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A Review on Energy Efficient Techniques for Wireless Sensor Networks

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Abstract
Recent advancements have demonstrated that Wireless Sensor Networks (WSNs) that harvest energy from the surrounding environment have the potential to enable continuous network operations using renewable energy sources. However, the spatio-temporal nature of such networks results in significant variations and only allows for intermittent recharging opportunities, leading to minimal data service sustainability. Among the numerous challenges faced by WSNs, energy-aware routing represents a critical constraint that limits the network's performance. Battery limitations also pose a significant challenge, particularly for battery-powered sensors that consume significant amounts of energy and quickly deplete their battery life. Therefore, this research paper explores various techniques for recharging sensor nodes (SNs) and proposes a robust model that can be utilized in an ad hoc on-demand distance vector routing protocol (AODV) scenario. This model not only improves the energy efficiency of WSNs but also enhances their overall lifespan and reduces traffic congestion.

1. Introduction

Energy is a crucial factor in evaluating the performance of Wireless Sensor Networks (WSNs). Since most of the Sensor Nodes (SNs) in WSNs are powered by batteries, the lifetime of the network is limited by the battery capacity [1]. Energy consumption primarily occurs during the transmission phase when one SN sends data to another. As a result, when the battery dies after a certain period, the network or SN becomes disconnected. While previous research has proposed various methods to extend the lifespan of sensor networks, most have followed traditional approaches such as limiting sensor usage or using energy-efficient algorithms [2]. Although these methods were effective, more improvement is necessary to address the problem [3]. Therefore, advanced techniques are required to improve the lifespan of the network. While there are numerous challenges in WSNs, energy is the most critical as the network's lifespan depends on energy usage [3]. This research work discusses several energy-saving mechanisms. However, the most effective method has been a matter of concern for decades. Before analyzing the efficient methods to increase sensor lifespan, it is essential to understand the definition of WSNs. WSNs consist of widely distributed SNs that record environmental conditions or data. There are two categories of WSNs: structured and unstructured. Structured networks are deployed in an ad hoc manner, while the other type contains nodes that are deployed in a pre-planned fashion. However, it is challenging to handle unstructured networks, while structured ones are easier to handle. Additionally, several devices make sensors intelligent, such as power supply, sensors and actuators, memory, and processors. Communication within SNs has several drawbacks, including link breakages that occur due to high mobility rates. Therefore, numerous protocols have been proposed to reduce link breakages between SNs, such as Ad hoc On-Demand Distance Vector (AODV), a strong and proficient protocol used to eliminate link breakage issues. One of the drawbacks of WSNs is that the nodes are battery-operated, which leads to dead SNs after a certain time. Thus, this paper discusses various re-energizing approaches along with different challenges.

The subsequent section of this paper is structured as follows. In Section 2, the difficulties associated with recharging Wireless Sensor Networks (WSNs) are discussed. Section 3 presents an overview of the various methods used to replenish Sensor Nodes (SNs) in WSNs. Energy storage techniques for WSNs are presented in Section 4, while renewable energy resources for WSNs are presented in Section 5. In Section 6 and 7, an overview of energy transfer techniques for WSNs is provided along with the desired techniques required to make an energy-efficient based model. The final part of this paper summarizes the preceding sections. Additionally, several research works proposed by different researchers along with their respective limitations are presented.

In [1], the authors proposed the introduction of multiple mobile sink nodes as a means of increasing the lifespan of Wireless Sensor Networks (WSNs). They implemented the "flow-based routing" mechanism for energy-efficient solutions and divided the network lifespan into time slices. Although this approach proved to be efficient, a

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more effective solution is still required as it takes a considerable amount of time to execute.

In [2], the author concluded that due to the expansion of application areas in WSNs, the load on sensors increases, leading to a reduction in the lifespan of Sensor Nodes (SNs). Although there are various methods available to minimize data communication over wireless channels, the author proposed a distributed algorithm that uses a local minimization technique to significantly reduce data. However, this technique is not effective in an environment that includes multiple sink nodes.

In [3], a load enhancement method was implemented, which involved the use of mobile data collectors to gather data from various SNs in WSNs. The sink node and data collector worked together, with an intermediator providing communication between the sink nodes and SNs. The network was partitioned into four sections, with a mobile aggregator introduced at the mid-point of each section. This helped to balance the sectional density and coverage, resulting in load balancing. However, there was no re-energization mechanism, indicating the need for an efficient approach to load balance and re-energize the node.

In [4], a mobile data collection design was proposed that not only gathered data but also uploaded it at the same time. The author used two methods, MIMO and Load Balancing, to save energy and achieve the maximum improvement in the lifespan of WSNs. However, the proposed work failed when the base station was dynamic, which is a major drawback of this approach.

It is evident from prominent surveys that there is currently no mechanism available that provides a combined approach of balancing the node traffic and re-energizing it. Therefore, it is a significant challenge for researchers to develop a technique that can provide dual functionality to balance the traffic and energize nodes when necessary. After identifying the major issues, it is necessary to consider additional challenges that may arise during the process of re-energization in WSNs.

