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Zero Power Wireless Sensor Nodes

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Abstract: Mote Network is widely used in the world, we have several kinds of motes, On Which we use for many applications but consider the drawback of one thing is effectiveness of drive power, commonly we use mote in lonesome area, and Drive power is replaceable battery or rechargeable battery, both are quickly drain due to consistent operation, Ultimate solution present with us, Environmental Energy huge solar power is with us, In this paper we present an model for solar power as a drive power of mote, tested on different environmental condition, we provide analysis for different operation level, power of solar is also provided to rechargeable lithium ion battery and simulate storage capacity at different time

Keywords:Solar power, RF to DC, Battery, Harvesting energy.

1. INTRODUCTION

Sensor network is an widely existing technology, now a day sensor network are almost used in every application, on before the arrival of sensor network ad hoc network is dominant but sensor networks emerged into huge power its consist of few hardware components that make an advantage compared to other networks like ad hoc and MANET, anyone can construct wireless sensor network at home itself and cost, power are comparatively less so its quit attractive new kind of sensors provide an alternative approach to sensor network as powerful tools, latest invention of sensor like to detect bomb using smart phone, food quality measurement are intelligent system

On the other hand development of sensors are in advanced process there is an limitation that make sensor node as non function able battery is an absolute drawback of sensor network for which we use battery which is non rechargeable and rechargeable both are not quit efficient in terms of life so all developers are working with energy and solution for energy harvesting common in cellular and ad hoc networks, it is widely used in sensor networks in recent years. Energy source, harvesting device, storage device, and consumer of energy are the essential parts of any energy harvesting model

The two basic concepts about energy harvesting theory are the total dependence of any system on ambient energy or using it as a supplementary source. Te first idea is very ancient and sometimes not applicable due to the random and stochastic nature of the environmental energy. Te most fundamental component of any energy harvesting system is the energy source. Te environmental energy sources, due to their stochastic nature, are categorized as uncontrollable but predictable, uncontrollable and unpredictable, fully controllable, and partially controllable . There is a variety of energy sources in the environment, but the most famous and widely used sources are thermal energy sources, mechanical energy sources, solar radiations.

2. RELATED WORK

Research groups have developed various different platforms, some of which have very specific characteristics depending on application requirements. In propose a hybrid wireless sensor networks architecture based on the Tmote sky and Fox board platform. Whereas in probably the most well-known platform is the Mica series from UC Berkeley. In the SENTIO plat form is present edas a hardware platform for rapid prototyping of WSN. Both Mica and SENTIO have similar computational power and consume approximately the same power. However, unlike these, Open-WiSehas greater computational power and similar power consumption because it is designed for either novices or expert WSN designers

Open-WiSe consumes approximately the same amount of power as Mica and SENTIO. It does so by disconnecting the Xbee wireless module and solely operating with the CC2420 radio. Furthermore, it also contains a solar charger module in the same PCB. Other recent platforms include Telo from UC Berkeley from Yale University, which consume significantly less power than many conventional platforms

In other work similar to the last design, a scheme that collects energy using solar panels but employing 34 W fluorescent lamps as an energy source, which are commonly found in the halls or rooms of hospitals was developed The energy harvesting module consists of a power management circuit that is connected to a group of ultra capacitors that store energy and manage the power supply to the nodes. After analyzing this work, we see that the total amount of energy used in the off and on states is 21 mA and the off state consumes only 9 mA, which is similar to the power in the on state of 12 mA. From these data can be summarized that energy employed in off state is wasted. A solar cell-based power supply for an agricultural environment monitoring server system for monitoring information concerning an outdoors agricultural production environment utilizing Wireless Sensor Network (WSN) technology is implemented in This technology could contribute to increasing crop yields and improving quality in the agricultural field by supporting the decision making of crop producers through analysis of the collected information

3. NEW DRIVE POWER MODEL WITH SOLAR HARVESTING

Energy scavenging from the environment is one of the attractive solutions to the power depletion problem in nodes participating in a wireless network. Its performance can be enhanced, if the harvested energy is efficiently managed . An energy harvesting model in conjunction with proper energy

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management system is presented in this paper. Each node in the network is equipped with this energy system

Our solar powered system which is divided into three sections: (3.1) Low Power Optimization (3.2) solar energy harvesting 3.3) solar panel 3.4) wireless sensor node 3.5) lithium ion polymer battery

The operation of each component is described separately below

3.1 Low-Power Optimization

Low-power modes on MCUs and wireless transceivers have been optimized in recent years to enable effective power management in wireless sensor applications. Figure 3.1 illustrates a typical wireless sensor node power cycle.

