A Proposal Mac Protocol for Integration of Hybrid Wireless Sensor Networks

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ABSTRACT

WSNs is evolving different kinds of networks depending on different circumstances, among those we have HWSNs (Hybrid Wireless Sensor Networks) which invokes sensor nodes mobility. In hybrid wireless sensor networks (HWSNs), reducing energy consumption of resource constrained and adaptability to the sensors nodes motion are the crucial problems; to overcome this we need a scalable MAC protocol. Many MAC protocols have been proposed by different researchers, but in this paper we propose LMAC because it outperforms S-MAC, T-MAC and D-MAC protocols comparing to its improvement of energy efficiency and mobile adaptability.

Keywords

Hybrid Wireless Sensor Networks, S-MAC, T-MAC, D-MAC, LMAC

I. Introduction

Recently, many researches about wireless sensor networks (WSNs) suppose that sensor nodes or base stations are stationary. Yet, there might be some circumstances where the base stations and sensor nodes need to be mobile.

Let's take the case of health care, when a patient is in an Ambulance, doctors can use mobile ad hoc nodes to take the role of the base stations in the WSN to monitor the status of their patients along the way to the hospital. In this situation, a heterogeneous network called "hybrid wireless sensor network (HWSN)" occurs, this HWSN is able to maintain the service when switching to a mobile network (see Figure.1). HWSNs are typically composed of wireless devices deployed over a geographical area in an ad hoc fashion and in a wireless sensor network. Unlike other wireless networks, it is generally hard to charge or replace the sensor node's battery, and this has the impact on sensor node lifetime. However, the medium access decision within HWSNs with low duty-cycles is a hard problem that must be solved in an energy-efficient manner and MAC protocol is responsible.

Therefore this paper presents a survey about 4 different MAC protocols and proposes the suitable for HWSNs. The rest of the paper is organized as follows: Section II gives the definitions for the key HWSNs and MAC protocol, Section III describes SMAC, TMAC, DMAC and LMAC protocols HWSNs. Section IV focuses on the LMAC protocol. Finally, Section V concludes the paper by comparing all the 4 protocols and provides a future direction to researchers.

II. Overview of HWSNs

Sensors are devices used to provide information on the presence or absence of an object[1]. A sensor node in a wireless sensor network is a node that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. The base stations are gateway between sensor nodes and the end user. Sink is a device that gathers data from the sensor nodes. Wireless network, is the interconnection between nodes without the use of wires.

A wireless ad hoc network is a decentralized network which is built spontaneously as devices are connected; Wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions at different locations. HWSN is a combination of wireless sensor network and ad hoc networks[2].

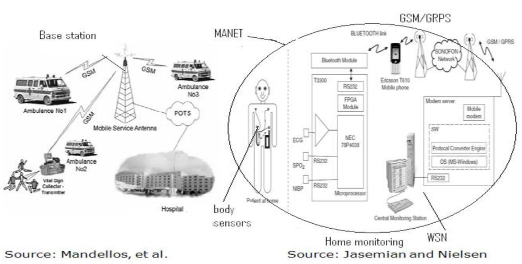

Figure 1. HWSNs in emergency care and home monitoring

III. Mac protocol and its features for HWSNs

With the objectives of reducing energy consumption, scalability, collision avoidance, MAC protocols can be classified as contention-based and TDMA based [3]. To design a good MAC protocol for the HWSNs, the following criteria must be considered: the energy efficiency, mobility of nodes, collision avoidance, scalability and adaptability to changes. Changes in HWSNs should be handled rapidly and effectively for a successful adaptation.

An efficient MAC protocol must gracefully accommodate such network changes. The following are MAC protocols that are considered in this paper.

1. Sensor MAC (S-MAC)[4]

S-MAC is a contention-based protocol [5]; it proposes an active/sleep cycle scheme to conserve energy by managing synchronization and periodic sleep/listen schedules. With SMAC neighboring nodes form virtual clusters by set up a common sleep schedule, if two neighboring nodes reside in two different virtual clusters; they wake up to listen periods of both clusters. This possibility of following two different schedules gives as results, more energy consumption via idle listening and overhearing. Schedule exchanges are accomplished by periodical SYNC packet broadcasted to immediate neighbors. Collision avoidance is achieved by a carrier sense. In addition to this, RTS/CTS packet exchanges are used for unicast data type packets.

As advantage of SMAC, the energy waste caused by idle listening is reduced by sleep schedules. As disadvantages, broadcast data packets do not use RTS/CTS. SMAC is not adaptable to traffic load conditions and increases latency.

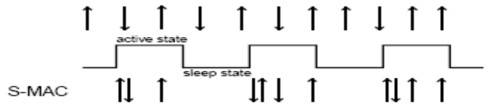

Figure 2. The S-MAC duty cycle

2. T-MAC (Timeout MAC)

T-MAC is developed from S-MAC [6]; however T-MAC decreases energy waste of idle listening. Timeout-MAC (T-MAC) is proposed to enhance the poor results of S-MAC protocol under variable traffic load.

In T-MAC, listening period ends when no activation event has occurred for a time threshold TA (see fig.3). T-MAC adds dynamic duty cycle feature to S-MAC with the aim to decrease the latency for delay-sensitive applications.

As advantages of TMAC, it transmits all messages in bursts of variable length and sleep between bursts; it saves energy and improves upon S-MAC by adding the ability for a variable duty-cycle to compensate for inconsistent data rates.

As disadvantage MAC presents early sleeping problem that limits the maximum throughput.

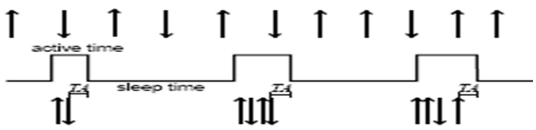

Figure 3. The basic T-MAC protocol scheme, with adaptive active times.

