Internet of Things
Developing an optimal wireless power transfer system for a real-world low power LED wristband application

Muhammad Wasif
Imara Speek
Delft University of Technology
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Abstract

Keywords: Wireless power transfer, low power, real-world application

1 Introduction

introduction

2 Related work

related

3 Prior knowledge

prior

4 Description of the proposed idea

decription idea

4.1 Working towards a realization

Our major goal is to provide with an efficient solution that best meet the challenges in battery charging systems using wireless power transfer. Those challenges include:

1. Charging the battery as quickly as possible. Though batteries can store large amount of charge but unfortunately there is a limit to how fast a battery can be charged and this limit gets smaller with the size (capacity) of a battery. Smaller the battery, smaller the charging current limit will be and exceeding this limit will deteriorate battery's life. To overcome this difficulty we proposed adding a super capacitor in parallel with a battery. Even though super capacitors can hold less amount of charge compared to the same size battery but they can be charged much faster [3].

2. Providing long battery life with large charge to discharge ratio. In our scenario we want to make the charging interval as small as possible which requires a need to store as much charging current as possible in this short interval and that makes the addition of super capacitor an ideal solution to overcome the battery charging limitation. During the charging interval, super capacitor can store large amount of charging current and then later use this current to charge the battery with slow pace. Which provides long battery life in terms of large charge to discharge ratio.

3. Working out efficient protocol for sharing the available charge.

4.2 Protocols concerning environmental impact features

The major goal of this report is to be able to develop a real-world application. In order to do this, all real-world implications need to be taken into consideration. Scenario's were developed to develop a charging protocol that accounts for all possible states. For these scenarios a user wearing a tranceiver wristband is considered. Other viewpoints for a scenario can be the user wearing a receiving wristband or the transmitting bar. However, these viewpoints are considerably easier to address and will implements parts of the protocol designed for a tranceiving system.

There are certain states in which the system can reside depending on its own battery state, the battery state of neighbour nodes and the availability of a charging bar. These states and their transmissions are displayer in figure 1. It can either be sufficiently full defined as Vfull, starving defined as Vstarve or dead which is defined by Vdead. These parameters are further specified in section 5.

A charging protocol has to be designed to account for these combinations. We considered three possibilities: an infinite network like design, a hop-to-hop spread of energy or an interactive behavior to selectively share energy. To stimulate interaction through this application we choose to apply a scenario where a user can choose to act upon energy requests and share with friends, or strangers.

To handle these protocols, an IC has to be added. This way whenever the battery reached Vstarve it will send out a request for energy visually by litting a red LED embedded in the wristband. Neighbouring nodes can then choose to react on this or save their own energy. Whenever the battery dies, the user either has to verbally ask for energy of visit an energy bar.

