An Efficient Duty Cycle Based Communication Scheme for Wireless Sensor Network

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Abstract

Due to the limitation of battery life time, energy is one of the most crucial issues for wireless sensor networks. Thus this paper proposes an energy efficient duty cycle scheme to conserve energy mostly. To handle the large varieties of data (i.e., both low and high traffic load) the proposed duty cycle scheme ensures a fair access period (FAP) and a prioritized access period (PAP). The idea presented in this paper able to reduce the collision probability and energy consumption. Finally simulation outputs have demonstrated the effectiveness of the proposed duty cycle task and showed a noticeable performance in terms of energy usage.

1. Introduction

Wireless sensor network is a striking resource for different types of applications. Especially, for a monitoring application the operation of a wireless sensor network is quite challenging, since in such application most of the time sensor nodes deal with very low traffic and have to handle very high traffic when any event occurs. Under these circumstances, to increase the life time of battery operated sensor network, it is needed to figure out an energy efficient scheme which can be designed to meet the following goals:

- Energy efficient communication bypassing the most common sources of energy wastes, i.e., idle listening, overhearing etc.
- Collision and contention reduction.
- Optimize delay in both low and high traffic load.
- Better throughput assurance under heavy load.

To meet the above mentioned goals lots of works has been done so far, which are mainly designed for duty cycle MAC protocol and can be categorized as synchronous and asynchronous MAC protocol. In the very early synchronous MAC protocol like S-MAC [1], it has been shown idle listening, overhearing, collision and control packet overhead as the major concerns of energy wastage in the sensor network. The existing synchronous protocols suffers sleep delay problem and the synchronization overhead has the impact on the network performance, hence asynchronous MAC protocols are always a better choice for sensor MAC design. In an asynchronous duty cycle based MAC protocol like, B-MAC [2], X-MAC [3]; a node sends preamble whenever it has data to send and receivers periodically sample the channel at their wakeup interval to detect the preamble. Upon detecting the preamble receiver gets ready to receive the data packet, which will be transmitted by the sender just after sending the preamble.

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But unfortunately, these kinds of MAC protocols have the drawbacks of idle listening problem and also overhearing occurs here for the non-destined nodes for preamble reception. Moreover, collision is significant when multiple senders exist in the network under high traffic load.

Therefore considering these factors we inspired to design an efficient duty cycle scheme for sensor network considering varying traffic load of monitoring applications (i.e., intruder detection, fire alarm detection).

2. Proposed Duty Cycle Scheme

In the proposed duty cycle scheme, first each node chooses a random amount of time called operational cycle (T_p) based on the following:

$$T_p = l + k \times (u - l); \qquad k \in (0,1) \qquad (1)$$

In the equation 1, l and u are the minimum and maximum sleep time between a wakeup interval of a sensor node respectively and k is random number uniformly distributed between 0 and 1.

Once a node picks up the T_p value, it maintains the wakeup interval accordingly. After each wake up if a node finds the medium is free then sends a beacon packet for announcing its wakeup information. The basic beacon transmission of proposed scheme is somewhat similar to receiver initiated RI-MAC [4], however proposed scheme differs with RI-MAC in terms of fair access period (FAP) and Prioritized Access Period (PAP) to ensure a better delivery ratio and delay performance both at low and high traffic condition.

2.1 Fair Access Period (FAP)

A receiver node starts its Fair Access Period (FAP) just after wakeup and receives one single packet from each of its upstream sender nodes. After sending the beacon packet, the receiver node waits for a maximum back-off period for possible data reception, similar to X-MAC [3]. After receiving each data packet, the receiver node sends an acknowledgement packet and request for more data from other sender, as shown in Figure 1. If it receives maximum number of packets equal to its upstream child/sender then at the final acknowledgement packet it announces the schedule of Prioritized Access Period (PAP).

