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# Battery Friendly Internet of Medical Media Things Networks

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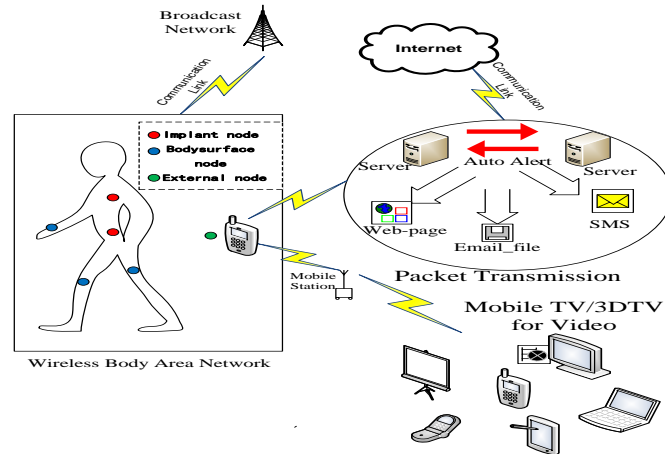
**Abstract.** The problem is motivated by the observation that most of the mobile and wearable healthcare devices used for wireless communication are battery-operated, and cannot be used indiscriminately because of limited energy sources and has to be regularly recharged from a power supply. We, therefore, design ON-OFF Battery Friendly Algorithm (OBFA) to prolong the life time of battery-operated devices by minimizing battery charge consumption. We select human vital sign signal Electrocardiogram (ECG) data from World's larger database, i.e., PhysioNet and tested with our proposed OBFA for further transmission over joint IoT and Wireless Body Sensor Networks (WBSNs). Experimental results reveal that battery charge consumption is minimized and lifetime is extended in comparison with conventional baseline algorithm.

**Keywords:** Battery Friendly, OBFA, ON-OFF Medical Media, WBSNs.

## 1 Introduction

Recently, Internet of Things (IoT) has become one of the most powerful communication paradigms of the 21st century. In the IoT paradigm, all objects in our daily life have connected to the internet because of their communication and computing capabilities including micro controllers, transceivers for digital communication. IoT encompasses the concept of the Internet and sorts it more widespread by allowing seamless interactions among different types of devices such as a medical sensor, monitoring cameras, so on. Therefore, IoT has become more productive in several areas such as healthcare system. In the healthcare system, IoT involves many kinds of cheap sensors (wearable, implanted, and environment) that enable aged people to enjoy modern medical health care services anywhere, anytime [1][2]. The WBSNs technology is one of the most important techniques used in IoT-based current healthcare system [3]. It is an association of low-power and lightweight wireless sensor devices that are applied to observe the individuals functions and the surrounding environment. Since, WBSN nodes are used to collect sensitive (life-critical) information and may operate in hostile environments, accordingly. A crucial challenge in all of these wireless technologies is battery's charge consumption and short lifetime during media (i.e., ECG) streaming over joint IoT and WBSNs. The main contribution of this paper is twofold. First, we design ON-OFF Battery Friendly Algorithm (OBFA) to minimize battery charge consumption and extend the lifetime of battery-operated devices for medical health, besides OFBA is tested with ECG data sets from PhysioNet. Second, a joint IoT and WBSN framework is proposed. The rest of the paper is organized as follows. Section 2, gives related work in detail. Section 3, discusses joint IoT and

WBSNs Architecture. Proposed OBFA is presented in Section 4. Experimental results are revealed in Section 5, and paper is concluded in Section 6.



**Fig. 1.** Limited Battery lifetime Problem during medical media streaming over joint IoT and WBSNs

## 2 Related Work

This section has two parts, first joint IoT and WBSNs, and second, battery model with recovery effect.

