NEXASENSEE: Next Generation Environmental Sensing

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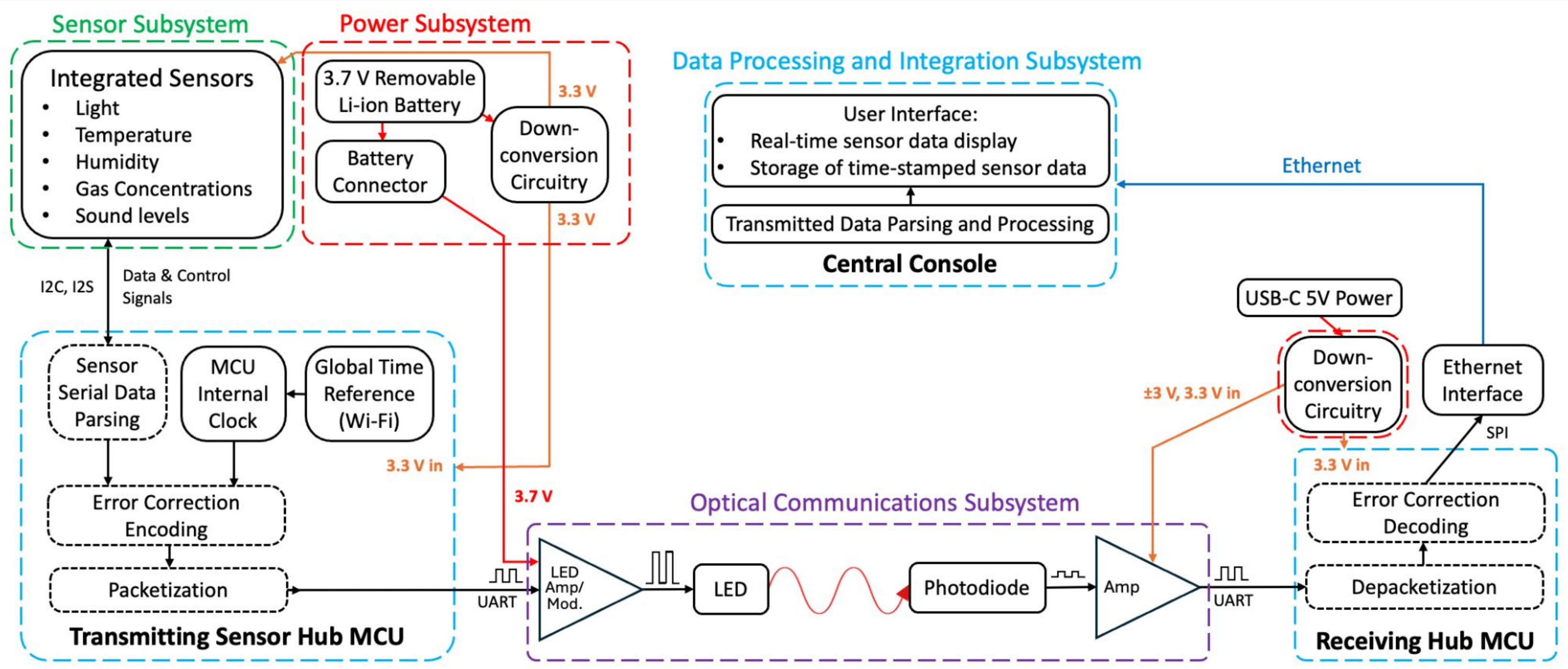
Introduction

Controlled settings such as hospitals and scientific laboratories demand precise tracking of environmental conditions to maintain safety, efficiency, and comfort. Traditional systems often rely on radio-frequency transmission, which contributes to electromagnetic congestion and interferes with critical equipment. As these environments become more electronically dense, the need for alternative, non-RF communication methods becomes more urgent.