2. Challenges in Re-energization of Sensor Nodes in WSNs

2.1 Unexpected Node Failures

If a node fails during data transmission, it can affect the performance of Wireless Sensor Networks (WSNs). There are several reasons for node failure, including communication issues among sensors, battery problems, and other factors. Nevertheless, it is possible to detect node failures and replace the failed nodes with healthy SNs.

2.2 Large-Scale Network

To maintain a scalable network, large-scale networks must incorporate multiple small-sized nodes. Additionally, for data transmission between source and destination nodes, large-scale networks require careful management.

2.3 Time

When developing energy-efficient mechanisms, it is essential to prioritize time as a crucial factor. Extensive research has shown that innovative approaches aimed at maximizing the network lifespan have successfully reduced the time complexities of algorithms in Wireless Sensor Networks (WSNs). As a result, equal importance should be given to the time factor when developing energy-efficient solutions.

2.4 When to Re-energize

Understanding when and how much to recharge is crucial. It is essential to determine the threshold value, which indicates the energy level at which a node needs to be recharged with the predefined amount of energy. This ensures that any node whose energy level drops below the threshold value can be recharged to maintain the desired energy level.

2.5 Re-energization of Mobile Sensors

The literature survey clearly highlights that the battery life of mobile data collectors is a significant limitation that has been extensively discussed by numerous researchers. However, this limitation can be addressed by either replacing the battery or recharging it.

3. Methods of Re-energization of Sensor Nodes in WSNs

SNs are deployed in specific regions to monitor various environmental conditions. These WSNs consist of low-cost, small sensor nodes with low power requirements. Sensor nodes have four fundamental units: Sensing Unit, which gathers data from the environment and converts it into digital form; Transceiver Unit, which shares data among various nodes; Processing Component, which processes raw information to store the outcomes; and Power Unit, which includes energy sink and energy management, as shown in Fig: 1. Fig: 2 shows the power component along with its sub-components: battery units and power management units. The lifetime of nodes in WSNs depends on these resources, and replacing the nodes' batteries with new ones is one method to increase their lifespan. However, in unreachable areas like the Amazon, where nodes are left unchecked for years, frequently changing batteries is a difficult task. In these scenarios, Photovoltaic Panels (PV) or combining various communication protocols can save energy. There are many situations in WSNs where battery replacement is almost impossible, such as in data dissemination-based applications, enemies' areas, water, underground monitoring, and volcanoes.

SNs have a significant restriction on their functioning time, and power must be used efficiently. One proposed approach to save energy is to switch off the nodes during their idle period, which is a common solution to the problem. A large number of researchers have demonstrated energy-saving and recharging techniques in WSNs. This section describes energy harvesting from renewable and traditional power resources in sustainable WSNs.

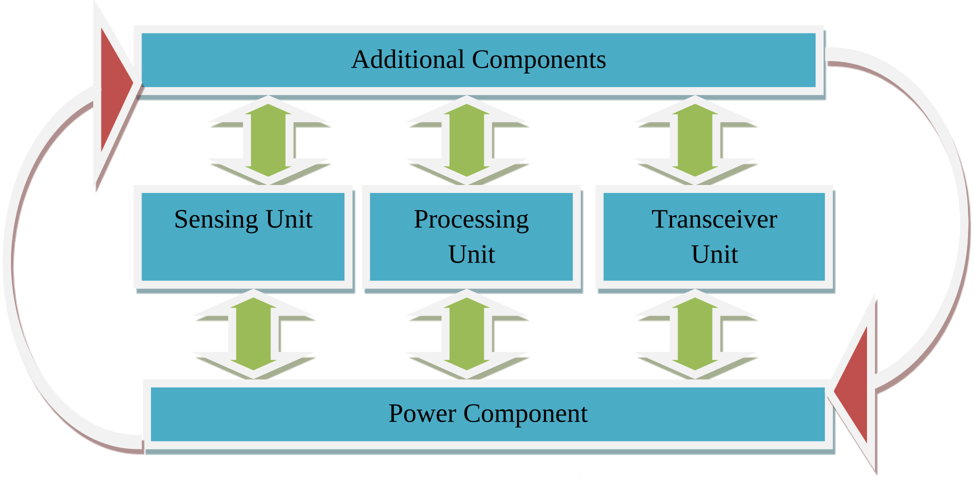

Figure 1: Basic Components of a Sensor Node.

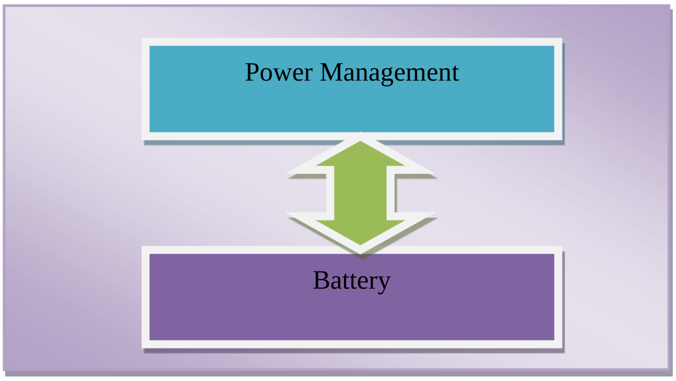

Figure 2: Sub-components of Power Unit.

