IALA GUIDELINE

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VHF DATA EXCHANGE SYSTEM (VDES) OVERVIEW

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DOCUMENT REVISION

Revisions to this document are to be noted in the table prior to the issue of a revised document.

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December 2016	First issue	Council 63
December 2017	Edition 2.0 Updated to reflect technical developments in VDES and to reflect transmission aspects (addressed / broadcast).	Council 65
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1. INTRODUCTION

1.1. PURPOSE OF THE DOCUMENT

This Guideline provides insights into the Very High Frequency Data Exchange System (VDES). It gives information about the development of the VDES, the concepts of VDES, the role within the e-Navigation concept of IMO and the potential of VDES in the maritime environment and the use cases supported by VDES.

The document is intended to assist in the understanding, integration, further development and promotion of VDES in the maritime domain.

1.2. BACKGROUND

The World Radiocommunication Conferences 2015 and 2019 revised Appendix 18 of the Radio Regulations, the VHF maritime radio frequency band, to designate frequency channels to be used for VDES in accordance with the most recent version of Recommendation *ITU-R M.2092* [1]. These VDES channels were duplex channels with two bands separated by 4.6 MHz, where both bands are used to facilitate VDES communications between ships, shore stations, and satellites.

Automatic Identification System (AIS) is well recognized and accepted as an important tool for safety of navigation and is a carriage requirement for SOLAS vessels (Class-A) [2]. With increasing demand for maritime VHF data communications, AIS has become heavily used for maritime safety, maritime situational awareness and port security. As a result, overloading of AIS 1 and AIS 2 created a need for additional AIS channels. Using the VHF marine band (International Radio Regulations Appendix 18) [3] AIS can broadcast data to vessels in the vicinity of the AIS unit. AIS can also transmit an addressed message.

International Telecommunications Union (ITU) has recognized the efficiency and the necessity for digital communications at sea. ITU, therefore, has produced technical standards and revised the VHF marine band [3] to designate channels for data transmission. It is recognized that both analogue voice communications and digital communications will share the band. The VDES, as envisioned by IALA and presented to ITU, addresses the identified need to protect AIS along with essential digital communications contributions for e-Navigation and Global Maritime Distress Satellite System (GMDSS) Modernization [4].

The VHF marine band [3] was initially used for transmission of voice communications on 25 kHz channels. The ITU introduced the first marine data transmission system, Digital Selective Calling (DSC) [5] to help ensure that calling and distress communications attempts were successful. VHF DSC transmits data at 1.2 kbps, slow by modern data standards, but very robust. At the request of the IMO to improve safety of navigation, ITU introduced another VHF data transmission system, AIS [6], which provides navigation and identification data for ships, shore stations, aids to navigation and search and rescue devices at 9.6 kbps.

ITU introduced a standard [7], with options for 25 kHz, 50 kHz and 100 kHz channels at data rates up to 307.2 kbps in order to improve spectrum efficiency in 2012. Both voice and data communications coexist in the VHF marine band. The developments in maritime radio technology, including the introduction of Software Defined Radios (SDR) coupled with enhanced capabilities for digital data exchange over existing VHF marine band spectrum resulted in the development of the VDES. VDES builds on the experience gained through the development of AIS, and provides the capability to communicate to:

- a specific vessel (addressed);
- all units in the vicinity (broadcast);
- a group of vessels (addressed); and

- a fleet of vessels (addressed).

Consequential to World Radio Conference 19 (WRC 19), Recommendation *ITU-R M.2092-1* [1]was published in February 2022.

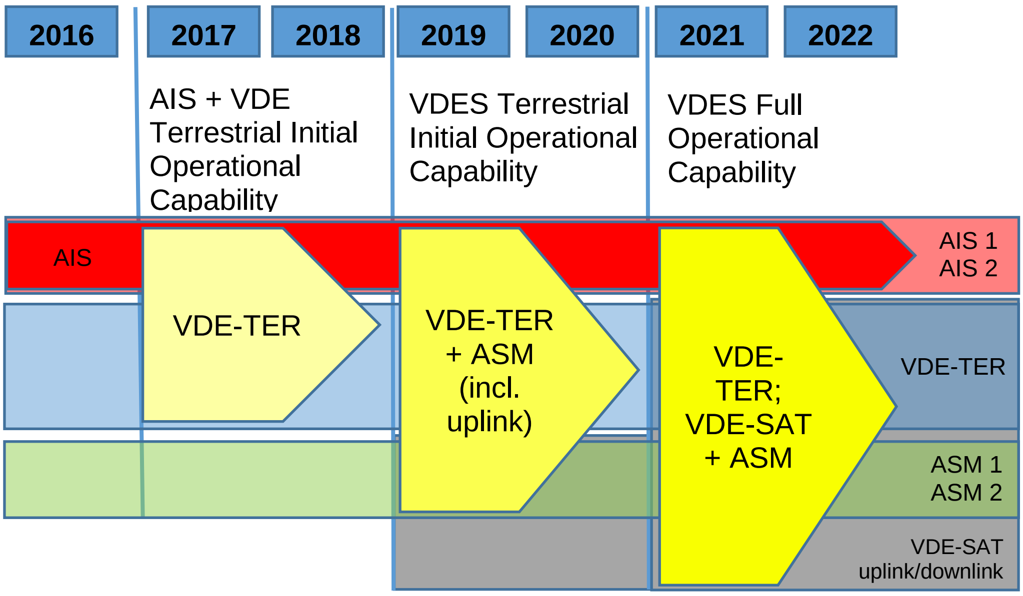

Figure 1 International availability of VDES spectrum (as ITU Radio Regulations App.18)

The introduction of VDES is expected to happen through following phases:

1 (2016) AIS exists as defined by *ITU.R M.1371-5* [6] on the AIS frequencies, and coastal stations use the Application Specific Messages (ASM) and VDE frequencies for Voice VHF.

2 (2017-2018) Post WRC-15 - AIS+ASM: Regionally, where there is an urgent need for offloading the AIS VDL from significant ASM traffic, it is recommended to allow the introduction of 4-channel AIS + ASM devices. These devices may receive and transmit ASM on the ASM1 and ASM2 frequencies, but shall discontinue their transmit capability, using the existing GMSK modulation after January 1st 2019 unless a software upgrade enables them to participate in the modulation and access scheme agreed for the ASM frequencies. Note that the ASM frequencies will need to be shared with the VHF voice service from Coast Stations in many areas during this time frame.

3 (2019) at the first of January 2019 the VDES VHF channels should only be used digital according to ITU. This led to operational problems and IMO postponed [8] the use until the 1st of January 2024. ITU decided at WRC-19 that the VDE frequencies are also available for VDE-SAT.

4 (2019-2020) Post WRC-19 operational capability established on global basis. Note that Administrations may need to coordinate their internal use of the frequencies in the transition.

5 (2021) When a satellite service is developed, full operational capability of the VDES including the Satellite component can be achieved.

6 (2022) ITU has published *ITU-R M.2092-1* [1] incorporating changes to add VDES Satellite functionality and updates consequential to feasibility tests.

7 (2024) All the VDES VHF channels shall only be used for the VDES *(MSC.1/Circ.1460/Rev.2)* [8] globally.

8 (2030) Administrations have until 2030 (footnote w) of Appendix 18 of the RR [3]) to completely vacate the VDES VHF channels from voice communications.

1.3. OVERVIEW

The VDES is seen as an effective and efficient use of radio spectrum, building on the capabilities of AIS and addressing the increasing requirements for data through the system. New techniques providing 32 times the raw data rates than those used for AIS are a core element of VDES. Furthermore, the VDES network protocol is optimized for data communication so that each VDES message is transmitted with a high confidence of reception. VDES increases the capability for digital data exchange in a manner similar to AIS, which includes provision of data to vessels in a geographic area (broadcast), to a specific vessel or a group of vessels in a geographic area (addressed) or to a fleet of vessels (addressed).

In this document, when communications from ship to shore are referenced, this includes ship to satellite to shore and shore to satellite to ship. It is noted that, following WRC-19, the full satellite capability of VDES is available. IMO *MSC.1/Circ.1460/Rev.2* [8] advises that the operational use of ASM and VDE frequencies is globally possible from the 1st of January 2024.

For simplicity, this document uses the term ship station, to refer to stations that are mobile and are not control stations. In contrast, control stations are stations coordinating the traffic of ship stations. Control stations can be coastal control stations, or satellite control stations, but follow, largely and for the sake of this document, the same basic concepts.

2. GENERAL DESCRIPTION

The VDES should improve the safety of life at sea, the safety and efficiency of navigation, and the protection of marine environment and enhance maritime safety and security. These goals will be achieved through efficient and effective use of maritime radiocommunications, incorporating the following functional requirements:

1 As a means of AIS.

2 As a means of radiocommunications equipment through exchange of digital data between ship to ship, ship to shore including satellite, via AIS, ASM and VDE.

3 As a means of applications external to the VDES equipment itself. These applications use AIS, ASM or VDE separately or combined.

2.1. SYSTEM CONCEPT

The VDES concept was originally proposed to address emerging indications of overload of the VHF Data Link (VDL) of AIS and simultaneously enable a wider seamless data exchange for e-navigation, potentially supporting the modernization of GMDSS. VDES could support the increasing communications requirements identified through the development of e-Navigation, as documented in the e-Navigation Strategic Implementation Plan (SIP) IMO *MSC.1/Circ.1595* [9].

The purpose of e-Navigation is to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment. e-Navigation seeks to enhance maritime safety through simplification and harmonization of information. In addition, e-Navigation seeks to facilitate and increase efficiency of maritime trade and transport by improved information exchange.

The VDES system concept recognizes the parallel work being carried out related to Maritime Service in the context of e-Navigation formerly known as Maritime Service Portfolio (MSP). Where applicable, these MS are referenced in this document as user requirements.

Table 1 identifies the Maritime Services in the context of e-Navigation as defined by IMO e-navigation strategic implementation plan (SIP) and their updated E-Navigation Strategy Implementation Plan - Update 1 (IMO *MSC.1/Circ.1595*)[9].

Table 1 Maritime Services, IMO update 1 - e-Navigation Strategic Implementation Plan

Service No	Service	Domain coordinating body	Identified responsible service provider
MS 1	VTS Information Service (INS);	IALA	VTS Authority
MS 2	Navigation Assistance Service (NAS)	IALA	VTS Authority
MS 3	Traffic Organization Service (TOS)	IALA	VTS Authority
MS 4	Local Port Service (LPS)	IHMA	Local Port/Harbour Authority
MS 5	Maritime Safety Information (MSI) service	IHO	National competent authority
MS 6	Pilotage service	IMPA	Pilotage Authority/Pilot Organization
MS 7	Tugs service	TBD	Tug Authority
MS 8	Vessel Shore Reporting	TBD	National competent authority and appointed service providers
MS 9	Telemedical Maritime Assistance Service (TMAS)	TBD	National Health Organization/dedicated health Organization
MS 10	Maritime Assistance Service (MAS)	TBD	Coastal/Port Authority/Organization
MS 11	Nautical Chart Service	IHO	National Hydrographic Authority/ Organization
MS 12	Nautical Publications Service	IHO	National Hydrographic Authority/ Organization
MS 13	Ice Navigation Service	WMO	National Competent Authority/Organization
MS 14	Meteorological Information Service	WMO	National Meteorological Authority/Public Institutions
MS 15	Real-time hydrographic and environmental information Services	IHO	National Hydrographic and Meteorological Authorities
MS 16	Search and Rescue Service	TBD	SAR Authorities

The system concept, including VDES functions and frequency usage is illustrated pictorially in Figure 2 (full system).

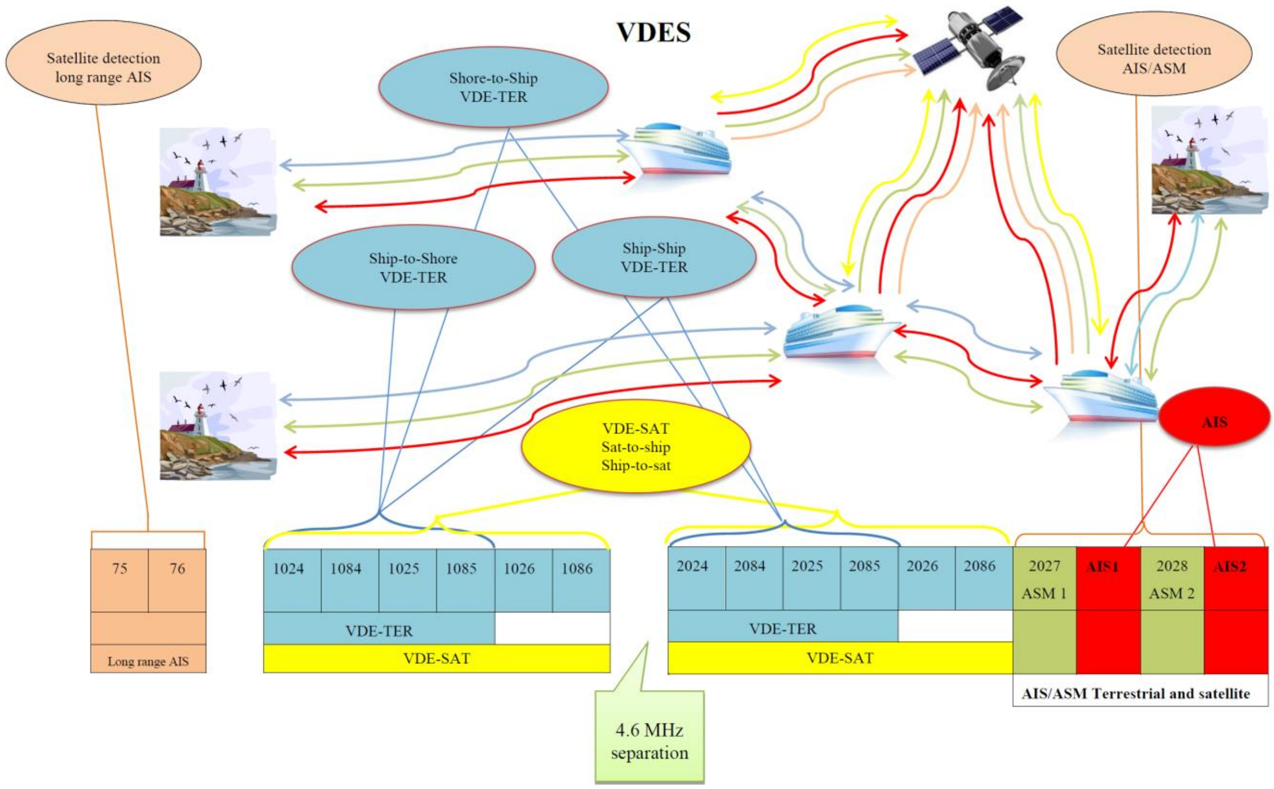

Figure 2 VDES functions and frequency use – full system

2.2. CONCEPT OF OPERATIONS

The key concept of operation of the VDES includes:

1 The VDES provides a capability of data exchange between ships and shore users by terrestrial or satellite link;

2 The operation of VDES is subject to control stations but it may operate autonomously without a shore infrastructure;

3 Data exchange from the ship may occur automatically or manually;

4 Data exchange uses the designated VHF channel(s);

5 Transmission and reception of the data occurs with the minimum involvement of ship's personnel;

6 The VDES includes existing AIS applications;

7 The VDES includes existing ASM;

8 VDES additional capabilities include support of the VDE;

9 The VDES related applications should support language independent communications (e.g., through the use of a digital data dictionaries);

10 The VDES implements data integrity monitoring at the VDES link level (e.g., check sum);

11 The VDES related applications address cyber security (e.g., authentication, key management and, if required, encryption);

12 The VDES has a high level of availability;

13 The VDES supports machine-to-machine communications (for example, interfaces with external equipment providing applications related to VDES); and

14 The VDES related applications enable clear comprehension of the information sent / received through the VDES.

The concept of operations is identified in Figure 3.

