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SIMULTANEOUS WIRELESS INFORMATION AND POWER TRANSFER FOR SUSTAINABLE WIRELESS OPERATIONS - A TECHNICAL STUDY

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ABSTRACT

Wireless Power Transfer (WPT) is a new technique that improves the energy sustainability of wireless devices with limited lifespan. Integrating WPT in wireless communication leads to Simultaneous Wireless Information and Power Transfer (SWIPT), which concurrently transfers information and power to wireless devices. This increases network's spectral efficiency significantly. SWIPT-aided Cooperative Relaying (CoR) is becoming a popular solution for Fifth Generation (5G) and Beyond 5G (B5G) networks to address their growing issues. Cooperative relaying and SWIPT can meet the expectations of next-generation wireless networks by improving data throughput, latency, coverage, and connectivity. A study of SWIPT based techniques in wireless devices is presented in this article.

Keywords:
SWIPT, IoT, Cooperative networks, Relays, Power switching, Antenna switching

I. Introduction

Simultaneous wireless information and power transfer (SWIPT) technology can be adopted as a way to achieve energy sustainable operation. SWIPT is a promising technology that allows devices to capture data and power simultaneously by the re-use of some of the energy obtained in information-bearing radiofrequency signals. A significant advantage of SWIPT over the basic wireless power transfer (WPT) is the fact that energy harvesting occurs when the receiver decodes an incoming signal. This way, energy harvesting is not a solitary task which consumes valuable channel resources. Energy harvesting systems are increasingly being integrated into communication networks. Numerous investigations have considered traditional renewable energy resources, including solar and wind, and have researched effective resource allocation approaches for various objective functions and topologies. Most of the traditional harvesting technologies. are only applicable in certain environments.

SWIPT can be considered as a technology to jointly support high throughput and energy sustainability. Among the major requirements of 5G systems recognized by industries and academia, the development of green technology and reduction in power consumption by devices are two key aspects. Efforts have recently been focused on implementing self-sustainable communication systems with EH techniques to support concepts like IoT and 5G wireless networks, while upholding desirable Quality of Service (QoS). (QoS).

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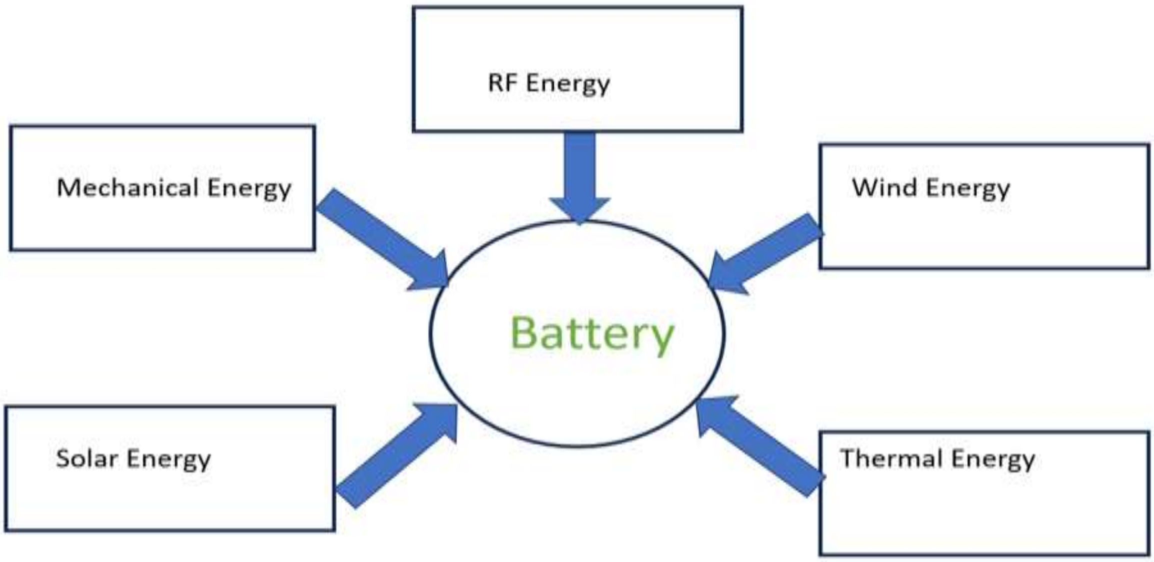

Figure 1 Energy Harvesting Methods

One EH technology that gets over the aforementioned restrictions is WPT [ ], in which the communication network's nodes use electromagnetic waves to recharge their internal batteries. It is possible to obtain green energy by two techniques in the WPT: either based on the surrounding signals or from a base station or other specialized, fully controlled power source. Based on WPT, more recent contributions have concentrated on short distance (near-field) transfer of energy as opposed to long distance (far-field). Distances between near and far fields are dependent regarding the application scenarios.

