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Design and Implementation of a Medium Access Protocol for a Heterogeneous Wireless Sensor Network

José Francisco Beltrán Chávez, Orcar Alejandro Lemus Pichardo, Víctor Barrera Figueroa, Mario Eduardo Rivero Ángeles, Miguel Félix Mata Rivera

Instituto Politécnico Nacional,
Unidad Profesional Interdisciplinaria en Ingeniería y Tecnologías Avanzadas,
Mexico City, Mexico

beltranchavezj@hotmail.com, oscarl.ocho@gmail.com, vbarreraf@ipn.mx, erivero@cic.ipn.mx, migfel@gmail.com

Abstract. The present work is focused on the development and implementation of a low energy consuming medium access protocol, based on the characteristics of the S-MAC (Sensor Medium Access Control) [7] protocol, with a test scenario of a homogeneous network that uses heterogeneous information. Several other protocols are being implemented under similar conditions but this has been proven to be far from optimal [4]. It is proposed the design of a protocol that allows, through a sleep-active time schedule,energy savings, synchronization and correct management of heterogeneous information. The approach to managing heterogeneous information is made by assigning different medium access priority to each kind of information. On the test scenario it's used "continuous monitoring" mode, where nodes use a CSMA/RTS medium acces protocol, and "priority mode", where nodes that need to transmit information that has higher information get to do so immediately while the rest of the nodes enter sleep mode. In this way we can guarantee there are energy savings and at the same time different kinds of information are being transmitted.

Keywords: Medium access protocol, wireless sensor network, software defined radio, S-MAC protocol, continuous monitoring and event detection.

1 Introduction

The MAC layer, which belongs to the Data Link Layer, is in charge of defining the protocols that dictate who gets to use the link and how he's supposed to do so. Some medium access protocols used in wireless sensor networks assume that every node and the kinds of information managed inside the network are all homogeneous. These kind of implementations don't guarantee stable communication amongst nodes due to different kinds of possible interference, limited frequency ranges or geographic related losses.

Medium access protocols designed for homogeneous networks tend to be centered around channel usage optimization, throughput efficiency and less energy conservation, however, when it comes to wireless sensor networks its actually the opposite [1]. These protocols are gaining importance because future development of wireless communications involve Wireless Sensor Networks [5].

The protocol proposed in this work was mostly based on the idea of combining the energy saving characteristics from S-MAC and an information classification system. The information classification system was implemented in a way that nodes would work under different roles depending on the kind of information that they need to deal with.

Another important part of this work is the development of a testbed that guarantees the communication between heterogeneous nodes and information. This approach has been chosen since heterogeneous sensor networks works have been analysed from the energy efficiency approach and not from the heterogeneous information approach [2].

2 Protocol Overview

In order to manage different kinds of information, int his case two, it is proposed to implement different kinds of active times based on their needs to access the channel. The proposed kinds are: continuous monitoring and event detection.

These active times must be preceded by a sleeping time in order to save energy through the most characteristic attribute of S-MAC, active and sleeping time regular intervals. In order to do so in a way that that all kinds of information can access to the medium, it is proposed that each active time implements a different Medium Access mode.

In continuous mode all nodes transmit and compete for the medium under a CSMA/CA protocol. This was chosen because continuous monitoring requires nodes to constantly transmit information that has low priority. If a transmission is under way and the continuous monitoring phase suddenly ends the whole transmission is discarded and the nodes enter sleep mode.

When event detection phase starts all nodes also compete for access to the medium through CSMA/CA since it's highly likely that several event detection nodes try to communicate the same event. If this phase ends when a transmission is under way the phase gets extended until the transmission ends successfully. If no events are detected during event detection or if no information needs to be transmitted during continuous monitoring phase the phase ending time doesn't change since this could lead to desynchronization among many nodes. It could also interrupt transmissions that occur during the last milliseconds of the phase. As we can see from figure 1 if the continuous phase is larger than the event detection phase, critical events may not be detected but if event detection phase is larger that continuous monitoring phase, drastic changes in continuous data could be detected with a certain delay.

