Energy Harvesting Sensor Nodes: Energy Benchmark And Implications On Transmit Power Adaptation

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Abstract

Battery powered sensor nodes can serve for very little life time. Prior studies have been done to improve the life time of the node by efficiently utilizing the battery power. *Energy-harvesting*, converting the ambient energy to electrical energy, has emerged as an alternative to power the sensor nodes. With the increase of the effective energy per day from the harvesting module, we have opportunities to tune the sensor node parameters. We have studied about the most suitable ambient source and came up with the design to develop a hardware to get the energy from the source. We have been doing some initial measurements about the energy harvested from the source and used by the application with the use of the hardware we designed. With the use of all this measurements, in the later part of the paper we will propose an energy-aware algorithm for the controlling the transmit power parameter for increasing the efficiency of the sensor node.

1 Introduction

Wireless Sensor Networks (WSNs) are widely used in today's world. Significant WSNs deployment in civilian applications is observed as sensors are more powerful, smaller and less expensive. A large number of sensors can be deployed in both friendly and harsh environments without any communication lines to periodically sense and transmit data to the sink or base station. There are applications like Habitat monitoring[22] - environmental monitoring in wildlife habitats like Great Duck Island and James Reserve, to study weather conditions and animal migratory patterns, Volcano monitoring[29] â network of seismometers used in a time-synchronized and event-triggered manner to measure volcanic activity, Structural monitoring[20, 4] - BriMon, a sensor network to detect incoming trains and measure the forced and free vibrations of a bridge; and Vehicle tracking[16] - sensors placed along or on roads, and on vehicles, detect road, traffic and environmental conditionsâinformation which can be used to warn drivers of potentially dangerous conditions or to inform about traffic conditions for better route planning. We don't have enough accessibility of the sensors to change the batteries and the life of the node simply depends on the life of the battery and power consumption rate of the sensor. These kind of applications give very important information about the places and life style of animals through very simple implementations. Some studies have proposed very good solutions techniques for utilizing the life of the battery power sensor nodes. Some of the improvement includes energy-aware MAC protocols (SMAC [30], BMAC [24], XMAC [3]), power aware storage, routing and data dissemination protocols [9, 12, 5], duty-cycling strategies [7, 6], adaptive sensing rate [21], tiered system architectures [8, 17, 18] and redundant placement of nodes [28, 19] to ensure coverage guarantees.

After this all optimizations still we have the battery as a constraint the life of the node. The solutions to enlarge the life of the battery is done by decreasing the power wasted in the path finding of routing a packet, by decreasing the duty cycle the node can be more in the power saving mode and only be active when there is sensing is needed to be done. Some proposals suggests about changing the MAC protocol such that the packet size is decreased and we need to send the less number of bytes over the wireless medium - decreasing all the possibilities of energy wast through wireless communication. Inspire of all this optimizations the life of node is still depends on the life of the battery, the bigger the battery more the life the node have, and when the battery dies the node becomes useless. Major deployment of this applications are in the region where you can not get the nodes back and put them back by simply changing the batteries. The solution to this problem is we need to gather the energy from the ambient resources and store it the rechargeable batteries and use them for the operations of the application. Currently, some researches are going on for using the ambient sources to constantly supply energy to the sensor node. Some of the deployments such as Hydrowatch[2], Prometheus[13], Heliomote[14], SolarBuiscuit has been an initial steps in the same direction. So now we have all the optimizations algorithms and we have additional harvested energy for further more optimizations so we need some of the modifications in existing proposals.

definition

We will try to improve the efficiency of the sensor node by addersing the following importanct aspects. This entire report is divided in 3 verticals: 1) We design a simple circuit which will harvest the energy from the solar panel. 2) We conduct measurement study on the amount of energy harvested from harvesting module. 3) We will propose an algorithm for tuning the transmit power based on the above study.

Energy Source	Characteristics
Solar	Ambient, Uncontrollable, Predictable
Wind	Ambient, Uncontrollable, Predictable
RF Energy	Ambient, Partially controllable
Body heat, Exhalation, Breathing and Blood Pressure	Passive human power, Uncontrollable, Unpredictable
Finger motion and Footfalls	Active human power, Fully controllable
Vibrations in indoor environments	Ambient, Uncontrollable, Unpredictable

Table 1: Energy Sources

The rest of the paper is organized as follows, Section 2 describes some of the previous work in the same domain, Section 3 describes about our initial steps, that we have taken to address the first vertical of our solution. In section 4 we will present some of the results that we got from the experiments. In section 5 we will discuss about the current status and future work.

