

Development of Ship Traffic Monitoring System in Restricted Areas Based on AIS Data

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Abstract. The utilization of Automatic Identification System (AIS) data in various specific aspects has been widely employed. AIS data can be used for tracking ship movements, predicting potential ship collisions, rescue missions, and more. Furthermore, AIS data can serve as information for ship traffic monitoring systems, particularly in forbidden zones containing vital objects and underwater infrastructure such as pipes and cables. The presence of vessel activities in these areas can pose risks to the integrity of vital objects within forbidden zones. Hence, a system capable of real-time ship traffic monitoring within these zones is highly essential. This research aims to develop a system that can automatically monitor ship movements in forbidden areas by mapping the coordinates data of these areas into a database. Subsequently, this coordinate data is used as a reference to detect vessels entering restricted zones based on AIS data received by the Remote Base Station at Polbeng. The functionality of the developed monitoring system is tested using the blackbox method, where test results demonstrate the successful operation of the system's overall functional features. On the web page compatibility side, all page components have been displayed successfully on desktop and tablet devices. As for performance, the measurement is based on webpage load times, with an average load time of 737ms on the Google Chrome browser and 907ms on the Microsoft Edge browser, indicating a satisfactory outcome. Thus, the overall real-time monitoring system that has been built is deemed suitable for implementation in real-world scenarios and is expected to assist stakeholders in monitoring vessel traffic activities around restricted areas.

Keywords: Monitoring System, Ship Traffic, Restricted Areas, AIS Data

1 Introduction

The maritime infrastructure and connectivity in Indonesia have undergone rapid development. This progress is undoubtedly a key pillar in realizing the government's vision to establish Indonesia as a global maritime axis. This vision aims to transform Indonesia into a large, strong, and prosperous maritime nation by revitalizing its maritime identity, safeguarding maritime interests and security, and harnessing maritime potential to achieve economic equity across Indonesia. Furthermore, the development of underwater infrastructure facilities within special economic zones, namely the Dumai-Rupat Strait and Bengkalis-Pakning Strait, situated along

the coastal regions of Sumatra Island, is notable. These infrastructure elements encompass underwater pipeline and cable routes. According to survey data from Submarine Cable Map, the coastal areas of Riau (Bengkalis, Dumai) host several underwater cable infrastructures such as the Batam Dumai Melaka (BDM) Cable System, Dumai Cable System, Dumai-Melaka Cable System, Indonesia Global Gateway (IGG) System, JASUKA, Palapa Ring West, and SeaMeWe-5. These cable infrastructures are managed by various global companies including Telkom Indonesia, Telekom Malaysia, Indonesian Government, Bangladesh Submarine Cable Company Limited (BSCCL), China Mobile, China Telecom, China Unicom, Djibouti Telecom, Myanmar Post and Telecommunication (MPT), Ooredoo, Orange, Saudi Telecom, Singtel, Sri Lanka Telecom, Tele Yemen, Telecom Egypt, Telecom Italia Sparkle, TransWorld, Turk Telekom International, Telin, and Triasmitra. Figure 1 illustrates the corridor route with pipeline segments and the map of underwater cable routes in the waters of the Malacca Strait (1).

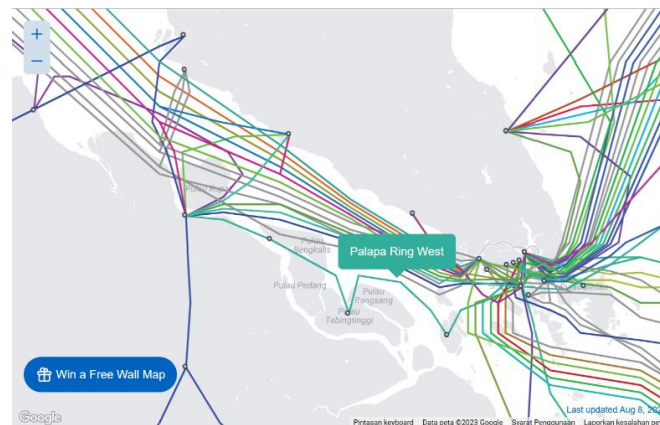


Fig. 1. Map of Underwater Pipeline and Cable Segments in the Malacca Strait Waters