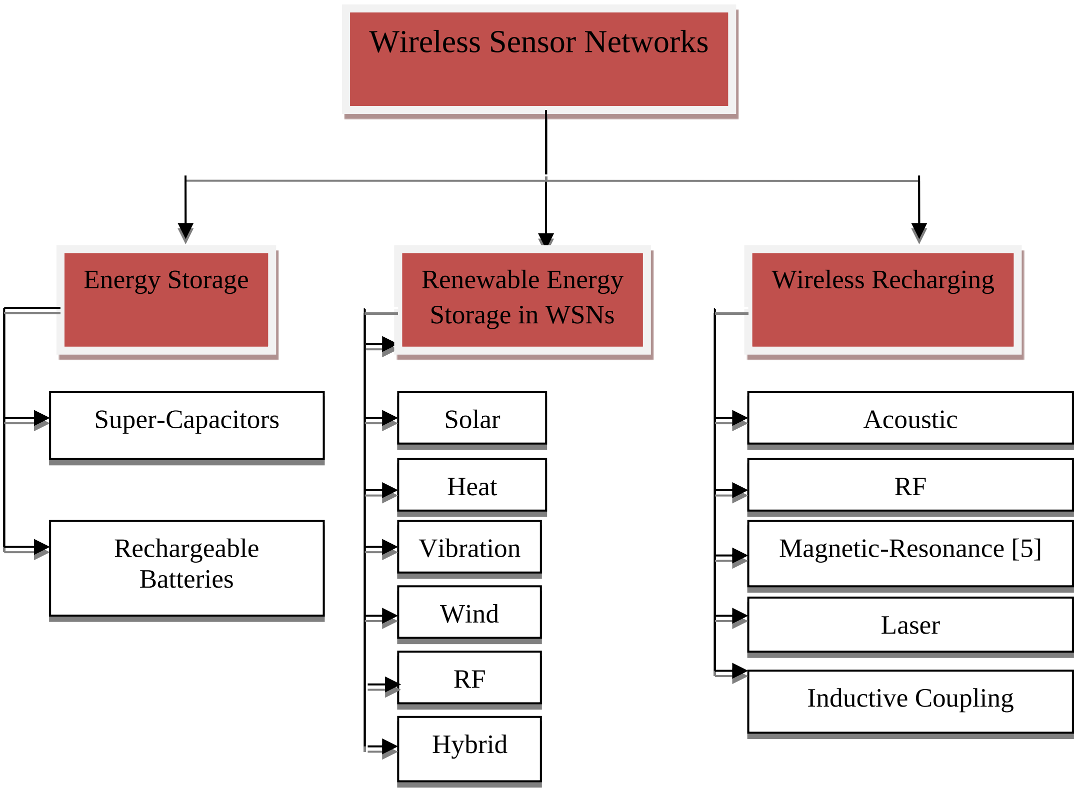

Figure 3: Categorization of WSNs Energy Renewable Resources.

4. Energy Storage Techniques in Sustainable WSNs

The use of SNs can be categorized into three different methods. The first method is to use super capacitors for low-powered applications because they do not rely on battery systems. The second method is to utilize rechargeable batteries for intensive and long-lasting results. Lastly, a hybrid approach can be taken by using both super capacitors and rechargeable batteries. To determine the optimal way of accumulating energy storage, it is necessary to examine each technology and its functioning in greater detail.

Efficient energy storage is crucial for portable devices like SNs. The effectiveness of different methods can greatly impact important factors such as cost, size, and lifespan of SNs. The two types of energy storage technologies used in SNs are super capacitors and rechargeable batteries, which differ in terms of lifespan, leakage, and other factors.

4.1 Super Capacitors

Super capacitors, also known as ultra-capacitors or electro-chemical capacitors, are capacitors that measure the charge stored on them in farads. They are distinguished from batteries and normal capacitors by their high power density. Super capacitors are referred to as double layered capacitors because of their structure. The distance between electrodes is reduced, which leads to an increase in capacitance and power density. Charge accumulates on the elevated surface area of these devices.

Supercapacitors provide many advantages compared to chemical batteries. Their electrochemical mechanism enables them to undergo numerous charge and discharge cycles without losing performance or capacity. Moreover, their highly irreversible mechanism allows for quick recharge, making them an ideal energy reservoir with high charge and discharge efficiency. Additionally, these devices exhibit negligible memory effect and can operate at high voltages and temperatures without requiring complex charging circuitry. Achieving high capacitance and voltage ratings often involves connecting multiple capacitors in series, which requires minimizing total capacitance and voltage balancing, as well as implementing a protection circuit to prevent voltage from exceeding the rated value. This protection circuit is similar to resistors in parallel.

