ElectroCap Project

VERTEXSHELL

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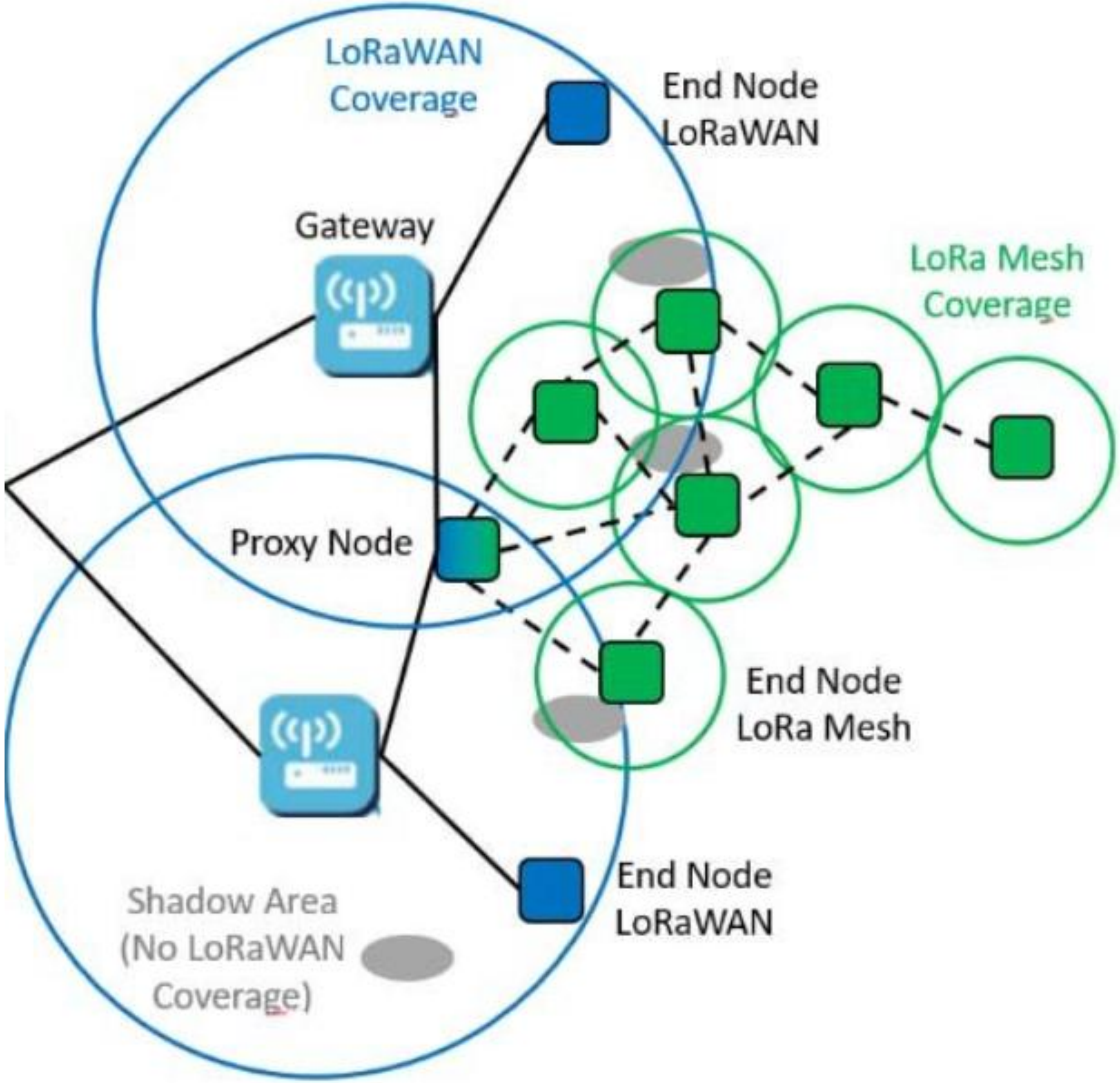
TÉCNICO LISBOA

FRAMEWORK AND PROBLEM

- **Problem:** Currently, traditional personal protective equipment is passive, protecting only against physical impacts.
- **Environmental Blindness:** In construction mines, workers face imperceptible issues invisible to the naked eye, such as toxic gases or electromagnetic fields, as well as the danger of communication failures due to weak networks underground.
- **The Risk:** Concrete structures and tunnels block standard Wi-Fi networks, causing communication failures. If network problems occur, communication delays worsen the performance of rescue and medical teams.

SOLUTION

- **The Solution:** An active smart helmet that warns against toxic gases and harmful electromagnetic fields, equipped with a self-healing "mesh" network.
- **What it does:** Detection of **falls**, measurement of toxic gases (CO/VOC) and proximity alert to high-voltage equipment (EMF).
- **The Innovation:** Uses LoRa and Mesh technology, which allows the network to communicate over long distances with low energy consumption, where each helmet acts as a "router" (node), allowing alerts to jump from helmet to helmet until reaching supervision, overcoming signal blockages.



COMPETITIVE ANALYSIS

- **Main competitors:** Guardhat, Proxyg (SmartHat), WakeCap and Xingtera.
- **Our differentiation:** While Guardhat depends on Wi-Fi/LTE (which fails in tunnels) and Proxyg/Xingtera do not focus on network communication, ElectroCap guarantees communication in blind spots through LoRa Mesh, also combining multimodal detection (gases and EMF) and energy autonomy.

