TRANSNAV the International Journal on Marine Navigation and Safety of Sea Transportation
http://www.transnav.eu
Volume 13
Number 1
March 2019

DOI: 10.12716/1001.13.01.05

# AIS-Assisted Service Provision and Crowdsourcing of Marine Meteorological Information

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ABSTRACT: Ship navigation and operational activities at sea need meteorological and hydrographic information to enhance safety and efficiency. Besides observations collected from deployed data buoys, marine meteorological information services rely on weather observation reports from ships to increase the data density and thus service quality. Automatic Identification System (AIS), adopted internationally to facilitate ship-ship and ship-shore data exchange, has developed into communication links between ship/shore and buoys with many potential applications. This paper presents AIS applications designed and implemented for marine meteorological information services in a long-term project initiated by the Central Weather Bureau of Taiwan. Achievements of this initiative include: versatile service delivery via shore-based AIS network to shipborne application platforms such as smart phones, remote controllable moving weather data collection, and assisted sharing of weather observation reports from ships. Typhoon forecast and warning is one of the key applications implemented for this region.

## 1 INTRODUCTION

Ship navigation and operational activities at sea need meteorological and hydrographic information to enhance safety and efficiency. On the other hand, besides observations collected from data buoys, marine meteorological information services rely on weather observation reports from ships to increase the data density and thus service quality.

Automatic Identification System (AIS) is a radio communication system which operates in the maritime VHF band [1]. It is designed to facilitate ship-to-ship and ship-shore data exchange. The purpose stated by the International Maritime Organization (IMO) is "to improve the safety of navigation by assisting in the efficient navigation of ships, protection of the environment, and the operation of Vessel Traffic Services (VTS)"[2]. As required by the Safety of Life at Sea Convention (SOLAS), carriage and operation of a Class A shipborne equipment of AIS is mandatory for vessels over 300 tonnage on international voyage and vessels over 500 tonnage on domestic voyage [3]. So far, major applications of AIS include the collision avoidance between ships, coastal vessel monitoring, and vessel traffic management. Such applications rely on the autonomous and continuous sending of static, dynamic, and voyage-related data about ships, using self-organized time division multiple access (SOTDMA) protocol. To be specific, each AIS-fitted vessel reports its identifications, ship/cargo type, destination, position, speed, course, heading, etc., at adaptively varying intervals. If needed, short safety-related messages, which allow the exchange of format-free ASCII-text, may be sent and read via the mandatory functions of the Minimum Keyboard and Display (MKD) of class A AIS.

Benefits of AIS have encouraged more and more non-SOLAS vessels, such as fishing boats and pleasure crafts, to carry either class A transceivers, class B transceivers [4] or simply AIS receivers. AIS Aids to Navigations (ATON) or data buoys fitted with AIS become common. Such widespread installations have triggered even more innovative applications.

AIS may use binary messages for transmission of Application-Specific Messages (ASM), either addressed to a specific AIS station or broadcasted. The technical characteristic and the structure of the AIS ASMs are specified in [1], while the content and format are to be tailored to different applications. The format of ASM can be defined for international or regional use, and identified by a Function Identification (FI) in the message. International ASMs are defined by IMO. In 2010, IMO approved a guidance on the use of AIS ASM, including 17 message formats recommended for international use [5]. Table I lists the IMO defined AIS ASM with potential application in marine meteorological services.

Table 1. Weather-related AIS ASMs defined by IMO

| FI | Message Name |
|---|---|
| 21 | Weather observation report from ship |
| 22 | Area notice – broadcast |
| 23 | Area notice – addressed |
| 26 | Environmental |
| 29 | Text description – broadcast |
| 30 | Text description – addressed |
| 31 | Meteorological and Hydrographic data |

However, not only the generation and transmission of ASMs but also the display of transmitted information require dedicated software and suitable equipment, which is not included in standard AIS or other shipborne equipments such as the Electronic Chart Display and Information System (ECDIS). To propose specific presentation and display standards for AIS ASMs was considered premature, therefore IMO only provided some examples, and states that the portrayal of AIS ASM should conform to the concept of operation envisioned for e-navigation [6]. It is expected that AIS ASM "will become means to achieve many of the core objectives of e-navigation."[6]

Based on the ASM mechanism of AIS, an operational system of systems is developed for service provision and crowd-sourcing of marine meteorological information[7]. This is achieved in an AIS-Weather project initiated by the Central Weather Bureau (CWB) of Taiwan and carried out by the ENC Center, Department of Communications, Navigation and Control Engineering, National Taiwan Ocean University (NTOU) from 2012 to 2015. Targeted coverage include coastal Taiwan waters and the routes of cross Taiwan Strait vessels.