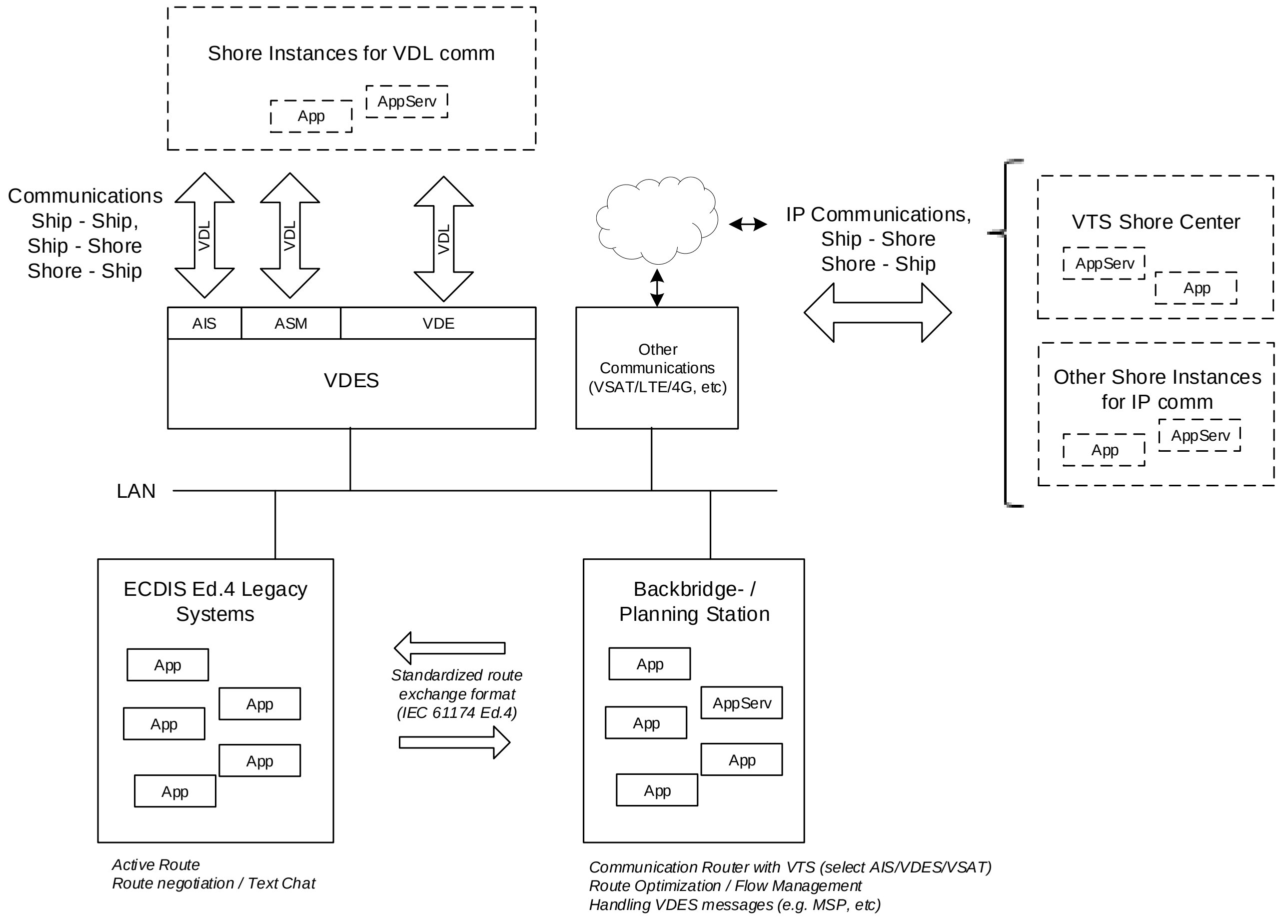

Figure 3 Concept for VDES

2.2.1. ARCHITECTURE USING MESSAGE CONTENT IDENTIFIER

In order to use VDE terrestrial or satellite messages, and being able to identify the content, following methods exist:

a) Identification of the content format and encoding by use of the VDES Source Station ID, i.e, "MSI Denmark Service S-100" uses an a-priory known encoding announced by the service authority.

b) Identification of the content format by using a 16-bit application identifier as defined by AIS for all VDE binary message content to clearly identify its format and encoding.

c) Identification of the content format using a 16-bit Protocol Format Identifier (VPFI) as described below in section 2.2.1.1.

Method (c) is the preferred method because it:

- is the most flexible and makes it possible by one VDES Station to use multiple formats from the same Source Station ID;
- allows ships directly to exchange content of different formats and encodings with other ships, clearly identified by the VPFI; and

- allows the transport of existing ASM formats and encodings, as defined by IMO and national authorities.

Therefore, this document assumes, that the VDE-TER and VDE-SAT binary messages will use the 16 bit VPFI in all applications. It should be noted that binary messages transmitted on the ASM channels will continue to use the 16-bit application identifier as defined by AIS.

2.2.1.1. VDE Protocol Format Identifier Description

The VPFI will help the various on-board systems and applications identify which VDE carried data is relevant for their processing.

VPFI consists of:

- 16 bit Protocol Format Identifier
- 0-1023 internationally standardized protocol formats defined by IALA
- 1024-65535: open allocation

Table 2 identifies VPFIs identified in this document.

Table 2 VDE Protocol Format Identifiers (VPFI) identified by this document

VPFI	Protocol Format category	Intended Use
00	Cryptography related messages	Distribution of public key certificates and certificates revocation lists.
01	VDES Management Messages	Capability interrogation, SAT orbit data, etc
02	VDES Application Specific Messages	ASM channels, VDE-TER and VDE-SAT optimized application specific messages. Includes authenticated or encrypted messages. Off channel authentication of legacy AIS messages transmitted on AIS channels. Text messages supporting international character encoding such as UTF-8.
03	Encapsulated AIS Messages	Legacy AIS messages as defined in rec *ITU-R M.1371* that will use the legacy AIS PI.
04	MCP Messages	Maritime Connectivity Platform related messages
05	S-100 series data objects messages	S-100 / S-200 / S-300 / S-400 data objects
06	Global Navigation Satellite System (GNSS) Augmentation	Correction data and integrity information
07 to 1023	Reserved by IALA for future internationally standardized protocol formats	
1024 to 65535	Can be used for other operational protocol formats	For example, manufacturer defined protocols for remote monitoring of ship equipment.

For some examples of protocol format messages, see ANNEX B.

2.2.2. Security Options

Authentication of messages is an important feature which VDES can offer. Authentication ensures the authenticity of the delivered data. Authentication is not part of AIS, but the use of ASM and VDE can provide this feature. Examples of use cases that would benefit from authentication are position reports (from AIS), safety related ASMs, repetitive ASM as well as single ASM, AtoN messages.

A broadcast authentication protocol may be the TESLA (Timed Efficient Stream Loss-tolerant Authentication) RFC 4082 protocol that uses a combination of asymmetric (public key-based) and symmetric (secret key) cryptography to minimize protocol overhead to meet the VDE-TER capabilities.

2.2.3. Platforms for the provision of Maritime Services

2.2.3.1. Example: Architecture using the Maritime Connectivity Platform

VDES can be used as data transport medium in the maritime domain to support many applications.

For applications that require the section 2.2 listed key features of:

- language independent and machine-to-machine communications;
- cyber security; and
- international service discovery.

The concept of the Maritime Connectivity Platform [10] contributes with following major key building blocks:

- Maritime Identity Register (MIR);
- Maritime Service Registry (MSR); and
- Maritime Messaging Service (MMS).

The MIR is a decentral register of maritime digital communication participants and enables authenticity between individual participating parties in the maritime digital communication domain. Authentication is provided by issuing digital certificates which are associated to unique maritime resource name (MRN, see Guideline *G1143 Unique Identifiers for Maritime Resources* [11]) according to accepted vetting procedures by vetted MCP identity service providers. Participants can use the MIR as a CA to verify maritime service and other individual participants' signatures for authentication, to fetch public certificates and to update revocation lists to invalidate certificates that were reported outdated or stolen. Participants listed in the MIR are vetted by the individual MCP identity service providers to ensure their authenticity. Each participant in the maritime digital communication domain is using a list of trusted MIR servers. Relevant certificates from the MIRs are cacheable on board to allow ad hoc secure communications without requiring direct connectivity to a MIR in real time.

The MSR is a decentral register listing vetted and quality checked services with their browsable and searchable key parameters such as:

- Service MRN;
- Service Name;
- Service Topic;
- Service geographical area; and
- Digital format used.

The MMS is a concept comprised of components that allow exchange of digital "messages", i.e., arbitrary digital data, organized in a predefined known way to be used by digital applications. The MMS provides a non-synchronous data exchange, that can be realized over changing, intermittent and heterogenous digital connectivity. The MMS supports both secure IP based transport through internet connectivity and through VDE-TER and VDE-SAT connections, and thus provides a solution to fulfil the requirements to securely transport trusted services and private communication between all maritime participants who at least have VDES or IP connectivity sometimes.

The concept of operations of MMS with VDES is identified in Figure 4.

Shore services are registered in a MIR and a MSR. The ship installation holds a cached version of certificates and service entries from these, shown in Figure 4 as MIR* and MSR*. Synchronization of these ship copies of MIR and MSR should happen through MMS when broadband connectivity is available. These MIR and MSR copies on board of the ship make it possible for ship applications to discover services and provide all security features of the MMS according to the principles of MCP.

Figure 5 shows an example system architecture with shore services that connect to a ship via optional IP connectivity, that might be intermittent, and terrestrial VDE or ASM, and VDE-SAT, which all can be utilized by the MMS, dependent on the availability.

The ship MMS applications may utilize human machine interfaces to facilitate the display of e.g., weather, ice, routes, virtual AtoN, and many more. Also, machine to machine services like engine monitoring or weather and/or hydrographic reporting are shown as possible examples, that can benefit from hybrid network connectivity in order to collect and report data when a connection is possible.

The MMS Edge Router functionality may be external to ship communication equipment in order to independently decide which communication means is the best for the type of application, data size and priority under the current connectivity conditions on the ship and in the area.

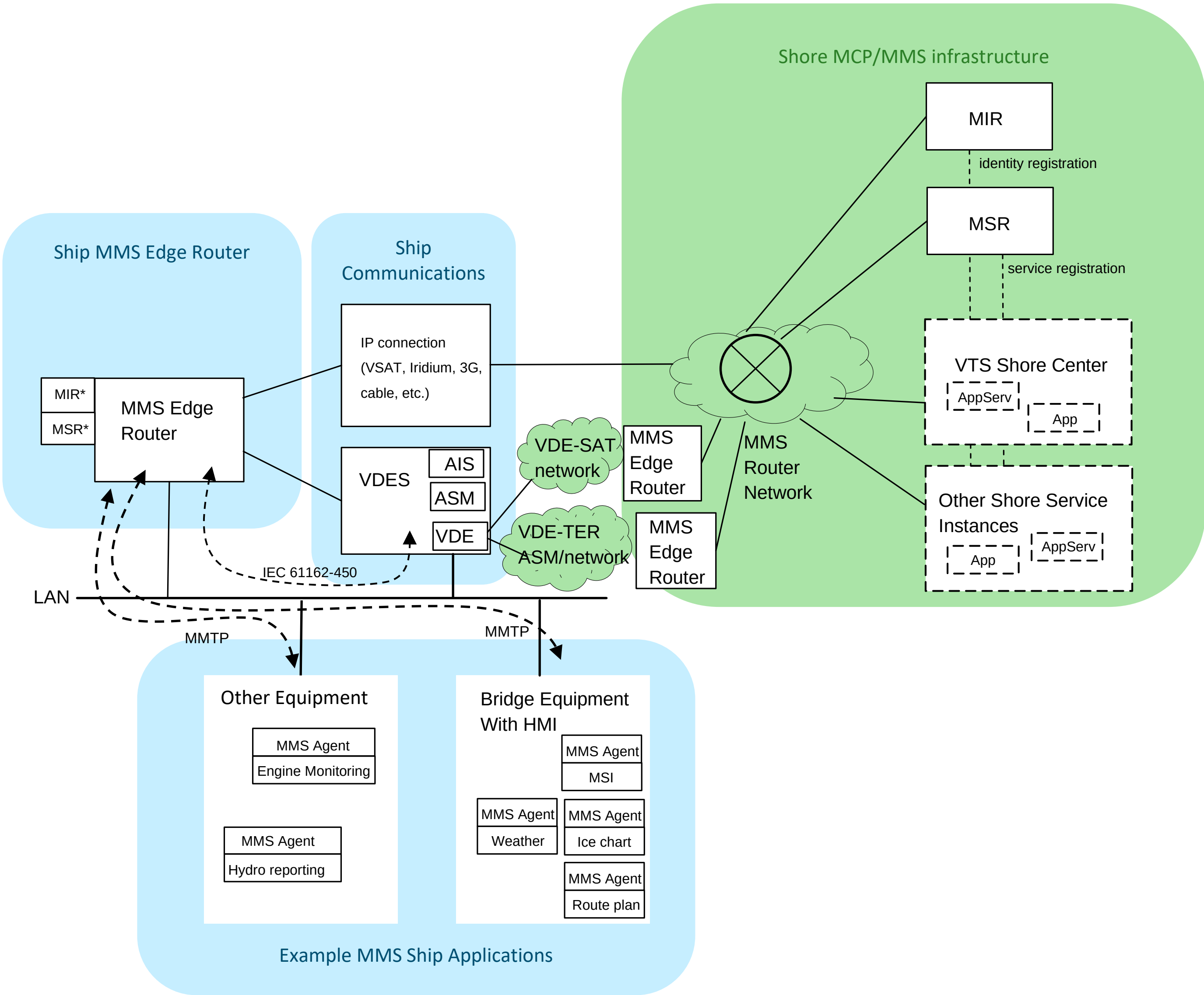

Figure 4 MMS with VDES, example System Overview

2.2.3.1.1 The MMS Architecture

In the MMS, all communication between applications happens through an application interface, the Agent, and an Edge Router to the decentralized MMS Router network.

In practice, a shipside application includes the open-source MMS Agent library, which communicates with the ship side MMS Edge Router. The shipside MMS Edge Router finds a communication link to the MMS Router Network, either:

(a) directly through an IP connection; or

(b) through non-IP networks and their respective shore side MMS Edge Routers.

The communication between the application Agents happens through these Protocols:

(a) The optional Secure Maritime Messaging Protocol (SMMP) used by applications requiring delivery and security guarantees.

(b) The Maritime Messaging Transport Protocol MMTP, used to transport MMS messages.

The basic MMS communication architecture with its components Agent, Edge Router and Router Network, and the two protocols is shown in Figure 5. For more details for MMS see ANNEX C.

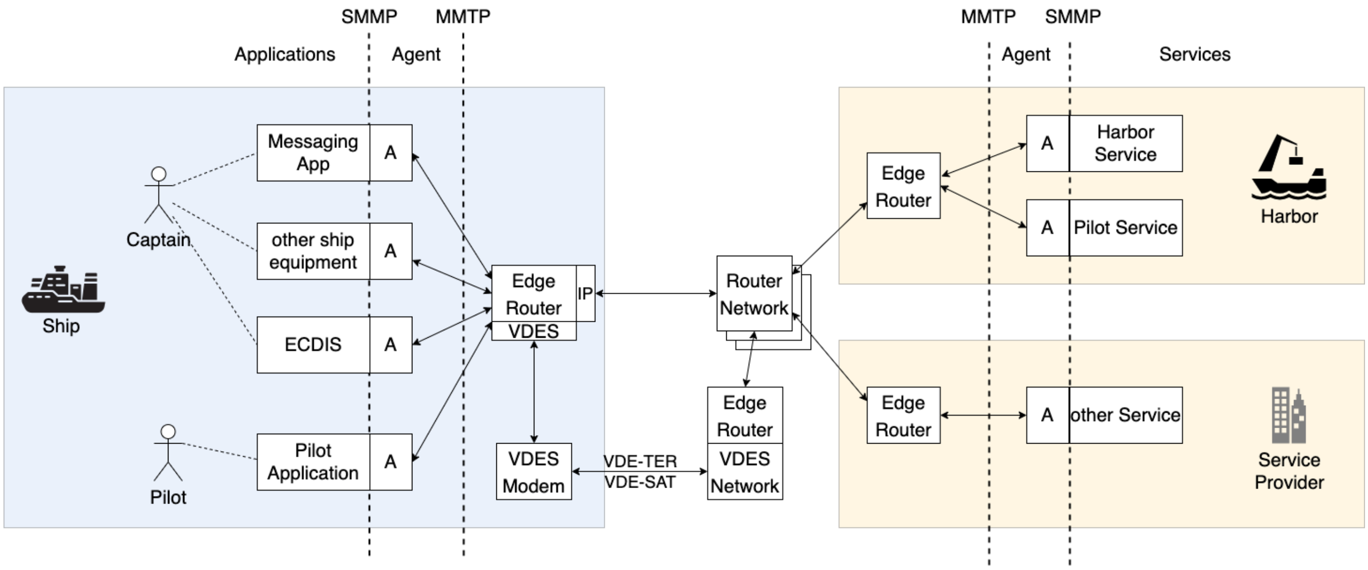

Figure 5 The MMS communication architecture with example applications

2.2.3.1.2 Status of Maritime Messaging Service

The MMS is currently under development at the Maritime Connectivity Consortium MMS Working group in 2022, to be published 2023.

