Expanded use of Automatic Identification System (AIS) navigation technology in Vessel Traffic Services (VTS)

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ABSTRACT

The Automatic Identification System (AIS) is a maritime navigation safety communications system that exchanges vessel information, including the vessel's identity, position, course and speed and other safety-related information automatically with other ships and shore stations. Since its introduction aboard ships in 2002, the information provided by AIS has proven invaluable for shipboard situational awareness and shoreside vessel traffic management use, particularly in Vessel Traffic Services (VTS). AIS has been very valuable in assisting VTS identification of radar targets and tracking of vessels in non-radar coverage areas. In some instances it has reduced voice radio communications by automating position reporting. However, the full benefit of AIS capability to VTS beyond these basic applications has yet to be realized, and in some cases even this basic usage could be improved upon, particularly as the concept of e-Navigation matures.

AIS has the capability to revolutionize VTS operations and provide vast benefit to the mariner in the form of properly presented information delivered at the right time. While recognizing that AIS is not a panacea, the future use of AIS will be information-driven, making information available for the mariner and other users and getting it to and from places that were not possible, not feasible and likely not even thought of in the past. AIS will be an integral part of an overall e-Navigation strategy.

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VESSEL TRAFFIC SERVICES

The U. S. Coast Guard operates Vessel Traffic Services (VTS) in the largest and busiest ports in the United States. These VTSs provide active monitoring and navigational advice for vessels in particularly confined and busy waterways. VTSs use a variety of land-based sensors (i.e., radar, AIS and closed circuit television sites), to enable VTS operators to build and maintain a traffic image in order to manage vessel traffic movement. Based on this traffic image, VTS operators provide mariners information, via VHF-FM voice radio, so they can make informed navigational decisions. VTS operators may also provide advisories or recommendations, and in rare instances may direct mariners in order to prevent vessel collisions, rammings, and groundings in the VTS area. VTS operations also serve to expedite ship and

cargo movements, increase transportation system efficiency, and improve all-weather operating capability.

To date, communications between VTS and the mariner have been almost exclusively via voice communications over VHF radio. The types of information routinely communicated include:

- Other vessel locations (traffic advisory)
- Navigational hazards
- Hydrological and meteorological information
- Traffic organization (lock order, procession through one-way channels)
- Status of aids to navigation

Communicating this information via voice can be cumbersome. There are a limited number of VHF frequencies available for use, the airwaves are increasingly congested and there are frequent misunderstandings and missed communications that necessitate repeat transmissions. As a result, only the most critical information is routinely communicated. Other valuable but less critical information such as weather and status of aids to navigation (AtoN) may be provided infrequently or not at all. Even critical information is sometimes difficult to communicate efficiently. For example, a traffic advisory may have to be repeated several times to the affected vessels to ensure they all have the information.

AUTOMATIC IDENTIFICATION SYSTEM (AIS)

AIS is a maritime navigation safety communications system that provides vessel information, including the vessel's identity, position, course and speed, navigational status and other safety-related information automatically to appropriately equipped shore stations, other ships, and aircraft; receives automatically such information from similarly fitted ships; monitors and tracks ships; and exchanges data with shore-based facilities.

AIS was developed in the late 1990's to ''improve the safety of navigation by assisting in the efficient navigation of ships, protection of the environment, and operation of Vessel Traffic Services (VTS), by satisfying the following functional requirements:

1. in a ship-to-ship mode for collision avoidance;
2. as a means for littoral States to obtain information about a ship and its cargo; and
3. as a VTS tool, i.e. ship-to-shore (traffic management).'' (IMO, 1998)

AIS equipment aboard vessels continuously and autonomously transmits information about the vessel. This information is transmitted using an international standard for ship-to-ship, ship-to-shore, and shore-to-ship data communication. Aboard the vessel, critical information about the ship (identity, position, course, speed) is processed and transmitted automatically over VHF-FM radio frequencies. The individual transceivers on vessels coordinate autonomously among themselves using the Self-Organizing Time Division Multiple Access (SOTDMA) protocol. SOTDMA ensures that vessel transmissions do not interfere with each other; information is sent out in short bursts in assigned time slots, and simultaneously

future time slots are reserved.

