ISSN 2229-5518

Energy Management in Battery Technology

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Abstract— Energy Expenditure and Power Management are the key features which determines the Usability, the Dependency and the Reliability of a Wireless Sensor Network system for its lifetime and the amount of data extracted. The Information gained from a device depends on the power management and the techniques used to save or harvest power. Determining the overall power requirements of the system we can design a sustainable efficient power harvester. Many attempts have been made to save the power of WSN devices in order to make them usable and extend their life time. The time taken for a WSN system to send data from an end node to final warning system to alert certain data is critical. This results in power hungry networking architectures. In order to achieve an effective, secure and reliable interaction of complex distributed systems. Distributed sensor Network systems which are loosely coupled and dynamic in nature are required. This feature ensures self-adaptability and data efficiency but also creates a whole new segment of power expenditure and energy losses for redundancy. The main focus of this paper is to present an insight to these problems and to propose solutions to deal with them efficiently.

Keywords—Energy Level Control; Life Span of WSN; Node Protocols; Plant Based Power Harvester; Self adaptively; Redundancy; Wireless Sensor Networks (WSN).

I. Introduction

In the world where information drives economics "arms race", it is pivotal to gather data seamlessly and efficiently. The amount of data gathered is currently dominated by the energy factor of a system. In the current era we need technological devices that can adapt and prowl from the shadows so that we can forget about them once deployed.

Wireless Sensor nodes have a limited amount of power available as they depend on the power source. Typical Lifetime of a sensor node would be the lifetime of the battery technology used which may or may not be rechargeable. Our goal is to provide as much as energy possible to the sensor node with minimal cost, weight, size of packaging, and recharging option as the node may or may not be accessible once deployed.[1]

This paper is organized as follows. We start by presenting the research problem in Section II and describe why we were motivated to this research and the problem domain in Section III. In the section IV we look into the related literature works done so far. Section V explains the Research method used with the Experimental procedures and sub results of each experiment by analyzing every element separately. While Section VI approaches a power harvester solution and explains it vitality in WSN. In Section VII, we present experimental results which confirm the validity of the approach. Finally, future research directions and conclusion are drawn in Section VIII and Section IX.

II. Research Problem

The research challenge or task is to support the current Industries with a Sustainable energy efficient WSN system which will self-harvest energy from the field in which it's deployed by adapting to the surroundings as well as provide essential data which will help understand and prevent hazards using an early warning system.Various ideas for finite network lifetimes of WSN's have been suggested over the years with different approaches to save power, like transfer power wirelessly, reduce system efficiency, gather less data, use lower duty cycles and to harvest energy in different ways. These methods work and also extend the battery life of a WSN system to a certain limit but they all come at a cost of mining less data and compromising using some trade-offs.

By revolutionizing power sources technology we would not be required to trade off any aspect of the system and can data mine till the lifetime of the system. But till then we have to understand the different methods which are used to save energy and compare with the best possible option to deploy our sensor nodes to maximize usability and extended lifetimes of the nodes.

Major hazardous scenario considered in this research would be wild fires, it can be extended to other scenarios as well but will be the future scope of the research. Using this we would differ upon the way and the location where the phenomenon occurs. [1], [8].

This research addresses such problems, seek for a WSN with enhanced energy capabilities, and power sufficiency to last its lifetime and self-adaptability for usability in real world applications and to provide a proposed solution.

III. Motivational senario

The Early warning systems use a very complex method for sensing and computation of the data which is received. Proper prediction is a significant task which when carried out intelligently has a potential to eradicate the threat completely. [9], [10].Due to this Continuous environmental monitoring is required. Thus the node energy plays a pivotal role to work the system even through if it consumes a lot of power. Hence a power management between the components is important to extend the lifetime of the system.

The overall power consumption of node is calculated and accordingly the duty cycle of the node is reduced to save power

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and a battery is provided. Here lies the next problem. All energy consumptions must be calculated correctly in order to determine the battery required. But in doing so we forget to calculate the life of the hardware or the lifetime of the system hardware like the sensors, actuators, controllers, MCUs etc. which are also an integral part of the node. [2]

Thus after the exhaustion of the energy source the entire node has to be replaced either by a new node or by replacing the energy source with a new one which becomes a cumbersome task and is sometimes not possible depending upon the scenario and deployment fields. Moreover the cost of changing the node or replacing energy source is additional. With current technology we have a maximum hardware life time of about a decade or two if designed very efficiently, while the energy source is of about 1/3rd of the decade. So we lose about 2/3rd of the functionality of a node. Practically this is a very inefficient method of deployment. [6]

IV. Literature Review

After performing an extensive research associated with WSN, various aspects came to light. A lot of research has been done in the field from 1950's and various methods were and are implemented to solve the problem. But investigation uncovered a limited amount of actual data is provided in real time.

Understanding each aspect for energy consumption would help us save energy bits by bits making the system energy efficient as a whole. [3] A research tested a typical WSN scenario with 300 sensors nodes in different real time environment in the laboratory with the method known as microcalimety to understand the lifespan. [18]. another research used the nodes and made to decay them with Hardware material decay Rate Algorithm. [17] The results from both were the hardware lifetime was around 25- 30 years in favorable conditions and 8-12 years in extreme environments. So the power source should be matched to this lifespan while designing a system. [11]

A different power saving technique was introduced by author [6] who claims that if we delay sensing values from sensors for a time period of sensor start up (Ts) depending on sensor types we can save around 3% error value energy losses. We will implement this in this report. A slight different approach is taken by [14] who uses time delay as a radial function for sampling sensor outputs.

