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Ad-ATMA : An Efficient MAC protocol for Wireless Sensor and Ad Hoc Networks

Md. Kowsar Hossain[a], Suprakash Datta[b,*], Jeff Edmonds[b]

[a]Department of Computer Science and Engineering, Khulna University of Engineering and Technology, Khulna-9203, Bangladesh
[b]Department of Electrical Engineering and Computer Science, York University, Toronto, Canada M3J1P3

Abstract

Efficient medium access control (MAC) algorithms are needed for nodes to share a transmission medium and achieve a high throughput. A MAC algorithm schedules packet transmissions so as to that minimize the time taken to send the packets without collisions. In wireless ad hoc and sensor networks, a MAC algorithm must conserve energy as well as provide good throughput. Most existing MAC algorithms for wireless networks are designed to work well under low traffic rates. In this paper we propose a new distributed algorithm Ad-ATMA for wireless ad hoc and sensor networks under relatively high traffic rates. We demonstrate using simulations that Ad-ATMA outperforms the best existing algorithms designed for higher traffic rates in terms of packet delivery ratio and latency while consuming almost identical energy as them.

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1. Introduction

Wireless sensor and ad hoc networks (WSANs) are widely believed to be of great use in many current and forthcoming applications panning diverse domains including environmental monitoring, battlefield tasks and tracking animals, equipment and humans. WSANs are formed using tiny nodes that have onboard a processor, memory, wireless transceiver and batteries. These nodes are typically deployed in some ad hoc manner and self-organize into a network that supports queries from an outside user. The nodes have limited computational power, memory, communication speeds and battery capacity. Conserving battery capacity is more important than optimizing performance metrics and thus most existing algorithms for wired networks are not feasible for WSANs. A key infrastructural component of WSANs is a medium access control (MAC) algorithm. A MAC algorithm allows nodes to access the shared wireless transmission medium efficiently.

The majority of the large body of work on MAC algorithms for WSANs are designed for light load conditions. As WSAN hardware evolves and applications keep growing, it is important to design networks that generate high

* Corresponding author. Tel.: +1-416-736-5053 ; fax: +1-416-736-5872.
E-mail address: datta@cse.yorku.ca

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data rates. In this paper, we propose a new MAC algorithm called Ad-ATMA that is designed to improve performance under relatively high traffic conditions while maintaining the energy efficiency of existing algorithms. We demonstrate using simulations that Ad-ATMA outperforms the best existing algorithms in terms of latency, packet delivery ratio and energy consumption.

1.1. Our model

We assume that our WSAN consists of nodes placed randomly in a rectangular two-dimensional region free of obstacles. Nodes are assumed to be identical and static, i.e., they do not change positions after deployment. We assume that the nodes are capable of sensing the channel and distinguishing between an idle channel, a single packet transmission in progress, and collisions (two or more packets being transmitted simultaneously). We assume that time is discretized and that all nodes operate in synchrony. Thus we assume implicitly that there is reasonable clock synchrony among nodes. We do not assume the presence of a routing infrastructure for our algorithm, since this is typically built using the MAC protocol.

We use two very simple models of traffic. The random traffic model assumes that each node generates a packet with probability p at each time step. The bursty traffic model assumes that a burst of data packets is generated at each sender periodically. Packet destinations are chosen uniformly at random from neighbours of the sender.

1.2. Our metrics

We evaluate the performance of our algorithm using latency, packet delivery ratio (PDR), and energy consumption as our metrics. Latency is the time taken by data packets in travelling from the senders to the receivers. We will use both the latency distribution as well as the average latency to compare algorithms. PDR is the fraction of data packets successfully delivered to the intended receivers. We measure the fractions of time a node is asleep, idle listening and transmitting or receiving. We approximate energy consumed by nodes from these times using energy consumption figures obtained from real sensor hardware.

2. Related Work

There are many ways to classify wireless MAC protocols. One way is to divide them into contention-based, contention-free and hybrid protocols.

Contention-based protocols allow nodes to access the medium with very few restrictions. Contention-based protocols often incorporate strategies to reduce the number of collisions, like the DCF in the IEEE802.11 family. *Contention-free protocols* (attempt to) prevent contention during packet transmission by explicitly scheduling packets. Frequency division multiple access (FDMA), code division multiple access (CDMA), and time division multiple access (TDMA) are all contention-free MAC protocols. Of these TDMA is considered the most suitable for WSAN nodes. *Hybrid protocols* attempt to combine the advantages of contention-free and contention-based protocols by allowing an initial contention period which is used by nodes to reserve time slots and then a contention-free period during which nodes that with reserved slots transmit their data without collisions.

2.1. MAC Protocols for WSANs

We do not survey the large body of existing work on MAC protocols designed especially for WSANs and instead refer the interested reader to the survey [1].

Some WSAN MAC protocols are TDMA based, e.g., [2,3] while others are contention-based protocols [4,5]. TDMA-based protocols are intrinsically more energy efficient due to the absence of collisions. However, this is hard to do in a distributed manner. Also, TDMA requires tight time synchronization of nodes, but this can be achieved using one of the many good time synchronization algorithms have been proposed in the literature [6].

Contention-based MAC protocols for WSANs can be further classified as synchronous and asynchronous. In synchronous approaches like SMAC [4], TRAMA [7] and ADV-MAC [8], nodes synchronize their sleep-listen schedule with the neighbours. Asynchronous protocols (e.g., BMAC [9], WiseMAC [10], and XMAC [11]) allow nodes to have independent