Low-Cost Edge-Enabled Sensor System for Small Farms and Households

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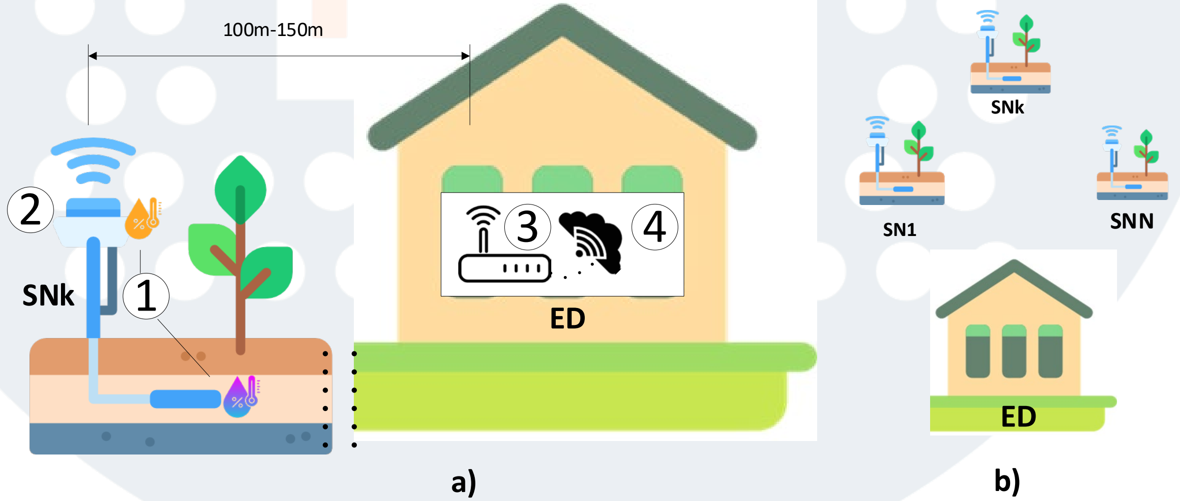
Motivation & Background

- Precision agriculture uses data-driven techniques to optimize crop inputs.
- IoT sensors enable real-time monitoring of soil and environmental conditions.
- Small farms and households face constraints: limited budgets, small plots, and low power needs.
- Aim: Develop a simple, low-cost, and energy-efficient sensor node (sensor network)



Research Objective

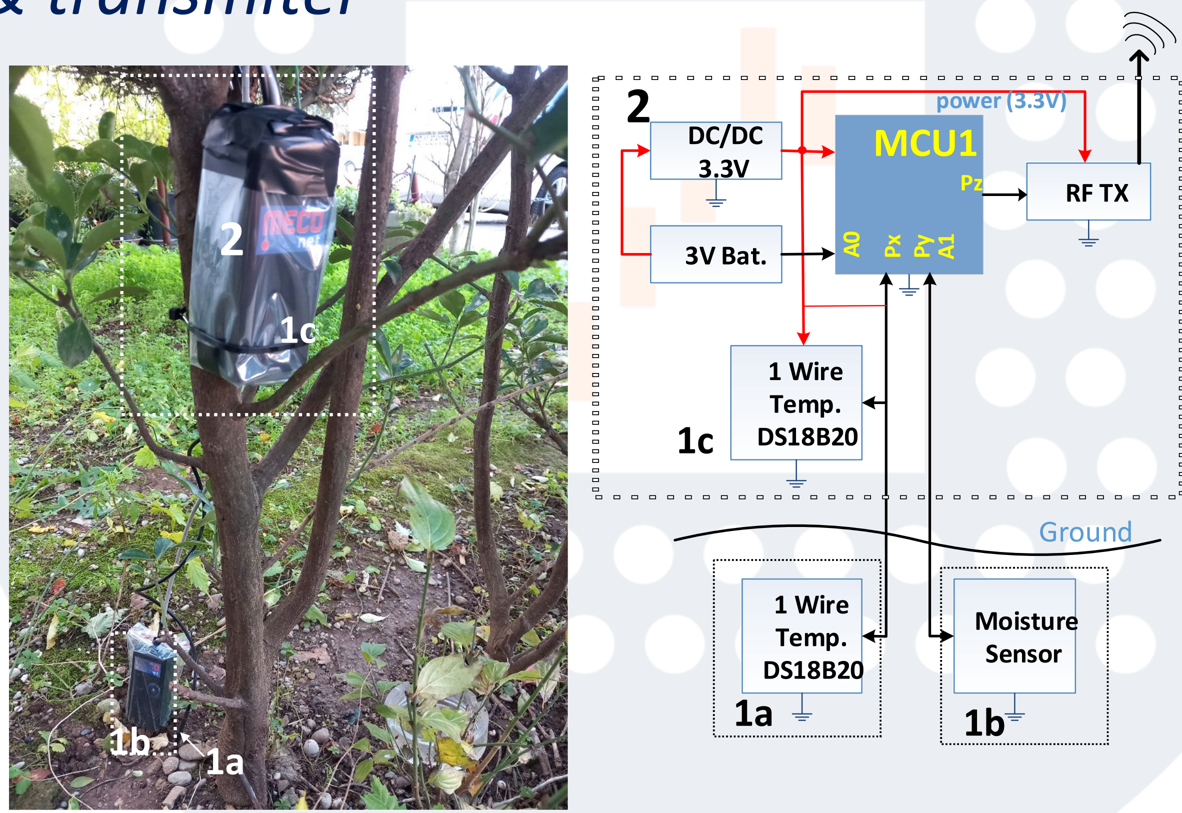
- Design and implement a low-cost, sensor-to-gateway architecture using off-the-shelf components.
- Enable 150 m range wireless communication via 433 MHz RF.
- Ensure rugged, battery-powered, and low-maintenance and zero setup operation.
- Demonstrate feasibility for small-scale precision agriculture.