To compensate the power consumption and to increase the duration of the lifetime of the energy source author [7] reduces the data mining by receiving the data after a burst of interval but this reduces the data availability in hard real time and can be problematic in time critical situations this becomes a problem and cannot be afforded. [9] Further another way is to compute data at the node level by data fusion technique, which reduces the data bits during communication. But this fails if the data required is frequently and switching radio frequently consumes more energy. A solution provided is greedy switching [13] which is implemented in this paper.

For data computation and compression many algorithms exists which use energy efficient methods like the CS/DCS (distributed compressed sensing) or the adaptive sensing Algorithm [12].They perform very well in compressing the sensor data that they acquire. The most promising amongst them all is the Adaptive Lossless Data Compression Algorithm [18] as results saved around 33 percent of less power compared to others. [19] Further author [16] looks at this in a different way. As the network is distributed over different data acquisition layers, the load reduces on the overall node power consumption and improves the data transfer efficiency by providing more accurate data. This thus also makes the system more redundant and less prone to false alarms in comparison to previous generation systems. [7]

Other researches are based on modes of operations of the node. Different modes of operation like the power on mode, active mode, sleep mode, idle mode etc. [10], [11], [13] are relayed upon to save power.

Various other researches state that the time for active mode and sleep mode should be in a ratio of 1/8 for the most optimal battery life [15]. But some researchers believe that the ratio is ineffective as it should depend on the amount of data gathered differs for every operation so the deployment plays an active role. [12], [17].

Dealing with power harvesters a plant based power harvester project was developed by a company named Plant-e. It has developed a Do It Yourself kits to explain the concept or photo-electro generation but has not progressed in this field, another research from National French Scientific Centre named as CNRS has contributed theoretical aspect to this field but is majorly concentrated on the research of Biomass. [16] Finally the Ekaia and Bioo lite has developed this technology for charging cell phones. [18] But are still in research and development stages. Applying photo-electro generation concept to WSN will not only solve the energy crisis that are faced in a WSN but will also make the system robust and dynamic for multitasking and additional features can be added to it .like making it hard real time system etc.[17]

V. Research Method

To perform the experiment we modelled the research into two parts. The first where we used a Physical hardware model to depict real world scenario in a laboratory and performed various experiments to note the energy consumption and power readings and the second Part we simulated this findings in MATLAB to extend the model to depict a working system when deployed. We shall discuss both the parts part by part as they rely on each other for actual data.

A. Hardware Used

To perform the experiment we use the Microduino module from Arduino series. We connect a 5 V and 3 V pins in series with 1ohms resistor with two AAA sized 1.5 V Batteries as the Power source to run the system on 3 Volts.

Fig. 1. Microduino Hardware with nRF24 transreciever.

The Arduino IDE is used to generate code and to program the Microduino Embedded Hardware. We have used the software, version 1.6.7 to write and implement the code. Additionally we use the Nordic nRF24 radio module as transrecievers. This hardware is used as it uses very good Power efficiency and energy savings with different power modes of operation. [21]

B. System Archetecture

A simulation of 100 nodes were deployed at random with sink nodes and coordinator nodes in a multi-hop scenario which would depict the real Wildfire environment. [15]
The Nodes were processed using the 3 Protocols. The LEACH the TEEN and the APTEEN. Thus various results were found. TEEN was the most efficient power saving protocol but Fig 2 Below shows the APTEEN implemented Protocol as it was found to be the most appreciable protocol in the study for this scenario. The Counter Timer used was 30 seconds.

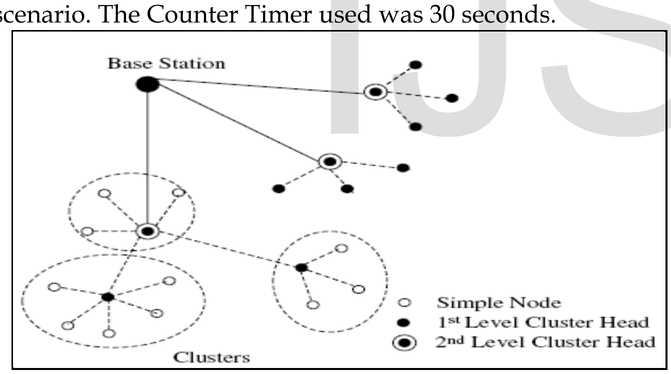


Fig. 2. APTEEN Protocol Structure for WSN.

Further experimentation was done to understand the correct size of packets in order to have the most efficient way of sending packets during communication.

Adaptive Lossless Data Compression Algorithm was researched but not implemented as it would be the future works of the research project. But theoretical results were very promising.

C. Experiments

I. For Calculating Power of Node

It's always said that computation requires less energy compared to communication. It's true, the amount of data that is gathered and computed is cheaper than to send over the data. This field relates to most of the energy used efficiently to process the data. If done correctly the life of the WSN can be increased up to 200 percent of its life that data collected at random or continuously. This aspect also contributes to 40 percent of the energy consumed by the node.

A. Background

Local data processing is very important aspect when it comes to minimizing power consumption especially when we use a multi-hop network to send data .The amount of processing done in this area defines the life expectancy of the system. Without computation we just send raw data consuming the entire node in less than a few months. Different modes of operation lie like the power on mode, active mode, sleep mode, idle mode etc.