5 The proposed system design

The Figure The transmitter is powered up by a voltage source V_i of 12 Volts capable of delivering 400 milli-Amps of i_{in} current. i_c is the constant current that is consumed by the transmitter circuitry and i_s is the induction current which flows through the transmitter coil such that $i_{in} = i_c + i_s$. i_c is constant and depends on the transmitter inner circuitry power consumption, in our case $i_c = 100 milli - Amps$. i_s depends on the distance between the two magnetically coupled coils, greater the distance smaller the i_s will be. Another factor that i_s could depend is on adding an iron core between the two coils, adding a core makes the magnetic coupling stronger and increases the i_s which enhances an overall efficiency of the system. The receiver circuit receives an induction voltage V_r, rectifies it through a rectifier containing a shotkey diode D_r and a capacitor C_r. A shotkey diode is used in order to have a good frequency response at the range of $300 - 400 Khz$ the transmitter working frequency also shotkey has lower forward voltage drop. The rectified voltage is then fed to the voltage regulator that produces constant voltage $V_{reg} = 5 Volts$.
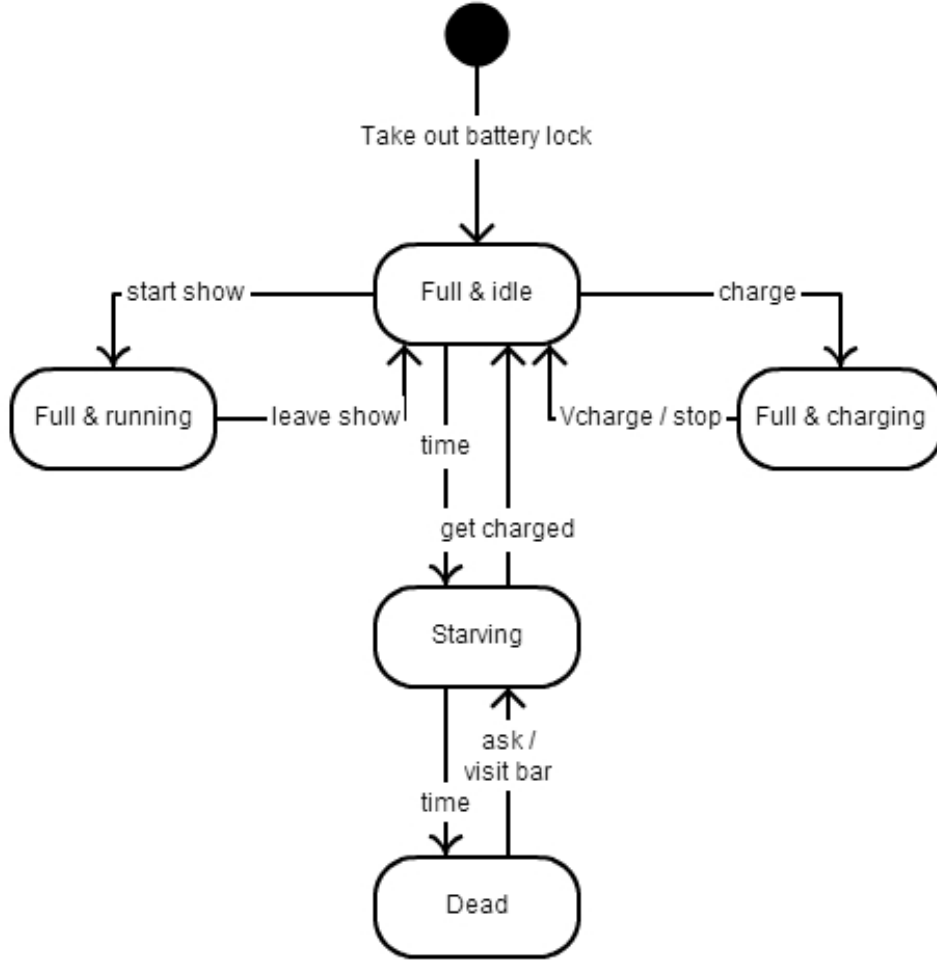
Figure 1: State diagram of a transceiving wireless power transfer system
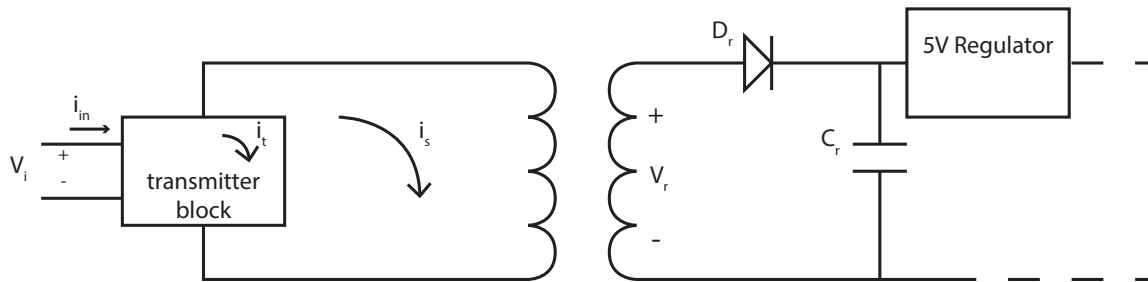
5.1   Analysis of the system design