Details of the system and services are described in the following sections.

## 2 THE SYSTEM AND SERVICES

### 2.1 *The Shore-side System and Network*

AIS-Weather uses AIS data link to provide service, therefore needs AIS shore stations to broadcast weather information, receive weather reports from ships and to remotely control operation parameters such as reporting interval of installations onboard cooperating vessels. The shore stations installed are mainly Type 3 AIS ATONs conforming to IEC 62320-2. Fig. 1 illustrates the system architecture on the shore-side.

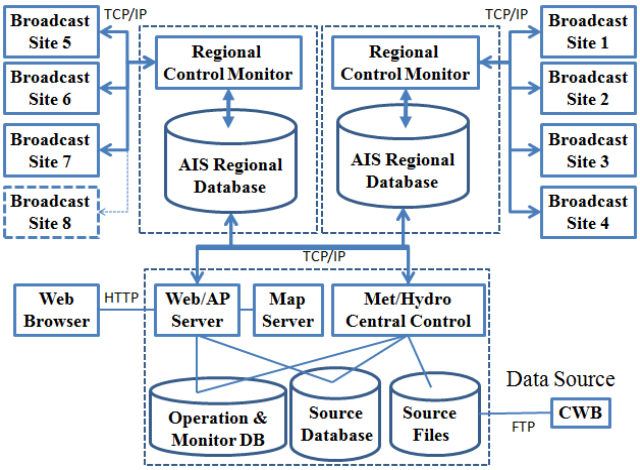



Figure 1. System architecture on the shore-side.

Each broadcast site (BS) consists of an AIS transceiver, i.e. the AIS ATON, and a serial-to-Ethernet device server, thus connected to a Regional Control Monitor (RCM) located in CWB via internet or intranet. For each connected BS, RCM collects the messages received by the AIS transceiver, and controls the transmission of AIS ASMs according to the schedule and priority set by the Met/Hydro Central Control (MHCC). RCM is also responsible for monitoring the status and operations of each BS, and handles the retransmission or reconnection accordingly. The status of each RCM is in turn checked by MHCC. Along with the MHCC software, there is a web/application server for accessing the system configuration, management and operation monitoring functions with web browsers. Fig.2, which is captured from the web page of the MHCC web site, shows the broadcast sites established up to 2015. Coverage area of each site shown in red color is the convex hull of AIS ship positions received within latest 6 minutes (adjustable), as an indication of possible service area at that moment. An online list of status codes, with explanation and suggested actions, is provided for users to recognize whether the point of failure or anomaly is at the BS transceiver or the network connection.

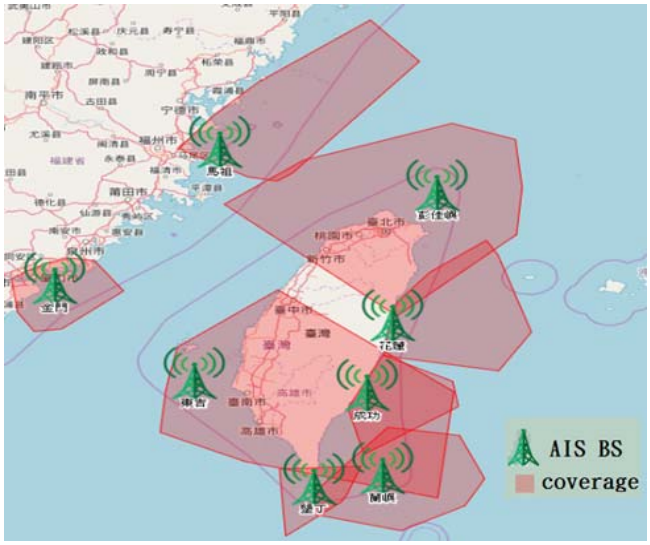



Figure 2. Realtime coverage and status of the broadcast sites.

## 2.2 *The Shipboard System and End-User Application*

This marine meteorological information service may be accessed onboard vessel via shipborne AIS equipment or wherever there is an internet connection. A mobile application (AIS-weather APP) can be downloaded and run on smart phones or tablets. Both Android and IOS are supported. For the APP to connect to the shipboard AIS equipment, a converter is required to convert the NMEA/RS-422/RS-232 serial to Wi-Fi. This APP will check its connection to the shipborne AIS and the internet. Even if the AIS data link is not available, it may still connect via internet to a server and receive all the broadcasted information as well as APP updates.

