# Battery Friendly Internet of Medical Media Things Networks

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**Abstract.** Rapid proliferation in the medical wearable device market has become the center of attention and changed the every corner of the medical world for the effective and economical information transmission, but because of the tiny size and high power drain more battery charge is consumed, so to remedy that problem this paper proposes ON-OFF Battery Friendly Algorithm (OBFA) to minimize the energy drain and hence to enhance the battery lifetime of these portable devices. Patient's bio-signals such as, electrocardiogram (ECG) data from World's larger database, i.e., PhysioNet is taken and examined with our proposed OBFA for further transmission over joint IoT and Wireless Body Sensor Networks (WBSNs). Experimental platform reveals that battery charge consumption is reduced and lifetime is improved in comparison with traditional baseline scheme.

**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 [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-

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power and lightweight wireless sensor devices that are applied to observe the individuals functions and the surrounding environment. 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 Sect. 4. Experimental results are revealed in Sect. 5, and paper is concluded in Sect. 6.

## 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. 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

Due to the emerging need of the wearable devices there is a highly demand of the battery models so this research proposes the impact of the recovery effect and the battery model by introducing the concept of the idle time $(\delta)$ between tasks during medical media transmission over joint IoT and WBSNs, as revealed by Fig. 2.

#### 2.2.1 Battery Model

To develop the battery-efficient techniques it is very vital to clearly understand the features of the battery, because it impacts a lot on the entire platform of the medical health from diagnosis to examination. So, analytical battery model is designed by following the [5]

$$\alpha(t) = \sum_{k=1}^{N} I_k \Delta_k + \sum_{k=1}^{N} 2I_k \sum_{m=1}^{\infty} \frac{e^{-\beta^2 m^2 (L - t_k - \Delta_k)} - e^{-\beta^2 m^2 (L - t_k)}}{\beta^2 m^2} \tag{1}$$

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

Parameter $\alpha$ presents the fully charged status of battery, and the $\beta$ depicts it's the non-linearity and provides information about rapid dispersal rate of the battery. The battery accomplishment will be appeared and un-available charge converts into charged ones with increased value of $\beta$. To find the battery charge depletion $\sigma(t)$ after the processing of $M$ ($M < N$) at time $T$ ($T < L$), then by changing $N$ with $M$ and $L$ with $T$ in Eq. (1), which gives Eq. (2). $m$ reveals the number of tasks and $T$ is the deadline time for finishing tasks. The battery's cost function $\sigma(t)$ in Eq. (2), includes two parts one is consumed charge $C(t)$, and other is unavailable charge $U(t)$ over time $t$. The $C(t)$ is the original charge value linearly connected to current $I_k$ and time between the two packets $\Delta_k$.

### 2.2.2 Recovery Effect

In Eq. (2) the empty level or unavailable charge $U(t)$ vanishes over time $t$ when charge is drained in a non-stop manner. Figure 1, reveals that a random charge drain enhances the lifetime of a battery because of ineffective schedule and charge recovery time. For an uninterrupted charge recovery, the slant is fixed according the need. For a regular discharge nevertheless, battery regains little depleted charge, leads to piecewise-regular discharge deviation. High residual charge will be kept at top most priority than the nodes with less charge capacity with backoff time. Battery charge will be increased by one unit with probability $R_{x_i,y_i}$ at unit $i$, as represented in Eq. (3).

