On Increasing Lifetime for Wearable Networks using Out-of-Band Wakeup Communication

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Abstract

The rapid growth of Internet of Things (IoT) has increased the application of sensor networks in healthcare. Wearable device communication is one of the major fields that benefited from it. A generic wearable device suffers from low resources especially in terms of energy. Controlling the power consumption is very important so that the devices may work for longer duration. To save power, a device is turned off. However, it needs to remain in on state to communicate. In this paper, we propose an efficient mechanism to handle the on/off periods using a radio triggered wakeup mechanism. Our aim is to maximize the sleeping time of a device and avoid unnecessary wakeup time (idle listening) to save power. It is found that our method is able to conserve power and prolong the lifetime of the device.

1. Introduction

The Internet of Things (IoT) has a positive influence on the rapid development of wearable devices and the supporting network. Such network can provide long-term health monitoring without disturbing the normal activities in a person or patient. It can contain a number of devices that monitor the human body for different functionalities as shown in Fig 1.

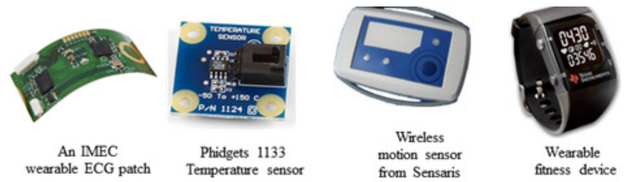

Fig 1. Wearable devices

The applications can be both medical and non-medical [1,2] as presented in Table 1.

Table 1. Some applications

Medical	Non-medical
ECG, EMG, EEG Blood pressure monitor Hear rate monitor pH monitor Fitness monitoring	Mp3, Music player MP4, Video player Gaming device File transfer

Several protocols to handle short-range communication between sensor devices are proposed. An efficient access control protocol can help to control and manage a wearable network. A protocol that supports all the major requirements of a wearable network can improve the performance and increase the lifetime of the devices. However, current standardized protocols lack direct mechanism to communicate if a device is not in the awake state. Therefore, in a scenario where the communication is directed towards a sleeping (off) recipient, the sender has to wait till the receiver device wakes up. To solve this problem, the majority of the protocols follow a schedule. They spend lots of power in scheduling. Similarly, unscheduled protocols waste time in idle listening. In this paper, we use an external radio triggered wakeup mechanism to handle such a problem. In this method, a wakeup radio circuit is used to trigger on a device from sleep state. A wakeup radio can save power by maximizing the sleeping time (main radio off) and wakeup only when it is necessary.

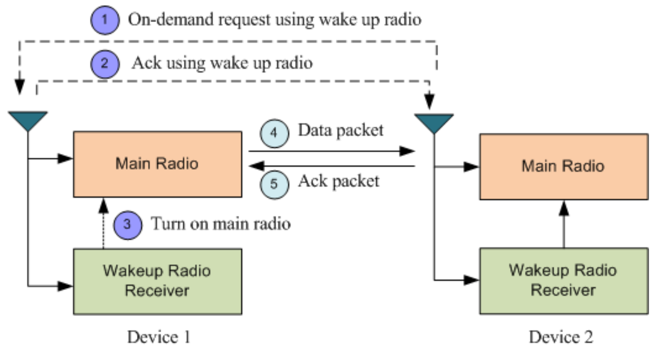

Fig 2. Radio triggered external wakeup mechanism

An external wakeup mechanism uses an unscheduled scheme as shown in Fig 2. A wearable device can be easily triggered on by an external wakeup signal. The cost of the wakeup radio is very low. It supports very low power consumption [4].

The purpose of this study is to use wakeup radio for communication to increase the lifetime of the devices. The rest of the paper is organized as follows. In

Section 2, we present system model. In Section 3, we present performance analysis. In Section 4, we present results and discussion. Finally, conclusions are drawn in Section 5.

2. System Model

The major design goal is to reduce the power consumption to prolong the lifetime. Our aim is to design a network model to meet the following requirements.

- Minimize idle listening time
- Maximize sleep time
- Minimize control packets overheads in the network
- Maximize lifetime

We have used a scheme that comprises Wakeup Radio/Wakeup-ACK/Data/ACK operation. We assumed that there are N devices in the system with all of them in range. We have used carrier sensing in a slotted CSMA. We use wakeup radio to enable communication with a sleeping device. The communication process and general MAC frame format are shown in Fig 3 and Fig 4 respectively.

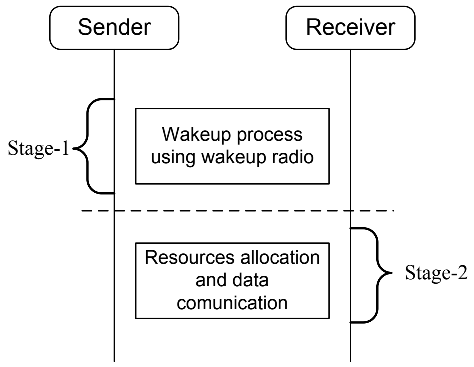

Fig 3. Communication process

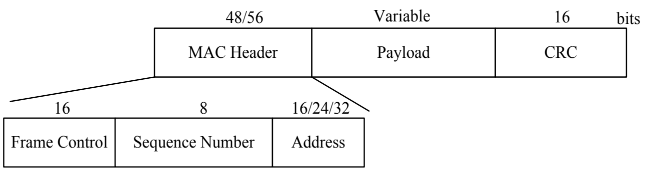

Fig 4. MAC frame format

3. Performance Analysis

We computed the power consumption and lifetime of the proposed scheme. Let P_{tx}, P_{rx}, P_{rxwk}, P_{sl}, P_{sw}, P_{setup} be the power consumption in transmitting, receiving, wakeup radio, sleep and setup states respectively. Let L_{wk}, L_{beacon}, L_{ack}, L_{data} be the length of wakeup, beacon, ack and data packet respectively. Let R be the transmission rate and T be the total time. Let T_{data}, T_{ack}, T_{setup}, T_{sw}, T_{sl} be the data transmission time, acknowledgement time, wakeup time, setup time and sleep time respectively. The average power consumption $\left(P_{avg}\right)$ for uplink data communication of the proposed protocol is calculated as follows.