In previous design, AIS-Weather APP comes with a reduced set of electronic navigational charts covering Taiwan waters in the web map tile service (WMTS) format[8]. New design has replace the map tiles with map data in vector format. Using the electronic chart as background, the APP displays the received marine meteorological data graphically as selectable overlay layers. The own ship symbol is also displayed according to the data decoded from the dynamic position reports transmitted by the own ship. Fig.3 illustrates the APP's display of the own ship symbol, information layer selections, as well as the switching between DAY/NIGHT color tables and UTC/Local Time. The language of user interface is automatically switched between Traditional Chinese and English according to the locale settings of the mobile device. In Fig.3, the APP was connected to the server in NTOU, that's why the own ship is located on land. The setting panel beside the map display can be shown or hidden via the home button. A tool panel for measuring relative range/bearing and cursor coordinate is accessed via the "arrow and plus" button, as shown in Fig.4. In addition to its location, time of the delivered marine meteorological information is essential for users to interpret and use that information correctly. Therefore, a sliding time bar, as shown in the upper right corner of Fig.4, is designed to control visibility according to the valid time of the data, which may be an observation with some age or a forecast. Touching the "i" button as shown in the lower right corner of Fig.4 slides in (and out) an information panel for the data point that user pick on the map, e.g. the data buoy as shown in Fig.5.

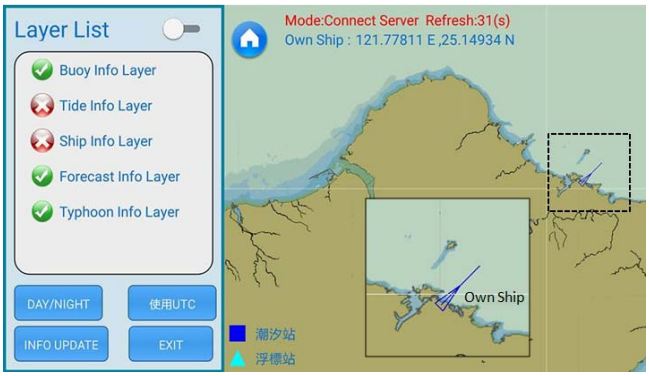



Figure 3. AIS-weather APP showing the map display, setting panel.

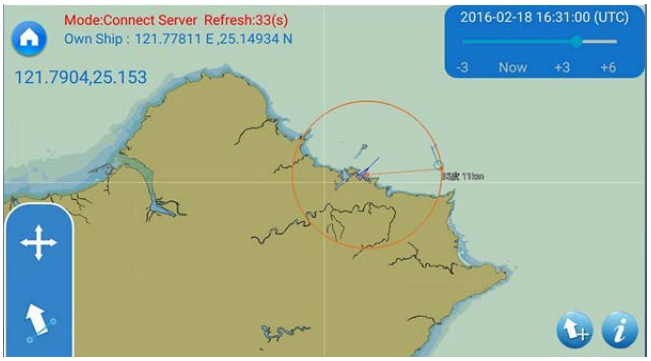



Figure 4. AIS-weather APP showing the measurement tool and the time bar.

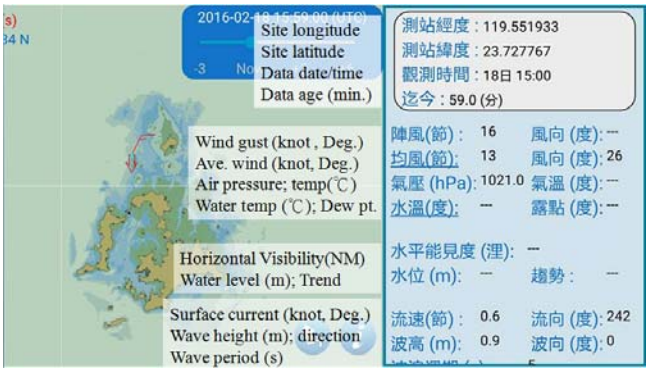



Figure 5. AIS-weather APP with the information panel showing data of the selected buoy site (highlighted in red).

Each underlined data item in the information panel, such as the average wind speed and water temperature, links to a chart of the data received in the past few hours to indicate the tendency.

## 2.3 *Protocols, Messages and Data Sources*

Among the AIS ASMs implemented in AIS-Weather to provide marine meteorological services, those defined by IMO for international use are listed in Table II.