### 2.1 Joint IoT and WBSN

The advancement of WBSN in healthcare applications has made patient monitoring more feasible. Recently, several wireless healthcare types of research and projects have been proposed, which can aim to provide continuous patient monitoring, in-ambulatory, in-clinic, etc. Some of the traditional research projects about healthcare system using body sensor networks are, CodeBlue [3] a modern healthcare research project based on BSN developed at Harvard Sensor Network Lab. In this architecture, several bio-sensors are placed on patient's body. These sensors sense the human body and transmit it wirelessly to the end-user device (PDAs, laptops, and personal computer) for further analysis. But until now battery charge consumption and its lifetime extension is still pending and is very imperative for critical healthcare applications [4].

### 2.2 Battery model and Recovery effect

In this section, first battery model is discussed in detail. Then, we compute battery recovery charge with the proposed charge recovery mechanism, in which unavailable charge disappears after inserting idle time ( $\delta$ ) between tasks during medical media transmission over joint IoT and WBSNs, as shown in Fig.2.

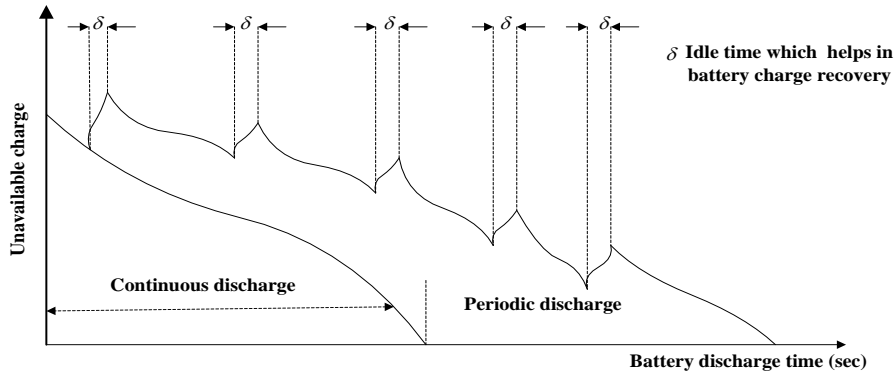
### 2.2.1 Battery Model

For designing Battery Friendly algorithm, the nonlinear behavior of battery must be studied. There has been remarkable research about battery characteristics in the last couple of years. D. Rakhmatov et al. [5] develop an accurate analytical battery model which is considered in our research.

$$\sigma(t) = \underbrace{\sum_{k=1}^M I_k \Delta_k}_{C(t)} + \underbrace{\sum_{k=1}^M 2I_k \sum_{m=1}^{\infty} \frac{e^{-\beta^2 m^2 (T-t_k-\Delta_k)} - e^{-\beta^2 m^2 (T-t_k)}}{\beta^2 m^2}}_{U(t)} \quad (1)$$

Whereby, the parameter  $\alpha$  exhibits the full charged state of the battery, and the parameter  $\beta$  shows the nonlinearity of the battery and gives knowledge about how fast the diffusion mechanism takes place with the rate of discharge. The battery performance improves and its discharge process slows-down with a higher value of  $\beta$ . The battery's cost function  $\sigma(t)$  in Equation (2), contains two parts. The first is the consumed charge  $C(t)$  over time  $t$ . The second is the unavailable charge  $U(t)$  over time  $t$ .

