MoBI Smart Buoy System for Marine Environmental Monitoring

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About me


2017 till to date
Assistant Professor
at UniCa
2017 Ph.D. in
Computer Science
and Electronic
Engineering
2012 M.Sc. in
Telecommunication
Engineering
2011 B.Sc. in
Electronic
Engineering

Research Group & Current Projects

Our team represents a collaboration between **Hedya srl** and the **University of Cagliari**, merging industrial expertise with academic research to create impactful environmental technologies.

Key Interests

- Advanced IoT Systems and Social IoT
- Cloud and edge computing
- Smart cities/home/buildings
- Environmental Sensing & Data Analytics
- xG networks and Augmented reality (AR)

Current Projects

- RETURN - Multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate (EU Funded Project)
- Ecomonitoring - MoBI Smart Buoy System Development

Introducing MoBI

An integrated solution for reliable, in-situ environmental data collection in coastal and marine areas using embedded hardware, multi-parameter sensors, and redundant communication technologies.

The Challenge: Marine Environmental Monitoring

Marine environmental monitoring is **critical** for:

- Sustainable management of natural resources
- Prevention of climate change-related risks
- Monitoring human activity impacts

Traditional methods often face connectivity challenges, limited data quality, and operational inefficiencies in harsh marine environments.

Introducing MoBI: Monitoring Buoy Interface

1

Semi-Autonomous Operation

Designed to be towed by Unmanned Surface Vehicles (USVs) to predefined positions for targeted measurements

2

3D-Printed HDPE Construction

Modular structure allows easy maintenance and component replacement while ensuring watertight protection

3

Multi-Parameter Sensing

Equipped with sensors for wave dynamics and water quality parameters including temperature, pH, conductivity, dissolved oxygen, and turbidity

4

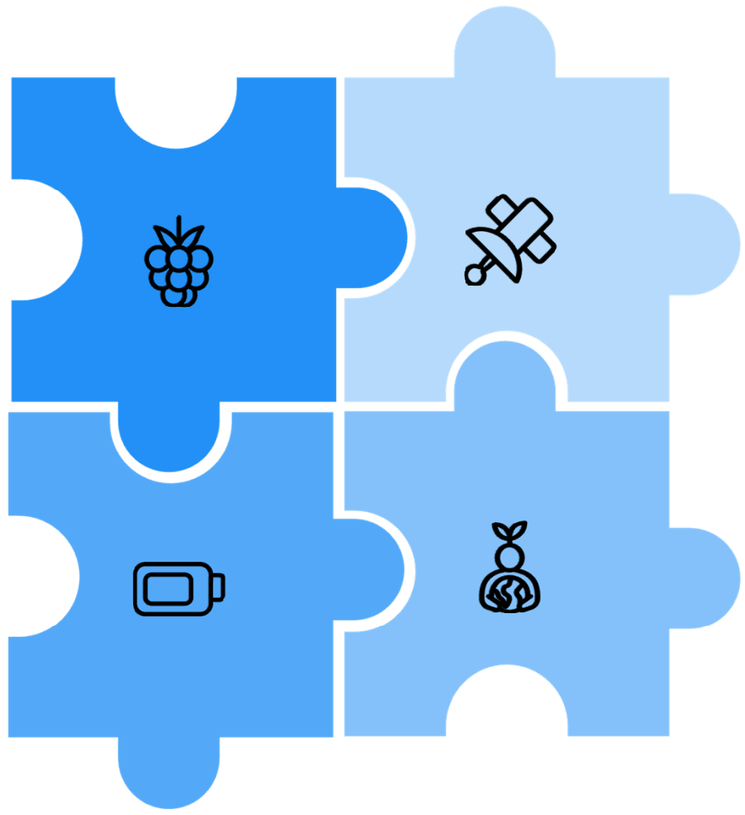
Dual Communication Strategy

Operates even under limited connectivity using redundant transmission methods

System Architecture

Processing Units

- Raspberry Pi 3B+
- Arduino Mega



Communication Modules

- 4G/LTE Module
- LoRa Module

Power System

Sensors Suite

- Multiparameter Probe (Water Quality)
- IMU & GPS (Wave & Position)

The system combines embedded processing, real-time sensor interfacing, and redundant communication systems to ensure data integrity even under challenging conditions.

Dual Processing & Communication Strategy

Processing Units

- **Raspberry Pi 3B+:** Handles high-level operations (probe communication, data formatting, logging)
- **Arduino Mega 2560 R3:** Manages low-level data acquisition from inertial and positioning sensors
- USB serial connection for bidirectional data exchange and power

Communication Strategy

4G/LTE Primary Channel

High throughput, low latency data transmission to remote servers when available

LoRa Fallback

Long-range, low-power transmission when cellular coverage is limited or absent

Local SD Storage

Ensures data availability for retransmission if both channels fail

Mission Operation Flow

1

Initialization

- Establish serial communication between Arduino and Raspberry Pi
- Request GPS coordinates from remote platform
- Initialize sensors, GPS module, and LoRa communication

2

Navigation

- Move toward measurement point (via USV or manual towing)
- Continuously update GPS position
- Stop when distance falls below configured threshold

3

Data Acquisition

- Initialize wave motion analysis algorithm
- Collect environmental probe data
- Process and prepare data for transmission

4

Data Transmission

- Send via 4G if network available; otherwise use LoRa
- Verify successful reception by platform
- Loop to next measurement point or conclude mission

Environmental Data Collection

Water Quality Parameters

The WMP6 multiparameter probe connects via RS485 interface to measure:

- Temperature
- pH
- Electrical conductivity
- Dissolved oxygen
- Turbidity

Wave Motion Detection

Inertial sensors capture wave dynamics through:

- Four-phase detection algorithm identifying complete wave cycles
- Z-axis acceleration monitoring for period calculation
- Double numerical integration for amplitude estimation
- Magnetometer data for directional orientation

Field Test Results (January–March 2025)

Positioning Accuracy

Average GPS error of ~10 meters relative to configured targets

GNSS module in later tests reduced both fix acquisition time and positioning error

Data Quality

Consistent values across most parameters

Turbidity occasionally produced null/negative readings that were filtered out

Wave detection reliable for heights above 5cm

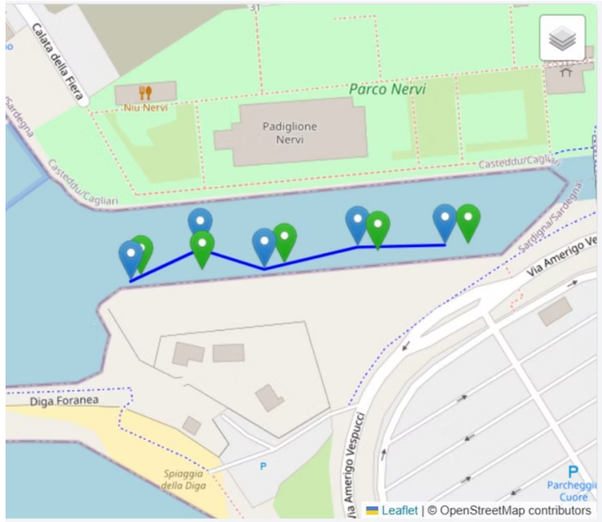
Communication Reliability

Successful data transmission over LTE in areas with good coverage

Fallback and retransmission logic worked as expected during network outages

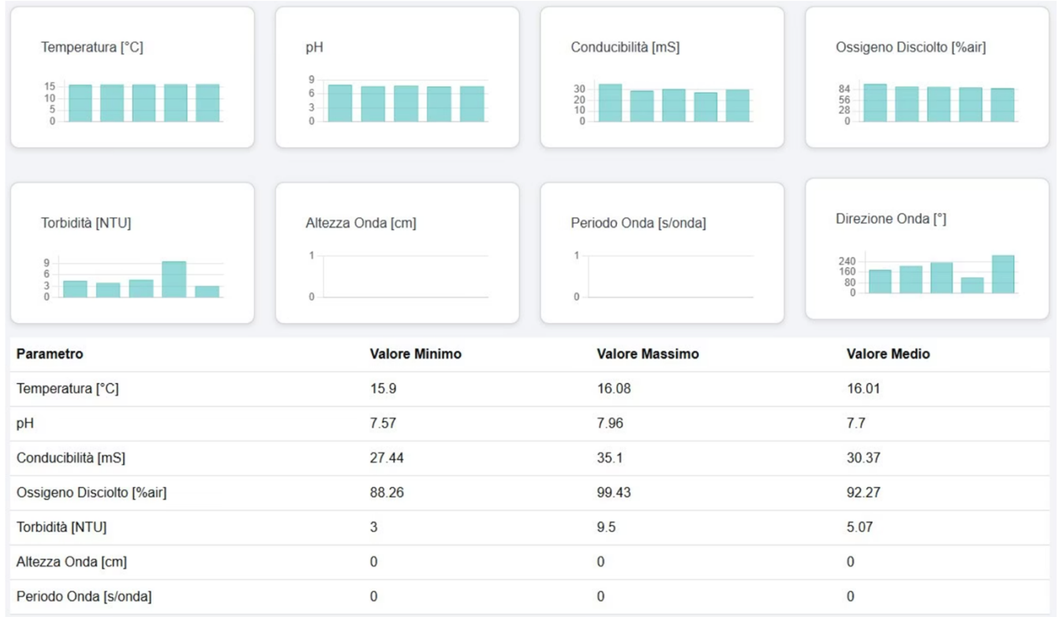
Local storage ensured no data loss

Field Campaign: Putting MoBI to the Test



Stato Missione: Completata

#	Latitudine	Longitudine
1	39.20051	9.12846
2	39.20064	9.12883
3	39.20056	9.12917
4	39.20065	9.12967
5	39.20066	9.13014



Parametro	Valore Minimo	Valore Massimo	Valore Medio
Temperatura [°C]	15.9	16.08	16.01
pH	7.57	7.96	7.7
Conducibilità [mS]	27.44	35.1	30.37
Ossigeno Disciolto [%air]	88.26	99.43	92.27
Torbidità [NTU]	3	9.5	5.07
Altezza Onda [cm]	0	0	0
Periodo Onda [s/onda]	0	0	0

- **Successful Mission Execution:** MoBI successfully navigated the predefined multi-point course, collecting georeferenced data at each target.
- **Data Integrity & Exception Handling:** The system recorded consistent environmental data and automatically filtered invalid readings, such as the negative turbidity value shown here.
- **End-to-End Data Pipeline Confirmed:** All collected data, from both the probe and wave sensors, was successfully transmitted, processed, and visualized.

Conclusions & Future Developments

System Achievements

- Reliable, flexible platform for marine environmental monitoring
- Effective dual-processor architecture with integrated sensor suite
- Robust data acquisition and transmission under varying conditions
- Successful integration with backend visualization systems
- Practical modular design facilitating field deployment and maintenance

Future Developments

- Improved power management for extended deployment
- Enhanced wave analysis under challenging conditions
- Support for additional sensor protocols
- Automated long-term mission handling
- Native integration with cloud platforms for real-time alerts

MoBI represents a significant advancement in the automation of environmental monitoring, combining technological reliability with operational practicality for real-world coastal deployments.

Thank You

Questions?

We appreciate your time and interest in the MoBI Smart Buoy System.