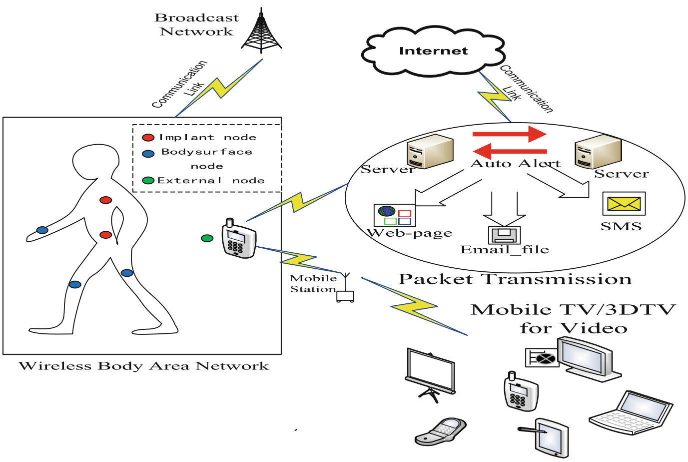



**Fig. 1.** Limited battery lifetime problem during medical media streaming over joint IoT and WBSNs

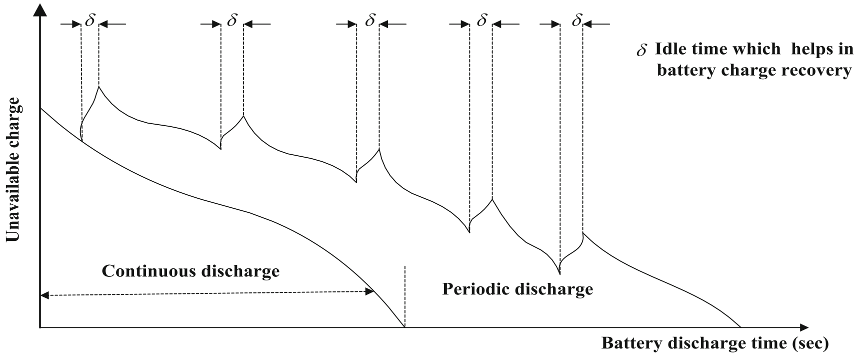



**Fig. 2.** Battery recovery effect during ECG data transmission over joint IoT and WBSN

$$R_{x_i,y_i} = \begin{cases} e^{-g\times(x-x_i)-\phi(y_i)} & x_i \in [1,x] \\ & y_i \in [1,y] \\ 0 & otherwise \end{cases} \tag{3}$$

Whereas, $g$ and $\phi(y_i)$ reveals the fixed value entities and function which is helping units transferred according to battery properties, respectively. Ordinarily, the value of $\phi(y_i)$ badly encounters the battery recovery. The $x$ and $y$ reveals the apparent and analytical storage of the battery, subsequently. IoT platform is very powerful in which various nodes communicate with and interlinked with the wireless link, by MAC protocol's mechanism [2, 6].

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

In the recent health monitoring environment, the selection of the IoT technologies creates the convenience and ease to the hospital staff with the extended support to the other inter-related services including patient information management, real-time monitoring, and healthcare management. The WBSN is the building block to establish the path towards IoT world to facilitate the common citizen with the emergence of the tiny wearable devices [4]. 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 (Fig. 3).