B. Method

After performing a lab experiment to calculate the energy consumption in different modes. We modelled an Arduino node with different modes of operations and a one to one communication was set up. This energy consumption will be the same for every node in the field when deployed regardless the conditions.[10]

We use the formula:

Emode = Σ Vdc x I x T mode

Where Emode is the energy per mode V is the voltage required I is the current drawn, and T is the time period of the mode active.

For Data gathering and processing we use:

Pp= F x C x V^2 + Vdd(Io x e^ (Vdd/n x Vt))

Where F is clock Frequency, C avg capacitance per cycle, Vdd is supply Voltage and Vt is thermal Voltage. [14, 16]

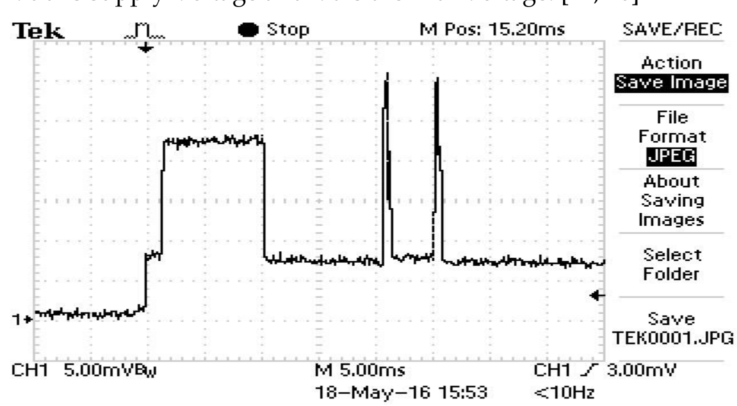


Fig. 3. DSO output for Different modes of the Power consumption. Power Consumption V/S Time Graph.

C. Results and Analysis

We observe that the energy consumed per cycle by the system is calculated around 8.34mAH with active mode for 30.035 seconds with active greedy switching.

The time plays a very crucial role in this segment. The amount of time the node is in ideal mode more the power is wasted if no computation is done. A single duty cycle should complete the entire process of computation with correct sensing in least amount of time. We adjust value P1 for more than sensor startup time Ts=0.011s inorder to avoid error readings from sensor.

D. Math Modelling and Realization

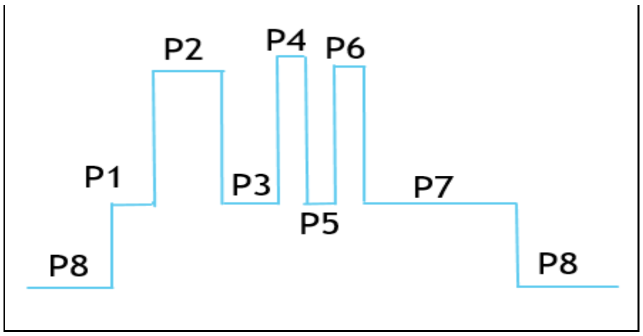


Fig. 4. Power Vs Time diagram for a WSN.

Pavg = {(P1xT1) + (P2xT2) + (P3xT3) + (P4xT4) + (P5xT5) + (P6xT6) + (P7xT7) / Ttotal

Where,

Ttotal = {T1+T2+T3+T4+T5+T6+T7}

We can observe this by varying the values time with different sleep modes. We now optimise the node circuit by choosing different data bit rates till we get the least value for P2 by adjusting time T2 to as minimum as possible. From experiment 2 we get an optimal bitrate of 1200bits which we implement at this stage.

Further we reduce P7 idle mode to improve energy performance and reduce power consumption. Here we perform data fusion of the data bits hence we make sure that time T7 is always more than data fusion time.

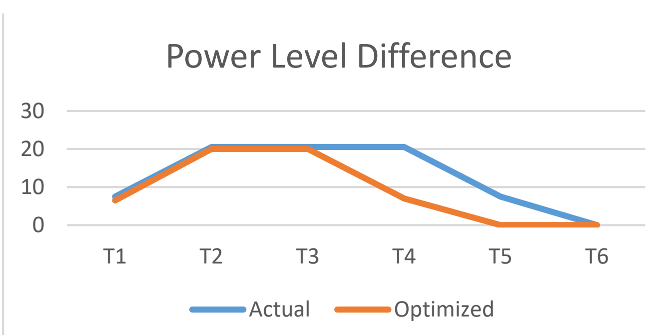


Fig. 5. Experimental Output difference between original and optimized WSN.

E. Limitation

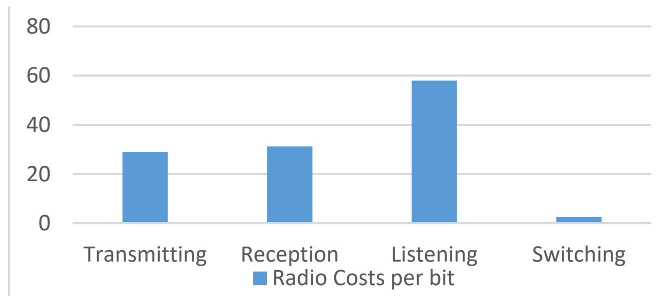
While in computation due to low duty cycles there is leakage energy which accounts to 10% of total dissipated energy. This becomes more prominent in the use of additional computation.

II. For Energy Efficient Routing Protocol

From previous experiment it is very clear that the maximum amount of energy is spend in this domain for both transmission and reception. Even ultra-low power modes of communication consume the maximum resource.

