Paper 42 - AIS next generation – the development of the VHF Data Exchange System (VDES) for maritime and inland navigation

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ABSTRACT: The Automatic Identification System (AIS) has been introduced by IMO in 2002. Since then, it has been successfully used in maritime and inland navigation for collision avoidance, as a VTS tool, as an aid to navigation, as a tool to support search and rescue and for satellite detection of ships. However, due to the expanding need of data exchange it is to be feared that the AIS radio link might be overloaded in the near future. Therefore, the next generation of AIS has been developed: the VHF Data Exchange System (VDES). Its features, possible applications and the road map for its development are described.

1 AIS – A SUCCESSFUL INTRODUCTION

The Automatic Identification System (AIS) has been successfully introduced by the International Maritime Organization (IMO) for maritime navigation in 2002. Since then, more than 100 000 commercial ships and recreational vessels have been equipped with AIS. AIS is widely used in many applications in maritime and inland navigation: AIS Class A is an IMO carriage requirement for maritime shipping according SOLAS Chapter 5. AIS Class B is used for pleasure craft and smaller vessels. AIS Search and Rescue Transmitter (SART) and AIS Man Over Board Device (MOB) are used for search and rescue purposes: AIS AtoN stations are used to equip aids to navigation (AtoN). AIS base stations and AIS repeater stations on shore provide the infrastructure for shore based applications like Vessel Traffic Services (VTS), River Information Services (RIS), traffic surveillance and ship reporting systems. Via satellite detection AIS is also used for global tracking of ships. In European inland waterways Inland AIS is used, which serves the specific needs for inland navigation while maintaining interoperability to maritime AIS.

Further, AIS has some capability for the exchange of safety and navigation related data between ships and between ship and shore. This functionality is known as Application Specific Messages (ASM) and can be used to send – for example – meteorological and hydrographic data, area notice, safety messages, route information or lock information.

However, recognizing the potential of ASM and considering the development of e-Navigation and River Information Services, additional possibilities for data exchange between ships and between ship and shore are required beyond the capability provided by AIS.

The expanding use of the AIS technology has already caused a significant load on the capacity of the VHF Data Link (VDL). First indications show an emerging high VDL loading in areas like Gulf of Mexico (64% channel load), Korea and Japan (almost 40% channel load). However, the introduction of new applications like e-Navigation or new or extended River Information Services with the expected additional need for digital data exchange has yet to come. The existing AIS will not be able to cope with this expanding need for navigation and safety related digital communication, therefore there is a need to allocate additional channels in order to allow for future developments.

The next generation of AIS – internationally called the VHF Data Exchange System (VDES) – will take into consideration the requirements for more data exchange capabilities. Thereby, the AIS radio channels (VHF Data Link VDL) will be protected from overload as AIS populations increase. First signs of AIS channel overload were seen in some busy areas like big seaports or areas

with a high amount of recreational vessels using AIS.

International organizations like the International Telecommunication Union (ITU), the International Maritime Organization (IMO) and the International Association of Maritime Aids to Navigation and Lighthouse Authorities (IALA) have recognized the growing use of AIS as well as the increasing need for data communication. Therefore, they have started the development of the next generation of AIS – the VDES. VDES will include the original function of AIS; it will provide extra channels for Application Specific Messages as well as additional functions of higher data exchange capability considering requirements for data communication like data protection or the assurance of data delivery. The VDES will provide terrestrial data communication as well as satellite components using VHF radio channels.

2 THE CONCEPT OF VDES

VDES aims for protecting the original functions of AIS while providing additional capacity for a wide range of applications in maritime safety communication. VDES is intended to be a globally available digital data exchange system dedicated to maritime safety, security, efficiency and the protection of the environment.

VDES has the potential to support maritime data communication, e-Navigation, River Information Services and possibly the modernization of GMDSS (Global Maritime Distress and Safety System).

VDES is a technological concept utilizing terrestrial and satellite radio communication links in the VHF maritime mobile band to facilitate globally interoperable digital data exchange between ships, between ships and shore, between shore and ships and between ship and satellite.

The concept of VDES comprises the functions of the existing AIS, an additional communication link for the exchange of Application Specific Messages (ASM) and an additional communication link enabling higher capacity VHF digital data exchange (VDE). The concept includes terrestrial radio communication links as well as the satellite radio communication links in the VHF maritime mobile band.