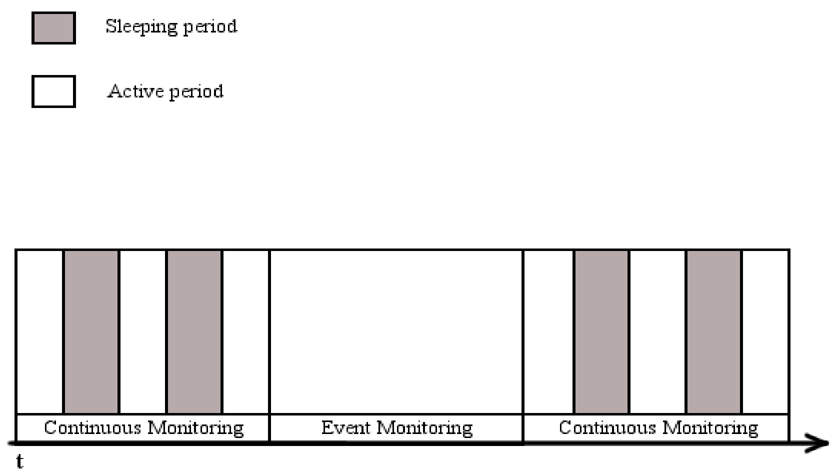

Fig. 1. Time relation between phases.

Another very important factor to keep in mind is the synchronization of neighbour nodes. This has been solved be proposing a synchronization role scheme where a node can be a master, which helps other nodes to synchronize, or a slave, which synchronizes its actions through the use of SYNC packets over the network. This is similar to the scheme proposed in [8]. Simply put, if a slave node doesn't get a SYNC packet after a few cycles assumes the master node has run out of battery or has unexpectedly left the network, in that case he assumes master mode and continues operating normally. So, in general the proposed protocol needs to implement the next characteristics:

- Implementation of an energy saving scheme through sleep and active phases.
- Synchronization through messages.
- Priority access for critical or important information.

It should also be noted that the next capabilities are desired, needed or innate in the final implementation:

- Implementation algorithm must be cyclic.
- Implementation code must use as little resources as possible.
- Packet fragmentation must be present.
- IEEE 802.11 compatibility because of its general acceptance.

The figure 2 illustrates the proposed workflow for the protocols implementation.

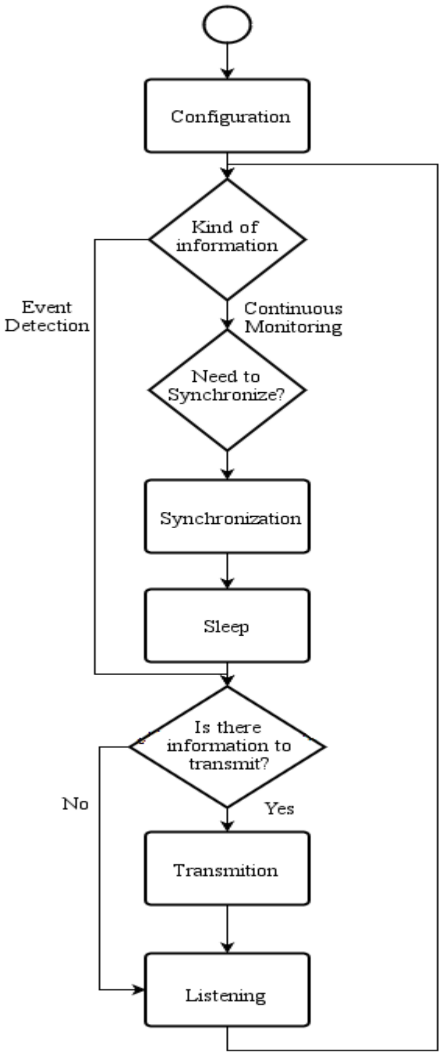

Fig. 2. Proposed workflow for the implementation of the protocol,

3 Testbed

The implementation of the protocol was made on nodes composed by a micro controller mounted on a prototyping platform, a software defined radio and a power module. Node control is achieved through the prototyping platform ChipKIT Uno32. ChipKIT platform was chosen over other more popular options, such as Arduino, because of its lower cost and higher performance [9].

The chosen software defined radio was the CC1101 radiofrequency transceiver due to its low cost, 10 USD aproximately, and its higly customizable capabilities such as base frequency, modulation, number of transmission channels, etc. This module is specially useful for low power applications since its specially designed for the ISM (Industrial, Scientific and Medical) / SRD (Short Range Devices) band [3].