Data is transmitted at varying rates via AIS depending on the vessels' maneuvering status; e.g., faster vessels transmit their information at a higher rate. This allows for a robust exchange of information that vessels can use in conjunction with other shipboard systems (such as electronic chart plotters or navigation systems and radars) to assist with safe navigation. AIS data is sent using 26 predefined messages, such as vessel position reports, static and voyage related data, and others. In addition, several message types are designated for "binary applications" which can be used to communicate data for which there is no predefined message. Several messages are used as telecommands by shoreside authorities, such as to change the reporting rate for vessels or the change the VHF frequencies used to communicate AIS data. The use of binary applications and telecommands will be discussed in more detail later in this paper.

The transmissions between ships can be received by properly-equipped entities ashore and used to identify and track vessels within VHF-FM range. In addition to receiving AIS messages, shoreside authorities can also transmit information via AIS to ships. This capability to transmit AIS information from shore holds promise to vastly expand the usefulness of AIS in the provision of vessel traffic services.

International requirements and United States' regulations require the carriage of AIS equipment aboard certain vessels. The International Convention for the Safety of Life at Sea (SOLAS) requires carriage of AIS on all ships of 300 gross tonnage and upwards and passenger ships irrespective of size engaged on international voyages; and, no later than 1 July 2008, by all cargo ships of 500 gross tonnage and upwards not engaged on international voyages. In the U.S., the Maritime Transportation Security Act of 2002 included requirements for AIS carriage aboard all commercial self-propelled vessels over 65 feet in length, most towing vessels, and certain passenger vessels in all navigable waters of the United States.

CURRENT USE OF AIS IN VTS

AIS is primarily used in vessel traffic services as a sensor to aid in vessel tracking, complimenting the information previously available through vessel voice reports, radar and other means. In general, use of AIS receive capability has improved the monitoring of vessels. It has allowed more accurate and frequent tracking in areas where there were limited sensors, it allows for the confirmation of the identity of vessels previously only observed as a pip on the radar or seen through remote television cameras. In certain circumstances, the use of AIS as an identification and tracking tool for VTS has reduced the requirement for voice reporting of vessel positions. However, in some ways the additional monitoring capability provided by AIS has resulted in an increase of voice communications, as more vessels can be observed and information better tailored to their situation can be passed; vessels also have more information about each other and may communicate with each other more often.

Some use of AIS transmit capability has been made to date. In the United States, this is primarily limited to transmission of meteorological and hydrological

information and lock procession order at one VTS location. The initial use of this capability resulted in problems with shipboard equipment (such as multiple messages being received and the AIS MKD alarming and requiring operator acknowledgement). Working closely with a relatively homogenous vessel user group, these problems were addressed, but use of this functionality in other VTS areas was discontinued until these problems could be worked out universally.

POTENTIAL EXPANDED USES OF AIS IN VTS

There are three general areas where expanded use of AIS capability can be applied within VTS: (1) dissemination of information the VTS currently communicates via voice radio or other means, or doesn't disseminate at all due to communications limitations; (2) telcommanding AIS equipment aboard vessels in order to accomplish the VTS mission of enhancing navigation safety; and (3) using AIS capability to perform some VTS functions, potentially moving toward what has been called "silent VTS."

An example of the first type of capability is the dissemination of meteorological and hydrological information, i.e., weather and water information. Currently VTSs provide this information to mariners in a limited manner, when requested or on scheduled voice broadcasts. This takes up valuable radio time and is subject to human error and potential misunderstanding with garbled transmissions. There is also a delay between the time the measurement is taken by the met/hydro sensor, quality checked, then presented to the VTS operator in a form for transmission via voice. Additionally, the VTS operator must wait for an available time to make the broadcast. The use of AIS binary messages to transmit this information would allow much of this process to be done automatically, allow for robust quality assurance, provide data from more sensors more frequently, and potentially provide it at the request of the mariner. In the United States, the National Oceanographic and Atmospheric Administration (NOAA) has partnered with local stakeholders to install and operate suites of meteorological and hydrological sensors and make the data gathered from them available via various means, including internet web services. This system is known as the Physical Oceanographic Real-Time System or PORTS® (http://tidesandcurrents.noaa.gov/ports.html).

