# Smart Maritime Monitoring System for Combating Illegal Fishing Using Autonomous Buoy Network


**Developed by: Daapes**

**Student Branch: IEEE FST SB**



**Date: April 2025**


Faculty of Science of Tunis
IEEE STUDENT BRANCH


This report presents the design and implementation of a smart surveillance system aimed at detecting and reporting illegal fishing activities. The solution combines decentralized edge-based detection—carried out by intelligent buoys—with centralized communication and reporting via a master node. Leveraging AI-based object detection, sensor-triggered camera activation, LoRa mesh networking, and GSM/MQTT communication protocols, the system ensures real-time monitoring, energy efficiency, and reliable data reporting. Each section of the report explores a key technological component in detail, offering insights into the hardware architecture, software design, and communication strategies used.

# Table of contents

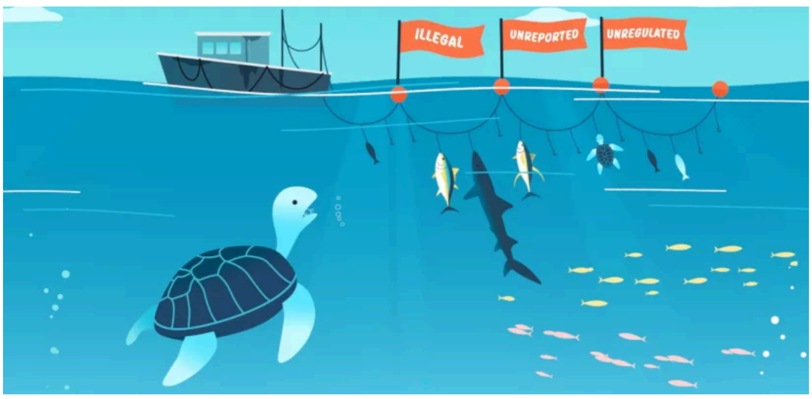
The following table of contents outlines the structure of this report, guiding the reader through each component of the system. Before each main section, a brief introductory explanation is provided to give context and clarify the purpose of the content that follows. This approach ensures a smooth and coherent understanding of the technologies, methodologies, and design choices that underpin our solution.

# Problem Statement

Tunisia's coastal and marine ecosystems are facing an escalating crisis driven by destructive and unregulated fishing practices. Among the most pressing concerns is the degradation of vital marine habitats, particularly the *Posidonia oceanica* seagrass meadows—an ecological treasure known for its ability to capture carbon, stabilize the seabed, and nurture marine biodiversity. These habitats are being systematically destroyed by illegal fishing methods that exploit both natural resources and legal loopholes.

Despite the existence of national and international regulations, enforcement remains alarmingly insufficient. Local practices like "kiss trawling," an illicit form of bottom trawling, have been openly documented in the Gulf of Gabès, causing extensive damage to protected seagrass beds and marine life. At the same time, foreign vessels continue to operate with impunity, deploying illegal driftnets that trap not only commercial fish species but also endangered marine animals. These practices result in high bycatch rates, destabilize fish populations, and disrupt the entire marine food web.

The consequences extend far beyond ecological damage. Traditional artisanal fishing communities guardians of sustainable, low-impact techniques like *charfia* fishing are being pushed to the brink. With declining fish stocks and mounting economic pressure, many local fishers find themselves either marginalized or compelled to adopt harmful practices to survive. This dynamic poses a dual threat: the collapse of a fragile marine ecosystem and the erosion of cultural and economic heritage tied to the sea.



# Objectives

This initiative seeks to design and implement a holistic, intelligent solution that enables the sustainable management and protection of Tunisia's marine zones. The system must leverage advanced technologies to monitor, detect, and deter illegal fishing activity while being accessible, scalable, and energy-efficient.

Key objectives include:

- **Real-time surveillance** of vulnerable marine areas using a network of satellite ,acoustic, and underwater sensors.

- **Early detection and alerting** of illegal activities through AI-driven data analysis, enabling rapid response from enforcement authorities.

- **Autonomous and low-energy operation**, ensuring long-term deployment in remote or resource-constrained regions without the need for constant maintenance.

- **Integration of diverse sensing and communication technologies** to build a cohesive, adaptable monitoring system that remains effective in varying environmental and operational contexts.

- **Support for regulation and community resilience** by providing actionable insights to policymakers and promoting the revival of traditional, sustainable fishing practices.

