A Slotted Contention based Access Mechanism for Wearable Medical Devices

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Abstract

Applications focused on monitoring health status of patients through wearable devices are being developed. Majority of these devices are resource constrained. In this work, we present our initial design of a mechanism to manage such a network by taking into consideration the device buffer capacity and packet retry limits. We present performance analysis and results for the proposed scheme in terms of energy consumption and delay.

1. Introduction

Healthcare is one of the major fields employing sensor devices [1]. These devises can offer rapid diagnosis and help doctors/users by providing relevant information. The data collected can be stored for long-term evaluation and use. Numerous applications focused on monitoring health status of patients are being developed around the world [2,3]. Some typical devices and applications are ECG, blood pressure monitor, heart rate monitor, and temperature monitor etc.

A majority of the exiting medical wearable devices have limitations in terms of processing power, battery and memory capacity. Therefore, a network of such devices must be energy efficient so that it works for longer duration. This is particularly true if the user is far away from any energy source. Some other key design factors are low delay, high QoS, security, reliability, and adaptability to variable traffic, etc.[3]. A comprehensive network of these devices monitors the human body for different functionalities. It can provide long-term health monitoring without disturbing the patient's normal activities.

In this paper, we propose a mechanism to reduce energy consumption and delay based on slotted contention access by considering memory of the device and packet retry limits. The rest of the paper is organized as follows. In Section 2, we present related works and motivation behind our works. In Section 3, we present the system model and analysis. In Section 4, we present performance results. Finally, the conclusions are drawn in Section 5.

2. Related Works and Motivations

Majority of research works for wearable medical devices are found in the physical layer domain. However, some authors have discussed the networking issue of such devices. Authors [4] have summarized the state-of-the-art of wearable medical systems for personal healthcare system (p-Health). Authors [5] present a wearable ubiquitous healthcare platform in wireless sensor network. Author [6] has discussed a short-range wireless network and wearable bio-sensors for healthcare applications.

Our work is motivated by the design goals to reduce the overheads and keep in mind the limited memory capacity of the devices. It does not use control packets. Existing protocols rarely mention buffer capacity. A sensor device has limited memory capacity and hence cannot hold unlimited number of packets. We want to use finite buffer capacity in each device for our analysis along with retry limit.

3. System Design and Analysis

The design assumes that the devices are in range of a central controller. Before attempting to transmit, a device uses back-off mechanism. It chooses the value from the range [0, B], where B is the maximum value. The value a device chooses is called as back-off counter (BC). After its back-off counter expires, it senses the channel. If the channel is idle, it transmits the packet. If it senses the channel busy, it chooses a new value for BC and the process is repeated. If a packet collides, it is retransmitted again. When it reaches the attempt limit, it results in a failure and the packet is dropped. The flowchart is shown in Figure 1.

For analysis, we used the following parameters,

- Packet blocked probability (p_b)
- Packet dropped probability (p_d)
- Utilization (σ)

- Retry limit (R)
- Average number of retransmissions (α)

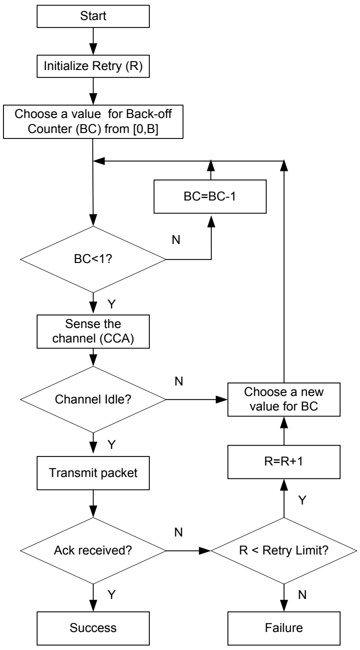

Figure 1. Flowchart

Service time is calculated from the time a packet arrives at the head of the queue until it is out from it (either due to successful transmission or discarded due to reaching maximum retry limit). It is given by,

$$\frac{1}{\mu}=\left(\alpha+1\right)\overline{B}T_{slot}+\alpha T_{co}+\left(\alpha+1\right)T_{cca}+T_{su} \quad (1)$$

The average number of retransmissions per packet (α) for a successfully transmitted packet is calculated in terms of the constant conditional collision probability (p_c) and packet dropped probability (p_d).

