Demo: Sensing Crops via Radio Attenuation Patterns

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Abstract

Agricultural processes for crop cultivation rely on Days Since Planting (DSP) growth models. To enable the use of these models for digitalized farming, they need to be calibrated. We show that a Wireless Sensor Network (WSN) can leverage the communication metrics, specifically the Received Signal Strength Indicator (RSSI) of LoRa nodes, to dynamically calibrate models via a characteristic attenuation dip during plant growth. In this demo, we reproduce the in-field effects using sensor nodes and a variable-height roll-up display representing the plant growth. This setup allows showcasing the characteristic signal attenuation dip in real-time, demonstrating the core principle of our methodology.

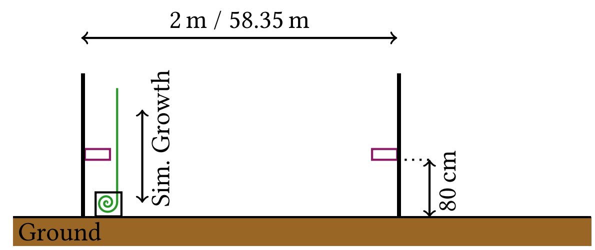

Figure 1: Schematic structure of the sensor nodes and setup dimensions. The demonstration uses a variable-height rollup banner between two LoRa nodes to emulate the growth-induced signal attenuation of maize.

Figure 2: Sensor node deployment on an conventional maize field in 2024.

1 Introduction and Motivation

The management of agricultural processes for crop cultivation commonly relies on simple Days Since Planting (DSP) growth models, as they require no additional sensor data. However, farmers routinely visit fields to visually estimate growth and calibrate these models based on their experience. To propel the digitalization of farming, especially regarding climate change, such calibration must be automated. Since Wireless Sensor Networks (WSNs) will likely become common in fields to collect soil, weather, or plant health data, the communication signal metrics (e.g., Received Signal Strength Indicator (RSSI) and Signal-to-noise ratio (SNR) values) between the nodes can also be used for sensing at no additional hardware cost, realizing the principle of Joint Communication and Sensing (JCAS) [2].

In recent years, we have deployed commercial off-the-shelf (COTS) LoRa nodes in maize fields to continuously measure the signal attenuation and to identify plant-specific attenuation patterns from the noise-affected RSSI signal. By extracting distinct events from these patterns, we dynamically calibrated existing DSP growth models.

The novelty of this work is the interactive demonstration of the concept, not a new sensing algorithm. This demo translates the field-observed attenuation pattern into a compact setup that makes the effect immediately visible.

2 The Concept: Identifying the Characteristic Dip

The core idea of our approach is based on the premise that distinct phenological events can be obtained from the daily LoRa RSSI. During early growth, we observed a characteristic U-shaped attenuation pattern in long-term data tracking maize growth cycles, similar to Hunt et al. [1]. In the early-growth data, however, an additional short-term dip between DSP 55 and 70 becomes visible, resulting in a distinct W-shaped temporal curve (see Figure 3). This distinct attenuation happens at early plant development when water content and vegetation density is high, and before a tunnel effect potentially occurs [3]. We smooth the signal and detect

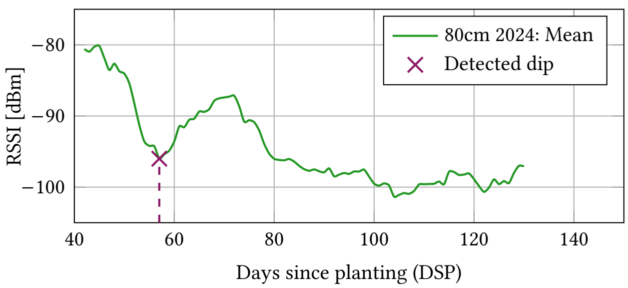

Figure 3: Measurement of RSSI over multiple months. A distinct characteristic early-growth dip occurs roughly between DSP 55 and 70.

the local minimum in the early-growth interval, yielding a robust temporal anchor point (t_{dip}). This anchor is then used to calibrate growth models to local seasonal delays.

3 Demo Overview and Setup Requirements

Our demo qualitatively reproduces the characteristic field attenuation dip through an interactive short-distance setup; small differences to the real RSSI values exist due to the indoor environment. The attenuation dip should be robust under conference conditions, dominated by obstruction (aluminium foil) rather than environmental noise.

3.1 Interactive Demonstration

We place two tripod-mounted rods representing the sensor-equipped nodes, as shown in Figure 1. On each rod, a COTS Lilygo TTGO T-Beam LoRa node is mounted at a height of 80 cm. These nodes are configured to continuously transmit and receive LoRa packets, simulating a typical agricultural link. We use the same setup as in the field, shown in Figure 2. Instead of real plants, we place a mechanical rollup banner between the two sensor nodes. The system contains a large banner with a life-size printed maize field. The rear side of this banner is layered with aluminum foil. This foil emulates the severe obstruction usually caused by the water-dense biomass of a real plant crossing the signal path.

The demonstration follows a three-step interactive process: First, a baseline RSSI is established with the banner fully retracted, representing a clear Line-of-sight (LOS) before plant emergence. Then, people are invited to manually pull the rollup banner upwards. As the height increases, the incorporated attenuating material progressively intersects the signal path between the two LoRa nodes. Finally, a connected laptop running a Python-based visualization script monitors the incoming RSSI via serial connection to a receiver node. Visitors observe the incoming signal strengths on a real-time dashboard. As the densest part of the emulated biomass obstructs the LOS, the dashboard will show the sharp signal dip, reproducing the characteristic in-field W-curve shown in Figure 3.

3.2 Setup Requirements

To successfully present this demo, we require spatial and technical conditions typical for a tabletop presentation:

- **Space:** A floor space of approximately 2.5 m × 1 m. A typical small table is needed for the laptop and visualization dashboard. The two tripod stands and the rollup banner will be placed vertically on the floor next to the table.
- **Power Requirements:** A standard 230 V power outlet to supply the laptop. The LoRa nodes are battery-powered and operate independently.
- **Wireless Environment:** The system operates in the 868 MHz ISM band.

4 Conclusion and Future Work

In this demo, we present an interactive representation of our SCRAP methodology, illustrating how the principles of JCAS can be practically applied to precision agriculture. By emulating the signal attenuation of a maize crop crossing the LOS of a typical LoRa link, attendees can observe the characteristic early-growth signal dip in real-time and without heading out into a maize field. As established in our long-term field deployments, this distinct attenuation event serves as a critical temporal anchor. It enables the automated calibration of simple DSP growth models, allowing them to adapt to unseasonable weather variations and localized delays without requiring labor-intensive manual sampling.

In our future work, we aim to evaluate the robustness of this sensing approach across diverse climates, varying link distances, and different crop types.

Acknowledgments

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