On the other hand, senders with data wait until the first beacon they receive and go to back-off immediately after reception of the beacon packet. Node that wins the contention sends the very first data packet and waits for acknowledgement. Senders those looses the contention pause their back-off value and resume counting again after reception of the acknowledgement from the receiver to the first sender and repeat the same procedure to send data at the fair access period. In addition, to have prioritized channel access schedule based on the higher load, senders piggyback the number of backlogged packet information at the data packet header. Hence, at the very last acknowledgement packet of FAP, receiver announces the weighted priority and number of packets to be sent at the Prioritized Access Period (PAP) to each of the senders with more data. Senders which have no more data immediately goes back to sleep after the fair access period.

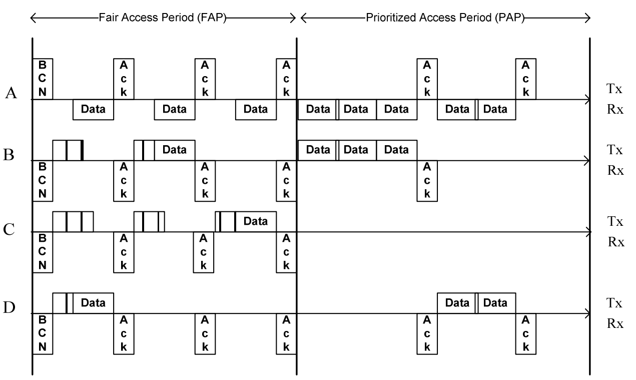

Figure 1: Proposed Duty Cycle Scheme includes Fair Access Period (FAP) and Prioritized Access Period (PAP).

2.2 Prioritized Access Period (PAP)

A sender with additional data gets the Prioritized Access Period (PAP) schedule by the final acknowledgement of the fair access period. Upon receiving the schedule, the node which have higher priority, immediately sends the number of packets allocated by the receiver. Here, for sending the allocated number of packets the back-to-back sending and block acknowledgement approach of 802.11e has been followed.

In the Figure 1, node A has the upstream children/senders B, C and D respectively. The scenario explains, even after fair access period node B and D have more data and sent the prioritized access request at the FAP. Receiver node A assigns higher priority for B than D, though node D sends data packet earlier at FAP period. It is to be notice that, as node C has no additional data it goes to sleep after FAP.

As node B got higher priority thus just after entering in to the prioritized access period, it sends back-to-back data packet without any back-off. On the other hand, receiver sends a block acknowledgement for the received data packets. Same procedure continues for node D also.

3. Experimental Validation

An experimental environment has been set up for simulation by deploying 100 sensors randomly in an area of 100 x 100 m^2 area. For the base station we choose a random position within the area of interest. Initially we consider each node with full of energy with energy level 1 and when a node is out of energy then its energy level goes to 0. For the sake of simplicity we considered the wake up interval of each node equal to 1 second. We compared our proposed duty cycle scheme with the always on protocol 802.11.

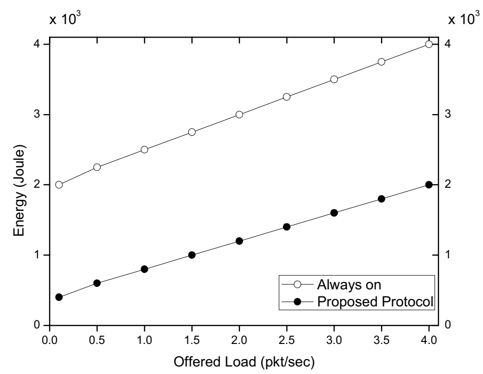

Figure 2: Energy usage at different traffic loads.

4. Conclusion

Wireless sensor networks are now a day becomes a key technology for the event monitoring applications. This paper addresses a different idea regarding the sensor duty cycle scheme in terms of energy utilization and throughput enhancement. Proposed scheme seems to be inexpensive and energy efficient for data transmission and reception in a wireless sensor network. The experimental result indicates that the performance of the proposed scheme has a well load distribution approach than the existing always on scheme. In future we have a plan to extend the proposed scheme in a larger extent for sensor network medium access.

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