2 Literature Survey

There is lot of work done in improving the life of the node by optimizing the parameters that affects the power consumptions of any sensor node.

2.1 Related work

There are verity of the ambient sources that can be used to harvest the energy from like Solar, Wind, RF Energy, Body Heat, Exhalation, Breathing, Blood Pressure, Finger motion, Foot Falls, Vibrations in indoor environment. But the initial study in identifying the most suitable energy source which provides facility to predict the availability of the energy, and the amount of energy that can be harvested. From Table 1 we came to conclusion that the most suitable energy source is solar energy which can be easily convertible to electrical energy and also satisfies other conditions. The solar energy is not available in the period where the sun is not in the sky we need to store the energy gathered in the day time which can be used to give supply the node at night. Now we have to choose the energy storage mechanism(battery) to suite the conditions that we have. In the study of the different storage mechanism shows that the Lion batteries have high energy density, power density, Efficiency, recharge cycles and low discharge rate. but the charging technique used to charge the Lion battery is very complex so we are concentrating on the next best batteries,NiMH battery, which doesn't require the complex circuit and also relatively batter choice in terms of the other parameters.

2.2 Study of solar harvesting models

As we have come to the conclusion that the solar energy is the most suitable energy that can be harvested for the approach that we are interested in we have studied some related work that have been implemented with the use of solar panels.

2.2.1 Hydrowatch

Hydrowatch is an application setup designed and deployed by Jay Taneja, Jaein Jeong, David Culler at Berkeley for getting the information about the climate changes in the woods. They have also tested the setup in the open ground. They have implemented the system on Telos motes. Figure 1 shows the architectural diagram of the Hydrowatch node. Hydrowatch uses a solar panel of area 2.3 inches x 2.3 inches which outputs 88.74mA at a voltage of 3.11V which is used to charge two NiMH batteries. The batteries are charged by trickle charging method which requires very simple circuit. The input regulator is connected to the solar panel which boost-up or buck down the voltages based on the solar panel is giving. Circuit also require some diodes to stop the current flowing in reverse direction when the sun

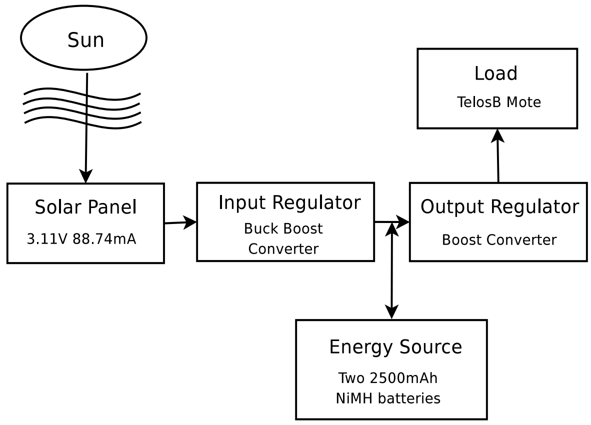

Figure 1: Architecture of the Hydrowatch Node [2]

is not present. similarly the boost converter is required to empower the mote from the battery. The Energy collected from the solar panel is measured by the small circuitry, and also the amount of energy used by the mote is also measured. The data are collected of how much energy is collected in a day and how much energy is used in 24 hours. The measurements suggests that the node requires the 79 mWh of energy per day and the least amount of energy which is gathered by one mote is also greater them what is required. Hydrowatch concludes that in normal condition based on the position on the earth and the sun's movement on the sky we can predict the energy that can be gathered by the solar panel and we can optimize the parameters.

