The development of internet-of-things (IoT)-based safety monitoring system in north sea madura

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Abstract. Internet of Things (IoT) is a concept where an object has the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction, used in the navigation and monitoring systems for ships safety. This monitoring system receives data from the AIS Transceiver, the equipment installed, and integrated with the ship’s network infrastructure. The equipment transmits signatures tracking the ships sailing and going ashore as the AIS Receiver receives them. By the increasing number of ships transporting fuels and natural gas from mine-producing areas in the north sea Madura, passenger and cargo ships heading to Surabaya port. The development of an IoT-based monitoring system is prominent, it will ease to monitor the movements of ships. It may also become the basis for further developing ships monitoring systems to improve safety operating in the north sea Madura. In the initial system design, the system can transmit and receive static data, such as ships’ ID and names. Then it can transmit and receive dynamic data, such as the ships’ geographical coordinate, to identify marine traffic around the areas. Later, this system could be developed so that it not only collects data but also proceeds the data to analyze the ships condition.

Keywords: IoT, Ships, Monitoring, North Madura.

1. Introduction
Madura Strait is the most crowded shipping lane in eastern Indonesia. In 2020, the Madura Strait channel was crossed by 30,000 ships a year. Meanwhile, capacity of the strait is 27,000 ships a year, width of 100m with depth about 9.5 m and length 130 m. The government plans to deepen and widen shipping lanes in the Madura Strait. However, there are still collisions between ships. With the planned opening of several new terminals and ports [1], the plan for widening and dredging will not have a significant effect, because it is certain that ship traffic will also increase so that the channel will also be more congested.

There are many reports to the government about Madura Strait channel, because this is the main access to the Port of Tanjung Perak (Surabaya) and Gresik. Based on observations, when cross along Madura Strait from the north, there was a density in the strait. Many ships anchoring right in the groove, It interferes ships movement of entering of Tanjung Perak and Gresik Ports and cause
accidents when the stream in the Madura Strait is strong. To prevent marine accidents, it is necessary to expand monitoring area to the North Madura Sea.

In previous research have development monitoring system IoT-based in south Madura strait, The development of ship monitoring system of IoT-based will make it easier to monitor amount and ships movement, AIS data as Early Warning System (EWS) enables an early detection of any probability of event which harm the facility of marine installations [2]. The increasing of shipping activities by bulk carrier ships from result of exploration in north Madura [3]. It is rational to begin developing monitoring system IoT-based in north Madura, with IoT system enable to transmit data through the internet network without any human-to-human or human-to-computer interaction. This is expected to increase in fishing communities’ safety and marine installations in the North Sea Madura.

2. Methods
2.1 AIS Data Communication Mode.

Figure 1 shown each ship will transmit or receive its ship data to all AIS equipped ships within the same VHF channel [4]. The unique communication scheme allows data transmission to take place independently without the need for a master control station [5].

In other ships data will be automatically received by AIS receiver in second during in the same VHF channel [6]. The data received ships to ships is in the form of a code and displayed for the AIS Operator. So that AIS data can be seen from all ships equipped with AIS transmitters in the range area of AIS. For up to date data, the latest AIS data is transmitted every few seconds, by ship-to-ship data exchange occurring automatically without operator, but rather automatically processed through data processing receiver.

Syabbandar or AIS Shore Station can build AIS stations to monitor ships movement crossing the area, it called Vessel Traffic System (VTS). This VTS can monitor AIS data from ships such as ships identity, destination, ETA, ship type, and other information. VTS can also use AIS channels for transmitted information from shore station-to-ship, with information about tides, notifications for sailors, and local weather forecasts. Several AIS shore stations and their repeaters can be formed into a WAN (Wide Area Network) data transmission network, which can transmit data together within the range of the WAN network itself [4]. The schematic of the data transmission network is schematically shown in the following figure 2 below.
2.2 AIS Monitoring System by Internet-of-Things (IoT)

Internet of Things (IoT) is a concept where certain object has the ability to transmit data through the internet network and without any human-to-human or human-to-computer interaction [7][8].

The IoT system works by utilizing programming algorithm, where each argument command can produce interaction between machines that have been connected automatically without human intervention and without being limited by any distance. Input will be processed according to the algorithm that has been compiled and will be continued until it produces the required information [9]. The topology of the IoT-based AIS monitoring system on the north coast of Madura is shown in Figure 3 below.

