Poster Abstract: A TDMA-based MAC Protocol for WSNs

L.F.W. van Hoesel, P.J.M. Havinga
Department of Electrical Engineering, Mathematics and Computer Science,
University of Twente, The Netherlands
{l.f.w.vanhoesel, p.j.m.havinga}@utwente.nl

Categories and Subject Descriptors

C.2.2 [**COMPUTER-COMMUNICATION NETWORKS**]: Network Protocols

General Terms

Algorithms

Keywords

Wireless sensor networks, medium access protocol, distributed time division multiple access, energy efficiency

1. INTRODUCTION

The technology that lets tiny and smart devices create their own network, allowing them to transport sensor data while requiring little power and transmission range is potentially 'the next big thing' to happen [1]. Recent advances in sensor technology, low power analogue and digital electronics, and low-power radio frequency design have enabled the development of these cheap, small, low-power sensor nodes, integrating sensing, processing and wireless communication capabilities.

This paper presents EMACs, a medium access protocol especially designed for wireless sensor networks. Wireless sensor networks differ greatly from traditional ad hoc wireless networks and therefore require the usage of new types of network protocols, which are energy-efficient to ensure a node lifetime of several years on a single battery and which can operate without assistance of central managers in a dynamic network topology.

Sensors equipped with transceiver, processor and memory will be deployed by the millions. Hence the costs of a single smart sensor must be at a minimum. This does not only translate to scarce resources –like energy and memory– in the sensors, but also to complexity of the hardware. Currently, multi channel transceivers are available on the market, but they will always be higher priced than single channel versions. During the design of the medium access protocol, we assumed a single channel transceiver, that has three operational states: transmit, receive and standby. Typically, transmitting consumes more power than receiving and standby lies beneath the power consumption of receiving by a factor 1,000 or more.

The presented medium access control protocol consists of a fully distributed and self-organizing TDMA scheme, in which each *active* node periodically listens to the channel and broadcasts a short control message. The MAC protocol is efficient in transmitting short omnicast messages from higher networking layers and passes along valuable local topology knowledge to those layers. This allows for a tightly integration between MAC protocol and e.g. routing protocol. Special of the MAC protocol described in this paper is that it includes an algorithm to decide the grade of participation of a sensor node to create a connected network based upon local information only. Energy can be saved in the so called *passive* nodes (nodes which are not necessary to create a connected network) by exploiting the created mesh-like backbone.

The presented approach is compared in simulation with the SMAC protocol [2] (a medium access protocol with coordinated adaptive sleeping) in a realistic multi-hop network setup where sensor reading are transported to a specific node and routes are established using the *dynamic source routing* protocol [3].

SenSys'04, November 3–5, 2004, Baltimore, Maryland, USA.
ACM 1-58113-879-2/04/0011.

2. THE EMACS PROTOCOL

In our research on energy efficient wireless sensor networks, we explore a medium access protocol whose operation is entirely distributed and localized. The main goal in designing a MAC protocol for WSNs is to minimize energy consumption, while limiting latency and loss of data throughput. Therefore, we have three modes of operation in our MAC protocol: *active*, *passive* and *dormant* mode. When a node is in *active mode*, it will contribute to the network by taking part in forwarding messages to a destination and accepting data from passive nodes. *Passive nodes* on the other hand conserve energy by only keeping track of active nodes, which can forward their data and inform them of network wide messages. The nodes in *dormant mode* put themselves in a low power state for an agreed amount of time or, for example, when their power source runs out of energy and has to be charged again using ambient energy, like light.

2.1 Frames and Time Slots

The medium access protocol is based upon *time division multiple access* (TDMA). Time is divided into *time slots*, which nodes can use to transfer data without having to content for the medium or having to deal with energy wasting collisions of transmissions. We assign *only one* time slot to each node and give this node control over this time slot. After the frame length, which consists of several time slots, the node again has a period of time reserved for it. To limit the number of time slot necessary in the network, we allow time slots to be reused at a non-interfering distance. But unlike traditional TDMA-based systems, the time slots in our protocol are *not* divided among the networking nodes by a central manager.

A time slot is further divided in three sections: *Communication Request* (CR), *Traffic Control* (TC) and the *data* section (see Figure 1). In the CR section other nodes can do requests to the node that is controlling the current time slot. Nodes that have a request to

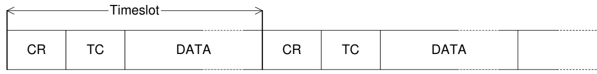

Figure 1: A time slot consists of three sections: 1) Communication Request 2) Traffic Control and 3) Data

the "time slot owner", will pick a random start time in the short CR section to make their request. These messages are comparable to RTS messages in SMAC. Communication in this section is not guaranteed collision-free. Nodes that do not have a request for the current slot owner, will keep their transceiver in a low power state during the entire CR section.

