Enhancing Cluster-Head Lifetime using Energy Harvesting

Ananya R.
Department of Electronics and Communication Engineering
Vidyavardhaka College of Engineering
Mysuru, India

Bhavana R.
Department of Electronics and Communication Engineering
Vidyavardhaka College of Engineering
Mysuru, India

Ananya S.
Department of Electronics and Communication Engineering
Vidyavardhaka College of Engineering
Mysuru, India

Deepthi K.M.
Department of Electronics and Communication Engineering
Vidyavardhaka College of Engineering
Mysuru, India

Amit Raikar
Department of Electronics and Communication Engineering
Vidyavardhaka College of Engineering
Mysuru, India

ABSTRACT
Considering the IoT in relation to the collection of field data, Wireless Sensor Networks (WSNs) offer a practical and efficient method. But the small battery capacities connected to each cluster head of a WSN may have a limit on how long it can last. The utilization of energy harvesting techniques to refill cluster head batteries is a growing trend in WSNs to overcome this difficulty and extend their lifespan. In order to satisfy the requirements of a realistic WSN system, this work explores a scenario of WSNs that includes cluster heads that can harvest solar energy. The hardware and software requirements, the methodology and the implementation are discussed in this paper.

Keywords
WSN, Cluster head, Energy harvesting, Solar energy, sensor nodes, Charging Circuit, Batteries.

1. INTRODUCTION
WSNs are decentralized networks made up of an abundance of tiny, energy-efficient sensor nodes that are arranged throughout a given space as shown in the figure 1. Together, these sensor nodes keep an eye on many environmental and physical factors, including vibration, pressure, temperature, humidity, and even pollution.

A certain node in a WSN is identified as a Cluster Head, and it is in charge of overseeing and directing the actions of other nodes in its cluster.

In many applications, such as smart cities, industrial automation, and environmental monitoring, WSNs are essential. The short battery life of sensor nodes, especially cluster heads (CHs), is still a major problem. Regular battery replacements cause disruptions to operations and raise maintenance expenses. By creating a solar-powered cluster head with improved battery longevity and dependability, this work seeks to overcome this constraint.

The suggested method gathers ambient light and uses solar panels to transform it into electrical energy. The CH battery will be charged with the energy that has been seized, lessening the need for the primary battery and increase its lifespan. The work also aims to implement circuits for energy-efficient charging. These circuits maximize battery life by streamlining the charging process and reducing energy waste.

Since the sensor nodes are irregularly placed throughout the detecting fields, it is not necessary to replenish their batteries. Consequently, extending a WSN's lifetime is a popular area of study. A WSN's lifespan can be determined by considering various parameters, such as the duration of time before every sensor node is dead and unable to transmit.

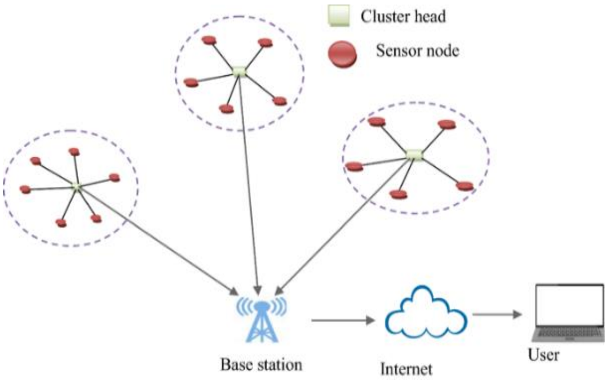


Figure 1: Wireless sensor network.

2. BACKGROUND STUDY
A WSN is utilized to track different systems, physical issues or environmental aspects. The prominent reasons for the evolution of these networks are: advancements in technology with respect to energy efficiency, the need for seamless connectivity, the cost factor, safety and security, etc. Achieving great energy efficiency in WSNs is critical for extending network longevity. Researchers looked into the different methods involving clustering-based methodologies. These techniques make use of low-power, multi-functional sensors that collaborate with cluster heads that have data capabilities.

A clustered WSN is normally made up of a base station (BS) and a number of clusters. A cluster head (CH) with certain non-cluster head (NCH) nodes constitutes each cluster.