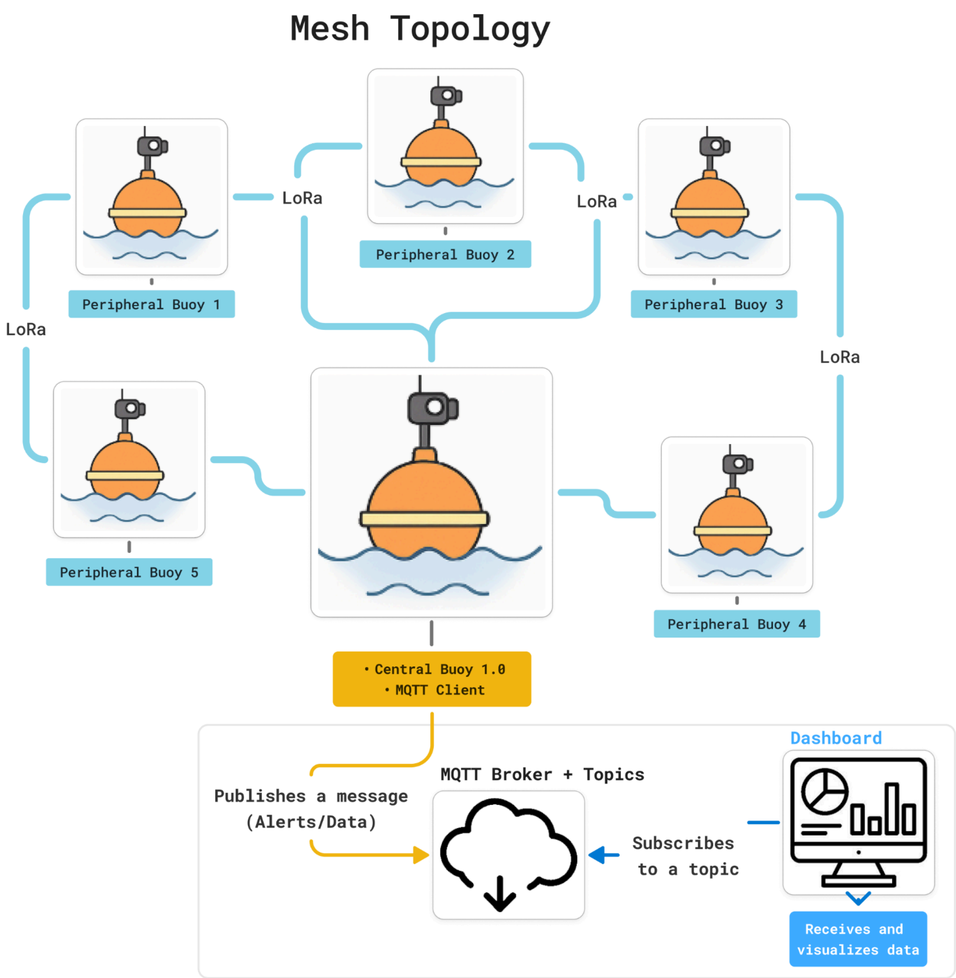
By combining innovation with ecological stewardship, this solution aims to not only combat illegal fishing but also reinforce Tunisia's commitment to marine conservation, economic justice, and cultural preservation.

# System Architecture

**This section Presents a comprehensive visual and technical overview of the solution**

Our solution as a smart buoy network represents a novel, real-time, low-cost solution to monitor and report illegal fishing, supporting ocean conservation, law enforcement, and sustainable fishing. By combining embedded hardware, wireless communication, and smart sensing, it offers a robust tool to safeguard marine biodiversity and national maritime interests.

**This is an explanatory diagram of the architecture of our solution :**



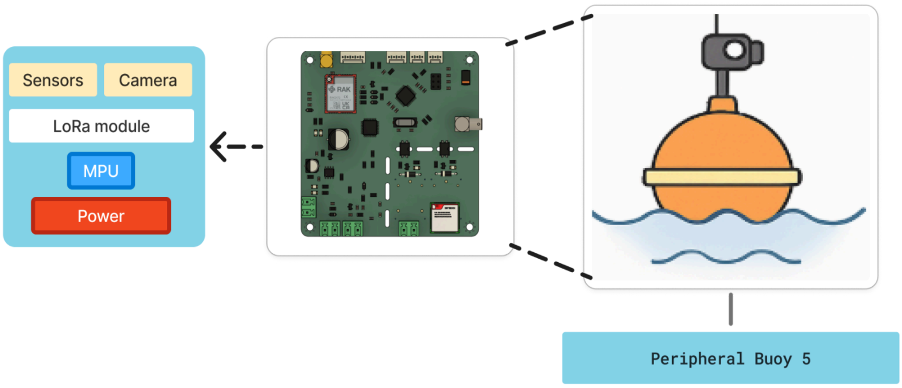

This system employs a **mesh topology** where multiple peripheral buoys communicate locally via **LoRa**, sending data to a **central buoy**. The central node acts as an **MQTT**

**client**, forwarding alerts and violation data over **GSM** to a cloud-based **MQTT broker**. The **dashboard**, acting as a subscriber, receives and visualizes this data in real-time.

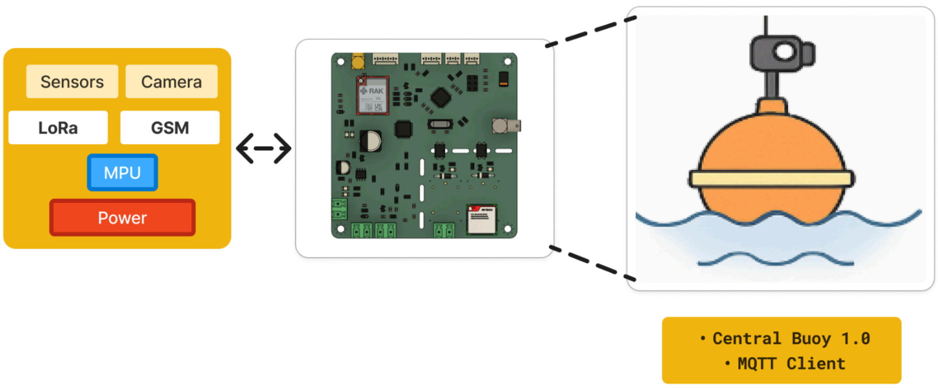
Each component—including sensors, cameras, communication protocols, and power management—will be explored in detail in the following sections.

The surveillance system is composed of two main types of nodes: **Peripheral Buoys** and a **Central Buoy**.

- **Peripheral buoys** are equipped with sensors and cameras for local detection of illegal activities. These buoys operate autonomously, analyzing their surroundings and transmitting relevant alerts.




- **Central Buoy** serves as the core communication hub, collecting data from all peripheral nodes and forwarding it to a cloud server via GSM.