A. Background

The cost of communication varies from the amount of data bits sent to the cost of operations. It constitutes of listening, transmitting, reception and switching.



More over these values differ with respect to the size of data packets transmitted and distance. The computation can store data packets up to a certain amount and can flush them all together in burst of data. [5].The amount of energy required to read and write data and the amount to send it over time interval is to be observed.

B. Method

The optimal method for finding out the best method for Radio to send the no of packets at a time and the size of each packet when the nodes are in the Trans receiving coverage area. A simulation of 100 nodes were deployed at random with sink nodes and coordinator nodes in a multi-hop scenario which would depict the real Wildfire environment.

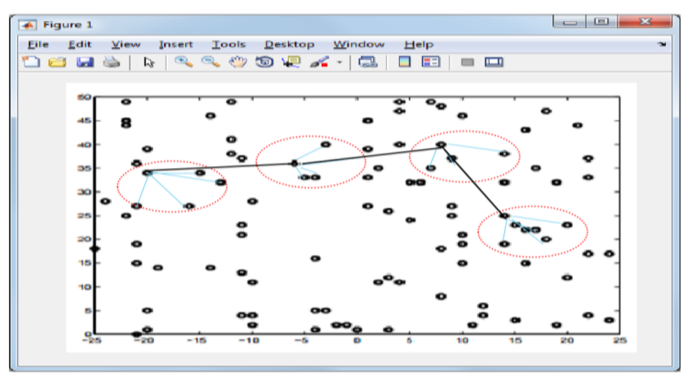


Fig. 6. Deployment senario of 100 sensors with 2000 Bit data rate.

By using the data from previous Experiment we plotted the energy consumption of different protocols and also investigated the different packet sizes and choose the best. We will be testing and confirming the results with 4 main protocols. The LEACH protocol, the MTE, Static clustering, TEEN, APTEEN and direct communication. Various other protocols are available but these are the prime. [8]. Hence we can eliminate the others or limit our paper to these.

C. Results and Analysis

The different types of algorithms were simulated and various results were highlighted.

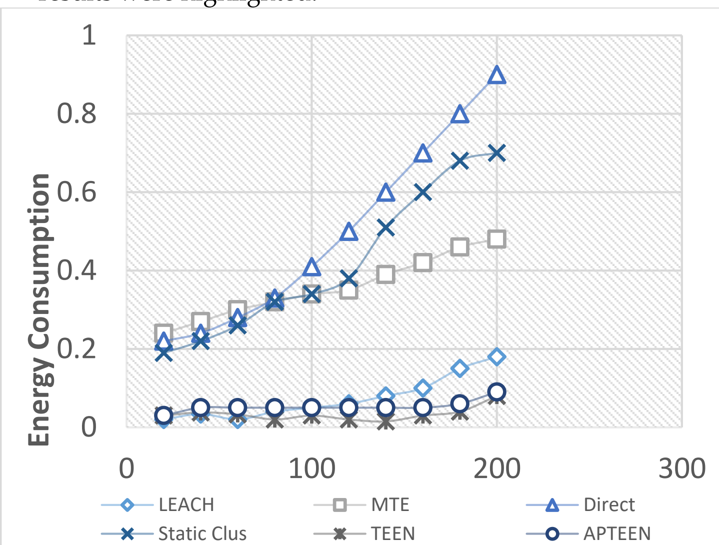


Fig. 7. Energy Consumption of Different Routing Algorithms.

Energy dissipation using 100 nodes using 2000 bits as date rate. It was observed that TEEN uses the minimum energy up to 85% efficient while APTEEN is around 78% while LEACH uses the minimum energy up to 70% lesser than direct and 50% less than MTE and static. While least energy consumed is by TEEN the preferred protocol is the APTEEN. We can say that even through it is most power efficient it does not have a time scheduling and cannot perform continuous data gathering.

Thus under time critical scenario such as a Hazard it will not alert immediately making it unreliable in emergencies Hence research states correctly as the most effective algorithm is available but should satisfy the deployment. [3], [5], [7]. We also observe multiple node deployment we ensure redundancy and Quality of Service (QoS) as it matches "Fit for Purpose" rule [16].

Further studies shows that the no of packets vs the amount of energy can be stated using the graph.

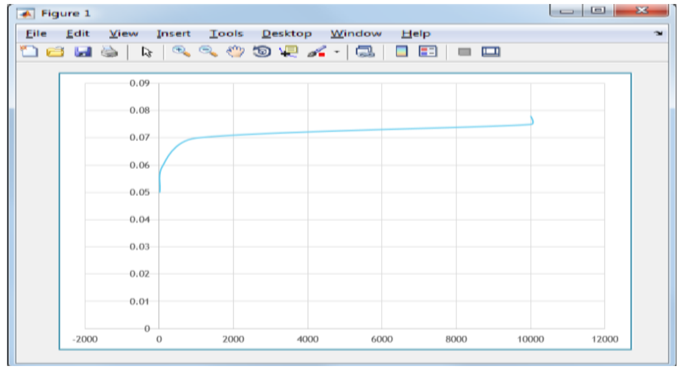


Fig. 8. Energy Consumed Vs Packet size in Bits.

Author [4] says that using a value between 1000-2500 bits per packet gives the most efficient size while author [3] claims a size not exceeding 2000 bits if more efficient. According to our experiment the Graph representing the Curve at the maximum angle from 1200 bits gives almost linear values .So using the energy which will cost minimum with transmission cost is appreciated.