![Figure 3 Topology Internet-of-Things of AIS](image)

The explanation of the research stages is as follows:
1. In the AIS Remote Base Station (RBS), Antenna received VHF signal from ships (AIS Transponder) [10] and then sending to AIS Responder.
2. AIS Responder Module proceeds NMEA data such as ordinates, directions, and ship identity are received in the form of a data logger and then sent to Raspberry [11].
3. Raspberry Pi with the algorithm is converts logger data into binary data and sends it to the GSM Modem.
4. Internet connection RBS using GSM modem and enabling a VPN Client that connects the RBS device to the Gateway/VPN in the AISITS server room by host to host connection.
5. Gateway/VPN Server can accept host to host connection from VPN Client RBS and forward data to AISITS server.
6. Server AISITS receive binary data will be stored in the MySQL database [12]. This data will be interpretation using PHP Programming to be displayed as a website by client request [13].
7. Clients can use a browser to access monitoring website by PC or Smartphone. The client can see how many ships are going to Madura strait within the radius of reception RBS. For special purposes, clients can remotely connect using Secure Shell (SSH).

2.3 Location of AIS Remote Base Station (RBS)
Location of the AIS Remote Base Station (RBS) at placed in strategic location that can receive signals from the AIS transceiver to the maximum, namely in Ketapang sub-district, Sampang district with an Ordinate of -6.893569, 113.287344, distance 73.57 kilometers from the AISITS server location as shown Figure 4 below.

Figure 4 AIS RBS Location (Google Maps)

Figure 4 show addition coverage area in Tanjung Perak and north Madura Sea. Black circle shows the previously coverage area and yellow circle shows addition coverage area. The VHF antenna has a coverage radius of 50 km, thus the addition of RBS in the north of Madura increases the monitoring range which was previously only around Tanjung Perak area increasing to the North Sea of Madura.

3. Result and Discussion
3.1 Display In Web Browser
Figure 5 shown web browser North Sea of Madura AISITS different types of vessels that could be seen from the color. The changes and the identity and type of each ship could be seen by clicking each
ship. By using web browser, it could be shown the ship condition that will go to the harbor Perak. Figure 6 is detail information the ships data such as ships name, MMSI, ships type, engine power, and Speed. On viewing the page, it can also show either the ships safe category or inspection without the need to click around the ship, in other words, it is possible to monitor existing vessels in North Sea Madura through that page.

![Figure 5 North Sea Madura in AISITS Web Browser](image)

![Figure 6 Ships Detail Information Data](image)
3.2 AIS Data Collection

AIS data is read directly through the AIS Responder module from RBS. This AIS Responder is capable of receiving data from AIS transponders in ships with a range of about 50 km. Recorded data is sent to the AISITS server to be displayed in the monitoring system or tracking ship movements.

The AIS data is needed in this study, such as AIS data that has been converted to database. Table 1 is example of data taken at a certain time. Date and time are required for tracking the movement and position of the ship. The MMSI number is a unique nine-digit number that is sent over VHF channel to identify the vessel. Information about the actual speed of the ship is recorded every 2-10 seconds. The position of the ship can be known from the longitude and latitude sent by the AIS transponder. The direction of the ship is detected through the ship course data with a range of 360 degrees. Every 6 minutes AIS will provide information on IMO Number, call sign, ship name, estimated time of arrival and destination of the ship.

| Table 1 AIS Responder Data at 14:03:39 – 14:03:51. |
|-------------------------------|---|---|---|---|---|---|---|---|
| Date  | Time  | MMSI  | IMO Number | Speed | Ship Name        | Longitude | Latitude | Course | Destination |
| 13/05/21 | 14:03:39 | 111668590 | 1100000 | 1.1 | KM. Tanjung Api | 113.698108 | -6.38578 | 264.5  | ID SUB      |
| 13/05/21 | 14:03:39 | 240901000 | 9412074 | 7.2 | Tilos           | 113.711718 | -6.39677 | 276.1  | ID SUB      |
| 13/05/21 | 14:03:39 | 244461000 | 9330238 | 0.1 | Amazon River    | 113.726333 | -6.30383 | 250.4  | ID SUB      |
| 13/05/21 | 14:03:40 | 245839000 | 9081368 | 0.1 | Erasmusgracht   | 113.721072 | -6.39361 | 266.5  | ID SUB      |
| 13/05/21 | 14:03:40 | 305560000 | 9511636 | 0   | Beluga Loyalty  | 113.733978 | -6.38929 | 230.5  | ID SUB      |
| 13/05/21 | 14:03:40 | 244461000 | 9330238 | 0.1 | Amazon River    | 113.726333 | -6.30383 | 250.4  | ID SUB      |
| 13/05/21 | 14:03:41 | 244461000 | 9330238 | 0.1 | Amazon River    | 113.726333 | -6.30383 | 250.4  | ID SUB      |
| 13/05/21 | 14:03:41 | 309692000 | 9046992 | 0   | Meratus Ultima 2| 113.7059207 | -6.39108 | 323.7  | ID SUB      |
| 13/05/21 | 14:03:51 | 477103000 | 9070278 | 0   | Tanto Abadi     | 113.705324 | -6.39203 | 225.7  | ID SUB      |