SWIPT has garnered a lot of interest in wireless communication [10], [11] networks. As 5G communication technology advances, SWIPT Technology can play a critical role in the energy and data exchange across many contemporary networks for communications. The main focus of this article is to present a brief survey on the importance of SWIPT, based on IoT and 5GB communication systems. SWIPT integrated next-generation wireless networks like mm Wave, Device to Device (D2D) communication, IoT and Wireless Sensor Networks (WSN) promises spectral efficiency and reliability in data communication by keeping the power, complexity, and cost to a minimum. Due to the rapid and cumulative effect of 5GB communication systems the network size increases rapidly due to the enhancement in the number of Machine (M2M) communications, sensor networks and massive IoT applications. Catering the power requirements of such a mass energy-hungry devices is a challenging task. So alternative sources like RF is required to accompany traditional power sources. Depending on the energy efficiency and battery size, wireless devices need to recharge their batteries, which results in high operational cost and practical difficulties, especially in scenarios like wireless sensors placed inside the human body for medical purposes or devices embedded in a building structure. Hence the limited life span of devices is a bottle neck in modern wireless technologies [22]. So the energy constrained devices in modern wireless systems, need to depend on an energy efficient technique to increase their life span. Also, the integration of wireless power and communications poses new challenges and opportunities, necessitating a paradigm shift in wireless network architecture. New research questions in communication theory, information theory, circuit theory, RF design, signal processing, protocol design, optimization, prototyping, and experimentation are necessary. So, studying SWIPT based systems is worth in this regard.

The main focus of this article is to present a brief survey on the importance of SWIPT based on IoT and Cooperative relay communication systems. This article is organized with a description of the: preliminary concepts in section-I, SWIPT- techniques, and related

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architecture in section-2, resource allocation in SWIP in section-3, and section IV concludes the article.

II. Simultaneous Wireless Information and Power Transfer (SWIPT) – Architecture

III. The most SWIPT is a cutting-edge wireless energy harvesting technique. SWIPT uses either dedicated or ambient RF sources for transmission. Figure 1 depicts the simultaneous transfer of energy and information. In a SWIPT system, the downlink transfers energy and information from various access points to one or more receivers. The Energy Receiver (ER) and Information Receiver (IR) may be co-located or separated. In SWIPT with separated receivers, ER and IR are distinct devices. ER is a low-power device that charges, while IR receives data.

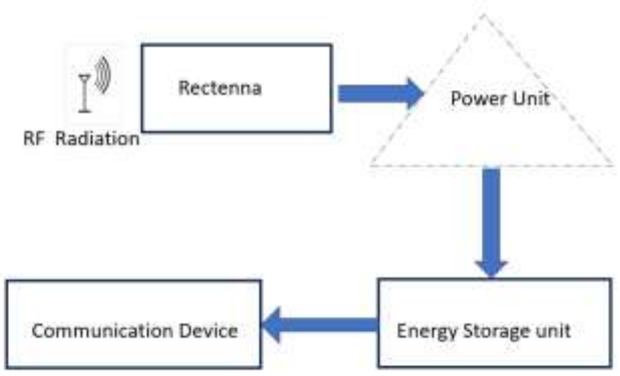

Figure 2 - General block diagram of a SWIPT enabled system

SWIPT allows for extraction of both energy and information from a single waveform. However, circuit design restrictions, such as varying power sensitivity of antennas at the receiver side, make practical implementation unfeasible. It is important to remember that energy harvesting requires a power sensitivity of 10dBm, while information decoding requires as low as 60dBm [6]. So, SWIPT requires splitting a signal into two parts: one for energy harvesting and the other for decoding information.

A SWIPT system can be designed either based on separate receiver architecture or integrated receiver architecture. Separate receiver architecture uses distinct antennas for EH and ID, which operate on independent fading channels [7]. This design enables parallel and independent execution of EH and ID tasks. Integrated receiver architecture eliminates the need for separate ID and EH antennas. This architecture consists of four different types of swiching domains like a) time switching; b) power switching; c) antenna switching; and d) space switching.