Figure 2: Internet of things chain of actions

split the figure into charge cycle and discharge cycle The Figure 2 shows a low level schematic of the receiver and charging circuit which will be the main focus of our project. The induction current i_r induced by the transmitter through magnetic coupling will be the main source of
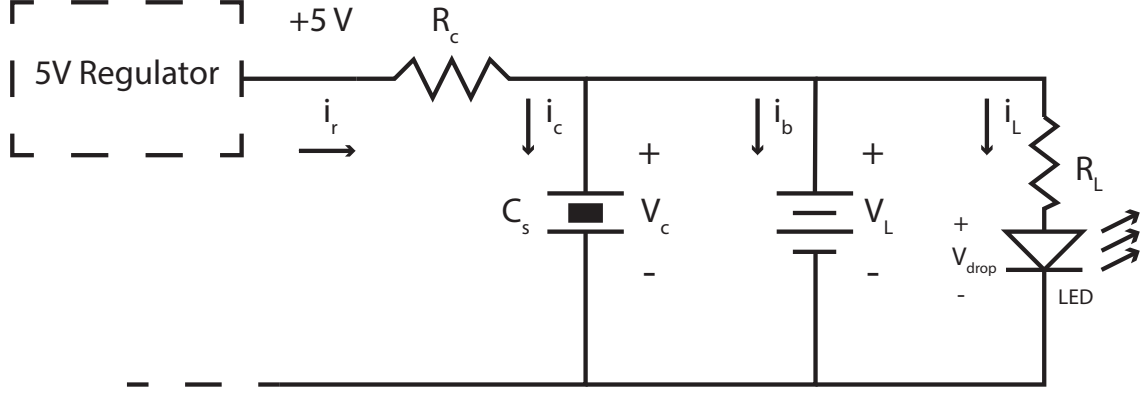
Figure 3: Internet of things chain of actions

charging current. The current i_c charges the super capacitor C_s up to the capacity of V_c, in our case $V_c \leq 5$ Volts the maximum voltage rating of super capacitor, i_b charges the battery and i_L is consumed by the current limiting resistor R_L and a light source LED. Where $i_r = i_c + i_b + i_L$. Now in analysis lets first consider the efficiency η of the circuit. If P_o is the power consumed by the receiver and P_i is the power provided by the transmitter, ignoring small power drops across D_r and C_r then:

$$\eta = \frac{P_o}{P_i} \tag{1}$$

where $P_o = V_{reg} \times i_r$ and $P_i = V_i \times i_s$ The battery at receiving end when fully charged can provide $V_l = 3$ Volts. For 3 Volts lithium-ion battery the output voltage normally drops by 0.2 Volts when battery is at 40% of its capacity and can go to 2.6 Volts when almost drained [3]. Hence a slight dim in LED brightness can be observed as battery drains with time. For normal brightness of LED with forward voltage drop of $V_{drop} = 1.7$ Volts we choose $i_L = 20$ mA then using equation 2 we found $R_L = 65\Omega$

$$R_L = \frac{V_l - V_{drop}}{i_L} \tag{2}$$

To find out with what power ratings of R_L should be used we can use $P_L = i_L{}^2 \times R_L$ which gives us $P_L = 400\mu$ Watts, which is the power dissipated at R_L and can be avoided if we use a LED that has exactly the same forward voltage drop V_{drop} as the battery output V_l that will remove the need of R_L. However, LED is very sensitive to even small change in the applied voltage, a voltage change of 0.1 Volt can cause the LED current i_L to shot up beyond the limits hence a more careful consideration is required if one chooses to omit the current limiting resistor R_L. The battery that we are using has a capacity of 50 mAh, which means if current I_B of 50 mA is continuously drawn from the battery then it can last for one hour. To find out total battery life for our circuit we need to consider the total power consumed P_c, for our case $P_c = i_L \times V_l$ from which we can calculate total life of fully charged battery.