The Distributed network reduces the overall node power consumption and improving the data transfer efficiency by providing more accurate data. This thus makes the system more redundant and less prone to false alarms in comparison to previous generation systems with centralized network. [7]

VI. Research Approach

We shall now discuss about the power harvester that will be required to harness the energy requirements of the system to perform various operations without any hindrance to our WSN.

A. Background

The research is based upon the photosynthesis process which takes place in plants. As the plants absorb energy from the sun in their chloroplasts. They synthesize this energy from the sun. The process absorbs $CO2$ and releases $O2$ in the atmosphere and also produces a by-product $C6H12O6$ into the roots of the plant. This substance is created in abundance in a plant on which the plant survives.

About 70% of this glucose is released in the nearby soil as a waste product. The waste product is basically known as fluxes and comprises of three main products: cellular respiration, net primary production and rhizodeposition. The flux creates a significant amount of carbon and energy in the soil. This deposition helps various heterotrophic organisms who digest and live on this livelihood.

Rhizo-deposition is generally in plant photosynthesis varies from one another .It can be anywhere from 30-50%, while in special plants like rhubarb it can be up to 80 %. The rhizodeposition is the treasure mine for our field for energy production. It comprises of four major ingredients: Detached dead cells, Lysates, Mucilage and Exudates

The detached cells are majorly the dead root caps which are short lived in the plant. These cells help in secretion of enzymes and proteins for microorganisms nearby. While the lysates benefit bacteria mainly the saprophytic strand and are made of autolysis of cortical tissues and Rhizo-dermal cells.

The catalyst of the growth of microorganisms and other soil particle is the mucilage. It is composed of poly-galacturonic acid. It enriches the soil rapidly as it is the most favored rhizosphere microflora metabolizer for the growth. Finally the exudates which contributes as the biggest part of rhizodeposition. This comprises of all the organic foods, glucose, amino acids hormones etc. required.

As seen above the entire photosynthesis helps in the growth of microbes in the soil naturally. Specific species of microbes have the ability to reduce oxidized metals such as ferrous oxide etc. These special strands are knows as electro genic microbes. Two outstanding species Shewanella and Geobactor are the most abundantly found electro genic species in every corner of the world soils. These Micro-bacterial organisms break down this compounds creating free radicals of H+ protons and e-electrons. This reaction is a redox reaction

B. Construction of Power Harvester

By The PPH is build using 3D printing. The structure is composed of high grade nylon which makes the material waterproof and last longer without decays. The 3D construction is made using Solid works framework 2014-2015 software. The design is symmetric with 3 legs each on which a copper wire is wound. The base of these legs lie joints in which graphite rods fit. These rods act as the anode for electrons. Between the legs are strong pieces of permanent magnets placed which produce a strong magnetic field. Tiny pieces of zinc strips are present at the base of the main structure. These will be explained in the working.

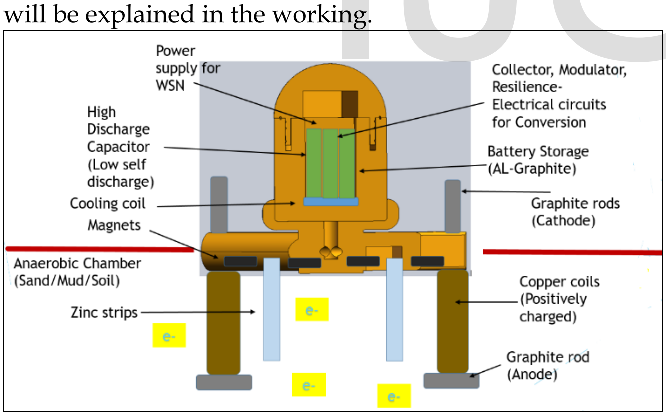


Fig. 9. Construction Diagram of a plants Based Power harvester.

The top oval shaped box is a waterproof box fitted with O-rings and silicone gel. This is the brain of the PPH where all the electronic components are present. The base of this box is designed in such a way that a tiny thermos-cooler is fitted. 2 major electronic power harvesters- BQQ25504RGTT from Texas Instruments and the LTC3588 from Spark fun are used.

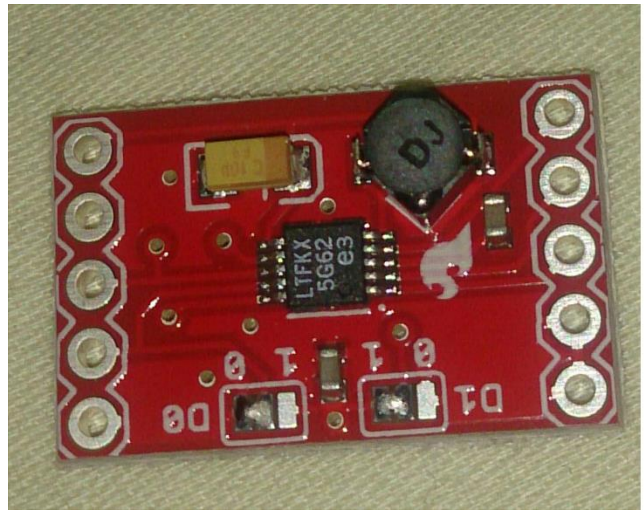


Fig. 10. Power harvester-LTC3588 from Sparkfun

All the simulation and design models were carried out using pspice software. A high discharge Capacitor is present which acts like a supercapacitor to provide electrical energy to WSN supply .A battery storage unit is available in case of rechargeable Li-ion backup unit. Outside the box three graphite rods are present which behave like the cathode of the PHH.

