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## Energy Harvesting Techniques for IOT Devices



### Abstract:

For optimal operation of IoT devices, a continuous and reliable supply of electrical energy is essential. Power Holding Companies may unexpectedly halt energy supply for many reasons. Moreover, many IoT devices situated in distant locations, such as dense forests, are unlikely to get electricity from Power Holding Companies. Once again, batteries are not an ideal solution due to their finite life cycle. To provide continuous power for the IoT gadget, it must gather its energy. energy derived from the surrounding environment. This will provide continuous power supply and an enduring life cycle for the gadgets. This paper discusses energy harvesting. The primary focus of discussion is the sources derived from the surrounding environment and the various methods used in their extraction. This study focuses on energy sources and their harvesting methods for IoT and other miniature electronic devices.

**Keyword:** Energy, source, ambient, harnesssing harvester, IoT, devices

### Introduction

Fifteen years before, the International Telecommunications Union (ITU) released its first study on the Internet of Things (IoT). The IoT paradigm was first defined as an additional dimension to the realm of Information and Communication Technologies (ICTs), facilitating connections for people and objects at any time and place, hence establishing a novel dynamic network of networks. Currently, the Internet of Things (IoT) is no longer a nascent movement. This technology has emerged as one of the most significant advancements of the present century, applicable across several sectors like transportation, energy, civil infrastructure, smart buildings, environmental monitoring, healthcare, military, manufacturing, and production. The Internet of Things (IoT) continues to expand. Experts anticipate that, by 2025, around 22 billion IoT devices will be interconnected and will interact inside this IoT ecosystem.

The IoT ecosystem comprises the following primary components:

IoT devices, including sensors and actuators, are tasked with data collection or process control. IoT connection, including protocols and gateways, facilitates data transmission in the online, cyber-physical realm. The IoT cloud serves as a repository for data and is the locus for decision-making. IoT analytics and data management are tasked with data processing.

End-user devices and user interfaces facilitate the control and configuration of the system.

### Literature Survey

Energy harvesting, or energy scavenging, is the technique of gathering energy from the ambient environment to power electrical equipment. The gathered energy is used to enhance the longevity and functionality of electronic

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equipment by supplementing battery consumption. It is also used for charging the battery when a supplementary battery is employed. This technique is used in energy harvesting systems to power tiny electronic devices, sensors, and wireless networks (Lloret, Garcial, Catala, & Rodrigues, 2016).

Ambient energy sources include solar radiation, which may be harnessed by photovoltaic cells or solar panels to turn sunlight into electrical energy.

Thermoelectric generators may transform heat energy from sources such as waste heat or temperature gradients into electrical power. Vibrations and mechanical motion may be used using piezoelectric materials or electromagnetic induction to produce power (Adrivan, Conde, Caberos, & Doloriel, 2019). The benefits of ambient energy harvesting include its sustainability potential, since it utilizes naturally existing and freely accessible energy sources. It further has the benefit of supplying electricity in distant or inaccessible areas where conventional energy sources may be impracticable or absent. Moreover, ambient energy harvesting may aid in diminishing our carbon footprint and advancing renewable energy solutions (Sanislav, Mois, Zeadally, & Folea, 2021).

The significance of energy harvesting for IoT devices is paramount. IoT (Internet of Things) devices are engineered to interconnect and communicate over the internet, allowing sophisticated functions and automation. Nonetheless, these gadgets are often diminutive and tiny, resulting in restricted capacity for conventional power sources such as batteries (Sanislav, Mois, Zeadally, & Folea, 2021).

Energy harvesting solutions are essential for addressing this restriction by providing a sustainable and efficient power source for IoT devices.

Energy harvesting entails the capture and conversion of ambient energy from sources like light, heat, vibration, or RF signals into useable electrical energy. Integrating these energy harvesting technologies into IoT devices guarantees their continued functioning independent of traditional power sources (Motlagh, Mohammadrezaei, Hunt, & Zaker, 2020).

Numerous significant advantages exist for energy harvesting in IoT devices. Primarily, it enhances their overall efficiency and dependability. With a consistent and sustainable energy source, IoT devices can function independently for longer durations, minimizing the need for frequent battery changes or recharging. This is particularly important for rural or hard-to-reach areas where routine maintenance may be difficult (Lloret, Garcial, Catala, & Rodrigues, 2016).

Furthermore, energy harvesting allows IoT devices to function in an eco-friendly manner. Utilizing renewable energy sources reduces our reliance on non-renewable resources and mitigates carbon emissions linked to traditional power production. This corresponds with the tenets of sustainability and conservation, making IoT implementation more environmentally benign (Adrivan, Conde, Caberos, & Doloriel, 2019).