Figure 1 explains the various functions of the VDES providing a robust data exchange between ships, shore and satellite.

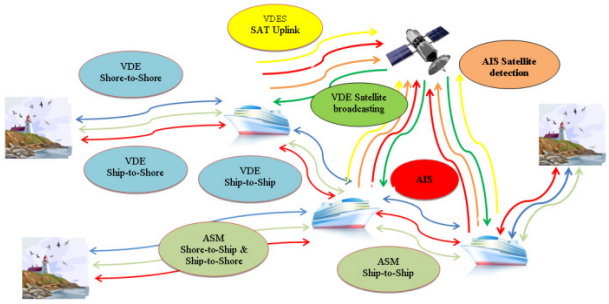

Figure 1: VDES functions for data exchange between ships, shore and satellite.

The functions of the VDES can be summarized as follows.

2.1 Automatic Identification System

The existing Automatic Identification System (AIS) as defined by IMO and ITU will be kept unchanged in its original purpose to provide identification and navigation data to support ship to ship collision avoidance, VTS, tracking of ship and locating in search and rescue. AIS position reports and ship data reports, AIS AtoN message and AIS SART messages will stay on channels AIS 1 and 2. For long range tracking of AIS channels 75 and 76 are used.

The existing ASM on the AIS channels will be gradually moved towards the new ASM channels to ease the channel load for the original AIS functions.

2.2 Application Specific Messages

The function of Application Specific Messages (ASM) is known from the existing AIS. ASM provides a kind of container for data which are supplied by external applications. The data structure and its interpretation must be known by the recipient to be able to decode and understand the content of the ASM.

IMO has defined several international Application Specific Messages like meteorological and hydrographical data, area notice or route information. In addition, regional defined ASM are used, e.g. in St. Lorenz Sea Way and in inland navigation. The use of ASM is slowly growing. With the introduction of e-Navigation and the increasing use of River Information Services the use of ASM is expected to rapidly increase due to the expanding need for digital data exchange.

VDES will provide ASM channels that might have higher capacity than AIS, however, the data structure of the messages shall remain as defined in AIS. This will allow for gradual transfer of existing ASM from the AIS channels to the new VDES ASM channels.

Utilizing the higher capacity of the ASM channel may allow acknowledging the reception of ASM and thus enabling an automatic delivery assurance of the ASM.

All new ASM and gradually all existing ASM should be transmitted on the VDES ASM channels.

2.3 VHF Data Exchange terrestrial

The VHF Data Exchange terrestrial (VDE terrestrial) will facilitate a seamless data exchange to enhance digital radio communication beyond the capabilities of ASM.

VDE terrestrial will enable a two way terrestrial data exchange between ships and between ships and shore in coastal coverage areas. The VDE may provide up to 32 times higher capacity than AIS. This will allow for data exchange which is not bound to the message structure of ASM. It will enable a whole range of new applications which may require data exchange of higher volume.

2.4 VHF Data Exchange by satellite

The VHF Data Exchange by satellite (VDE SAT) will provide data exchange between ships and shore via satellite. This will enable a global coverage of the VHF data exchange. VDE SAT should complement the VDES terrestrial outside the coast station coverage area. This will extend the VDES coverage to high sea, to polar regions and to remote areas, where no shore infrastructure is available.

2.5 VHF Data Exchange satellite reception (satellite uplink)

Like the satellite reception of AIS today, satellites which are equipped with the appropriate VDES receivers can receive data exchange transmissions from the ships.

For AIS and ASM this will be most likely the reception of the regular terrestrial transition. For satellite reception of VDE transmissions an optimized protocol for satellite reception might be used to ensure a robust data exchange from ship to satellite.

VDE transmission received by satellite (satellite uplink) will be forwarded from the satellite to a ground station on earth and from there further to the shore based user.

2.6 VHF Data Exchange satellite transmission (satellite downlink)

VDES will provide the capability for data transmission from satellite to one or more ships. VDES satellite transmission will allow sending data to ships at high sea, in remote areas or in the polar region.

The capability of satellite reception and satellite transmission of VDES has the potential to provide a mechanism to ensure high confidence of data delivery through the acknowledgement of message reception by ships or by satellite depending on the direction of the data exchange.