The SMART Navigation project uses an early version of MMS over IP and VDE-TER, in operations since 2020/2021 in Korea, and the MARIOT project will demonstrate MMS functionality through 4G and VDE-SAT during 2023, both frequently presented at IALA ENAV conferences.

2.3. OPERATIONAL CHARACTERISTICS

The VDES operates according to Recommendation *ITU-R M.2092-1*[1], which includes the following operational characteristics:

- The system gives its highest priority to the automatic identification system (AIS) position reporting and safety related information.

- The system installation is capable of receiving and processing the digital messages and interrogating calls.
- The system installation operates continuously while under way, moored or at anchor.
- The system, for the terrestrial links, uses the appropriate time-division multiple access (TDMA) techniques, access schemes and data transmission methods in a synchronized manner.
- The system is capable of various modes of operation, including the autonomous, assigned and polled modes.
- The system prioritizes applications and adapts parameters of the transmission (robustness or capacity) while minimizing system complexity.

2.4. SYSTEM OVERVIEW

The VDES includes:

- antenna(s), capable of transmitting and receiving data through terrestrial and satellite link;
- an AIS as set out in resolution *MSC.74(69) Annex 3* [12];
- a multi-function data communication and timing process that is interoperable with AIS, ASM and VDE;
- a multi-function transmitter, capable of operating on the designated AIS, ASM and VDE frequencies;
- multi-function receivers, capable of operating on the designated AIS, ASM and VDE frequencies;
- a means to automatically input data from other sources;
- a means to automatically output data to other devices;
- a means of ensuring the integrity of the data;
- a means to automatically or manually update the device software as needed;
- functionality of a built-in test equipment (BITE); and
- GNSS receiver to support AIS and to possibly serve as a secondary source of Positioning Navigation and Timing (PNT).

2.5. ASSUMPTIONS AND DEPENDENCIES

The applications related to the VDES address the following assumptions and dependencies:

- VDES operates within the existing AIS environment.
- VDES respects and supports requirements for GMDSS communications, including SAR, urgency, and safety related messages.
- VDES applications are uniquely identified.
- The VDES related applications operate in a manner that ensures there is no unnecessary repetition of messaging.
- VDES contains AIS and may extend its capabilities.
- While AIS is used primarily for position reports, it is assumed that VDE will be used for other data communications. For ASM, AIS channels may still be used, but in high traffic areas, ASM channels are preferred.

2.6. SERVICES THAT USE VDES

The following aspects may be of help when deciding on implementation of VDES as a transport for maritime services. VDES shore station operations should consider:

- AIS system load;
- services to be provided;
- existing equipment (for existing sites);
- antenna requirements, including interaction with other services/systems;
- power requirements;
- installation costs (which may include mobile station, tower access);
- operational costs; and
- coordination with other administrations may be required.

Provision of VDES shore infrastructure may be managed through:

- a regular scheduled lifecycle process for existing AIS shore stations;
- through an upgrade of existing AIS shore stations; or
- through the implementation of VDES at a new location where there is no existing AIS shore station.

The services offered by a VDES system will allow for priority with essential services / safety related services having the highest priority and non-essential / commercial service having the lowest priority.

The transfer of data using VDES should consider that the available VDES data transfer capacity is shared by all users within the coverage range of a VDES base station.

A technical overview of VDES is provided in ANNEX A.

Other means could be considered but take into account specific characteristics of these communication systems:

- Near real time small messages
- No streaming or large files
- Doesn’t need shore infrastructure
- No need for subscription at provider
- Support for PNT consistency system near shore - Ranging Mode (R-Mode)

3. POTENTIAL USES OF VDES

To assist in identifying possible options for use of VDES several potential scenarios have been developed. These are presented to provide context for development and implementation of digital communications, including VDES. The potential uses of VDES presented here are not intended to be an exhaustive list. It is expected that VDES uses will evolve as the system is implemented. The use cases are cross referenced to Maritime Service in the context of e-Navigation as noted in Table 3. Other potential use cases of VDES are presented in Table 4.

Table 3 Potential VDES Uses cross-referenced to IMO SIP MS update 1

Potential uses of VDES	MS in the context of e-Navigation Reference
SAR Communications	MS 9 - Telemedical Maritime Assistance Service (TMAS) MS 16 - Search and Rescue (SAR) Service
Maritime Safety Information	MS 5 - Maritime Safety Information (MSI) service MS 13 - Ice navigation service MS 14 - Meteorological information service MS 15 - Real-time hydrographic and environmental information services
Ship Reporting	MS 8 - Vessel shore reporting MS 15 - Real-time hydrographic and environmental information services
Vessel Traffic Services	MS 1 - VTS Information Service (INS) MS 2 - Navigation Assistance Service (NAS) MS 3 - Traffic Organization Service (TOS) MS 4 - Local Port Service (LPS) MS 6 - Pilotage service MS 7 - Tugs service
Charts and Publications	MS 11 - Nautical chart service MS 12 - Nautical publications service MS 15 - Real-time hydrographic and environmental information services MS 17 – AtoN service (including PNT and Satellite Based Augmentation System)
Route Exchange	MS 1 - VTS Information Service (INS) MS 2 - Navigation Assistance Service (NAS) MS 3 - Traffic Organization Service (TOS) MS 4 - Local Port Service (LPS) MS 5 - Maritime Safety Information (MSI) service MS 6 - Pilotage service MS 7 - Tugs service MS 8 - Vessel shore reporting MS 10 - Maritime Assistance Service (MAS) MS 11 - Nautical chart service MS 12 - Nautical publications service MS 13 - Ice navigation service MS 14 - Meteorological information service MS 15 - Real-time hydrographic and environmental information services MS 16 - Search and Rescue (SAR) Service
Logistics	MS 7 - Tugs service

Table 4 Other potential VDES Uses

Potential uses of VDES	New services that may utilize VDES
Loss of GNSS (PNT)	R-Mode (provides backup PNT)
Message forwarding	Message forwarding to prevent shadowing or for redundancy
AtoN	Adding VDES capability (including ASM on ASM channels) to AtoN
Vessel Monitoring Systems (VMS)	Adding VDES capability as a tool for enforcement of fishing territories. VMS is a general term to describe systems that are used in commercial fishing to allow environmental and fisheries regulatory organizations to track and monitor the activities of fishing vessels.
Autonomous collision avoidance manoeuvres	Ship to ship information exchange for safety of autonomous navigation in MASS.
Maritime domain awareness (MDA)	MDA is the effective understanding of anything associated with the maritime domain that could impact security, safety, the economy, or the marine environment
Disaster response	A natural catastrophe, such as tsunami, causes great damage or loss of life. Satellite VDES can ensure communication with coastal navigation vessels in the event of loss of VDES shore station infrastructure due to natural disasters.

VDES is intended to support the following use cases by terrestrial and satellite communication. The VDES extends the capabilities of AIS.

3.1. IALA TEST BEDS

IALA has provide a list of test beds that have been performed by administrations (refer to IALA website).

3.2. INTEGRITY CHECK / AUTHENTICATION

VDES comprises AIS, ASM, VDE-TER and VDE-SAT with different data rate capabilities. Therefore, AIS and ASM have no or very limited capabilities to authenticate the data for the receiver. The authentication of the AIS and ASM messages allows the necessary trust in the shared messages to make safe decisions. VDES can be used to extend messages from AIS, ASM and VDE to provide additional authentication information, e.g., by the data format specified in the international VDE application identifier, see B.2.8, or the TESLA protocol.

3.2.1. SCENARIO - AUTHENTICATION FOR POSITION REPORTS

Positioning reports are broadcasted without authentication by ships and AtoN through AIS. Without authentication, there is no way for the recipient to verify the content of the positioning report. VDE may complement the continuous broadcast stream of AIS positioning reports to authenticate the content through, e.g., by the TESLA protocol.

As an alternative approach, shore may use VDE channels to query a signed position report from a ship via VDE in regular intervals, augmenting the AIS information received by that ship. This authentication status then is degraded over time until another signed position report is queried. As data format, the international VDE application identifier VDE Protocol Format 11 is recommended to be used, see B.2.8.

3.2.2. Scenario - Fishing vessels certification

Independent authentication of the location of a fishing vessel with time will be used for the fishery certification to prevent Illegal, Unreported and Unregulated (IUU) fisheries. Consistency between R-mode and GPS location will be an endorsement.

For example, fishing vessels may provide information on fish catch (fish name/type, amount) together with the AIS information (ship ID, location, date). This information is sent to port of fish unloading and fishing operation control authority/center. The authority may send a certificate of fish catch to the vessel. Fishing vessels that do not send information about fish catch, may be suspected of IUU fishing.

3.3. MASS

Maritime Autonomous Surface Ships (MASS) may navigate by their own AI systems. However, it is necessary to monitor and observe the movement of, and if necessary to control, MASS from remote (land-based) operation/control facilities. VDES provides reliable ship to shore, shore to ship and ship-to-ship communications using low data-rate exchange for MASS navigation safety purposes to prevent incidents such as grounding, collision with other ships, the adverse consequences of bad weather etc. VDES can also provide ship-to shore data communication of situation/status/condition of MASS. It is also anticipated that VDES communication protocols will be established between MASS AIs for collision prevention. The format of data will be defined/specified by other technical standards (ISO, IEC). Regulatory framework for MASS will be established by the IMO.

As a means of autonomous collision avoidance manoeuvres, VDES is capable of ship-to-ship information exchange for the safety of autonomous navigation.

3.4. POSITIONING, NAVIGATION AND TIMING

3.4.1. Scenario - R-mode

VDES may be used to provide ranging signals allowing vessels to enhance position integrity and determine their position and accurate time when GNSS performance is degraded, refer to Guideline *G1158* [39].

3.4.2. Scenario - Broadcasting GNSS augmentation data

GNSS receiver has progressively acquired increasing relevance as primary means of PNT information, integrated with other functions as ECDIS, GMDSS and AIS. However, GNSS and other radionavigation and data services are vulnerable to intentional and unintentional interferences and common failure mode.

To increase the level of PNT resilient there are currently different alternatives available such as the use of GNSS multi-constellation and multi-band receivers (see Multi system GNSS receiver IMO Resolution *MSC.401(95)* [13]), the use of augmentation systems (SBAS/GBAS)(compliant with Operational Requirements IMO *Resolution A.1046(27)* [14]), the use of Receiver Autonomous Integrity Monitoring (RAIM) algorithms for maritime, the provision of redundancy of the Electronic Position Fixing System (EPFS), the use of new GNSS services (e.g., Galileo High accuracy service (HAS) and Galileo Open Service Navigation Message Authentication (OS-NMA) among others). VDES and R-Mode will also contribute to minimizing these sources of vulnerabilities on board.

In that sense SBAS together with RAIM provides increased accuracy and integrity associated to PNT solution, complementing Differential GNSS (DGNSS) services and providing additional capabilities (e.g., extended regional coverage or and the evolution to include dual frequency multi-constellation – Dual Frequency Multy Constellation (DFMC).

SBAS is aligned with Guideline *G1152 SBAS Maritime Service* [15]. SBAS maritime receiver will be type approved equipment and compliant with the future new standard *IEC 61108-7* that sets up the performance requirements and method of testing of this equipment.

SBAS corrections can be used as a source of differential corrections that can be retransmitted following the methodology and rules fixed in the Guideline *G1129 for Marine Aids to Navigation (AtoN) service providers* [16], which explain how to implement and use SBAS as a data source for DGNSS. These SBAS corrections can be retransmitted using Medium Frequency (MF) IALA beacons and AIS stations.

SBAS information is re-transmitted in MF IALA beacons and AIS leveraging the Radio Technical Commission Maritime (RTCM) format in place to inject the differential corrections.

SBAS information could also be transmitted in Radio Technical Commission Aviation (RTCA) native format in the new VDES, especially in areas where there is not coverage or a proper reception of SBAS signal in space (SiS). Note that the current RTCA format allows the implementation of the corrections, without any change, with independent of the VDES transmitter location of the VDES transmitter, including Satellite VDES.

SBAS information and corrections can be also re-transmitted using VDES architecture and functions, enhancing safety of navigation, in accordance with the current transmission rules through AIS message application.

Moreover, SBAS information will be able to be transported through VDES using a new VDES binary message in RTCM format (if it is applicable). This VDES message will allow indicating that one differential corrected position is used on-board based upon SBAS corrections (set differential flag). In addition, the VDES message will also provide a GNSS health report to clarify the current status of this PNT source.

SBAS information can be provided to external equipment via the PI, using a -450 interface (a new PI message may also be required).

When spoofing or jamming attacks are made on GNSS signal, GNSS augmentation systems provide additional data to users of GNSS equipment to improve accuracy, reliability and availability. Integrity and correction data are generated based on measurements from the ground network and relayed from VDES shore stations or VDES satellites to GNSS users. VDES provides means to communicate GNSS augmentation data by satellite (SBAS), and terrestrial (similar to AIS Message 17).

3.5. SAR COMMUNICATIONS

SAR Communications are defined in existing documentation (ref SOLAS IV, SAR 79, IAMSAR Manual, NAVTEX manual and SafetyNet manual).

VDES is a technology that supplements AIS communications, and as such may be used for data communication of MSI and supplementary distress communications. VDES supports both addressed (unicast and multicast) and broadcast communications to support SAR response.

When available, the VDES satellite component (VDE-SAT) may be an effective means to extend the VDES to areas outside of coastal VHF coverage. The VDES-SAT may deliver information in a broadcast, multicast or unicast mode to a broad area, addressing many ships using only minimal radio spectrum resources. The VDE-SAT will provide a communication channel that is complementary to GMDSS and the terrestrial components of the VDES system (i.e., coordinated with terrestrial VDES, ASM, and AIS functionalities and their supporting systems).

As a communications medium, VDES may be used to relay distress alerts and locating signals (i.e., SARTs). VDES has also potential to supplement other GMDSS functional requirements which require further development through the GMDSS review process.

In this use case the mix of current communications and developing communications techniques can enhance and improve the sharing of information in prosecution of a SAR incident. This would include text in free form / standard formats; transfer of waypoints/route information[1] for display on on-board equipment; transfer of GIS information /search patterns; images; etc.

1 IEC standard *61174* Ed. 4 includes route exchange.

The VDES can be used in SAR planning, execution and decision making.

3.5.1. Scenario - Distress Communications – Distress Relay

Once a distress alert is initiated and the information has been forwarded to a Rescue Coordination Centre (RCC) through the established GMDSS process, the RCC forwards information of the incident to vessels in the area. The forwarding of information, using existing formats, could be provided by various communications means, including VDES. The forwarding of data over a digital communications system such as VDES could facilitate the integration and display of information on external systems on-board (for example, Radar, ECDIS). Information could then be passed to the RCC and other vessels in the area including course to intercept, Estimated Time Arrival (ETA) on-scene, on-scene conditions, sharing of a common operating picture, etc.

3.5.2. Scenario - SAR Operations – initiate search / response

SAR Mission Coordinator (SMC) develops response to SAR using resources, search plan, etc. Information to prosecute SAR operation is transmitted to the On Scene Commander (OSC) and SAR Response Units (SRU) (for example information on resources, plan, waypoints for search pattern, SRU responsibilities, etc.). This could be done using VDES, providing a common operating picture and information using standard templates and formats.

3.5.3. Scenario - SAR Operations – information exchange

During a SAR mission, the OSC and SRU provide regular updates on the search / response to the SMC. In addition, the OSC and SRU share information between each other to facilitate the response. The VDES could be used to exchange information on the SAR plan, SAR execution and other pertinent information to facilitate SAR operations. Information could be automatically integrated with, and portrayed on, external systems both ashore and on-board, including the RCC GIS, decision planning and support systems.

Using information from other systems, such as vessel route, information provided could be tailored to be relevant for the vessel based on its route.

In addition, the OSC and SRU could share information between each other to facilitate the response.

3.5.4. Scenario - Tele-medical

A tele-medical happens when a person is injured or sick on-board a vessel or platform and there is a need to communicate with a doctor ashore for medical assistance and prognosis. The conversation with doctor could be by voice, with transfer of images/photos/indication from medical equipment on patient’s condition. VDES could be used to transfer advice, images or other information. Where there are language difficulties, VDES could assist with machine to machine communications and/or language independent communication. Information exchange could be integrated with, and portrayed on, external systems on-board or ashore (medical facility).

3.5.5. Scenario - Medical Evacuation (MEDEVAC)

A MEDEVAC may be necessary to evacuate a severely injured or sick person. VDES may be used to exchange pertinent medical information from the ship to the SRU and destination medical facility. The SAR Mission Co-ordinator (SMC) develops the response to prosecute the MEDEVAC and could use VDES to provide the plan to the ship and responding unit. Information on the status of the patient could be transferred during the MEDEVAC from medical equipment on the SRU.

