservation response message $R_{res}$. At that point, the nodes use a pre-allocated time slot so as to avoid possible collisions at the sink node. The $R_{res}$ contains a node-group number, a transmission order inside the node group, and a received signal strength indicator (RSSI), which denotes the discrete-leveled underwater channel quality. Then, to improve the overall system performance, the sink node searches for the most suitable OFDMA sub-channels for individual member nodes, based on the aggregated values of $R_{res}$. Finally, the OFDMA sub-channel allocation results are broadcasted by the sink node in the form of the reservation confirmation message $R_{con}$.

![Figure 2: An example of collision at the overlapping area between clusters](image)

Figure 2 illustrates a possible collision at the overlapping area between clusters. Suppose that nodes 1 and 2 belong to clusters 1 and 2, respectively. Because of the independent up/down transmission scheduling of each cluster, the uplink transmission period of cluster 1 might conflict with the downlink transmission period of cluster 2. That is, in Figure 2, the packet sent by node 1 and the packet sent by the sink of cluster 2 collide at node 2.

3. CORE CONCEPT OF McNOGO-MAC

McNOGO-MAC is designed for use on a multi-cluster sensor network so as to avoid the collisions described in the previous section.

Unlike NOGO-MAC, where the entire frequency bandwidth is shared by up- and downlink transmissions, McNOGO-MAC divides the bandwidth into two sub-bands, namely, uplink channel (UpCH) and downlink channel (DwCH), for uplink and downlink transmissions, respectively. Then, to avoid collisions in any overlapping area, contiguous clusters schedule the UpCH and DwCH in a synchronous manner, such that they cross each other, as shown in Figure 3. That is, the same frequency channel is never used at the same time in contiguous clusters. In the case in which there are more than 3 clusters that overlap, a “pause” period in which nodes do nothing is necessarily inserted, so as to ensure that no single frequency should be used at the same time in contiguous clusters, as shown in Figure 3 (b). In the general case of $n$ clusters that overlap, $n$-2 pause periods are required.

On the other hand, McNOGO-MAC requires each cluster to manage an equal duration of up/down transmission periods to maintain the synchronous property between clusters. The length equality may cause inefficiency in terms of time utilization, when compared to NOGO-MAC. The cost of this inefficiency is currently being evaluated.

4. CONCLUSIONS

In this paper, we proposed McNOGO-MAC as an extended version of NOGO-MAC for use in multi-clustered underwater sensor networks. Computer simulation is currently being performed to compare the existing underwater MAC for use on multi-clustered networks in terms of its energy efficiency, throughput, and latency.

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6. REFERENCES