An additional benefit of energy harvesting is the possibility for more flexibility in the positioning and deployment of devices. As IoT devices may autonomously produce electricity, they are not limited to areas with accessible power outlets or batteries. This expands the potential for the implementation of IoT devices over a broader spectrum of locations and applications, including some that were hitherto problematic or impossible owing to power limitations (Pozo, Garate, Araujo, & Ferreiro, 2019).

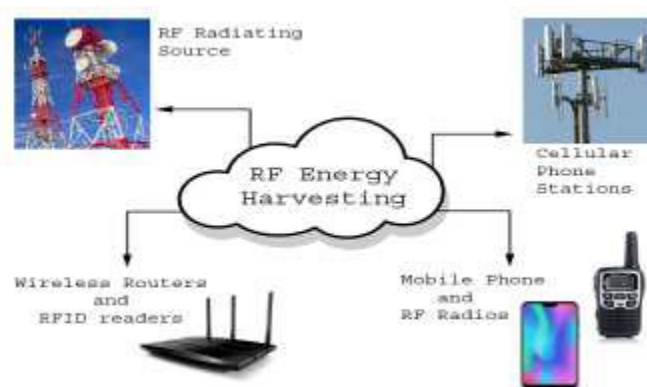
### Ambient Energy Sources For Iot Devices

In the contemporary era, characterized by rapid technological advancement, the Internet of Things (IoT) has emerged as a prominent term. The Internet of Things (IoT) has transformed our interaction with technology, including smart homes and wearable gadgets. However, one facet of the Internet of Things that often receives little attention is energy. How do these always linked gadgets maintain their power supply? The solution is found in ambient energy sources (Sanislav, Mois, Zeadally, & Folea, 2021).

Ambient energy sources are energy sources present in the surrounding environment. These sources may be used to energize IoT gadgets, obviating the need for conventional power sources like batteries or electrical outlets. This enhances the convenience of IoT devices while also reducing their environmental effect. The following are energy sources:

#### 1.RF Energy:

Radio Frequency (RF) energy denotes electromagnetic radiation with frequencies spanning from 3 kilohertz (kHz) to 300 gigahertz (GHz). It is a kind of energy used in several applications, such as telecommunications, broadcasting, and wireless communication (Pavithra & Arunadevi, 2017). As stated by Nechibvute, Chawanda, Taruvinga, and Luhanga (2017), the many devices used to capture RF energy include:



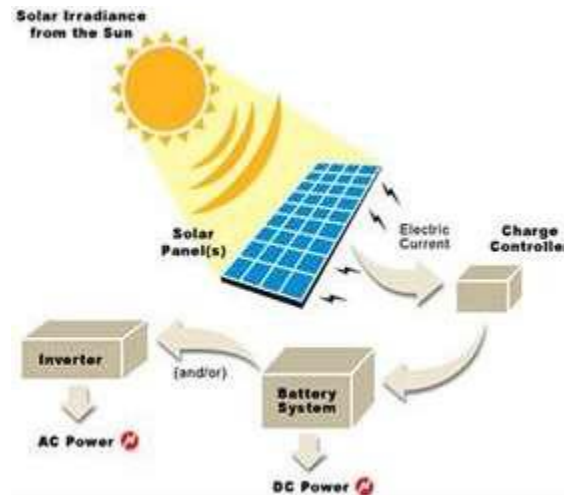
Antennas are apparatuses designed for the transmission and reception of radio frequency radiation. They are essential for collecting RF energy and transforming it into an electrical signal, and vice versa. Antennas are available in many configurations and dimensions, depending upon the specific frequency range and application. To enable an IoT device to gather RF energy using this technology, it is essential to construct the antenna in conjunction with the device.

- **Wireless Power transmission:** Radio frequency energy facilitates wireless power transmission, enabling devices to get power without physical connections. This technique is often used in applications such as wireless charging, where RF energy is transformed into electrical power to charge devices across short distances.
- **RFID (Radio Frequency identifying) Technology:** RFID employs radio frequency energy for identifying and tracking applications. It comprises tags that possess a unique identification and react to RF signals, together with readers that produce RF signals to facilitate communication and data collection from the tags. This technology is extensively used in supply chain management, asset tracking, and access control systems.
- **RF Harvesting:** Ambient RF waves in the environment may be used for energy harvesting. This entails the

acquisition and transformation of RF energy into functional electrical power. RF harvesting technology remains in its nascent phase of research but has significant promise for energizing low-power electronic devices.