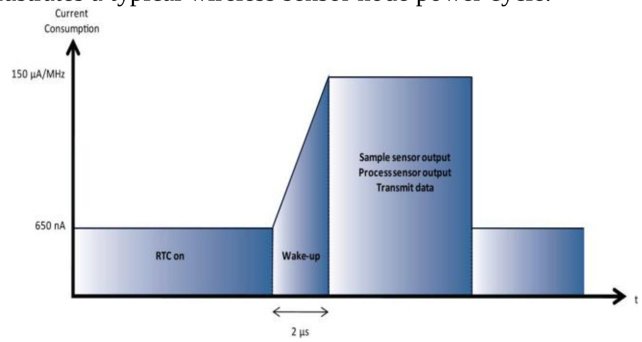

Figure 3.1 Wireless Sensor Node Power Cycle

The designer's objective is to minimize the area under the curve in Figure 1, which corresponds to power consumption. Power consumption can be minimized by optimizing the relative amount of time spent in low-power sleep mode and reducing the active mode time. A fast processing core enables the MCU to execute the control algorithm very quickly, enabling a rapid return to low-power sleep mode and thereby minimizing the power-hungry area under the curve

Wireless sensor nodes spend most of their time in sleep mode. The only subsystem that stays awake is the real-time clock (RTC). The RTC keeps time and wakes up the wireless sensor node to measure a sensor input. Low-power RTCs typically integrated onto microcontrollers consume only a few hundred nano amps. It is important to minimize the system's wake-up time because power is consumed during this time. An RTC uses a free-running counter in the MCU timer subsystem. When the free-running counter rolls over, it generates an interrupt that wakes up the MCU often. If a 32.768 kHz crystal is used, a 16-bit free-running counter rolls over every two seconds and wakes up the MCU. If a wider free-running counter, such as a 32-bit counter, is used, the periodic interrupt occurs less often, and additional power may be conserved.

When a wireless sensor node wakes up, it is usually intended to measure a sensor signal using the analog-to-digital converter (ADC). It is important to note the wake-up time of the ADC as well as the digital wake-up time since there is little point in waking up the CPU very quickly if the ADC takes an order of magnitude longer to wake up. A low-power MCU should wake up both the CPU and the ADC in a couple of microseconds. When the sensor node is awake, the MCU current is typically approximately 160 μA/MHz. When the sensor data has been measured, the algorithm running in the MCU decides whether the data should be transmitted by the radio. To send the data, a low-power ISM band radio consumes somewhat less than 30 mA for only a millisecond or so. When this peak current is averaged out, the overall average current consumption of the wireless sensor node is in the low microampere range

The radio transmission consumes most of the current in the system. Minimizing the amount of time the radio is on is essential to conserving energy. One way to achieve this is to avoid complicated communications protocols that require the transmission of many bits of data. Steering clear of standards with large protocol overhead is desirable when power is at a premium. It is also important to consider the desired range. Wireless range can be traded for power consumption. An interesting approach to balancing this trade-off is to use dynamic ranging, which allows full-power transmissions when maximum energy is available but reduces the output power level when harvested energy is limited.

3.2 SOLAR ENERGY HARVESTING

The ability to power wireless sensor nodes from solar harvested energy sources allows embedded designers to offer systems with significantly reduced cost of ownership for the end-user as well as benefits to the environment. The cost of replacing batteries housed in out-of-the-way sensor node locations can be quite significant. These wireless sensor nodes, for example, can be embedded in structures, such as buildings or bridges, or even buried underground. The three key enabling technologies needed to create self-sustaining wireless sensor nodes are readily available today: cost-effective energy harvester devices, small and efficient energy storage devices and single-chip ultra-low-power wireless MCUs. Wireless sensor nodes powered by harvested energy sources will soon become commercially viable and commonplace technologies used in our homes, offices, factories and infrastructure.