System Architecture

- Client–server model: Sensor Nodes (SNk): Measure soil & air parameters.
- Edge Device (ED): Collects, displays, and optionally forwards data to cloud.
- Two modes: Standalone (local display/alarm).Networked (cloud connectivity).
- Communication: RF 433 MHz ASK/OOK
- TX: Sensors: Soil temperature (DS18B20), soil moisture (capacitive), air temperature.
- TX: Microcontroller: ATtiny85 (ultra-low power).
- TX: Power: 2×AA batteries with DC/DC boost (3.3 V).
- TX: RF Comm Module: SYN115 transmitter (+10 dBm, 1 µA standby).
- RX: Edge MCU: ATmega328P or ESP32 (for Wi-Fi/Bluetooth).
- RX: SYN480R: Receiver
- RX: Power: Battery or external

System Architecture

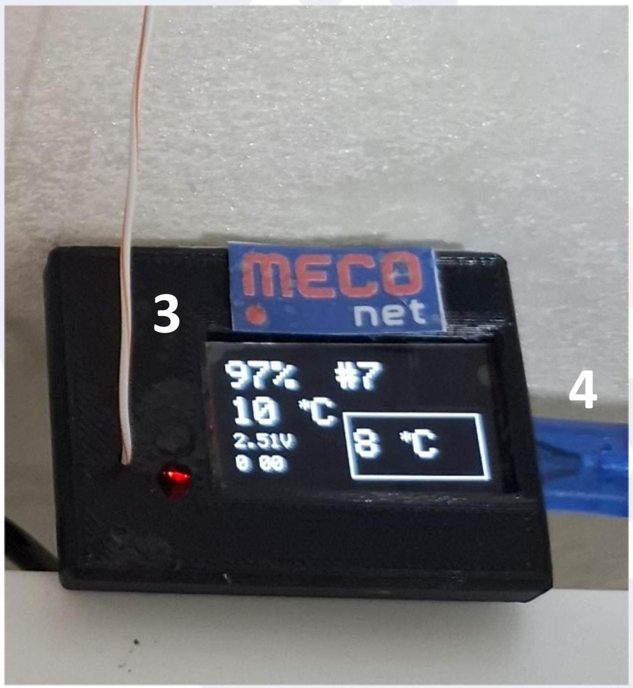
- *Sensors & transmiter*



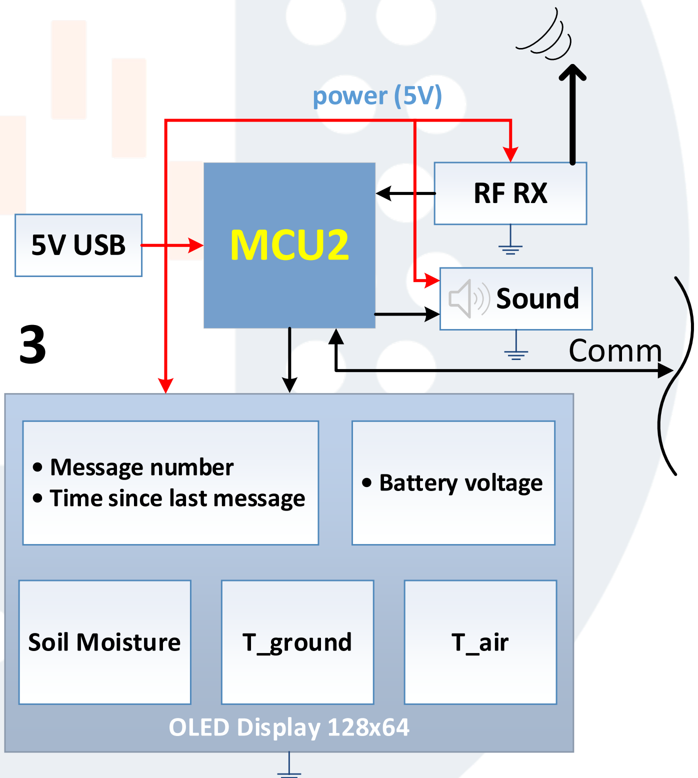
a) b)