The CH is in charge of collecting data from NCHs, processing it, and then delivering it to the BS, either straightaway, via other CHs, or via one or more relay nodes.

An inconvenient CH position may compel the CH node to interact with the BS over a long distance, consuming its stored energy quickly.

Thus, so as to overcome this issue, the replaceable batteries are replaced by the rechargeable batteries via traditional renewable energy harvesting method.

Energy harvesting (EH) is the technique for gathering energy from outside sources. This energy is subsequently stored for use by small, wireless autonomous devices, such as those used in condition monitoring, wearable electronics, and WSNs. It is also known as power harvesting, energy scavenging, or ambient power.

Due to its abundance, solar energy was found to be the most suitable renewable energy source for designing the prototype. With greater expertise, alternate sources of energy can also be used.

The deployment of EH-enabled nodes within the network imposes both a price burden on users and performance limits due to environmental dependencies. The author presents the EH-enabled Energy-Efficient Routing (EHEER) technique for sustainable communication in Wireless Sensor Networks. The selection of cluster heads (CHs), is based on The Spotted Hyena Optimizer (SHO) algorithm to maximize the fitness parameters for CH selection. [1]

A dynamic strategy is used to decrease the energy consumption of wireless sensor nodes because there are various energy-saving techniques available in the EH-WSN that are based on a static approach of sensor nodes. The primary goals are to optimize node battery usage and distribute energy from the energy harvester efficiently to shorten the distance between the cluster head and the power supply.[2]

Enhanced Energy Harvesting Clustering (EEHC) system has been presented for energy harvesting aware WSN. It offered balanced energy harvesting and distribution during the cluster creation and data transmission stages.[3]

WSNs face a challenge with finite battery energy, impacting their lifespan. To address this, energy harvesting (EH), particularly using solar power, proves effective. Employing the low energy adaptive clustering hierarchy protocol alongside solar EH enhances network longevity [4].

WSN is the way to boost the network lifetime at the same time as preserving the coverage Requirement. Since the power of sensor node is restrained, the network lifetime is extraordinarily limited. Recent studies have validated that energy harvesting era can Potentially alleviate the energy difficulty [5].

Energy harvesting is the significant technique for developing long-lasting and/or self-sustaining battery-powered WSNs. Another intriguing issue for establishing realistic WSN deployments is the consideration of WSN heterogeneities [6].

One potential cure for the issue is to employ a wireless sensor network's energy harvesting system to constantly power sensor nodes. Sensor nodes can acquire energy from the environment they are in. Solar, wind, and thermal energy are just a few of the many natural energy sources that can be captured and used for WSNs [7].

Through the inclusion of energy-harvesting (EH) nodes, an approach is put forth to increase the lifetime of the network in which EH nodes act as cluster heads('CHs') dedicated relay nodes [8].

3. METHODOLOGY

In the era of Internet of Things (IoT), sensor nodes play a critical role in gathering real-time data for several applications, which includes environmental monitoring. An IoT sensor node is a compact device equipped with sensors, microcontrollers, and communication modules that enable it to collect, process, and transmit data wirelessly. These nodes are commonly deployed in diverse environments, ranging from industrial to agricultural fields, to monitor parameters such as temperature, humidity, air quality, and more.

- The enhancement of cluster head battery lifetime is achieved by using solar panel systems for charging the battery where battery is charged with the help of dc charge controller M634 with solar panel inputs.
- This charge controller circuit model helps to maintain the battery with 100% to 40% of charge, increase the life span of the battery and also it protects battery from overcharging and discharging to zero.
- Concept of IoT is used to study the battery performance and load consuming current.
- Remote monitoring helps to study the performance of cluster head and also the usage of battery power across the load which helps to set sensor data acquisition interval. So that the battery performance can be improved more in further days.
- The performance is evaluated using charging voltage across battery and the SOC performance are evaluated using OCV method.
- The SOC is calculated at every interval of 1min and this can be varied according to user requirement.
- During this interval of time when OCV are measured the batteries will be disconnected from charging module and the OCV voltage are obtained and the SOC are calculated.
- Similarly, to measure the battery discharging current across load current sensor is used.
- Above obtained SOC, charging Voltage, current across load and sensor data are remotely sent to IoT cloud for further actions.

