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Performance analysis of IEEE 802.11 based MAC for underwater acoustic networks

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ABSTRACT

This paper deals with the performance analysis of the IEEE 802.11 MAC in the DCF mode, which is a basic international protocol of wireless LAN, for underwater acoustic networks. Due to harsh underwater environments, underwater acoustic networks have shown poor characteristics such as resulting in long propagation delays, low data rates, and short communication coverage.
In this paper, we present a modified MAC protocol based on IEEE 802.11 in the DCF mode that removes DIFS and SIFS which are useful to prevent packet collision in traditional wireless networks. We aim at the performance analysis of the modified MAC protocol, along with the existing 802.11 MAC to show the performance differences when dealing with underwater acoustic networks.

KEY WORDS: Underwater acoustic networks; MAC; IEEE 802.11; throughput; delay; performance analysis; underwater MAC.

INTRODUCTION

Some of the many potential applications using the underwater acoustic network include oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications. Despite the many applications where UWANs can be used, underwater networking is a rather unexplored area.
The basic multiple access methods in possession of the restricted resources are consists of FDMA (Frequency division multiple access), TDMA (Time division multiple access), and CDMA (Code division multiple access).
Seaweb '98 and '99 used FDMA due to modem limitations. With the limited bandwidth and frequency selectivity of the underwater channel, this was not ideal. More recent Seaweb experiments have used hybrid TDMA-CDMA clusters with MACA-style RTS/CTS/DATA handshakes. Freitag, et al, describe a single-hop, star-topology AUV network for Mine Countermeasures (MCM) operations. A central gateway buoy provides remote operator control of the AUVs using TDMA with low rate (e.g. 80 bits/sec) commands sent to the AUVs and high rate (e.g. 5kbits/sec) data returned to the operator via the gateway buoy. Acar and Adams describe ACMENet, which uses a centralized TDMA protocol, with adaptive data rates and power control. They report results from sea trials, and provide background discussion on multiple access and MAC protocols for underwater networks.
However, FDMA is impractical method due to the narrow bandwidth in underwater acoustic channels and the vulnerability of limited band systems to fading and multipath. TDMA require clock synchronization between all the nodes, but the accurate time synchronization is so difficult among underwater equipments because of absence of DGPS. Also, the time slot allocation for individual nodes becomes hard to manage when the number of nodes grows. The CDMA can be a conflict-free multiple access method, however, implementing a CDMA-based underwater network is very challenging due to the hardware complexity. Therefore, even though multiple access methods such as TDMA, FDMA, CDMA are able to give an advantage of stable data communication in underwater network and low confliction probability, it has critical limitation of network management such as the restriction of available node numbers in network, difficulty in expansion of network scale, and hardship of supervising network for the entering of a new node and the leaving of a node in network.
Therefore, the protocols of the radio-based terrestrial network such as an IEEE802.11 have been studied for the underwater communications, recently. Smith, et al, describes an ad-hoc network protocol based on CSMA/CA, with prioritized messaged and improved access for multi-packet transfers. They report results from a small demonstration. Lapierre, et al, propose using CSMA/CD, although it is unclear how the collision detection will work in a half-duplex channel [Partan et al, 2006].
Currently, with expansion of research projects related to underwater communications and explorations, the fundamental research efforts in underwater protocols is also in progress[Akyildiz et al, 2005]. However, MAC protocols of terrestrial networks are not suitable for underwater acoustic networks due to unique characteristics of the underwater channel as will be discussed in next section.
Since contention-free MAC schemes mentioned above are more applicable to static networks and/or networks with centralized control, we shall focus on contention-based MAC schemes in this paper. Contention-based schemes such as ALOHA, Slotted-ALOHA, and CSMA/CA used in IEEE 802.11 are aware of the risk of collisions of transmitted data. Especially, this paper deals with a performance analysis of IEEE 802.11 DCF (Distributed Coordination Function)