Idea: Free-Space Optical Communication

Design Requirements & Subsystems



- Design must minimize EMI.
- Monitor temperature, humidity, pressure, gas, light, and sound.
- Interface over I²C, I²S, or SPI with ≥100 kbps data rates.
- Support optical transmission with error detection and correction.
- Transmitter hub battery powered; Receiver hub USB powered.
- GUI must support real-time display and data logging.
- Design must prolong battery life.
- Housing must not impede data collection.

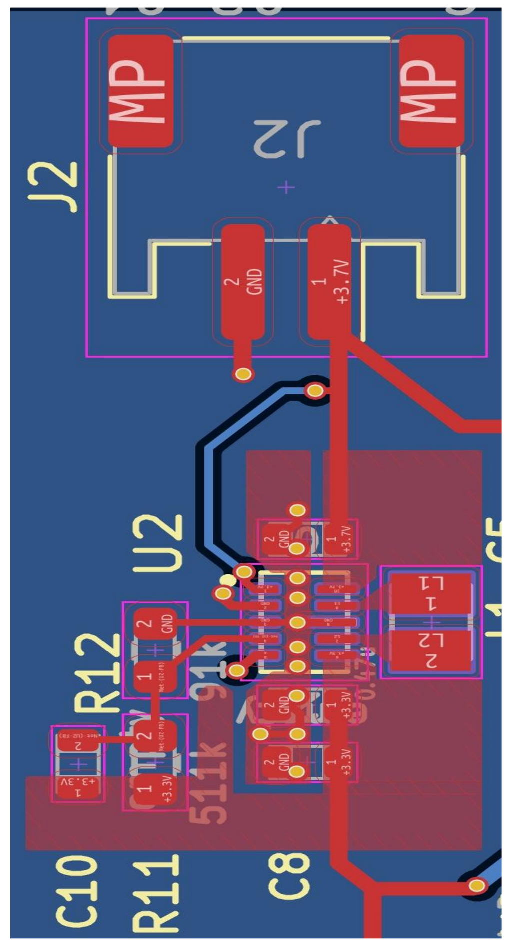
Sensors and Data Encoding

The sensor hub collects temperature (°C), humidity (% RH), pressure (hPa), gas concentration (Ω), light (lux), and sound (normalized 1–1000 scale). Measurements are time stamped and prepared for optical transmission. Communication with sensors occurs over high-speed I ²C and I ²S interfaces.

Optical Communication

The system uses a near-infrared optical link for wireless data transmission. An infrared LED (λ = 940 nm) transmits encoded data packets at 115.2 kbps (OOK). At the receiver, a photodiode circuit detects and amplifies the incoming signal. Amplification ensures the system can distinguish the transmitted signal from ambient light and electrical noise. A comparator generates a clean digital signal to be read by the MCU.

