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A Model Approach Towards Energy Harvesting And Battery less Self Powered Internet of Things (IoT) Applications

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Abstract: Wireless sensor networks has ruled the market for decades and later evolved a similar sensor network using Internet of Things where the sensors sense the data and manage to push to a cloud backend processing system for further processing. For this to happen the ability of Internet-of-Things (IoT) based applications to sustain for an uninterrupted operation based on energy harvesting and natural power sources plays a key role. In this paper, we discuss the need and various ways of saving power involving selection of proper controllers which process the data in wireless IoT based sensor network and also we propose a power saving method to deploy an IoT system for various indoor and outdoor applications. Our aim is to provide an efficient strategy for harvesting energy and use mechanisms of battery less deployments for IoT sensor nodes for achieving a completely unattended and maintenance free system.

Keywords: Internet of Things (IoT), Energy harvesting in IoT, Battery less IoT

1. INTRODUCTION

The advent of diverse enhancements led to the revolution of IoT in home automation, wearables, and industrial applications. This brought up the demand to miniaturize and improve the portability of sensing and communication electronics in the field of IoT. The existing technology supports either battery operated or direct power injected systems. Some low energy consuming systems use 3.3 volts microcontrollers in conjunction with sensors powered by low cost coin cells as a popular low-cost choice for power supply in a small form factor. The major complication lies in its maintenance if the sensors are placed at a remote and an inaccessible place. Further in case of abundant number of sensor being deployed for a specific application like home automation then the things like changing battery and maintaining them becomes a lot more tedious[6]. One important aspect in providing an efficient IoT sensor application is to harvest energy either by scavenging the wasted power or powering the application via a naturally available energy source such as a photovoltaic cell[8]. Energy harvesting is therefore considered to be an important feature of IoT applications. Here it is very important to understand the need of energy harvesting and properly manage the power source within the electronic system so as to lengthen its life and reduce the overall power requirements of the whole application. The field of energy harvesting have no strong evidence in providing a rigid battery less or energy harvesting system which creates a bottleneck in the enhancements of a true IoT sensor system [1][8]. Having said that it is very important to define a model approach that would fit in any IoT application especially battery less or energy harvested IoT based sensor network.

Now imagine a complex network where there are thousands of sensors so called the edge devices or the nodes in terms of the Internet of Things terminology collecting abundant amount of data altogether forming a big data source. Of course this data needs to be processed by some processing unit in the IoT architecture of the said application. With a keen observation its very evident that not all sensors sense and push the data for processing by the low voltage microcontroller, which reflects our model of saving energy by selecting only a power source which would be sufficient enough to source only a required amount of nodes at a given amount of time. This makes us think over the build of the complete framework of the application in terms of the selection of the processing unit, power sourcing capacity at a given moment of time where the application is intended to do the maximum out of it.

1.1. Means of Energy Harvesting

Based on observations and theoretical survey [3] we summarized various means of energy harvesting as shown below in table-1, which gives an estimate of power harvested through various natural sources such as ambient light using solar cells and mechanical vibrations in industries. This could be of a great advantage in terms of sourcing IoT applications in comparison to battery powered applications.

Energy Source	**Power Harvested**
Mechanical vibrations	100µW/Cm^2
Temperature difference	1-10mW/Cm^2
Ambient light	10mW/Cm^2
RF (GSM or WiFi)	0.1µW/Cm^2or 0.001mW/Cm^2

Table-1: Energy harvesting sources and harvested power. (Source: Texas Instruments)

This harvested energy can play a crucial role though it is in the range of microwatts and milliwatts. This table also showcases the new demand that all our IoT applications need to be designed in such a way that they would operate with limited power merely in the range of few microwatts to tens of milliwatts at any given period.

2. THE ENERGY HARVESTING SYSTEM

In order to effectively design a power harvesting we need to first estimate the power demands of the wireless sensor node and identify whether the harvested energy is sufficient enough to source all the blocks in the energy harvesting block diagram shown below in Figure-1. The block diagram shows a typical energy harvesting system for a wireless IoT sensor node. One of the basic building blocks of any power harvesting system is the transducer, which actively captures the energy being wasted in either case and converts it into usable electrical signals. These electrical signals are then passed onto the power management system which further processes and regulates the energy for storage. Here the Power Management Unit (PMU) performs a very crucial task of keeping track of the energy harvested in the storage until it is sufficient enough to source the third stage (composed of sensors, microcontrollers and actuators) of the block diagram for at least one complete cycle of Sense-Process-Upload activity. Then depending on the power storage availability the PMU sends appropriate power signals to either *halt* or *proceed* for the third stage again. Thus the power management system adds some sort of intelligence to the complete IoT sensor node [2]. This smartness is achieved generally by employing specific low power consuming power management IC designed for the same intended purpose. On receiving a proceed signal the microcontroller is powered on and it merely takes few milliseconds to boot-up, sense the data from the sensor and upload it to the cloud storage using internal or external RF transceiver.