However, supercapacitors are prone to leakage issues due to their higher self-discharge rate than normal batteries. They discharge around 11% of their total charge, resulting in a lifespan of only 10 days. Nonetheless, this problem can be alleviated by employing fast recharging techniques.

4.2 Rechargeable Batteries

The use of rechargeable batteries is a viable option in the context of Wireless Sensor Network (WSN) technology. This approach is more efficient than the use of supercapacitors, and has an improved power density. Rechargeable batteries work through a reversible electro-chemical reaction based on chemical compositions. They can be divided into several categories, such as SLA (Sealed Lead Acid), Ni-MH (Nickel Metal Hydride), Ni-Cd (Nickel Cadmium), and Lithium-ion Polymer (Li-Po). While rechargeable batteries are not commonly used for energy storage due to the memory effect, Ni-MH and Li-Po are cost-effective and can store a large amount of energy. Additionally, these batteries can be charged faster and take up less space. Ni-MH is prone to the memory effect, but Lithium-based batteries are lightweight, provide more power, and operate under high voltage. To maximize battery life, it is important to discharge it in a way that extracts the most amount of charge.

In Wireless Sensor Networks (WSNs), it is essential that Sensor Nodes (SNs) are designed to be self-monitoring and energy-efficient. Each unit in a node must use energy in a proficient way, taking into account various parameters such as battery type, current state, and discharge time. To achieve power efficiency, proper design, routing, energy-aware algorithms, and communication range must be applied. A potential method to limit battery discharge is to decrease the extracted charge.

5. Renewable Energy Resources for WSNs

Renewable energy exists naturally in various forms in our surroundings and can be converted to electrical energy through harvesting. This is a well-established method used worldwide for various purposes. Recent advancements in electronics allow for the integration of energy harvesting modules on Sensor Networks (SNs), also known as energy harvesting SNs. This integration enables SNs to perform traditional functions while also recharging through the Scavenging Process (SP), which relies on the harvesting module. There are two SP methods, one utilizing a constant utilization approach and the other storing energy for later use, based on the design of the harvesting unit. By replacing batteries with harvesting units, the limitations of battery life can be overcome, and energy demanding functions can be performed as needed. Figure 4 shows the replacement of the battery with the harvesting unit for improved performance and smaller size. Collected energy storage is depicted in Figure 5.

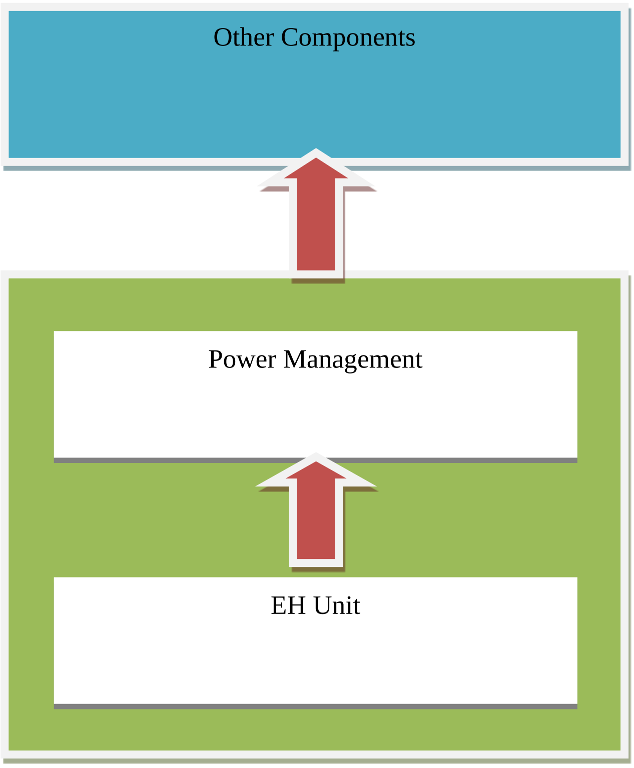

Figure 4: Scavenging Process.

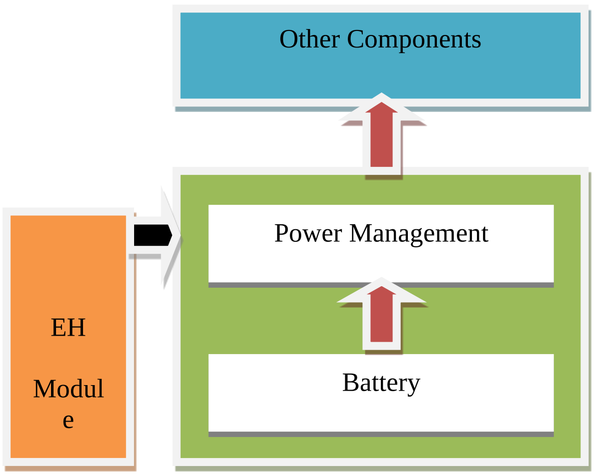

Figure 5: Harvested Energy Storage through SP.