The second type of capability, to telecommand shipboard AIS equipment, may be useful in areas such as Louisville, Kentucky. The Coast Guard operates a VTS on the Ohio River in the vicinity of Louisville to control vessel traffic during high-water periods. At high water, vessels need to proceed one at a time along a narrow track to avoid being carried into danger by strong river currents. In order to monitor their progress, the VTS currently uses voice reports from the vessels and television cameras placed at critical locations along the river. AIS capability is currently being installed to assist in monitoring these transits; however, the speed of the vessels in this area will be slow enough that the AIS will only provide a position report automatically approximately every 10 seconds. In order for the VTS to more closely monitor these vessel's transits, an AIS telecommand will be transmitted to vessels in the critical part of the river instructing their shipboard equipment to transmit position

reports every 2 seconds. Ideally this capability will be automated, such that vessels in a pre-defined area, transmitting at a slower rate than required would automatically be telecommanded to change rate, without the intervention of the VTS operator. The vessels would also automatically be telecommanded to shift back to their default rate once out of the area.

The third means of using AIS capability in VTS is to use AIS to perform some VTS functions that are currently done manually, primarily via voice communications by VTS operators. A simple example of this might be the use of AIS to automatically repeat or rebroadcast the positions of vessels the VTS is tracking via AIS or other means. This would allow vessels to "see" other vessels of interest that are located too far away to be detected by their navigation sensors. This could be accomplished by having the VTS AIS automatically repeat all AIS targets it receives and rebroadcast as "pseudo AIS" targets those the VTS is tracking via other sensors. A more sophisticated arrangement would allow the VTS operator to designate specific VTS targets to be rebroadcast or directly transmitted to certain vessels, potentially augmenting or replacing the "VTS traffic advisory" function. Another form of active traffic management is the queuing or ordering of vessels through a narrow channel or structure such as a lock or bridge. AIS could be used to broadcast lock order or narrow channel passage assignments. A substantial concern with using AIS capability to replace or augment current voice-based operations is the requirement for some means to ensure that the mariner aboard a vessel receiving this critical information, advisory or direction actually received and understood it. With current procedures this is accomplished through voice acknowledgement, but with AIS there is currently only acknowledgement that the message was received by the AIS equipment aboard, and not that the navigating officer received and comprehended it.

In addition to such operational concerns, there are a variety of technical and policy challenges that must be addressed as the expansion of AIS use is considered. From a technical perspective, the additional load that may be placed on the AIS VHF data link needs to be considered. Initial studies by the USCG Research and Development Center indicated sufficient capacity on the VDL except in areas of very dense AIS vessel traffic (Pietraszewski). However, this study primarily focused AIS on communications between vessels. The reliability of being able to send and receive non-vessel AIS messages (i.e., binary applications) is less understood and may limit the usability of binary applications in areas with dense AIS traffic. More extensive use of AIS base stations will require close coordination between adjacent base stations to ensure they do not interfere with each other and that their use of slots on the VDL is managed efficiently.

From a policy perspective, a major issue is that there are no requirements for shipboard carriage of an AIS display or interface beyond the minimal keyboard and display (MKD). The MKD only allows for limited text information to be displayed; for the advanced AIS capabilities under consideration AIS information will need to be displayed graphically, preferably on an electronic charting system (ECS) or electronic charting display and information system (ECDIS). Binary applications require specific software to be available on the ECS, ECDIS or other shipboard presentation in order to decode and display the information to the mariner. This equipment must

be compatible with AIS and other shipboard equipment and readily available for installation. Consideration may need to be given to mandating the carriage of such equipment and software if the advanced capabilities of AIS are to replace any current VTS services.