$TotalBatteryLife = \frac{BatteryCapacity}{PowerConsumed} = \frac{I_B \times V_l \times 1hour}{i_L \times V_l} = \frac{50mA \times 3V \times 1hour}{20mA \times 3V} = 2.5 hours$

Now lets consider how the charging and discharging of the receiver circuit works. According to manufacturer specification $i_r \leq 400$ mA , which enforces the limit for the system to function properly. In figure the super capacitor C_s has very low series resistance of 0.07Ω compared to $R_L = 65\Omega$ hence during charging we can say that $i_c \approx i_r$ and if the $i_r(t)$ is not constant and

depends on time then the capacitor charging is governed by the following equation

$$V_c = V_{reg} \left(1 - e^{\frac{-t}{R_c C}} \right)$$ (3)

where R_c is the series limiting resistance of receiver circuit whose value depends on the maximum value of i_r and C is the total capacitance of super capacitor which in our case $C_s = 5$ Farads R_c can be chosen using $R_c = \frac{V_{reg}}{i_r}$ for maximum allowed $i_r = 400$ mA which gives us $R_c = 12.5\Omega$
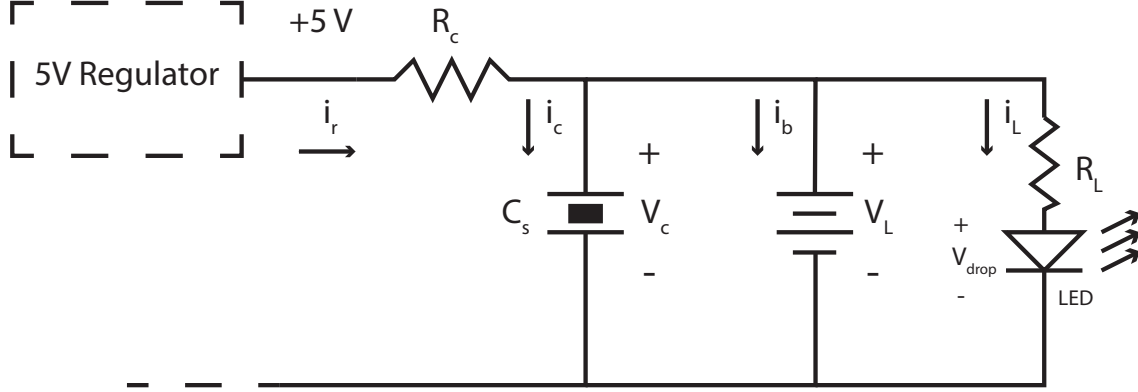

Figure 4: Internet of things chain of actions

Figure 4 shows charging, discharging and idle profile of the super capacitor during the system operation. In initial charging cycle t_{ci}, C_s is charged using $i_r(t)$ following equation 3 and during discharge cycle t_d, the $i_r(t) = 0$ and discharge current is supplied in the form of i_b and i_L. Finally during the equilibrium cycle t_{eq} the voltage is reduced to equal the battery voltage ($V_l = 3$ V) such that no current flows between the battery and super capacitor and $i_b = 0$, at this stage only battery's charge is used to power the LED. At last during the second charge cycle t_{c2}, the capacitor's charging starts from equilibrium voltage instead of 0 and is charged to V_{reg} un till the discharge cycle starts again.

5.2 Charge to Discharge ratio

If current i_r is provided for a time period t then how long the system will keep running with this provided current is defined by the charge to discharge ratio C_r and is given as

$$C_r(t) = \frac{i_r(t)}{i_L}$$ (4)

where $i_r(t) = \frac{5 - V_c(t)}{R_c}$ is the current provided for charging at time t and is given by

$$i_r(t) = \frac{5 - V_c(t)}{R_c}$$ (5)

