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Hybrid Power Saving Technique for Wireless Sensor Networks

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Abstract

In wireless communication, idle listening, receiving and transmitting are the main source of consumption of energy. This paper gives an overview of several techniques used for wireless networks. We incorporated PSM and PC to gain the advantage of PSM (reduce idle listening) and PC (reduce receiving and transmitting power) and implemented them in the IEEE 802.15.4 protocol. The results show that the new hybrid technique saves more power than PSM and PC individually.

1. Introduction

Wireless sensors are generally powered by batteries that give a finite amount of energy. Techniques for decreasing the consumption of energy are necessary to prolong the network life time as much as possible and there are many mechanisms for achieving this task. Most of the energy is consumed in the wireless network interface, so many energy saving mechanisms work in this area.

The standard technique is Power Saving Mechanism (PSM) [6]. PSM is used in common wireless networks such as 802.11, 802.16 and 802.15.4. In these networks, the node or sensor is allowed to sleep for a period of time switching its wireless network interface off to conserve energy. A common alternative technique is Power Control (PC) scheme [9,10,11]. This scheme changes the transmit power according to the distance between the transmitter and receiver to reduce the consumption of energy. In addition, PC is also used to improve spatial reuse of the wireless channel. The two techniques (PSM and PC) are most commonly used in conserving energy in wireless ad hoc networks. In this study, the two schemes are combined and implement in IEEE 802.15.4 standard.

The rest of the paper is organised as follows: related work in energy efficiency and the IEEE 802.15.4 standard is presented in Section 2. Section 3 gives an overview of our protocol and simulation methodology. Results and discussion are presented in Section 4. Section 5 discusses conclusion and future work.

2. Related work

Increasing the life time of a wireless node - or increasing the whole network life time - mostly depends on the power consumption of nodes in the wireless network. Therefore, power saving has been a hot topic in the last few years for many researchers. In [6] a technique called power management is introduced. Nodes are generally in one of two modes: the active mode where nodes can transmit and receive data and the sleep mode where nodes can sleep to reduce their energy. In other words, nodes turn off their network interface and they are not able to send or receive data, but they save energy. In PCM proposed in [10] before sending or receiving any packets, a handshake protocol occurs between transmitter and receiver. These handshake messages include request to send (RTS) and clear to send (CTS) signal. The purpose of these handshake messages is to prevent collisions and tell the node what required transmission power for data and acknowledgment message packets.

Directional antennas are also used to reduce energy consumption. Kranakis et al [5] compared omni-directional and directional antennas. Because Omni-directional antennas transmit in all directions, they consume unnecessary energy. However, directional antennas focus radio frequency (RF) energy in a particular direction where it is needed [14]. Wieselthier et al [7] proposed that using directional antennas can conserve power by concentrating transmission energy in a specific direction.

Power Aware Routing (PAR) [12] is a protocol that increases the life time of the network and reduces energy consumption by establishing the route from source to destination. It selects the minimum total transmission power path to maximise the network life time. Chatterjee et al [16] have incorporated PAR where the issues of energy efficiency and power aware data routing strategies were addressed within an ad hoc network as crucial criteria while determining the route for a data packet to transmit.

Chen, B et al. proposed SPAN [13] based on electing a "coordinator" from all nodes or sensors in the network to act as an access point (AP). Snow et al [1] show how a low power Time Division Multiple Access (TDMA) protocol can be implemented over a wireless network. The On-demand wake up scheme is also used to save power [2].

IEEE 802.15.4 standard [8] defines the PHY and MAC layer specification for low rate WPAN (LR-WPAN). This standard's main features are that of ease of installation and reliable data transfer. It also works with short-distance operation and very low cost. The hybrid power saving protocol described in this paper is applied to the IEEE 802.15.4 standard.

3. Hybrid power saving protocol

The protocol we propose incorporates the PSM and PC schemes. The IEEE 802.15.4 standard supports sleep mode, however, the period of sleep may affect the throughput. For example, if the active period in the superframe is very short compared to the inactive period, the chance for accessing the channel will be very weak especially when the load of the network is heavy. On the other hand, if the active period is very long compared to sleep length, the node or the sensor will have a good chance to access the channel. This means that the throughput will increase, but the power consumption will increase. Therefore, the length of active and inactive period must be compatible to get satisfied Quality of Service (QoS) and power conservation.