EFFORTS UNDERWAY TO EXPAND AIS USAGE

The U. S. Coast Guard, in cooperation with NOAA, the Army Corps of Engineers (ACOE) and the Committee on the Marine Transportation System (CMTS), has begun efforts to develop expanded AIS capability. The USCG Research and Development Center established a project in 2007 to implement AIS transmit capability within VTS. There are three main efforts associated with this project. First, a requirements study was conducted (Gonin, 2007). This study gathered high-level requirements from various AIS transmit capability stakeholders, including data providers, data users, mariners, the navigation equipment manufacturers and others. Through a series of interviews, site visits and other outreach, the study cataloged dozens of discrete user needs. The study also looked at existing AIS binary message guidance (IMO, 2004) and input from the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Vessel Traffic Services committee (IALA, 2007). This requirements study found that the information needs could be grouped into three general areas: environmental (e.g., meteorological/hydrological), area-related (e.g., locations of hazards, restricted areas) and waterways management information (e.g., vessel queuing, lock procession order). The results of this study have guided the efforts of the overall project and determined the course of action for test bed and demonstration projects.

A second effort was to establish a test bed for specific capability. As various AIS capabilities are developed to meet the needs identified in the requirements study, they are implemented in a limited, controlled manner in an operational setting. The VTS in Tampa, Florida was selected as the test bed, due to its relatively low level of AIS density, the accessibility of the AIS equipment and the cooperation of the local maritime community. The Tampa Bay Pilots use specific software to assist them in navigating vessels through Tampa Bay. They agreed to modify this software to decode and display the information in the binary messages sent by the VTS and provide feedback on their usefulness. The first capability to be tested was development of a new environmental message to transmit data from the PORTS® locations in Tampa Bay. This testing began in September 2008 and was very successful, with positive feedback from the pilots. The capability has subsequently been implemented in the Columbia River and it is planned to be implemented at other VTS areas where there are PORTS® sensors available in early 2010.

During the completion of the requirements study it became apparent that a means was needed to tap into the experience and expertise of stakeholders and experts on use of binary applications. It was decided to establish a working group, and in order to provide structure and linkage to similar AIS work, the working group was established under Special Committee 121 (SC 121) of the Radio Technical Commission for Maritime Services (RTCM). The goals of the working group are to

review current VTS AIS capability within US waters, review the potential uses of AIS transmitted messages as part of an expanded VTS AIS capability, identify both the challenges and opportunities associated with this capability, to recommend new or revised AIS transmit/broadcast messages suitable for regional and international implementation and identify changes needed for AIS equipment to support new/expanded capabilities (RTCM, 2007). The working group membership consists of representatives from government agencies, manufacturers, end users, AIS technical experts and other stakeholders who can help in the development of this capability. The workgroup has played an important role in coordination with international bodies and other national authorities. These efforts achieved success in the summer of 2009 when, in coordination with the IMO Correspondence Group on binary messages, several of the messages developed by the workgroup were successfully submitted to IMO for international adoption.

CONCLUSION

The expanded use of AIS capability holds great potential to improve to level of services provided by VTS. AIS transmit capability may be used to provide expanded information that VTSs currently provide via voice or not at all, use telecommand functions to improve VTS operations and potentially automate, augment or replace certain VTS procedures. Several technical, operational and policy challenges and issues must be addressed in considering implementation of this capability. The U. S. Coast Guard is working to develop this expanded AIS capability and to address these issues in cooperation with stakeholders. Development, testing and evaluation of these capabilities is underway at a test bed in Tampa, Florida and several demonstration projects elsewhere in the United States. Most testing has been focused on transmission of information via AIS, however future work will hopefully include testing of the telecommand capabilities and use of the technology to augment or replace certain VTS functions currently accomplished through VHF voice radio communications. As the capability is implemented and proved useful in VTS areas, it is anticipated that it will be expanded for use in areas without VTS, in order to provide additional services to mariners, based on their user needs.

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