2.2.2 Heliomote

Heliomote is also harvests the energy from the solar panel and uses that for the charging the batteries. Figure 2 shows the architecture of the Heliomote node. This model uses a solar panel of area 3.75 inches x 2.5 inches which outputs 60mA at a voltage of 3.3V. They have implemented the system on the Mika2[1] mote. The power from the solar panel is charging 2 NiMH batteries. The undercharging of the NiMH batteries affects the performance of the battery even overcharging of the battery leads to the

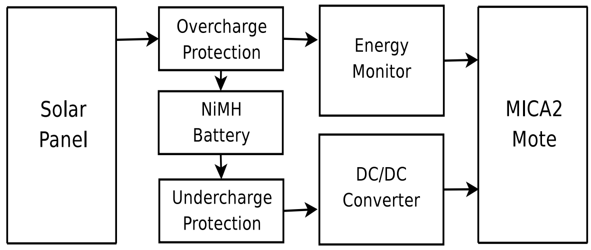

Figure 2: Heliomote Architecture

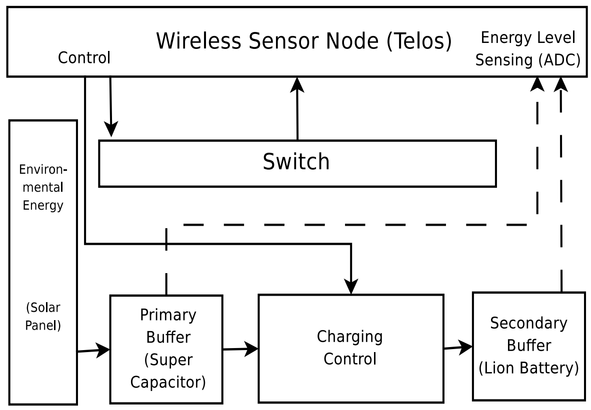

Figure 3: Prometheus Architecture [13]

battery instability, so they have designed the circuit such that the undercharging the overcharging of the batteries is prevented.The mote also measures the energy, the energy monitor keeps checking the energy used and spent. Heliomote paper concludes by the mathematical analysis that if the energy gathered in a unit time is more energy used in a unit time then the node can sustain.

2.2.3 Prometheus

Prometheus is having the double storage sources. The primary source is a super capacitor which is directly charged from the solar panel. As we don't need any special circuit for charging the capacitors. While the Lion battery needs pulse charge which is very well provided by the capacitors. So the entire charging circuit is working as follows, The solar panels charges the super capacitors with the highest voltages and current gathered from the sun, when the capacitors are sufficiently charged they sends a pulse of charge which charges the Lion Battery. When the sun is not up in the sky the capacitors are first choice to use the energy from, and when the capacitors are out of charge the mote gets the energy from the secondary source(Lion Battery). This gives the advantage of decreasing the number of the discharge cycles of the secondary battery which has less number of charging cycles. While the primary storage source is the capacitor which is having far more number of recharge cycles then that of any battery technology available. This give the advantage of the shallow discharge cycles caused by a cloud or some instantaneous lake of power supply from the solar panel. The main advantage of the Prometheus node is it is able to achieve the maximize the battery capacity while having the lowest self-discharge rate of the battery, so the mote can utilize the maximum effective energy. And the Lion battery is charged from the super capacitor so we can have big capacity battery attached.

From the above study, we conclude that there are many possibilities of the designing of the circuit. The harvesting capacity and the life of the node also changes with the design and the ambient source of energy from which we are harvesting the energy. Hydrowatch is having simplest design of circuit and the solar panel is charging the battery with trickle charging method which is efficient use of the available energy, but the problem with the Hydrowatch is the batteries are hardly utilized by the node application so the batteries goes under shallow discharge cycle which is affecting the battery efficiency over a period of time. Heliomote overcomes this problem with having the overcharging and undercharging circuit added to the design, but here also the problem remains about the utilization of the battery capacity. These two designs has only one battery as the storage so because of this any small fraction of the time when the harvesting is stopping the battery starts discharging which causes that bigger problem. this problem was taken care by the Prometheus paper design they have used two energy storage sources to address this problem. By this design the second battery goes is