The entire experiment was conducted in black garden soil with a depth of 26 cms and the area covered 5m x12m with a temperature varying between 8 degrees -17 degrees.

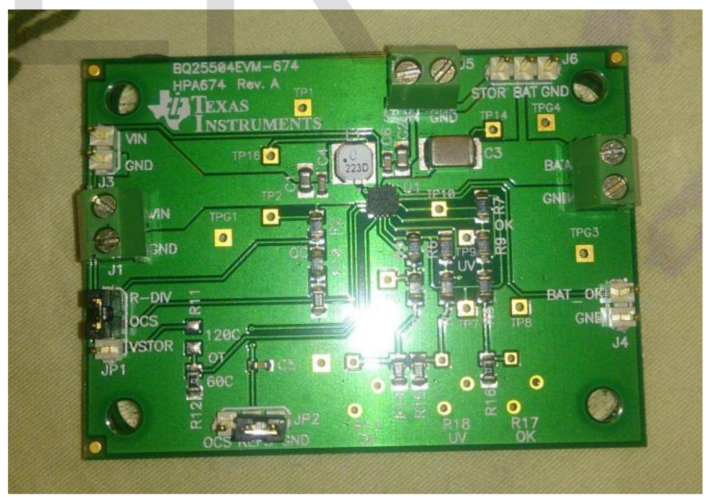


Fig. 11. Power harvester-BQQ25504RGTT from Texas Instruments

C. Method

By using a gold nanowire with a positive charge we can attract these electrons and store it in form of energy. This would create an energy store in a battery which can be used by the WSN sensor network. But Due to limited funding this had to be discarded and a different approach had to be taken.

When the device is inserted in soil close to a tree the circuit completes and the generation of electricity takes place. Firstly

ISSN 2229-5518

this device has to be inserted in soil to the marked level as seen in the picture in the construction. The cathode graphite rod has to come in contact with the top layer of the soil and also has to be exposed to air.

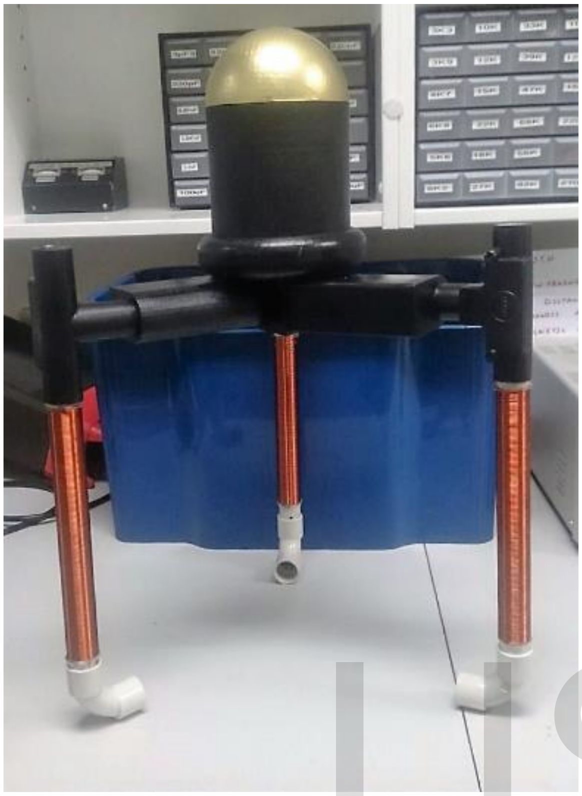


Fig. 12. Photograph of actual constructed unit

The process begins with the generation of zinc ions in the zinc strip available or present in the soil and it moves towards the copper due to electron affinity process. This is similar to a basic electrolytic cell. As soon as copper starts gaining electrons the electronic circuit is charged in the box above the soil. This starts charging the capacitor. It has to be noted here that zinc is not physically connected to the copper wire through any circuitry as this is not a zinc copper cell.

As the electronic circuits start they start inducing current through the copper coil. Due to this reason copper is overloaded with electrons and it starts repelling zinc ions away. The zinc electrons now try to move to the top of the soil towards the base of the box. They collide with the thermos cooler present. Note that due to the reason zinc has Due to the strong magnetic field present at the base we observe using right hand thumb rule the velocity vector is perpendicular to the magnetic field present and perpendicular to the electric field.

Fig. 13. Photograph of actual constructed unit during live trial

This creates a hydrophobic whirlpool of electrons in the soil present. The Shewanella and Geobactor by this time have consumed electrons and are available in the soil. Due to the movement of zinc electrons present they are agitated and having an affinity towards carbon they are forced to the anode graphite. The charge flows from this graphite to the primary power harvester circuit which is completed by the cathode present at the top of the soil interacting with air. A full redox reaction occurs creating a working stable fuel cell. This would create an energy store in a battery which can be used by the WSN sensor network.

On an average this source of energy will work till the life span of the trees around it. This makes abundant free energy for harvesting as there are large amount of tree found in the forest. It is not dependent on any other aspect like the sun, water or wind etc. The graphite's present will decay eventually but are estimated with a lifetime above 8-10 years under optimal conditions.

D. Results and Analysis

Theoretical calculations and Initial model showed that the harvester will produce around 350uW per unit at 30Degree Celsius. And a Power Density of around 8.57mW if we use an area of 1 x 1 meter of anode surface area.