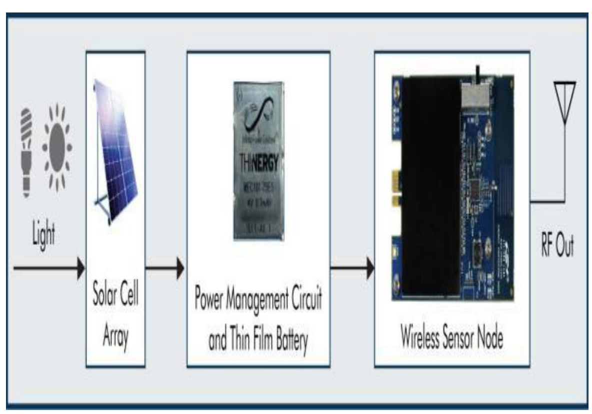

Fig 3.2: solar energy

3.3 SOLAR PANEL

Solar panel refers either to a photovoltaic module, a solar thermal energy panel, or to a set of solar photovoltaic (PV) modules electrically connected and mounted on a supporting structure. A PV module is a packaged, connected assembly of solar cells. Solar panels can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 320 watts. The efficiency of a module determines the area of a module given the same rated output - an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. There are a few solar panels available that are exceeding 19% efficiency. A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

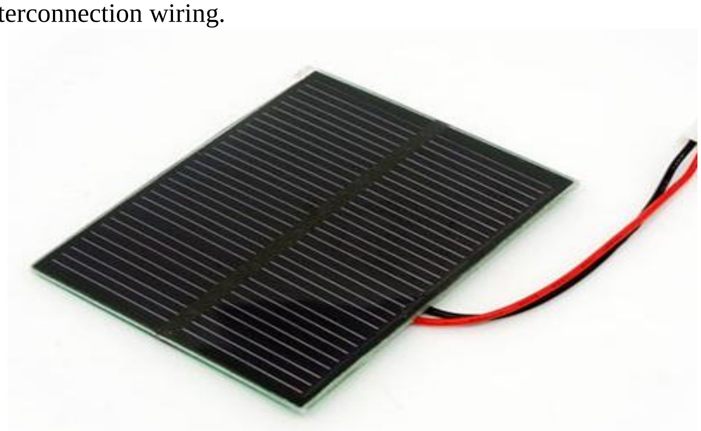

Figure 3.3: solar panel

Table 3.1: solar panel Key specifications

PET	Package
Typical peak power	0.55W
Voltage at peak power	5.5v
Current at peak power	100mA
Length	70 mm
Width	55 mm
Depth	1.5 mm
Weight	17g
Efficiency	17%
Wire diameter	1.5mm
Connector	2.0mm JST

3.4 WIRELESS SENSOR NODE

There are many important design aspects of a sensor node, especially when the application is environmental monitoring. The important parameters which should be considered while designing a sensor node are resource such as battery power onboard limited processing capability, and node intelligence. So the node should be designed in such a way that it consumes minimum power to extend the life time and to use minimum hardware which makes the node more compact and reduces cost and also the node should be equipped with various smart protocols to perform various error detection and correction. A typical node is equipped with multiple sensors, battery, processing unit and a wireless communication module for transmitting and receiving various sensed signals and commands, commands are special instructions given by the base station to sensor node. Sensors provide different types of output signal it may be analog, quasi digital or digital o/p. In some chemical gas sensors it is essential to supply high current to the heater coil of the gas sensor. So the signal conditioning circuit should be smart enough to drive and process variety of signals with minimum hardware. The sensor nodes are generally placed in remote areas for e.g. in hilly areas, forests, etc. It is very difficult to maintain or calibrate these sensors in these areas where accessibility is a major problem. To avoid this, we require an intelligent system which will enable the sensor to automatically detect its errors, transmit this error information to the base station, as well as correct this error if possible. There should also be a flexibility by which the base station can control various aspects like switching ON/OFF of the nodes by sending command signals and also it can select the proper sensor.

