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Review on Energy Harvesting and Power Management for Low Power Wireless Sensor

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ABSTRACT: The greatest challenge faced by wireless sensor networks is power. When a sensor is depleted of power, it cannot fulfil its role unless and until the source of power is replenished. Therefore, it is considered that the smartness of a wireless sensor expires when its battery power is finished. However, there are emerging wireless sensor applications like building automation, agriculture and so on. In such applications, sensors are supposed to operate for much longer durations (such as years or decades) after they are installed on the field. In such cases batteries are hard (or impossible) to replace or recharge after they are discharged. Energy can be scavenged from renewable energy source and will be stored in super-capacitor as a battery source. Proposed system will harvest energy to make wireless sensor self-power sufficient. This small amount of generated power can be made sufficient for sensor operation using power management technique and battery lifetime will be calculated for estimating lifetime of sensor once battery is fully charged.

KEYWORDS: Energy harvesting, power management, super-capacitor, Duty cycle, super – capacitor capacity etc.

I.INTRODUCTION

A wireless sensor network (WSN) is collection of spatially distributed autonomous sensors. These sensors are used to monitor physical or environmental parameters such as humidity, temperature, light, sound, pressure, etc. and send processed data through the network to a server location. From a technical perspective, a sensor is a device that translates parameters or events in the physical world into signals that can be measured and analysed. Transducer is a device that converts energy from one form into another. A sensor, then, is a type of transducer that converts energy in the physical world into electrical energy that can be passed to a computing system or controller. Fig.1 shows architecture of wireless sensor node. It consists of several subsystems [1].

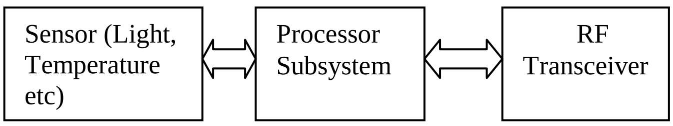

Fig.1 Architecture of wireless sensor node.

The Sensing Subsystem: - The sensing subsystem consists of one or more physical sensors and one or more analog - to-digital converters as well as the multiplexing mechanism to share them. The sensors interface the virtual world with the physical world.

The Processor Subsystem: The processor subsystem integrates together all the other subsystems and some additional peripherals. Its main purpose is to process (execute) instructions pertaining to sensing, processing and communication.

Communication Subsystem: - Its main purpose is to modulate the processed data by processor and transmit it wirelessly. It is also responsible to receive packets from surrounding nodes or central node.

A wireless sensor network is made up of large number of low power wireless sensors. In WSN, the main source of energy is usually battery power. Sensors are often indented to be deployed in areas such as a battlefield or remote areas.

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Once deployment of sensor network is done, it is impossible to recharge or replace batteries of all sensors. But long system life time is needed for any monitoring application. Important challenge to the design of a wireless sensor network is energy efficient problem [2].

II. LITERATURE REVIEW

There are different energy harvesting sources available for power generation for wireless sensor. A survey of energy harvesting sources has been done and classified on the basis of the sources they use to scavenge the power [3]. A few energy harvesting sources are listed in Table [1] for comparison.

Table 1: Energy harvesting sources

Energy harvesting Source	**Power Density**
Solar cells	$15mW/cm^2$
Piezoelectric	$330\mu W/cm^3$
Vibration	$116\mu W/cm^3$
Thermoelectric	$40\mu W/cm^3$

A wide variety of harvesting sources are now feasible, but as seen from comparison shown in table [1], solar energy harvesting through solar cells conversion provides the highest power density. So solar energy harvesting makes most suitable choice to power wireless sensor that consumes several milliwats (mW) using efficient harvesting module. A more efficient power management results in a longer network lifetime. Several methodologies are available at hardware and system level for wireless sensor network. Power management of wireless sensor network is a challenging issue and can be handled in various ways. Few of them are addressed below [4].