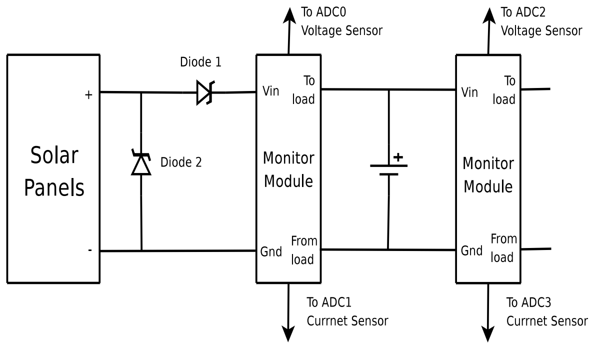

Figure 4: Architecture of an energy harvesting node

discharge cycle only when the primary source is completely out of energy. We came to conclusion that the Prometheus charging design is very optimized in terms of energy utilization and maintaining battery efficiency, but it has very complex charging circuit design. We choose to go for NiMH battery as the storage source and design the Hydrowatch circuit is one of the good designs and we are focusing on using the entire deep cycles to utilize the full battery capacity of a recharge cycle the shallow discharging is not problem to us. The selection of ambient source is also a big solution designing criteria, as we have stated earlier the solar energy is the easiest and most suitable energy source to harvest the energy from. We will describe more about the design in the next section.

3 Approach

As our entire areas of interest are divided in to 3 different verticals we have decided to approach them one after another. So first of all we have decided to work on the first domain which includes the characterization of the solar panel which we will be using for the experiments and design a circuit for harvesting the energy from that.

3.1 Design of Solar-Harvesting Module

The design of the circuit is greatly influenced by the Hydrowatch paper circuit design and will improve the design if any requirement arises. We have designed the charging circuit for the NiMH batteries that can be used to charge the batteries keeping track of the how much energy is transferred from the solar panel to the battery and how much also how much energy is used from the battery when the battery is not being charged from the solar panels. The circuit contains the *monitor module* that monitors how much current is passed through it and at what voltage. There are also two diodes in the circuit which controls the current flow of the circuit, and we are using Telos mote for collecting and processing the sensed data. Following description about each module and how it is connected the the circuit. The node is mainly maintaining 3 parts 1) energy harvesting & charging module 2) monitoring module 3) data processing module.

3.1.1 Circuit Design

First module is energy harvesting and charging module. It is responsible of the harvesting the energy from the solar panels and charge the batteries. We also need to take care of the batteries that the current doesn't flow in the reverse direction to the solar panel discharging the batteries. This component contains the 2 diodes for preventing this scenario to occur. The architecture of the charging circuit is show in the Figure. As shown in figure the diode 1 is responsible for letting the current flow from the solar panel to the battery while the charging the batteries, but when the charging is not happening then the current cant flow in the reverse direction. The second zenor diode is connected in the reverse bias to hold the voltage of the solar panels to 3 V, so when the solar panel is generating more voltages then the 3 V the diode cuts down the voltage to 3 V.

Second module, Monitor Module, is the component that constantly senses the voltages and current flowing through the circuit. We have used the ZXCT 1010 chip for sensing the current in the circuit. ZXCT 1010 gives the value of current flowing through the load by

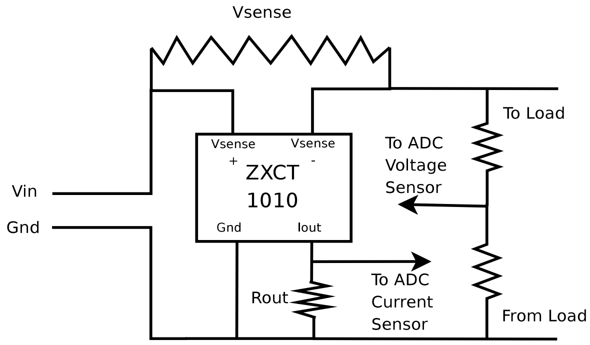

Figure 5: Monitor Module

connecting the Vsense resistance of the circuit in the series. The current monitor gets the voltages across the Vsense and generates the appropriate voltages at the Iout point. We can get the voltage at Iout point which maps to the appropriate current reading with following equations.