3.5.6. Scenario - Initial Distress Position Sharing (IDPS)

The Galileo Search and Rescue Service (SAR/Galileo), designed in order to support the COSPAS-SARSAT (C/S) International Satellite System for Search and Rescue (MEOSAR) Programme, introduces the SAR/Galileo Return Link Service (RLS) [17]. Once an emergency beacon (EPIRB, PLB,…) RLS-enabled is activated, its signal and alarm message is forwarded via the Galileo satellites in view to the corresponding Mission Control Center (MCC), and following the established operational chain, an acknowledgment receipt is sent to the beacon, the return link message (RLM), which indicates that the emergency signal has been received and the help is coming.

This RLM includes the 15 Hexadecimal ID of the 406 MHz Beacon in distress, with 19 bits indicating its coarse position [18]. This information is used to build the NMEA sentence, understandable by any compatible equipment compliant with IEC standards [19][20].

Any Galileo-enabled receiver implementing the Galileo Open Service Signal-In-Space Interface Control Document (OS SIS ICD) is able to read and decode the RLM and provide the standardized NMEA sentence, including the beacon ID and the gross position of the located beacon (c.a. 30 nm). VDES equipment (either shoreside or shipside) with a GNSS receiver implementing Galileo OS SIS ICD can receive and decode the RLM, including the beacon ID and its position, and then put this information available to the VDES equipment itself so that it can be able to retransmit the information about a vessel/mariner in distress in the specific location specified in the RLM. This information can be sent to any vessel in the area with VDES onboard equipment (even if they are not using a Galileo-enabled receiver) and (potentially displayed in the vessel ECDIS) thus allow them to help, when possible, in the assistance of the mariners in distress after contacting the corresponding search and rescue service for confirmation of last known position (if possible[2]).

Search and Rescue services can use this mechanism as an initial communication to vessels in the area. This is linked to 3.4.1.

The above proposed service can be used as a secondary supplement to GMDSS.

3.6. SAFETY RELATED INFORMATION

Information regarding safety of navigation and protection of the environment can be transmitted through the VDES. Safety related information could use the broadcast aspect of VDES.

This includes Maritime Safety Information (MSI) as defined in IMO *SOLAS V, regulation 4 (navigational warnings), SOLAS V, regulation 5 (meteorological services and warnings) SOLAS V, regulation 9 (hydrographic services) and SOLAS V, regulation 31 (Danger Messages)* [2]. Other references include *MSC.1/Circ.1287 rev1* [21]; *MSC.1/Circ.1288* [22]; (additional reference COMSAR Cir.15) the IMO Worldwide Radionavigation System IMO *Resolution A.706(17)* [23] (as amended) sets out the Worldwide Radionavigation System (WWRNS).

Real-time information on meteorological and hydrographical information may be provided.

In this use case, information shall be transmitted in standardized formats that can take advantage of the VDES capabilities (for example - IHO S-124 formats).

The requirement includes the ability to send information to a predetermined area (i.e., NAVAREA and METAREA) or an area of particular interest defined by administration.

3.6.1. SCENARIO - METEOROLOGICAL SERVICES AND WARNINGS / NAVIGATIONAL WARNINGS

It is important to have up to date information on the weather that can be expected along a ship's planned route. VDES could be used to facilitate information exchange relating to the route of the vessel, integrated with, and portrayed on external systems onboard.

3.6.2. SCENARIO - ICE MAPS

Information on sea ice conditions around a vessel is important to help ensure safe passage at sea. Knowledge of areas with sea ice along a ship's planned route allows ships to find the most efficient route at an early stage. Together with prognoses for expected ice movements, ice charts allow mariners to plan ahead and significantly reduce the risk of vessels becoming ice locked. VDES could be used to provide this information, which could then be integrated with, and portrayed on external on-board systems. Ships may also provide information from

2 Note that according to regulation V/33 of SOLAS convention, the master of a ship at sea which is in a position to be able to provide assistance, on receiving information from any source that persons are in distress at sea, is bound to proceed with all speed to their assistance, if possible informing them or the search and rescue service that the ship is doing so. This obligation to provide assistance applies regardless of the nationality or status of such persons or the circumstances in which they are found. If the ship receiving the distress alert is unable or, in the special circumstances of the case, considers it unreasonable or unnecessary to proceed to their assistance, the master must enter in the log-book the reason for failing to proceed to the assistance of the persons in distress, taking into account the recommendation of the Organization to inform the appropriate search and rescue service accordingly.

observations back to the service provider to update the ice maps. In addition, information on the latest version of ice maps may be provided ship to ship.

3.6.3. SCENARIO - NOTICES TO MARINERS

Notices to mariners are a means to disseminate navigational safety information (as part of maritime safety information). SOLAS V, Regulation 9 (Hydrographic Services) notes that administrations should undertake to arrange the dissemination and update of all nautical information necessary for safe navigation (for example. predictive and real-time tides and currents). VDES could be used to provide this information, and changes to information, with respect to the waterway.

3.6.4. SCENARIO - GNSS AUGMENTATION

SOLAS Chapter V, Regulation 19 notes that all ships, irrespective of size, shall have a receiver for a global navigation satellite system or a terrestrial radio navigation system, or other means, suitable for use at all times throughout the intended voyage to establish and update the ship's position by automatic means. IMO Resolutions *A.915(22)* [24] and *A.953(23)* [25] provide the requirements for Maritime Radio navigation Systems. Distribution and/or retransmission of GNSS augmentation information via VDES could allow GNSS users to get timing, integrity data and improved position accuracy.

3.6.5. SCENARIO - CROWD SOURCED INFORMATION

Information from users or ship systems may enhance and/or validate meteorological hydrological and hydrographic information that is made available to other vessels in the area and authorities. VDES could be used to facilitate crowd sourced information.

3.7. SHIP REPORTING

Ship reporting can include mandatory and voluntary reports required for a number of purposes by vessels to various shore authorities. Information on ship reporting is provided in IMO SOLAS V, regulation 11 (ship reporting systems), 19-1 Long Range Identification and Tracking (LRIT), regulation 31 (danger messages), regulation 32 (information required in danger messages), MARPOL and SAR Convention, Chapter 5. Additional information on ship reporting is contained in IMO Resolution *A.851(20)*[26] and *FAL.5/Circ.36*[27].

Information forwarded through VDES may transfer data for integration into national and/or regional systems could be sent by VDES to a Maritime Single Window (MSW) platform. (e.g., SafeSeaNet, VTS). Information may also be sent to the ship agent or owner or a service provider. Ship reporting could use the addressed (unicast and multicast) aspect of VDES.

3.7.1. SCENARIO - SUBMIT UPDATED INFORMATION

As the voyage continues, updated information will be provided. This can include updated estimated time of arrival; change in condition of the vessel; change in route of the vessel. This is a user defined report, which could be based on a set template for “updated information” or free-text report. VDES could facilitate exchange of information. The vessel may be interrogated for information on request, based on its route, operating area or position.

3.7.2. SCENARIO - SUBMIT ARRIVAL NOTICE

A notice of arrival report is based on known content and could be set in a template form. The aspects of the template report, such as information on the ship particulars, would be pre-populated. Where possible, additional information related to the voyage, such as destination, ETA destination, last port(s) could be populated from other systems that contain such information. Other information that may be provided include International Ship and Port Facility Security (ISPS) reports, ship crew information or information specifically required by the shore authority. This may be submitted using data populated automatically from other systems or may require manual input by the mariner. VDES could facilitate exchange of information.

3.7.3. Scenario - Provide initial report to shore (prior to departure)

Prior to departure specific, standard information is required. This may include information required for clearance to depart. Reports could be pre-populated from available information where possible. Specific information may be required to be entered manually.

3.7.4. Scenario - Secure ship reporting

There can be times when it is necessary for secure ship reporting, including times when the vessel may disable AIS transmissions. Using VDES, information could be forwarded through a secure communications link.

3.7.5. Scenario - Danger Message

The master of a vessel is required to report dangerous conditions (SOLAS V, regulation 31 and 32) as well as any irregular conditions referring general marine domain awareness, such as: dangerous ice, derelicts, dangers to navigation, tropical storm, severe weather, ice accretion. VDES could facilitate the provision of this information to both shore authorities and other vessels in the area. Information exchange may be integrated with, and portrayed on, external systems on-board.

3.7.6. Scenario - Reporting 3D position

Currently, vessels automatically report their absolute horizontal position (i.e., latitude and longitude) via AIS. They also report their current draught, which gives the vertical position related to the surface of the sea. Horizontal position information is obtained (usually) via GNSS, while draught is reported manually by the crew.

The vertical component of GNSS provided position is less accurate than the horizontal component, but with current GNSS technologies with multifrequency receivers supported by augmentation [30] information, it is possible to achieve submeter accuracies also for absolute vertical position. Thus, if the location of the GNSS antenna related to the keel and to the highest point of the vessel is known, it would be possible to monitor and report the absolute and accurate 3D position of the vessel in real time.

In cases, where the seabed and/or any above water obstruction (e.g., bridge) has been charted/mapped using a stable reference level (geodetic datum), which can be related to GNSS reference level, it is possible to monitor the safe distance to seabed (i.e., under keel clearance) (http://www.famosproject.eu/activities/future-navigation/ [28]) or to the bridge structures using GNSS position. This information could assist the vessel but also VTS when monitoring the vessel's safe journey in the VTS area.

The current AIS messages do not allow the automatic reporting of vertical component of the GNSS position, but this might in the future be something that would be useful information also for shore authorities. In addition to the 3D position, report could include additional sensor information related to the vessel's movements caused by wind and waves if such information is available (i.e., pitch, roll and heave in vertical direction and sway, surge and yaw in the horizontal plane). IMO *MSC.1/Circular.1575* [29] defines requirements on data output of PNT, establishing several grades, and where the most complete one (Grade IV) considers the ship's hull (3D).

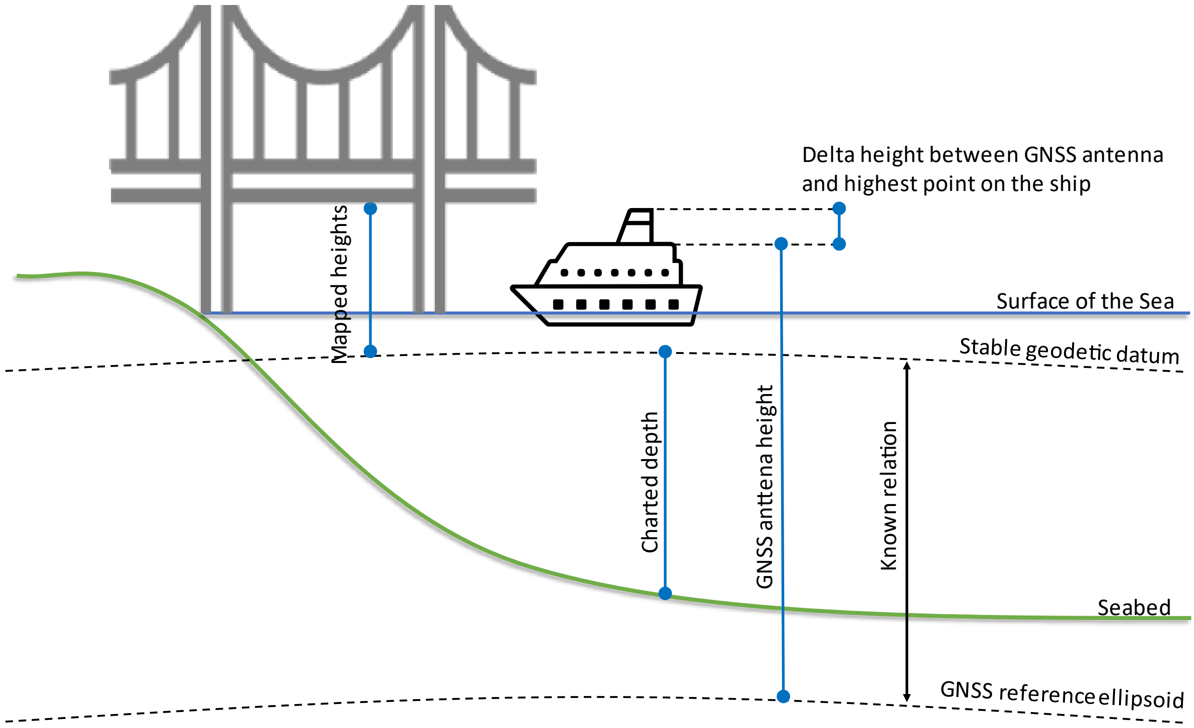

Figure 6 Bridge Clearance for Ships

It is suggested to include a field in the VDES message indicating if the 3D position is authenticated, following the recommendation on the *Guidelines on cyber security onboard ships* [31], where it is stated that cyber incidents can arise as the result of loss of or manipulation of external sensor data, critical for the operation of a ship. This includes but is not limited to Global Navigation Satellite Systems (GNSS).

3.7.7. SCENARIO - SHIP WEATHER OBSERVATION REPORT FROM SHIP

Ships may participate in the provision of weather observations, as noted in *MSC.1/Circ.1293* [32]. This is a Voluntary Observing Ship (VOS) scheme with information provided to the World Meteorological Organization (WMO). VDES could facilitate this reporting, with information provided directly from on-board sensors.

VDES may improve the reliability of the reception via the global satellite capabilities of VDE-SAT for weather information provided by IMO *SN.1/Circ.289 Guidance on the use of ais application-specific messages* [33].

The Circ.-289 weather messages can be transported via VDE-SAT using VDES messages.

The WMO Weather observation report from ship message is intended for ships which have been recruited by national meteorological services to undertake weather observations at sea in accordance with the provisions of SOLAS chapter V, regulation 5, and the WMO's VOS Scheme. Because national meteorological services are the intended primary users of this message it has been developed to reflect the coding principles prescribed by WMO in its Binary Universal Form for the Representation of meteorological data (BUFR), and as contained in Part B of WMO Publication No.306, (Manual Codes, Volume I.2). The parameters coded in this message are therefore not fully compatible with the recommendations set out in ITU *M.1371* [6].

3.8. VESSEL TRAFFIC SERVICES

Vessel Traffic Services is included in SOLAS Chapter V, Regulation 12, with further information in IMO Resolution *A.1158(32) Guidelines for Vessel Traffic Services (NCSR7/23 Annex 5)* [34].

IMO Resolution *A.1158(32)* [34] states that:

"The purpose of VTS is to contribute to safety of life at sea, improve the safety and efficiency of navigation and support the protection of the environment within the VTS area by mitigating the development of unsafe situations through:

1. *providing timely and relevant information on factors that may influence ship movements and assist onboard decision-making. This may include:*
    1. *position, identity, intention and movements of ships;*
    2. *maritime safety information;*
    3. *limitations of ships in the VTS area that may impose restrictions on the navigation of other ships (e.g., maneuverability), or any other potential hindrances;*
    4. *other information such as reporting formalities and International Ship and Port Facility Security Code (ISPS Code) details; and*
    5. *support for, and cooperation with, allied services;*
2. *monitoring and managing ship traffic to ensure the safety and efficiency of ship movements. This may include:.*
    1. *planning ship movements in advance;*
    2. *organizing ships under way;*
    3. *organizing space allocation;*
    4. *establishing a system of traffic clearances;*
    5. *establishing a system of voyage or passage plans;*
    6. *providing route advice; and*
    7. *ensuring compliance with and enforcement of regulatory provisions for which they are empowered,*
3. *Responding to developing unsafe situations, which may include:*
    1. *a ship unsure of its route or position;*
    2. *a ship deviating from the route;*
    3. *a ship requiring guidance to an anchoring position;*
    4. *a ship that has defects or deficiencies, such as navigation or maneuvering equipment failure;*
    5. *severe meteorological conditions (e.g., low visibility, strong winds);*
    6. *a ship at risk of grounding or collision; and*
    7. *emergency response or support for emergency services.*

To achieve their purpose, VTS should provide information or issue advice, warnings and instructions, as deemed necessary".

The Guideline *G1089 on Provision of Vessel Traffic Services (VTS)* [35] has the purpose to provide guidance for the provision of VTS to participating ships in a harmonized manner, in accordance with IMO Resolution *A.1158(32)* [34] and IALA standards.

Information required by the VTS can be both standardized (supported by templates) or specific to a situation. VTS could use geographical area, addressed and broadcast aspects of VDES. This would improve the efficiency of the port operations and would expedite the ships equipped with VDES for those ports also equipped with VDES.