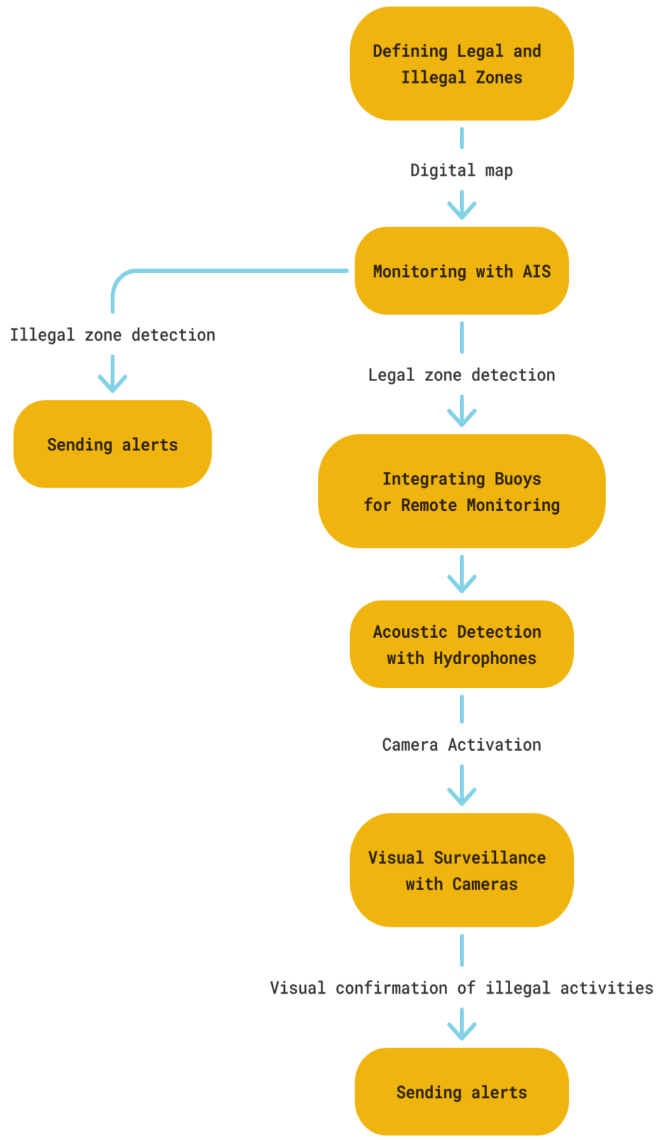

→ Together, they form a robust and scalable architecture designed for efficient, real-time marine monitoring.

# Methodology

**This section Describes the step-by-step process of how the system functions in practice—from environmental sensing to detection, decision-making, alert generation, and data reporting. It provides a clear operational flow.**

**Explanatory sequential diagram of the architecture of our proposed :**

**1. Defining Legal and Illegal Zones:**




**Objective:** Create a clear map that distinguishes between legal fishing zones and illegal fishing zones.

**Approach:**

- Satellite Imagery: High-resolution satellite images from providers such as Sentinel Hub and Google Earth Engine were analyzed. These images helped identify coastal zones and marine protected areas (MPAs) along the Tunisian coast.

- Regulatory Data: The data on fishing regulations was obtained from Tunisian maritime authorities to further refine the zones.

**Outcome:**
A digital map containing clearly defined legal and illegal fishing zones was created.

**2. Monitoring with AIS and Identifying Violations:**

**Objective:** Monitor vessel positions using AIS and detect when vessels enter restricted zones.

**Approach:**

- AIS Data Collection: Real-time AIS data from satellite and shore-based stations were gathered to track the movement of vessels along the coast.

- Geofencing: The legal and illegal zones were mapped into geofences using the previously created digital map. Each AIS point (vessel's position) was checked to determine if it entered an illegal zone.

- AIS Gap Detection: If a vessel turned off its AIS signal, the system was configured to flag this event, as vessels often disable AIS to avoid detection while engaging in illegal fishing.

**Outcome:**
The system was able to detect violations by matching the vessel's position against the geofenced zones, triggering alerts if any vessel entered an illegal zone or turned off its AIS.

**3. Integration of Buoys for Remote Monitoring:**

**Objective:** Extend the monitoring coverage into remote areas where infrastructure is limited, ensuring no area is left uncovered.

**Approach:**

- Buoy Deployment: Buoys equipped with hydrophones, and cameras were strategically deployed in areas without existing infrastructure.

- Data Transmission (LoRa Network): The buoys are equipped with LoRa (Long Range) communication technology to communicate with each other and form a mesh network. This allows the buoys to relay data between one another, extending the communication range.

- Centralized Buoy (MQTT Hub): One buoy, typically located in a region with better communication coverage (closer to shore or near a lighthouse), is designated as the centralized buoy. This buoy aggregates data from all surrounding buoys and sends the information to a central server via MQTT protocol, a lightweight, efficient communication protocol ideal for IoT systems.

**Outcome:**
The buoy network enabled real-time data sharing between buoys even in remote areas, allowing data to be transmitted to the central server efficiently and minimizing the need for each buoy to have direct internet access.

**4. Acoustic Detection with Hydrophones:**

**Objective**: Detect suspicious underwater activity such as trawling using hydrophones and trigger camera activation only when needed to save energy.

**Approach:**

- Hydrophone Installation: Hydrophones were installed on the buoys to continuously monitor underwater sounds, such as the engine noise of trawlers, winch operations, or net deployment.

- Acoustic Pattern Recognition: The hydrophone system was equipped with onboard signal processing algorithms to identify the unique acoustic patterns of illegal fishing activities.

- Camera Activation: When suspicious sounds (trawling winches) were detected, the hydrophone would automatically trigger the cameras to start recording or streaming live footage.

**Outcome:**
The use of hydrophones ensured that the cameras were only activated when necessary, saving energy and reducing data transmission, while still providing real-time evidence of illegal activities.

**5. Visual Surveillance with Cameras:**

**Objective:** Visually confirm illegal fishing activities, such as trawling, and provide clear evidence.

**Approach:**

- Camera Selection: A combination of thermal cameras for nighttime and low-visibility conditions, and PTZ (Pan-Tilt-Zoom) cameras for tracking vessels, were used. High-definition optical cameras were installed to capture clear images of vessels and fishing methods.