$Vsense = Vin - Vload$

$Vout = 0.01 * Vsense * Rout$

$Vsense = Isense * Rsense$

Here the values of Vsense and Rout can be selected as per our requirements of the voltage range. Here 0.01 value in the second equation is the because of the internal 100 ohm resistance. We have chosen Rsense as 0.1 ohm to decrease the series resistance as minimum as possible so that the actual load can get use of the maximum voltages available. We choose Rout as 1000 ohm so when ever the current passes through the circuit and we get equivalent voltage at the Iout by applying the above formula we can get the Isense value which is nothing but the current passes through the load because Rsense is in series with the load. The voltage across the load can also be measured by getting the voltage difference between the to points of the load. As the maximum voltage range that can be measured by the the Telos mote is 2.5 V, We have connected the two 1000 ohm resistance parallel to the load and measured the voltage across one of the resistance and doubled the value to get the actual voltage. There are two Monitor Modules as the part of the charging circuit where one of the module is connected between the solar panel and the batteries and the second module is connected between the batteries and the load. The first module is collecting data of the current and the voltages as what the charging is done at the time sun is up in the sky and based on that we can calculate the amount of energy gathered from the solar panel to the batteries. The second module is collecting the data of the energy which is used by the load from the batteries or from the solar panel. So by taking the difference of the both the energy calculations we can calculate the actual amount of the energy the batteries have at any particular instance of time.

Third module is data collection and processing module, we used the Telosb mote as the processing module. Telos is an ultra low power wireless sensor module ("mote") for research and experimentation. Telos is the latest in a line of motes developed by UC Berkeley to enable wireless sensor network (WSN) research. Telos' new design consists of three major goals to enable experimentation: minimal power consumption, easy to use, and increased software and hardware robustness. The hardware components are selected and integrated in order to achieve these goals. The mote is having Texas Instruments MSP430 micro-controller, Chipcon IEEE 802.15.4-compliant radio, and USB for interfacing. We are using the ADC pins for getting the data from the *Monitor Module*. The ADC pins are used for collecting the voltage and current readings from the circuit as the voltage difference between ground pin and ADC pins. We have done only the initial measurements so we have used very simple setup for the implementation and generating the required data. So we have used two Telosb motes one mote is sensing the data from the sensors via ADC channels and sends that to base-station which is one more mote connected to the server collecting and logging the data on a computer.

3.1.2 Solar Panels

A photo-voltaic module or solar panel is a packaged interconnected assembly of photo-voltaic cells, also known as solar cells. Solar Panels use light energy (photons) from the sun to generate electricity through photo-voltaic effect. The electrical connections can be made in series to achieve a desired output voltage and/or in parallel to provide a desired amount of current source capability from the solar panel. There are 3 different kind of the solar panels, mono-crystalline solar panels, polycrystalline solar panels and amorphous solar panels. We will be using amorphous solar panels for our study. These types of solar panels have lower efficiency then the other two types of solar panels but they are the cheapest to produce, and the one and most important advantage of amorphous solar panels over the other two is that they are shadow protected. That means that the solar panel continues to charge while part of the solar panel cells are in a shadow. Our initial experiments uses two VEGAKIT[1] modules of the solar panel of type GESPM01 of size 3.25 inch X 2.25 inch whose ratings are 3V / 150mA, Voc[2] is 3.6V and Isc[3] is 165mA.

We have built the circuit that can monitor the voltage and the current flowing through any two points of the circuit, and we can also charge the batteries with it. we will be using the GPS module which will be running as an application as load and we will do some of the measurements with it. We have tried to do some if the initial experiments with the SPK-GPS-GS405 Module but there were some issues regarding the data collection and parsing the collected data as per the requirements so we have used simple resistance as the load as of now for performing any experiments. We will be using the GPS module in our future implementations.

3.2 Sensor Module Energy Benchmarking

As we have built the circuit we have performed some initial experiments for verifying the different components of the circuit. We have also built one small circuit to characterize the solar panels. As our requirement of the voltages is matching with the solar panel voltages we have connected the panels in parallel so that they gives the voltage as 3V but gives the total current collected from both the panels. The characteristics of the panel is generated by plotting the voltages Vs Current graph. This plot gives the verification about the ratings which are given by the company. We have got this configurations by doing an simple experiment on the solar panel. The Experimental setup is shown in Figure . We have connected the solar panels in parallel to get the maximum current possible from the panels keeping the voltage at 3V. we are sensing the voltages and current with the circuit that we have built for taking the measurements of the energy. The X axis of the graph is current generated from the circuit at a particular time and Y axis is the voltage. From th figure when we increase the resistance R, by going short circuit to open circuit we get different voltage and current from the solar penal. The plot conforms that the we can get the maximum voltage 3V from the solar panel and as the ZXCT 1010 has the limitation that it can not generate the voltages bellow 1.25 V. For getting the correct results we have performed the experiments only from 1.5V to maximum voltage given by the solar panel. We can see from the graph that the solar panel is generating the 320 mA current at 1.5V and if we extend the graph further it will reach to at-least 330 mA which is expected. There is one more characteristic of the solar panel is the MPP[4], Which tells the maximum power that can be generated from the solar panels, and we can built the

