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Proposing a New MAC Layer Schedule with the Aim of Reducing Energy Consumption in Wireless Sensor Networks

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ABSTRACT

Recent advances in the field of electronics and wireless telecommunications have created the capability and potential for designing and manufacturing sensors which have low power consumption, small size, reasonable price and various applications. These small sensors, which based on their type, can perform different tasks such as receiving environmental information, processing it and then sending that information, have shaped an idea to create and expand networks known as wireless sensor network (WSN). A sensor network consists of a large number of sensor nodes which are widely distributed in the environment and are engaged in collecting information. The sensors have significant limitations, and one of the most important limitations is the low capacity of these sensors' battery, which makes the efficient use of the energy a vital issue. When the energy in the battery ends, the sensor, functions completely stops. This would result in the loss of a part of the network. Moreover, in most of the sensor, applications, replacing the battery is impossible either because the evaluated area is too large or because it is unsafe. Therefore, minimizing the energy consumption, by designing communication protocols and applications for these networks, is one of the most important issues. So designing a MAC Layer schedule to reduce energy consumption in wireless sensor networks which can significantly reduce power consumption but also would be compatible with IEEE 802.15.4 is an important and unavoidable challenge.

1. INTRODUCTION

A wireless sensor network is a network of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, motion, contamination etc. in different locations within a specific range. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and non-military applications such as industrial process monitoring and control, machine health monitoring, house or perimeter monitoring, Health care monitoring, smart homes and traffic control. Despite advances in this type of networks, sensor nodes are still dependent on small batteries for their energy supply since their application involves characteristics such as large number, small size and contingency placement. Usually there is no possibility of recharging or replacing the sensor nodes because they are often used in harsh and inaccessible environments. Therefore, a severe limitation in energy supply is one of the most important challenges in wireless sensor networks. Also, since the performance of sensor networks strongly depends on their lifetime and coverage, it is vital to consider energy saving algorithms in the design of long term sensor networks. Generally, wireless sensor networks are idle for most of the time and only occasionally send data. Meanwhile, the amount of energy required to listen to an idle channel (without use) is equal to the energy consumption when data is being sent and received, And it is much more than the energy consumed in sleep mode. The main objective of the sensor networks is wise and rational management of energy resources. So, first it is necessary to know where the energy is consumed. Some of the energy consumption in sensor node may be helpful and productive such as: 1- sending or receiving data, 2- Processing query requests, and 3- Sending queries and data to neighbor nodes. However, some energy consumed in the sensor node is wasteful and useless such as: 1-Passive listening, i.e. listening to an inactive channel for possible traffic, 2- Collision, i.e., when a node receives more than one packet at a time, Even when it receives two packets scheduling, and hybrid methods. Preamble-sampling MAC Protocols [8], [9] use the Low Power Listening [10] (LPL) to sample the initial data packets. B-MAC [8] is a link layer protocol And provides the interface with the upper layer that is CSMA based on protocol that provide Low power listen states to low power consumption. Wise MAC [9], [10] is based on the preamble sampling technique. This technique consists of regularly sampling the medium to check for activity. By sampling the medium, we mean listening to the radio channel for a short duration. If the medium is found busy, a sensor node continues to listen until a data frame is received or until the medium becomes idle again. At the access point, a wake-up preamble of size equal to the sampling period is transmitted in front of every data frame to ensure that the receiver will be awake when the data portion of the packet arrives.