(a) TIME SWITCHING

Time switching (TS) allows the receiver to switch between decoding information and harvesting energy [8]. Signal splitting occurs in the time domain, using the full signal received in a single time slot for either decoding or power transmission (Fig. 3a). The TS approach has a simple hardware implementation at the receiver, but requires precise time synchronization and information/energy scheduling.

(b). POWER SPLITTING (PS)

Power splitting (PS) technique divides a received signal into two streams with varying power levels. One stream is sent to the rectenna circuit for energy harvesting, while the other is converted to baseband for information decoding (Fig. 3b). The PS technique is

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more sophisticated than TS and involves optimizing the PS factor a. However, it provides instantaneous SWIPT by decoding and transferring information in a single time slot. This makes it ideal for applications requiring critical information, energy, or delay, and is closer to the theoretical optimum.

(c). ANTENNA SWITCHING

The antenna switching technology achieves SWIPT in the antenna domain by dynamically switching each element between decoding and rectifying (Fig. 3c.). The antenna switching method divides the receiving antennas into two groups, one for information decoding and the other for energy harvesting.

(d). SPATIAL SWITCHING (SS)

Spatial switching type SWIPT is used in MIMO settings by utilizing the spatial domain. The communication link transformed into parallel eigenchannels can transfer either information or energy. Each eigenchannel contains a switch that drives the channel outputs to either to the rectification or decoding circuit.

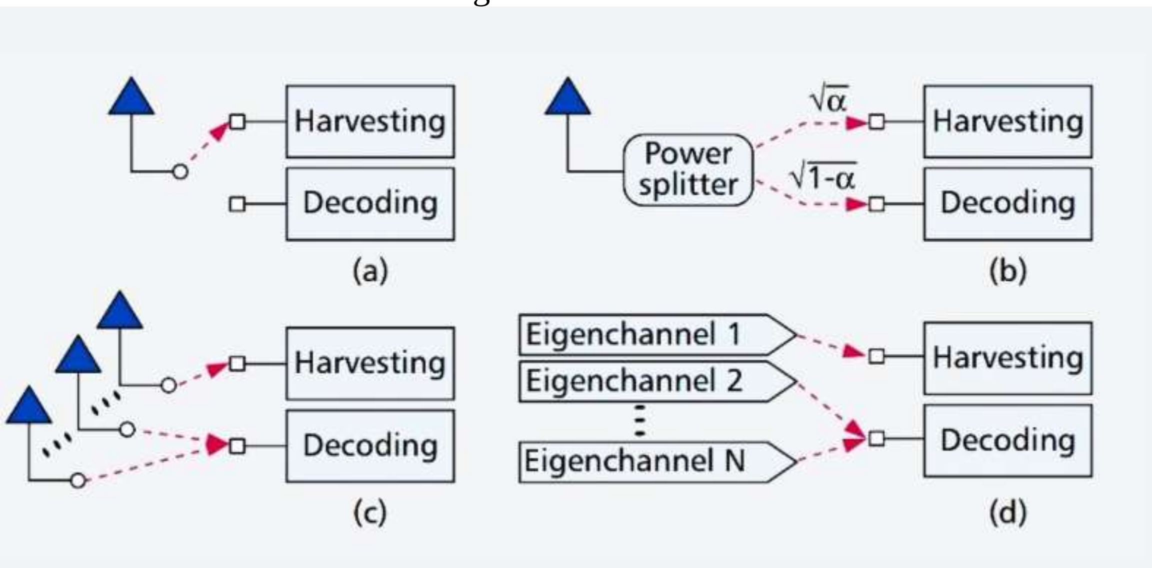

Figure 3 Different SWIPT Transmission Techniques

I. **Resource allocation in SWIPT based systems**

The benefits of employing SWIPT on resource allocation applications is discussed in this section. The RF signal serves, both to transport information and energy to receivers, allowing for joint power control and user scheduling, simultaneously. However, the wide dynamics range of power sensitivity for energy harvesting (-10 dBm) and information decoding (-60. dBm) is a barrier to achieving SWIPT. As a result, simultaneous power management and user scheduling is a critical component for facilitating SWIPT in practice. For example, idle users with high channel gains can be scheduled for power transfer will extend the life of the communication network. Furthermore, opportunistic power management - channel fading can be exploited for increased energy and information transit efficiency.

