# Monitoring of water resources in the Allier basin

# (Post-doctoral research fellowship in Computer Science)

**Duration:** 18 months

**Funding:** CPER IDEAL

**Summary of the position:**

The monitoring and the management of water resources is a major challenge for the society, in the context of global warming. One consequence of this global warming is the reduction of the average water flow and of the low water in the dry season, inducing drastic impacts on the water quality and increasing usage conflicts. Water restriction orders during droughts are based on the knowledge of water flow thresholds that enable priority usages while preserving the fairness among users of each region, and the required solidarity of upstream and downstream of watersheds. One of the enabling features for such a decision is the availability of robust data on the current level of resources, on the dynamics of water provision, and on water consumption.

In this context, it is essential to have a wireless sensor network allowing a real-time monitoring of the water resource and of its evolution, as a function of weather and usages. The number of sensors should be sufficient to have fine-grained measurements, and the collection of a long-term history is necessary to determine the water flow thresholds. Since the last five years, the academic community at Clermont-Ferrand has developed an operational chain in which wireless devices transmit heterogeneous data using an open and secure communication protocol (LoRa), until a cloud hosted in the Clermont Auvergne datacenter [3]. This operational chain is deployed today for environmental monitoring purposes, and the objective of this post-doctoral research fellowship is to explore its extension thanks to innovative approaches for water management, on the whole Allier watershed.

The proposed work consists mainly of <u>developing a wireless sensor network</u> for the measurement, the collection and the analysis of <u>data on water quality</u>, as well as the design of energy-efficient, robust and secure communication protocols, in order to reach good performance on the scale of the whole watershed. The main missions are the following:

- Participate to the user community [1] of this wireless sensor network. The users include researchers on water resource monitoring, on data management, on sensors and on wireless sensor networks [2].
- Participate in the <u>design and implementation of this wireless sensor network</u>.
    - Analyse the requirements definition for the real-time monitoring of water level and water flow level for a sustainable management, and evaluate the required number of sensors. This analysis will be made jointly with researchers on water resource monitoring.
    - Study innovative technical solutions to answer to water monitoring challenges at the scale of the watershed, notably through the use of <u>long distance technologies</u> (LoRaWAN with the LoRa modulation) or <u>satellite technologies</u> (LoRaWAN with the LR-FHSS modulation). Indeed, new low-cost satellite communication technologies and infrastructures (a few tens of euros of equipments, and a few euros for the monthly subscription) are coming from the Internet of Things domain, and enable low-power consumption and thus lifetimes of several months. This type of communication should

    - allow to address the challenges of transferring data from autonomous sensors, isolated in their surroundings, and often unreachable by traditional terrestrial means, to send data. These technologies seem very promising for the deployment of a network over the wide area of the Allier watershed, but the actual quality of service that can be obtained has to be evaluated on site.
    - Study the performance of the deployed network, in order to propose to final users a good quality of service.
    - Deploy the data collection along rivers thanks to linear wireless sensor networks, and evaluate the quality of service of such a linear network. While the principles of such topologies have been largely studied and documented, few actual deployments are operational in the literature, except from simple proofs of concept.
- Study the possibility of integration of artificial intelligence and machine learning at each level of the network or of the data analysis process.

The work will lead to the submission of scientific articles in high-ranked international conferences, as well as in top-level international journals.

Several trips will be organized on site.

**Required skills:**

- Human skills: autonomy, working in a team, working on site;
- Scientific skills: English proficiency;
- Technical skills: wireless sensor networks, knowledge of LoRa and LoRaWAN, embedded programming, C or C++ programming, script programming (such as Python), architecture of microcontrollers.

Additional skills in artificial intelligence and machine learning are considered a bonus.

**Gross salary:** about ### euros per month

**Location:** Campus Universitaire des Cézeaux, Avenue Blaise Pascal, 63 170 Aubière, France

**Supervision:** Laure Moiroux (TSCF – INRAE), Laurent Royer (LPC – CNRS), Alexandre Guitton (LIMOS – CNRS)

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**Context: the CPER IDEAL project**

The IDEAL project (from distributed intelligence to machine learning: innovative approaches for the management of big data in research) is a project from researchers of Clermont-Ferrand, focused on the design of sensors, and on the management and analysis of big data. This project has both fundamental and applied targets, and in particular focuses in the fields of the environment, the agriculture, the health and the cosmology.

The current monitoring of the Allier watershed is one of the first academic success stories of French researchers where a wireless sensor network is actually deployed by a variety of researchers from different fields. Deployed notably for the needs of the monitoring of agroecosystems, the network provides an operational chain where wireless sensors can transmit heterogeneous data with an open and secure communication protocol (LoRa), up to a cloud hosted in the Clermont-Auvergne datacenter.

Based on this solid foundation, the objective of the IDEAL project is to optimize the whole collection and data processing chain, from the sensor to the machine learning, while focusing on four fields:

- The distributed intelligence. The objective is to improve the robustness and the performance of applications, by moving the computations towards the objects themselves, within self-adaptable infrastructures.
- The energy-consumption reduction of the whole chain, from the connected sensors to the computation infrastructure in the cloud. The objective is (i) to design autonomous, low-power wireless sensors, thanks to recent advances in the field of energy harvesting, and (ii) to reduce the energy consumption of high-performance servers located in the data-center thanks to software innovations.
- The management and analysis of large-scale big data. New paradigms are emerging for the distribution and massive parallelization of data. These paradigms enable new computational models, while keeping central the challenges of data quality and measurement uncertainties.
- The machine learning from data of high-dimension. The challenge is to study the network architecture in order to analyze dense and heterogeneous sensor data, very-high resolution images, time series, or to perform multimodal learning.

**References:**

[1] « ConnecSenS : du capteur au cloud », https://www.uca.fr/recherche/presentation/lactualite-scientifique/institut-des-sciences/connecsens-%C2%AB-du-capteur-au-cloud-%C2%BB-linternet-des-objets-au-service-de-lenvironnement [in French]

[2] https://www.connecsens.org/

[3] Moiroux-Arvis, L. ; Royer, L. ; Sarramia, D. ; De Sousa, G. ; Claude, A. ; Latour, D. ; Voldoire, O. ; Chardon, P. ; Vandaële, R. ; et al. "ConnecSenS, a Versatile IoT Platform for Environment Monitoring: Bring Water to Cloud." *Sensors* 2023, *23*, 2896. https://doi.org/10.3390/s23062896