The power control scheme is the one of the protocols that is used to save energy at nodes or sensors. As it is mentioned in the introduction section, before transmitting or receiving any data, a handshake must take place between sender and receiver [9,10]. The handshake is named RTS and CTS. They are used to prevent collisions and set up the required for power transmitting and receiving. The process is as follows:

1. The transmitter sends a RTS packet at the maximum power.
2. When the receiver receives the RTS packet, it calculates the power level that transmitter should use. The receiver calculates this power according to the power that it received from sender where:-

$$P_{\text{desired}} = \frac{P_{\text{max}}}{P_r} * R_{x \text{ threshold}} * C \quad (1)$$

Where P_r is the received power, $R_{x \text{ threshold}}$ is the minimum necessary power (received signal strength) and C is constant. After calculating the power value, the receiver replies with CTS packet to the sender. This packet has the value of the power that the sender should transmit at.

3. If the CTS packet is received successfully by the sender, the transmitter begins sending the data with the desired power.
4. After sending data, an Acknowledgment packet is sent by the receiver to inform that the data has been received successfully.

We combine these two techniques (PSM and PC) together to have the advantage of sleep mode and the advantage of the power control. The graph in Figure 1 shows our protocol.

3.1 Simulation model

In our simulation, we use ns-2 (ns-2.34) Software. The simulation environment is 100 m by 100 m and only the star topology was simulated. 915 MHz frequency is used for the channel. This means the data rate of each node is 40kbps where each node generates packet size of 100 bytes every 0.032 sec. Also, each node or sensor in the network transmits constant Bit Rate (CBR) traffic. The number of nodes changes each time from 2, 6 or 10. Each run of the simulation lasts for 1000 seconds.

4. Results and discussion

In this section, we are comparing between the data rate and the consumed power which is affected directly by Beacon Order (BO) and Superframe Order (SO) values. We also examine the effect of power control on power consumption. When two nodes deployed, it is clearly noticed that if the value of BO and SO is equal, the data rate is at the highest point. This is because the sleep period is zero and the node has the maximum chance to access the channel. Further, because the load on the channel is not heavy, the collision which is an important factor on the throughput is very rare. However, when the BO value is increased and the SO remains fixed at 3, for example, the duty cycle (the ratio of the length of an

Figure 1. Combination of PSM and PC

active period SD to the length of a BI ($\frac{1}{2}^{BO-SO}$) will decrease. This leads to degrading of throughput because as mentioned earlier (Section 3), the probability of giving access to the channel is proportional to the duty cycle.

On the other hand, the consumption of the power is inversely proportional to the duty cycle. That is because the sleep period increases when the BO parameter reduces which affects duty cycle. Therefore, from Figure (2b) we can see clearly that when the BO increase and SO is fixed the power saving increase. Figure 2c shows the average energy consumption of the nodes when power control is used with PSM. It can be noticed that the consumed power is decreased while the data rate remains the same.

Figures 2 and 3 present the scenario of implementing 2 and 10 nodes respectively. The difference is only on the data rate where the number of the nodes increases, causing the throughput to decline. This is since the collision increases and the attempts to access the channel rises.

From all figures, it can clearly be seen that when the duty cycle is large, that implies the active period is long which provides increased bandwidth resource for nodes, so the throughput increases. Power consumption, however, increases since the nodes stay in active mode for a long time.

On the other hand, when BO is large compared to SO, the inactive period is extended which leads to latency of transmission increases. Further, with long sleep time, most intensive competition on the channel by buffered packets will occur at the beginning of the next active period. As result, the packet drop rate will increase which leads to degrading of the throughput. With incorporation of power control to the PSM, the consumed energy decreases because only required power is used as shown in Figures 2c and 3c.

5. Conclusion and future work

In this paper, we presented the incorporation of PSM with PC to decrease the power consumption in IEEE 802.15.4 standard. The BO and SO parameter significantly impacts on throughput and energy conserving. In IEEE 802.15.4 standard, if the BO is very large and the SO small, the throughput degrades. And if the duty cycle is large, the throughput increases but the energy gain from sleep mode becomes small since the node remains awake for longer time. Adding power control to PSM gives improved performance in terms of conserving power. Future work includes mobility and another propagation model, also adding another protocol such as TDMA to this one to save more power.

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(a) Aggregate throughput

(b) Energy consumption without PC

(c) Energy consumption with PC

Figure 2. Data for 2 nodes

(a) Aggregate throughput

(b) Energy consumption without PC

(c) Energy consumption with PC

Figure 3. Data for 10 nodes

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