With the presence of underwater infrastructure networks as mentioned above, potential hazards can arise, particularly for underwater pipeline and cable networks associated with ship operations while at sea and during anchorage near pipeline and cable areas, such as anchor dragging, anchor drop incidents, ship-platform collisions, ship sinkings, and the like (2). These activities have the potential to damage underwater cable and pipeline infrastructure. At present, some of the Submarine Cable Communication Systems (SCCS) in Indonesian waters are still unprotected. This means that if there is any disruption to the SCCS, such as a cable break, there are no alternative SCCS routes available, which would result in a communication blackout in that area. Triasmitra, as the provider of the Jakarta-Bangka-Batam-Bintan-Singapore (B3JS) Submarine Cable Communication System (SCCS), has stated in their conducted survey that the primary causes of SCCS network disruption are ship anchoring, vandalism, and fishing activities. During the period from 2013 to 2018, there were at least five instances of damage to the B3JS Submarine Cable Communication System (SCCS). These included cases such as the underwater cable network disruption along the Jakarta-Batam and Batam-Pontianak segments, which affected the local operators Telkom and Smartfren, leading to service disruptions in the Batam region (3). One of the contributing factors is the relatively shallow depth of the sea in the waters around Batam, which is approximately 20-40 meters. This shallowness makes the undersea cables in that area vulnerable to anchor disturbances from haphazardly thrown ship anchors. Therefore, early information regarding the precise locations of underwater cables and

pipelines is essential to avoid the potential for damage to such infrastructure. This can be achieved by establishing zones or areas where ship anchorage is prohibited, ensuring the protection of underwater cable and pipeline infrastructure.

Based on data from the Indonesian Submarine Cable Communication Association (ASKALSI) in 2022, 47 percent of underwater infrastructure disturbances in Indonesia were caused by ship grounding and anchoring, 28 percent by fishing activities, especially with fish aggregating devices (rumpon), 14 percent by natural factors, and 11 percent by mining and theft activities. There were at least 97 cases of submarine cable communication system (SCCS) damage caused by ship anchors between 2018 and 2020. ASKALSI also points out that the risk of underwater cable damage is quite significant, especially in areas with heavy ship traffic, such as those near Singapore and the Malacca Strait (4). In accordance with the Republic of Indonesia Law No.1 of 1973 regarding the Indonesian Continental Shelf, Article 6 Paragraph 2 is intended to protect installations, vessels, and/or other equipment. The government has the authority to designate a prohibited area with a width not exceeding 500 meters, measured from each outermost point of the installations, vessels, and/or other equipment surrounding the installations, vessels, and/or other equipment present within the Continental Shelf and/or above it (5).

A real-time monitoring system based on Automatic Identification System (AIS) data is currently essential to enhance the security of underwater infrastructure, encompassing both pipeline and cable networks. The utilization of AIS can lead to reduced operational costs incurred for ship patrols during inspections of vessels entering prohibited zones (6). Additionally, AIS data can be employed for search and rescue missions in maritime accident scenarios, where vessel position, speed, and closest route data to the rescue location can be determined, streamlining the evacuation process (7). Addressing the aforementioned issues, we propose a real-time ship traffic monitoring system within restricted areas, based on AIS data, with the aim of overseeing underwater infrastructure.

2 Research Methods

To ensure a more structured implementation process of the research, a system development methodology is required that provides an organized overview of the systematic steps in system development. The system development method used in this study is the waterfall method. The waterfall method was selected because the system requirements are clearly defined, and there is no significant possibility of changing the system requirements during the development process (8)(9). This methodology guides the sequential progression of the development phases (10). The stages of the waterfall development method can be observed in Figure 1 below.