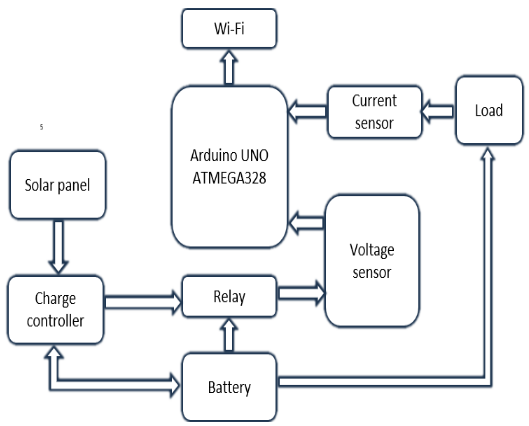


Figure 2: Block diagram of the charging circuit.

3.1 Components of an IoT Sensor Node:

- **Microcontroller**: At the heart of the IoT sensor node lies a microcontroller, such as Arduino Uno, which serves as the brain of the system. The microcontroller is responsible for interfacing with sensors, reading sensor data, and executing control algorithms.
- **Sensors**: Various environmental characteristics are measured using sensors. For temperature and humidity monitoring, sensors like DHT11 or DHT22 are commonly employed. Current sensors, for example the ACS712, enable measurement of load currents, while voltage sensors monitor battery voltage levels.
- **Communication Module**: To transmit data to a central monitoring platform, an IoT sensor node requires a communication module. Wireless modules like Node MCU ESP8266 facilitate communication over Wi-Fi networks, enabling remote monitoring and control.
- **Power Management System**: In scenarios where continuous operation is essential, such as remote environmental monitoring, a reliable power source is crucial. Solar charging systems, comprising solar panels and charge controllers, harness solar energy to charge onboard batteries, ensuring uninterrupted operation even in off-grid locations.

3.2 Design Considerations:

- **Energy Efficiency**: IoT sensor nodes are frequently deployed in remote or inaccessible locations where power sources may be limited. Therefore, designing energy-efficient systems is paramount to prolong battery life and minimize maintenance requirements.
- **Accuracy and Reliability**: Data Accurate sensor readings are essential for reliable environmental monitoring. Calibration and validation procedures must be implemented to guarantee that sensor data accurately reflect real-world conditions.
- **Wireless Connectivity**: Wireless communication enables seamless data transmission from sensor nodes to central monitoring platforms, eliminating the requirement for physical wired connections and allowing for scalability and flexibility in deployment.
- **Environmental Adaptability**: IoT sensor nodes must be designed to endure harsh environmental conditions, like temperature variations, humidity, dust, and moisture. Enclosures and protective measures may be necessary to ensure long-term reliability.

3.3 Solar Charging System:

- The IoT sensor nodes can be powered by solar panels, which transform sunlight into electrical energy. The size and capacity of the solar panel depend on factors such as geographical location, solar irradiance, and power requirements of the sensor node.
- Maximum Power Point Tracking (MPPT) charge controllers optimize solar energy harvesting by adjusting the electrical load to attain optimum power output from the solar panel. This enhances the efficacy of the solar charging system, especially under varying sunlight conditions.
- Batteries, typically rechargeable lithium-ion or lead-acid batteries, store the harvested solar energy to serve during the periods of low sunlight or at night. Proper battery management, including voltage regulation and charge-discharge cycle monitoring, is essential to extend battery lifespan and ensure reliable functioning of the sensor node.

3.4 Data Transmission and Monitoring:

- Once sensor data is collected, it is transmitted wirelessly to a central monitoring platform for visualization and analysis. Platforms like Blynk provide user-friendly interfaces for creating customizable dashboards to display real-time sensor data.
- Remote monitoring platforms allow users to visualize sensor data, set threshold alerts, and remotely control connected devices or systems. This enables timely decision-making and proactive intervention in response to changing environmental conditions.