### 2.2.2 Recovery Effect



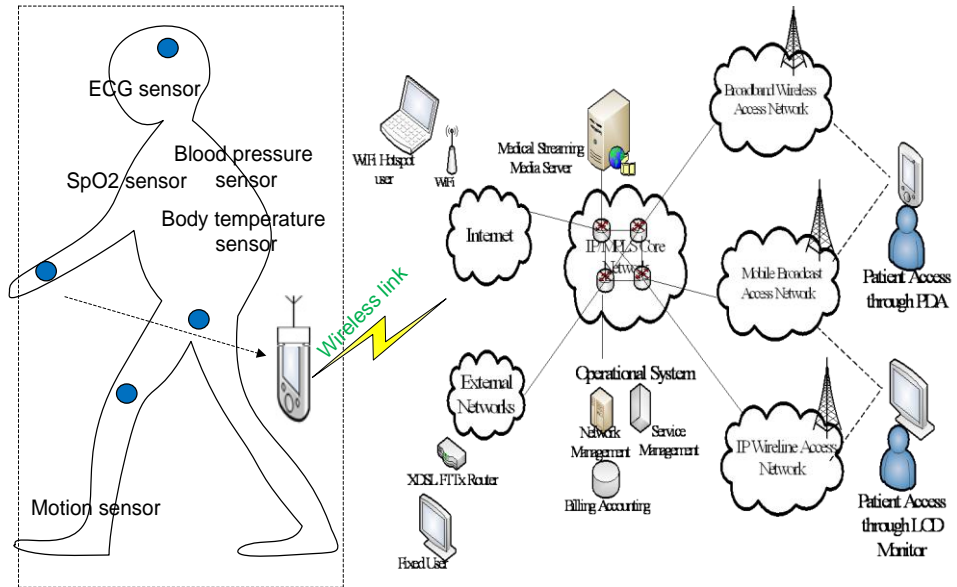
**Fig. 2.** Battery recovery effect during ECG data Transmission over joint IoT and WBSN

Fig. 2 shows that a periodic discharge extends the lifetime of a battery due to the idle time and recovery effect. For a continuous discharge, the slope remains reasonably consistent as anticipated. For a periodic discharge, however, the battery can recover some of the lost charges, resulting in a piecewise-continuous discharge slope which results in the longer lifetime of the battery. During medical media transmission over joint IoT and WBSN, we will let the sensor nodes with more remaining charge capacity to access the wireless link first by introducing a backoff period, which helps other sensor nodes with less remaining charge capacity to get sufficient idle time for charge recovery. We assume that when a receiving sensor node gets packets from transmitter node or ECG data transmission suspends for a while due to continuous

drop of packets; the battery recovers one unit of charge with probability  $R_{x_i, y_i}$  at unit  $i$ , in which  $R_{x_i, y_i}$  is given as in eq. (2). For further detail see [2][6].

$$R_{x_i, y_i} = \begin{cases} e^{-g \times (x - x_i) - \phi(y_i)} & x_i \in [1, x] \\ & y_i \in [1, y] \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

### 3 Joint Internet of Things and Wireless Body Sensor Networks Architecture



**Fig. 3.** Proposed joint IoT and WBSNs Architecture for medical media transmission

In the recent health monitoring environment, the usage of IoT technologies brings the suitability of doctors and patients. Subsequently, they are applied to numerous medical areas including patient information management, real-time monitoring, and healthcare management. The WBSN technology is one of the essential technologies of IoT advancement in the healthcare system, where subjects can be monitored by using various tiny-powered and lightweight sensor nodes [4]. Also, WBSN can connect with other wireless networks, such as IoT, WiFi, WiMAX and cellular networks, etc. So, in this paper we have proposed an architecture for ECG data packet transmission from the human body to the base station (BS) or receiver, then that data is transmitted through a wireless link (i.e., channel) to the central internet cloud. From central internet cloud, ECG data is further disseminated and observed in the wearable sensor devices. In this regard for a long time watching and analysis of the data at handheld wearable devices such as mobile, PDAs, LCDs, etc. there must be longer lifetime and less charge consumption.

## 4 ON-OFF Battery Friendly Algorithm (OBFA)

We design OBFA which takes longer time in ECG data packet transmission in an ON and OFF manner and arranges Current values higher to lower order. Besides, OFBA avoids from increasing Current value, by dynamically adjusting the average ECG packet transmission time according to the remaining idle time and size of the backlog (i.e., buffer). The interarrival time and arrival times of ECG data packets are denoted by  $\Delta_k$ ,  $t_k$ , respectively, as shown in the Figs. 4 and 5. Suppose, there are  $M$  ECG data packets which are processed in the time interval  $[0, T]$ .

$$d_M = T - t_M \quad (3)$$

$$\sum_{i=1}^M d_i = T \quad (4)$$

Assume the transmission duration of the  $M$  deadline constraint packets obtained by the transmission schedule is,  $\bar{\tau} = [\tau_1, \tau_2, \dots, \tau_M]$ . The transmission time of the  $j$ th packet that begins to be transmitted at a time  $t$  ( $0 < t < T$ ).