As $C_r(t)$ is only meaningful during the time when $i_r(t) \neq 0$ which corresponds to time intervals t_i and t_n in the figure 4. Hence we can plot $C_r(t)$ for these intervals as shown in figure 5 (a) and 5 (b). From figures we can observe that $C_r(t)$ decreases with time till the value of 2. This is because of the capacitor's charging nature, as C_s starts to charge up,$V_c(t)$
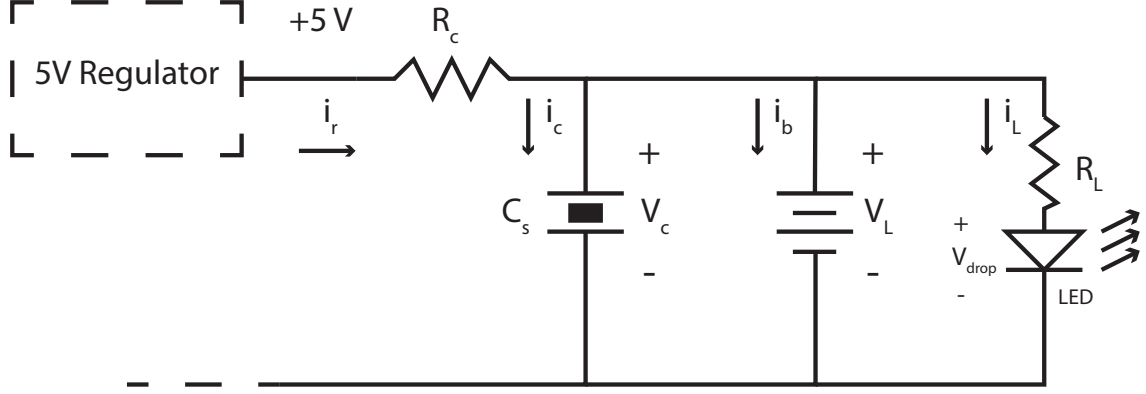
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Figure 5: Internet of things chain of actions

starts increasing which decreases the value of $i_r(t)$ [eq:[?]] and eventually $C_r(t)$. To make more meaningful analysis of charge to discharge ratio one can find the average value of $C_r(t)$ using

$$C_{avg} = \frac{1}{T} \int_t C_r(t)\mathrm{d}t. \tag{6}$$

In figures 5 for t_i and t_n we can see the value of C_{avg} to be 6 and 3.14 respectively. The value 3.14 for t_n is of more importance as this value represents the rest of the charging cycles through out the system operation. $i_r(t)$ is responsible for the decrease in $C_r(t)$ which means that the receiving energy is not fully exploited. C_{avg} can be further improved if we can somehow exploit the $i_r(t)$ to its maximum value for all times t. This can be achieved by using a component that can provide constant current regardless of the change at its output voltage. Such components have internal DC to DC convertor and are referred as constant current capacitor/battery chargers. If such a component is added to charge the super capacitor than it is possible to get $i_r(t)$ as constant maximum allowed value for all times t.
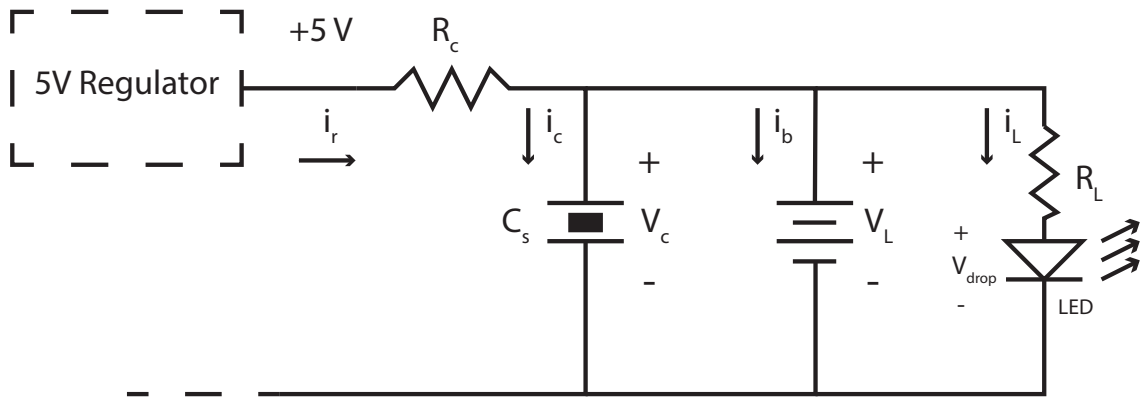

Figure 6: Internet of things chain of actions

For constant i_r, $C_r(t)$ profile is shown in figure 6, we can observe that $C_r(t)$ value has been improved to 15 and it stays constant for all values of t.