System Architecture

- *Receiver*



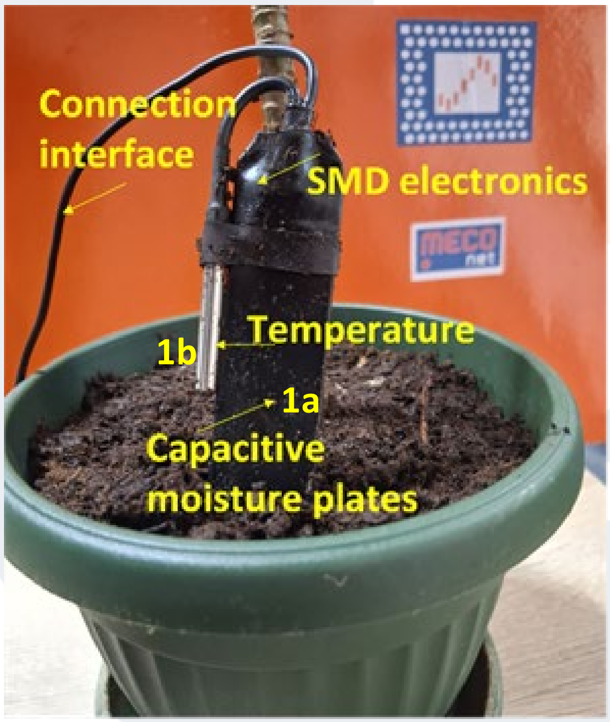
a)



b)

System Architecture

- *Standalone sensor*



a)

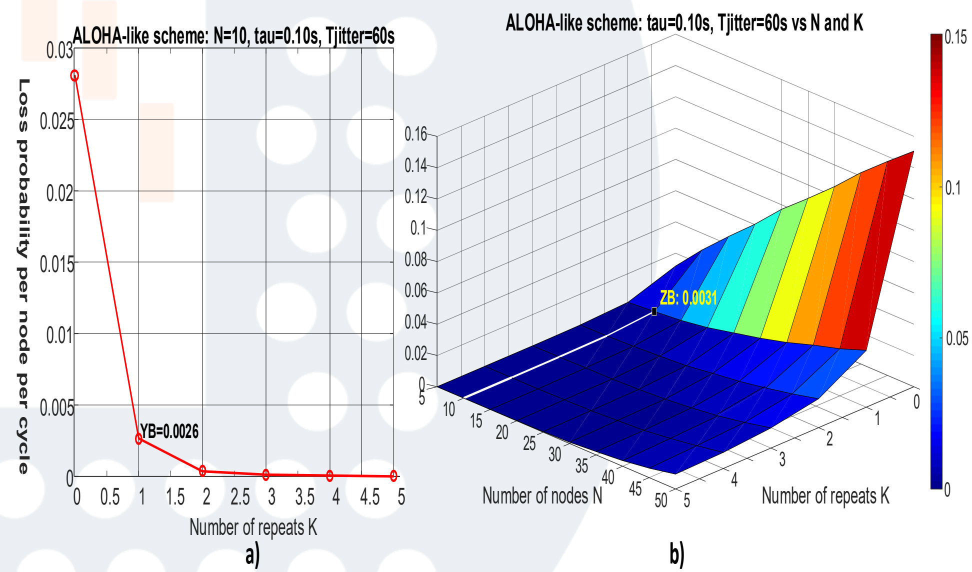
b)

Optimization Strategies

- **Energy efficiency:** Duty cycling, adaptive transmission, deep-sleep modes.
- **Edge intelligence:** Local preprocessing and event-driven data reporting.
- **Lightweight protocols:** Short unidirectional RF packets.
- **Hybrid reporting:** Periodic + event-triggered alerts.
- Goal: ≥6 months battery life

Collision Avoidance Mechanism

- **Challenge:** Multi-node RF transmission without ACK → possible packet collisions.
- **Solution:** ALOHA-like random jitter & limited repeats (K).
- **Simulation results:** Loss ~3% (no repeat), <0.5% (1 repeat), negligible (2+ repeats).
- **Balance:** Energy efficiency vs. reliability.



Sensor Deployment Strategy

- Optimize cost & accuracy: Low-variability (air temperature): 1 sensor per field (≤10 ha).
- High-variability (soil moisture/temp): 1–3 per management zone.
- Greenhouses: 2–6 sensors capturing microclimate gradients.
- Outcome: Reliable monitoring with minimal nodes.

Results & Performance

- Test environments: Open-field & greenhouse (1-year trials).
- Range: 50–150 m (stable in both indoor/outdoor).
- Battery life: ~6 months (10 min reporting).
- Communication: Reliable with minimal packet loss.
- Max nodes: 50 per gateway (acceptable loss rate).

Conclusions & Future Work

- Proven low-cost, low-power, edge-enabled system for small farms.
- RF 433 MHz communication effective up to 150 m.
- Optimized power & collision management = extended battery life.
- Supports data-driven small-scale agriculture.
- Future work:
  - Add more environmental sensors.
  - Explore solar/hybrid power.
  - Scale to larger networks.

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Thank you, Q&A?