- Camera Deployment: Cameras were mounted on buoys or existing infrastructure such as lighthouses and AtoN. The cameras were able to capture real-time footage and provide visual confirmation of suspicious activities.

- Data Integration: The camera system worked in tandem with the AIS data and hydrophone detection to ensure comprehensive monitoring. When a violation was detected, both video evidence and AIS vessel details were sent to the central server.

**Outcome:**

The camera system provided visual confirmation of illegal activities, helping authorities to identify perpetrators and take appropriate action.

# Concept Overview

**This section presents the architectural concept of the system, which relies on a distributed network of intelligent buoys performing local detection, and a central node aggregating and reporting critical data.**

### Decentralized Detection + Centralized Reporting

The system is built around a distributed network of intelligent **peripheral buoys** that perform localized detection, and a **central buoy** that aggregates and relays critical alerts. Each peripheral node is equipped with underwater sensors and a camera, controlled by an STM32MP257 microcontroller. Cameras are only activated when environmental sensors (motion, vibration, or acoustic anomalies) are triggered—saving power and extending system lifespan.

Once triggered, video feeds are processed in real-time using lightweight AI models (e.g., YOLOv8 via TinyML) to identify suspicious activity such as unauthorized boats or harmful fishing gear. If a violation is confirmed, cropped images with unique identifiers are saved, and alert metadata is transmitted via LoRa to the central buoy.

The **central buoy**, acting as an MQTT client, uses GSM to forward alerts to a cloud-based platform or authority dashboard for visualization and documentation. This hybrid edge-cloud approach balances fast, low-power local detection with centralized monitoring and long-term scalability.

### System Architecture

#### Input Stage: Sensor-Triggered Surveillance

Cameras remain off by default and only activate upon sensor detection, ensuring energy efficiency and reducing hardware wear. Once active, each camera runs a dedicated script for frame-by-frame analysis.

#### Processing Stage: Intelligent Detection

1. **Real-Time Object Recognition:**
   YOLOv8, fine-tuned on a custom dataset, detects and classifies illegal activities in video frames.

2. **Detection Logic and Evidence Capture:**

   - Draws bounding boxes on detected objects.
   - Limits image storage to 4 unique captures per event.
   - Saves cropped images with randomized filenames for traceability.

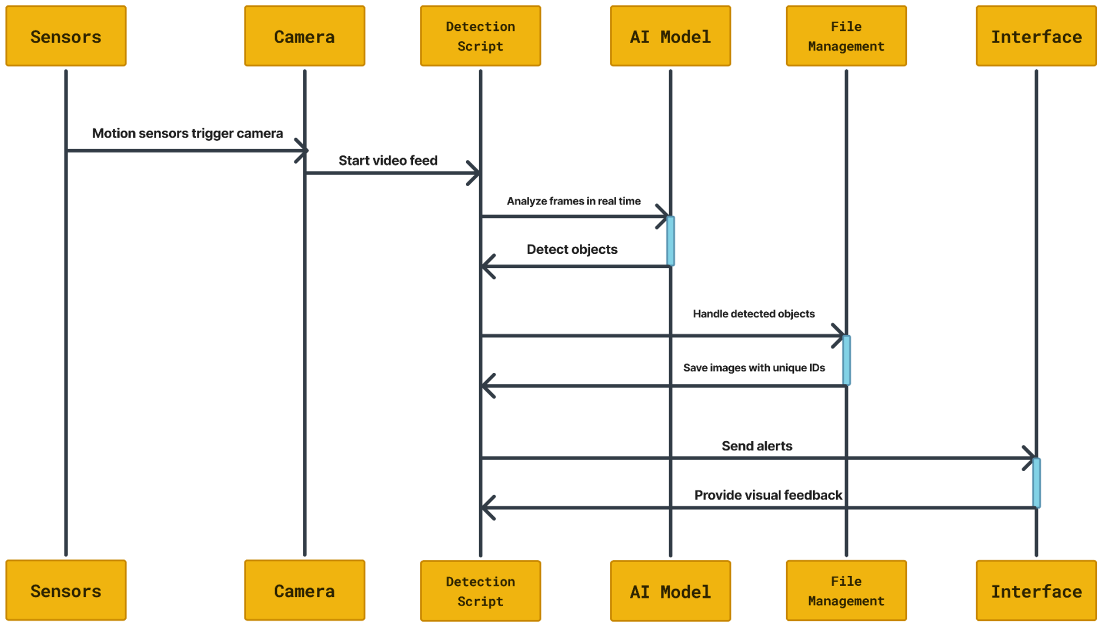
3. **File Organization:**

   - Stores images in labeled directories (e.g., boat_detected/) for easy access and reporting.

