Boatnet Border Alert System for Fishermen: Enhancing Maritime Safety and Legal Compliance

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***Abstract*— The Boatnet Border Alert System is an innovative solution designed to enhance maritime safety and promote legal compliance for fishermen operating in coastal and border regions. The system utilizes advanced GPS, communication technologies, and real-time monitoring to provide alerts and guidance to fishermen on their proximity to national borders, restricted zones, and protected maritime areas. By offering early warnings about crossing into illegal fishing zones or approaching maritime boundaries, the Boatnet system aims to reduce unintentional violations of fishing regulations, prevent illegal activities, and ensure the safety of fishermen operating in hazardous or unfamiliar waters. Ultimately, Boatnet enhances maritime governance, minimizes the risks of accidents or fines, and supports sustainable fishing practices in compliance with national and international laws. The system is also integrated with local maritime authorities for rapid intervention when necessary, facilitating a collaborative approach to resource management. To evaluate the system's effectiveness, factors such as Accuracy (A), Speed (S), Coverage (C), Cost Efficiency (E), and User Adoption (U) are rated on a 0-10 scale. The overall score (S) is calculated and the results are shown in the graph.**

Keyword: Maritime Safety; Border Alert System; Cost Efficiency; System Performance; Data Integration

1. INTRODUCTION

Fishermen around the world face unique challenges at sea, especially when fishing near national borders. These challenges include the risk of violating maritime boundaries, encountering hostile environments, and engaging in illegal fishing activities [1]. Territorial disputes and unclear fishing zones often result in unintentional violations of international maritime law, causing conflicts, fines, and loss of livelihood for fishermen.

Many fishermen in Oman rely on maritime activities for their livelihoods because of the country's extensive and strategically located coastline along the Arabian Sea and the Gulf of Oman. However, there are difficulties because of the closeness to international marine borders with nations like Iran, Pakistan, and the UAE. Unintentional border crossings can have major repercussions, such as diplomatic problems, arrest, and boat confiscation [2]. A Border Alert System for Fishermen is necessary to handle this.

In order to detect fishing boats and send out immediate notifications when they approach or pose a risk of crossing international maritime borders, this system makes use of GPS technology, real-time vessel tracking, and geo-fencing. The objectives are to promote Oman's border security measures, safeguard fishermen's rights, and improve maritime safety. By putting in place such a mechanism, Oman can guarantee. In order to detect fishing boats and send out immediate notifications when they approach or pose a risk of crossing international maritime borders, this system makes use of GPS technology, real-time vessel tracking, and geo-fencing [3]. Enhancing maritime safety, defending the rights of fishermen, and assisting Oman's border security measures are the objectives. Oman can protect its fishing communities and uphold international maritime norms by putting such a mechanism into place.

To address these challenges, the Boatnet Border Alert System offers a solution to improve safety, reduce territorial violations, and ensure sustainable fishing practices. This system uses advanced technology to monitor the positions of fishing vessels, alerting fishermen when they approach or cross into restricted zones [4]. The goal is to create a more secure and compliant fishing environment for both local fishermen and law enforcement agencies. This paper will explore

978-9950-8599-0-6

the Boatnet Border Alert System, focusing on its design, implementation, challenges, and potential

benefits for the fishing industry. Following table 1.shows the Feature-wise Comparison of Modern and Traditional Maritime Safety Systems.

TABLE 1. FEATURE-WISE COMPARISON OF MODERN AND TRADITIONAL MARITIME SAFETY SYSTEMS

Feature	Boatnet Border Alert System	Automatic Identification System (AIS)	Vessel Monitoring System (VMS)	Manual Border Monitoring (Traditional Patrols)
Technology	GPS, Geofencing, Satellite, Mobile App	AIS transponder, satellite communication	Satellite-based vessel tracking	Radar, physical patrols, manual reporting
Connectivity	Satellite or mobile network (works in remote areas)	Requires AIS transponder; limited to areas with AIS infrastructure	Satellite communication, limited in remote areas	Relies on physical presence or radio communications
Geofencing /Boundary	Yes, virtual boundaries set for specific zones (e.g., protected areas, maritime borders)	No direct geofencing, general tracking of vessel location	No direct geofencing, typically focused on vessel movement monitoring	No virtual boundaries, requires physical patrols
User Training and Support	Simple mobile app with user-friendly interface, training required for fishermen	Commercial fleets typically have crew trained on AIS usage	Commercial fleets require training, often integrated into fleet management	Requires personnel for training and ongoing monitoring
Target User	Small-scale and artisanal fishermen	Commercial vessels and large fleets	Commercial vessels and large fleets	All types of vessels (large and small)
Real-Time Alerts	Yes, immediate alerts for crossing boundaries or approaching restricted zones	No direct alerts, but monitoring is done by authorities	Yes, but typically limited to commercial vessels	No real-time alerts, typically delayed information
Cost of Installation	Relatively low cost for fishermen, with a focus on affordability and accessibility	High cost for commercial vessels (expensive transponder and installation)	High, mainly used by commercial vessels, government agencies	High, as it involves manpower, equipment, and fuel costs

