

# LELEC2102 / LELEC2103 - Project in Electrical Engineering

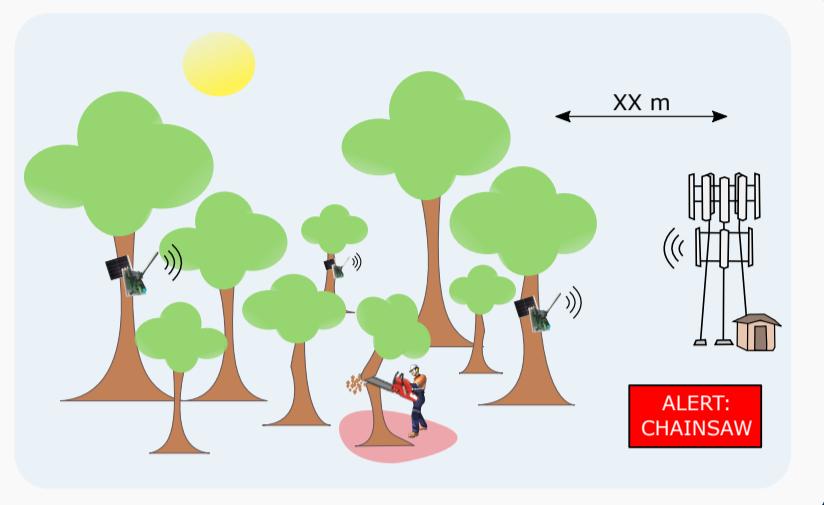
## Integration and Optimization of Wireless Embedded Sensing Systems

**Goal:** Audio detection of abnormal events in natural ecosystems with a wireless embedded sensing system.

**Description:** During a full year, several groups of ELEC master students designed and optimized an embedded system for monitoring forest ecosystems and detecting events such as wildfires or illegal sawing. This ambitious project involved all disciplines included in the Master degree in Electrical Engineering, i.e., electronic circuits and systems, communication systems, information and signal processing, cryptography, electronic materials and devices, energy, as well as embedded software programming.

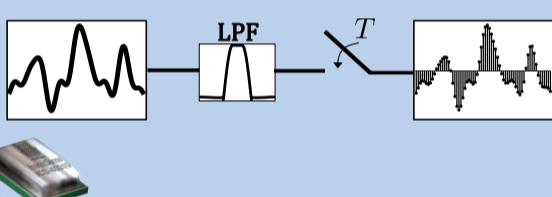
**Learning method:** Lectures and applied project, groups of four students

**Time period:** 1 year (Q1: design and characterization - Q2: optimization)



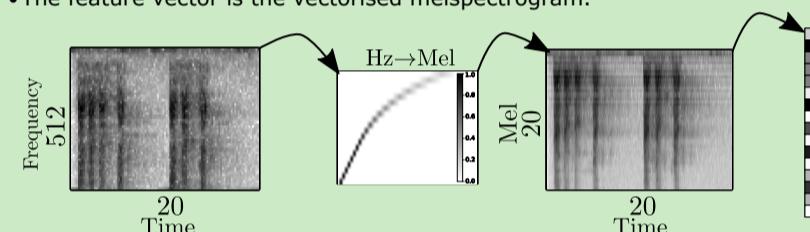
### Sound acquisition

- The ambient sound is sensed through a low-power microphone embedded on the wireless node.
- The continuous audio signal is low-pass filtered, sampled and discretised for computation.



### Time-freq analysis & feature extract.

- A spectrogram is obtained applying the short-time Fourier transform (STFT) to the discrete audio signal.
- The spectrogram is compressed using a Hertz to Mel transformation.
- The feature vector is the vectorised melspectrogram.