## Output Stage: Alert Generation & Visualization

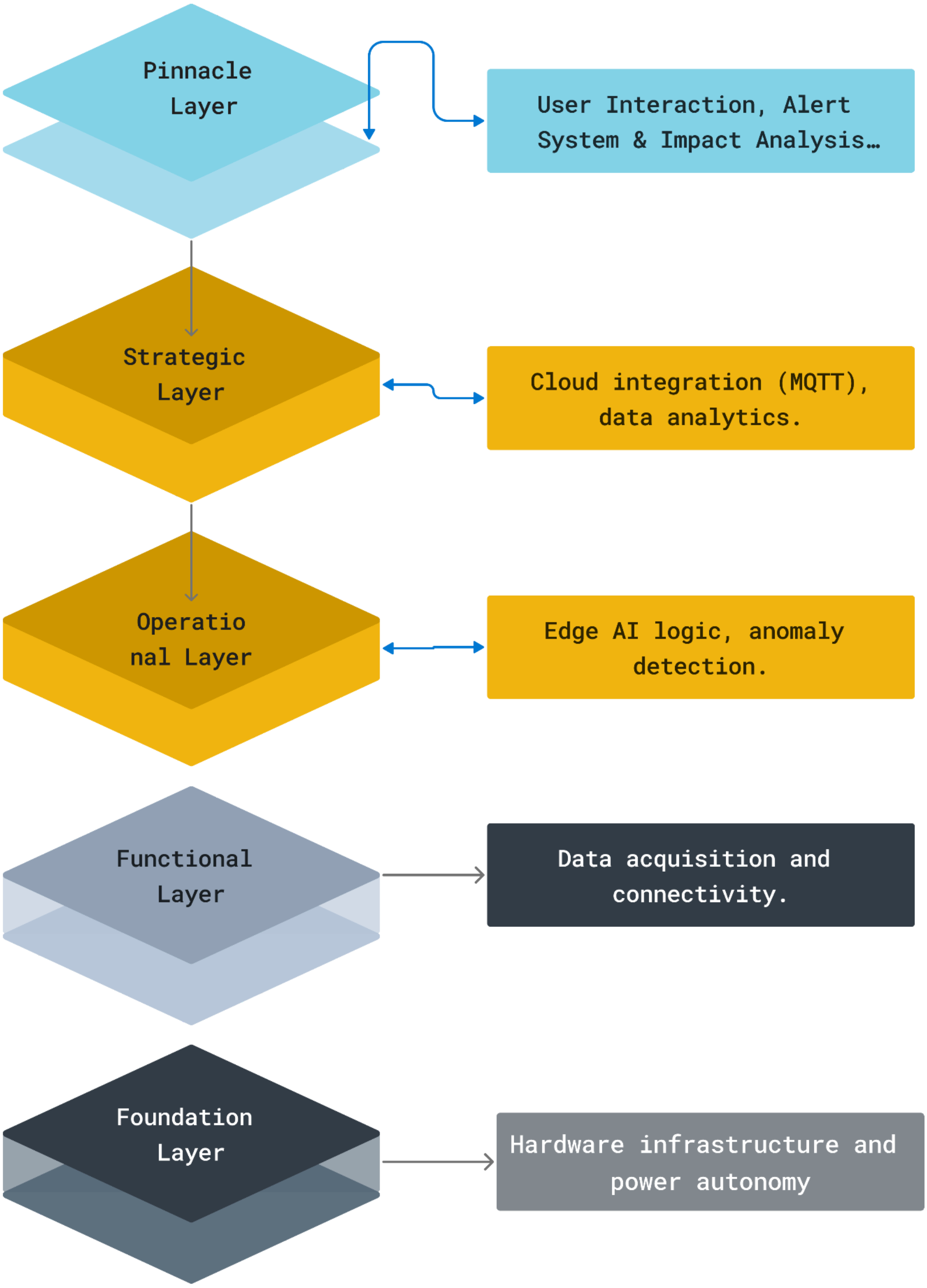
- **Saved Violation Records:** Cropped evidence is stored locally with clear metadata.
- **Dashboard Feedback:** Real-time GUI alerts and blinking status indicators inform operators of detected violations.

The following diagram illustrates the system architecture of the Decentralized Detection + Centralized Reporting model, detailing how peripheral buoys detect events locally and transmit critical data to the central node for reporting and visualization :



# Technology stack

**This section details the hardware and software components that form the backbone of the proposed solution. The system is designed to be robust, low-power, and autonomous, with edge intelligence and multi-modal communication.**



## Foundation Layer :Hardware Backbone: Electronics + Energy Autonomy

This layer forms the **physical infrastructure** of each buoy device, supporting all sensing, computing, and communication capabilities. It addresses the mechanical, electrical, and energy challenges of deploying smart devices in **harsh marine environments**.

**Microprocessor Unit (MPU) :** At the heart of the system lies the **STM32MP257 MPU**, selected for its unique dual-core architecture combining :

- **Cortex-A35**: for Linux-based edge processing, AI inference, and MQTT client stack.
- **Cortex-M33**: for real-time control of sensors and communication interfaces (UART, SPI, I2C).
- Integrated hardware features like **ADC, camera interface (DCMI), SPI/I2C/UART**, and **secure boot** make it suitable for edge deployment.

**Custom designed PCB :** With EMI shielding and marine-grade connectors. It Integrates the STM32MP257 MPU, communication modules (LoRa, GSM), sensor interfaces, and power management circuitry into a compact, multi-layer board engineered for durability, low power consumption, and seamless operation in marine environments.

**Power Management system :**

Each buoy operates autonomously using:

- **Solar panels** (5–10W) to recharge
- **Lithium-ion batteries (3.7V/6600mAh+)** for night and cloudy conditions
- **MPPT charge controller** to maximize solar input
- **Low-power design strategy** (deep sleep, sensor polling, LoRa scheduling)

**Communication Base**: LoRa (RAK3172) and GSM (SIM7600/BG95) modules.

**Ruggedization and Deployment :** The device is enclosed in a marine-grade plastic to ensure durability.

## <u>Functional layer</u> : Data acquisition and connectivity.

The Functional Layer serves as the **input-output gateway** between the physical ocean environment and the intelligent layers above it. It ensures:

- Real-time detection and location-based context
- Reliable, secure, and scalable communication
- Minimal energy consumption through smart sensor polling and efficient data routing

It presentes primary **functional capabilities** of each deployed buoy, namely **environmental sensing**, **position tracking**, and **inter-device communication**.

It acts as the nervous system of the network — gathering critical field data and ensuring its flow across nodes for situational awareness and decision-making.