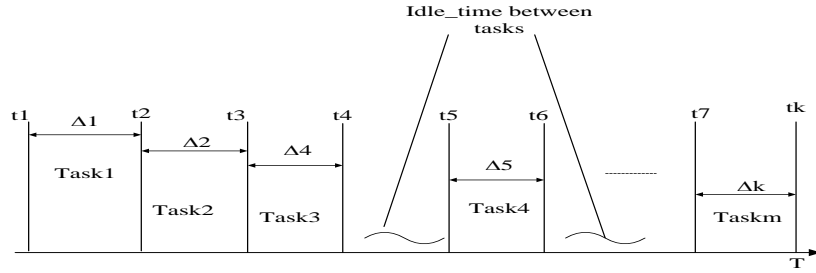


Fig.4. ECG data packet arrival  $[0, T]$  in OBFA

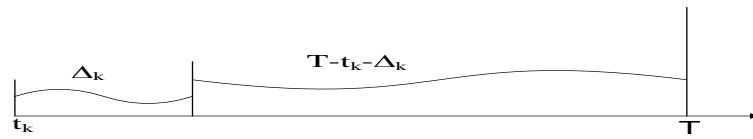


Fig. 5. Idle time of ECG data packets

$$\tau(j, b_j, t) = \frac{1}{M - j + 1 + b_j} \sum_{i=j}^M d_i \quad (5)$$

Whereby,  $d_i$  is the inter-arrival time of  $(M - j + 1)$  ECG packets arrive in period  $(t, T)$

## 5 Experimental Results and Discussion

In this preliminary analysis with MATLAB, we used ECG data sets (average size 200 bytes) from PhysioNet, the maximum Current value  $I$  of 200mA and packet transmission time of 7 minutes to minimize battery charge consumption during medical media streaming in over joint IoT and WBSN. Assume that there are four communication tasks with arrival time  $t = 0$ . For each transmission task, the duration, load Current, and deadline are described in Table 1. It is also evident that non-increasing Current profile does significantly better, which is 9.5% improvement in the residual charge for same data set duration of only 40 min. Therefore, proposed OBFA generates load profiles that enhance battery performance, with decreasing Current profile.

**Table 1.** Initial Task Specification

Task	Duration(min)	Deadline(min)	Current(mA)
1	10	25	300
2	10	25	200
3	20	25	150
4	40	25	75

**Table 2.** Charge consumption of OBFA and Baseline

Algorithm	Charge Consumption ( $\sigma$ ) [mA.mint]	RemainingCharge= $(\alpha-\sigma)$ [mA.mint]
Baseline	1068.70	34163.3
OBFA	1051.07	34180.93