3.5 Applications and Benefits:

- IoT sensor nodes find applications in various sectors, including agriculture, environmental monitoring, smart cities, and industrial automation. In agriculture, for instance, Sensor nodes have the ability to track temperature, humidity, and soil moisture levels in order to achieve optimal crop yields and irrigation schedules.
- The integration of solar charging systems enhances the sustainability and autonomy of IoT deployments, particularly in remote or off-grid locations where access to conventional power sources may be limited or costly.
- By offering real-time data on environmental parameters, IoT sensor nodes enable data-driven decision-making, resource optimization, and early recognition of anomalies or potential hazards. This contributes to improved efficiency, productivity, and sustainability across diverse domains.

4. RESULTS AND DISCUSSIONS

In figure 3, the lower limit is set to 6.0V and upper limit is set to 6.8V(battery voltage) and the circuit is in charging condition. The battery automatically starts charging when its voltage decreases less than 6.0V and charging stops after reaching 6.8V.

The circuit is kept for charging with all the components turned off except charge controller, which displays the battery voltage. So that the changes in the voltage can be observed.

The circuit is connected as shown in the figure below

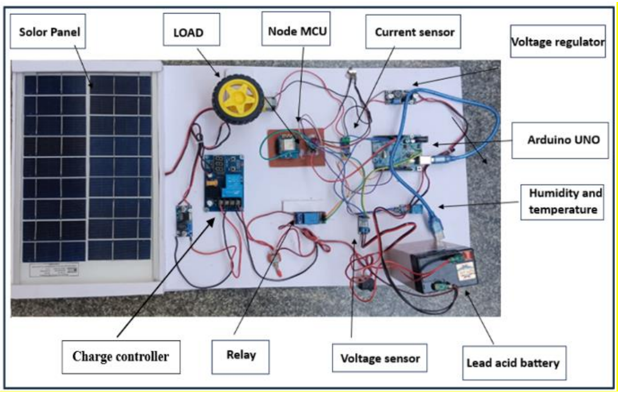


Figure 3: Circuit Connection

Case 1: Ideal condition where parameters are displayed using Blynk IoT.

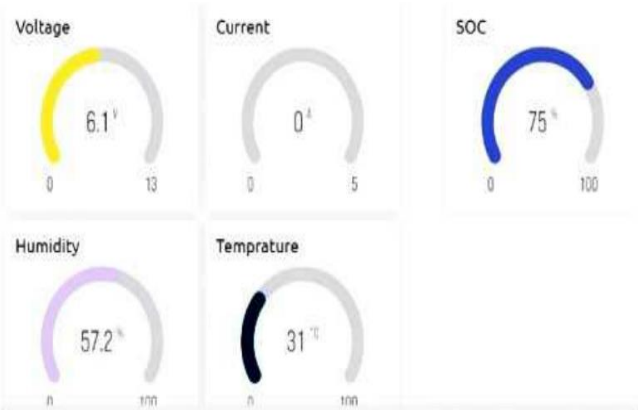


Figure 4: Extract of Blynk IoT(a)

The parameters like voltage, current, SOC of the battery, humidity and temperature are analyzed using Blynk IoT as shown in the figure 4. The voltage of the battery is obtained from the charge controller using voltage sensor, the current is obtained using current sensor when the load is switched ON. The humidity and temperature of the surrounding is obtained using DHT sensor.

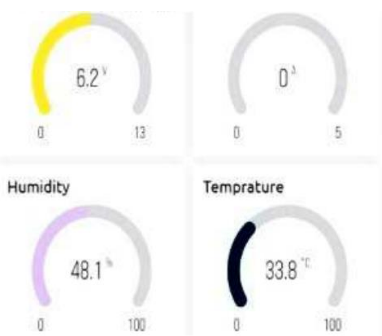
Case 2: When the load is switched on, the current drawn by the load is observed.

Figure 5: Extract of Blynk IoT(b)

In figure 5, it is observed that when the load (DC motor) is switched on, the current drawn is displayed to be 0.28A.

Case 3: The time required to increase the SOC of battery by 1% using solar panel.

