Simultaneous information and energy emission: a review

Carl Hatoum, 3TC INSA Lyon

In today's world, all communication systems are powered by electricity. There are critical situations, such as in remote areas, in war, or even inside the human body, where access to resources is severely limited. An affordable, but not sustainable, solution would be to equip these systems with batteries. However, techniques for harvesting ambient energy, or energy harvesting, have recently been developed, which is present in different forms: light, vibrations, heat, etc...

However, the use of renewable energies poses various problems. Their intermittent and unpredictable nature, their dependence on the location of the systems they power, make it impossible to use them for applications where quality of service (QoS) is very critical. A technique that addresses these constraints is wireless power transfer (WPT). This technique consists in recovering energy from ambient electromagnetic radiations. WPT is a promising technique, which can be applied among others in systems of simultaneous information and energy transfer (SIET). SIET would allow significant gains and optimizations in terms of spectrum occupation, delay, and energy consumption. In the era of the Internet of Things (IoT), sensors, decentralized networks, information and energy transmission become totally inseparable [6] .

Theoretical work on SIET indicates that the same signal can transmit both energy and information without loss. However, in the current state, the simultaneous transfer of information and energy is not possible in practice, because the energy harvesting operation on the radio frequency domain would destroy the information. In order to implement a SIET solution, the received signal must be split into two distinct parts, one for energy and one for information. There are several approaches to split the signal into two parts.

1 Time switching (TS)

With the time-switching approach, the receiver will alternate over time between information decoding and energy harvesting [1]. In this case, during an entire time interval, the entire signal is used to communicate or transmit energy. The TS technique has the advantage of being easy to implement materially, but requires good synchronization between the transmitter and the receiver

2 Power Splitting (PS)

This technique consists in realizing the SIET by splitting the received signal into two parts using a hardware component. One part is sent to a component that converts the signal into energy, and the other is brought back to baseband to decode the information [1]. The PS requires a more complex receiver compared to the TS, but has the advantage of realizing the SIET instantaneously, since a signal received at time t is used for both information and energy transmission, so this solution is more relevant for applications with strong temporal constraints, or asynchronization transmitter / receiver.

3 Antenna Switching (AS)

Here the idea is to build the receiving antenna as an array of small physical antennas. Usually, antenna arrays are used to generate an energy source, inspired by this approach, the so-called AS technique is a SIET approach at the antenna level, by dynamically allocating to each physical sub-antenna the function of energy harvesting or information reception. The AS technique can be seen as an optimization problem, deciding how many, and which antennas occupy which tasks (energy harvesting or information reception), in order to perform the SIET properly. This optimization problem is very complex, in practice AS implementations are simpler [2]. Specifically, the antennas with the lowest losses are allocated to the most critical function (information or energy as the case may be) and the less powerful ones to the other, less demanding function.

4 Cooperation and smart radio

SIET offers new opportunities for cooperative communications. Smart radio, or cognitive radio, is a new paradigm for improving and optimizing bandwidth sharing. Let's imagine two systems, one primary and one secondary. These systems could, depending on the constraints of one or the other, help each other. However, to enable this cooperation, both systems must have good links and the ability to transmit energy. SIET presents a promising solution to this problem, by enabling inter-system cooperation at both the information and energy levels. The primary system would transmit information and energy to the secondary system, and in exchange, the secondary system can relay the transmission of the primary system, or assist it in case of heavy traffic [4] [5] . Compared to traditional approaches, this approach offers real advantages to both systems and, in view of the mutual benefits, strongly encourages them to cooperate, and thus improves the overall quality of operation

5 Conclusion and perspectives

Different SIET techniques and approaches have been compared and discussed here. We have seen that SIET has brought great and promising changes in the different problems of communication systems that we have to face nowadays, such as resource allocation, energy control and access, bandwidth occupation, interference management etc. Finally, we have considered that SIET could be applied to inter-systems cooperation network, allowing an exchange of both information and energy. Nevertheless, SIET still faces many difficulties and limitations [6]:

-Path loss: the efficiency of SIET is still insufficient for long distance transmissions. One can, in the current state of affairs, imagine a set of nodes that follow one another, relaying information and energy to the final destination. One can also imagine a transmitter that would be distributed in several smaller transmitters, allowing to collect more energy and transmit more information.

-Safety: In some cases, the transmitter increases the signal strength more than necessary to make it easier for the receiver to harvest energy. However, this can also increase the risk of the signal being tapped by an unwanted third party. In addition, receivers that need energy can falsify their state, and recover more energy than they really need. So we have new security and trust issues, which appear with the SIET.

-Hardware: despite the existence of different approaches and techniques for SIET, the majority of hardware implementations are wireless energy transmitters only, which harvest ambient energy. Thus, the development of SIET circuits will be decisive for the future of the research. For example, the TS approach is, in theory, less efficient than the PS, but the latter is disadvantaged by the losses incurred by the signal cut-off, something that remains to be measured experimentally.

Finally, SIET has promising applications in various sectors where the need for ultra low power devices is essential. This can range from infrastructure monitoring with embedded sensors on roads, bridges, buildings. The medical sector with the incorporation of biomedical sensors on a person, or even in his body that can monitor and control certain indicators such as blood, heartbeat etc... For all these potentially revolutionary products to succeed with the help of SIET, it must still meet many technical challenges, whether it is at the level of hardware, protocols, and architecture of systems.

References

[1] R. Zhang and C. K. Ho, "MIMO broadcasting for simultaneous wireless information and power transfer," IEEE Trans. Wireless Commun., vol. 12, pp. 1989–2001, May 2013.

[2] I. Krikidis, S. Sasaki, S. Timotheou, and Z. Ding, "A low complexity antenna switching for joint wireless information and energy transfer in MIMO relay channels," IEEE Trans. Commun., vol.62, no.5, pp.1577–1587, May 2014.

[3] G. Zheng, Z. Ho, E. A. Jorswieck and B. Ottersten, "Information and energy cooperation in cognitive radio networks," IEEE Trans. Sig. Process., vol. 62, no. 9, pp. 2290–2303, May 2014.

[4] O. Simeone, I. Stanojev, S. Savazzi, Y. Bar-Ness, U. Spagnolini, and R. Pickholtz, "Spectrum leasing to cooperating secondary ad hoc networks," IEEE J. Sel. Areas Commun., vol. 26, no. 1, pp. 203–213, Jan. 2008.

[5] G. Zheng, S.H. Song, K. K. Wong, and B. Ottersten, "Cooperative cognitive networks: Optimal, distributed and low-complexity algorithms", IEEE Trans. Sig. Process., vol. 61, no. 11, pp. 277 –2790, June 2013.

[6] I. Krikidis, S. Timotheou, S. Nikolaou, G. Zheng, D. W. K. Ng, and R. Schober, "Simultaneous wireless information and power transfer in modern communication systems," IEEE Communications Magazine , vol. 52, no. 11, pp. 104–110, Nov. 2014