Dynamic Operation modes:
The main aim of Dynamic Power Management (DPM) is to shut down the peripherals when not required and wake them up when necessary. Depending on the present and anticipated activity, the subsystems of a wireless sensor node can be configured to operate in different power modes as shown in Table [2]. If all the components are in active state, that state is called active state and is represented as T0 and consumes highest power. And if all the components are in off state, the state is called deepest sleep state and is represented as T4 and consumes lowest power.

Table 2: Different states of component

State	Processor	Memory	Sensor	Radio
T0	Active	Active	On	TX/RX
T1	Idle	Sleep	On	RX
T2	Sleep	Sleep	On	RX
T3	Sleep	Sleep	On	OFF
T4	Sleep	Sleep	OFF	OFF

Task scheduling:
The battery aware task scheduling method is one kind of system level power management technique. This method is based on the analysis of the battery model and treats battery discharge as an additional constraint on task scheduling. To achieve the best scheduling efficiency supplied by high level algorithms, when a task is running, only the related

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hardware is activated. In this paper duty cycle based power management technique has been presented along with battery life estimation.

III.PAPER CONTRIBUTION

In this paper one of the greatest challenges faced by wireless sensor i.e. Energy has been highlighted. Different harvesting sources of energy are surveyed and listed in table [1] for comparison. Proposed methodology is demonstrated through block diagram for solar energy harvesting. Whenever solar energy is available system will charge the super-capacitor and power the sensor node. When solar energy is not available stored energy will be used to power sensor node. Duty cycle methodology has been presented for low power consumption of sensor. Power requirement calculations have been demonstrated for battery life estimation. Finally expected results have been discussed with paper conclusion.

IV.PROPOSED SYSTEM

As shown in Fig. 2, based on available ambient light energy, solar panel will generate small amount of power which is given to solar energy harvesting & battery charging Chip. As per the efficiency and power management charging circuitry, bq25570 chip has been selected. The chip is specifically designed to efficiently acquire and manage the microwatts (μW) to milliwatts (mW) of power generated from a different DC sources like photovoltaic (solar) or thermal electric generators. The bq25570 is designed with the flexibility to support a variety of energy storage elements such as re-chargeable battery, super capacitor, or conventional capacitor. Super-capacitors (also referred to as ultra-capacitors or electrochemical capacitors) have advantage over batteries when considering, capturing and supplying short pulses of power due to their higher power density and ability to charge and discharge very rapidly[5]-[8]. So super-capacitor has been chosen as energy storage element.

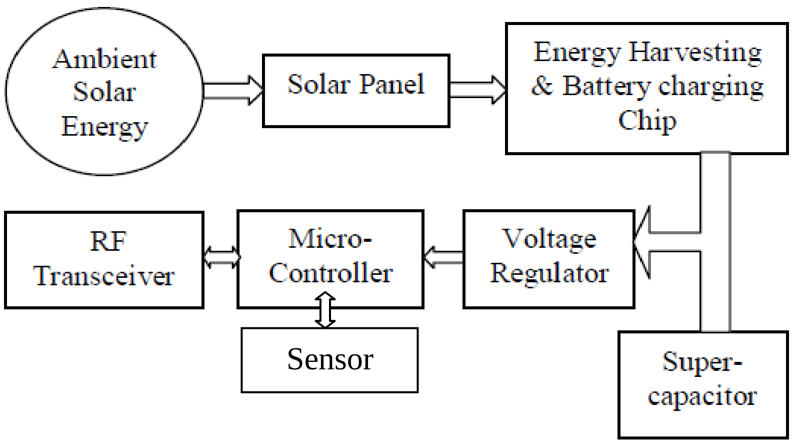

Fig 2 Proposed system diagram.

Whenever solar energy is available, BQ25570 chip will charge the storage element up to the set overvoltage to avoid damage of storage element. So this stored energy can be used to provide power to sensor node when there is no sunlight available. This chip has feature of under voltage and overvoltage protection for proper operation of storage element. Chip starts working as soon as input voltage is greater than 330mV. Voltage regulator has been used to regulate to constant voltage for operation of sensor node.