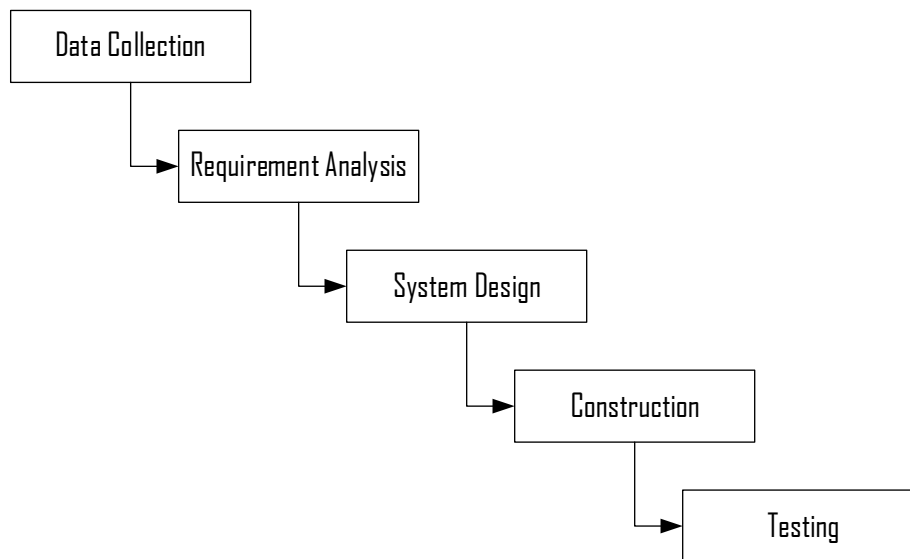


Fig. 2. The System Development Method

The system development is divided into several stages. The initial step involves gathering the necessary data for the research, specifically identifying the required data to design the real-time monitoring application. This is followed by an analysis of the functional and non-functional requirements of the application, leading to the creation of the application's design. Once the application design is complete, the subsequent stage is the construction phase of the system. Following construction, the next step involves testing and analyzing the results of the constructed monitoring system design, aimed at assessing the application's performance level for its future implementation. To provide further clarity, the following sub-section will elaborate on these stages.

2.1 Data Collection

The initial step in system development involves gathering the necessary data. The research data utilized is in the form of AIS NMEA Messages. This data format is used for encoding (converting raw AIS data format) into encoded data (plain data). The AIS NMEA Message format consists of two types:

1. !AIVDM : Data received from other ships
2. !AIVDO : Information originating from the own ship

However, in this study, the focus is on data received from other ships, as all the data received originates from other ships captured by the RBS Polbeng. In general, the AIS data format transmitted by vessels equipped with the AIS system is of type NMEA0183, consisting of 27 different message types (11). These messages are classified into two categories of data: static and dynamic (position) ship data. Static data includes MMSI, IMO, callsign, ship name, ship type, and destination, while dynamic data includes MMSI, status, turn, speed, accuracy, longitude, latitude, course, and heading. In the designed monitoring system, the static data stored in the database consists of messages 5, 19, and 24, while the stored dynamic data includes

messages 1, 2, 3, 18, 19, and 27. This is done to enhance performance and storage efficiency (12).

2.2 Requirements Analysis

Requirements Analysis is conducted to ascertain user needs for the system, describe functional and non-functional requirements, and prioritize requirements based on their level of importance (low, medium, and high). From the initial analysis, the following list of functional requirements has been obtained:

Table 1. Functional requirement list

No	Code	Functional Requirement	Priority
1	UC-01	Users can add restricted area coordinate data	High
2	UC-02	Users can modify restricted area coordinate data	High
3	UC-03	Users can delete restricted area coordinate data	High
4	UC-04	The system can display restricted area coordinate data	Medium
5	UC-05	The system can provide information about vessels entering restricted area coordinates	Medium
6	UC-06	The system can provide information about the number of vessels entering restricted area coordinates	Medium
7	UC-07	Users can manage Base Station data	Low