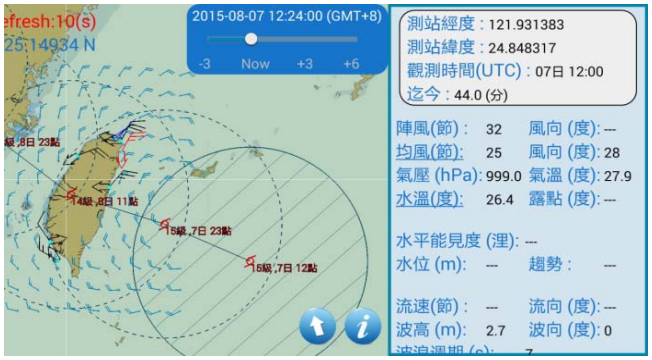
Table 2. IMO-defined AIS ASMs Implemented in AIS-Weather

| FI | Message Name | Data Sources |
|---|---|---|
| 21 | Weather observation report from ship | Shipborne weather stations |
| 26 | Environmental | Tidal water level observations and predictions |
| 31 | Meteorological and Hydrographic data | Data buoy observations: wind, wave, current, water temperature, air temperature and pressure |

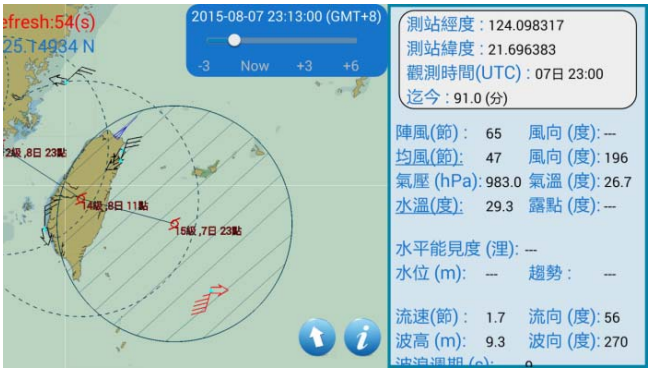
Data broadcast using FI 31 are hourly observations collected from offshore data buoys. When broadcast after the quality control process, the data age can easily become over 1 hours. In response to user needs regarding the timeliness and forecast information, two more regional AIS ASM messages are designed and implemented in AIS Weather, namely "Regional Wind Forecast" and "Typhoon Warning".

For the regional wind forecast, each two-slot message with FI=34 and DAC=416 delivers 8 grid data of wind force vectors. Therefore, feature extraction and broadcast scheduling are designed for ships to receive data of the whole area as soon as possible, then incrementally increase the data density.

ASM for typhoon warning is designed according to CWB's warning sheet, which consists of two parts : (1) current position, radius and wind force of the typhoon; (2) forecast position, radius and wind force of the typhoon in12h, 24h, 36h, and 48h. A two-slot regional ASM are designed utilizing FI 22 "Area Notice" linked with FI 29 "Text Description" to broadcast the dynamic geospatial information and the wind force values, respectively. When received by the AIS-Weather APP, such linked pair of messages are combined to present the typhoon warning. Fig. 6 shows two screen shots of shipboard AIS-weather application running on an android smart phone. These were captured when typhoon Soudelor was approaching Taiwan.




(a) Regional wind forecast, observations from data buoys, and warning of the approaching typhoon Soudelor