Table 1 provides a summary of the different functions of VDES and their envisaged functionality.

VDES functions	VHF Data Communications		AIS	
	ASM	VDE	AIS for safety of navigation	AIS long range
Functionality	• Marine safety information • Marine security information • Short safety related messages • General purpose information	• General purpose data exchange • Robust high speed data exchange • VDE satellite communi-cations	• Safety of navigation • Maritime locating devices	• Satellite detection of AIS • Locating during SAR
Applications	• Area warnings and advice • Meteorolo-gical and hydrogra-phic data • Traffic manage-ment • Ship-shore data exchange • Channel manage-ment	• High message payload • Satellite commun-ications	• Ship to ship collision avoidance • VTS • Tracking of ships • Locating in SAR • VDL control (by Base Station)	• Detection of vessels by coastal states beyond range of coastal AIS base stations
Message types	• IMO SN.1/ Circ.289 international application specific messages • Regional application specific messages • Base Station		• Vessel identifi-cation • Vessel dynamic data • Vessel static data • Voyage related data • Aids to Naviga-tion • Base Station	• Long range detection of AIS
Radio channels (proposed)	• Proposed channels 27 and 28 (simplex)	• Proposed channels 24, 84, 25, 85, 26, 86	• AIS-1 and AIS-2 (simplex)	• Channels 75 and 76 (simplex)

Table 1: Functions of VDES and their envisaged functionality.

3 TECHNICAL CHARACTERISTICS OF VDES

At the World Radio Conference 2012 (WRC 12) the ITU has allocated a set of radio channels in the VHF maritime mobile band[i] to permit their use by digital systems. Furthermore ITU encourages studies for enhanced AIS technology applications and enhanced radio communication[ii]. This matter will be further discussed at WRC 15 under agenda item 1.16.

The VDES concept intends to use the channels permitted for digital data communication. Some of the channels are already assigned for testing future AIS applications; they are planned as ASM channels. Other channels that shall be used for VDE in the future still need assignment by ITU.

An example for a channel plan of globally available VHF radio channels for VDES is shown in Figure 2. Future studies and tests may require amendments for the final arrangement of channels.

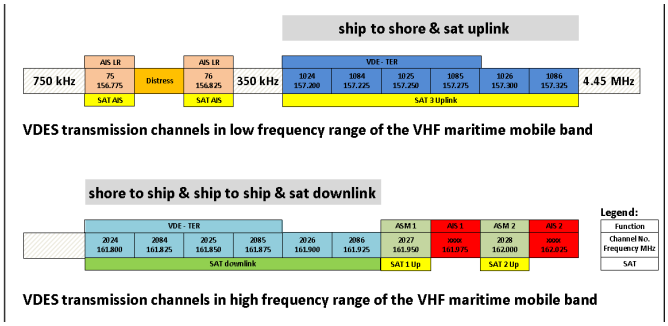

Figure 2: Example of channel designation for VDES in the VHF maritime mobile band.

Figure 2 shows the usage of VHF channels by VDES. AIS 1, AIS2, ASM1 and ASM2 are simplex channels used by ship station and shore station transmission and reception of messages. Channel 75 and 76 are used for AIS long range transmissions.

The VDE channels are duplex channels (blue colour). Four of the six 25 kHz bandwidth channels may be bundled to a 100 kHz wide band channel for higher data rate. Channels in the low frequency range of the maritime mobile band (dark blue) are used for ship station transmission. Channels in high frequency range (light blue) are used for shore station transmission as well as for ship station transmission operating in simplex mode (ship to ship data exchange). VDE channels in the high frequency range are also used for satellite to ship transmissions (satellite downlink). VDE channels in the low frequency range and the ASM channels are used for ship to satellite transmissions (satellite uplink).

The VDES concept utilises technical characteristics specified in Recommendation ITU-R M.1842[iii]. This recommendation describes general transceiver characteristics for digital data exchange systems ranging from 25 kHz bandwidth providing 43 kbps data rate to 100 kHz bandwidth providing 307 kbps.

Further considerations need to address standardized communication protocols, coverage range, robustness, channel spacing data rate and modulation schemes.

Sharing the same radio channels by all VDES participants worldwide is the most efficient use of the spectrum in the VHF maritime mobile band as requested by ITU. However, the VDES shall always give priority to AIS position reporting and safety related information and shall not impair the functions of Digital Selective Coding (DSC), voice distress and safety communication on Channel 16.