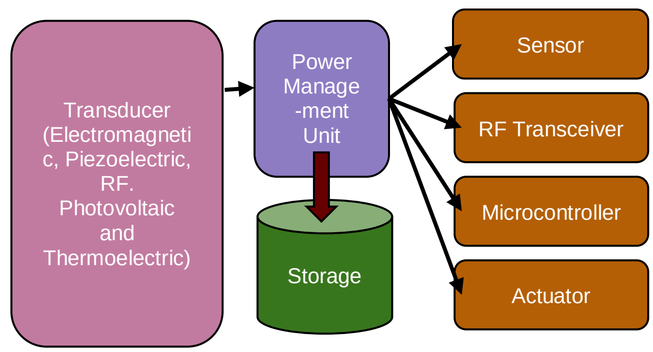

Figure 1: Block diagram of a typical energy harvesting system

The proposed system consists of a practical setup which is referred as a test bed for demonstrating an RF energy harvesting system. The test bed is basically composed of a RF antenna for receiving RF signals transmitted by any radiating device such as a cell phone. This radiating energy can only be received wirelessly at near distances in the range of few centimeters. An RF antenna designed specifically to capture these high frequency radiations is connected further to a signal booster which amplifies the signal level to an appropriate energy level. The use of rechargeable batteries or accumulators is not suitable for long run and maintenance free establishment and there is an immense need for the deployment storage devices possibly of electrostatic-type component.[9][10]. These amplified signals are stored in a super capacitor in the form of energy until sufficient amount of energy is generated to drive the controller and the sensor nodes. The use of power management unit becomes more critical here where it has to precisely monitor the super capacitor energy level and take a quick decision to drive the next stage for next sense and send cycle for data transmission.

This whole process of harvesting energy from the radiating antenna from cell phone and capturing data packet simultaneously to send an acknowledgement signal back to the cell phone takes 6 to 8 seconds on an average on the test bed. Most often analog devices offer ultra-low power design solutions to build high-performance, low-power energy harvesting applications.

3. EXPERIMENTAL RESULTS

The proposed test bed constitutes several components like RF transceiver connected to a cell phone for transmitting some random data, an RF receiving antenna for receiving the energy, a small circuit to convert the RF energy coming from the antenna to a DC power supply followed by a storage stage for storing the energy temporarily. Super capacitors tend to play a vital role in minimizing the tedious process of long charging and discharging battery cycles[7]. The use of a super capacitor as shown in the diagram for the storage purpose. The main motive for performing this experiment was to demonstrate that a self-powered battery less system in practically possible. Our results showed that when a cell phone connected to a RF transceiver is brought near the self-powered IoT node it actively participates in the process of sensing the energy[4], converting it into DC equivalent energy, storing it into a super capacitor followed by powering the entire system for few milliseconds within which the controller senses and builds up a low energy bluetooth packet and transfer it back to the transceiver connected to the cell phone. This proves that by properly managing the design aspects of the wireless sensor nodes, an effective battery less self-powered application can be designed[5]. The advantages self-power managing edge nodes are significant. Intelligent decision making at the edge minimizes power used because there's little need for power-intensive data transmission to the cloud. Whenever information is processed at the node, it can send the data to the cloud directly rather than sending abundant amount of data at a single moment of time.

3.1. Proposed Approach

The approach can be summarized as below:

1. Calculate the power required specific to the sensor node
2. Use ultra-low power consuming microcontrollers and sensors for all IoT based applications
3. Source only some nodes at a given time, thereby eliminating heavy power surge
4. Add intelligence to nodes so that some power specific decisions could be taken at node level
5. Use natural sources whenever possible and rely on free energy in the surroundings like thermoelectric chips, piezo generators, solar cells, etc.

4. CONCLUSION

In this paper, a harvesting mechanism for building battery less self-powered IoT perspective is discussed and found that energy harvesting based on ambient energy requires few basic elements like transducers that tend to play an important role in delivering the initial source of energy that may come at random times. We've theoretically analyzed major energy harvesting sources: light, heat, vibration and RF and also practically verified the deployment of an RF energy harvesting system in an IoT scenario. Thus to deploy a battery less self-powered system one has to design the complete IoT sensor application keeping in mind various natural sources. The type of transducer used will also greatly affect the amount of energy harvested and the overall efficiency of the application. Proper selection of sensors and ultra-low power microcontrollers will greatly enhance the power management at the node level.

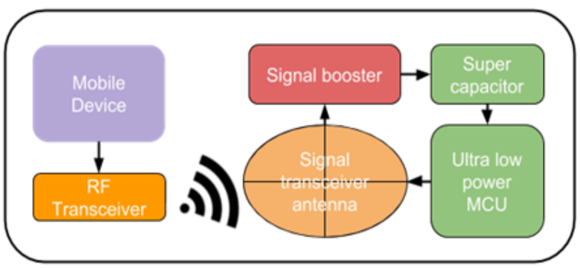

Figure 2: RF energy harvesting test bed

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