In order to improve the performance of the energy supplied to SN, the MPPT (maximum power point tracking) scheme is utilized, which reduces the power loss that occurs during energy transfer [1]. This method enables non-stop charging and maximizes energy harvesting efficiency from the unit [2-5]. It is applicable to all renewable sources, which are only available intermittently, resulting in wasted energy or no energy at all. To address this issue, the Exponentially Weighted Moving Average (EWMA) scheme has been proposed, which uses data and algorithms to determine the duration of harvesting, enabling complex energy demand functions during harvesting periods. Harvesting nodes in WSNs cannot rely on traditional designs due to the availability of various renewable energy methods. Therefore, a self-sustaining method must be implemented to mitigate this issue.

The selection of a renewable source poses the challenge of determining whether the source can provide the desired energy level or not. While it is possible to harvest energy from multiple sources simultaneously, the effectiveness of the method depends on the environment. Energy storage in nodes is not constant and is uncontrollable due to the spatial distribution between the nodes in WSNs.

5.1 Light

Artificial light and sunlight are the two primary sources from which energy can be harnessed and they are considered to be the most promising renewable resources. It is possible to collect energy from both indoor and outdoor surroundings as there is enough available to operate the system effectively. When energy is collected from sunlight, it is referred to as solar energy. However, due to environmental disruptions, solar energy is not available throughout the day and is dependent on the time of day and season. If gathered efficiently, the energy collected during the day can be used at night. Artificial lights can be used indoors to collect energy for proper node functioning. Low-powered SNs are typically used in indoor environments as artificial lights cannot provide the same amount of energy as outdoor sources. Waspmote node is an example of a solar-based node.

5.1.1 Light Harvesting Systems

PV cells, also known as Photovoltaic cells, have the ability to convert light into electrical energy without the need for any external device. When exposed to light, these cells release electrons, thereby generating electric energy. The output energy of a PV cell is determined by various factors such as the intensity of light, the size of the cell, and its efficiency. To generate a higher voltage energy, multiple cells are connected together. The type of material used to fabricate the cell has a direct impact on its cost, efficiency, and flexibility. Polycrystalline, thin film, and monocrystalline are some of the different types of PV cells available in the market. Crystalline silicon-based cells have the highest energy conversion efficiency, which ranges from 15% to 25%.

5.1.2 Solar Biscuit

The solar-powered system, known as Solar Biscuit, operates without batteries and utilizes a 5 cm solar panel as well as a 5V super capacitor in conjunction with other components. In typical weather conditions, the system can collect up to 20 mA of energy. One example of a solar-powered node that employs super capacitors is the Everlast.

5.1.3 Heliomote

Heliomote operates on a solar-based recharging system. In order to charge dual pack AA Ni-MH batteries, the system employs a 3.75 by 2.5 inch 400-megawatt solar panel. To ensure smooth operation, the system utilizes both over and undercharging methods. Additionally, Heliomote incorporates a power monitoring component that enables the activation of energy-conscious harvesting decisions.

5.2 Vibration

Our environment is filled with vibrations that result from rotation, pressure, or kinetic energy. These vibrations can be converted into usable electric energy using various tools. However, the availability of this energy is unpredictable, although it can be partially controlled. For example, the vibrations produced by a bridge are random throughout the day, while the vibrations generated by bio-motion can be regulated.

5.2.1 Vibration harvesting systems

This type of harvesting system uses three primary methods: electromagnetic, piezoelectric, and electrostatic, to scavenge various types of vibrational energy. Piezoelectric systems utilize the piezoelectric effect, where electric charge is produced directly from pressure on deformable piezoelectric materials without any external source. Mechanical movement or human motions can generate the pressure necessary for piezoelectric systems to operate. Piezopolymer Polyvinylidene Fluoride (PVDF) and Piezo-ceramic Lead Zirconate Titanate (PZT) are the two most commonly used materials. PZT has a high electromechanical coupling coefficient, making it efficient at conversion, but it can break under excessive stress and produce cracks. PVDF is flexible, but it has a low electromechanical coupling ability. The cantilever is the most commonly used piezoelectric vibrational technique for harvesting, and its design is simple and generates additional deformation. The PZT material used in this type provides an output power of 375 W from a vibrational source of 2.5 ms-2 at 120 Hz.

Advancements in piezoelectric systems have led to the development of innovative nano generators, which are highly flexible. The properties of zinc oxide nanowires are used to convert biomechanical pressure into electric power.

5.3 Heat

Heat is a pervasive element in the environment, stemming from a variety of sources such as mechanical equipment, electrical tools, organisms, and structures. One effective method of energy harvesting involves converting the heat produced by these sources or the temperature differences between them into electrical energy, which can provide a long-lasting supply of power. This technique is particularly useful in situations where energy losses result in the production of heat.

The harvesting of heat energy can be accomplished through two primary methods: pyroelectricity and thermoelectricity. Pyroelectric systems, which require no external device or power source, are able to maintain a higher efficiency and operate at higher temperatures within a limited area. In contrast, thermoelectricity utilizes the Seebeck effect to convert heat energy into electrical energy through the flow of heat between two plates with differing temperatures. However, the efficiency of thermoelectric producers is low and they can only operate in a constant heat environment for a limited period of time. Pyroelectricity, on the other hand, modifies the polarization of materials when heat is applied, resulting in the production of electric potential. This method uses polyvinylidene fluoride trifluoroethylene and lead lanthanum ziconate titanate ceramics for energy conversion.