$$P_{transmit} = \left(P_{tx} \times \frac{\left(L_{ack} + L_{data}\right)}{R} \right) / T \quad (1)$$

$$P_{receive} = \left(P_{rxwk} \times \frac{L_{wk}}{R} + P_{rx} \times \frac{\left(L_{beacon} + L_{ack}\right)}{R} \right) / T \quad (2)$$

$$P_{overhead} = \left(P_{setup} \times T_{setup} + P_{sw} \times 2T_{sw} \right) / T \quad (3)$$

$$P_{sleep} = \left(P_{sl} \times T_{sl} \right) / T \quad (4)$$

The total sleep time is calculated as,

$$T_{sl} = T - \left(T_{wk} + T_{setup} + 2T_{ack} + T_{beacon} + T_{data} + 2T_{sw} \right) \quad (5)$$

The lifetime ($L_{lifetime}$) can be calculated using the simple expression as follows.

$$L_{liftime} = \frac{C_{battery} \times V}{E_{total}} \times 60 \times 60 \quad (6)$$

Where, $C_{battery}$ is the total battery capacity, E_{total} is the total energy used and V is the voltage.

4. Results and Discussion

In this section, we present the performance evaluation of Power consumption and lifetime.

4.1 Simulation Setup

We have used the Network Simulator NS-2 (release v2.31) and TCL scripts to simulate[5]. 11 devices are used with device 0 acts as the controller. Rests of the devices are randomly placed in a 3m x 3m area. Each device is assumed to have a wakeup radio transceiver. The simulation parameters are presented in table 2.

Table 2. Simulation parameters

Parameters	Value
Network dimension	3m X 3m
Total no. of devices	11
Data rate	25kbps
Packet size	70bytes
Controller range	5m
Traffic type	Poisson

We have compared the results of the proposed protocol with some of the existing protocols viz. X-MAC [6], WiseMAC[7] and ZigBee MAC [3].

Fig 5 shows performance for power consumption. It is observed that the wakeup radio based system is able to outperform the rest of the protocols in terms of power consumption. The main reason for this is that the wakeup radio is able to reduce the idle listening time, which is a major cause of power wastage.

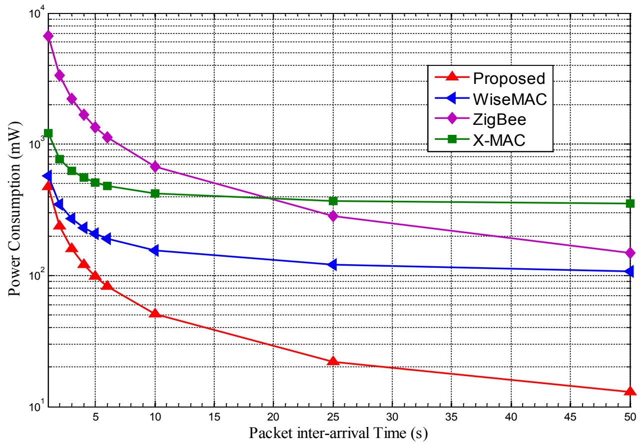

Fig 5. Power consumption

Fig 6 shows lifetime performance in terms of number of events. It is observed that reasonably low power consumption leads to higher lifetime for the proposed protocol. The wakeup radio is able to maximize the sleeping time of the devices, which saves a lot of power. It is also able to reduce idle listening and control packets overheads in the network.

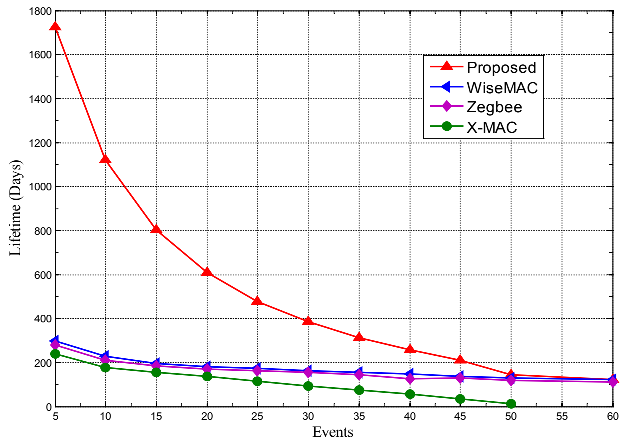

Fig 6. Lifetime

A wakeup radio based system is able to keep the devices in the network in sleep state whenever not in use. It reduces the potential causes of power wastage in idle listening and periodic wakeups. The rest of the protocols have no mechanism for sleeping device communication. It spends time in waiting for the device to wakeup for communication which wastes power.

5. Conclusion

Lifetime is a major design issue for wearable networks. Here, we present a simple and efficient external wakeup radio based protocol for wearable device communication. The major advantage is that it can be used to wakeup a sleeping device to communicate as and whenever it is necessary. It reduces several potential causes of power wastage such as idle listening and periodic wakeup intervals. We compared it with the existing protocols for performance evaluation. It is observed that the proposed scheme has better performance with an added advantage of the ability to communicate with a sleeping device without waiting for it to wakeup on its own time. This has increased the lifetime of the proposed protocol.

Acknowledgement

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