- **Sensors**:
  - Hydrophone (Aquarian Audio H2a/H1a) for noise detection.
  - Doppler sonar/ADCP for underwater movement tracking.
  - Turbidity (TSD-10), for measuring water clarity and sediment concentration therefore Detects destructive bottom trawling
  - GPS (Neo-6M),Acquires real-time location of the buoy and Validates presence in restricted areas
  - temperature (DS18B20),Detects abnormal thermal variations in marine habitat and Supports environmental trend tracking
- **Camera : OV2640 or ArduCam Mini** Used for real-time image capture when suspicious activity is detected.
- **Communication Protocols**:
  - LoRa **(e.g., RAK3172)(** UART or SPI connected to Cortex-M33) **:enables long-range, low-power communication between distributed buoys, forming a mesh network to relay alerts and sensor data efficiently across the sea.**
  - GSM **(e.g., SIM7600 or BG95) (**UART to Cortex-A35 running Linux) for central buoy-to-cloud MQTT **transmits critical events to cloud servers or authorities in real time using the MQTT protocol.**

## Operational Layer :

This layer is the brain of each buoy, responsible for **processing data locally**, identifying critical events, and triggering real-time actions like activating the camera, raising alerts, or logging events. It enables **smart, responsive behavior without relying on constant connectivity**.

Technology involved are :

- Edge AI Logic : At the core of the operational layer lies an AI **Model-based decision engine**, deployed directly on the STM32MP257's Cortex-A35 core.
- Event Trigger System : A **multi-sensor fusion algorithm** (movement, sound, turbidity) to detect anomalies, based on thresholds or learned patterns

→ The model is **trained offline and deployed** via firmware updates over LoRa or GSM.It is later on updated using OTA ( over -the-air).

## Strategic Layer :

Ensures that critical data collected and processed at the edge is **transmitted to the cloud** for **centralized monitoring, storage, and analysis**. It uses the **MQTT protocol** over GSM for lightweight, real-time messaging between the main buoy (central node) and remote cloud servers.

It enables :

- **Real-time alerts** to be sent to responsible authorities.
- **Data aggregation** for long-term insights and trend analysis.
- **Remote updates and configuration** of the buoys if needed.

## Pinnacle Layer

**User Interaction, Alert System & Impact Analysis**

The Pinnacle Layer represents the **user-facing**. It transforms processed data and cloud insights into **actionable outcomes** for stakeholders such as coast guards, marine conservation agencies, and policy makers.

It doesn't just detect — it **acts**. It empowers humans with clarity, speed, and actionable insights to **enforce marine laws**, **preserve biodiversity**, and **measure environmental recovery** over time.

# Communication & Data Flow:

**This section explains how buoys communicate using LoRa in a mesh network to share sensor data and alerts. A central Central Node collects these messages and sends them to the cloud via GSM using the MQTT protocol. Alerts are organized into structured topics (e.g., /alerts/zone1/boat_detected) for clarity, with optional integration into a dashboard for real-time monitoring.**

The success of the proposed buoy-based surveillance system depends significantly on the **efficiency**, **reliability** and **energy-conscious design** of the communication and data transmission mechanisms. To achieve this, the system adopts a hybrid approach combining **LoRa-based inter-node communication**, **a GSM-enabled Central Node for external communication** and **MQTT for structured message delivery** to a centralized server or dashboard.

This architecture is tailored to function in **offshore and low-connectivity environments**, while ensuring **real-time data delivery**, **geospatial tagging**, and **low power consumption** to support long-term autonomous operations.

## 1. LoRa-Based Event Routing Between Buoys:

The foundation of the intra-buoy communication system is a **LoRa (Long Range) network**. LoRa provides:

- Long-range communication (2–15 km depending on terrain and antenna)
- Low power consumption
- Compatibility with various topologies (star, mesh, hybrid).

### 1.1 Event Generation and Transmission:

Each buoy node continuously monitors its environment using onboard sensors ( hydrophones, turbidity sensors, etc...). When an anomaly is detected:

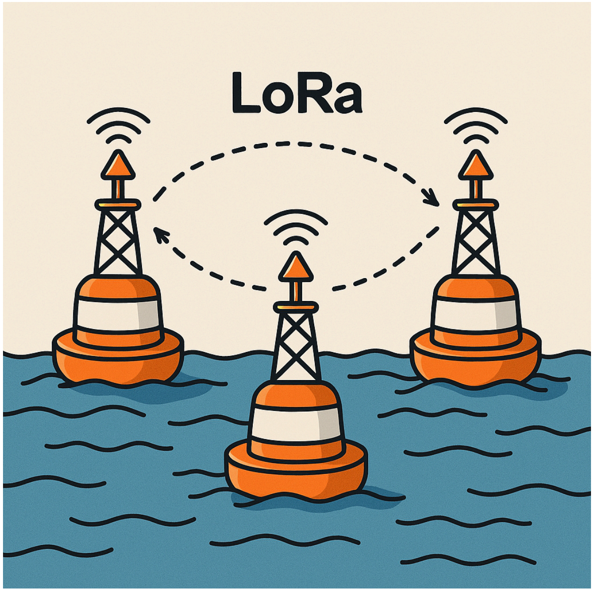
- The microcontroller activates the camera and processes preliminary sensor and image data.

- An **event packet** is assembled, containing:
  timestamp,
  buoy ID,
  GPS coordinates,
  event classification (boat detected, trawling suspected)

This packet is transmitted over **LoRa** to neighboring nodes or directly to the Central Node.