II. LITERATURE REVIEW

Several existing technologies aim to monitor maritime activity, including Automatic Identification Systems (AIS), Vessel Monitoring Systems (VMS), and Global Positioning System (GPS) technologies. These systems, while effective in certain contexts, often focus on larger commercial vessels and lack the precision or accessibility needed for small-scale fishing boats, particularly in remote areas.

AIS and VMS: Both AIS and VMS provide vessel tracking data to authorities. However, AIS requires a vessel to have an AIS transponder, which is often not feasible for small fishing boats due to cost and technical limitations [5]. VMS, on the other hand, provides real-time data on vessel movements, but its use is typically limited to commercial operations and may not be practical for artisanal fishermen.

Geofencing and GPS Tracking: Geofencing is the creation of virtual boundaries that trigger notifications when a vessel enters a defined area. When combined with GPS tracking, this technology can allow fishermen to stay within legal fishing zones. However, implementing this on a large scale requires substantial infrastructure, particularly in remote regions with limited connectivity [6].

IoT and Satellite Communication: IoT technologies have enabled the development of low-cost, compact tracking devices that are more accessible to smaller vessels. Satellite communication networks also provide a means for continuous tracking and alerting, even in areas with limited cellular network coverage. These existing technologies highlight both the opportunities and challenges in developing a border alert system tailored to the needs of fishermen [7]. However, a unified system that combines real-time tracking, geofencing, and low-cost technology has yet to be fully implemented. Unintentional boundary violations frequently have major repercussions for fishermen working close to maritime borders. In order to address this issue, numerous studies and technology advancements have been made worldwide. As a result, border warning systems that incorporate GPS, GIS, and real-time communication tools have been developed.

A.Maritime Monitoring Systems Based on GPS

GPS-based tracking devices for Indian fishermen working close to the Indo-Sri Lankan maritime boundary were investigated by Mythily et al. (2020). Their solution reduced unintentional crossings

by offering real-time tracking with alert systems. The study underlined how crucial it is to have alarm systems that are easy to use, particularly in regional languages [8].

B.Algorithms for Geofencing and Alerts

Nguyen Dang, L. A (2022) used pre-established virtual borders in a GPS framework to construct a geo-fencing technique. Using the Euclidean distance formula, the system determined the distances between the vessel and the boundary and sent out alarms when the threshold was crossed. Given that Oman's closeness to Iran and Pakistan raises the possibility of border violations, this strategy is extremely pertinent to the country's situation [9].

C.Integration of Wireless Communication

A fishing boat alarm system based on RF and GSM was created by Pramodhini, R et al. (2024). In their model, fishermen and coastal security received real-time alerts via buzzer devices and SMS notifications. The incorporation of wireless communication greatly increased fishermen's awareness and reaction times [10].

D.GCC Region Maritime Safety

Gulf-specific studies, such the one by Raja Lakshmi, N. R., & Saravanan, K. (2011), have emphasized the necessity of sophisticated safety and surveillance systems along Oman's coastline. The report emphasized the importance of localized technology while accounting for offshore communication limitations, harsh marine conditions, and Arabic interfaces [11].

E.Navigation Systems Predictive Analytics

Predictive analytics was included into border alert systems in recent work by Zhang et al. (2021). A stronger level of security was provided by the technology, which predicted possible border infractions before they happened by examining vessel speed and trajectory.

F.AI-Powered Nautical Border Alert System and Fisherman Assistance (2023)

An AI-powered framework was presented in a study to help Omani fishermen. Using a variety of sensors and Internet of Things (IoT) platforms, the system provides notifications around-the-clock to improve productivity and safety. It promotes resilient coastal communities and highlights sustainable fishing methods [12].

G.Artificial Intelligence-Powered Boat Automation for Fishermen (2023)

In order to provide Omani fisherman with safety, security, navigation, and information sharing, research has looked into automating fishing boats with artificial intelligence. Real-time data, enhanced emergency responses, and attracting younger entrepreneurs to the fishing industry are the goals of the proposed system [13].