Before Charging:



After Charging:

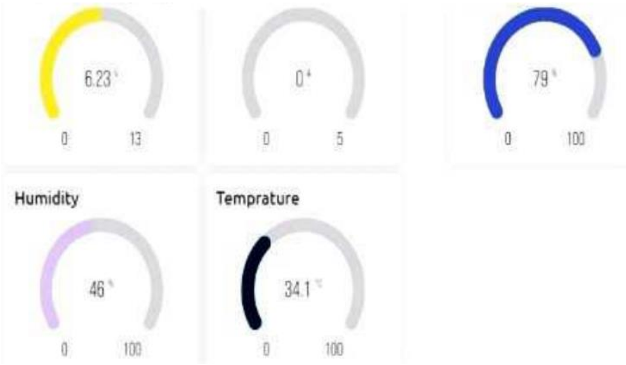
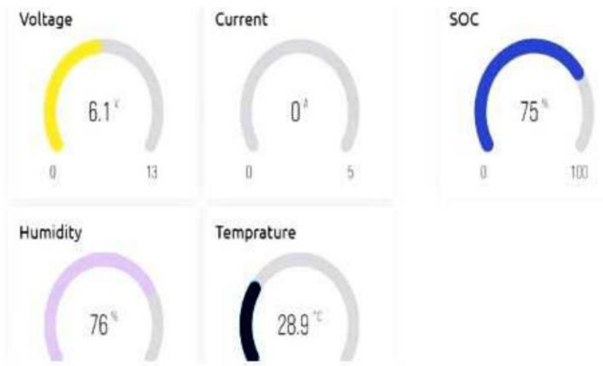


Fig 6: Extract of Blynk IoT(c) Before and After Charging of battery.

The required time for the SOC of battery to increase by 1% is around 4 to 5 minutes. The SOC has increased from 78% to 79% as shown in figure 6.

Case 4: The time required to decrease the SOC of battery by 1% using solar panel without load.

Before Discharging:



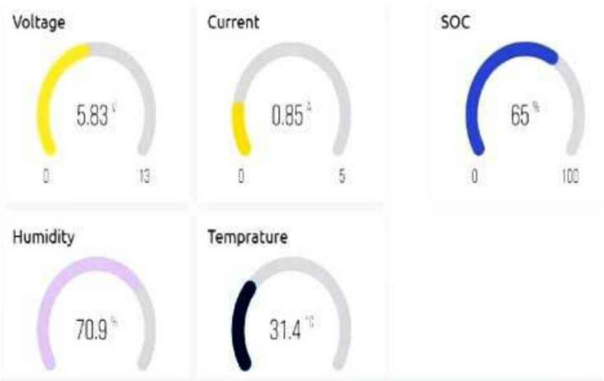
After Discharging:

Fig 7: Extract of Blynk IoT(d) Before and After Discharging of battery.

The time required to decrease the SOC by 1% i.e. from 75% to 74% is approximately 30 minutes as shown in figure 7.

Case 5: The time required to decrease the SOC of battery by 1% using solar panel with load.

Before Discharging:



After Discharging:

Fig 8: Extract of Blynk IoT(e) Before and After Discharging battery.

The time required to decrease the SOC by 1% i.e. from 65% to 64% with load (DC motor) is approximately 5 minutes as shown in figure 8.

5. CONCLUSION

Cluster head lifetime plays an important role in selection of any WSN. More the life time, the more we can rely on the network. With an intention to make the wireless network more dependable after many research attempts authors have put-forth a lot of algorithms regarding the placement of Cluster head in any network. Likewise, to enhance the Cluster head lifetime along with the proposed Algorithms, the energy harvesting technique can be used. That is out of background research it is found that on harvesting natural energy like solar energy, wind energy or tidal energy in to the batteries of cluster heads considering the location of that particular WSN. Likewise, for duck land, solar and water energy can be used and in high altitude areas, the wind energy is used and so on. Hence the source of the natural energy is efficiently selected based on the location.

In this paper, considering solar energy as the source for energy harvesting, a model is built that exhibits continuous charging of the battery via solar panel, which in future has the scope to improve its efficiency by using other forms of natural resources too. Here there is IoT application too for the purpose of monitoring the SOC and other parameters. This ensures the reliability of the WSN without replacing the battery on regular basis and therefore ensuring efficient performance from the network.

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