In Table 1, there are 7 user requirements used as prerequisites for the development of the monitoring system, each sorted by priority level. Meanwhile, the non-functional requirements of the application can be seen in Table 2 below:

Table 2. List of non-functional requirements

No	Code	Non Functional Requirement	Priority
1	NFR-01	The system can display restricted area coordinates data in GEOJSON form	High
2	NFR-02	The system can display restricted area coordinates data on maps	High
3	NFR-03	The system can display the maximum signal coverage range of the Base Station	Medium
4	NFR-04	Average web page response time is within 1 second	Medium
5	NFR-05	The system can provide notifications about the number of vessels anchoring in restricted areas	Low

The non-functional requirements stipulated in the system development focus on performance aspects and the availability of relevant information for users when accessing the system. After obtaining several required system requirements, the next step is system design.

2.3 System Design

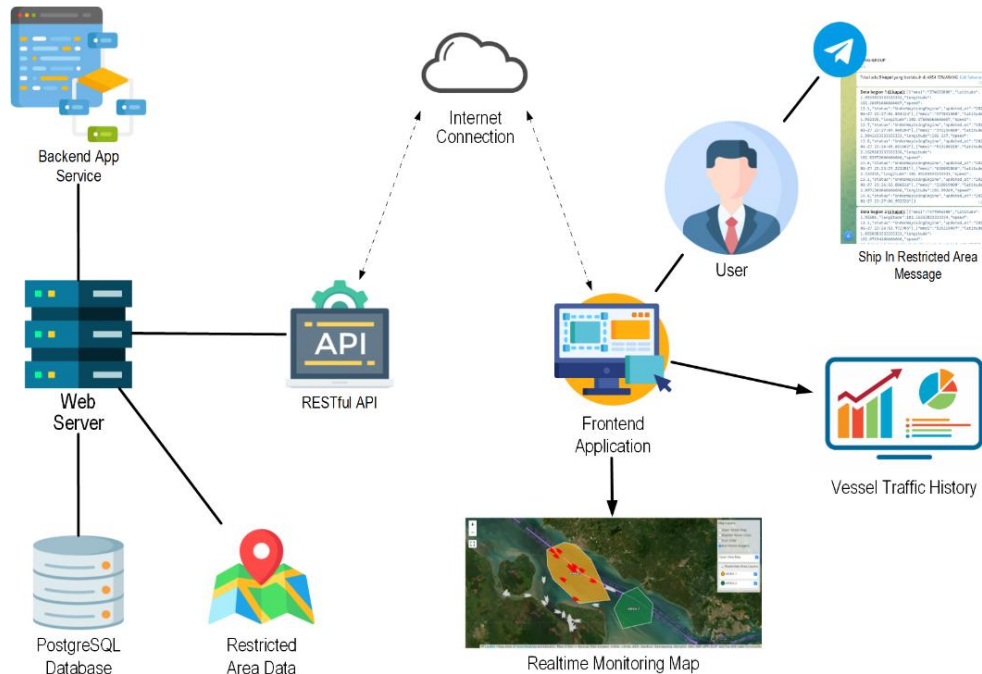


Fig. 3. Monitoring system architecture

Figure 3 illustrates the operation of the developed monitoring system, comprising two distinct applications: the backend and frontend applications. The backend application serves as a service to access data stored in the database, while the frontend application is a web-based map-centric application for end users. In the initial stage, the system requests ship data from the database via a Restful API service within the backend application, previously designed. The received ship data is then temporarily stored in JSON file format. This caching process is implemented to enhance the speed of loading data onto maps. The requested ship data is filtered and uniquely stored in the file, which is subsequently loaded into the server's memory. During system operation, the system detects vessels entering restricted areas. If a vessel is detected within the prohibited zone and suspected of anchoring, the system sends a notification message via Telegram. The frontend application displays the stored ship data in both map and tabular formats. Additionally, historical ship data stored in the database can be queried using the available API services in the backend application.