## 2. Solar energy:

Solar energy is a renewable energy source derived from the sun. It may be used and transformed into practical energy forms. Hussain (2021) elucidated many systems used to capture solar energy, including:



Solar cells provide an electric current that might be used to power residences, enterprises, or other electrical products.

- Solar thermal systems: These systems harness solar energy to produce thermal energy. They use several methods such as flat-plate collectors, evacuated tube collectors, or parabolic troughs to concentrate and harness solar energy. The heat may be used for heating water or air, or for producing power via steam turbines.
- Concentrated solar power (CSP) facilities use mirrors or lenses to focus sunlight onto a focal point, where a fluid is heated.

The heated fluid then propels a turbine to produce power. Concentrated Solar Power (CSP) systems are often used for extensive power generating.

- Solar water heating systems: These systems use solar collectors to harness solar energy and transmit it to water. This heated water may serve home hot water requirements, space heating, or industrial applications.
- Solar air conditioning systems use solar energy to operate absorption chillers, delivering cooling for structures. The harvested solar energy is used to provide heat for the absorption chiller, eliminating the need for conventional power.

## 3. Kinetic energy

Kinetic energy denotes the energy a thing has as a result of its motion. It is a kind of energy that may be used for several applications.

Beeby, Torah, and Tudor (2018) elucidated many methods capable of successfully harnessing kinetic energy. A turbine is a prevalent device used to capture kinetic energy. Turbines are apparatuses that transform the kinetic energy of a fluid (such as water or steam) into mechanical energy, which may subsequently be used to produce electricity. Hydroelectric power plants use turbines to transform the kinetic energy of flowing water into electrical energy. Additionally, regenerative braking is a technique often employed in electric automobiles. When a vehicle

decelerates, kinetic energy is transformed into electrical energy and stored in the battery for further use. This enhances the efficiency and range of electric cars. Moreover, piezoelectric materials may be used to capture kinetic energy. These materials produce electrical energy when exposed to mechanical stress or vibration. Kinetic energy may be exploited by integration into different devices, including roads and floors, to absorb energy generated by cars or footfall. Additionally, technologies such as flywheel energy storage systems and ocean wave energy converters can also exploit kinetic energy.

Flywheels accumulate kinetic energy in a rotating rotor, which may be discharged as needed to produce electricity. Ocean wave energy converters use the kinetic energy of ocean waves to produce electrical power.

#### **4. Light energy:**

Light energy is a kind of energy seen via visible light and other electromagnetic waves. It serves a vital function in several facets of human existence, particularly in technology. Harnessing light energy entails using it for several applications, including power generation, communication, and lighting. Jabbar and Jeong (2022) identify the following strategies for capturing light energy:

Solar power is one of the most used systems for capturing light energy. Solar panels are designed to harness sunlight and transform it into power. The process known as photovoltaic conversion utilizes semiconductors that absorb light and emit electrons, so generating an electric current.

### **Energy Management In IOT Devices**

Energy management in IoT devices is essential for optimizing performance and overall efficiency. Various tactics and strategies may be used to efficiently regulate energy consumption in IoT devices:

1. Energy-efficient hardware: Choosing components and hardware for IoT devices that prioritize energy efficiency may significantly reduce power usage. This encompasses the use of low-power microcontrollers, sensors, and efficient power sources.

2. Sleep modes and wake-on-demand: The incorporation of sleep modes in IoT devices enables energy conservation during periods of inactivity.

Wake-on-demand functionalities allow the gadget to activate just when required, minimizing superfluous power consumption.

3. Data compression and processing: Utilizing data compression methods and executing data processing locally on the device, rather than transferring unprocessed data to the cloud, may significantly decrease energy usage. This obviates the need for continual communication and data transmission.

4. Adaptive transmission techniques: Modulating transmission power and rate according to signal strength and distance may effectively reduce energy consumption in wireless communication. Utilizing low-power wireless protocols like Bluetooth Low Energy (BLE) or Zigbee may be advantageous.

5. Energy harvesting: Integrating energy gathering systems, such as solar panels or kinetic energy harvesters, may assist in supplementing or recharging the device's power supply. This guarantees extended functionality without only depending on battery power.

6. Intelligent scheduling and job prioritization: Employing advanced scheduling algorithms that prioritize essential operations and reduce idle time may enhance energy efficiency in IoT devices. This may be achieved by aggregating and batching data transfers or processing operations for optimal energy management.

Utilizing these energy management strategies, IoT devices may function more effectively, prolong battery life, and diminish overall environmental impact.