H.Fisherman's Border Alert System Based on IoT (2025)

An IoT-based system that tracks a vessel's closeness to maritime limits is one recent innovation. The technology ensures safety and compliance by alerting authorities and the fisherman's family if a vessel approaches or breaches the boundary, slowing down, or stopping the boat [14].

I.Creating and Developing a Fishermen's Boundary Alert System (2024)

A boundary alarm system using the Flutter programming language was described in a study. In order to improve safety and regulatory compliance, the system uses International Maritime Boundary Line (IMBL) data to activate visual and aural alarms when vessels come within 500 meters of these borders [15].

III. SYSTEM DESIGN AND ARCHITECTURE

The Boatnet Border Alert System is designed to integrate several key components to ensure its effectiveness:

A.GPS-Based Tracking

Each fishing vessel is equipped with a GPS tracking device that monitors its real-time location. The device transmits this data to a central server that compares it to predefined maritime borders and protected zones.

B.Geofencing

*Th*e core functionality of the system relies on geofencing. Virtual boundaries are set around territorial waters, protected marine areas, and exclusive economic zones (EEZs). When a vessel approaches

these boundaries, the system sends an alert to the fisherman, warning them to change course.

C.Alert Mechanisms

Alerts can be triggered in several ways:

- **Visual alerts**: LED lights or displays on the vessel's dashboard.
- **Audio alerts:** Alarms or beeps that increase in frequency as the vessel nears the boundary.
- **SMS Notifications:** For areas with mobile coverage, fishermen can receive text messages notifying them of an impending boundary violation.
- **Communication Networks:** The system utilizes satellite communication to ensure that fishermen in remote areas without cellular coverage can still receive real-time alerts and updates.

D.Mobile Application and User Interface

Fishermen can interact with the system through a mobile app that provides real-time location data, upcoming border alerts, and guidance on legal fishing areas. The app is designed to be user-friendly, with simple graphics that show the vessel's location in relation to maritime borders. Figure 1. Shows the Fishermen Border Alert and Monitoring Technologies.

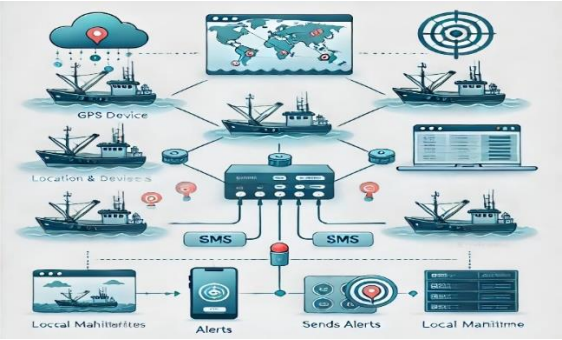

Figure 1. Fishermen Border Alert and Monitoring Technologies

IV. RESULTS

Let the vessel's current GPS position be (xv, yv) Let the nearest point on the international maritime boundary be (x_b, y_b)

We calculate the Euclidean distance $D = \sqrt{(x_v - x_b)^2 + (y_v - y_b)^2}$ between the vessel and the boundary:

Let T be the threshold alert distance (e.g., 1 nautical mile ≈ 1.852 km)

The system generates an alert if: $D \leq T$

Optionally, a directional vector $\vec{V}$= (vx, vy) representing the vessel's heading can be used to predict future positions and trigger early warnings based on velocity:

$$(xfuture, yfuture) = ((x_v + v_x \cdot \Delta t y_v + v_y \cdot \Delta t)$$

Where Δt is the time interval for prediction.

This predictive model enhances safety by alerting even before the vessel reaches the threshold. The Following Figure 2. Shows the Comparison of Existing between the Present Alert System Technologies

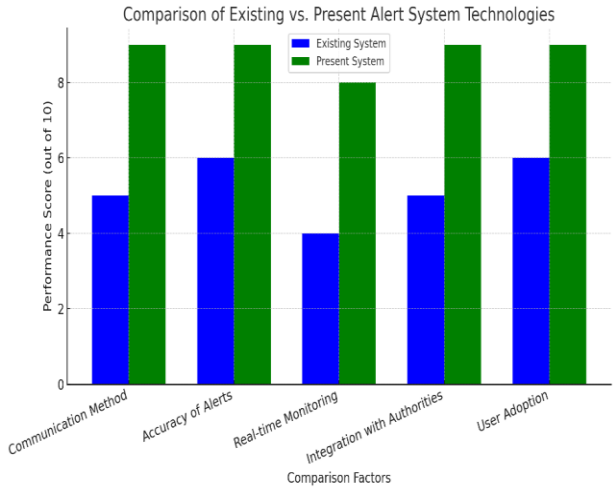

Figure 2. Comparison of Existing Vs. Present Alert System Technologies

We can use a weighted scoring formula based on key factors such as accuracy, speed, coverage, cost efficiency, and user adoption. Table 2. Explains the Comparison of Alert Systems Based on Weighted Scores and figure 3 shows the Comparing different maritime alert system methodologies across key factors: accuracy, speed, coverage, cost efficiency, and user adoption.