**1.2 Mesh Topology:**

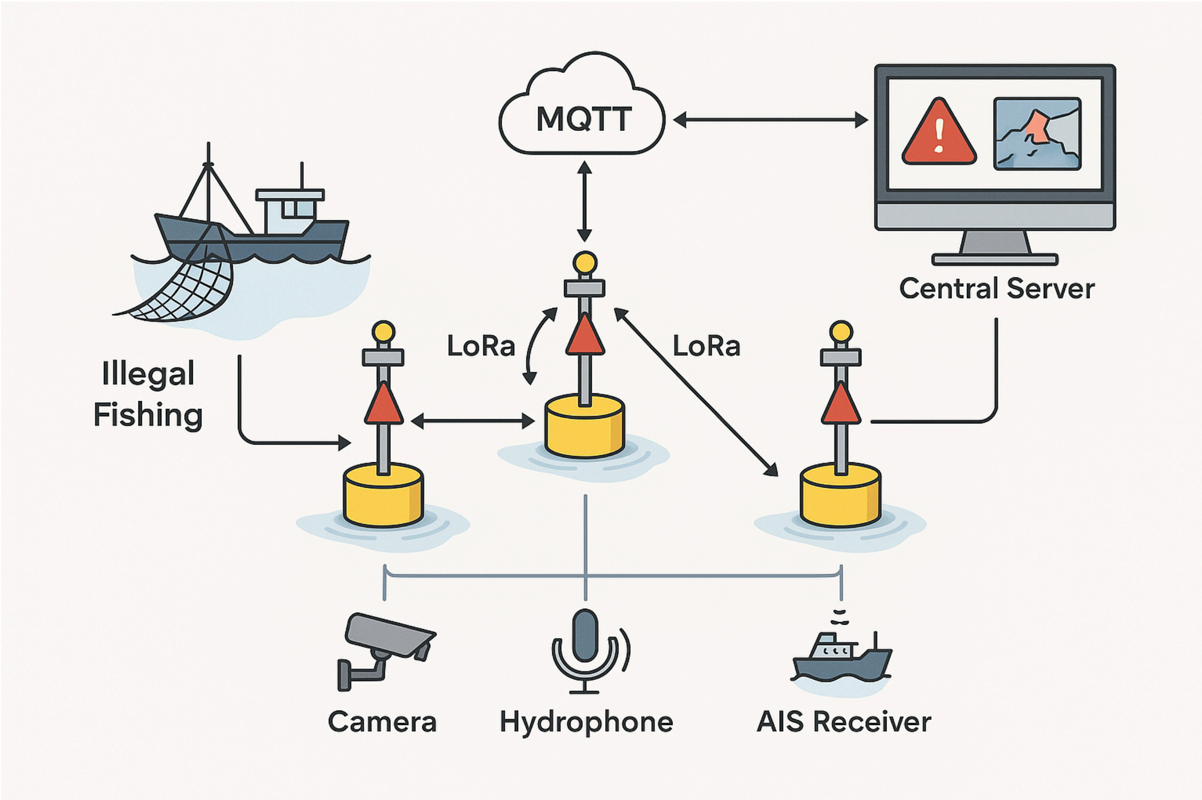
The communication network is configured as:




**Mesh topology**: Intermediate buoys relay messages from distant nodes, extending coverage over wide marine zones.
In this configuration, each buoy not only monitors its own environment but also acts as a relay node, capable of forwarding messages from other buoys toward the central Central Node. This decentralized approach allows data packets to hop between multiple buoys until they reach the Central Node, even when the source buoy is outside its direct transmission range.

This significantly extends the overall communication coverage and enhances network reliability, particularly in harsh or variable ocean conditions where direct line-of-sight communication is not guaranteed. The mesh topology also improves resilience; if a buoy becomes unreachable or fails, the data can be rerouted through alternate paths, ensuring continuous operation without a single point of failure.

### 2. Central Node as the Communication Gateway:




The **Central Node** serves as the **central gateway** between the offshore buoy network and the onshore data processing and alert system. It is equipped with:

- A **LoRa transceiver**, to receive alerts from surrounding buoys.
- A **GSM module** , providing cellular connectivity to the Internet.
- An **MPU** to manage data buffering, format conversion and transmission.

Once an event packet is received via LoRa:

1. The Central Node validates and parses the data.
2. If media is included, it may store it locally or upload it to cloud storage (depending on bandwidth).
3. It then transmits the metadata and any media references using the **MQTT protocol** to an MQTT broker (hosted in the cloud or local server).

The Central Node also serves as the **intelligence center**, optionally running lightweight machine learning models or image classification algorithms to assist in confirming and prioritizing alerts before transmission.

→ To optimize both **power efficiency** and **connectivity reliability**, the **GSM module is integrated exclusively into the Central Node**, which is positioned closest to the shoreline.

GSM-based communication relies on terrestrial cellular towers, which typically **do not provide coverage in deep-sea or offshore areas**. Instead, our system leverages **LoRa mesh networking**, allowing all buoys to communicate and relay data amongst themselves until it reaches the Central Node. Once an event packet arrives at the Central Node, it uses its GSM module to **forward the alert via MQTT** to a cloud server or monitoring center on land. This hybrid architecture ensures **long-range coverage**, **energy efficiency**, and **cost-effective scalability**, especially in remote marine zones where infrastructure is limited or absent.

### 3. MQTT Topic Structure and Message Handling:

MQTT (Message Queuing Telemetry Transport) is a publish-subscribe messaging protocol designed for constrained environments. It is ideal for this application due to its:

- Low overhead,
- Support for **QoS (Quality of Service)** levels,
- Persistent sessions, and
- Efficient bandwidth usage.

#### 3.1 Topic Hierarchy Design

The MQTT topics are structured to allow flexible filtering and subscriptions by region, buoy ID, and event type. A hierarchical topic naming convention enables scalable management.

***Sample Topics:***

**fishing-alerts/capbon/buoy-04/fishing-boat-detected**

fishing-alerts/khalij_gabes/buoy-12/suspected-trawling

fishing-alerts/skanes/buoy-01/high-activity

***MQTT Payload (Example in JSON):***


```
{
 "timestamp": "2025-04-13T15:22:00",

 "buoy_id": "buoy-04",

 "location": {"lat": x,"lon": y },

 "event_type": "suspected-trawling",
 }
```


**3.2 MQTT Broker**

- Clients (Dashboard/Monitor center in our case) subscribe to relevant topics to receive real-time updates.