3.3 Analysis Data of Ship Arrival

Query results of database from May - July 2021 showed that the density of ship visits occurred in July 2021, by amount 3.229 ships with average of 104 ships a day. Furthermore, database analysis is carried out to determine the busiest day of the ship in July. The database processing is carried out from the 1st to the 31st of the existing AIS data and the highest number of ship arrival is found on 22 July 2021. Table 2 below is the ship arrival data from May – July 2021.

| Table 2 Data Ships Arrival May – July 2021 |
|-------------------------------|---|---|---|---|
| No.  | Date  | May | June | Juli |
| 1    | 1     | 80  | 81  | 97   |
| 2    | 2     | 91  | 88  | 100  |
| 3    | 3     | 79  | 80  | 102  |
| 4    | 4     | 75  | 83  | 100  |
| 5    | 5     | 75  | 79  | 98   |
| 6    | 6     | 80  | 90  | 93   |
| 7    | 7     | 86  | 74  | 96   |
| 8    | 8     | 79  | 81  | 103  |
| 9    | 9     | 88  | 85  | 106  |
| 10   | 10    | 91  | 80  | 113  |
| 11   | 11    | 85  | 75  | 108  |
| 12   | 12    | 83  | 80  | 110  |
| 13   | 13    | 74  | 88  | 104  |
| 14   | 14    | 76  | 88  | 104  |
| 15   | 15    | 85  | 80  | 94   |
| 16   | 16    | 78  | 84  | 107  |
On 22 July 2021, it analyzes ships about flag state and ship type. In table 3 is known that amount of Indonesian flagged was 83 ships or 69.17% of the number of ships monitored on that day and in table 4 is known that the General Cargo ships type was 49 ships or 40.83% of the number of ships monitored.

### Table 3 Ships amount by flag state

| No. | Flag State          | Qty | %    |
|-----|---------------------|-----|------|
| 1   | INDONESIA           | 83  | 69.17|
| 2   | Liberia             | 3   | 2.50 |
| 3   | Vanuatu             | 1   | 0.83 |
| 4   | Vietnam             | 2   | 1.67 |
| 5   | Thailand            | 1   | 0.83 |
| 6   | Marshall Islands    | 3   | 2.50 |
| 7   | Hong Kong, China    | 2   | 1.67 |
| 8   | China Republic      | 2   | 1.67 |
| 9   | Panama              | 7   | 5.83 |
| 10  | Cambodia            | 1   | 0.83 |
| 11  | Dominica            | 2   | 1.67 |
| 12  | Bahamas             | 2   | 1.67 |
| 13  | Korea (Republic of) | 1   | 0.83 |
| 14  | Antigua and Barbuda | 3   | 2.50 |
| 15  | Iran                | 1   | 0.83 |
| 16  | Norway International| 2   | 1.67 |
| 17  | Netherlands         | 2   | 1.67 |
| 18  | Greece              | 2   | 1.67 |
|     | **Total**           | **120** | **100** |
4. Conclusion

By increasing number of ships transporting fuels and natural gas from mine-producing areas in the North Sea of Madura increasing risk marine accidents. Expansion of an IoT-based monitoring system will ease to monitor the ships amount and movement until to the North Madura Sea. The system can transmit and receive data from RBS to AISITS Server about static data, such as ships id and names. Then it can transmit and receive dynamic data, such as the ships coordinate, to identify marine traffic around the areas. This research could be improved so that it not only collect data but also analyze detail ships condition. It may also become the basis for further developing ships monitoring systems to improve safety operating in the North Sea Madura. In the future, it can be used for many online marine monitoring systems to avoid the subsea gas pipeline damage, leakage and finally it could induce fire consequences. EWS system of AIS has an early detection on a ship motion which possibly doing an anchorage near the facility. A notification will be sent to the owner of facility or other third party which responsible with this the safety in North Sea Madura.

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Table 4 Ships amount by ship type

| No. | TYPE       | Qty | %     |
|-----|------------|-----|-------|
| 1   | Tanker     | 23  | 19.17 |
| 2   | Gen. Cargo | 49  | 40.83 |
| 3   | Container  | 21  | 17.50 |
| 4   | Passenger  | 4   | 3.33  |
| 5   | Tugs       | 6   | 5.00  |
| 6   | Bulk Carrier | 8  | 6.67  |
| 7   | Landing Craft | 5  | 4.17  |
| 8   | Buoy vessel | 2  | 1.67  |
| 9   | Supply Vessel | 2  | 1.67  |
|     | Total      | 120 | 100   |
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Acknowledgments
We would like to thank AISITS Research Consortium, PUI KEKAL ITS, Director of Politeknik Negeri Madura (POLTERA), the Chairperson of the P3M POLTERA, Colleagues of Poltera, All Committee 6th International Conference on Marine Technology (SENTA 2021) which has been approve and publish the results of this research, and my beloved family always support.