ITU-R Working Party 5B is developing a new Recommendation on Technical Characteristics for VHF Data Exchange Systems (VDES) in the VHF maritime mobile band. This recommendation will define the functions of VDES and its performance on the radio channels.

Further steps towards the implementation of VDES are needed. VHF channels need to be assigned for VDES, technical standards need to be drafted, VDES equipment needs to be developed and prototype stations need to be tested.

VDES is envisioned to play an important role for digital data exchange in safety radio communication. It will supplement existing systems like VHF voice radio telephony, DSC and GMDSS and pave the way for e-Navigation, future RIS applications and possibly the modernization of GMDSS.

VDES is not intended to be a free public correspondence service, but it can be easily complemented and expanded by commercially available data services, thus serving the needs for commercial and public communication.

4 VDES APPLICATIONS

The following section provides some examples of possible applications of VDES in maritime as well as in inland navigation. The stated examples are derived from discussions within the International Maritime Organization IMO, the International Association of Maritime Aids and Lighthouse Authorities IALA and the European River Information Services Expert Groups for inland navigation.

Since VDES is designed to be a higher speed, robust and global data exchange system in VHF

band, the most possible application is e-Navigation that is aimed to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment. However, VDES is not limited to e-Navigation only. The capability of VDES will also enhance River Information Services in inland waterways and improve other activities such as efficiency of shipping and logistics.

5 VDES APPLICATIONS IN E-NAVIGATION

In 2010, IMO defined the following international AIS Application Specific Messages[iv]:

- Number of persons on board
- VTS-generated/synthetic targets
- Clearance time to enter port
- Marine traffic signals
- Berthing data
- Weather observation report from ships
- Area notice – broadcast
- Area notice – addressed
- Extended ship static and voyage-related data
- Dangerous cargo indication
- Environment
- Route information – broadcast
- Route information – addressed
- Text description – broadcast
- Text description – addressed
- Meteorological and hydrographic data
- Tidal window

In the development of its e-Navigation strategy IMO has defined three potential solutions which will benefit from the VDES:

- Means for standardized and automated reporting (S2)
- Improved reliability, resilience and integrity of bridge equipment and navigation information (S3)
- Improved communication of VTS Service Portfolio (S9)

Standardized and automated reporting (S2) can be supported by two ASMs, "Extended ship static and voyage-related data" and "Dangerous cargo indication". The ASM "Extended ship static and voyage-related data" contains various information such as air draught, last port of call, SOLAS equipment status, VHF working channel, type of bunker oil. The ASM "Dangerous cargo indicator" contains amount and type of dangerous cargo using IMDG code, IGC code, BC code or MARPOL list. Therefore these two ASMs will be directly converted to VDES applications and, if necessary, additional information, for example ISPS code, will be incorporated into the application.

However, in order to exchange such information by VDES, security should be considered. AIS has been designed as an open system and thus it is difficult or even impossible to secure its data. By using VDES, protection of data will become possible by encryption or authentication.

There are many ASMs for improved reliability, resilience and integrity of bridge equipment and navigation information (S3). For instance, the ASM "Meteorological and Hydrographic data" provides weather data in an internationally standardized form. Other ASMs such as "Clearance time to enter port", "Marine traffic signals", "Berthing data", "Area notice", "Environment", "Tidal window" are also useful for navigation information- These -ASMs will also be directly converted to VDES applications.

Regarding improved communication of VTS Service Portfolio (S9) there are two ASMs: "VTS-generated/synthetic targets" and "Route information". The ASM "VTS-generated/synthetic targets" can transmit four targets in one message using two slots. VDES will be able to increase the number of the targets in one message. The ASM "Route information" can transmit 16 way points in one message using five slots. VDES will also be able to increase the number of the way points.

6 VDES APPLICATIONS IN GMDSS

VDES has also the potential to become a useful and valuable tool in the future GMDSS, especially for the promulgation of MSI and assistance to SAR operation.

Since ASM "Area notice" already has the capability of transmitting and receiving Maritime Safety Information (MSI) in machine readable format, VDES may support this functionality, especially the function of Navigational Warning and Notice to Mariners. The ASM "Area notice" can draw a circle, rectangle, sector, polyline or polygon with associated text on a navigational display. VDES will be able to draw a more complex shape or figure using its higher speed data transmission capability. With regard to this possible application, using VDES satellite downlink capability, it will also be possible to inform ships of the ice boundary in polar areas for the safety of navigation.