3. D-MAC (Directional MAC) [7]

D-MAC is a TDMA based protocol [5]; it has a low latency by utilizing data gathered in trees. Convergecast is the mostly observed communication pattern within sensor networks, these unidirectional paths from possible sources to the sink could be represented as data gathered in trees (see fig.4).

The main objective of DMAC is to achieve very low latency at the same time still being energy efficient. In DMAC, slots are assigned to the sets of nodes based on a data gathering tree, during the receiving period of a node, all of its children nodes transmit periods and contend for the medium. As advantages, DMAC achieves very good latency compared to other sleep/listen period assignment methods and Self organization.

As disadvantages, in DMAC collision avoidance methods are not utilized. DMAC is not adaptable to traffic and mobility.

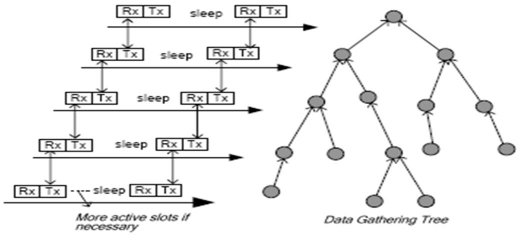

Figure 4. A data gathering tree and its DMAC implementation

4. LMAC (lightweight MAC)

It is based on a TDMA scheme [8] [5]. In this protocol, time is divided into time slots, which nodes can use to transfer data without having to contend for the medium.

A time slot consists of two parts: the Control Message (CM) which is always transmitted by a node in the time slot(s) it controls the Data Message (DM), which also contains the higher protocol layer data. The CM and DM have fixed length. Unlike other MAC protocol TDMA-based systems, the time slots in LMAC are not divided among nodes by a central manager; instead, the nodes use an algorithm that is based on local information only to choose time slots to control.

The LMAC protocol includes the necessary functionality to transport messages to gateways without requiring additional routing protocols.

Using the LMAC protocol message delays can be significantly reduced. LMAC protocol is self-configuring even when nodes are mobile, robust against high peak loads and energy-efficient therefore it ensures a long-lived network and it fits HWSNs.

IV. Proposed Mac protocol:"LMAC"

The LMAC protocol is based upon scheduling.

1. Organization of frames and time slots in LMAC

In LMAC protocol, time is organized into time slots, which are grouped into frames. Each frame has a fixed length of a number of time slots [9]. In order to be capable of receiving messages, nodes always listen at the beginning of time slots of other nodes to determine whether they are addressed either by node ID or by broadcast address. In the LMAC protocol, nodes can receive multiple data messages per frame, but they are only allowed to transmit once per frame. A higher layer in the protocol stack should combine data fragments into one message for transmission whenever possible.

A time slot is divided into two parts of unequal length (Figure.5): control message (CM) and data message (DM). Between the CM and DM there is a small gap, which allows the MAC layer to process the just received CM.

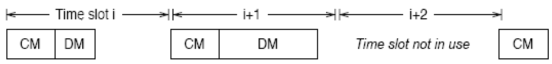

Figure 5. Time slot contents of the LMAC protocol

2. Control message composed of:

- **identification,** this is the node's ID that is transmitted at the beginning of CM, it is useful for routing.
- **Current slot,** this is a number that reflects the position of the time slot in the current frame.
- **Distance to gateway,** this is used for synchronization and find the shortest path routing of messages to the gateway and the destination node respectively.
- **Occupied Slots,** with this, nodes keep track of controlled time slots around them and share this information with neighbors.
- **The collision in slot,** this is to indicate that a collision has occurred, if the latter found, nodes immediately stop controlling their time slot and return to the process of finding a free time slot.
- **Destination Address,** this field is used for addressing neighboring nodes. When nodes discover by listening to the CM that they are not the intended receiver, they immediately turn off their power-consuming receiver and wait until the next time slot comes around. Therefore energy is saved and no idle-listening.
- **Acknowledgement,** LMAC protocol has a bit vector for acknowledgment, to acknowledge received data messages. When data received a

logical 1 is placed at the position of the appropriate time slot in the acknowledgement field. If no message or an incorrect message was received, a logical 0 will be placed. A special feature of this acknowledgement method is that the recipients also acknowledge broadcast messages and this can greatly improve the reliability and efficiency of those messages.

Table 1. Contents of the control message (assuming 32 time slots in a frame)

Description	Size(bit)
Identification	16
Current Slot	5
Distance to Gateway	8
Occupied Slot	32
Collision in Slot	5
Destination ID	16
Acknowledgement	32
Total	114

V. Conclusions and future works

In this paper we have seen that LMAC outperforms TMAC, SMAC and D-MAC in terms of energy efficient, self organization and mobile adaptability. The reason is that LMAC targets the two main causes of energy-waste in MAC protocols: collisions and idle listening. The LMAC protocol is able to schedule the access to the wireless medium and, therefore, it does not suffer from collisions when the payload increase, this results in good delivery ratios.

MAC, T-MAC and D-MAC all suffer from synchronization overhead and periodic exchange of sleeping schedules. LMAC is able to reduce this idle listen time to a large extent; the protocol becomes even more energy-efficient for increasing payloads due to an increased ratio of data bits and "overhead" by using CM. Besides, Even if the topology of the network might change over time due to mobility of nodes or due to wake-up of sleeping nodes, LMAC is adaptable to mobility of the sensor node.

It might happen that a time slot is not used by one of the neighbors of a node. Since the topology of the network might change over time due to mobility of nodes or due to wake-up of sleeping nodes and this slows the response of the network. This problem is left to future work.

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