2.4 Construction

The technology employed in the development of this monitoring system includes the Python programming language with the Flask framework, along with a PostgreSQL database that performs well in processing AIS data (13), a WSGI web server, Leaflet and Mapbox for the map interface, and GeoJSON for presenting restricted area data.

2.5 Testing

The designed monitoring system is subjected to testing to assess the performance level of the built system. Testing is carried out on the system's functional features using the blackbox method, as well as on the application's performance in terms of webpage load time. Webpage load time is measured in accordance with recommended web page load standards, which are 1 second (1000ms) for content, 50ms for idling, 16.7ms for animations, and 50 to 200ms for user input responsiveness (14). The testing is conducted within a local server environment, with hardware and software specifications employed during the testing process outlined in Table 3 below:

Table 3. Hardware and software testing specifications

No	Hardware/Software for Testing	Specification
1	Processor	Intel Core i5 Gen 8
2	RAM	16 GB Dual Channel
3	Display	14inch with Intel UHD 630 Graphics
4	Storage	SSD NVME 1 TB
5	Operating System	Windows 11
6	Database	PostgreSQL Version 14.0
7	Programming Language	Python Version 3.19
8	Browser	Chrome Version 115.0.5790.171

3. Result and Discussion

3.1 Blackbox Test Results

Functional testing of the developed monitoring system is conducted using the blackbox method. Testing involves assessing several application features, including login functionality, user management, user account updates, remote base station data management, ship monitoring settings updates, and restricted area management. The results of the testing are presented in table 4 below:

Table 4. The results of functional testing of the system

No	Test Case	Actual Testing Result	Conclusion
1	Test the user login feature with incorrect user account	Displays a notification that the user has entered incorrect data.	Successfull
2	Test the user login feature with correct user account	Redirects to the application dashboard page.	Successfull
3	Display the user list page	Navigates to the user management page.	Successfull
4	Add user account data	Displays a successful data addition message, and the data is successfully added to the user list table.	Successfull
5	Modify user account data	Displays a successful data change message, and the changed data is visible in the user list table.	Successfull
6	Delete user account data	Displays a data deletion message, and the user is removed from the user list table.	Successfull
7	Update user account personal data	User account data is successfully modified. A data change success message is displayed.	Successfull

No	Test Case	Actual Testing Result	Conclusion
8	Display the remote base station list page	Navigates to the Remote Base Station page.	Successfull
9	Add remote base station data	Displays a successful data addition message, and the data is added to the remote base station list table.	Successfull
10	View added remote base station data on the ship monitoring page	Navigates to the Ship Traffic Monitoring page. The RBS-KEMARITIMAN icon and data are visible on the map.	Successfull
11	Modify remote base station data	Displays a successful data change message, and the changed data is visible in the remote base station list table.	Successfull
12	Delete remote base station data	Displays a data deletion message, and the deleted RBS data is no longer in the remote base station list table.	Successfull
13	Update ship monitoring settings data	Ship monitoring settings data is successfully modified. A data change notification is displayed.	Successfull
14	Display the restricted area settings page	Navigates to the restricted area settings page.	Successfull
15	Add new restricted area data	Successfully saves restricted area data.	Successfull
16	Modify restricted area data properties	Successfully modifies data. When the restricted area settings page is reloaded, the data properties are retained.	Successfull
17	Delete restricted area data	Successfully deletes data. When the restricted area settings page is reloaded, the restricted area data has been deleted.	Successfull

There are 17 test cases derived from 6 developed application features. Based on the test results of these 17 cases, it can be concluded that all features have successfully operated according to their functions.