INTERVIEWS AND CONTACTS

- **Workers/End Users:**
  Mine and construction workers;
  Identification of real risks and validation of ergonomics.
- **Occupational Health and Safety Specialists (OHS):**
  Validation of standards, safety and certification requirements.
- **Technical Partners:**
  INESC-ID — validation of the LoRa Mesh network and algorithms
  ISQ — EMC testing and future ATEX certification

ARCHITECTURE AND TECHNICAL SPECIFICATIONS

- **Main Hardware** (Estimated budget ~80€/unit):
  Processing and Communication: ESP32-S3 with integrated LoRa (Mesh + low consumption);
  Sensors:
  - 6-axis IMU (falls);
  - Toxic gases (CO / VOC);
  - Electromagnetic field detection (EMF).

  Local Alerts: Visual LEDC LED + active acoustic buzzer

  Power:
  - 18650 battery (hot-swappable);
  - Autonomy: 12–16 hours in active Mesh mode.

- **Fixed Nodes (Repeater Posts):**
  To ensure coverage in deep areas or areas with many obstructions, the system will include **stra**
  These posts have the same LoRa Mesh communication hardware as the helmets, but **without se**
  with **continuous power supply**.
- **Hardware Development:**
  PCB Design: Altium Designer for creating and optimizing printed circuit boards, ensuring compact integration of components (ESP32, sensors, LoRa) into the helmet.

AUTONOMOUS OPERATION AND USER DATA

- **Autonomy (Power):** The design uses a "hot-swappable" system with 18650 Lithium batteries (3000mAh at 3.7V), housed at the back to balance the weight. It guarantees 12 to 16 hours of runtime in active Mesh mode.
- **Firmware Logic (Behavior Acquisition):** The system has event-driven logic. The helmet is programmed to sleep and wake up every 5 seconds for routine checks, saving battery.
- **Detection:** Sensors constantly track high G-force impacts followed by 10 seconds of inactivity to detect user falls and generate immediate hardware interrupts to send an SOS request.

```
// Use RTC-capable pins for wakeup
#define SENSOR_INTERRUPT_PIN 32

void setup() {
  // 1. Configure sensors to pull this pin HIGH when a threshold is met
  pinMode(SENSOR_INTERRUPT_PIN, INPUT_PULLDOWN);

  // 2. Setup Wakeup Sources
  // Wake up instantly if the sensor pin goes HIGH
  esp_sleep_enable_ext0_wakeup((gpio_num_t)SENSOR_INTERRUPT_PIN, 1);

  // Also wake up every 5 seconds for a routine heartbeat/check
  esp_sleep_enable_timer_wakeup(5 * 1000000);
}

void loop() {
  // --- 1. SENSE ---
  // Check why we woke up
  esp_sleep_wakeup_cause_t cause = esp_sleep_get_wakeup_cause();

  if (cause == ESP_SLEEP_WAKEUP_EXT0) {
    // Immediate danger detected by hardware interrupt
    if (checkFall()) sendSOS("FALL");
    if (checkEMF())  sendSOS("EMF");
  }

  // Always check gas as it is often an analog value

   if (analogRead(GAS_PIN) > LIMIT) sendSOS("GAS");

   // --- 2. TRANSMIT ---
   sendHeartbeat(); // Keep supervisor updated

   // --- 3. SLEEP ---
   Serial.flush(); // Ensure logs are sent before CPU stops
   esp_light_sleep_start();

   // Execution resumes right here after wakeup!
}
```

TEAM PLANNING AND TASKS

TEAM TASKS DIVISION

- **Vivian Chipanga**
  LoRa Mesh network development; Communication software implementation; Project logistics; Poster creation; Contribution to Pitch Deck.
- **Afonso Lopes**
  Development of sensor data acquisition and processing software; Interpretation and filtering of signals (IMU, gas, EMF); Data preparation for transmission over the LoRa Mesh network; Production and editing of the demonstration video; Contribution to Pitch Deck.
- **Tomás Santiago**
  3D printing of the prototype; Packaging and physical integration of components; Helmet design production for user comfort and safety; Website development; Project logistics.
- **Duarte Biscaia**
  Electronic circuit implementation; Battery system management and integration; Website development.
- **João Campos**
  Software development; Support for electronic circuits; Multimedia content production; Contribution to Pitch Deck.

PHASE PLANNING

- **Phase 1: Research, Design, and Procurement (Weeks 1–3)**
- Research LoRa Mesh libraries and sensor calibration techniques.
- Finalize the component list.
- Develop the initial wireframe for the Landing Page and the structure of the Pitch Deck.
- **Phase 2: Individual Module Development (Weeks 4–7)**
- Hardware Implementation
- Conduct basic point-to-point LoRa communication tests.
- **Phase 3: Mesh Network Implementation (Weeks 8–10)**
- Develop and test the self-healing Mesh protocol.
- Integrate sensor data into the Mesh packets.
- **Phase 4: System Integration and Housing (Weeks 11–13)**
- Integrate all sensors, the mesh radio, and the alarm system into a single battery-powered unit.
- Design and secure the hardware inside the physical helmet prototype.
- **Phase 5: Testing, Validation, and Content Production (Weeks 14–15)**
- Conduct field tests in signal-blocked environments.
- Script and film the Demonstration Video showcasing the helmet's reaction to hazards.
- Design the Project Poster and finalize all visual assets.
- **Phase 6: Final Polishing and Pitch Preparation (Weeks 16–17)**
- Complete the Pitch Deck with real data and metrics gathered during the testing phase.
- Final review of the Landing Page, Video, and Poster to ensure they meet all evaluation criteria.