5.4 Radio Frequency (RF) energy

This type of energy can also be harvested for power generation, particularly in areas where potential RF sources are abundant, such as densely populated urban regions. RF harvesting systems use a rectifying antenna to convert RF energy into electrical energy. However, the low energy levels available for harvesting due to radiation spreading away from source nodes limit the efficiency and sensitivity of the harvesting system. The selection of specific frequency bands and deployment positions must be carefully considered to achieve high conversion proficiency.

5.5 Wind

Wind is another readily available resource for energy harvesting, although it can be unpredictable and inefficient at low speeds. Wind turbines are typically used to generate electricity from the linear movement of air flow, but recent advancements in small turbines have made it possible to produce enough power to charge sensor nodes. Anemometer-based wind pickers and piezoelectric materials are used to generate electricity from wind flow, and windproof belts can produce up to 5mW of power. The harvester also utilizes vibration and aeroelasticity, such as a membrane and magnets coated with mylar, to generate power from wind.

Finally, to ensure a constant supply of power, hybrid harvesting systems can be utilized to collect energy from multiple renewable sources. One example of this is the Ambimax system, which integrates solar and wind energy collection modules and a 70 mAh lithium polymer battery with 22F supercapacitors to act as secondary shock absorbers. By collecting energy from multiple sources, a sensor node can continue to function even when one source is unavailable.

6. Energy Transfer in WSNs

Transfer of energy to a SN is far good option rather than generating energy in node by collecting from the environment. Direct contact charging and wireless charging are the two main categories for WSN energy transfer. The former approach makes use of physical contact charging that involves recharging the batteries by physical contact. However, laying cables for SNs recharge will mitigate wireless networking concept. Another method to recharge the batteries is by using hybrid approach which is a combination of wired and wireless system. In this case, primary approach is wired, and secondary approach is wireless. The secondary system gets activated when the primary system fails. There is another solid wired/wireless design which uses various distribution protocols. In such hybrid methods, more maintenance is required, and more cost of installation is needed. Wireless charging is the main aim and is detailed as under:

6.1 Energy Transfer through Wireless Recharging

When the power source transmits its power to the distributed SNs without wired support, it is known as wireless charging. This concept exists since many decades. Nikola Tesla firstly introduced device for wireless transmission [6-10]. Researchers perfected their concepts to ameliorate the distance, efficiency, and portability since the beginning of wireless power transfer. For few methods used in wireless energy transfer needs some interoperability standards. These standards are defined by the wireless energy consortium. Efficient transmissions are possible on portable devices owing to the recent technological advancements [11-15]. Moreover, designers can take this advantage of wireless charging to increase the network lifetime permitting easier and controllable battery replenishment methods for inappropriate environments.

This section describes various energy transfer mechanisms and distribution techniques which can be applied to WSN to handle the limited energy drawback of sensor nodes [16-18]. An application type and implementation type decide the choice of techniques. Wireless charging is only possible with the techniques discussed:

6.1.1 Inductive Coupling based Energy Transfer

In recent years, the proper usage of inductive coupling in energy transfer has been well practiced. The inductive coupling operates on the principle of electromagnetic induction. In this the voltage firstly generates fluctuating electromagnetic field and during this, if some other coil is positioned in this field, the voltage gets induced in the secondary coil via terminals. This means that energy can be transferred via inductive coupling in efficient and safe way. There is no need of electrical cable connection for the devices which use inductive charging. These devices are normally sealed and protected in a compact form. One example of this is electric Toothbrush. It consists of a charger holder along with a coil containing brush unit. The holder generates the magnetic field and when the brush unit meets the magnetic field, the power gets transmitted to the brush unit which recharges the battery. Thus, inductive energy transmission can be easily integrated to ameliorate the lifespan of network.

Inductive load makes use of mobile host which consists of a charger shaped circuit along with a power supply to activate the SN. However, network size can vary from small to large. Also, well established schemes need to ensure that node and network remain functional. The Faraday's and Biot-Savart's Law has been used in the theories of inductive coupling-based wireless power transmission. The magnetic field is calculated using the Biot-Savart's Law which is produced by a random distribution of current as shown below:

$$B = \frac{\mu_0}{4\pi} \int \frac{\mathrm{I} d_I \times \mathrm{r}}{|r|^{\,3}} \qquad (1)$$

In (1), magnetic constant is represented by 'μ0', I represent the transmitter coil having current, d_I represents the vector and finally, 'r' is the full displacement vector. Over the receiver coil, the induced voltage (V_{Ind}) can be computed using the Faraday's Law. This happens due to change in rate of magnetic field 'B' through 'S' (an effective surface area) as shown in (2) below:

$$V_{Ind} = \frac{\partial}{\partial t} \int B.\, d_S \qquad (2)$$

For good efficiency and precise alignment between the transmitter and the receiver, an inductive load needs close contact up to 3 cm. The increase in distance also leads to charging efficiency.