Once the **Central Node** receives an alert from other peripheral buoys via LoRa, it uses the **GSM module** to transmit the data to land. This is done using the **MQTT protocol**, a lightweight messaging system designed for IoT.

**How MQTT Works:**

- The Central Node acts as an MQTT **publisher**.
  It connects to a cloud-based **MQTT broker** (a central server that handles messages).
- The event data is sent (or **"published"**) to a specific **topic**, such as: /skanes/alerts/buoy-3

Onshore systems (monitoring centers) act as **subscribers**. They **listen** to that topic and instantly receive any message published to it.
A **dashboard** is used for **real-time visualization and management** of the alert/ data in the received message.

**Key Features:**

- **Live Map Interface**: Buoy locations displayed on a marine map.
- **Event Feed**: Real-time feed of alerts, filterable by type, region or time.

- **Media Viewer**: Preview images linked to specific alerts.
- **Health Monitoring**: Battery level, signal strength and stats of each buoy.
- **User Notifications**: Authorities can receive push notifications or SMS alerts for high-priority events.

# Alignment with UN Sustainable Development Goals (SDGs)

### SDG 7: Affordable and Clean Energy

- Target 7.3: "*Double the global rate of improvement in energy efficiency...*"
  ➢ Energy-saving strategies like activating cameras only when hydrophones detect illegal activity align with this goal.

### SDG 9: Industry, Innovation and Infrastructure

- Target 9.5: "*Enhance scientific research and upgrade technological capabilities...*"
  ➢ The project uses IoT (buoys, LoRa, MQTT), AIS, and satellite-based innovation to improve marine surveillance.

### SDG 13: Climate Action

- Target 13.1: "*Strengthen resilience and adaptive capacity to climate-related hazards...*"
  ➢ By preserving marine ecosystems and fish populations, your project helps maintain oceanic carbon sinks, which are essential for climate regulation.

- Target 13.2: "*Integrate climate change measures into national policies...*"
  ➢ Surveillance and data collected from your system can inform policy-making to better regulate marine activity and support climate-smart fisheries management.

- Target 13.3: "*Improve education, awareness-raising and human and institutional capacity...*"
  ➢ The system fosters awareness and capacity-building in marine conservation through technology and monitoring.

### SDG 14: Life Below Water

- Target 14.4: "*By 2020, effectively regulate harvesting and end overfishing...*"
  ➤ Your system helps detect illegal fishing methods like trawling and supports enforcement of fishing regulations.

- Target 14.2: "*Sustainably manage and protect marine and coastal ecosystems...*"
  ➤ Monitoring activities preserve marine biodiversity and ecosystems.

### SDG 16: Peace, Justice and Strong Institutions

- Target 16.6: "*Develop effective, accountable and transparent institutions...*"
  ➤ Your system enhances transparency in maritime activities and supports maritime law enforcement.

- Target 16.10: "*Ensure public access to information...*"
  ➤ With visual and data-based evidence, the project supports accountability in fishing practices.

# Challenges & Risk Mitigation

1. Harsh Marine Conditions
   ➤ Risk of corrosion and physical damage.
   ✔ Use marine-grade materials and stable buoy designs.

2. Power Constraints
   ➤ Cameras and sensors consume energy.
   ✔ Use solar panels and activate cameras only when hydrophones detect activity.

3. Data Transmission
   ➤ Offshore areas lack strong communication infrastructure.
   ✔ Use LoRa between buoys and transmit to shore via MQTT (cellular/satellite).

4. AIS Deactivation by Vessels
   ➤ Some boats may turn off AIS to avoid detection.
   ✔ Apply AIS gap detection and combine it with camera or hydrophone data.

5. Lack of Infrastructure
   ➤ Some zones have no existing supports.
   ✔ Identify coverage gaps and install additional low-cost buoys where needed.

6. Regulatory & Operational Barriers
   ➤ Deployment may require legal permissions.
   ✔ Work with local authorities and ensure compliance.

# Future Work & Scalability

**Wider Area Coverage**

➢ Expand buoy deployment to cover more coastal zones and deeper waters, especially high-risk areas.

**Community Involvement**

➢ Train local fishermen and authorities to use and maintain the system, encouraging collaboration and awareness.

**International Data Sharing & Cooperation**

➢ Connect with regional partners to exchange illegal fishing data and coordinate surveillance efforts.

**Modular System Upgrades**

➢ Design the system to allow easy hardware and software upgrades.

# Executive summary

Illegal, Unreported and Unregulated (IUU) fishing is a critical global issue that threatens marine biodiversity, disrupts coastal economies, and undermines legal fishing efforts. In response, we propose a **real-time, autonomous surveillance system** based on a distributed network of smart buoys to monitor and report suspicious fishing activities in remote marine zones.

Each buoy is equipped with **underwater sensors**, **camera module**, a **microcontroller**, **GPS** and a **LoRa transceiver**. These buoys detect anomalies such as unusual boat activity, capture relevant visual data and communicate with one another through a **LoRa mesh network**. When an event is detected, the alert is routed through the mesh to a strategically placed **Central Node** located near the coast.

The Central Node, equipped with a **GSM module**, transmits alerts to a cloud server using the **MQTT protocol**, allowing for real-time notification to the monitoring center. The system is powered by **solar energy and batteries**, enabling long-term, autonomous operation with minimal maintenance.

This solution offers a **cost-effective**, **low-power** and **scalable approach** to protecting marine environments, even in areas lacking internet or cellular coverage. It ensures fast detection, reliable communication and timely reporting, making it a powerful tool against illegal fishing activities.