III.i SWIPT BASED INTERNET OF THINGS (IoT)

An Internet of Things (IoT) network is outfitted with specialized sensors, transmitters, batteries, and control processors that are affixed to every device in order to monitor and gather information from the real world

Time Switching (TS) based SWIPT for secondary IoT devices will harvest energy while acting as a relay to primary IoT nodes.[9] studied outage performance taking into account a primary and secondary IoT system. A MIMO system with several energy and information receivers that took into account an IoT network was suggested for SWIPT in [10]. Based on maximizing harvested energy at energy receivers and security at information receivers, an algorithm for allocating resources was created. In place of traditional PS and TS schemes, authors in [11] developed an inventive SWIPT algorithm for the Internet of Things. They did this by transmitting information using a small modulated wave to reduce interference and increase power efficiency, and sending wireless power via unmodulated Continuous Wave (CW). They created a novel receiver design for Internet of Things (IoT) devices. Since IoT device receiver circuits must be of low complexity and low power consumption, they recommended using envelope detection for information decoding to maximize power harvesting for different IoT device components. This avoids the use of active components that consume power, such as mixers and oscillators.

In IoT applications, EH devices are compact sensors with minimal hardware and circuit complexity. Therefore, nonlinearity in EH must be addressed. This may be difficult to implement. Energy harvesters in order to alleviate nonlinear effects is studied in [12]. An algorithm to maximize energy efficiency in D2D is studied in [13] and a resource allocation algorithm to enable secure networking with enhanced energy efficiency was presented in [14].

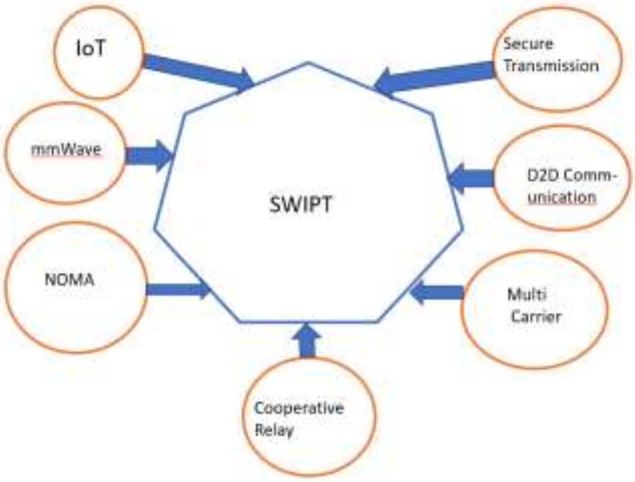

Figure 4 SWIPT enabled wireless techniques

III. ii Cooperative relaying

According to [15], cooperative communication in wireless networks allows multiple nodes to deliver signals to a destination concurrently. Cooperative communication can significantly increase performance by boosting capacity, spatial diversity, and transmission reliability [16]. In a cooperative communication system, the relay node not only relays messages but also transmits their own. Cooperative diversity refers to the voluntarily sharing of information among individuals [17,18]. Different protocols like, fixed amplify and forward relaying protocol in which the relay amplifies the signal before forwarding it to the receiver, fixed decode and forward relaying protocol where the relay decodes the signal before forwarding to the receiver, code and forward relaying protocol where repeated version of data are transmitted, an adaptive relaying mechanism called selective decode and forward relaying protocol are some of the protocols used in cooperative relaying communication.

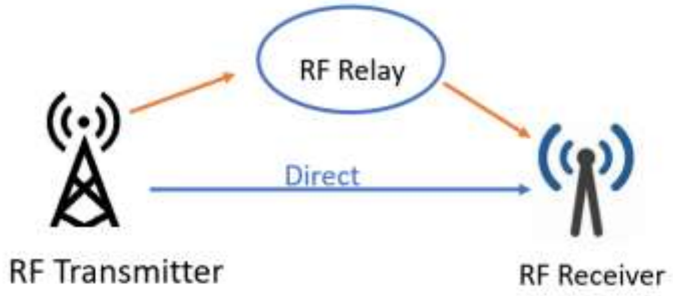

Figure 6 - Cooperative relay communication system

IV. Conclusion

This article discusses SWIPT and its uses in wireless networks. SWIPT is a new technique that transmits energy and information simultaneously, resulting in energy-efficient resolution for 5G and future wireless networks. This article focusses on SWIPT's architecture and applicability in IoT networks. It also gave a review of CoR and its application in IoT technologies.

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