# DIPARTIMENTO DI INGEGNERIA
# CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE - PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 34TH CYCLE

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| Title of the research activity: | Electronic Systems and Technologies for Precision Farming **EST4PF** |
| State of the Art: | "Precision farming" as well as "smart agriculture", are increasingly popular keywords in the scientific community. This popularity is due to the recent development of several technologies that enable architectures and solutions considered unaffordable less than one decade ago (see for instance [1]. Among these technologies it is worth mentioning, not exhaustively: RFID [2], smart sensors [3], printed electronics [4], additive manufacturing, green electronics [5], flexible materials, recyclable and even compostable materials, organic semiconductors and, last but not least, two technologies mostly related to energy issues: environmental energy harvesting [6] and wireless power transfer (WPT)[7]. All these emerging technologies, concurrently form the so called "underground" layer of the IoT pyramid, i.e. the technological substrate that can be considered below what is commonly recognized as the lowest layer of the famous ICT ISO/OSI diagram: the physical layer. To this extent, in fact, these technologies allow objects to become smart, i.e. to gather information by hosting sensors and to transfer it to several communication platform (existing or purposely conceived) such as, as the most paradigmatic example, a smartphone. Going into details, the exploitation of these technologies accounting for the specific needs of the agriculture world, leads to envisage solutions, mostly based on a massive deployment of smart autonomous sensors [8], able to provide real time information on a plethora of relevant parameters. These parameters will be gathered with a spatial density that can reach the level of the single plant [9], and even beyond, at an overall cost (recurring plus non recurring costs) per plant much lower than the value of the plant itself. Moreover, these results will be achieved at the prize of a minimal, mostly negligible, environmental impact.<br>Separately selected, these technologies have reached an acceptable level of maturity. In order to address these emerging technologies, for instance, the scientific community have been organizing, in the last decade, several topical conferences (i. e. IEEE-RFID-TA, -WPTC, -WiSNet…) as well as specific sessions in more mature events. Nevertheless, the adaptation to these technologies to specific needs demanded by the targeted application (smart agriculture) is still at this infancy. Nowadays, in fact, the solutions available on the market are mostly based on the exploitation of existing sensing and communication technologies that provide only basic functionalities and performance compliant with the final applications but are not able to smash those barriers, |

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| | mainly represented by real autonomy (i.e. battery independence), recyclability or compostability and ultra low cost per unit. A massive deployment of smart systems for agriculture is thus expected but yet to come. |
| Short description and objectives of the research activity: | This research proposal aims at bridging the gap between existing solutions based on available technologies and the expected ones based on emerging technologies. The former solutions, in fact, are acceptable, and sometimes in excess in terms of several performance (connectivity, scalability, coverage, miniaturization and so forth), but not in terms of functionalities (full autonomy, recyclability, ultra-low cost…). To target the latter, the development of the most promising technologies will be pursued according to an harmonized holistic vision prospectively enabling a technology down-scaling, a dramatic cost per unit reduction, a minimization of the environmental impact and, ultimately, a massive deployment of smart systems able to provide precise as well as real time information about the status of the parameter of interest for specific farming (as a mere exemplification, consider: soil and air humidity and temperature, leaf temperatures on both surfaces, local wind intensity, sunlight exposure, local atmospheric pressure, leaf wetness and so forth); ultimately provide a dense meshing of these parameters ending up in a sort of augmented reality to be checked remotely by means of very user-friendly GUIs.<br>In order for that the activity will start from a deep analysis of the state of the art of the technologies of interest, starting from the extensive background already developed in our institution. Then some significant applications will be chosen and targeted. The whole set of requirements, performance, functionalities and industrial constraints will be defined. Basic system architectures will be proposed for the selected cases. Relevant technologies will be developed accounting for specific requirements and system architectures considered. Eventually, demonstrators, hopefully till TRL-5 (technology validated in relevant environment), will be realized.<br>This activity is tuned to be compliant with a PhD fellowship program lasting three years; approximately the first six months will be devoted to the progressive definition of the state of the art, including the analysis of the most significant problems to cope with in the field; than the technology development will start according to the classical iterative methodology continuously refining theoretical consideration, cad design, experimental realization and validation to increase progressively the TRL from TRL-2 (technology concept formulated) to -5. It is worth mentioning that the inherent positioning of all this activity above the state of the art, makes reasonable to expect high impact publications since the first level of development, that is about after one year. Since that time at least one publication on high IF international reviews at each TRL step forward (that is three high IF publications during the project) is expected and at least a couple of intermediate contribution to publish the specific advancements and solutions run-time, will be targeted between two consecutive review contributions to credited international topical conferences.<br>These are the expected outcomes beyond the final validation of the demonstrators conceived.<br>The activity will be synergic to the development of the approved EST4IoT (Electronic and Sensor Technology for |

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| | IoT) laboratory in the sense that, on the one hand it will be carried out in the lab, on the other hand it will contribute to address the development of the EST4IoT lab to include the targeted technologies. |
| Bibliography: | [1] L. Roselli, N. Borges Carvalho, F. Alimenti, P. Mezzanotte, G. Orecchini, M. Virili, C. Mariotti, R. Goncalves, and P. Pinho, "Smart Surfaces: Large Area Electronics Systems for Internet of Things Enabled by Energy Harvesting," *Proc. IEEE,* vol. 102, no. 11, pp. 1723–1746, 2014.<br>[2] L. Roselli, Green RFID Systems, EuMA High. Cambridge UK: Cambridge University Press, 2014.<br>[3] T. Islam, S. C. Mukhopadhyay, and N. K. Suryadevara, "Smart Sensors and Internet of Things: A Postgraduate Paper", *IEEE Sesnor Journal,* vol. 17, n. 3, Feb. 2017, pp. 577-584.<br>[4] F. Alimenti, P. Mezzanotte, M. Dionigi, M. Virili, and L. Roselli, "Microwave Circuits in Paper Substrates Exploiting Conductive Adhesive Tapes," *IEEE Microw. Wirel. Components Lett.,* vol. 22, no. 12, pp. 660–662, Dec. 2012.<br>[5] Yei Hwan Jung et al. "High-performance green flexible electronics based on biodegradable cellulose nanofibril paper" *Nature Communications volume 6,* Article number: 7170 (2015).<br>[6] S. Chalasani, J. M. Conrad, "A Survey of Energy Harvesting Sources for Embedded Systems", *IEEE SoutheastCon*, Apr. 2008.<br>[7] L. Roselli, S. Kawasaki, and F. Alimenti, "Guest Editorial," *IEEE Trans. Microw. Theory Tech.*, vol. 62, no. 4, pp. 2012–2014, 2014.<br>[8] V. Palazzi, F. Alimenti, P. Mezzanotte, G. Orecchini, and L. Roselli, "Analysis of a multi-node system for crack monitoring based on zero-power wireless harmonic transponders on paper," in *IEEE WiSNet*, 2018, pp. 92–95.<br>[9] V. Palazzari, P. Mezzanotte, F. Alimenti, F. Fratini, G. Orecchini, and L. Roselli, "Leaf compatible 'eco-friendly' temperature sensor clip for high density monitoring wireless network," *Wirel. Power Transf.*, vol. 4, no. 1, pp. 55–60, 2017. |
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