VTS involves maintaining a vessel traffic image and relies on vessel tracking from sensors such as radar, AIS, CCTV, other VTS centres. The vessel traffic image may be supplement with crowd-sourced information from vessels data (sensor data from ships provided to the shore to expand the traffic image range).

VTS also requires interaction with traffic to respond to developing traffic situations.

VTS relies on the ability to provide essential and timely information; monitor the actions of vessels in the VTS area, including monitoring routes and changes in route; interacting with other VTS centres in the region; interact with other port agencies (allied services).

Ports may also provide a specific local port service where it is deemed through a risk assessment that a VTS is not required.

3.8.1. SCENARIO - WATERWAY MONITORING

VTS provides monitoring and other services. VDES may be used to monitor vessels and autonomously provide information to these vessels based on predetermined parameters as defined by the shore authority. In addition, VDES may enable sharing of information on synthetic VTS targets from the VTS to vessels transiting the VTS area. Information exchange may be integrated with, and portrayed on, external systems ashore and on-board.

3.8.2. SCENARIO - VTS TIMELY AND RELEVANT INFORMATION SERVICE

VTS Timely and Relevant Information Service is provided by broadcasting information at fixed times and intervals or when deemed necessary by the VTS, or at the request of a vessel. The information provided may include safety information as previously defined. Additional information could include specific limitations for navigation in the VTS area (for example, manoeuvrability limitations; draft restrictions; channel closures; diving operations). Information exchange may be integrated with and portrayed on, external systems ashore and on-board. For example, timely information exchange to achieve mutually coordinated shipping will reduce potential risk. Computer-based automated notification between ships is useful. Further, as noted in section 3.10 below, the efficiency of the port operation would be improved by considering the scheduling of intermodal transportation services to expedite the delivery of the ships' cargoes and the reloading of the ships with new cargoes.

3.8.3. SCENARIO - VTS RESPONDING SERVICE

The VTS Responding Service is described by IMO as **"**a service to prevent the development of dangerous maritime traffic situations and to provide for the safe and efficient movement of vessel traffic within the VTS area". The purpose of the VTS Responding Service is to prevent hazardous situations from developing and to ensure safe and efficient navigation through the VTS area. VDES could be used to exchange this information (e.g., a suggested route). Information exchange may be integrated with, and portrayed on, external systems ashore and on-board.

3.8.4. SCENARIO - VTS MONITORING AND MANAGEMENT SERVICE

The VTS Monitoring and Management Service is described by IMO as **"**a service to assist on-board navigational decision-making and to monitor its effects**".** VTS Monitoring and Management Service may be provided on request by a vessel in the circumstances such as equipment failure or navigational unfamiliarity. VDES could be used in the exchange of information during the provision of VTS Monitoring and Management Service. Information exchange may be integrated with and portrayed on, external systems ashore and on-board.

3.9. CHARTS AND PUBLICATIONS

IMO SOLAS Chapter V, Regulation 27 (nautical charts and nautical publications) notes that charts and publications necessary for the intended voyage shall be adequate and up to date. Provision of information on charts and publications could use the addressed and broadcast aspects of VDES.

The aim of nautical chart and publication services is to safeguard navigation at sea by providing information such as nature and form of the coast, water depth, tides table, obstructions and other dangers to navigation, location and type of aids to navigation.

The nautical chart and publication services ensure the official distribution, update and licensing of electronic charts and publications to vessels and other users.

Nautical publications include a list of lights, sailing directions, tide and current tables, etc.

There may be a requirement for a “user pays” aspect for some services (i.e., ENC updates), and novel ways to perform chart updates.

3.9.1. Scenario - Updates linked to a ship’s route

An example of this would be a vessel proceeding to a specific location. At the time of sailing, the vessel had all required charts and publications for the voyage. These charts and publications were the most up to date at the time of sailing, however some information may have changed during the voyage. Updated information could be provided through VDES as the vessel as it continues on its voyage, providing information based on the route of the vessel, and limiting the updates to only that information that has changed. Information exchange may be integrated with, and portrayed on, external systems ashore and on-board.

3.9.2. Scenario - charts and nautical publications dynamic updates

In order to allow for incremental updates, a ship would report the revisions of existing charts and nautical publications in order to request relevant updates.

3.10. ROUTE EXCHANGE

The development of e-Navigation has highlighted the opportunity to make effective use of digital data exchange to support safe and efficient vessel movements.

Route exchange could enhance safety by providing early indication of deviation from the reported voyage plan which may be due to fatigue, weather conditions, or condition of the vessel (possible malfunction).

The use of route exchange could assist with fleet management, whereby information on routes can be exchanged with shore personnel as well as other vessels in the fleet.

In addition, the use of route exchange could assist with route and speed optimization based on weather and currents, just in time arrival, and traffic congestion.

Route exchange could take advantage of the addressed (unicast and multicast) and broadcast aspects of VDES.

Details for route exchange are specified by *IEC 61174* [36] *edition 4 annex S* and *IEC 63173-1* [37].

3.10.1. Scenario - Ship to Ship

Ship to ship exchange could be sequential, i.e., allowing a route to be exchanged between stations via message forwarding (multiple hops i.e., stations in between). Ship to ship route exchange would assist vessels on a transit by predicting when interactions may occur. VDES could assist in the exchange of digital data to facilitate ship to ship route exchange in order to allow exchange of intentions. Route exchange is essential for the safe passage of MASS.

When a ship meets another ship at a close distance, it is necessary to communicate promptly to know and clarify each other the intention of the operation of the ships to avoid a collision. VDES provides direct ship-ship communication when meeting on the sea. In addition, automatic translation/interpretation is introduced in this system, the communication can be done among different languages. (Existing system takes a longer time to establish such communication; firstly, obtain the ship’s call sign by AIS and then secondly, call the ship by VHF. Such voice communication shall be done in the common international languages; this procedure is many times more difficult for local fishermen than receiving a route from the other ship directly and getting it displayed, avoiding miscommunication in eventually foreign languages.)

3.10.2. Scenario - Ship to Shore

To inform shipping and other waterway users of possible hazardous situations, shore authorities need information about the intentions of the waterway users, such as their intended route. Based on this information, the authorities could organize traffic and, when needed, recommend other routes/possibilities for a safer passage and also provide information about the waterway.

3.10.3. Scenario - Shore to Ship

Before ships enter a sea area monitored by a shore authority, information about this area could be provided to assist in a safe and efficient passage. If the route of the vessel is known, information can be tailored to the route. The shore authority could link the vessel planned route with other information received, such as cargo, and adjust the information as may be required. Route plans received from ships can be used for detecting possible traffic congestions and high-risk situations in advance. Shore authorities can also send alternative route recommendations to ships when needed. This allows ships to choose the route that is most suitable for its navigation. VDES can facilitate reception of route plans which may be integrated with, and portrayed on, external systems ashore.

3.10.4. Scenario - Navigational Disruption

There may be some event or circumstance that impacts the normal operation of the waterway requiring urgent traffic management to ensure the continuity of operations. VDES could be used to share information on the circumstance and proposed alternate routing could assist in effective movement of vessels throughout the incident.

3.10.5. Scenario - High priority ship

In some areas, there are ships that have a high priority and should have “free sailing” in a specific time slot over a specific route. Examples are tide/tidal ships and ships with special cargo. VDES could be used to share such information.

3.11. LOGISTICS / SERVICES

When sailing from berth to berth before, during and after the voyage, there are several logistical aspects that must be addressed. Most of these are done by an agent on the shore but are changed because of different reasons. The means of communicating these logistical aspects would depend on the location of the ship/shore elements involved and could include VDES. In cases where cargo is transferred at sea (transhipment) the location could be out of range of other communications, and VDES would be the preferred communication exchange platform.

Information transfer could assist with efficiency of the overall cargo chain. The standard S-211 Port Call Message defines message formats that can help different stakeholders to efficiently coordinate and synchronize processes related to a port call (e.g., pilots, tugs and terminal functions). Logistics/services could use the addressed (unicast and multicast) aspects of VDES.

Sharing of route information could assist with allied services related to shipping and ship movements - this could include locks, pilotage, tug allocation, shore resources, and other logistical aspects. This use case represents the business to business aspect.

Logistical elements where VDES may be an appropriate communication method include:

- Transfer of vessel loading plan
- Tug operations
- Pilotage operations
- Stores/supplies/ship bunkering requirements and waste removal
- Coordination of ships and vessel traffic with port operations

3.11.1. Scenario - Logistic services – ship to shore

Ship arriving at a port forwards revised time of arrival and requests confirmation for stores, fuel, and access to waste facilities. The vessel also requires information on pilots and tugs and other aspects for the transit. VDES provides an opportunity for automated exchange of information to support these types of requests.

3.11.2. SCENARIO - LOGISTIC SERVICES – SHORE TO SHIP

As the ship arrives, the shore authority will provide confirmation regarding offloading, loading of the vessel and respond to requests from the ship. VDES provides an opportunity for automated exchange of information to support these types of requests.

3.12. MARITIME DOMAIN AWARENESS (MDA)

MDA is the effective understanding of anything associated with the maritime domain that could impact security, safety, the economy or the marine environment. The maritime domain is defined as all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, ships, and other conveyances. VDES is capable of ship to shore information gathering.

3.13. DISASTER RESPONSE

Marine disasters include both man-made disasters, such as large scale marine pollution caused by oil spills, and natural disasters, such as tsunami. When terrestrial communications infrastructure is damaged by a natural disaster, VDES satellites can provide a communications link to meet emergency information transmission needs. Satellite VDES can ensure communication with vessels navigating along the coast in the event of the loss of VDES shore station infrastructure due to a natural disaster.

4. DEFINITIONS

The definitions of terms used in this Guideline can be found in the International Dictionary of Marine Aids to Navigation (IALA Dictionary) and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

5. ABBREVIATIONS

ACCSEAS	Accessibility for Shipping, Efficiency, Advantages and Sustainability (EU research project)
ACK	Acknowledgement
ACM	Address Complete Message
AIS	Automatic Identification System
AIS 1	AIS Default Channel 1 - 161.975 MHz (Ch. 87B/2087)
AIS 2	AIS Default Channel 2 - 162.025 MHz (Ch. 88B/2088)
App	Application
ASC	Assignment Channel
ASM	Application Specific Messages
BBM	Broadcast Binary Messages
BITE	Built-in test equipment
CCTV	Closed-Circuit Television
Circ.	Circular (IMO document)
COMSAR	Sub-Committee on Communications and Search and Rescue (IMO)
DSC	Digital Selective Calling
ECDIS	Electronic Chart display & Information System

ENC	Electronic Navigation Chart
ETA	Estimated Time of Arrival
FAL	Facilitation Committee (IMO)
FEC	Forward error correction
GIS	Geographic Information System
GMDSS	Global Maritime Distress and Safety System
GMSK	Gaussian Minimum Shift Keying
GNSS	Global Navigation Satellite System
IAMSAR	International Aeronautical and Maritime Search and Rescue (manual)
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organization
IMO	International Maritime Organization (UN)
INS	Information Service
ISPS	International Ship and Port Facility Security (Code)
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union-Radiocommunication Sector
kbps	kilobits per second
kHz	Kilohertz
LPS	Local Port Service
LRIT	Long Range Identification & Tracking
MARPOL	International Convention for the prevention of pollution from ships (IMO 1973 as amended)
MAS	Maritime Assistance Service
MCS	Modulation and Coding Scheme
MEDEVAC	Medical evacuation
METAREA	Geographical sea region for the purpose of co-ordinating the transmission of meteorological information
MHz	Megahertz
MMSI	Maritime Mobile Service Identity
MSC	Maritime Safety Committee (IMO)
MSI	Maritime Safety Information
MSP	Maritime Service Portfolio(s)
NACK	Not Acknowledgement
NAS	Navigation Assistance Service
NAVAREA	Geographic area in which various governments are responsible for navigation and weather warnings
NAVTEX	Navigational Telex (service)
NCSR	Navigation, Communications and Search and Rescue (IMO Sub-Committee)
OSC	On-scene commander
PI	Presentation Interface
PSK	Phase-Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying

RCC	Rescue Co-ordination Centre
RA	Random Access
RACH	Random Access Channel
RF	Radio Frequency
RR	Radio Regulations
RTCM	Radio Technical Commission for Maritime Service
SAR	Search and Rescue
SART	Search and Rescue Transponder
SAT	Satellite
Serv	Server
SIP	Strategic Implementation Plan
SOLAS	International Convention for the Safety of Life at Sea, (IMO 1974 as amended)
SRU	Search and Rescue Unit
TBB	Terrestrial Bulletin Board
TDMA	Time-division multiple access
TMAS	Telemedical Maritime Assistance Service
TOS	Traffic Organization Service
UDCH	User Data Channel
UTC	Co-ordinated Universal Time
VDE	VHF Data Exchange
VDES	VHF Data Exchange System
VDL	VHF Data Link
VHF	Very High Frequency (30 MHz to 300 MHz)
VOS	Voluntary observing ship
VTS	Vessel Traffic Service
WRC	World Radiocommunications Conference
WWRNS	World-wide Radionavigation System

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ANNEX A TECHNICAL OVERVIEW OF VDES

A.1. INTRODUCTION:

The VHF Data Exchange System (VDES) extends the Automatic Identification System (AIS) as defined in the ITU-R *M.1371* [6] by adding new technology. VDES is defined in ITU-R *M.2092* [1].

This technical overview assumes a basic knowledge of AIS and provides an overview of VDES.

A.2. VDES DESCRIPTION:

VDES is a combination of technologies that includes AIS, ASM and VDE. VDE consists of a terrestrial (VDE-TER) and a satellite (VDE-SAT) part. The VDES Presentation Interface (PI) uses NMEA sentences and is similar to the AIS PI but will include several new IEC *61162-1* [19] sentences to allow for the configuration of the VDES capability and facilitate the transfer of larger amounts of data.

The primary differences between AIS and the two new VDES technologies, ASM and VDE, are:

1. New modern Modulation and Coding Scheme (MCS).
2. New dedicated Radio Frequencies (RF) used the Radio Frequency bandwidth.
3. Higher data bandwidth.
4. New methods used by the Link Layer.
5. ASM MCS is designed to improve reception on low-earth orbit satellite.
6. VDE includes dedicated MCS and Link Layer for satellite uplink and downlink (VDE-SAT)

VDE has been designed to efficiently transfer relatively large volumes of arbitrary data. Unlike AIS, the definitions of the data being transferred are not defined by VDE. VDE only defines the data transfer mechanism. It can provide data transfer up to 32x higher when compared to AIS.
VDE has been designed to co-exist with AIS as not to interfere with AIS.
VDE-ASM is intended to move ASM traffic away from the existing AIS channels in order to improve safety at sea.

A.2.1. THE MODULATION AND CODING SCHEMES

The modulation and coding schemes range from Gaussian Minimum Shift Keying (GMSK) for AIS to π/4 Quadrature Phase-Shift Keying (π/4QPSK) for ASM and π/4QPSK and 16 Quadrature Amplitude Modulation (16QAM) for VDE.

The Radio Frequency (RF) bandwidth on the technologies differs with AIS and ASM both having a RF bandwidth of 25kHz per channel and VDE having a bandwidth of 25kHz, 50kHz or 100kHz per channel.

AIS uses AIS1 and AIS2; ASM uses ASM1 and ASM2; and VDE uses VDE-TER lower leg and VDE-TER upper leg; VDE-SAT lower leg and VDE-SAT upper leg (refer to Table 5 below).

AIS and ASM are simplex channels (can carry traffic in one direction at a time), and VDE-TER lower leg and VDE-TER upper leg allows for data to be transferred in both directions at the same time.