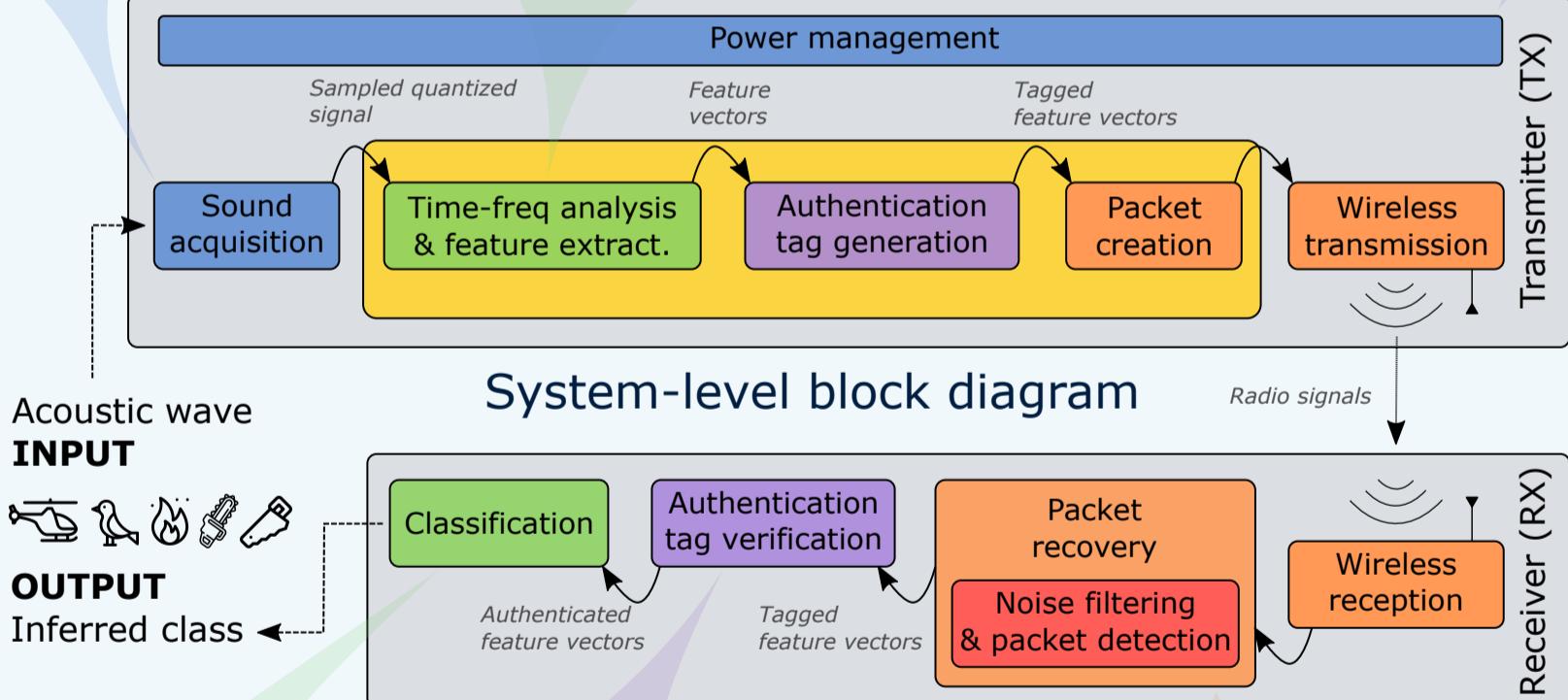
### Power management

- The wireless node harvests solar energy thanks to PV cells and dedicated circuitry. The energy is then stored on a capacitor.
- Depending on the ambient conditions, more or less power can be harvested, which can impact the strategy for the monitoring.
- This avoids the need for using a battery but it sets strong constraints on the power available: optimization is therefore needed to bring the total power budget below 5 mW.



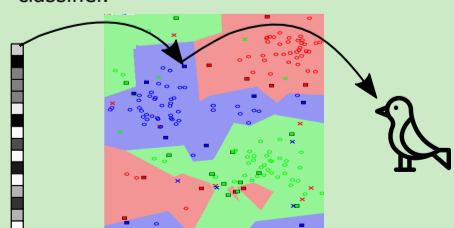
### LEGEND

- Signal processing
- Security
- Wireless comm.
- Analog & power elec
- Digital electronics
- Embedded progr.



### Classification

- A K-Nearest Neighbor (KNN) classifier uses known examples to map a new acquired feature vector to a given class.
- Goal: (largely) beat the random guessing classifier.



### Authentication

- Message Authentication Code for detecting if the message :
  - was sent by an adversary,
  - has been corrupted,
  - thanks to a secret key shared between the TX and the RX.



### Wireless communication

- Digital communication making use of **continuous-phase frequency shift keying (CPFSK)**
- Dedicated carrier frequency per group (from 860 MHz to 868 MHz), with 1 MHz bandwidth
- Packet structure:

Preamble	Sync word	Payload	CRC
4 bytes 0xAAAAAAAA	4 bytes	0:65535 bytes	1 byte Based on payload

CRC: Cyclic Redundancy Check

- Transmitter:** programming of S2-LP device from STMicroelectronics
- Receiver:** implementation of a software-defined radio (SDR) using GNU Radio

- Reception chain: Complex baseband signal → Low pass filter → Preamble detection → Synchronization (CFO estimation, STO estimation) → Demodulation → Packet parser → Payload bits