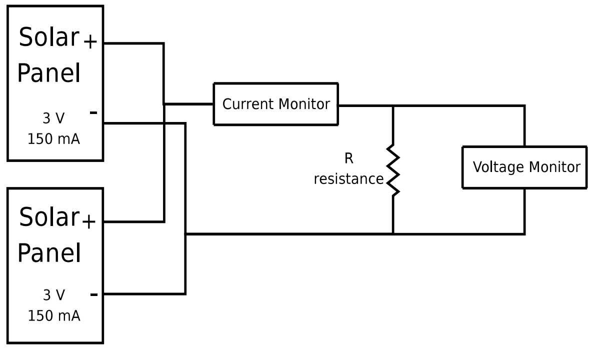

Figure 6: Setup for characterizing solar panel.

[1]www.vegakitindia.com
[2]Open Circuit Voltage
[3]Closed Circuit Current
[4]Maximum Power Point

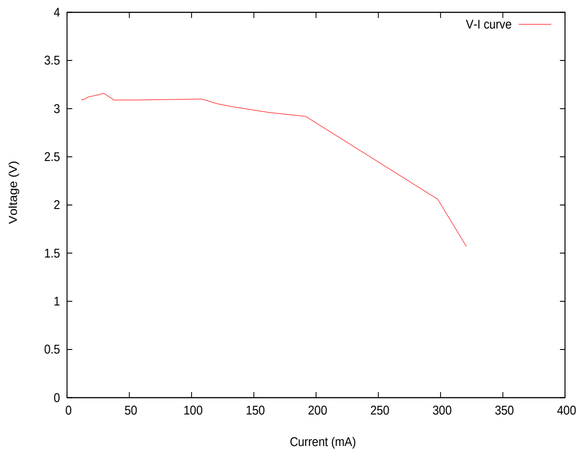

Figure 7: V-I characteristics of the Solar Panels

intelligent circuit for keeping the circuit working on MPP, but as we are worried about that at this point we can implement MPPT[5] in the future part of this work.

Based on the logs which we get from the sensor nodes we can calculate the energy generated from the solar panel and used by the load. From the Figure we can see that the ADC0 and ADC1 pins are collecting the data that how much energy is harvested from the solar panel and the ADC2 and ADC3 pins are collecting the data about how much data are being use by the load. So by getting this information. we can calculate the amount of energy collected in the batteries at any particular instance of time. generally energy is calculated in the kWh units but as we have the energy generated in very low values we will be measuring the energy in mWh. As the V-I graph says that we are getting the current in mA and voltages in V, following is the equation for calculating the energy from the data.

$Energy(mWh) = [Voltage(V) * Current(mA) * Time(s)]/3600$

From this equation we can calculate the amount of energy generated by the solar panels and amount of energy use by the load so by the difference we can get the amount of energy stored in the batteries. This collection of the energy repeats on the period of a day so we can calculate the amount of energy collected in a day and if the other factors doesn't change we can also predict the amount of energy we will be receiving the next day.

The energy graph can be plotted of a period of a day for getting the results of how much of energy is generated and used by the load in a day and this pattern repeats with minor correction over period of time with the change in the seasons. The amount of energy generated from the same solar panels also changes with geographical location of the deployment. There are also other factors affects the energy gathering from the solar panel. The weather conditions - in a sunny day you will be getting the maximum amount of energy but in cloudy weather the amount of energy gathered decreases. The Hydrowatch paper points out one results by saying that in a fairly cloudy day the node in the woods gets more energy then that of the sunny day because of the diffusion effect. The orientation of the solar panel also affects the energy gathering. the dust on the solar panel and if the one of the solar panel connected in series connection gets damaged makes big impact on the amount of energy generated by the solar panel.