This technology has a low current, high impedance power source. Due to this reason the choice of specific hardware was made for the electronics. The use of two power harvesters was done to use one as a charge pump boost conversion circuit to boost the input voltage to usable voltage. The input voltage was measured around 800-900mV as input which was converted to higher voltage above 3 V and less than 3.5V to avoid overloading.

The results were collected after every 30 min using the Microduino from the first experiment. It was used to collect n store important values such as voltage, current, moisture in soil and temperature.

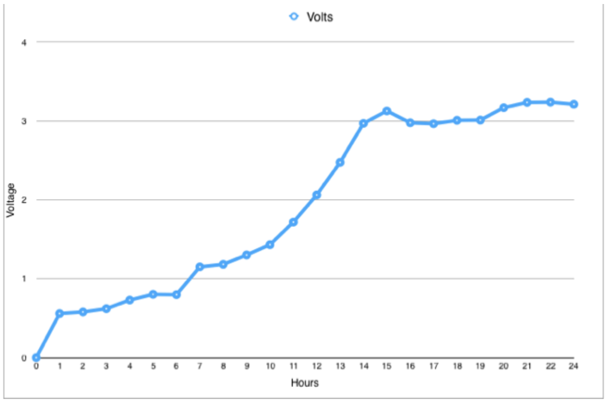


Fig. 14. Recorded Voltage V/S Time Graph.

As mentioned earlier the voltages were quite low so the outputs collected were after the boost circuit. The above graph represents about 600 percent after the upboost of the actual voltage produced. It can be seen that the voltage remains stable between 3V and 3.5V after it reaches it optimal conditions. The power management board could easily manage these low voltages of less than 90uW with a 30 minute sampling/transmission rate. With laboratory test between sampling rates, quiescent power drawn from complete system was less than 30µW.

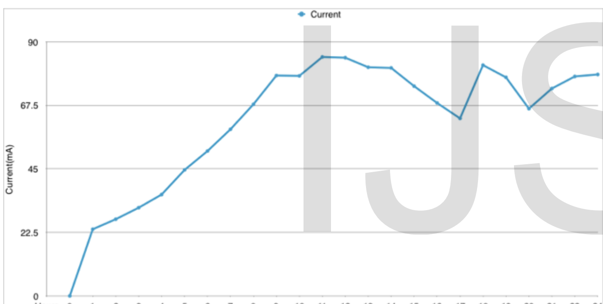


Fig. 15. Recorded Current V/S Time Graph

The current rises in the PPH in an abrupt manner .This happens due to the change of elctrolytic cell. As we can se the initial rise of current is steep then the switching cycle reduces the rise . Finally when the PPH begins the rise is gentle. As it reaches saturation we observe that the current values change according to the moisture levels .

Certain abnormalities in this steady state occurs due to the charging and discharging cycle of the capacitor which provides energy to the WSN to work. This can be regulated if a current stabiliser is introduced but while doing so we will lose the current production . Furthermore due to induced current in the copper coils we observe some stray currents are genrated which which further degrades the system to certain degree. The overall current generated is sufficient to run a WSN continuously for 30 minutes as mentioned earlier .

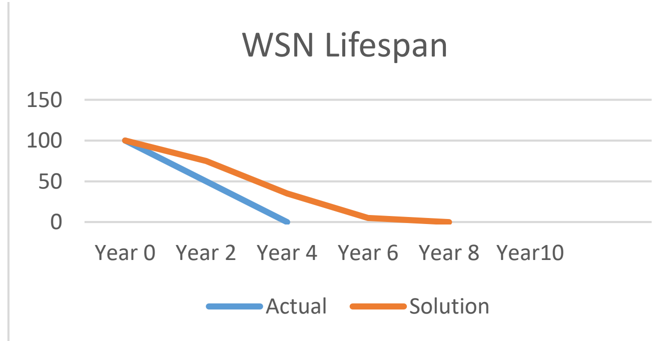


Fig. 16. Power harvester Lifespan with regards to regular WSN.

Hence this is the most ideal form of power harvester which can be used and will work till the degradation of the electrodes as it is self-powered using plants. The amount of energy it will produce is sufficient to use each node as a power node or individual node with high powered transmission capabilities as the power generated from this harvester will be far more than energy consumed.

E. Limitation

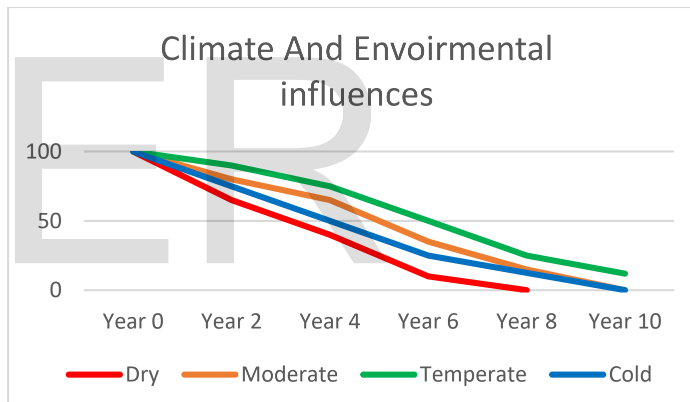


Fig. 17. Working of Power Harvestor in Diffent envoirnments.

Considering the amount of Moisture available in soil and Temperature of the environment the harvester will produce the following amount of power as shown in graph. Since it is not consistent and has some external factors it could be a chance that it may sometimes produce less energy than expected.