3.2 Web Page Compatibility Testing

Below are the results of the compatibility testing for displaying web pages of the developed monitoring system through several different devices, namely desktop, mobile and tablet:

Table 6. Web Page Compatibility Testing

No	Pages	Device Type		
		Desktop	Mobile	Tablet
1	Login Page	✓	✓	✓
2	Dashboard Page (Load Data From API)	✓	X	✓
3	Dashboard Page (Load Data Without API)	✓	X	✓
4	Restricted Area Monitoring Page	✓	✓	✓
5	Ship Traffic Monitoring Page	✓	✓	✓
6	Realtime Data Page	✓	✓	✓
7	Ship Traffic Data Page	✓	✓	✓
8	Ship Category Data Page	✓	✓	✓

No	Pages	Device Type		
		Desktop	Mobile	Tablet
9	Ship Type Data Page	✓	✓	✓
10	History Data Page	✓	✓	✓
11	My Account Setting Page	✓	✓	✓
12	User Management Setting Page	✓	✓	✓
13	Remote Base Station Page	✓	✓	✓
14	Add Remote Base Station Page	✓	✓	✓
15	Edit Remote Base Station Page	✓	✓	✓
16	Ship Monitoring Setting Page	✓	✓	✓
17	Restricted Area Setting Page	✓	✓	✓
18	User Manual Page	✓	X	X
19	About Developer Page	✓	✓	✓

The web page created fully supports display on desktop devices. However, it's not entirely compatible with mobile devices due to the presence of three pages that are not supported. This lack of support is caused by elements overlapping in the footer area when displaying the interface. Additionally, the user manual page is not supported on mobile and tablet views because it uses the embedded file feature for displaying the user manual page.

3.2 Performance Testing: Page Loading

Below are the results of the performance testing for loading web pages of the developed monitoring system:

Table 5. Web page load time testing

No	Pages	Size (kilobytes)	Load Time (milliseconds)		
			Chrome	Edge	Firefox
1	Login Page	3477	433	666	799
2	Dashboard Page (Load Data From API)	3307	571	794	1740
3	Dashboard Page (Load Data Without API)	3320	532	737	1700
4	Restricted Area Monitoring Page	3108	940	1450	1640
5	Ship Traffic Monitoring Page	3302	2170	2260	2680
6	Realtime Data Page	2737	448	742	1340
7	Ship Traffic Data Page	2734	518	818	1150
8	Ship Category Data Page	2765	485	676	1740
9	Ship Type Data Page	2740	574	694	1580
10	History Data Page	2735	653	931	2550
11	My Account Setting Page	2735	498	556	897
12	User Management Setting Page	2745	524	735	755
13	Remote Base Station Page	2874	525	761	1520
14	Add Remote Base Station Page	3070	1060	1370	1940
15	Edit Remote Base Station Page	3076	1080	1160	2060
16	Ship Monitoring Setting Page	2734	431	603	1380
17	Restricted Area Setting Page	3494	1620	1060	2650
18	User Manual Page	2731	458	718	2080
19	About Developer Page	2766	481	498	1580
Total Rata-Rata		2971	737	907	1673

In the overall performance testing, the average web page load time is quite good, measuring 737 ms (less than 1000ms) for Google Chrome Browser, 907ms for Microsoft Edges, and 1673ms for Mozilla Firefox, with the average page size loaded is 2971 kilobytes. There are 4 pages that have load times exceeding 1 second: Ship Traffic Monitoring Pages, Add and Edit Remote Base Station Pages, and Restricted Area Setting Pages. These pages have longer load times due to the loading of resources such as a large number of ship objects on maps and other configuration resources.

4. Conclusion

The developed monitoring system has been thoroughly tested using black-box methodology, as well as performance testing focusing on web page loading. The results obtained indicate that all functional features of the system have performed well in the black-box testing. Meanwhile, in overall performance testing, the average web loading time is quite good, with 737ms on the Google Chrome browser and 907ms on the Microsoft Edge browser. However, significant attention is needed for interfaces that load map resources, especially on the Ship Traffic Monitoring Page, which still requires optimization in displaying a large number of ship objects on the maps. For compatibility testing, all components of the page were displayed successfully on desktop devices. However, there were minor issues when displaying the user manual page on Android and Tablet views. Consequently, the constructed monitoring system is ready to be integrated and implemented within the production environment of the existing operational AIS system.

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