3.3 Algorithm for transmit power control

The optimization of the energy consumption can be done by changing many parameter of the wireless communication components. We have chosen the transmit power because the majority of the power consumptions is done by the radio via transmitting the messages. So if we can implement some of the algorithm that can optimize the transmit power. Now as we have now the additional harvested energy we can batter utilize the energy gained by the solar harvesting module. We have not yet done any sufficient progress in this area but we had some literature survey and here is the summary of what we have learned.

The change of any parameter like what we have discussed earlier will cause the change in the other parameters or affects the efficiency of overall performance. So by changing the transmit power also

[5]Maximal Power Point Tracking

changes some of the aspects of the wireless communication.

- Transmitting data at high power may reduce the number of hopes required to reach its destination. How ever it will cause more interference to the other nodes in the region. Moreover, my node is already having limited power so the collisions are not acceptable.
- If we minimize the transmit power it will increase the bit error rate which leads to more number of retransmission of the same data.
- As we have the energy limited to the battery capacity and we also predict the next recharge cycle of the charging profile we can very well consider one component as the next recharge time and can optimize the transmit power parameter as per the available energy.
- Generally the routing table of the static nodes are not changing as much so some of the papers also discuss the transmit power by assuming the static routing table, but as we have not the energy as one more component of interest if the battery capacity of the node is not sufficient the node will not accept the packet and will behave like dead node which will be live once it has the enough amount of energy harvested from the sun next day. By this scenario even if the network is static we will be having the change in the routing tables.

4 Experiments

We have done some of the initial experiments as the part of touching the second vertical of our work. We have gathered some of the initial data about the batteries and the solar panel that we have used. Following are the experiments that we have performed.

4.1 Battery measurements

As we are using the rechargeable NiMH 1.2V batteries of capacity 2050mAh each. We have preformed the experiment for checking the total energy that can be stored in the batteries. For getting the total capacity of the batteries we have charged the batteries from the normal charger having the overcharging protection. After keeping the batteries for charging about 10 hrs we have kept them for 1 day for best performance. After that we have connected the 35 ohm of the resistance and collected the voltage and current from the basic current monitor circuit that we built and plotted the energy. Figure 8 gives data collected from the sensors. The graph shows that the batteries can give the 2.5 V, because of the connected in series, for entire period of the time when the batteries are discharged then the voltage goes down to the 1 voltage, which is the characteristics of the NiMH batteries.

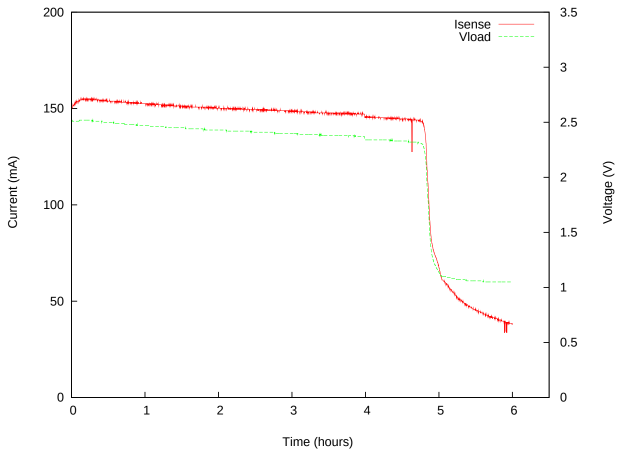

Figure 8: Discharging of the Battery

4.2 Solar Panel on the window facing the sunset.

The experiment is performed at the window facing the west side so we will not be able to get any sunlight until afternoon, the experiment shows that we will get the immediate increase in the current when the sun rays falls on the solar panel and then when the time passes by the current value decreases with the time but still the voltage remains above 2.7V even when we are getting very low current. The spikes in

