

# Wakeup Scheduling to Increase Lifetime for Wearable Networks

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## Abstract

Recent advances in sensing technologies and microelectronics have increased the use of wearable devices to monitor human body functions and its surroundings. A wearable network is an important research topic in the Internet of Things (IoT) domain. A typical wearable device has low resources in terms of power and processing capabilities. Reducing the energy consumption is one of the key design factors in a wearable network so that the devices may work for longer duration. Idle listening and overhearing are major causes of energy consumption. In this paper, we aim to address these issues by maximizing the sleeping time of a device (switched off) and avoid unnecessary wakeup time (idle listening) to save energy. We propose an external wakeup scheduling to handle the sleep/wakeup cycle of a device. Our method is able to reduce the idle wakeup time through the use of an out-of-band mechanism. It is found that the proposed method is able to conserve energy and prolong the lifetime.

## 1. Introduction

The wearable wireless sensor network is a popular research field [1,2]. An wearable network can monitor the human body functions and its surroundings to provide efficient health and personal care as shown in Fig 1.

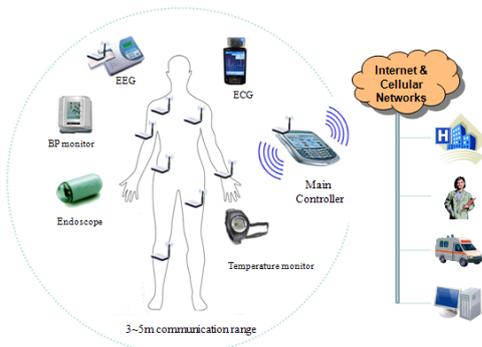


Fig 1. A typical wearable network

The wearable network can be used to monitor both medical and non-medical functions as presented in Table 1.

Table 1. Some applications

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

In a typical network, the receiver device must be switched on (awake) before the sender can transfer the packets [3]. Due to this reason, a receiver spends

extra time in the on state, which causes energy wastage. Sometimes, a device remains in the on state in anticipation of packets from a potential sender, which also causes energy wastage. The majority of the protocols use a sleep/wakeup scheduling to conserve energy. The schedule can be periodic or aperiodic. Wakeup scheduling is a major design issue in energy constrained networks. Current standardized protocols lack mechanisms to communicate if a device is not in the awake state at the time of communication. Therefore, in an event-based unscheduled packet transfer scenario, a sender must wait till the receiver device is awake causing delay and energy wastage.

To resolve this issue, we propose an external radio triggered wakeup scheduling for a wearable network. An external wakeup mechanism is shown in Fig 2. In this model, a low cost, low power wakeup radio circuit is attached to a wearable device.

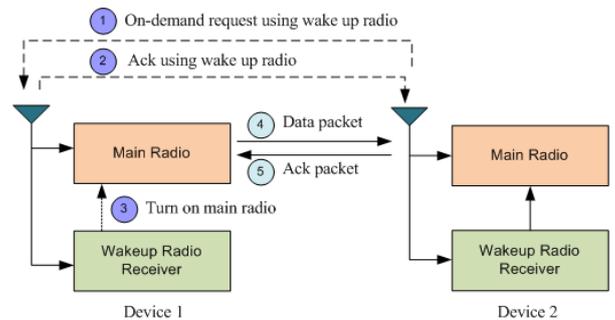


Fig 2. An external wakeup mechanism

In this work, we used an external radio to trigger on the receiver device as and when needed. This method

can avoid periodic scheduling, which reduces energy wastage. 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 complete protocol is comprised of two stages as shown in Fig 3. In the first stage, we model the wakeup schedule. In the second stage, we model the data communication.

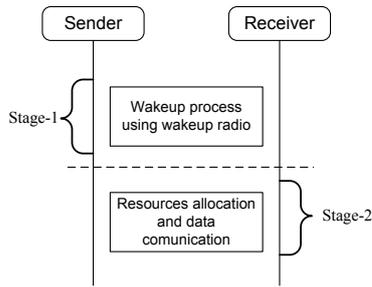


Fig 3. Communication process

The flow chart of the wakeup schedule is shown in Fig 4.

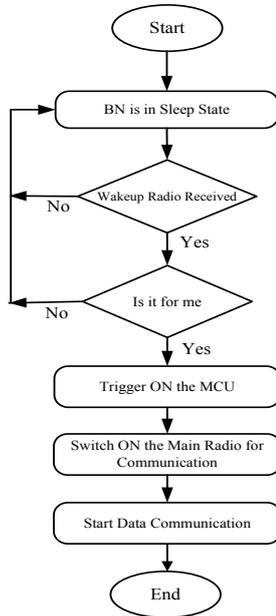


Fig 4. Flow chart

In the data communication stage, we have used the concept of cycles as shown in Fig 5.

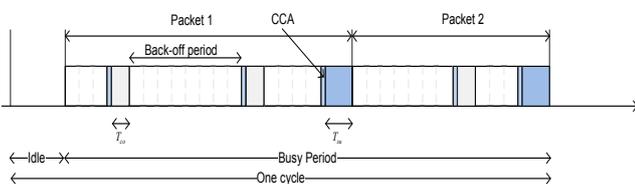


Fig 5. Two packets transmission in a cycle

In one cycle, a node spends time in the idle period and busy period. In the idle period, it sleeps and in the busy period it tries to transmit the packets. We have used a Wakeup Radio/Wakeup-ACK/Data/ACK operation.