A.2.2. THE RADIO FREQUENCIES USED AND BANDWIDTH

At an overview level, the AIS and ASM use 2 X 25kHz bandwidth channels. VDE-TER can use 25kHz or 100kHz bandwidth channels. VDE-SAT can use 50kHz, 100kHz or 150kHz bandwidth channels. The allocated frequencies in the maritime VHF band as specified by Appendix 18 of the Radio Regulations are as follows:

Technology	Radio Frequencies used	Radio Regulations channel number
AIS 1	161.975 (25kHz)	2087
AIS 2	162.025 (25kHz)	2088
AIS Long Range 1	156.775 (25kHz) (ships are TX only)	75
AIS Long range 2	156.825 (25kHz) (ships are TX only)	76
ASM 1	161.950 (25kHz)	2027
ASM 2	162.000 (25kHz)	2028
VDE-TER (lower leg)	157.200 to 157.275 (100kHz)	1024, 1084, 1025 and 1085 combined
VDE-TER (upper leg)	161.800 to 161.875 (100kHz)	2024, 2084, 2025 and 2085 combined
VDE-SAT (lower leg)	157.200 to 157.325 (150kHz)	1024, 1084, 1025, 1085, 1026 and 1086 combined
VDE-SAT (upper leg)	161.800 to 161.925 (150kHz)	2024, 2084, 2025, 2085, 2026 and 2086 combined

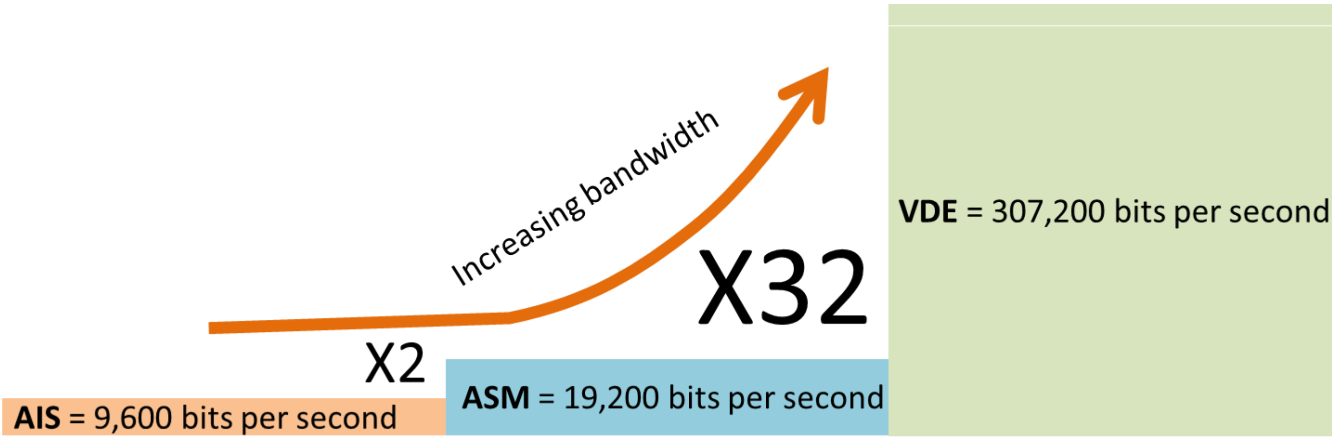
Table 5 Frequencies allocated to VDES

A.2.3. THE DATA BIT RATE

The modulation schemes π/4QPSK (ASM and VDE), 16QAM (VDE only) allow more data to be transferred in the same Radio Frequency (RF) bandwidth than was possible with AIS (GMSK).

The increase in bit rates is illustrated in Figure 7.

Figure 7 Increasing bit rates in VDES



A.2.4. THE METHODS USED BY THE LINK LAYER

The link layer imposes an overhead resulting in the following usable data rates. The ASM and VDE technologies use the same AIS slot map of 2,250 slots per RF channel (4,500 slots for two RF channels used in parallel in AIS and ASM technologies). Due to the higher spectral efficiency resulting from the use of π/4QPSK modulation, the number of bits transferred in any one slot is increased in ASM when compared with AIS. VDE-TER can transfer up to 210.6 kbps (Link Id 19), and VDE-SAT has a maximum transfer rate of 47.75 kbps (downlink) (Link Id 29) and 94.70 kbps (uplink) (Link Id 20). The VDE frequencies, Modulation and Coding Scheme (MCS) are dynamic and are chosen by a combination of the Terrestrial Bulletin Board (TBB) (section A.4 refers) and by the Link Layer.

The Link Layers of AIS, ASM and VDE are different, and each is optimized for the data bandwidth available.

The VDE Link Layer is more complex and uses a different Link Layer to facilitate communication between vessels (ship to ship) and between the shore and a vessel (shore to ship).

A.3. FORWARD ERROR CORRECTION

ASM and VDE use Forward Error Correction (FEC) which allows for the correction of errors in the data transferred in both ASM and VDE without retransmissions, i.e., in broadcast messages. FEC thereby increases the integrity and reliability of the transmission, adapting to the maritime channel, and optimizing its resources.

A.4. THE TERRESTRIAL AND SATELLITE BULLETIN BOARD

The VDE technology for terrestrial and satellite use a Terrestrial Bulletin Board (TBB) and Satellite Bulletin Board (SBB), respectively to assign the primary operating environment parameters to the Control Station Service Area. This includes which frequencies are being used and the service area dimensions amongst a range of other technical detail. To provide a level of protection to the VDES communication environment, the TBB may be authenticated. Authentication confirms that the TBB is transmitted by a trusted entity.

VDE Channel resources for data transfers are managed by the Control Station. Ships are within a Control Station service area when they receive a valid TBB that also overlaps their position.

A.5. LOGICAL CHANNELS IN VDE-TER

Terrestrial VDE Channel resources are managed as logical channels. One of 5 logical channels are dynamically allocated (shown as logical channel 8, 9, 10, 11 and 12 in the diagram below) to carry the data in the User Data Channel (UDCH). The TBB (TBB), Assignment Channel (ASC) and Random Access Channel (RACH) are defined too ensure that the VDE channel is optimally used to carry user data. Figure 6 provides an example of channel configuration.

A ship station requests access to a logical channel from the Control Station when it needs to transfer data over VDE. The logical channels have been designed in such a way that a VDES terminal can provide both VDE and AIS functionality without affecting AIS. Multiple terminals can simultaneously transfer using a TDMA access scheme that makes optimum use of the available resources.

The Random Access Channel are used to request resources and can also be used for small data messages allowing the User Data Channels to be available for larger messages.

The User Data Channel is allocated to the ship station for a fixed period. The user can continue to request the resource for as long as it has data to transmit. This is done in an optimal way on the Data Channel without having to use the Random Access Channel again. The Control Station determines if the request is granted or not.

The VDE control station transmits the TBB at the start of a frame. Just as in AIS, the VDE frame is one minute in duration comprises 2250 slots.

When a ship station is outside the service area of a control station, the ship can transmit data directly to another ship using ship to ship mode. A ship is out of the service area when it does not receive a valid TBB from a VDE Control Station for 15 minutes, or the vessel is in a position outside of the service area of any received TBB.

A.6. LOGICAL CHANNELS IN VDE-SAT

Satellite VDE Channel resources are managed as logical channels to carry link layer and user data between the Control Station on the Satellite and the Ship Stations.

Logical channels are the Satellite Bulletin Board (SBB), Assignment Channel (ASC), Data Channels for broadcast and addressed data in up- and downlink direction, and Random Access Channel (RACH) are defined to ensure that the VDE channel is optimally used to carry user data.

A ship station requests access to a logical channel from the satellite Control Station when it needs to transfer data over VDE-SAT. Due to the power flux density limit chosen for satellite transmissions in ITU-R *M.2092-1* [1], VDE-SAT can be received on board a ship without affecting AIS reception range. Multiple terminals can simultaneously transfer using a TDMA access scheme that makes optimum use of the available resources. TDMA limits ensure that ship transmissions do not interfere with the reception of AIS or DSC messages.

The Random Access Channel is used to request resources and can also be used for small data messages allowing the User Data Channels to be available for larger messages.

A User Data Channel is allocated to a ship station for a fixed period. The user can continue to request the resource for as long as it has data to transmit. This is done in an optimal way on the Data Channel without having to use the Random Access Channel again. The Control Station determines if the request is granted or not.

The VDE-SAT control station transmits the SBB at the start of a frame. Just as in AIS, the VDE frame is one minute in duration comprised of 2250 slots.

An orthogonalization technique is used to distinguish transmissions from different VDE satellites, should these happen simultaneously. Transmissions from ships are always directed to a specific VDE satellite to avoid ambiguity to which satellite a ship intent to transmit a message.

A.7. VDES STATION

A VDES station consists of multiple radio receiving processes handling AIS, ASM, and VDE. AIS, ASM and VDE all share the same transmitter. Every transmitter and receiver is connected to the VDES controller that manages the radio protocol. The VDES controller takes its input from the PI and outputs received radio messages from all the receiving processes. GNSS for positioning and timing is done in the same way as for AIS. The VDES station can have either combined or separate VHF antenna(s). A logical diagram of a VDES station with combined antenna is shown in Figure 8.

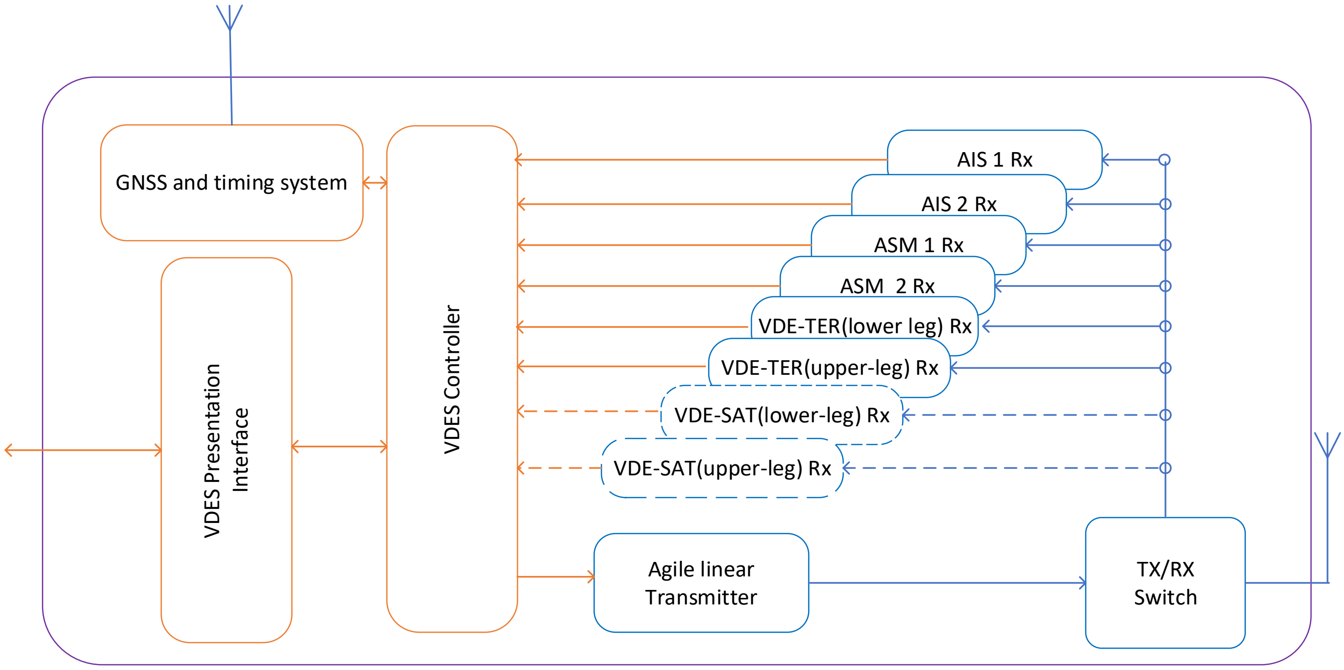


Figure 8 Logical description of VDES station, where VDE-SAT (dotted lines) may not be relevant for shore control stations.

For further details and examples, refer to the most recent version of Recommendation ITU-R M.2092 [1].

A.8. ASM OVERVIEW

A.8.1. CHANNEL ACCESS SCHEMES

The access schemes for ASM transmission are MITDMA, RATDMA, and FATDMA. The transmissions slots are typically selected when it's time to transmit an ASM burst, using a rule set that prioritizes the reception of AIS messages and avoids conflict with AIS transmissions. These transmissions may use MITDMA communication states to reserve future transmission slots, thus improving the reliability of the reception of an ASM message by avoiding transmission collisions. A single MITDMA transmission may be used to schedule up to three future transmissions, with each transmission occupying up to three slots. A total of 15 MITDMA transmissions may be chained together.

A.8.2. DATA LINK CONGESTION RESOLUTION

A number of rules are in place to address congestion when the ASM channels are heavily loaded. The maximum number of slots allocated by one station on one channel shall not exceed 50 slots over a period of one minute (2.2% duty cycle). After the completion of a single ASM channel transmission or a complete MITDMA transmission chain, the ASM station shall wait for a specific time before additional transmission can be scheduled. As channel loading goes up, the quiet time's length increases.

A.8.3. ASM MESSAGES

The ASM messages listed in Table 6 below will support various applications. ASM messages may use different addressing modes, including individually addressed, geographically addressed, and broadcast. Depending on the environment and application, these messages may or may not utilize FEC. In addition, these messages may or may not use MITDMA communication states.

Table 6 Message summary

Message ID	Name	Description	Access scheme	Communication state
0	Broadcast AIS ASM Message	Encapsulated AIS ASM messages.	RATDMA	None
1	Scheduled Broadcast Message	Broadcast data using communication state.	FATDMA RATDMA MITDMA	MITDMA
2	Broadcast Message	Broadcast data with no communication state.	FATDMA RATDMA	None
3	Scheduled Individual Addressed Message	Individual addressed data with communication state. Requires acknowledgement.	FATDMA RATDMA MITDMA	MITDMA
4	Individual Addressed Message	Individual addressed data with no communication state. Requires acknowledgement.	FATDMA RATDMA	None
5	Acknowledgment Message	This message is used to provide and acknowledgment for one or more addressed messages.	FATMDA RATDMA MITDMA	None
6	Geographical Multicast Message	Addressed to a group of stations defined by their geographical location with no communication state. No acknowledgment required.	FATDMA RATDMA	None

ANNEX B EXAMPLES OF VDE PROTOCOL FORMAT MESSAGES

B.1. VPFI 1: VDES MANAGEMENT MESSAGES

B.1.1. VDE-SAT NETWORK ORBIT DATA

This VDE Protocol Format may be used by VDE Satellites to inform about updated orbital data for a set of VDE-SAT satellites in a VDE-SAT network or VDE-SAT roaming network. Equipment may use the orbital data to estimate when connectivity to a satellite can be expected.

Orbital data is represented in the two-line element (TLE) format.

Table 7 VDE-SAT Network Orbit Data

Parameter	Number of bits	Description
VPFI	16	1
Message ID	8	0
Primary network ID	8	Values 0-255 allowed, see ITU-R M.2092-1, Annex 5, §3.1.9
Roaming network ID	8	Identifying which roaming network group the satellites of this list belong to.
n	8	Number of orbital data sets transferred in this VDE Protocol Format
Satellite ID[0]	8	ID [0] of the satellite
TLE [0]	828	TLE data[0] for the first satellite: 2 lines of 69 ASCII 6-bit encoded characters
Satellite ID[1]	8	ID [1] of the satellite
TLE [1]	828	TLE data[1] for the second satellite: 2 lines of 69 ASCII 6-bit encoded characters
…	…	…
Satellite ID[n-1]	8	ID [n-1] of the satellite
TLE [n-1]	828	TLE data[n-1] for the nth satellite: 2 lines of 69 ASCII 6-bit encoded characters
Valid until	32	Unsigned integer number of seconds after the 1st of January 1970 00:00:00 UTC. After the 19th of January 2038 03:14:07 UTC, the number is the number of seconds after this new date (wraps around); To avoid replay attacks, this value shall be used by the receiving application to verify the validity of the data.
Signature	512	Signature over above data, applied over all bits from the start of the VPI field to the end of the last bit, just before the signature, generated as described for the terrestrial bulletin board, see ITU-R M.2092-1, Annex 4, §4.15
Total number of bits	variable	

B.2. VPFI 2: VDES APPLICATION SPECIFIC MESSAGES

B.2.1. TEXT USING 6-BIT ASCII

This VDE Protocol Format may be used by applications that use VDE stations to transfer 6-bit ASCII encoded text. The text can be sent over VDE-TER or VDE-SAT as broadcast or addressed message. The parameter, “acknowledge required flag”, should be set to 0 when broadcast is used.

When long text strings are sub-divided, an 11-bit “text sequence number” is used. The text sequence number is used by the originating application to sub-divide the text and by the recipient application to re-assemble the text. The text sequence numbers for each sub-division should be selected to be contiguous and always increasing (110, 111, 112, …). If longer text strings are being transferred, the text sequence numbers should be chosen to associate correctly the sub-divided text with the correct text strings. For international compatible text or authentication / encryption, other VDES messages are defined below.

Table 8 Text in 6-bit ASCII encoding

Parameter	Number of bits	Description
VPFI	16	2
Message ID	16	0
Acknowledge required flag	1	1 = reply is required, optional for addressed messages and not used for broadcast messages 0 = reply is not required, optional for an addressed message and required for broadcast messages
Sequence number	2	0 – 3; see ITU-R M.1371-5, § 5.3.1, Annex 2
Text sequence number	11	Sequence number to be incremented by the application. All zeros indicates that sequence numbers are not being used
Last text in sequence	1	0: more text will follow 1: this is the last message in a sequence
Text string	VDE-TER: 6-6000 VDE-SAT: 6-60000	6-bit ASCII as defined in ITU-R M.1371-5, Table 47, Annex 8.
Spare bits	0-7	Byte boundary padding, value of the bits is set to 0;
Total number of application data bits	variable	

B.2.2. TEXT USING UTF-8 ENCODING

This VDE Protocol Format shall be used by applications that use VDE stations to transfer UTF-8 encoded text. The text can be sent over VDE-TER or VDE-SAT as broadcast or addressed message. The parameter, “acknowledge required flag”, should be set to 0 when broadcast is used.