5.3 The internet of things

The assignment of this report conveyed critizing and accessing system-level Internet of Things components in scientififc literature. Because the assigned paper [4] did not include anything IoT related, we will present our own idea. In this section we will provide a short introduction to the Internet of Things and its key features, we will also present our idea and focus on the practicality and entrpreneurial aspect of the idea.

The Internet of Things refers to uniquely identitfiable objects, or things, and their virtual representations in an Internet-like structure. [5]. The intelligent application is the key feature here. Important aspects to be taken into consideration when designing such systems are security, privacy and scalability.

The anatomy of Internet of Things is initiated by a certain event, that is detected and logged by devices that include self-properties [5]. This data is then uploaded by a ubiquitous and interoperable network. The unique feature of the internet of things is that this system is smart and can generate knowledge and by analyzing this data and understands the system. Certain events are then triggered and reported as response. The intelligence of these systems lie in the adapting mechanisms that analyse and understand the environment in order to deal with the complex dynamics of a real-world environment.

Internet of Things has already been employed at multiple festivals and initially used as a ticketing solution in 2004 at the SXSW festival in Austin. It emerged in the form of wristbands and cut down significantly on gate crashing and lost tickets [7]. SXSW announced that each tag contained a unique ID code, correlated with personal information availabe by SXSW [6]. It has further been introduced at Coachella and Bonnaroo. [1] [2] RFID now even support cashlesh payments and integration with social networks, allowing people to upload pictures to facebook via the so-called "Live Click Stations"[7]. We can conlude that it safe to say that the Internet of Things hasn't reached its peak yet concerning festival and concerts.

Because our scenario already portrays users wearing a wristband throughout the festival containing the discussed electronics, we can add some small features to play into current trends concerning Internet of Things and music festivals. By adding a RFID tag into each wristband, users are assigned unique IDs. These tags can be applied fairly easy and can obviously contain functionality such as a unique entrance ID or even cashlesh payments. In this report however, we want to focus on the fun factor of connecting with friends and strangers. Users can prior to arriving at the festival use their unique ID and optionally link it to all the accounts of their friends are the accompanying social media. When the users enter the festival site and receive their wristbands, these are connected to their unique id priorly received. Whenever they charge their wristband, either at the bar or at check in points near every site of interest, their friends that are not near them will receive a message containing their location and if made, an image at the check-in location. Based on certain check-in's at time in the schedule of the festival, the system can recognize their interests (if not already mentioned in their id page online) and even give them recommendations to go next to. The sequence of this Internet of things can be seen in figure 7.

Our system goed beyond simply assigning a unique id to a user, it also adds functionality and connects ids to exchange information. In this manner, it mines the data when users check in at charging points where they can even choose to make a picture. These check-ins are logged and send to a server, where the users ID is processed and connected IDs of friends are notified. The system can then analyze the data and generate knowledge by searching for common factors of interest. Based on this intelligence, the system can in turn return some recommendations back to the user. This doesn't just improve the experience of the user, but it gives the organization a better insight into the behavior of their visitors.
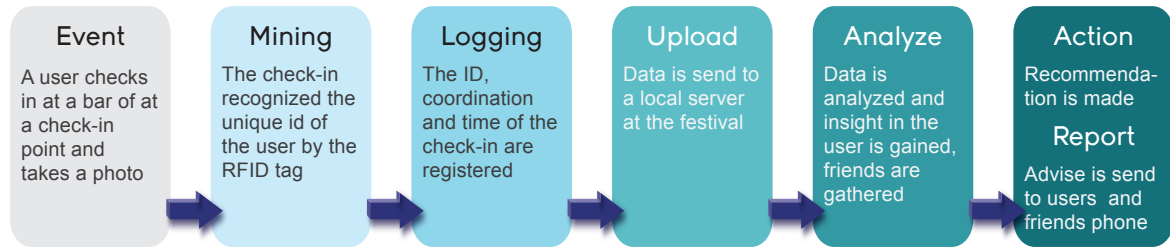
Figure 7: Internet of things chain of actions

6 Results

results

7 Conclusion

conclusion

References

[1]

[2]

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