The owner of a time slot will always transmit a TC message in the time slot, unregarded whether a request was filed or not. All nodes within one-hop distance of the controller of the current time slot will put effort in receiving this message, since this message is used for synchronization purposes and control information. When a time slot is not controlled by any node, all nodes will remain in sleep state during that time slot.

The time slot owner also indicates in its TC message what communication will take place in the data section. If a node is not addressed in the TC section nor its request was approved, then the node will resume in standby state during the entire data section. The TC message can also indicate that the controlling node is about to send an omnicast message. In case the controlling node announced that it is going to send data, the data will be glued directly after the TC section and hence saving additional energy of transmitting a preamble and preventing wastage of valuable data throughput.

A passive node neither controls nor claims a time slot. It is still able to communicate to the network by filling its requests to an active node. This allows significant energy conservations in the passive nodes and the lifetime of the network is largely extended, certainly if the role of active and passive nodes is changed over time.

Routing protocols that allow messages to be routed over the ad hoc network, typically require the knowledge of the actual topology in order to efficiently route the packets over the network and to deliver them at the destination. By listening to TC sections of neighboring nodes, nodes have knowledge of the *local topology*. This assists routing and reduces the number of routing messages in the network. A special portion of the TC section is reserved to efficiently transmit the short omnicast messages that are generated by the routing protocol.

3. SIMULATION RESULTS

In this section we will discuss comparison of results, obtained by simulation, between the SMAC protocol and the EMACs protocol. In the multi-hop network two types of messages are generated and have to be delivered by the MAC protocols: *sensor data* (These messages model sensor data. They are transmitted with a certain interval by five nodes in the network and have a fixed length of 16 bytes) and *Network control data* (We use the DSR protocol [3] to take care of routing in the multi-hop network, which consists of 46 nodes in total. The messages will be send to one central sink).

In the simulator, a *physical layer* with energy model is implemented to record the sending, receiving and standby energy consumption of the nodes. Additionally, switching between sending and receiving takes time and consumes energy. These parameters also have been taken into account. The nodes are randomly placed in a square area that has an area of 8 by 5 times the transmission range of a single node. The placement of nodes is identical for the SMAC and EMACs scenarios.

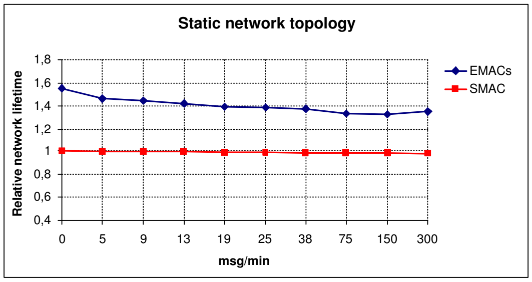

Figure 2: Comparison of network lifetime of SMAC and EMACs in a static network

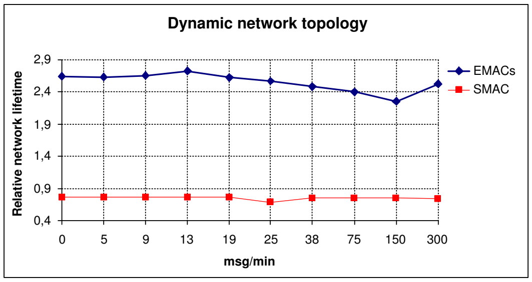

Figure 3: Comparison of network lifetime of SMAC and EMACs in a network where nodes are mobile

We use *network lifetime* as metric to evaluate the performance of the MAC protocols, since this metric is of actual interest in WSNs. In these simulations the network is said to be expired when 30% of the nodes have depleted their energy reserves. The five nodes which generate the sensor data (16 bytes per message) and the sink node in the network are given an infinite energy budget. The network lifetimes are compared for both static and mobile cases. In the mobile case, all nodes move in the simulated area according to the *random way-point model* with random speed and waiting times.

Figure 2 and 3 show the lifetimes in static and mobile scenario. In the static scenario the EMACs protocol suffers from the fact that the roles *active* and *passive* are not changed, while in the mobile scenarios this roles are often changed, resulting in a better spreading of the energy consumption throughout the network. Hence the lifetime of the network can be improved to large extents. In the mobile scenario, this results in a lifetime increase of at least 2.6 compared to SMAC.

4. REFERENCES

[1] R.D. Hof. *The quest for the next big thing*. BusinessWeek, August 25 2003, pages 91-94.

[2] W. Ye, J. Heidemann and D. Estrin. *An Energy-Efficient MAC Protocol for Wireless Sensor Networks*. Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM), Vol. 3, pp 1567-1576, June 2002.

[3] D. Johnson, Y. Hu and D. Maltz, *The dynamic Source Routing Protocol for Mobile Ad Hoc Networks*. http:/www.ietf.org/internet-drafts/draft-ietf-manet-dsr-09.txt, IETF Internet draft, April 2003.