V.METHODOLOGY

One of the basic and most common power management technique used is duty cycling of node's operation. In duty cycle based methodology, majority of the cycle is spent in low power sleep mode [9]. Duty cycling methodology has been graphically represented in Fig 3.

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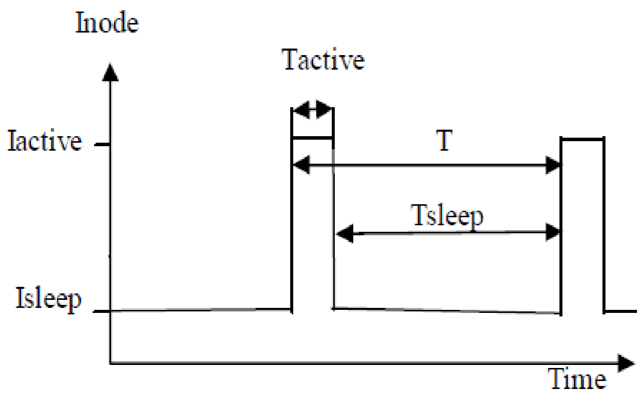

Fig. 3 Duty cycling of Node.

Duty cycle of sensor node is defined as fraction of time when node is active of total time.

$$D = Tactive/T \quad (1)$$

Where T = Tactive + Tsleep

As presented in Fig.3 Iactive and Isleep are the current consumed by sensor node in active mode and sleep mode respectively. Average current (Iavg) consumption of node is calculated by following equation

$$Iavg = (Iactive*Tactive + Isleep*Tsleep)/T \quad (2)$$

As power in sleep mode is significantly lower than power in active mode, so we can approximate average power consumption as follows

$$Iavg = Iactive * D \quad (3)$$

VI.SUPER-CAPACITOR'S CAPACITY ESTIMATION

Because of advanced technology, now a day's micro-controllers are operating at as low voltage as of 2V and as high as voltage of 5V. So based on this voltage range super-capacitor of 5V with 1F capacitance is chosen as energy storage element. Super-capacitors have no limit to number of their charge-discharge cycles (since there are no chemical reactions involved in their energy storage mechanism). As capacitance is related to voltage (V) and charge (Q) as follows

$$C = Q/V \quad (4)$$

Unit wise, equation (4) can be written as follows

$$Farad = (Ampere * Sec)/Volts \quad (5)$$

Converting Ampere into milliampere and Sec into hours we get

$$Farad = (1000mA *(1/3600)\ hour)/volts \quad (6)$$

Rearranging equation (6), we get milliampere Hour (mAh) as follows

$$mAh = (Farad * Volts)/0.2778 \quad (7)$$

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So energy storage capacity of super-Capacitor is given by

$$\text{Capacity (mAh)} = (C * V)/0.2778 \quad (8)$$

But for chosen capacitor of 5 V and 1F rating, micro-controller will operate from 2 to 5V.Practically V = voltage difference = 5V – 2V = 3V.

$$\text{Capacity (mAh)} = (3 * 1)/ 0.2778 = 10.97 \quad (9)$$

Once Super capacitor is fully charged to 5V, it will provide Iavg (from Equation 2) current for Nhours as follows

$$\text{Nhours} = (\text{Capacity (mAh)})/\text{Iavg} \quad (10)$$

Whenever sunlight energy is available it will charge the super –capacitor to set voltage and then it can provide required average current given by equation (2) for Nhours given by Equation (10) even if there is no sunlight.

VII.CONCLUSION

In this paper literature survey of available energy harvesting sources has been highlighted. Proposed system has been presented which will work for lifetime without battery replacement or maintenance. Super-capacitor is used as energy storage element due to its high energy density and large number of charge and discharge cycle. Duty cycle based methodology is represented along with super- capacitor capacity calculations. Super-capacitor lifetime has been estimated once it is fully charged from solar panel. The proposed system can be implemented in application like agricultural, building automation, etc where sunlight is easily available.

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