When long text strings are sub-divided, an 11-bit “text sequence number” is used. The text sequence number is used by the originating application to sub-divide the text and by the recipient application to re-assemble the text. The text sequence numbers for each sub-division should be selected to be contiguous and always increasing (110, 111, 112, …). If long text strings are being transferred, the text sequence numbers should be chosen to associate correctly the sub-divided text with the correct text strings.

If the application requires encryption, other VDES messages are defined below.

Table 9 Text in UTF-8 encoding

Parameter	Number of bits	Description
VPFI	16	2
Message ID	16	1
Acknowledge required flag	1	1 = reply is required, optional for addressed messages and not used for broadcast messages 0 = reply is not required, optional for an addressed message and required for broadcast messages
Sequence number	2	0 – 3; see ITU-R M.1371-5, § 5.3.1, Annex 2
Text sequence number	11	Sequence number to be incremented by the application. All zeros indicates that sequence numbers are not being used
Last text in sequence	1	0: more text will follow 1: this is the last message in a sequence
Spare bits	3	Byte boundary padding, bit values set to 0;
Text string	VDE-TER: 8-8000 VDE-SAT: 8-80000	UTF-8 encoded text (see ISO/IEC 10646:2021).
Valid until	32	Unsigned integer number of seconds after the 1st of January 1970 00:00:00 UTC. After the 19th of January 2038 03:14:07 UTC, the number is the number of seconds after this new date (wraps around); To avoid replay attacks, this value shall be used by the receiving application to verify the validity of the data together with the signature field.
Signature	512	Signature over above data, applied over all bits from the start of the VPI field to the end of the last bit, just before the signature, generated as described for the terrestrial bulletin board, see ITU-R M.2092-1, Annex 4, §4.15
Total number of application data bits	variable	

B.2.3. TEXT USING UTF-8 ENCODING, ENCRYPTED

This VDE Protocol Format may be used by applications that use VDE stations to transfer UTF-8 encoded text between applications that require encryption to provide privacy. The text can be sent over VDE-TER or VDE-SAT as broadcast or addressed message. The parameter, “acknowledge required flag”, should be set to 0 when broadcast is used.

When long text strings are sub-divided, an 11-bit “text sequence number” is used. The text sequence number is used by the originating application to sub-divide the text and by the recipient application to re-assemble the text. The text sequence numbers for each sub-division should be selected to be contiguous and always increasing (110, 111, 112, …). If long text strings are being transferred, the text sequence numbers should be chosen to correctly associate the sub-divided text with the correct text strings.

Encryption is applied after forming the format described in Table 10, using the public key of the receiver, according to IEC *63173-2* [38], §7.6.2 Encryption Algorithm.

The exchange of certificates is managed through VPFI 0.

Table 10 Text in UTF-8 encoding, encrypted content

Parameter	Number of bits	Description
VPFI	16	2
Message ID	16	2
Acknowledge required flag	1	1 = reply is required, optional for addressed messages and not used for broadcast messages 0 = reply is not required, optional for an addressed message and required for broadcast messages
Sequence number	2	0 – 3; see ITU-R M.1371-5, § 5.3.1, Annex 2
Text sequence number	11	Sequence number to be incremented by the application. All zeros indicates that sequence numbers are not being used
Last text in sequence	1	0: more text will follow 1: this is the last message in a sequence
Spare bits	3	Byte boundary padding, bit values set to 0;
Text string	VDE-TER: 8-8000 VDE-SAT: 8-80000	UTF-8 encoded text (see The Unicode Standard, Version 11.0.0, 2018).
Valid until	32	Unsigned integer number of seconds after the 1st of January 1970 00:00:00 UTC. After the 19th of January 2038 03:14:07 UTC, the number is the number of seconds after this new date (wraps around); To avoid replay attacks, this value shall be used by the receiving application to verify the validity of the data together with the signature field.
Signature	512	Signature over above data, applied over all bits from the start of the VPI field to the end of the last bit, just before the signature, generated as described for the terrestrial bulletin board, see ITU-R M.2092-1, Annex 4, §4.15
Total number of application data bits	variable	

B.2.4. VIRTUAL ATON

This VDE Protocol Format may be used to distribute one or multiple Virtual AtoN to be output by the equipment via legacy PI VDL sentences to be able the use of the enhanced capacity of VDE-TER and VDE-SAT in combination with legacy application equipment connected to the PI interface.

Table 11 Virtual AtoN

Parameter	Number of bits	Description
VPFI	16	2
Message ID	16	3
Source ID	30	Identity of the virtual AtoN station (see Article 19 of the RR and Recommendation ITU R *M.585*)

Parameter	Number of bits	Description
Type of aids-to-navigation	5	0 = not available = default; refer to appropriate definition set up by IALA;
Longitude	28	Longitude in 1/10 000 min of position of an AtoN (±180°, East = positive, West = negative 181 = (6791AC0h) = not available = default
Latitude	27	Latitude in 1/10 000 min of an AtoN (±90°, North = positive, South = negative 91 = (3412140h) = not available = default
AtoN status	8	Reserved for the indication of the AtoN status see, IALA Recommendation R-0126 00000000 = default
Virtual AtoN flag	1	0 = default = physical AtoN at indicated position; 1 = virtual AtoN, does not physically exist.
Cancellation	1	0 (default) = station is valid and should be stored for VDM PI output until the timeout has passed or until the storage limit is reached. 1 = remove any stored station with matching Source ID and Lat and Long fields.
Name of Aids-to-Navigation	6-204	Maximum 34 characters 6-bit ASCII "@@@@@@@@@@@@@@@@@@@@" = not Available = default.
Spare bits	0-7	Spare, not used. Should be set to zero. Padding to ensure complete message is complete bytes
Valid until	32	Unsigned integer number of seconds after the 1st of January 1970 00:00:00 UTC. After the 19th of January 2038 03:14:07 UTC, the number is the number of seconds after this new date (wraps around); To avoid replay attacks, this value shall be used by the receiving application to verify the validity of the data together with the signature field.
Signature	512	Signature over above data, applied over all bits from the start of the VPI field to the end of the last bit, just before the signature, generated as described for the terrestrial bulletin board, see ITU-R M.2092-1, Annex 4, §4.15
Number of bits	variable	Does not include "Message ID" (the first parameter)

B.2.4.1. Resulting PI-Port output

VDM encapsulating Message 21: Aids-to-navigation report:

Table 12 Virtual AtoN Message

Parameter	Number of bits	Description
Message ID	6	**Value: 21** Identifier for Message 21
Repeat indicator	2	**Value: TBD** Used by the repeater to indicate how many times a message has been repeated. See § 4.6.1, Annex 2; 0-3; 0 = default; 3 = do not repeat any more 3
Source ID	30	**Value: As received** Identity of the virtual ATON station (see Article **19** of the RR and Recommendation ITU R M.585)
Type of aids-to-navigation	5	**Value: As received** 0 = not available = default; refer to appropriate definition set up by IALA; see Table 13
Name of Aids-to-Navigation	120	**Value: As received in first 120 bits of corresponding Name field. Pad up to 120 bits if shorter (with zero).** Maximum 20 characters 6-bit ASCII, as defined in Recommendation ITU-R M.1371-5 Table 47 "@@@@@@@@@@@@@@@@@@@@" = not available = default. The name of the AtoN may be extended by the parameter "Name of Aid-to-Navigation Extension" below
Position accuracy	1	**Value: 0** 1 = high (≤10 m) 0 = low (>10 m) 0 = default The PA flag should be determined in accordance with Recommendation ITU-R M.1371-5 Table 50
Longitude	28	**Value: As received** Longitude in 1/10 000 min of position of an AtoN (±180°, East = positive, West = negative 181 = ($6791AC0_h$) = not available = default
Latitude	27	**Value: As received** Latitude in 1/10 000 min of an AtoN (±90°, North = positive, South = negative 91 = (3412140h) = not available = default
Dimension/ reference for position	30	**Value: 0** Reference point for reported position; also indicates the dimension of an AtoN (m) (see Recommendation ITU-R M.1371-5 Fig. 41bis and § 3.19.1)
Type of electronic position fixing device	4	**Value: 7** [0 = not available = default 1 = GPS 2 = GLONASS 3 = Combined GNSS 4 = Loran

Parameter	Number of bits	Description
		5 = Chayka 6 = INS 7 = manually input = surveyed or charted position. (The accurate position enhances its function as a radar reference target) 8 = Galileo 9 = BDS 10 & 11 = not used, reserved for future use 12 = integrated PNT system] 13 = inertial navigation system 14 = terrestrial radio navigation system 15 = internal GNSS
Time stamp	6	**Value: 61** UTC second when the report was generated by the EPFS (0-59 or 60) if time stamp is not available, which should also be the default value or 61 if positioning system is in manual input mode or 62 if electronic position fixing system operates in estimated (dead reckoning) mode or 63 if the positioning system is inoperative)
Off-position indicator	1	**Value: 0** For floating AtoN, only: 0 = on position; 1 = off position. This flag should only be considered if time stamp is equal to or below 59. For floating it denotes that the AtoN exceeds the zone parameters set for on station.
AtoN status	8	**Value: As received** Reserved for the indication of the AtoN status, refer to IALA R0126. 00000000 = default
RAIM-flag	1	**Value: 0** RAIM (Receiver autonomous integrity monitoring) flag of electronic position fixing device; 0 = RAIM not in use = default; 1 = RAIM in use see ITU-R M.1371-5, Table 50
Virtual AtoN flag	1	**Value: As received** 0 = default = physical AtoN at indicated position; 1 = virtual AtoN, does not physically exist.
Assigned mode flag	1	**Value: 0** 0 = Station operating in autonomous and continuous mode = default 1 = Station operating in assigned mode
Spare	1	**Value: 0** Should be set to zero. Reserved for future use
Name of Aid-to-Navigation Extension	0, 6, 12, 18, 24, 30, 36, ... 84	**Value: As received after first 120 bits of corresponding Name field. Excluded if Name is shorter.** This parameter of up to 14 additional 6-bit-ASCII characters for a 2-slot message may be combined with the parameter "Name of Aid-to-Navigation" at the end of that parameter, when more than 20 characters are needed for the name of the AtoN. This parameter should be omitted when no more than 20 characters for the name of the A-to-N are needed in total. Only the required number of characters should be transmitted, i.e., no @-character should be used
Spare	0, 2, 4, or 6	**Value: as required for byte alignment** Used only when parameter "Name of Aid-to-Navigation Extension" is used. Should be set to zero. The number of spare bits should be adjusted in order to observe byte boundaries
Number of bits	272-360	

Table 13 The nature and type of aids to navigation can be indicated with 32 different codes

Parameter	Code	Definition
	0	Default, Type of AtoN not specified
	1	Reference point
	2	RACON or Mobile AtoN
	3	Fixed structures off-shore, such as oil platforms, wind farms. (NOTE 1 – This code should identify an obstruction that is fitted with an AtoN AIS station)
	4	Emergency Wreck Marking Buoy
Fixed AtoN	5	Light, without sectors
	6	Light, with sectors
	7	Leading Light Front
	8	Leading Light Rear
	9	Beacon, Cardinal N
	10	Beacon, Cardinal E
	11	Beacon, Cardinal S
	12	Beacon, Cardinal W
	13	Beacon, Port hand
	14	Beacon, Starboard hand
	15	Beacon, Preferred Channel port hand
	16	Beacon, Preferred Channel starboard hand
	17	Beacon, Isolated danger
	18	Beacon, Safe water
	19	Beacon, Special mark
Floating AtoN	20	Cardinal Mark N
	21	Cardinal Mark E
	22	Cardinal Mark S
	23	Cardinal Mark W
	24	Port hand Mark
	25	Starboard hand Mark
	26	Preferred Channel Port hand
	27	Preferred Channel Starboard hand
	28	Isolated danger
	29	Safe Water
	30	Special Mark

Parameter	Code	Definition
	31	AIS Mobile Marker used to mark vehicles, platforms, objects such as Light Vessel/LANBY/Mobile offshore drilling units/Rigs, unmanned autonomous vehicles, debris, etc.

NOTE 1 – The types of aids to navigation listed above are based on the IALA Maritime Buoyage System, where applicable.

NOTE 2 – There is potential for confusion when deciding whether an aid is lighted or unlighted. Competent authorities may wish to use the regional/local section of the message to indicate this.

B.2.5. APPLICATION ACKNOWLEDGEMENT TO AN ADDRESSED MESSAGE

When requested, this VDE Protocol Format may be used by an application to confirm the reception and processing of a VDES addressed specific application message. An application should never acknowledge a broadcast message.

Manual acknowledgement by human interaction is not covered by this mechanism.

If the interrogating application does not receive this acknowledgment reply, even though it was requested, then the application should assume that addressed VDE protocol format is not handled by the interrogated station.

The interrogated protocol format handling application shall respond with this message within 1 second after receiving the addressed interrogation message.

Table 14 Application acknowledgement

Parameter	Number of bits	Description
VPFI	16	2
Message ID	16	3
Received Message ID	16	As received
Sequence number	2	0-3; see ITU-R M.1371-5 § 5.3.1, Annex 2
Text sequence number	11	Sequence number in the message being acknowledged as properly received 0 = default (no sequence number) 1-2 047 = sequence number of received VFM
Message ID available	1	0 = received but Message ID not available 1 = Message ID available
Spare bits	2	Not used, should be set to zero, reserved for future use
Total number of bits	64	

B.2.6. ASM MESSAGE

This VDE Protocol Format may be used to embed multiple ASM functional messages using the ASM standard header, to utilize the higher bandwidth capabilities of VDE-TER and VDE-SAT and/or to offload ASM traffic from the AIS channels.

Table 15 ASM Message

Parameter	Number of bits	Description
VPFI	16	2
Message ID	16	4

Parameter	Number of bits	Description
n	8	number of encapsulated ASMs 0: unused value 1-255: valid values
Length of ASM [0]	16	Number of bits of ASM [0]
ASM data [0] (first ASM)	variable	16 bit: Application Identifier[0], see ITU-R M.1371-5, Annex 5 m[0] bits: ASM Data Content [0]
Length of ASM [1]	16	Number of bits of ASM [1]
ASM data [1] (second ASM)	variable	16 bit: Application Identifier[1], see ITU-R M.1371-5, Annex 5 m[0] bits: ASM Data Content [1]
…	…	…
Length of ASM [n-1]	16	Number of bits of ASM [n-1]
ASM data [n-1] (last ASM)	variable	16 bit: Application Identifier[n-1], see ITU-R M.1371-5, Annex 5 m[0] bits: ASM Data Content [n-1]
Valid until	32	Unsigned integer number of seconds after the 1st of January 1970 00:00:00 UTC. After the 19th of January 2038 03:14:07 UTC, the number is the number of seconds after this new date (wraps around); To avoid replay attacks, this value shall be used by the receiving application to verify the validity of the data.
Signature	512	Signature over above data, applied over all bits from the start of the VPFI field to the end of the last bit, just before the signature, generated as described for the terrestrial bulletin board, see ITU-R M.2092-1, Annex 4, §4.15
Total number of bits	Variable size	

B.2.7. VDE-SAT AIS Position Report Retransmit

This VDE Protocol Format may be used by VDE Satellites that optionally retransmit AIS position reports as received (AIS Msg. 1, 2, 3), to give better situational awareness for navigation beyond the AIS reception range of ships, e.g., in remote areas.

The satellite should only repeat AIS position reports that contain a repeat indicator value of 0.

The signature authenticates the identity for who received the AIS data and for proper retransmission, not for the authenticity of the single AIS data, however.