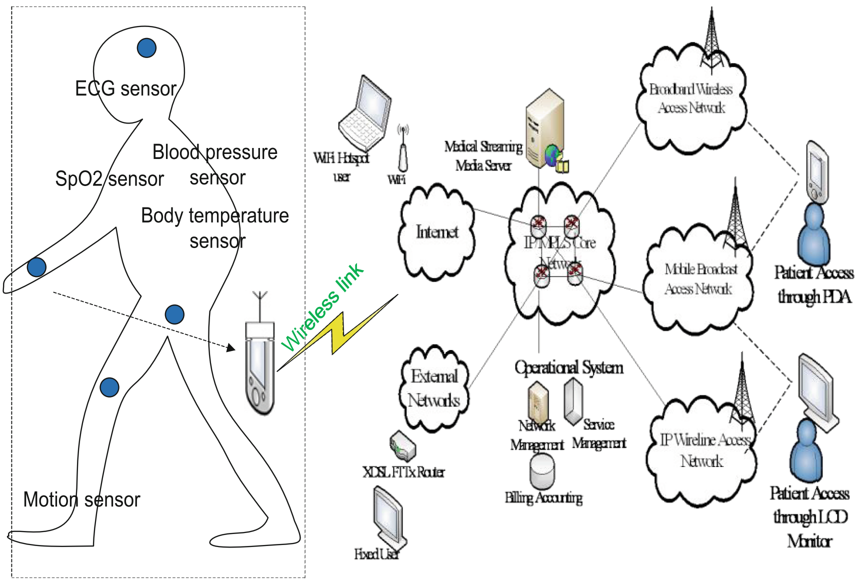



**Fig. 3.** Proposed joint IoT and WBSNs architecture

## 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 $[0, T]$.

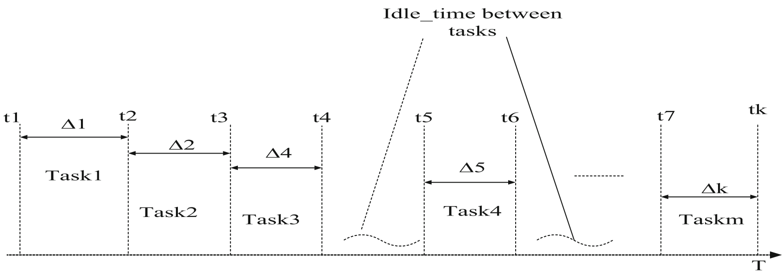



**Fig. 4.** ECG data packet arrival [0,T] in OBFA

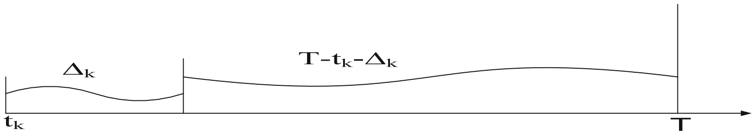



**Fig. 5.** Idle time of ECG data packets

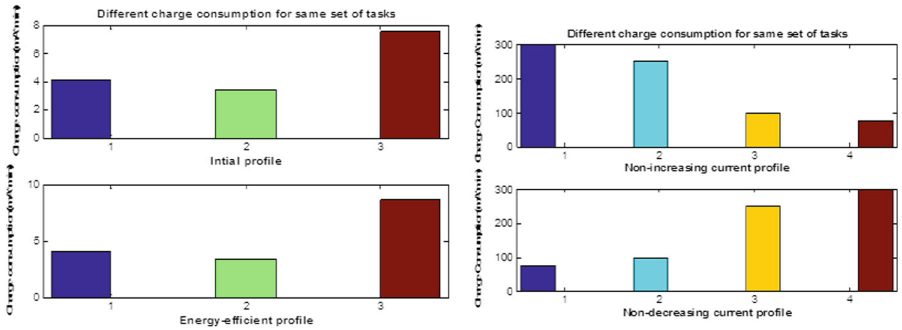
$$d_M = T - t_M \tag{3}$$

$$\sum_{i=1}^{M} d_i = T \tag{4}$$

Assume the transmission period of the $M$ deadline constraint data received by the transmission schedule is, $\vec{\tau} = [\tau_1, \tau_2, \ldots\ldots\ldots\tau_M]$. The transmission of the $jth$ packets will be started at a time $t(0 < t < T)$.

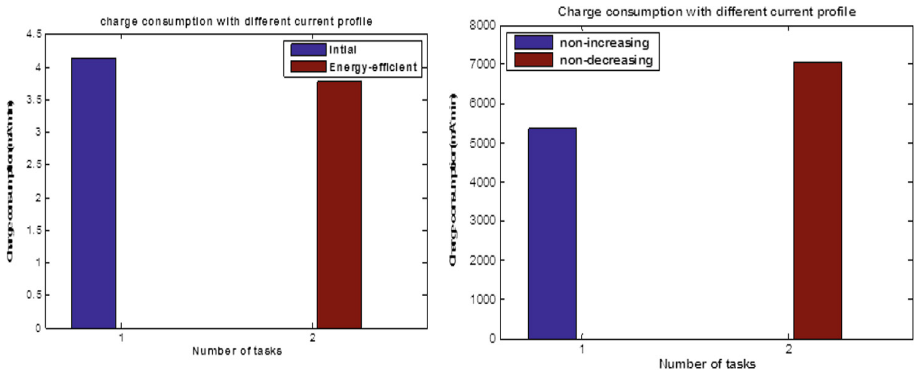
$$\tau(j, b_j, t) = \frac{1}{M - j + 1 + b_j} \sum_{i=j}^{M} d_i \tag{5}$$

Whereby, $d_i$ is the inter-arrival time of $(M - j + 1)$ ECG packets arrive in period $(t, T)$ (Figs. 6 and 7).




(a) (b)

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




(a) (b)

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

## 5 Results and Discussion

Particular analysis in MATLAB, we used ECG data sets (average size 200 bytes) from PhysioNet, the maximum Current value $I$ of 200 mA and packet transmission time of 7 min 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 value (Table 2).

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

| Charge drain (σ) [mA.mint] | Supplent charge = (α − σ) [mA.mint] |
|---|---|
| 1068.70 | 34163.3 |
| 1051.07 | 34180.93 |

## 6 Conclusion and Future Research Work

Battery properties are the key to analyze the performance of the entire system then to made changes accordingly in terms of lifetime enhancement 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. In near future IoMT and the Telemedicine will be focused.

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