Powering neural network based wake-up radio with radio-frequency energy harvesting

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Keywords : Internet of things, Wake-up radio, Energy harvesting
Candidate skills : Signal processing and electronics are mandatory, backgrounds in digital communication, IoT, microcontroller programming are welcome.
Location : Shared between Lannion and Lyon (to be discussed)
Expected starting date : September 2021
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1 Context

Internet of Things (IoT) is becoming a reality. It will greatly impact our daily lives (city, housing, transportation, health, environment) and many economic sectors (agriculture, industry...). Unlicensed bands (868 MHz, 2.4 GHz) play an important role in this evolution with technologies like LoRa, SigFox or IEEE 802.15.4. However, energy consumption remains a major bottleneck, with many applications requiring the lifespan of objects to reach several years, even decades, without changing the batteries. Many efforts have been deployed to push the boundaries of energy autonomy, without however a full success [1].

The radio transceiver often turns out to be the most energy consuming part of a wireless node, due to both the transmitting and also receiving phases. For instance, initiating a communication requires that the source and the destination are awake at the same time. It can be difficult to plan and usually requires some highly penalizing signalling protocols. In short range multi-hop networks, ernergy consuming MAC strategies are implemented in order to synchronize the source and the destination. Low Power Wide Area Networks solved this issue by having always turned-on base stations using single hop communications and a simple ALOHA protocol, but this only works for the uplink. Wake-up receivers form an emerging technology, which allows continuous channel monitoring, while consuming orders of magnitude less power than traditional receivers [2]. These receivers wake up a main transceiver using interrupts only when a specific signal is detected. Thus, fully asynchronous communication can be achieved, resulting in a huge decrease of energy waste. However, most wake-up receivers are still relying on low power microcontrollers that perform signal recognition but consume peak powers higher than 200 μW, making IoT nodes unable to reach their ultimate energy efficiency.

ANR U-Wake project aims to achieve a breakthrough in the field of IoT by developing a disruptive wake-up receiver solution based on **(1) a bioinspired architecture** achieved with an industrial CMOS technology (with transistors operating in deep sub-threshold regime) [3] and **(2) Electro Magnetic energy harvesting** [4]. The originality lies in the association of a Radio Frequency (RF) demodulator to a neuro-inspired detector and data-processing through a spiking neural network (SNN), resulting in a complete ultra-low power wake-up radio supplied with a voltage of a few 100 mV.

2 Objective of the PhD

The proposed receiver will be woken up when detecting a dedicated off-line learned sequence and implemented in a hardware fashion using an ultra-low power SNN. The main advantage of such a design is that it requires a few mW or less for the whole wake-up receiver. Furthermore, it can work in the 868 MHz or 2.4 GHz bands and has the ability to recognize different types of signals (on-off keying, BPSK or chirp spread spectrum modulation for instance). Requiring such a low consumption opens up the possibility to be powered using RF energy harvesting or Wireless Power Transfer, and opens the way to a wide range of applications.

This PhD will focus on the energy efficiency of the proposed solution at both hardware and software levels. It will address the global node design, including RF energy harvesting unit, the integration of neuro-inspired circuits and related wake-up mechanisms, and will propose adequate power management policies.

The steps of the PhD are :

— **Energy modelling and management** : This task aims to design the energy unit of the wake-up radio. Energy will be harvested from ambient RF sources with the possibility to complement it with an optimized dedicated source. Choices made on the rectifying circuit will impact the waveform optimization. The energy consumption of the full architecture will be modelled in order to tune both harvesters and storage units.

— **Waveform design and protocols** : Pattern recognition must be embedded in the wake-up receiver to identify pre-defined sequences at a low energy level. A waveform design to jointly harvest energy and wake up the node will be addressed. The wake-up mechanism will also be included in a use-case, considering short-range nodes (IEEE 802.15.4) or two-hop links with LoRa, in order to evaluate the system in a full network.

— **Global node design** : Finally, the global node design will include RF energy harvesting unit, the integration of neuro-inspired circuits and related wake-up mechanisms. It will also propose adequate power management policies.

3 Supervision IRISA/CITI

The work proposed in this thesis will leverage the complementarity between CITI lab (INSA Lyon) and IRISA lab (University of Rennes 1). The CITI lab has recognized expertise in RF energy harvesting [5][6] and waveform design for wake-up radio [7]. On its side, the Granit team from IRISA is interested in both MAC protocols [8] and platforms [9] for wake-up radio and in algorithms for energy harvesting management [10].

Références

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