### **Technical Challenges**

Despite recent advancements in the design and development of energy harvesting devices over the last decade, several technical difficulties must to be resolved before the widespread production of self-sustaining IoT devices can occur. Among them are:

**Energy modeling of harvested resources.** A equilibrium between the produced power and the used power must be maintained. This indicates the efficient power profiling of IoT devices and the adjustment of their operation to the quantity of captured energy. The availability of captured energy fluctuates mostly over time in an indeterminate fashion. Consequently, the assessment of the energy scavenged is calculated via predictive methodologies, while traditional power management strategies, such as Maximum Power Point Tracking (MPPT) and software Phase Locked Loops (PLL), are used to regulate the power derived from the energy sources. Recently developed energy forecasting models need enhancement to provide precise findings, while power management decisions should aim to reduce energy loss. Furthermore, the power source must provide sufficient energy for the following functions: data processing operations, transmission and/or reception activities, and sleep intervals. In many instances, data processing is not the most energy-intensive activity. It involves the transmission and receipt of data over wireless Internet. Consequently, subsequent researchers have to formulate optimum consumption models to reduce energy expenditures during wireless data transfers and explore innovative methods to adjust wireless communication protocols in accordance with the peculiarities of the energy harvesting process.

**Harvested energy storage.** This entails the creation of appropriate storage components, including rechargeable batteries and supercapacitors, since the technology used for energy storage influences the cost, dimensions, and operational lifespan of IoT devices. Batteries provide high energy densities; nonetheless, they are unsuitable for long-lasting IoT devices owing to the phenomena of cycle deterioration [161]. Furthermore, both elevated and decreased temperatures impair their functionalities. Supercapacitors possess a lesser energy density compared to batteries; nevertheless, they are not adversely impacted by cyclic deterioration. Moreover, supercapacitors have heightened current leakage, which may deplete a significant portion of the captured energy. Consequently, subsequent researchers ought to explore novel methodologies to identify the optimal candidate for harvested energy storage, which must satisfy the following criteria: minimal cycling degradation, low current leakage, high energy density, and sustained functionality in extreme environments, including very low and very high temperatures.

### **Conclusion**

The energy sources derived from the surrounding environment are examined. Sources include solar, luminous, radiofrequency, kinetic, and biological energy. When gathered using a specific technique, the energy from these sources is insufficient to power IoT devices; hence, energy management or amplifier circuits are included into the system. It is noteworthy that the predominant energy sources for powering IoT devices include solar, radio frequency, kinetic, and light energy. This study discusses the technology for gathering energy from different sources.

### Reference

1. Adrivan, R. V., Conde, R. K., Caberos, a., & Doloriel, C. T. (2019). An Energy Combiner for Multi-Source Energy Harvesting with Charge Control.
2. 2019 19th International Symposium on Communications and Information Technologies (ISCIT) (pp. 371-376). Ho Chi Minh City: ResearchGate.
3. Beeby, S. P., Torah, R. N., & Tudor, M. J. (2018). Kinetic Energy Harvesting. *Acta Futura*, 44-51.
4. Hussain, B. (2021). Methods for Harvesting Solar Energy. *Journal of Applied Engineering Science*, 504-514.
5. Jabbar, H., & Jeong, T. (2022). Ambient Light Energy Harvesting and Numerical Modelling of non-linear Phenomena. *Applied Science*, 1-14.
6. Lloret, J., Garcial, M., Catala, A., & Rodrigues, J. J. (2016). A group-based wireless body sensors network using energy harvesting for soccer team monitoring. *International Journal of Sensor Networks*, 208-225.
7. Motlagh, N. H., Mohammadrezaei, M., Hunt, J., & Zaker, B. (2020). Internet of Things (IoT) and the Energy Sector. *Energies* 2020, 1-27.
8. Nechibvute, A., Chawanda, A., Taruvinga, N., & Luhanga, P. (2017). Radio Frequency Energy Harvesting Sources. *Acta Electrotechnica et informatica*, 19-27.
9. Pavithra, B. G., & Arunadevi, M. (2017). Review on RF energy harvesting technology. *International Journal of Engineering Research and Technology (IJERT)*, 1-3.
10. Pozo, B., Garate, J. I., Araujo, J. A., & Ferreira, S. (2019). Energy Harvesting Technologies and Equivalent Electronic Structural Models-Review. *MDPI Electronics*, 1-31.
11. Proskurina, S., Stolarski, M. J., & Vakkilainen, E. (2023). Bioenergy perspective in the EU regions: Carbon Neutrality Pathway. *Journal of Sustainable Bioenergy Systems*, 16-39.
12. Sanislav, T., Mois, G. D., Zeadally, S., & Folea, S. C. (2021, March 4). Energy Harvesting Techniques for Internet of Things (IoT). *Special Section on Emerging Trends of Energy and Spectrum Harvesting Technologies*, pp. 39530-39549.