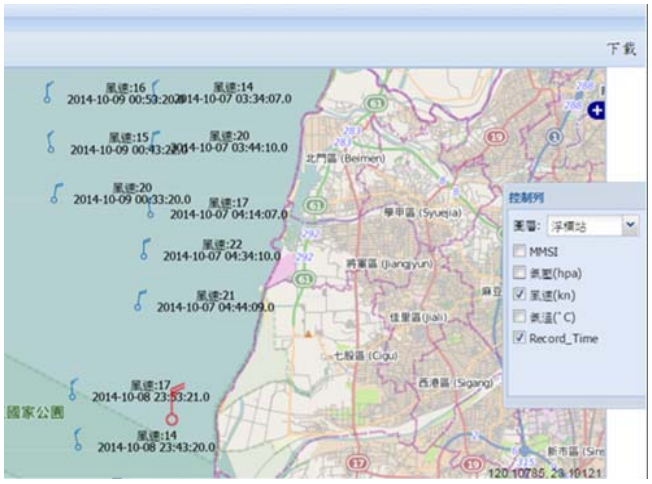



(b) data buoy observation within the radius of typhoon Soudelor

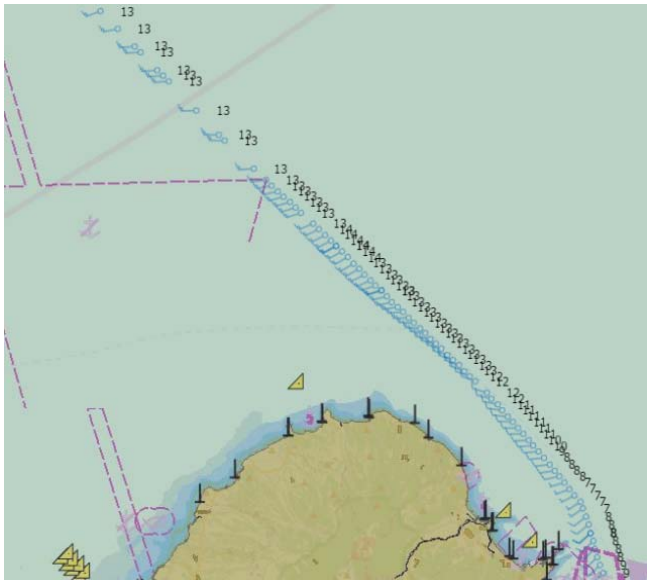
Figure 6. Screen cpatures of the AIS-Weather APP during typhoon warnings.

## 2.4 *Automatic Reporting of Shipboard Weather Observations*

According to the standard ITU-R M.1371-5, Class B shipborne AIS equipments using Carrier-sense time division multiple access (CSTDMA) technique should not transmit binary messages, i.e. message 8 or message 6. Therefore, only ships fitted with Class A AIS or Class B AIS using Self-organized time division multiple access (SOTDMA) technique may participate in the automatic reporting of shipboard weather observation using AIS ASM. AIS-Weather project provides a software platform that interfaces with shipborne weather stations of the participating vessels, encodes the output data into ASM (Type 8, FI 21), and control the automatic reporting via the shipborne AIS transceiver. Shipboard weather observation reports may also be entered manually via the user-interface of the AIS weather APP. Manually entered data are tagged when encoded into ASM, to differentiate them from those automatically generated. Shipboard weather reports received by the coastal AIS network are automatically delivered to the database of CWB for use in the analysis and forecast. Fig.7 shows shipboard weather observation reports from the participating vessels.




(a) wind speed reported from NTOU research vessel



(b) Wind speed reported from a passenger ship
Figure 7. Shipboard weather observation reports received at MHCC in CWB.

Shipboard weather reports broadcast via AIS may be directly received by other vessels, which however may be rather limited in range due to the antenna height of shipborne AIS, hence reduce the usefulness of the information. In order to make the most use of such valuable data, a retransmission function has been designed and implemented to automatically have the received weather reports from ships re-broadcasted to a suitably wider area via the shore-based AIS network.

## 3 CONCLUSIONS

AIS-Weather services delivered from the shore-based AIS network to the shipborne application include quality-controlled observations of wind, wave, current, air pressure, and sea surface temperature data collected from offshore buoys, observed tides from coastal tide stations, as well as inshore tidal forecasts. These official source data are automatically encoded into several internationally recognized message formats, i.e. AIS ASM formats recommended by IMO.

Service area of each AIS shore station is limited to its VHF radio coverage. Therefore the distribution and scheduling for data broadcast is designed to deliver data contents throughout the AIS-network, without overloading the VHF data links of AIS.

Besides international ASMs, regional ASMs are designed to deliver services such as regional wind field forecast and the Typhoon warnings, to meet local user needs. To deliver these information services with minimum radio resources requires careful design in the data model, encoding, updating management as well as the portrayal of the data.

The shipborne application platform may connect to the shipboard AIS equipment and optional shipborne weather instruments via Wi-Fi. Weather observation reports may be automatically generated or manually entered via the user interface, broadcast via AIS, and received by shore stations as also by other vessels within VHF radio range. Such crowd-sourced observation data received by the shore stations are not only delivered to the database of CWB but also arranged by the AIS-weather network to be re-broadcast to other areas of interest. The timeliness and coverage of observation-related information services are improved in this way.

All the above mentioned platform and services are in operation, with increasing shipboard installations and shore-based service coverage.

## ACKNOWLEDGMENT

Authors would like to thank the Central Weather Bureau of Taiwan for initiating AIS-Weather project and the continuing support for the operation of the system and service developed in the project.

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