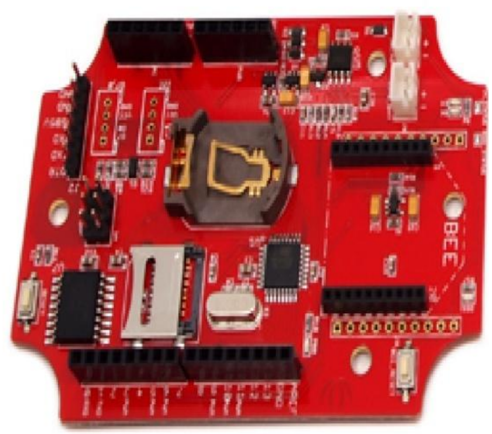

Fig 3.4 wireless sensor node

3.5 LITHIUM ION POLYMER BATTERY

A lithium polymer battery, or more correctly lithium-ion polymer battery (abbreviated variously as LiPo, LIP, Li-poly and others), is a rechargeable battery of lithium-ion technology in a pouch format. Unlike cylindrical and prismatic cells, LiPos come in a soft package or pouch, which makes them lighter but also lack rigidity.

The denomination "lithium polymer" has caused confusion among battery users. It may be interpreted in two ways. Originally, "lithium polymer" stood for a developing technology using a polymer electrolyte instead of the more common liquid electrolyte. The result is a "plastic" cell, which theoretically could be thin, flexible, and manufactured in different shapes, without risk of electrolyte leakage.

The second meaning appeared when some manufacturers started applying the "polymer" denomination to lithium-ion cells in pouch format. This is the most extended use nowadays, where "polymer" went from indicating a "polymer electrolyte" to mean a "polymer casing", that is, the soft, external pouch. While the design is usually flat, and lightweight, it is not a true polymer cell, as the electrolyte is still in liquid form, albeit it may be "plasticized" or "gelled" through a polymer additive. These cells are sometimes known as "LiPo", however, from the technological point of view, they are the same as the ones marketed simply as "Li-ion", as the underlying electrochemistry is the same.The name "lithium polymer" (LiPo) is more widespread among users of radio-controlled models, where it may indicate a single cell or a battery pack with cells connected in series or parallel. The more general term "lithium-ion" (Li-ion) is used almost everywhere else, including consumer electronics such as mobile phones and notebook computers, and battery electric vehicles.

4. IMPLEMENTATION

To test the concept we developed a simple application where two wireless sensor nodes were used to measure the humidity, temperature, and light.

4.1 Measurement Setup

We used the Fluke 87-V multimeter to measure the consumption of the mote at different duty-cycle rates for one hour (e.g., radio duty-cycle 2%, radio awake time: 1,028 ms, message transmission interval: 5 s).

To measure the received signal strength indication (RSSI), one node sensor was declared the transmitter, sending 10 packages per second and measurements were taken every 5 m. The values of the physical variables were programmed to update every 250 ms. The second node acted as a receiver and forwarded the RSSI value to a personal computer. For this test no particular routing algorithm was programmed into the node. Only the PaRTiKle Operating System and a few lines of code were needed.

The maximum energy harvesting by solar cell in the tests was 2.09 W and its efficiency of conversion was 15% (e.g., Vmp: 5.8 V, Imp: 342 mA, Pmax: 2.09 W).

4.2 Results

As we can see in Tables 1 and 2 the difference between average current (I_{avg}) and the estimated current (I_{node}) is very small, thus the estimation of current consumption can be done using Equation. Also, we can see that the mote current consumption using the CC2420 radio is smaller than using the Xbee radio and that is because the Xbee radio contains an 8-bit microcontroller (ATMEGA328P) with both the network and the application layer. In the case of XBEE radio transceiver, the system consumes an energy of 6.30 mA in sleep state and 69 mA in wake-up state, relationship that goes beyond the results presented in the cases analyzed in

Table 1. Current consumption at sleep and wake-up state for different duty-cycle rates (XBEE radio transceiver).