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

The parameter p_c and p_d are given by,

$$p_c=1-\left(1-\tau\right)^{N-1} \quad (3)$$

$$p_d=p_c^{R+1} \quad (4)$$

The parameter τ is the steady state probability that a tagged device transmits in a random time slot given that it has packet to transmit. For buffer not empty, it is given by,

$$\tau=\frac{\rho\left(1-p_b\right)}{\overline{B}+1} \quad (5)$$

where $\overline{B}$ and p_b are the average number of slots a device waits (back-off) before it transmits and packet blocked probability respectively.

$$\overline{B}=\frac{B-1}{2} \quad (6)$$

$$p_b=\frac{\left(1-\rho\right)\rho^k}{1-\rho^{k+1}} \quad (7)$$

A device has two periods - idle and busy. The total energy consumption (E) takes into account the energy consumption in transmitting packet, the energy consumption in receiving acknowledgement packet, the energy consumption during back-off, the energy consumption during channel sensing (CCA), the energy consumption during sleep state (idle period), and the energy consumption in overheads (transceiver switching and network synchronization).The expression for E is calculated by combining all the energy consumptions as follows,

$$E=N_{pkt-b}\left(\frac{L_{pkt}}{r}P_{tx}+\frac{L_{ack}}{r}P_{rx}+(\alpha+1)\overline{B}T_{slot}P_{active}+(\alpha+1)T_{cca}P_{cca}+2(\alpha+1)T_{sw}P_{sw}\right)+\frac{1}{\lambda}P_{sleep} \quad (8)$$

where, the parameter, N_{pkt-b} is the average number of packets served in the busy period. It is given by,

$$N_{pkt-b}=\frac{1-\rho^K}{1-\rho} \quad (9)$$

The average energy consumption (E_{avg}) is given by,

$$E_{avg}=\frac{E}{T} \quad (10)$$

where T is the length of one (idle and busy) period and given by,

$$T=\frac{1}{\lambda}+\frac{1-\rho^K}{\mu\left(1-\rho\right)} \quad (11)$$

The average packet delay (D) is calculated as follows,

$$D=\frac{\rho\left[1+K\rho^{K+1}-\left(K+1\right)\rho^K\right]}{\left(1-\rho\right)\left(1-\rho^{K+1}\right)}\Bigg/\left[\frac{1}{\lambda\left(1-p_b\right)}\right] \quad (12)$$

4. Performance Results

We have simulated the works in Network Simulator NS-2 (release v2.31). In the scenario, the number of devices is varied along with the packet arrival rate (λ). The retry limit is increased from initial 5 to 10 retries per packet. Other input parameters are presented in table 1.

Table 1 Input parameters

Symbol	Value
P_{tx}	26mW
P_{rx}	13.5mW
L_{data}	Variable
L_{ack}	10Bytes
r	25kbps
B	16, 32

The low energy consumption is very encouraging as shown in Figure 2. The proposed scheme does not use request to send (RTS) and clear to send (CTS) packets before commencing the transmission. This helps reducing the overheads and thereby improves the energy conservation. Increasing the retry limit causes increase in energy consumption. It is also observed that increasing the number of device increases the energy consumption due to the obvious reason.

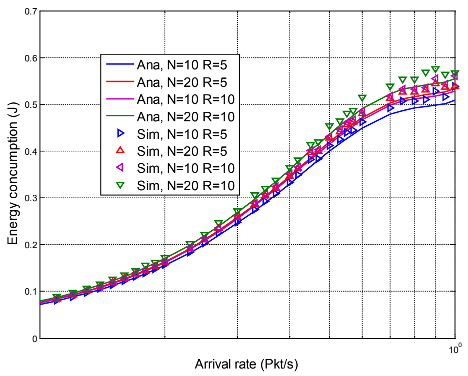

Figure 2. Energy consumption

Figure 3 shows delay results. The delay is reasonably low for the proposed scheme. Increasing the retry limit has increased the per packet delay. This is due to the fact that a packet can be retransmitted several times more before it is successful which increases the access time. The proposed scheme is able to avoid packet overheads, which causes the busy time for the transceiver to be shorter.

5. Conclusion

Wearable devices have very high growth potential in the healthcare domain. In this paper, we present a slotted contention based mechanism for wearable devices by taking into consideration of buffer capacity and retry limit. The proposed mechanism avoids the use of control packets. We have analyzed and simulated the energy consumption and delay and show promising results. Our future work includes modeling priority based access for different types of traffic in the network and test bed based implementation.

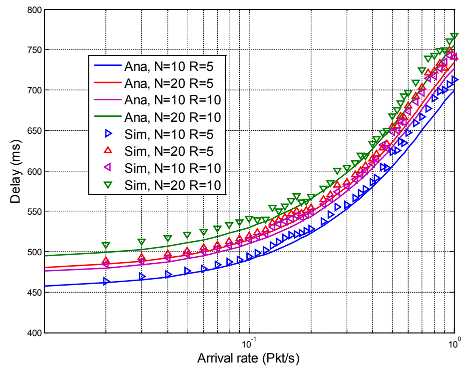

Figure 3. Delay

Acknowledgement

This research was supported by Basic Science Research Program through National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2014R1A2A2A01005900). Dr. CS Hong is the corresponding author.

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