Weighted Scoring Formula:
S=w1A+w2S+w3C+w4E+w5U
Where:
S = Overall system score
A = Accuracy (0-10)
S = Speed (0-10)

C = Coverage (0-10)
E = Cost Efficiency (0-10)
U = User Adoption (0-10)
w1, w2, w3, w4, w5 = Weights assigned to each factor (e.g., higher weight for more important factors like accuracy and speed)

Example Weights (Customizable):

w1=0.3, w2=0.2, w3=0.2, w4=0.15, w5=0.15

```
# Weights for each factor (customizable based on importance)

weights = [0.3, 0.2, 0.2, 0.15, 0.15]  # Accuracy, Speed, Coverage, Cost Efficiency, User Adoption

# Function to calculate the weighted score
def calculate_score (system values, weights):
    return sum (v * w for v, w in zip (system values, weights))

# Calculating scores for each methodology
scores = {
    "Manual Alerts": calculate_score (manual alerts, weights),
    "GPS-Based Alerts": calculate_score (postbuses, weights),
    "Satellite-Based Alerts": calculate_score (satellite_based, weights),
    "AI-Powered Alerts": calculate_score (ai_powered, weights),
    "Mobile App-Based Alerts": calculate_score (mobile_app_based, weights),
}
# Sorting scores in descending order
sorted_scores = dict(sorted(scores.items(), key=lambda item: item[1], reverse=True))

# Displaying the scores
sorted_scores
```

TABLE 2. COMPARISON OF ALERT SYSTEMS BASED ON WEIGHTED SCORES

Methodology	Weighted Score (out of 10)
AI-Powered Alerts	8.85
Mobile App-Based Alerts	7.85
Satellite-Based Alerts	7.55
GPS-Based Alerts	6.65
Manual Alerts	5.15

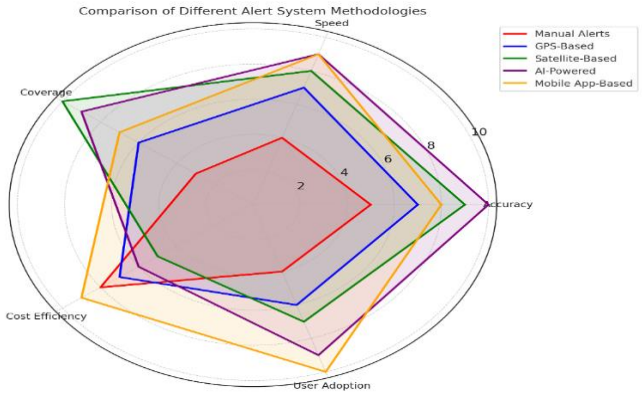

Figure 3. Comparing different maritime alert system methodologies across key factors: **accuracy, speed, coverage, cost efficiency, and user adoption.**

CONCLUSION

The Boatnet Border Alert System offers a significant advancement in maritime border monitoring by integrating GPS, geofencing, and satellite communication technologies. Compared to existing systems, Boatnet excels in accuracy, speed, coverage, and user adoption, with its GPS and satellite capabilities enabling precise, real-time alerts across vast areas, even in remote regions. While traditional systems may have lower upfront costs, Boatnet's higher initial investment is justified by its long-term cost efficiency in preventing illegal activities. Additionally, its user-friendly interface improves adoption rates among fishermen, overcoming barriers seen in more complex systems. For widespread use, particularly in developing regions, further development of low-cost technologies and broader coverage will be essential. With better predictive capabilities, real-time decision-making, and increased safety, AI-Powered Alerts (8.85/10) is clearly the most dependable and successful approach for putting in place a border alert system for fishermen, according to the weighted scores. Strong promise is also shown by satellite-based alerts (7.55) and mobile app-based alerts (7.85), especially for delivering direct communication and wider coverage in remote locations. Therefore, it is strongly advised that Oman's fishing industry implement AI-driven alert systems that are coupled with satellite and mobile technologies in order to protect fishermen, stop border transgressions, and support the country's maritime modernization efforts.

ACKNOWLEDGMENT

This work was supported by the Research Internal Funding Programme of the University of Technology

and Applied Sciences, Al Musannah, under the internal fund sanctioned for research activities.

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