LGEF

Ph.D. proposal

VIBRO-WSN : acoustic Wireless Sensing Network

Type: Ph.D.
Duration: 36 months (Oct. 2020-Sept. 2023)
Domain: Electrical engineering, physics
Labs.: Laboratoire de Génie Electrique et Ferroélectricité (https://lgef.insa-lyon.fr/)
Ampère (http://www.ampere-lab.fr/)

Advising committee: Fabien MIEYEVILLE (fabien.mieyeville@univ-lyon1.fr)
Mickaël LALLART (mickael.lallart@insa-lyon.fr)

Keywords: wireless sensing networks, acoustic mechanical energy, distributed computation, acoustic propagation, machine learning.

IMPORTANT NOTICE
The grant for this Ph.D. proposal is not yet secured. The doctoral school steering committee will decide upon the Ph.D. funding after an interview during which the candidate will have to present his/her curriculum and the project

Context

Wireless sensing networks that appear during the 2000's have been perceived for long as structuring elements of ubiquitous intelligence. With the development of Internet of Things (IoT), they have lost part of their visibility although they still constitute a fundamental element in the core of every IoT system. Despite the evolution of their hardware (moving from 8 bits to 32 bits, or even ARM, microcontrollers), every smart wireless sensor (also called node) constituting a network is currently used only for gathering data and send them wirelessly through the network to a central node for data processing. Additionally, the challenge of their energy autonomy is still an open question, while many of these sensors are supposed to be operating in remote and/or relatively harsh environments that prevent the use of conventional primary batteries. A very few works currently take advantage of new generation nodes capacity in performing distributed processing, at the local scale of the unit or even considering machine learning at the network scale in order to enhance its efficiency, while ensuring effective power management.

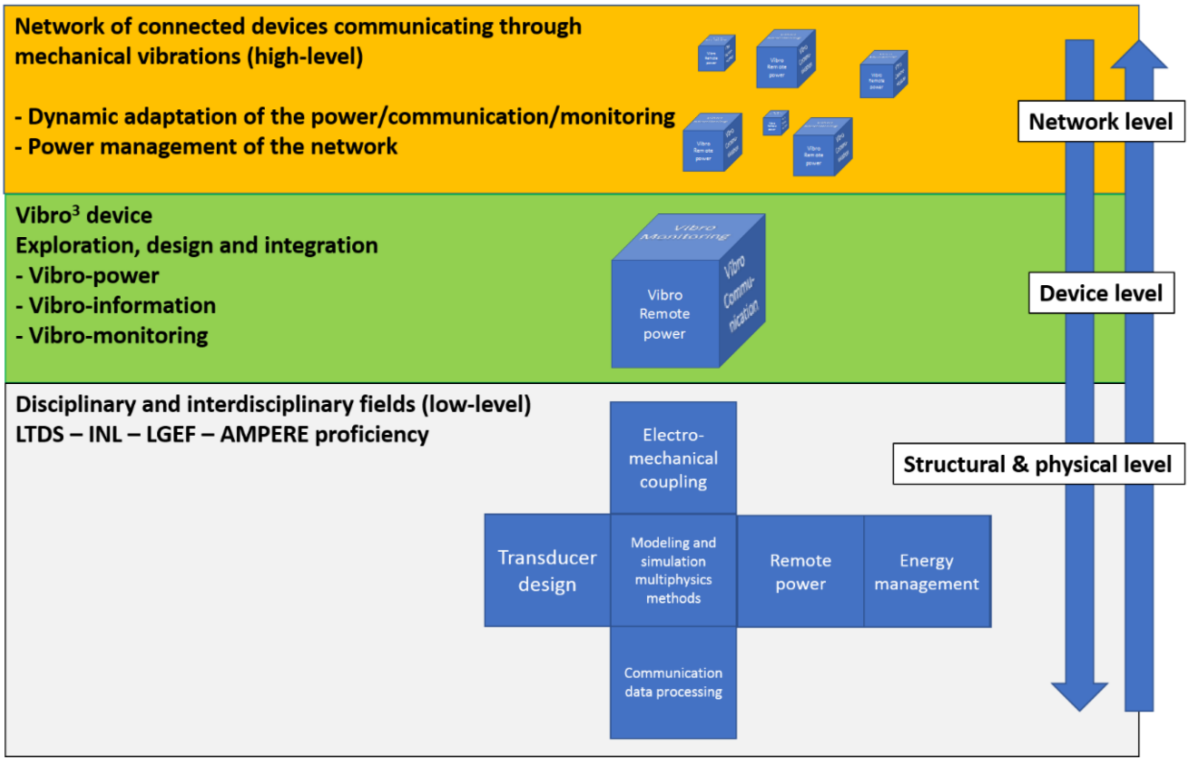
Objective

The two involved teams from LGEF (https://lgef.insa-lyon.fr/) and Ampere Lab (http://www.ampere-lab.fr/) have already demonstrated that it was possible to design autonomous network nodes able to extract their energy supply from a mechanical signal that it is also monitored: this mechanical signal is both information source and power source. The objective of this Ph.D. is to utilize this same mechanical signal at a third scale. As RF communications are a central element in the energy consumption of a wireless network and thus responsible of the lifespan of the latter, the idea here is to use mechanical vibratory sources that exist in the system and its environment for:

1. Extract physical information on the mechanical structure state (healthy/damaged)
2. Extract enough power to supply the network
3. Communicate within the network using the same vibrational energy

During the first year, after state-of-the art review and familiarization with the wireless nodes for fulfilling points 1 & 2, the student will investigate Lamb waves as a mean of surface communication at medium distance. The work will also be devoted to evaluate to what extend this mechanical wave for communication can also serve as power supply.

This Ph.D. work is part of a more ambitious research project also including LTDS and INL labs (with which the student could be interacting) as shown in the following figure:



The objective of this Ph.D. is to work at the structural and components scales: design and implementation of the device integrating mechanical, electronic and embedded (intelligence) data to realize a first prototype of the "Vibro^3" device.

Scientific deadlocks

Up to now a very few amount of works have explored the use of vibratory wave for telecommunication at small and medium range: this will thus be a first challenge of the Ph.D.. If some studies have demonstrated the capacity to pair data gathering, energy harvesting or telesupplying, no demonstration of combining all of the three components has been made to date, especially considering common medium (vibrations here). The effective realization of this combination cannot be successful by only following conventional optimization methods in a separate way for each of the objectives (energy harvesting, data gathering…), and will necessitate a new systemic approach for global optimization of the mechatronic system.

Expected original contributions

The main contribution will be the demonstration of a triple use of a unique signal to (1) gather an information regarding the physical state of a system, (2) remotely supply the measurement system and (3) communicate the information to other network elements. This contribution will therefore permit removing most of the previously mentioned deadlocks.
In addition to this global approach, progresses in each of the three above-mentioned axes are also expected. For instance, the use of an acoustic medium for wireless information transmission, or the coupled optimization (electrical and mechanical) for remotely supplying through vibrations.

Workplan and proposed methodology

The first three months of the Ph.D. will be devoted to state-of-the-art review as well as familiarization with existing devices in the teams. Then, during the first year, the Ph.D. candidate will focus on the structural part (cf. above figure) to investigate the electromechanical coupling for elaborating preliminary communication and tele-supply solutions using acoustic medium. This will include electrical and mechanical aspects.

The second year will focus on the components level of the solution: it will consist in pairing features, for ultimately combining the three aspects of the use of the combined vibrational energy and signal. This will lead to the implementation of a first functional prototype of the network node.

Finally, the last year will consist in optimizing the device, elaborate a generic optimization method, consolidate the model and associated simulations with a systemic target (connected object scale) and proceed to the functional demonstration of a first network using 3 nodes.

Advising committee

Name	Lab.	Scientific competence	Advising ratio
Fabien MIEYEVILLE	Ampère EE department	Wireless sensor networks, conception methods for heterogeneous communicating systems	50%
Mickaël LALLART	LGEF	Electroactive conversion, energy harvesting, mechanical structures and electrical energy extraction interfaces	50%

Integration within labs and teams: the Ph.D. work will be integrally completed in La Doua campus with a shared localization between Omega building (Ampère, 3rd floor) and Gustave Ferrié building (LGEF, 3rd floor).

Sought profile

The candidate should have a general curriculum in electronics or mechatronics. A first experience in implementing embedded devices (microcontroller programming) would be highly appreciated as well as knowledge in energy conversion/harvesting (piezoelectric patches) and in RF systems (Wifi, Bluetooth, Zigbee,…). Skills in programming (C, C++, python) will also be an advantage.

Valorization objectives

1. Qualitative aspects: scientific publication in SCI journals, communications in international conferences. Patents may be envisioned according to the progress of the Ph.D. work.
2. Quantitative aspect: 1 SCI journal publications, 1 national conference, 1 international conference each year from the second year.

Skills that will be developed during the Ph.D.

Energy harvesting, electromechanical coupling, modeling and simulation of mechatronic systems, embedded device development, design and implementation of wireless sensor nodes, communication protocol development.

Professional outlook after the Ph.D.: private company career (R&D) or in academia (researcher, teacher-researcher)

External potential collaboration/partnership: this Ph.D. may rely on an experimental device deployed in Cameroun in the framework of a partnership agreement with Buea University (Cameroun)

Bibliographic references related to the Ph.D. subject

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[6] V. Nkemeny, **F. Mieyeville**, J. Verdier, P. Tsafack, *Distributed Kalman Filter: Application to Leak Detection in Water Pipeline Monitoring Using Wireless Sensor Networks with Non-intrusive Sensors*, SENSORCOMM 2019, 13th Int. Conf. on Sensor Technologies and Applications, Oct 2019, Nice, France.

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