### 3. Performance Analysis

We computed the energy consumption and lifetime of the proposed scheme. The traffic is modeled using Poisson distribution with arrival rate  $\lambda$  and service time  $\mu$ . We used M/M/1/K queuing model, where K is the buffer size. If a new packet finds the queue full, it is blocked. For analysis, we used packet blocked probability ( $p_b$ ), packet dropped probability ( $p_d$ ), utilization factor ( $\sigma_q$ ), retry limit (R) and average number of retransmissions ( $\alpha$ ).  $\rho$  is the offered load.

The energy consumption in a cycle is calculated as follows,

$$E = N_{pkt-b} \left( \frac{L_{pkt} P_{tx} + L_{ack} P_{rx} + (\alpha+1) \bar{B} T_{slot} P_{active}}{r} + (\alpha+1) T_{cca} P_{cca} + 2(\alpha+1) T_{sw} P_{sw} \right) + \frac{1}{\lambda} P_{sleep} \quad (1)$$

The packet delay is calculated as follows,

$$D_{pkt} = \left( \frac{\rho [1 + K \rho^{K+1} - (K+1) \rho^K]}{(1-\rho)(1-\rho^{K+1})} \right) / (\lambda(1-p_d)) \quad (2)$$

The number of retries is  $(\alpha+1)$ .  $\alpha$  is calculated as follows,

$$\alpha = \frac{1-p_c}{1-p_d} \left[ \frac{p_c [(R-1) p_c^R - R p_c^{R-1} + 1]}{(p_c - 1)^2} \right] \quad (3)$$

Where,  $P_{tx}$ ,  $P_{rx}$ ,  $P_{rx}$ ,  $P_{sl}$ ,  $P_{sw}$  be the power consumption in transmitting, receiving, sleep and transceiver switching states respectively. Let  $L_{ack}$ ,  $L_{pkt}$  be the length of ack and data packet respectively. Let  $r$  be the transmission rate and  $p_c$  is the constant conditional collision probability. Let  $T_{slot}$ ,  $T_{cca}$ ,  $T_{sw}$ ,  $T_{sl}$  be the data transmission time, acknowledgement time, transceiver switching time and sleep time respectively.

The lifetime ( $L_{lifetime}$ ) is calculated using the expression as follows.

$$L_{lifetime} = \frac{C_{battery} \times V}{E_{total}} \times 60 \times 60 \quad (4)$$

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

### 4. Results and Discussion

In this section, performance evaluation of energy consumption, delay and lifetime are presented.

4.1 Simulation Setup

The Network Simulator NS-2 (release v2.31) and TCL scripts are used to simulate the network [4]. The devices are placed in a 3m X 3m area. Each device uses 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	10
Data rate	25kbps
Packet size	70bytes
Controller range	5m
Traffic type	Poisson

Fig 6 shows the results for energy consumption. It is observed that the proposed model has very low energy consumption. Increasing the retry limit causes an increase in energy consumption.

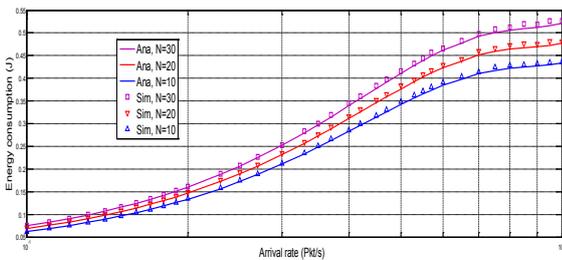


Fig 6. Energy consumption

Fig 7 shows delay results. The proposed model has a low delay due to prompt wakeup of the receiver. Increasing the retry limit has increased the per packet delay due to retransmissions increasing the access time.

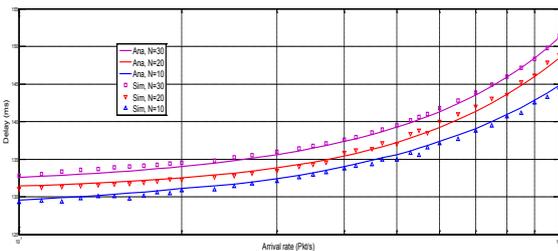


Fig 7. Delay

The lifetime is compared with some well-known protocols viz. T-MAC [5] and WiseMAC [6] protocols as shown in Fig 8. It is observed that the lifetime at low event rate is significantly higher than the rest of the protocols. The proposed model is able to avoid packet overheads, which causes the busy time for the transceiver to be shorter than other protocols. This results in lower energy consumption and packet delay, which in turn increased the lifetime.

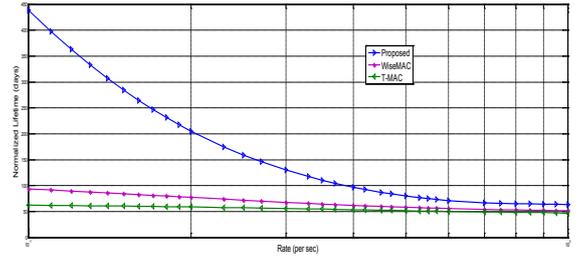


Fig 8. Lifetime comparison

5. Conclusion

In this paper, we present an external wakeup radio based scheduling for wearable device communication. It is observed that a wakeup radio based scheduling can keep the devices in the network in off (sleep) state whenever not in use thereby reducing energy consumption. A prompt wakeup causes lower delay, which reduces access time thereby saving energy. The proposed model is able to increase the lifetime of the wearable devices.

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