Table 16 VDE-SAT standard AIS Position Report Retransmit

Parameter	Number of bits	Description
VPFI	16	2
Message ID	16	5
n	8	number of encapsulated AIS position reports 0: unused value 1-255: valid values

Parameter	Number of bits	Description
Time [0]	40	UTC year, month, day and hours, minutes, seconds for the first AIS Message reception, as defined in ITU-R M.1371-5, Message ID 11, starting with year, ending with seconds.
AIS Msg [0]	168	AIS Message [0]: first retransmitted message
Time [1]	40	UTC year, month, day and hours, minutes, seconds for the second AIS Message reception, as defined in ITU-R M.1371-5, Message ID 11, starting with year, ending with seconds.
AIS Msg [1]	168	AIS Message [1]: second retransmitted message
…	…	…
Time [n-1]	40	UTC year, month, day and hours, minutes, seconds for the n-1th AIS Message reception, as defined in ITU-R M.1371-5, Message ID 11, starting with year, ending with seconds.
AIS Msg [n-1]	168	AIS Message [n-1]: n-th retransmitted message
Valid until	32	Unsigned integer number of seconds after the 1st of January 1970 00:00:00 UTC. After the 19th of January 2038 03:14:07 UTC, the number is the number of seconds after this new date (wraps around); To avoid replay attacks, this value shall be used by the receiving application to verify the validity of the data.
Signature	512	Signature over above data, applied over all bits from the start of the VPI field to the end of the last bit, just before the signature, generated as described for the terrestrial bulletin board, see ITU-R M.2092-1, Annex 4, §4.15
Total number of bits	Variable	

B.2.8. AIS MESSAGE AUTHENTICATION OVER VDE-TER

This VDE Protocol Format may be used by equipment transmitting a digital signature for a message previously sent via the AIS channels, i.e., the transmission being signed. The AIS messages may not be older than 59 seconds when the authentication message is transmitted. The transmission may be triggered by interrogation from a coast station or be scheduled by the transmitting application.

The AIS channel content is not repeated but used to generate a signature for authentication by receiving equipment.

To allow receiving equipment to link the authentication message with the transmission being signed, the message ID, MMSI, channel ID, slot number and time stamp is provided in the authentication message.

Equipment receiving this VDE Protocol Format should output the message as VDE message at the PI.

Applications may use the VDE message to augment received AIS messages on shore and ship.

Table 17 AIS Authentication message over VDE-TER

Parameter	Number of bits	Description
VPFI	16	2
Message ID	16	6
AIS Message ID	6	AIS Message ID 1, 2, 3, … 27

Parameter	Number of bits	Description
MMSI	30	Ref. 1371-5
Channel ID	2	Channel where the transmission being signed occurred: 0: AIS 1 1: AIS 2
Slot number	12	Slot number value 0 .. 2249, for the transmission being signed, on the specified channel, as defined in ITU-R M.2092-1. To be set to 2250 if unknown.
Time stamp	32	Unsigned integer number of seconds after the 1st of January 1970 00:00:00 UTC. After the 19th of January 2038 03:14:07 UTC, the number is the number of seconds after this new date (wraps around); Set to the time when the transmission being signed was transmitted. To avoid replay attacks, this value shall be used by the receiver application to verify the validity of the data
Signature	512	Signature of a concatenation of the above data (all bits from the start of the VPFI field to the end of the time stamp field) and all message bits of the AIS transmission being signed, as defined in Rec. ITU-R M.1371-5. The bits corresponding to the AIS message shall form the least significant bits of the concatenated bit-string. String_to_sign = this_msg + ais_message; The signature generation, algorithm to be used is as described for the terrestrial bulletin board, see Rec. ITU-R M.2092-1, Annex 4, §4.15
Total number of bits	626	

B.3. VPFI 4: MARITIME CONNECTIVITY PLATFORM

B.3.1. MARITIME MESSAGING TRANSPORT PROTOCOL (MMTP) MESSAGE

This VDE Protocol Format may be used for the MCP MMTP over VDE-TER and VDE-SAT, in order to utilize the Martitime Connectivity Platform Maritime Messaging Service as defined by the Maritime Connectivity Consortium.

Table 18 MMTP

Parameter	Number of bits	Description
VPFI	16	4
Message ID	16	0
MMS Data	Variable size	See 2.2.3.1
Total number of bits	Variable size	

ANNEX C DESCRIPTION OF THE MCP MMS

C.1. MMS DESCRIPTION

This informative Annex describes the draft MMS architecture in more detail, to be referred to until an international standard specification is published and available for reference.

First, the 2 applicable protocols and the 3 main architectural components are described.

Finally, the integration of the MCP MMS with VDES is described and a protocol overview diagram is shown.

C.1.1. MARITIME MESSAGING TRANSPORT PROTOCOL

MMTP is the transfer protocol between MMS Agents via MMS Routers. This protocol handles three central aspects:

(a) registration of agents based on MCP-MRNs,

(b) message transfer (send/receive), and

(c) message subscriptions based on subjects.

Senders are identified by authenticated MCP-MRNs. Recipients of direct messages are specified using MCP-MRNs. Senders and Recipients of the MMTP are agents. The MCP MRN that defines then, however, comes from the Actors as these are needed for authentication. Multicast messages are identified with a subject-string.

Note, that the MCP MRN used by an MMS Agent is provided by the associated Actor. This comes from the need for authentication, which will require a MIR certificate associated with the MRN. For the example a ship crew sending a message to the Danish Maritime Authority (DMA), DMA might have several MRNs which it uses, depending on the specific message. Similarly, when a person today sends an e-mail to DMA, they would not just send it to the generic e-mail address like info@dma.dk, but instead to a specific address for their specific purpose. Thus, DMA may choose to have one (or more) Agent(s) running with a general DMA MCP MRN, but most MRNs would address specific purposes, like for example:

(d) ..:Navelink:DMA:NW for navigational warnings, or

(e) ..:Navelink:DMA:GreenposReporting for GREENPOS reporting, and so on.

C.1.2. OPTIONAL SECURE MARITIME MESSAGING PROTOCOL

The system provides the following end-to-end guarantees through the SMMP:

(a) Confidentiality: A message sent between users cannot be read by a third party.
(b) Integrity: The receiver of an authenticated message for a given receiver; message cannot be altered and is guaranteed to come from the sender.
(c) Authenticity: Knowing who sent the message.
(d) Availability: In this case also called delivery guarantee. A message from a sender must either arrive at an available receiver within reasonable time or if the receiver cannot be found the sender must be notified of the failure to deliver.
(e) Non-repudiation: The receiver needs to to give proof of reception.
(f) Segmentation of larger messages.
(g) Streaming of data.

C.1.3. MARITIME MESSAGE SERVICE AGENT

An MMS Agent is a client software that interfaces with System Actors and provides connectivity to the MMS. MMS Agents connect to MMS Edge Routers via the Agent-Router Network interface using MMTP.

An MMS Agent is either MIR authenticated, meaning that it

(a) has been assigned a MCP-MRN[10] document IDSEC2], in a MIR, and

(b) has been assigned a MIR certificate,

or

(c) operates anonymously.

An MIR authenticated MMS Agent may use the full functionality of the MMS.

An anonymous MMS Agent cannot receive direct messages or send messages. This is, however, useful for System Actors that only need to receive broadcast/multicast messages.

C.1.4. EDGE ROUTER

An MMS Edge Router handles the messages between a set of local MMS Agents and the MMS Router Network.

An MMS Edge Router authenticates the associated MIR authenticated MMS Agents before these may receive direct messages or send messages through the MMS Edge Router.

An MMS Edge Router either is MIR authenticated, meaning that it

(a) has been assigned a MCP-MRN [10] document IDSEC2, in a MIR, and

(b) has been assigned a MIR certificate

or

(c) operates anonymously.

An MMS Edge Router may connect to one or multiple MMS Routers. An MMS Edge Router may have a preferred MMS Router defined; it also is able to find an MMS Router through a connection dependent lookup. If an MMS Edge Router chooses to operate as MIR authenticated MMS Edge Router, it needs to authenticate for each MMS Router it connects to.

While an MMS Edge Router is not connected to an MMS Router of the MMS Router Network, it limits message forwarding to be between local MMS Agents only.

An MIR authenticated MMS Edge Router may expect the full functionality of the MMS Router Network.

An anonymous MMS Edge Router shall expect the need to resubscribe when changing from one to another Router and accept possible loss of messages.

An MMS Edge Router provides message broker functionality to its local set of MMS Agents.

Message broking includes:

(a) local transport of MMS messages between Agents in the same set,

(b) store and forward of MMS messages between the Router Network and the local Agents,

(c) subscription to Router Network provided subjects on behalf of the local Agents, and

(d) distribution of subject messages received from the Router Network to the local Agents.

Message broking thereby allows the distribution of a single received message to multiple subscribed MMS Agents, and by that avoiding that multiple MMS Actors' subscriptions to the same MRN or subject result in increased traffic over the link between MMS Actor and MMS Router.

C.1.5. ROUTER NETWORK

The MMS Router Network consists of zero or more MMS Routers. The Router Network shall handle message routing and forwarding to MMS Edge Routers.

An MMS Router handles MMS message transport for a set of subscribed MMS Agents. Subscriptions are either for a specific subject or a specific MRN. An MMS Router queues messages that an MMS Agent has subscribed to until they are fetched by that MMS Agent. An MMS Router deletes stored subscriptions and queued messages after a timeout occurs.

The MMS Router Network handles the transfer of stored subscriptions and queued messages between the MMS Routers in case an MMS Agent roams from one Router to another.

The MMS Router Network supports the lookup of an MMS Router by request from an MMS Agent, according to its current connectivity situation.

The Router Network has the capability to exchange the knowledge about subscribed MMS Agents, and subjects between each other.

C.1.6. USING MARITIME MESSAGING SERVICE WITH VDES

The VDES may be used as means to transport MMS traffic by connecting the ship side Edge Router with the Router Network over a VDES Network.

VDES provides AIS, ASM, VDE Terrestrial (VDE-TER) and VDE Satellite (VDE-SAT) services.

VDE-TER and VDE-SAT provide capabilities to route MMS traffic, as described in this specification.

Note: AIS and ASM data channels are reserved for small messages and thereby not of value for the MMS.

In order to allow MMS transport (see Figure 9 over VDES)

(a) the ship shall be equipped with a VDES enabled Edge Router,

(b) the ship shall be equipped with a VDES Modem according to ITU-R M.2092-1,

(c) the ship shall be in a MMS enabled VDES Network coverage area,

(d) the current available VDES Network shall provide MMS routing services into the MMS Router Network.

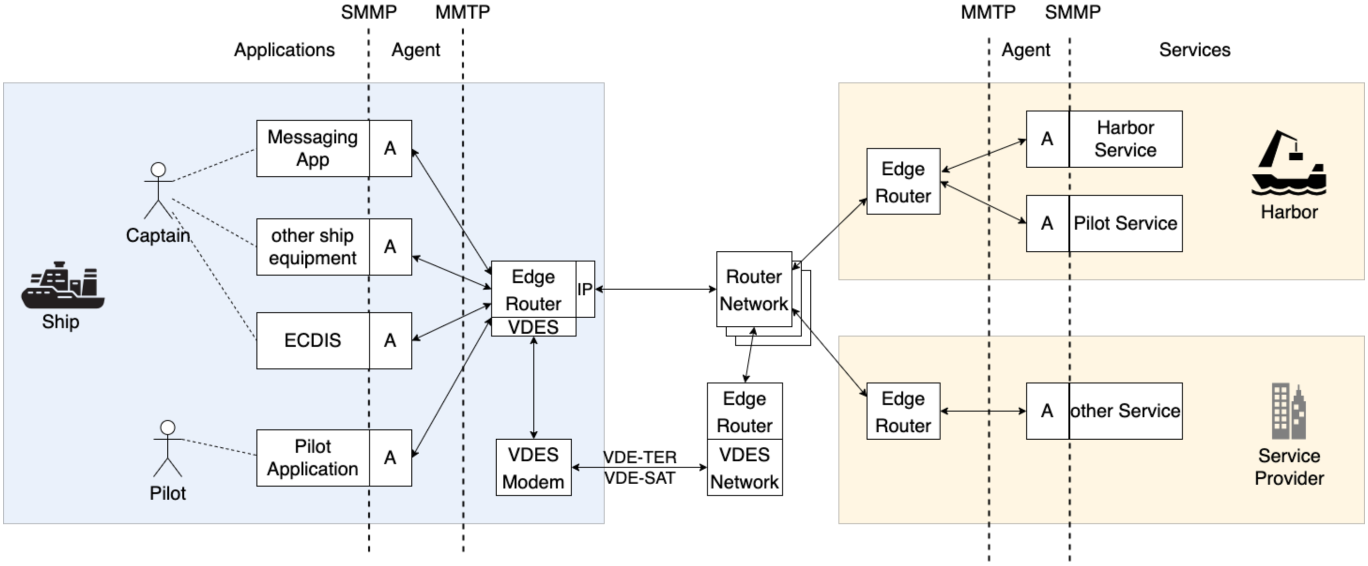


Figure 9 MMS with VDES as transport

Figure 9 shows how VDE bridges the VDES Network side Edge Router to the ship Edge Router, seen from the Router Network. For the MMS Router Network, the VDES Network Edge Router provides the same functionality, as the ship Edge Router with a direct IP connection.

A VDES enabled ship Edge Router shall take into account:

(e) that an arbitrary VDES Network may or may not provide MMS capabilities, and therefore needs to be interrogated before use for each new VDES Network the ship roams into;

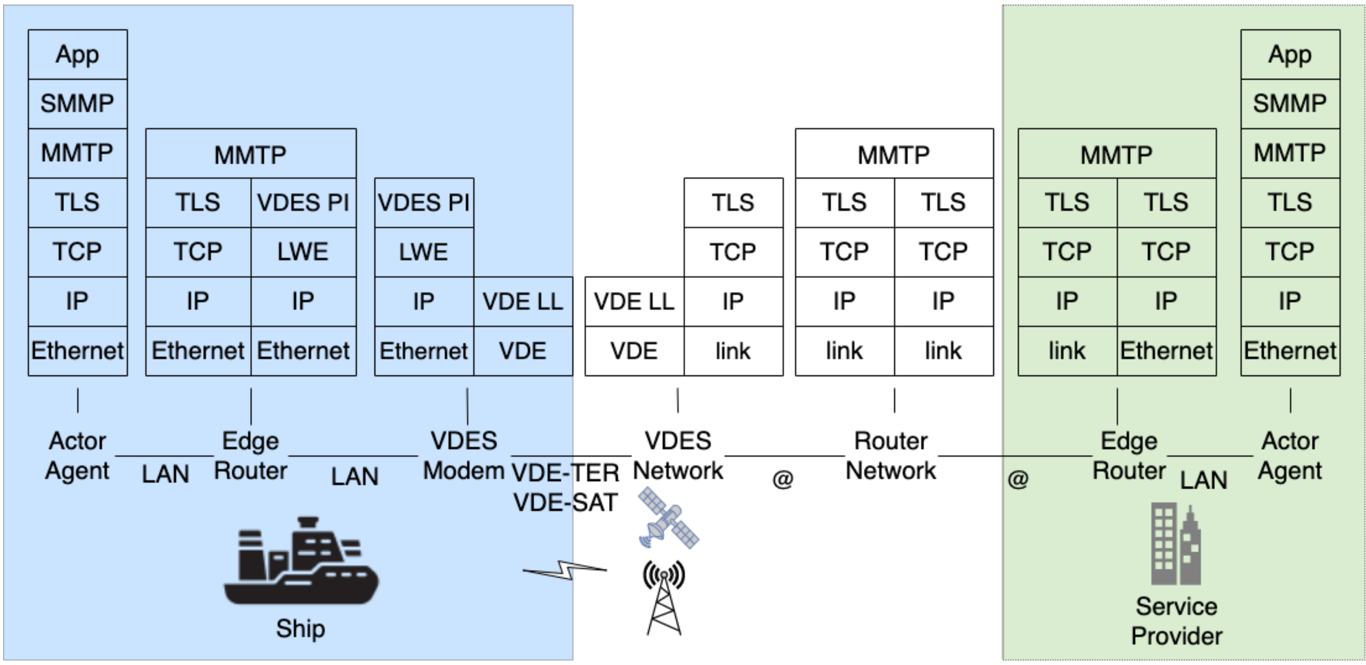
(f) that an arbitrary VDES Network may provide access to selected MMS services only, to be interrogated before use;

(g) that terrestrial VDE (VDE-TER) provides coverage along coastlines where the distance between ship and coast station reduces the connection quality and speed;

(h) that satellite VDE (VDE-SAT) provides world-wide satellite coverage over open water, which is expected to be available only for a few minutes at a time with coverage gaps of several hours in-between; and

(i) that VDE-SAT based VDES Networks may not have direct connectivity with the Router Network over all territories, resulting in transport delays of up to 90 minutes.

An overview of the different protocols used between two Actor Applications on ship and shore, when using VDE-TER or VDE-SAT as a means of MMS transport, is shown in 0.



Note: according to the open system interconnection layers (OSI); in the model the optional SMMP is added, it should be omitted by applications that do not need the SMMP provided properties.

Figure 10 MMS over VDES protocol overview