# CLUSTER-BASED MAC PROTOCOLS FOR UNDERWATER AD HOC SENSOR NETWORKS

*by*

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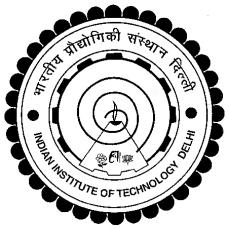
Submitted
in fulfillment of the requirements of the degree of
**Doctor of Philosophy**

*to the*

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# Certificate

This is to certify that the dissertation entitled **Cluster-Based MAC Protocols for Underwater Ad Hoc Sensor Networks**, submitted by **Mr. Priyatosh Mandal**, a Research Scholar, in the *Department of Electrical Engineering*, *Indian Institute of Technology Delhi*, *India*, for the award of the degree of **Doctor of Philosophy**, is a record of an original research work carried out by him under my supervision and guidance. The dissertation fulfills all requirements as per the regulations of this Institute and in my opinion has reached the standard needed for submission. Neither this dissertation nor any part of it has been submitted for any degree or academic award elsewhere.

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# Abstract

Underwater wireless ad hoc sensor networks are aimed at remotely monitoring various aquatic activities, such as marine biological and zoological lives, geological changes, and underwater human activities. There are some similarities between UWSN and terrestrial wireless networks, such as, limited channel bandwidth, high bit error rate in the wireless channel, limited battery power of sensor nodes. Therefore, both types of networks have common performance measures, such as, throughput, delay, and battery life. But there are many differences between the two types of network. Propagation delay uncertainty and delay variability are the most sensitive differences between the two networks.

Unlike in radio frequency communication networks, achieving a high radio resource utilization and guaranteeing target quality of service is more difficult in underwater networks due to large underwater propagation delay and propagation delay uncertainty.

The objective of this research has been to develop a step by step framework for efficient collection of underwater field data and its delivery to a remotely located monitoring and control centre. Such communication typically happens over two hops. The first hop is underwater, where a set of field nodes send their data to a gateway node. A set of gateway nodes in turn communicate the data to a remote sink, via satellite link.

Considering that the sensed data may be sporadic, we first analyze the basic Aloha and slotted Aloha protocol performances and formulate optimum slot size in slotted Aloha variants that are respectively transmitter synchronized and receiver synchronized. Here the impact of propagation delay and field node to gateway node distance dependent propagation delay variability are accounted.

Further, observing that propagation delay could be comparable or larger than the packet transmission time, which precludes the use of CSMA variants, we investigate the use of reservation protocols similar to the ones in satellite communication. To this end we account the additional constraints of uncertain delay variability in underwater networks. We propose and optimized two new variants of dynamic reservation schemes for field nodes to a gateway communication.

To consider the entire network communication, we consider a two tier network where a set of gateway nodes are connected to a remote sink via radio frequency wireless multiaccess links. We obtain the optimum clustering condition for maximizing the throughput at the sink and show that, gateway throughput maximization condition does not necessarily maximize the sink throughput.

# Contents