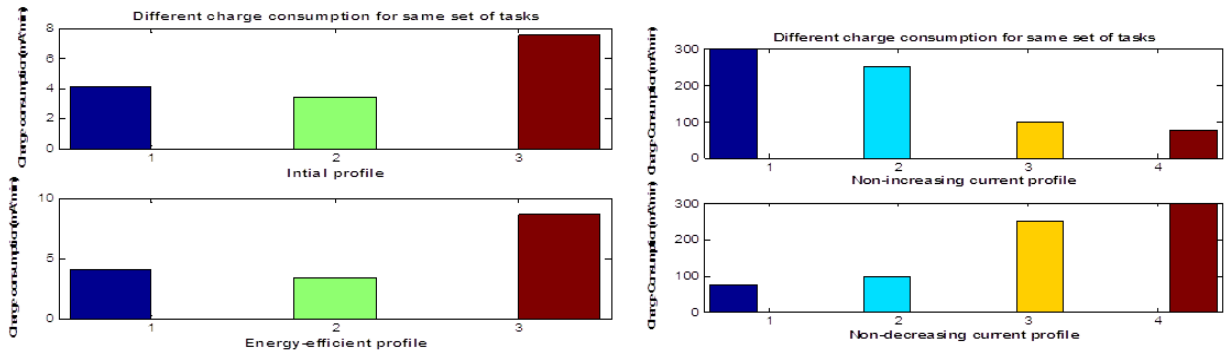
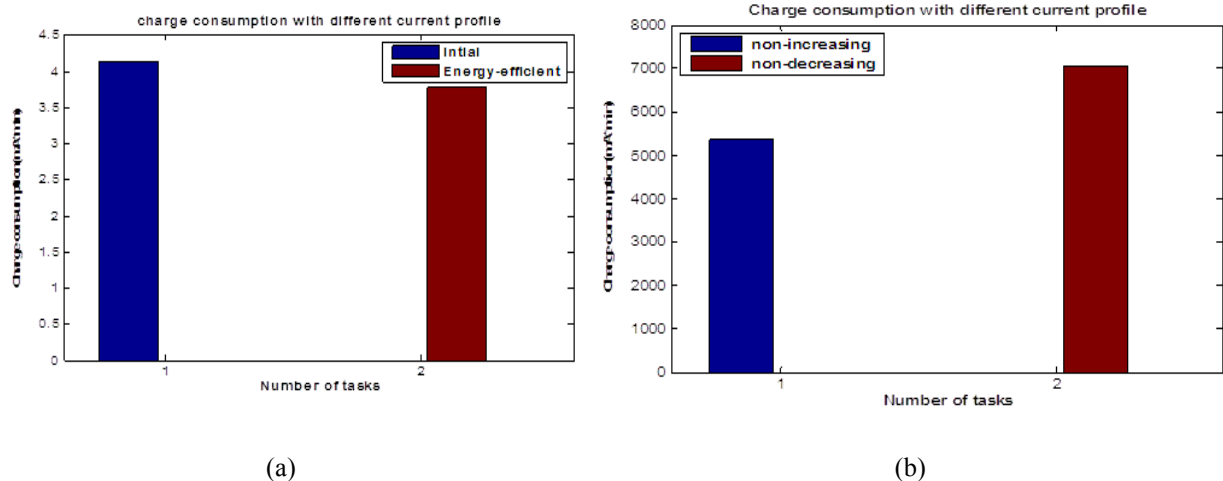


Fig.6. a) Charge consumption with different current profile, b) Charge consumption with same energy



**Fig.7.** a) Charge consumption with decreasing Current profile. b) Charge consumption with increasing current profile

Fig. 6 (a) reveals non-increasing and a current nondecreasing profile for the same data set respectively, besides it is observed that non-increasing current profile does significantly better, which is 9.5% improvement in the residual charge for same data set duration of only 40 mints. In Fig.(b) as current increase then battery performance will be degraded because in initial profile task3 has worst battery performance while in the energy efficient profile task3 has less present value and better battery performance than initial profile. In Fig.7(a) task1 has inferior performance because of the large current profile as compared to task2, so task2 has better performance and more energy-efficient. In Fig.7 (b) task1 has a small current profile and is energy-efficient while task2 has a large current profile and less energy-efficient, so we can say that task2 performs better than the task1. This simple experimental analysis reveals that battery performance is dependent on the discharge characteristics of an application rather than merely energy consumption.

## 6 Conclusion and Future Research Work

According to the features of the battery, to minimize battery charge consumption during vital sign signal transmission is not equivalent to extending its life time. So the best way to broaden the lifetime of battery-driven devices is to design Battery Friendly Algorithm. We first develop a battery model according to the behavior of the IoT and WBSNs, second, we developed OFBA and tested with selected ECG data over joint IoT and WBSNs, third, due to the battery recovery effect, rate capacity, charge minimization is minimized as compared to the conventional baseline scheme. Our future work is to focus on research directions regarding energy conserving issues in wireless networking-based IoT.

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