Climate Type	**Soil Moisture**	**Temperature (Degrees)**	**Power Op (mA)**
Dry	20%	45 C	63
Moderate	60%	20 C	75
Temperate	80%	30 C	**80**
Cold	40%	10 C	69

Fig. 18. Output power table of Power harvester in Different climates.

ISSN 2229-5518

The water content threshold must be above 7.8 % in order for the cell to begin to work. After this point we see a gradual rise in power as water content increases. The actual value will change according to soil content. A way to increase moisture can be by using Absorbent polymers. We see that the PPH begins to rise gradually after its time of deployment. After a while there is a gradual drop in power level. This is due to the reason that the moisture of the soil drops eventually. We can see that the value of power reaches zero as soil moisture drops below 7.8 % as found during the experiment.

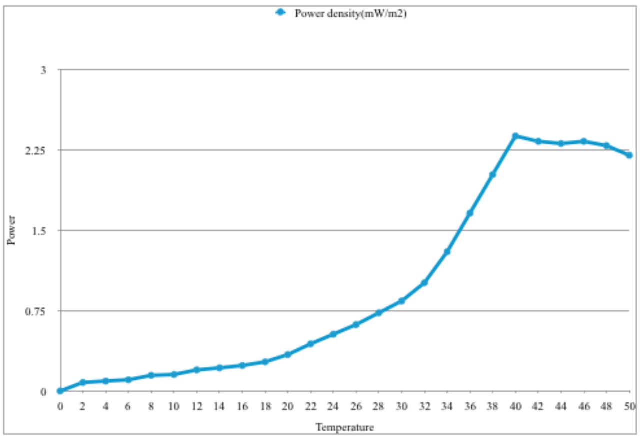


Fig. 19. Power Density V/S Temperature

From the experimental results it is can also be seen that temperature is also an active participant which affects the power of the PPH. The metabolic rates of microbes needs to be taken into consideration. The temperature in which they can survive will be the range of this technology. If we look into the temperature conditions power improves drastically when temperature crosses 25 degree Celsius. There is a power spike. While reaching temperature above 40 degrees we see a fall in temperature. This is due to the fact that microbes do not perform well under extreme temperature. So ideally a temperature range between 15-35 degrees Celsius will give optimal performance. Envoirmental influences

VII. Results

After Researching and Experimentation it found that the overall output capacity and efficiency of WSN improves if we deploy the sensor network by using the above parameters. We could finally make an experimental working model of a WSN system and simulate the outputs .The Lifespan of the system is 7% more than the original lifespan using experiments and will be twice the original if we deploy it using the power harvester concept suggested. The form Factor of the system is high initially but in the long lifespan overlook we save around 25 % overall in investments and maintenance.

VIII. Future Scope

The Future of this technology seems very promising by the results obtained over the research period. Making the Power harvester and implementing it in real time will boost the WSN networking capabilities to a great extent .Further research in this direction will prove beneficial to the field.

• Improving the current and voltage stability and boosting the circuit to work above 5V will enable a new range of device accessibility.

• With development in this field we will be able to charge simple household items like: lamps, fans and mobile phones in future which will use with this technology using house plants.

• Farmlands and remote inaccessible areas can use this device to deploy WSN where other sources are not available for harvesting energy.

• Since the technology depends on a plant it will increase and promote the use of green clean technology and solve global warming issues too.

IX. Conclution

WSN's are designed with great power saving and energy efficient methods. Using APTEEN protocol for routing a distributed system will save energy to a very large extent. The sensing with comparator makes computation simpler and can be reproduced using Nyquist plot.

The Adaptive Lossless Data Compression Algorithm method is far more efficient when we have large amount of data to sense than the processing using computation as more energy is saved. Using Greedy switching we can reduce the idle time in computation hence improving power losses. Making use of data bursts for communication reduces the switching cost if data communication is frequent.

The plant based power harvesting system was also successfully demonstrated to save energy and produce energy to a very large extent. The PPH converted the energy using standard low power hardware and standard WSN. Thus proving the technology to be reliable, robust and efficient. The experimentation faced many tough challenges and technical problems initially. But it was a success during the results it displayed. Currently the technology has to be limited to warm and wet environments where sufficient power can be generated. Mostly to temperate or moderate climates.

Further we see that more experimentations using absorbent polymers would increase the power output of the system with promising results. Other investigations that need to be done are the PPH needs to run for a year to find exactly the complete range of hurdles it has to face. Current deployment was in summer in 17 degrees temperature so this may enable it to produce reliable content levels of power output with minimal variation. The design cost had been kept low to maintain cost effectiveness when deployed in masses. This project also provides great insight to the emergence of microbiology with physics bringing new set of tools to be used to harness power.

For the current generation we need unique methods to increase the lifespan of the WSN as most of the usable aspect of a node is lost due to its power budgeting for data acquiring.

This is a good method but we can optimize the same resources hardware and have a single node work with greater efficiency if we provide a correct source of power and stable form of energy. This would make the WSN not only reliable and time extendable but also will be cheaper for deployment as the life expectancy will increase drastically

And lastly by using a cluster architecture we can build a network which will be highly efficient. But we need to look into the setbacks of this system and find out a much efficient way if there is any or formulate a new technique. The key for long life is power and power is available scarcely using battery or power harvesting technology. But by using smart techniques we can improve this field help in energy saving and increase the lifetime of the network as a whole.

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