Transmitted information was simulated, but it can be easily generated since the ChipKIT platform has many input methods available. The final implementation of a node can be appreciated on figure 3.

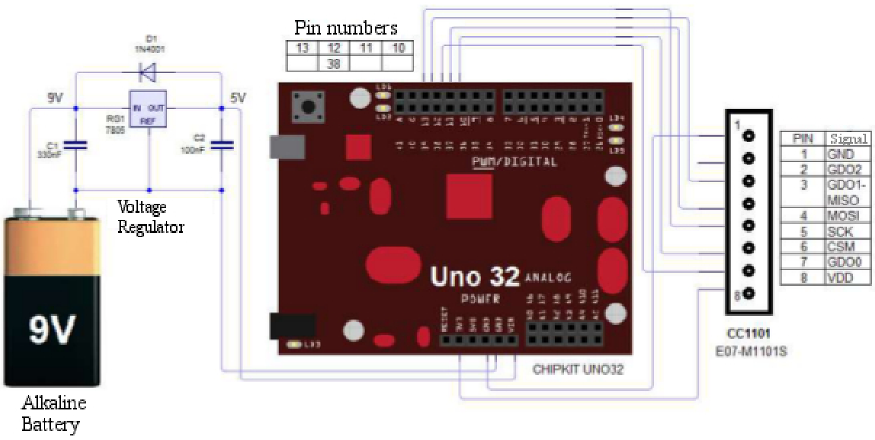

Fig. 3. Physical implementation of a node.

4 Tests

Four different tests were run and all information was logged through serial port to PC to validate the correctness of the test.

4.1 First Test: Hidden Terminal

In the first test three nodes were used in such a manner that the hidden terminal problem was present. In this case scenario three nodes, A,B and C, are connected in an unstructured network. Node A is in range of node B, Node C is in range of node B but Node C and A are out of range. Node A transmits regularly continuous monitoring information to node B while node C transmits event detection information to node B as well. Normally nodes C and A would cause a collision on node B since both of them try to communicate with it, but the implemented protocol uses CSMA/CA and timed phases so node A and C won't cause a collision since their transmissions occur during different phases and even if they occurred in the same phase CSMA/CA would prevent them prof colliding.

4.2 Second Test: Time Synchronization

In this test four nodes are turned on at random times. The first node that was turned on assumed master role and started transmitting SYNC packets periodically. When continuous monitoring phase is active a led is supposed to turn on on every single node and when event detection phase is active said led is supposed to flicker. By sending each phase initial time through the serial port we were able to make sure that all nodes were synchronized.

4.3 Third Test: Medium Access and throughput

Again, in this test case four nodes were used. The first two would generate and transmit data to the fourth node. The third node would be used as a "data bridge" between the first, the second and the fourth node of the network. Data was generated in such a manner that it would cause collisions, however thanks to CSMA/CA the delay caused by simultaneous transmissions is very small.

4.4 Fourth Test: Lifetime Test

In this test three nodes are used, one of the three nodes is connected to a PC, works as a master synchronizer and logs every single package that is transmitted. The other two send continuous information from both kinds and after a fixed time consumed energy was measured. Because of time restraints more accurate tests couldn't be run, however it was shown that after 20 minutes the variance in energy was of only about ten millivolts.

5 Conclusion and Future Works

The main focus of this work was to develop a medium access protocol that provided many features needed in very specific areas. This protocol was developed alongside a testbed that simulated a wireless sensor network, said testbed proved to be highly customizable and powerful, however if this protocol gets to be implemented a dedicated hardware platform would be much more suitable when it comes to performance.

The measurements made when the tests were run weren't more accurate than values of the 1x10-3 order due to the tools available at the time. It's proposed that further and more exact measurements are done in order to be able to make a more complete analysis.

A big part of this protocol is the use of synchronizing nodes. This goes along well with the concept of clustering, so a clustering method focused on making the network scalable would be a great addition to this protocol, that as of the writing of this paper, lacks a complex routing method. Many clustering methods have been proposed specially for Wireless Sensor Networks so no further research might be needed [5].

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