	2%	10%	25%	50%
I_{avg} (mA)	7.52	12.45	21.89	37.25
I_{sleep} (mA)	6.29	6.27	6.31	6.28
I_{awake} (mA)	68.4	68.2	68.9	68.5
I_{node} (mA)	7.5322	12.463	21.9575	37.39

Results of experimental tests a comparative study of the power consumed by the wireless sensor nodes developed in this work and modules was carried out. If for this analysis the relationship between wake-up and sleep state is considered, the system proposed in this work is better than the modules presented by other authors However, it is note worthy that some of the WSNs only consider the state wake up and do not mention the sleep state. Another result obtained from the analysis is that, although there is enough data to do it, it cannot be determined exactly which system is best because there are differences between the modules analyzed like amount and type of elements, by example the solar cell with a Pmax = 200 mW and Imp = 30 mA,

The maximum power is achieved from the plot between voltage and power shown in Figure 6, also known as PV curve of a solar cell. It is clear from the plot that power of solar cell increases with the increase in voltage, until a point arrives at$V$max, where we achieve maximum power. After this, there is a drastic decrease in the power as V approaches to VOC.

The IV and PV curves vary for different values of

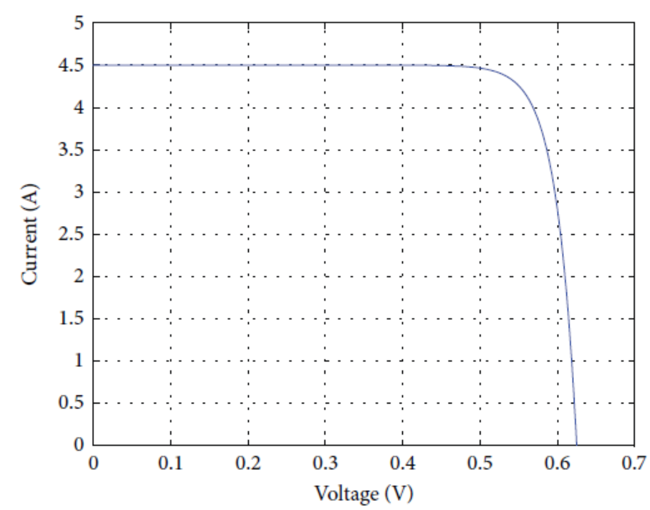

FIGURE 5: IV curve of a photovoltaic cell.

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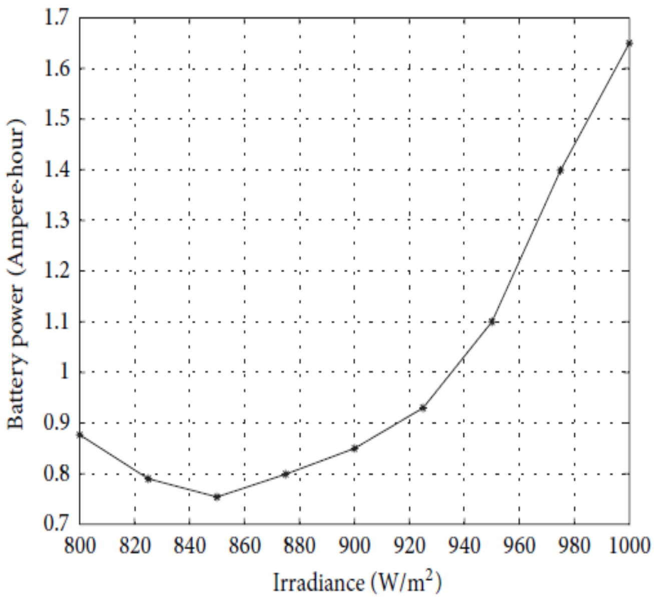

Battery power VS different values of G in the Morning hours

In the morning hours, the value of G is small and the maximum power extracted by solar panel is also less than the power required for the load (transceiver's operation). During this period, the power of storage device is used along with the harvesting power for the transceiver's operation. The battery power decreases initially with the increase in irradiance level, till the maximum power achieved crosses the power limit required to run the operation of a transceiver. After this point, the power of the storage device increases. Until again the maximum power achieved falls below the power required for load. When the Sun sets the load is shifted on the storage device and its power starts consuming continuously.

5. CONCLUSION

As the environmental energy is randomly distributed overall the nodes of a wireless network, therefore, an energy harvesting model along with energy management system is proposed. The analytical behavior of the model is also described. Some numerical simulations are presented to show the characteristics for IV and PV parameters. The proposed model is simple and efficiently manageable in order to obtain a better performance of the network in a perpetual fashion. This also assures the connectivity and long life of the network. In the future, the energy management algorithm on network layer will be proposed.

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