6.2 Magnetic Resonance based Energy Transfer

One technique which is like inductive coupling is known as Magnetic Resonance based Energy Transfer. In this case, when the variable electric current is passed to a coil at specific resonant frequency, the floating magnetic field is created around the coil. However, placing other tunned coil at the same frequency can lead to coupling of this coil with the former one, thus creating strong resonant coupling. The magnetic coupling occurs among the transmitter and the receiver when the source excites the transmitting coil. The resonator's Q factor is defined as:

$$Q = \frac{1}{R}\sqrt{L/C} = \frac{W_0 L}{R} \quad (3)$$

In (3), W_0 is $\frac{1}{\sqrt{LC}}$ which is resonant frequency, R is resistance and capacitance is C. The energy loss is there when value of Q is high. Therefore, mutual inductance can be represented in the following way:

$$M = K\sqrt{L_1 \times L_2}$$

In (4), coupling coefficient is represented with k and L1 and L2 being the self-inductance. They can exchange power remotely if both the coil resonates at same frequency. This is called resonant coupling and is compared with inductive coupling. This method does not create any interference with neighboring environment. Also, this is an effective medium range power transfer method. The size of the transmitter and the receiver in this case is proportional to the power transmission range.

6.3 Range of RF

Total of 3 KHz to 300 GHz range is covered by radio waves in an electromagnetic spectrum. Further, by using far field radioactive waves, some part of this range transmits energy from source to receiving antenna.

Low efficiency has been observed in case of omni-directional transmissions. As radiations are a big risk for an individual's health, therefore the output is limited by regulations. Therefore, it is utilized for low power applications. This technique does not require Line of Sight (LOS) among the receiver and the transmitter, as the power is generated by the sending antenna in every direction. Thus, multiple devices can receive the transmitted energy. Also, switching of antenna consumes lot of energy. The microwaves in the range of 3 to 300 GHz are the range for sub-section of radio waves [19-23]. Further, energy can be transmitted over large distance with more capacity. However, uni-directional waves need to have strong link with receiving device. Additionally, it is very difficult to produce microwaves as the receiver and the transmitters are sufficiently large, thus makes it unsuitable for WSNs. Intermittent microwave energy transfer is carried out in ZigBee device without using battery. Using the similar frequency of 2.46 GHz, the transmission and communication occurs in ZigBee. Also, it is possible to transmit the energy within 1.5 m radius with 35% efficiency.

6.4 Laser Based System

Lasers can be used for transmitting the energy like RF [24-28]. This can be done by converting the energy source into an intense laser beam and focusing it on photovoltaic cell panel positioned in the receiver [29-34]. Lasers reside in the visible or near infrared region and it ranges from 30 THz to 3 PHz. The usable electricity can be gathered from the PV cells in the receiver, using the principle like solar collection [35-38]. It can achieve 98% efficiency depending on the photovoltaic cell type. Compared to other EM waves, the transmitter and receiver dimensions are quite small because of shorter wavelength. Also, there is a need of uninterrupted LOS among two devices [39-42]. However, the limitation can be mitigated with cube angle reflectors or mirrors. On the other side, large capacitors could be used which acts as energy absorbers [43-45]. Second disadvantage is of laser beam i.e., due to its intensiveness, these beams could be detrimental for human beings.

7. Comparative Analysis of Various Energy Transfer Techniques

After reviewing various power transfer mechanism, table 1 below gives summarized view of advantages, disadvantages, range, and applications.

Table 1: Comparative analysis of various wireless power transfer mechanisms.

Energy Transfer Technique	Advantages	Disadvantages	Distance	Applications
RF Radiation [50]	Charging distance is long effective	Low charging efficiency and not safe for humans	Large Kilometres	Mobile applications
Magnetic Resonance Coupling [51]	It can charge multiple devices parallelly, good efficiency	Suitable for smaller distance and it has complex implementation	Upto metres	5G Wireless power transmitter
Magnetic Inductive Coupling [52]	Safe for humans and easy to implement	Generates heating effect	Covers short distance, up to few centimeters	Transformers
The Electromagnetic Radiation [53]	For long distance wireless energy transmission	Line of sight is required for radiation	Long kilometres	Biomedical applications
Microwaves [54]	Long range transmission	High cost of installation and occupies more space	Long Kilometres	Drones, Solar Power
Laser Beams [55]	High efficiency	Very high initial cost	Several hundred metres	Portable device charging

8. Desired Techniques Required for Efficient Robust Model for WSNs

The classification of renewable energy resources leaves the way to the selection of wireless recharging mechanism for designing the model. Wireless Recharging is performed by the moving SN which visits every other sensor within WSN to recharge it. In this Wireless Recharging model, any of the above power transmission mechanism could be installed depending on the type of application. In this work based on the review (Refer table 1), we suggest to use the RF power transmission as it can charge the SNs placed at larger distance. In RF power transmission, the readers send RF signals via circularly polarized antennas and through the linearly polarized dipole antennas, Wireless Identification and Sensing Platform (WISP) tags receive the signal. The block diagram for selected Recharging model is shown in Fig: 6:

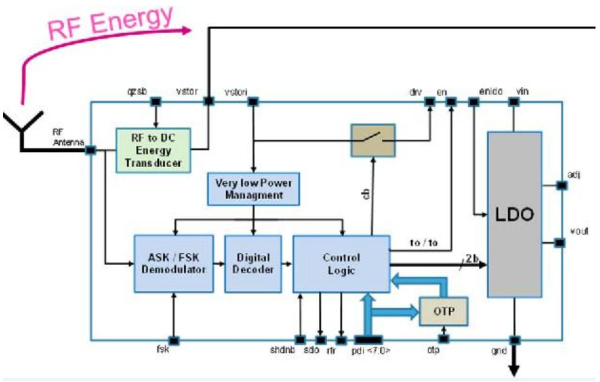

Figure 6: Block Diagram of SoC [5].

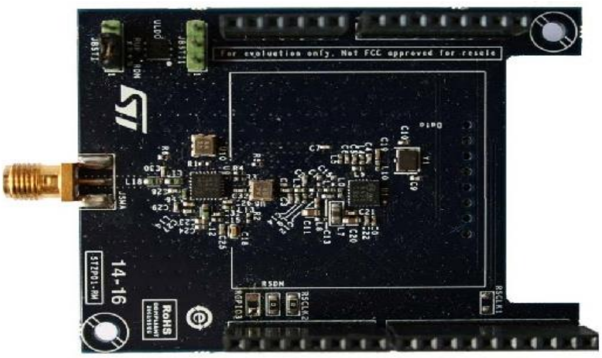
Figure 7: Power Transmitted Board [5].

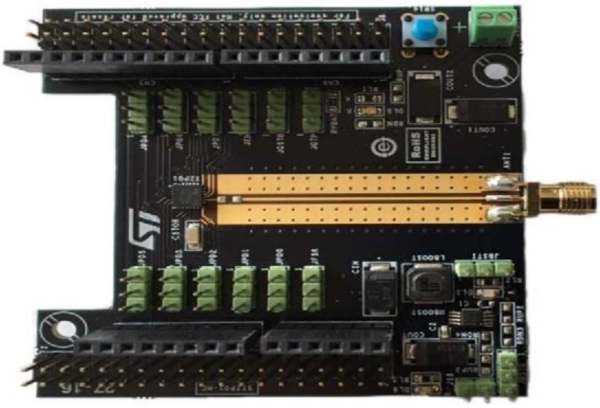
Figure 8: RF Energy Harvesting Board [5].

The energy transmitter is shown in Fig: 6 for transmitting the power wirelessly, while Fig: 8 shows RF Energy Harvesting Board (EHB) particularly used at the receiver end. In the UAV based models or charging robotics cars (SenCars), static SNs can be embedded with EHB board, while Mobile SN contains power transmitted board. RF EHB is an IC (System on Chip) SoC chip which is fully Integrated Chip (IC) having high performance (350MHz to 2.4MHz) with 188dBm. The average output voltage of IC SoC is 2.4 Volt. In Fig: 5, received RF power at antenna can be calculated using Friis transmission equation. However, the RF energy stored in the battery depends on the following factors:

1) Transmitted Power
2) Transmitting Gain
3) Receiving Antenna Gain
4) Distance between transmitter and the receiver

The battery type used for the model can be any battery like lithium ion because of its high energy density. Also, this type of battery is lighter than other rechargeable batteries. Further, to reduce the problem of traffic congestion which may arise because of heavy traffic on some nodes, modified AODV can be used. In the modified AODV, the modification extends the working of AODV by simple Load balancing technique [56]. The AODV routing algorithm has route discovery phase and a route maintenance phase. In this (Route Request (RREQ) is flooded to the neighboring node and Route Reply (RREP) is sent by the destination node through reverse path [57]. Then, during the phase of route maintenance, when HELLO packet is sent to other nodes, each node uses the HELLO packet and informs every other node about its queue length. In this way, if a node finds that the route is getting congested i.e. having the traffic more than 75% of its total queue length, it discards that route and an alternate route is chosen in that case. Thus, such proposed models with Recharging and Load Balancing combination techniques can improve the overall life time of WSNs. However, as like the authors who focused on various other aspects in the WSNs including temperature sensing, security, Bit Error Rate and IoT based WSNs must also be taken into account while working with the energy efficient solutions build robust models [58-61].

Conclusion

In today's era, energy harvesting is used as a power supply in SNs for WSNs. This is because periodic battery replacements are too costly to be implemented. Hence, energy harvesting mechanism eliminates this expensive WSNs drawback. Thus, it leads to the conclusion that if energy harvesting is combined with modified AODV, the new recharging model can be formulated which when implemented can outperform the existing models in a way that it not only improves the overall life span but also reduces the congestion in a network. Therefore, the model must be proposed with the combination of appropriate selection of energy recharging and Load Balancing technique to form robust architecture for WSNs.

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