The ASMs "Number of persons on board", "Extended ship static and voyage-related data" and "Dangerous cargo indication" will provide useful and valuable information to search and rescue (SAR) operation. VDES application will be able to include the same information and to improve it by additional necessary or supplemental information of SAR operation such as SAR pattern.

7 VDES APPLICATIONS IN RIS

In the framework of RIS and the use of Inland AIS in Europe several inland application specific messages are defined which may benefit from VDES, i.e.:

- Estimated Time of Arrival (ETA) at lock/bridge/terminal
- Requested Time of Arrival (RTA) at lock/bridge/terminal
- Weather warnings (EMMA)
- Water level
- Signal status
- Inland number of persons on board

In addition to those already defined messages further inland application specific messages are in development by the European Vessel Tracking and Tracing Expert Group:

- Bridge clearance message
- Standardized Safety-Related Message (SSRM)
- Convoy message

The ETA message might be sent from ship to shore (lock, movable bridge or terminal) in order to inform that the vessel is heading towards the object and desires handling (locking, passing, berthing, transhipment, etc.) at the submitted date and time.

The RTA message might be sent as an answer from the shore location to the vessel to confirm the requested time of arrival or to propose a different schedule. An RTA message might also be solely initiated by a shore application, e.g. a lock, to inform the addressed ship of the requested time of arrival.

The EMMA warning might be used to warn shippers on the ECDIS screen of heavy weather conditions. It will not replace the Notices to Skippers warnings. This message might be used locally.

The Water Level message might be sent from shore only, to give water level information to all vessels in a certain area. This message should give actual values of the current water level in the area of interest in which the vessel is navigating.

The Signal Status message might be sent by base stations only to inform about the status of different light signals to all vessels in a certain area.

The Bridge Clearance message might be sent by a shore station to inform about the minimum vertical clearance of a certain bridge opening.

The Standardized Safety-Related Message (SSRM) might be sent by shore station information about unplanned incidents of temporary nature in a certain area on the waterway.

The Convoy Message might be sent by vessels sailing in pushed convoys to inform about the size and the outline of the convoy. The main target group are lock operators to receive barge IDs and convoy outline in advance. Also logistics users could benefit from the possibility of tracking single barges.

VDES is suitable for transferring tactical information regarding the vessel's navigation or the efficiency of the voyage. Information which needs to be up to date as well as information on short notice are suitable to be provided using VDES. This is in port areas and waterways with well-established shore base infrastructure as well as in remote areas via satellite communication.

In the course of the introduction of VDES it can be expected that many other application specific messages will be defined as soon as the benefits of an established machine to machine communication between ships and between ship and shore is fully understood.

8 OTHER VDES APPLICATIONS

Besides its contribution to e-Navigation, GMDSS and RIS, VDES will contribute to the efficiency of shipping and other purposes.

The ASM "Weather observation report from ships" automatically sends a weather report observed by a ship navigating on sea. Then the shore authority collects the report via satellite. At present, a lack of appropriate connection between AIS and weather sensor or measuring device onboard prevents the usage of this message. As the ocean largely affects world climate, collecting more data of ocean weather will significantly contribute to the prediction of climate change and thus to the protection of marine environment. If VDES is equipped with a port to connect a weather sensor or a measuring device, this application will become very helpful to automatically collect the data of the ocean.

The ASM "Berthing data" sends useful information of berthing such as water depth, length, mooring position, type of service available to a ship from the shore authority. VDES will be able to send more data or information regarding the berthing and it will be useful for the efficiency of navigation.

Another new possible application of VDES is remote sensing of a ship or of the equipment condition of a ship via satellite. Using this application, manufacturers will be able to monitor the ship or its equipment from shore side and might prevent a failure of the ship or its equipment in advance.

9 COORDINATION OF APPLICATIONS

As mentioned above, VDES will be able to accommodate various applications, that will contribute to the implementation of e-Navigation and RIS. However, in order to utilize these possible

applications, the key element is not only VDES. The integration and presentation of available information in graphical displays received via communication equipment is also a very important aspect for the success of VDES. Therefore the development of VDES should be coordinated and harmonized with the development of the appropriate displays for the applications like e-navigation and RIS.