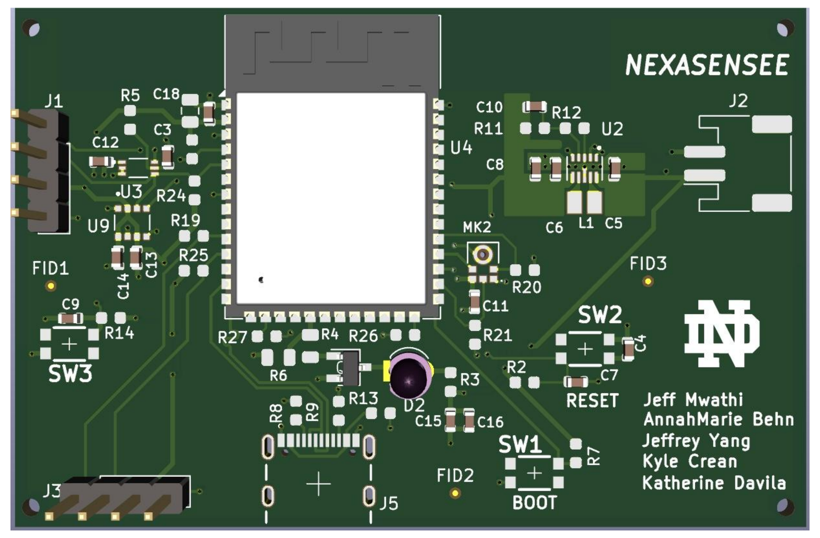
Power

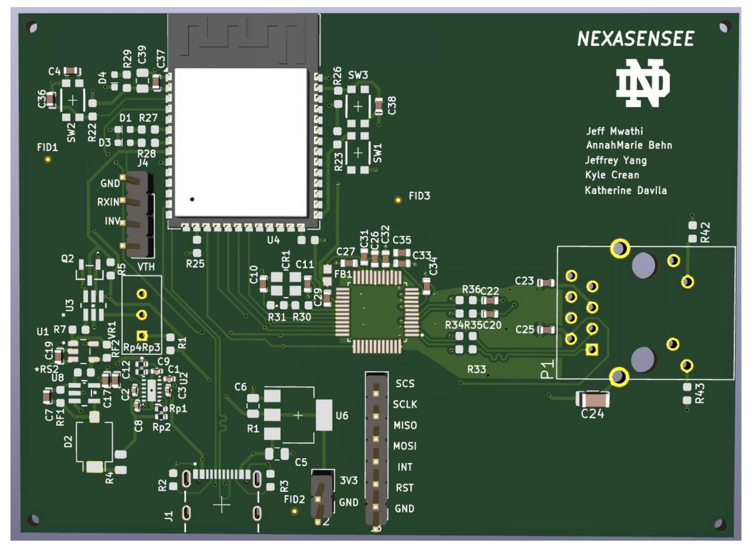


The transmitter is powered by a 3.7V lithium-ion battery, regulated down to 3.3V using a buck-boost DC-DC converter for efficient conversion across the full battery voltage range.

The receiver hub is powered by a 5V USB-C input, stepped down to 3.3V with an LDO regulator. ±3V rails for photodiode signal amplification are generated using a charge pump IC.

Board Design





Transmitter

- ESP32-S3
- Header pins for debugging
- 2nd i2c bus for possible LCD Display
- Large copper pours for power management
- USB-C for programming

Receiver

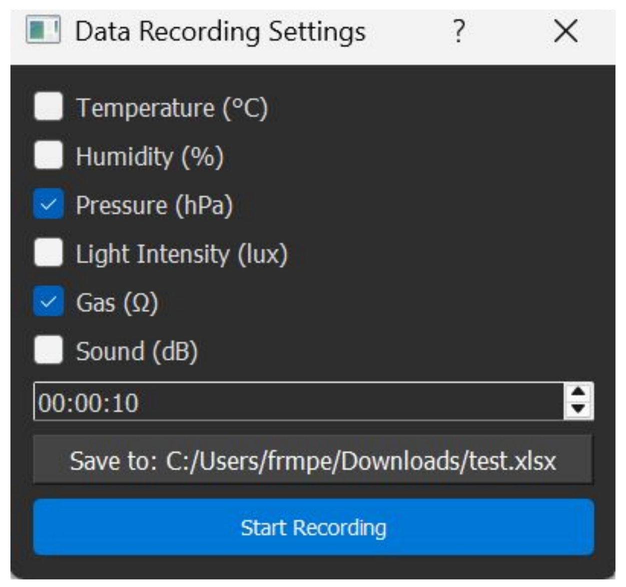
- ESP32-S3
- Header pins for debugging
- Ethernet circuitry
- USB-C for power, programming

Ethernet

The WIZNET ethernet chip requires a MAC address assignment to communicate collected data. In the receiver code, the MAC address and central console IP address is defined.

User Interaction

Data decoded by the receiver is sent via ethernet to a GUI on a central console. The user can view live environmental data and can record specific parameters to their device.



Conclusion and Future Work

- Removing wiring completely would streamline installation.
- Ethernet is outdated.
- Sleep modes for energy efficiency.