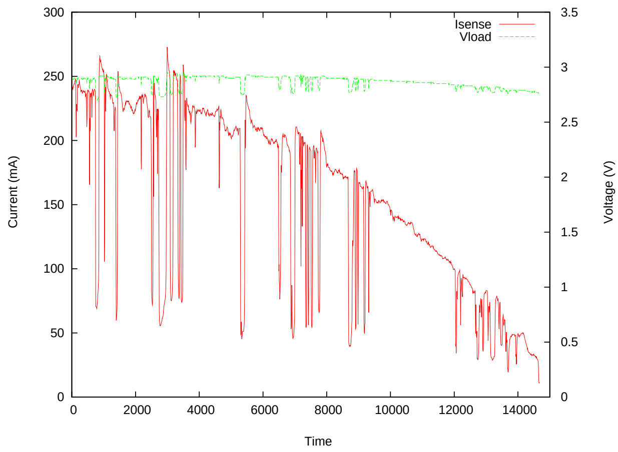

Figure 9: Window facing west side of the building - voltage and current.

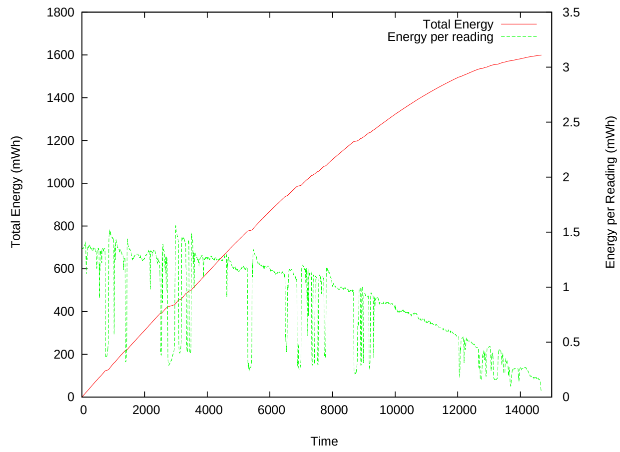

Figure 10: Window facing west side of the building - Energy

the experiment results are because of the few clouds. When ever the cloud covers the sun there is sudden decrease in the current we are not facing any shadow effect here because there is no spot lighting happening the window is widely facing the sun after the noon till the sun set. At the end of the day we are able to get around 1600 mWh of energy harvested from the solar panel to the batteries, which is near to the total amount of energy gathered in a day by the highest gathering node of the Hydrowatch paper. From this we can say that we have got the correct readings because the highest amount of the current they are getting at the same voltage is 80 mA while we are able to get 250 mA at the noon.

4.3 Experiences with the Experiments

Following are some experiences which we would like to share with designing the H/W and measurements with solar panel.

- We have started our approach by designing the circuit of the current monitor and then expanded it to the charging circuit. Our main goal to design the current monitor is to get the current ratings in the voltage reference because the ADC pins of the Telos mote can only sense the voltage difference with reference to the Gnd pin on the Telosb mote. So we choose ZXCT 1010 as the current sensors.
- There were also issues with the selection of the Rsense and the Rout for getting the correct readings and maintaining the highest efficiency of the because the more energy wested in the monitoring the less energy we get for the actual application.
- When the current is not flowing from the solar panel the reverse flow flows from the batteries at this time we will get the voltage readings across the load but the current readings will be zero because ZXCT doesn't give output the Iout if the current is flowing in reverse direction.

5 Current Status

As we have said earlier we have 3 different verticals in our approach. We have started working on the designing the charging circuit and with the current monitor and charging circuit measurements we can say that we have achieved the first mile stone. As we have also performed some of the initial experiments for gathering the related measurements about the solar panel and the battery we have also collected some of the results which we can use in the future implementations.

6 Future Work

Till now we have completed our circuit designing and some of the initial experimentation. So now we have the measurements about the energy gathered by the solar panel to the battery and we also have the measurements about the energy spent by the application so we can now further look in to the third vertical of our work and can start working on the designing of the algorithm for the transmit power control.

Main goals to achieve are as follows.

- We still need to interface the GPS application as the load, the data format conversion and the parsing of the data is left to be implemented in the TinyOS.
- We have designed the circuit but still we have not tested it with the real applications as the load.
- We have done some of the initial experiments with the resistance as keeping the load but we still have to perform the measurements with actual GPS device and need to use that for tracking the node.
- We have to come-up with the algorithm where we can dynamically and precisely predict the next recharge cycle and this can be done for all different charging profiles based on the placement of the node.

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