This technique provides a very low power consumption when the channel is idle. The disadvantages of this technique are that the (long) wake-up preambles cause a throughput limitation and large power consumption overhead in reception. The overhead in reception is not only born by the intended destination, but also by all other nodes overhearing the transmission. X-MAC [11] is a low power MAC protocol for wireless sensor networks (WSNs). Standard MAC protocols developed for duty-cycled WSNs such as BMAC, which is the default MAC protocol for TinyOS, employ an extended preamble and preamble sampling. While this "low power listening" approach is simple, asynchronous, and energy-efficient, the long preamble which introduces excess latency at each hop is suboptimal in terms of energy consumption, and suffers from excess energy consumption at non-target receivers. X-MAC proposes solutions to each of problems by employing a shortened preamble approach that retains the advantages of low power listening, namely low power communication, simplicity and a decoupling of transmitter and receiver sleep schedules. SMAC protocol [13], is based on sleep, a node sleeps for a period and after waking up listens to channel and receives the packets. Basically, a node periodically follows the path that includes Listening and sleep interval. SMAC avoids hidden terminal problem using RTS/CTS packet.

2. TOPOLOGY CONTROL STRATEGY

Given the large number of nodes in a wireless sensor network, there are some redundant nodes in any given area of a region. With regard to this phenomenon in the wireless sensor networks, controlling the topology of the network is another popular method to reduce energy consumption. SPAN protocol was one of the first sleep based topology control techniques for ad hoc wireless network. SPAN protocol tries to reduce energy consumption without affecting the connections and topology of network. SPAN tries to minimize the number of coordinators in order to reduce the delay time. In this protocol, the decision of a node to become a coordinator is based on local data gathered from locally broadcasted messages.

2.1. The Strategy of Clustering / Grouping

Grouping or clustering nodes together is another strategy which is often used to create energy-efficient protocols. LEACH protocol puts nodes that are close to each other into a cluster and then selects one of the nodes from the cluster as the cluster head. The cluster head node acts as a local base station for that cluster. So anything that cluster head node receives from the rest of the cluster members will be sent directly to the base station [19]. PEGASIS protocol is very similar to LEACH protocol and utilizes the cluster heads, but instead of having a direct communication between each cluster head and base station, it forms a path of cluster heads toward the base station [20]. Geographical Adaptive Fidelity (GAF) protocol has been suggested to help reducing the energy consumption in Ad-Hoc wireless network [21]. GAF protocol uses nodes' location data and decides which nodes should continue their work while also maintaining throughput of network connections.

3. METHOD

In each period of the duty cycle, a node wakes up to send and receive data, but the receive-wake ups, will be scheduled according to send-wake ups of the neighboring nodes. By using the information collected during the initial phase, each node only activate its radio transceiver when it wants to receive or send data to its neighbors. This schedule can reduce unnecessary wake ups associated with idle listening. Announcement Packet (PktANN) is a signal packet which is used by a node when it joins the network. It is used to announce the presence of node and the time of its next send-wake up. Waking table (WTBL) is a data structure in which a node stores the send-wake up schedule of its neighbors. In the initial setup of the network, all nodes exchange information about their transmission time using PktANN. When such message from an unknown neighbor is received, the proposed schedule updates WTBL table by storing a new entry. But before storing, Information of neighbor's transmission time is converted to an offset which refers to the duration between the start of the duty cycle and the moment when the neighbor sent the packet (in seconds). Each node randomly selects its own transmission time within an appropriate range, considering the choice that is made by neighbors. This difference in neighboring nodes ending schedule leads to reduced competition for access to the channel.

3.1. Location of the Base Station

In this section we discuss the impact of base station location on the efficiency of wireless sensor network. What is desirable in a wireless sensor network is reducing energy consumption and thus extending the life of the network. It is clear that changing the location of base station greatly changes the network performance.

4. RESULTS AND DISCUSSION

In our simulation, packet rate was 0.1 packets per second and T0 was 20 seconds. Diagrams represent power consumption in network implementation, delays, and delay of realtime packets respectively. From these diagrams, we can conclude that our proposed method consumed less energy than the AS-MAC2 method. In addition, Fig.6 shows the delay of packet arriving to the base station which was lower in the proposed method compared with AS-MAC2.Also as shown in Fig.7, the delay of real-time packets in the proposed method was much lower than that of AS-MAC2 method. In general it can be said that based on the criteria measured in this scenario, the proposed method performed better than AS-MAC2.

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