10 ROADMAP AND TEST BED

A possible roadmap of the development and implementation of VDES is shown in Figure 3 as drafted by IALA.

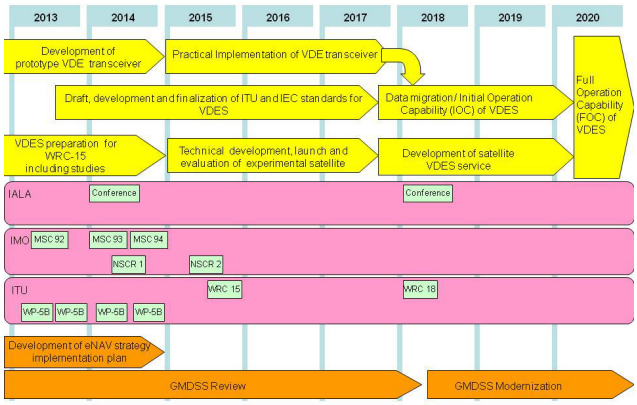

Figure 3: Possible Roadmap for VDES.

As shown in this roadmap, VDES will be implemented in two steps, terrestrial and satellite. For the terrestrial part, some radio manufacturers are developing prototype VDES radios for field tests including sea trials. Simultaneously, studies will prove that the satellite VDES will not interfere with other land VHF communication. The results of those studies are submitted to World Telecommunication Conference 2015 (WRC-15) and, if appropriate, WRC-15 will allocate new frequencies for VDES.

Assuming the new frequencies allocation, the development of VDES standards by ITU and IEC will be started. During the development, it is important to evaluate the usability of VDES. VDES test beds will be conducted similar to e-Navigation test beds such as EfficienSea project, MONALISA project and ACCSEAS project. To cover as much aspects as possible of VDES, the different test beds should be coordinated and harmonized. The IALA e-Navigation Committee has already started to develop the basis for the coordination and harmonization.

One of the major events in the development of VDES will be the launch of experimental satellites for VDES. By the means of these experimental satellites, the technical features of satellite VDES communication will be established.

For the terrestrial VDES, shore stations will be constructed to cover littoral VDES communication, since one of the important roles of VDES is to exchange digital data between shore authorities and ships. Like AIS shore infrastructure, VDES shore stations will be set up gradually to cover busy areas first and, in the course of the introduction of e-Navigation communication, it will be networked regionally, nationally and even internationally. After the establishment of VDES shore station network, VDES will be given the initial operation capability (IOC) and ships will be able to receive numerous data containing various important information for the safety and efficiency of navigation in littoral area by 2018.

Compared with the terrestrial VDES, the satellite VDES may need more time for the implementation. In order to ensure world-wide coverage in nearly real time, several satellites including polar orbit satellites for the coverage of remote region will be needed along with the establishment of earth stations. Since the operation of these satellites will require coordination, a coordination body should be established. This body will be connected to the VDES shore station network. So the full operation capability (FOC) of VDES will be established. If things go well, the FOC of VDES will start in 2020.

11 CONCLUSION

The VHF Data Exchange System has the potential to play a major role in digital radio communication for shipping and thus become a cornerstone for the introduction of e-Navigation, GMDSS and River Information Services. VDES integrates the function of AIS, ASM and VDE using terrestrial and satellite communication and is capable of facilitating numerous applications for safety and security of navigation, efficiency of shipping and the protection of the maritime environment. Along with the development of the technical characteristics of VDES, applications and other relevant features need to be developed based on user requirements.

VDES will ensure a harmonized and standardized digital data exchange system and those will be a further step into the digital world of maritime communication.

[i] ITU Radio Regulation Appendix 18 "Table of transmitting frequencies in the VHF maritime mobile band"

[ii] ITU Resolution 360 (WRC12) "Consideration of regulatory provisions and spectrum allocation for enhanced Automatic Identification System technology applications and for enhanced maritime radiocommunication"

[iii] Recommendation ITU-R M.1842 "Characteristics of VHF radio systems and equipment for the exchange of data and electronic mail in the maritime mobile service RR Appendix 18 channels"

[iv] IMO SN.1/Circ.289 "Guidance on the use of AIS Application Specific Messages"